Fisheries Assessment Plenary

May 2020

Stock Assessment and Stock Status

Volume 1: Introductory section and Alfonsino to Hake

Fisheries New Zealand
Tini a Tangaroa

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Stock Assessments and Stock Status
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PREFACE

Fisheries Assessment Plenary reports have represented a significant annual output of Fisheries New Zealand and its predecessors for the last 36 years. The Plenary is now more than 2200 pages long and is split into four volumes, three of which are produced in May and one in November of each year. The Plenary reports provide summaries of the available fisheries and scientific information and are in turn supported by 70–100 more detailed reports published on-line each year, with a cumulative total of almost 2000 such supporting, detailed documents.

The May 2020 Plenary summarises fisheries, biological, environmental, stock assessment and stock status information for 83 of New Zealand's commercial fish species or species groups in a series of Science Working Group (SWG) or Plenary reports. In the early years of New Zealand's efforts to conduct fish stock assessments, all such assessments went through a Plenary process (meaning that as many as possible of all experts and involved parties had the opportunity to participate in the review). However, as more data has been collected; more analyses have been conducted; more sophisticated models have been developed; peer review processes have become increasingly more rigorous and incorporated into research and science standards and terms of reference; more experts have been trained; and more constructive collaborations with industry, recreational and environmental interests have developed, it has become expedient to finalise increasingly more stock assessments in SWG processes alone.

The main reasons that a new stock assessment is subjected to the additional Plenary review nowadays is if it:

- Results in a substantially different assessment of stock status compared to the previous assessment, particularly if the new assessment is likely to result in fisheries management actions to alter catch limits or other regulatory measures, in order to address either sustainability concerns or utilisation opportunities;

- Is novel, complex, or contentious; for example, it is the first time a successful assessment has been conducted for a given stock, or the relevant SWG was divided on its validity, or if the methodology is of sufficient complexity as to warrant a further layer of review;

- To suggest future research considerations that could contribute to the objective of continually improving future assessments for that stock.

Each species or species group is split into 1–10 stocks for management purposes. However, the boundaries of biological stocks often differ from the management boundaries. In general, biological stocks tend to occur at smaller scales than management boundaries, although in a few instances the reverse is true. Most stock assessments are conducted at biologically meaningful scales.

In addition to this May Plenary report, the mid-year Plenary is produced each November for species that operate on different management cycles and includes 17 SWG and Plenary summaries for highly migratory species, rock lobster, scallops and dredge oysters.

Over time, continual improvements have been made in data acquisition, stock assessment techniques, the development of reference points to guide fisheries management decisions, the provision of increasingly comprehensive and meaningful information from a range of sources, and peer review processes. SWG and Plenary meetings have continued the effort to populate the Status of the Stocks summary tables, which are used to provide comprehensive summary information about current stock status and the prognosis for these stocks, to evaluate fisheries performance relative to the 2008 Harvest Strategy Standard for New Zealand Fisheries and other management measures, and to rank the quality of stock assessment inputs and outputs based on the 2011 Research and Science Information Standard for New Zealand Fisheries. Even when complete information is not available, it is sometimes possible to at least make scientifically sound statements about recent trends in stock size and fishing intensity levels.

Over the past few years, sections on environmental and ecosystem considerations have also been developed for some species by the SWGs that oversee aquatic environment and biodiversity issues associated with New Zealand fisheries and the ocean environment in which they reside. Chapter sections on how ocean warming, ocean acidification and other ecosystem trends affect, for example, productivity and fish distributions will be incorporated as new information becomes available. Fisheries New Zealand recognises the need to increase our knowledge of the impacts of important environmental factors.

The Plenary reports take into account the most recent data and analyses available to SWGs and Fisheries Assessment Plenary meetings, and also incorporate relevant analyses undertaken in previous years. Due to time and resource constraints, recent data for some stocks may not yet have been fully analysed by the SWGs or the Plenary.

I would like to recognise and thank the large number of research providers, scientists and other representatives from research organisations, academia, the seafood industry, marine amateur fisheries, environmental NGOs, customary non-commercial interests and Fisheries New Zealand; along with all other technical and non-technical participants in present and past SWG and Plenary meetings for their substantial contributions to this report. My sincere thanks to each and all who have contributed.

I would also like to pay particular tribute to Fisheries New Zealand's past and present Science Officers who put tireless effort into checking and collating each Plenary report. The Science Officer for this report was Josh van Lier. Our technical science editors also deserve a tribute. This year we had two science editors conscientiously working on this report: Marianne Vignaux our out-going science editor of many years and Suze Baird our incoming science editor. Both have put in a phenomenal effort.

I am pleased to endorse this document as representing the best available scientific information relevant to fisheries and stock status, as at 31 May 2020.

Pamela Mace

Dr Pamela Mace
Principal Science Advisor Fisheries
Fisheries New Zealand

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Introduction

This report summarises the conclusions and recommendations from the meetings of the Fisheries Assessment Working Groups and the Fisheries Assessment Plenary held since last year's Plenary report was published. The meetings were convened to assess the fisheries managed within the Quota Management System, as well as other important fisheries in the New Zealand EEZ, and to discuss various matters that pertain to fisheries assessments.

In addition, summaries of environmental effects of fishing from research presented to the Aquatic Environment Working Group (AEWG) and the Biodiversity Advisory Group (BRAG) that have relevance to fisheries management have been incorporated for selected species. Paragraph 11 of the Terms of Reference for Fisheries Assessment Working Groups (FAWGs) includes "…information and advice on other management considerations (e.g., …by-catch issues, effects of fishing on habitat…)", and states that "Sections of the Working Group reports related to bycatch and other environmental effects of fishing will be reviewed by the Aquatic Environment Working Group although the relevant FAWG is encouraged to identify to the AEWG Chair any major discrepancies between these sections and their understanding of the operation of relevant fisheries". In addition, the Terms of Reference for the AEWG (Paragraph 9) specifies the need "to review and revise existing environmental and ecosystem consideration sections of Fisheries Assessment Plenary report text based on new data or analyses, or other relevant information".

The report addresses, for each species, relevant aspects of the Fisheries Act 1996 and related considerations, as defined in the Terms of Reference for Fisheries Assessment Working Groups for 2020. In all cases, consideration has been based on and limited by the best available information. The purpose has been to provide objective, independent assessments of the current status of the fish stocks.

There are two types of catch limits used in this document – total allowable catch (TAC) and total allowable commercial catch (TACC). The current definition is that a TAC is a limit on the total removals from the stock, including those taken by the commercial, recreational and customary non-commercial sectors, illegal removals and all other mortality to a stock caused by fishing. A TACC is a limit on the catch taken by the commercial sector only. The definition of TAC was changed in the 1990 Fisheries Amendment Act when the term TACC was introduced. Before 1990, the term TAC applied only to commercial fishing. In the Landings and TAC tables in this report, the TAC figures equate to the TACC unless otherwise specified.

Only actual TACCs are provided. The actual TACCs are the values as of the last day of the fishing year; e.g., 30 September.

In considering customary non-commercial, and recreational interests, the focus has been on current interests and activities rather than historical activities. In most cases, there is little information available on the nature and extent of non-commercial interests, although estimates of recreational harvest are available in some instances. Information on illegal catches and other sources of mortality is provided where available.

Yield Benchmarks
The biological reference points, Maximum Constant Yield (*MCY*) and Current Annual Yield (*CAY*) first used in the 1988 assessment continue to be used in a small number of stock assessments. This approach is described in the section of this report titled "Guide to Biological Reference Points for Fisheries Assessment Meetings".

Sources of Data
A major source of information for these assessments is the fisheries statistics system. It is important to maintain and develop this system to provide adequate and timely data for stock assessments.

Other Information
For some assessments, draft Fisheries Assessment Reports that more fully describe the data and the analyses have been prepared in time for the Working Group or Plenary process. Once finalised, these documents are placed on the Fisheries New Zealand website in a searchable database.

Environmental Effects of Fishing
The scientific information to assess the environmental effects of fishing and enable this outcome comes primarily from research commissioned by Fisheries New Zealand and, for protected species only, the Department of Conservation (DOC). The work is reviewed by the Aquatic Environment Working Group (AEWG) (or a similar DOC technical working group) or by the Biodiversity Research Advisory Group (BRAG). Fisheries New Zealand has developed an "Aquatic Environment and Biodiversity Annual Review", which summarises the current state of knowledge on the environmental interactions between fisheries and the aquatic environment. The Aquatic Environment and Biodiversity Annual Review assesses the various known and potential effects of fishing on an issue-by-issue basis (e.g., the total impact of all bottom trawl and dredge fisheries on benthic habitat), whereas relatively brief fisheries-specific summaries have been progressively included in this report since 2005, starting with hoki. These fisheries-specific sections are reviewed by AEWG rather than by the FAWGs responsible for the stock assessment sections in each Working Group report.

Status of Stocks Summary Tables
Since 2009, the key information relevant to providing more comprehensive and meaningful information for fisheries managers, stakeholders and other interested parties has been summarised at the end of each chapter in a table format using the Guidelines for Status of the Stocks Summary Tables on pages 46–52. Beginning in 2012, Status of Stocks tables have incorporated a new science information quality ranking system, as specified in the Research and Science Information Standard for New Zealand Fisheries (2011). Beginning in 2013, Status of Stocks tables have incorporated explicit statements regarding the status of fisheries relative to overfishing thresholds.

Glossary of Common Technical Terms

Abundance Index: A quantitative measure of fish density or abundance, usually as a relative time series. An abundance index can be specific to an area or to a segment of the **stock** (e.g., mature fish), or it can refer to abundance stock-wide; the index can reflect abundance in numbers or in weight (**biomass**).

AEWG: The Aquatic Environment (Science) Working Group.

Age frequency: The proportions of fish of different ages in the **stock,** or in the **catch** taken by either commercial fisheries or research fishing. This is often estimated based on a sample. Sometimes called an age composition.

Age-length key: The proportion of fish of each age in each length-group in a sample of fish.

Age-structured stock assessment: An assessment that uses a model to estimate how the numbers at age in the stock vary over time in order to determine the past and present **status** of a fish **stock**.

a_{50}: Either the age at which 50% of fish are mature (= A_M) or 50% are recruited to fisheries (=A_R).

AIC: The Akaike Information Criterion is a measure of the relative quality of a statistical model for a given set of data. As such, AIC provides a means for model selection; the preferred model is the one with the minimum AIC value.

A_M: *Age at maturity* is the age at which fish, of a given sex, are considered to be reproductively mature. See **a_{50}**.

AMP: *Adaptive Management Programme*. This involves increased **TACCs** (for a limited period, usually 5 years) in exchange for which the industry is required to provide data that will improve understanding of **stock status**. The industry is also required to collect additional information (biological data and detailed catch and effort) and perform the analyses (e.g. **CPUE** standardisation or age structure) necessary for monitoring the **stock.**

ANTWG: Antarctic (Science) Working Group.

A_R : *Age of recruitment* is the age when fish are considered to be **recruited** to fisheries. In **stock assessments**, this is usually the youngest age group considered in the analyses. See **a_{50}**.

a_{to95} : The number of ages between the age at which 50% of a stock is mature (or recruited) and the age at which 95% of the stock is mature (or recruited).

B_o: *Virgin biomass, unfished biomass*. This is the theoretical **carrying capacity** of the **recruited** or **vulnerable** or **spawning biomass** of a fish **stock**. In some cases, it refers to the average **biomass** of the **stock** in the years before fishing started. More generally, it is the average over recent years of the biomass that theoretically would have occurred if the stock had never been fished. B_0 is often estimated from stock modelling and various percentages of it (e.g., 40% B_0) are used as **biological reference points (BRPs)** to assess the relative status of a **stock**.

B_{AV} : The average historical **recruited biomass**.

Bayesian stock assessment: an approach to stock assessment that provides estimates of uncertainty (**posterior distributions**) of the quantities of interest in the assessment. The method allows the initial uncertainty (that before the data are considered) to be described in the form of **priors**. If the data are informative, they will determine the posterior distributions; if they are uninformative, the posteriors will resemble the **priors**. The initial model runs are called **MPD** (mode of the posterior distribution) runs, and provide point estimates only, with no uncertainty. Final runs (Markov Chain Monte Carlo runs or **MCMCs)**, which are often very time consuming, provide both point estimates and estimates of uncertainty.

B_{BEG}**:** The estimated **stock biomass** at the beginning of the fishing year.

$B_{CURRENT}$**:** Current **biomass** in the year of the assessment (usually a **mid-year biomass**).

Benthic: The ecological region at the lowest level of a body of water, including the sediment surface and some sub-surface layers

Biological Reference Point (BRP): A benchmark against which the **biomass** or abundance of the **stock,** or the **fishing mortality rate** (or **exploitation rate**), or **catch** itself can be measured in order to determine **stock status**. These reference points can be **targets**, **thresholds** or **limits** depending on their intended use.

Biomass: Biomass refers to the size of the **stock** in units of weight. Often, biomass refers to only one part of the **stock** (e.g., **spawning biomass, vulnerable biomass** or **recruited biomass**, the latter two of which are essentially equivalent).

B_{MSY}**:** The average **stock biomass** that results from taking an average catch of ***MSY*** under various types of harvest strategies. Often expressed in terms of spawning **biomass**, but may also be expressed as **recruited** or **vulnerable biomass.**

Bootstrap: A statistical methodology used to quantify the uncertainty associated with estimates obtained from a **model**. The bootstrap is often based on **Monte Carlo** re-sampling of residuals from the initial **model** fit.

BRAG: Biodiversity Research Advisory Group.

B_{REF}**:** A reference average biomass usually treated as a management target.

Bycatch: Refers to fish species, or size classes of those species, caught in association with key target species.

B_{YEAR}**:** Estimated or predicted **biomass** in the named year (usually a **mid-year biomass**).

Carrying capacity: The average **stock** size expected in the absence of **fishing**. Even without fishing the **stock** size varies through time in response to stochastic environmental conditions. See ***B_o***.

Catch (C): The total weight (or sometimes number) of fish caught by fishing operations.

CAY**: Current annual yield** is the one year **catch** calculated by applying a reference **fishing mortality**, F_{REF}, to an estimate of the fishable **biomass** at the beginning of the fishing year. Also see ***MAY***.

CELR: Catch-Effort Landing Return.

CLR: Catch Landing Return.

Cohort: Those individuals of a **stock** born in the same spawning season. For annual spawners, a year's **recruitment** of new individuals to a **stock** is a single cohort or **year-class**.

Collapsed: Stocks that are below the **hard limit** are deemed to be **collapsed**.

Convergence: In reference to **MCMC** results from a **Bayesian stock assessment**, convergence means that the average and the variability of the parameter estimates are not changing as the **MCMC** chain gets longer.

CPUE: Catch per unit effort is the quantity of fish caught with one standard unit of fishing effort; e.g., the number of fish taken per 1000 hooks per day or the weight of fish taken per hour of trawling. CPUE is often assumed to be a relative **abundance index**.

Customary catch: Catch taken by tangata whenua to meet their customary needs.

CV: Coefficient of variation. A statistic commonly used to represent variability or uncertainty. For example, if a biomass estimate has a CV of 0.2 (or 20%), this means that the error in this estimate (the difference between the estimate and the true biomass) will typically be about 20% of the estimate.

Density-dependence: Fish populations are thought to self-regulate: as population biomass increases, growth may slow down, mortality may increase, recruitment may decrease or maturity may occur later. Growth is density-dependent if it slows down as biomass increases.

Depleted: Stocks that are below the **soft limit** are deemed to be **depleted**. Stocks can become **depleted** through **overfishing**, or environmental factors, or a combination of the two.

Discards: the portion of the catch thrown away at sea.

DWWG: The Deepwater (Science) Working Group.

ECER: Eel Catch-Effort Return.

ECLR: Eel Catch Landing Return.

Ecosystem: A biological community of interacting organisms and their physical environment.

EEZ: An **Exclusive Economic Zone** is a maritime zone beyond the **Territorial Sea** over which the coastal state has sovereign rights over the exploration and use of marine resources. Usually, a state's EEZ extends to a distance of 200 nautical miles (370 km) out from its coast, except where resulting points would be closer to another country.

Equilibrium: A theoretical model state that arises when the **fishing mortality**, **exploitation pattern** and other fisheries or **stock** characteristics (growth, natural mortality, **recruitment**) do not change from year to year.

Exploitable biomass: Refers to that portion of a **stock's biomass** that is available to fisheries. Also called **recruited biomass** or **vulnerable biomass**.

Exploitation pattern: The relative proportion of each age or size class of a **stock** that is vulnerable to fishing. See **selectivity ogive.**

Exploitation rate: The proportion of the **recruited** or **vulnerable biomass** that is caught during a certain period, usually a fishing year.

***F*:** The **fishing intensity** or **fishing mortality rate** is that part of the total mortality rate applying to a fish **stock** that is caused by fishing. Usually expressed as an instantaneous rate.

$F_{0.1}$: The **fishing mortality rate** at which the increase in **equilibrium yield per recruit** in weight per unit of effort is 10% of the **yield per recruit** produced by the first unit of effort on the unexploited **stock** (i.e., the slope of the **yield per recruit** curve for the $F_{0.1}$ rate is only 1/10th of the slope of the **yield per recruit** curve at its origin).

$F_{40\%B0}$*:** The **fishing mortality rate** associated with a biomass of 40% ***B_0 at **equilibrium** or on average.

***$F_{40\%SPR}$*:** The **fishing mortality rate** associated with a spawning biomass per recruit (**SPR**) (or equivalently a spawning potential ratio) of 40% B_0 at equilibrium or on average.

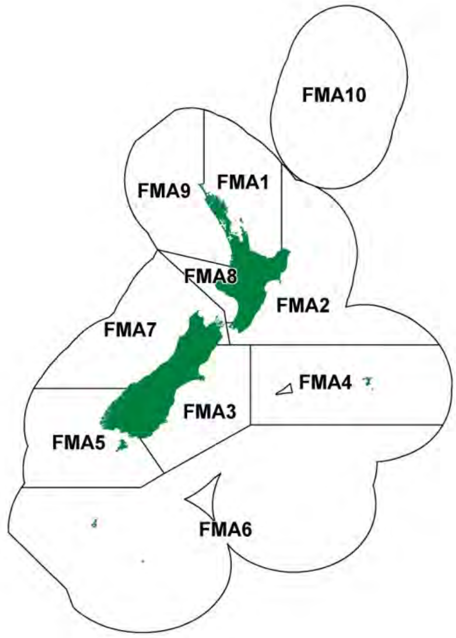
FAWGs: Fisheries Assessment (Science) Working Groups.

Fishing intensity: A general term that encompasses the related concepts of **fishing mortality** and **exploitation rate**.

Fishing mortality: That part of the total mortality rate applying to a fish **stock** that is caused by fishing. Usually expressed as an instantaneous rate.

Fishing year: For most fish stocks, the fishing year runs from 1 October in one year to 30 September in the next. The second year is often used as shorthand for the split years. For example, 2015 is shorthand for 2014–15.

FMA: Fishery Management Area. The New Zealand **EEZ** is divided into 10 fisheries management units:



F_{MAX}*:** The **fishing mortality rate** that maximises **equilibrium yield per recruit**. ***F_{MAX} is the **fishing mortality** level that defines **growth overfishing**. In general, F_{MAX} is different from ***F_{MSY}*** (the **fishing mortality** that maximises **sustainable yield**) and is always greater than or equal to ***F_{MSY}***, depending on the **stock-recruitment relationship**.

***F_{MEY}*:** The fishing mortality corresponding to the maximum (**sustainable**) economic yield.

F_{MSY}*:** The **fishing mortality rate** that, if applied constantly, would result in an average catch corresponding to the **Maximum Sustainable Yield** (MSY***) and an average biomass corresponding to ***B_{MSY}***. Usually expressed as an instantaneous rate.

F_{REF}*:** The **fishing mortality** that is associated with an average biomass of ***B_{REF}.

FRML: Fisheries Related Mortality Limit.

Growth overfishing: Growth overfishing occurs when the **fishing mortality rate** is above $\boldsymbol{F_{MAX}}$. This means that on average fish are caught before they have a chance to reach their maximum growth potential.

Hard Limit: A biomass limit below which fisheries should be considered for closure.

Harvest Strategy: For the purpose of the Harvest Strategy Standard, a harvest strategy simply specifies **target** and **limit reference points** and management actions associated with achieving the **targets** and avoiding the **limits**.

HMS: Highly Migratory Species.

HMSWG: Highly Migratory Species (Science) Working Group.

Hyperdepletion: The situation where an abundance index, such as **CPUE**, decreases faster than the true abundance.

Hyperstability: The situation where an abundance index, such as **CPUE**, decreases more slowly than the true abundance.

Incidental capture: Refers to non-fish and protected species which were not targeted, but were caught.

Index: Same as an **abundance index**.

LCER: Longline Catch-Effort Return.

Length frequency: The distribution of numbers at length from a sample of the **catch** taken by either commercial fisheries or research fishing. This is sometimes called a length composition.

Length-Structured Stock Assessment: An assessment that uses a model to estimate how the numbers at length in the stock vary over time in order to determine the past and present **status** of a fish **stock**.

Limit: A **biomass** or fishing mortality **reference point** that should be avoided with high probability. The Harvest Strategy Standard defines both **soft limit**s and **hard limit**s.

***M*:** The (instantaneous) **natural mortality rate** is that part of the total mortality rate applying to a fish **stock** that is caused by predation and other natural events.

MAFWG: Marine Amateur Fisheries (Science) Working Group.

MALFIRM: Maximum Allowable Limit of Fishing Related Mortality.

Maturity: Refers to the ability of fish to reproduce.

Maturity ogive: A curve describing the proportion of fish of different ages or sizes that are mature.

MAY*: Maximum average yield** is the average **maximum sustainable yield** that can be produced over the long term under a constant fishing mortality strategy, with little risk of **stock** collapse. A constant fishing mortality strategy means catching a constant percentage of the biomass present at the beginning of each fishing year. *MAY* is the long-term average annual catch whereas the catch each year is the *CAY*. Also see ***CAY.

MCMC: Markov Chain Monte Carlo. See **Bayesian stock assessment**.

***MCY*: Maximum constant yield** is the maximum sustainable yield that can be produced over the long term by taking the same catch year after year, with little risk of stock collapse.

MIDWG: Middle-depths (Science) Working Group.

Mid-year biomass: The biomass after half the year's catch has been taken.

MLS: Minimum Legal Size. Fish above the MLS can be retained whereas those below it must be returned to the sea.

Model: A set of equations that represents the population dynamics of a fish stock.

Monte Carlo Simulation: An approach whereby the inputs that are used for a calculation are re-sampled many times assuming that the inputs follow known statistical distributions. The Monte Carlo method is used in many applications such as **Bayesian stock assessments**, parametric bootstraps and stochastic **projections**.

MPD: Mode of the (joint) posterior distribution. See **Bayesian stock assessment**.

***MSY*: Maximum sustainable yield** is the largest long-term average catch or yield that can be taken from a **stock** under prevailing ecological and environmental conditions, and the current selectivity patterns exhibited by fisheries.

MSY*-compatible reference points:** *MSY*-compatible references points include B_{MSY}, F_{MSY} and ***MSY itself, as well as analytical and conceptual **proxies** for each of these three quantities.

Natural mortality (rate): That part of the total mortality rate applying to a fish **stock** that is caused by predation and other natural events. Usually expressed as an instantaneous rate.

NCELR: Set Net Catch-Effort Landing Return.

NINSWG: Northern Inshore (Science) Working Group.

Objective function: An equation to be optimised (minimised or maximised) given certain constraints using non-linear programming techniques.

Otolith: One of the small bones or particles of calcareous substance in the internal ear of teleosts (bony fishes) that are used to determine their age.

Overexploitation: A situation where observed **exploitation** (or **fishing mortality**) rates are higher than **target levels**.

Overfishing: A situation where observed **fishing mortality** (or **exploitation**) rates are higher than **target** or **threshold** levels.

Partition: The way in which a fish stock or population is characterised, or split, in a stock assessment model; for example, by sex, age and maturity.

PCELR: Paua Catch-Effort Landing Return.

Population: A group of fish of one species that shares common ecological and genetic features. The **stocks** defined for the purposes of **stock assessment** and management do not necessarily coincide with self-contained populations.

Population dynamics: In general, refers to the biological and fishing processes that result in changes in fish **stock** abundance over time.

Posterior: A mathematical description of the uncertainty in some quantity (e.g., **biomass**) estimated in a **Bayesian stock assessment**. This is generally depicted as a frequency distribution (often plotted along with the **prior** distribution to show how much the two diverge).

Potential Biological Removal (PBR): An estimate of the number of seabirds that may be killed without causing the population to decline below half the carrying capacity.

Pre-recruit: An individual that has not yet entered the fished component of the **stock** (because it is either too young or too small to be vulnerable to fisheries).

Prior: Available information (often in the form of expert opinion) regarding the potential range of values of a parameter in a **Bayesian stock assessment**. Uninformative priors are used where there is no such information.

Production Model: A **stock model** that describes how the **stock biomass** changes from year to year (or, how **biomass** changes in **equilibrium** as a function of **fishing mortality**), but which does not keep track of the age or length frequency of the stock. The simplest production functions aggregate all of the biological characteristics of growth, **natural mortality** and reproduction into a simple, deterministic **model** using three or four parameters. Production models are primarily used in simple data situations, where total catch and effort data are available but age-structured information is either unavailable or deemed to be less reliable (although some versions of production models allow the use of age-structured data).

Productivity: Productivity is a function of the biology of a species and the environment in which it lives. It depends on growth rates, **natural mortality**, **age at maturity**, maximum average age and other relevant life history characteristics. Species with high **productivity** are able to sustain higher rates of **fishing mortality** than species with lower **productivity**. Generally, species with high productivity are more resilient and take less time to rebuild from a **depleted** state.

Projection: Predictions about trends in stock size and fisheries dynamics in the future. Projections are made to address "what-if" questions of relevance to management. Short-term (1–5 years) projections are typically used in support of decision-making. Longer term projections become much more uncertain in terms of absolute quantities, because the results are strongly dependent on **recruitment,** which is very difficult to predict. For this reason, long-term projections are more useful for evaluating overall management strategies than for making short-term decisions.

Proxy: A surrogate for B_{MSY}, F_{MSY} or ***MSY*** that has been demonstrated to approximate one of these three metrics through theoretical or empirical studies.

q**: Catchability** is the proportion of fish that are caught by a defined unit of fishing effort. The constant relating an **abundance index** to the true biomass (the **abundance index** is approximately equal to the true biomass multiplied by the catchability).

Quota Management Areas (QMA): QMAs are geographic areas within which fish stocks are managed in the **TS** and **EEZ**.

Quota Management System (QMS): The **QMS** is the name given to the system by which the total commercial catch from all the main fish **stocks** found within New Zealand's 200 nautical mile **EEZ** is regulated.

Recruit: An individual that has entered the fished component of the **stock**. Fish that are not recruited are either not catchable by the gear used (e.g., because they are too small) or live in areas that are not fished.

Recruited biomass: Refers to that portion of a **stock's biomass** that is available to fisheries; also called **exploitable biomass** or **vulnerable biomass**.

Recruitment: The addition of new individuals to the fished component of a **stock**. This is determined by the size and age at which fish are first caught.

Reference Point: A benchmark against which the biomass or abundance of the **stock** or the **fishing mortality rate** (or **exploitation rate**) can be measured in order to determine its **status**. These reference points can be targets, thresholds or limits depending on their intended use.

RLWG: Rock Lobster (Science) Working Group.

SAMWG: Stock Assessment Methods (Science) Working Group.

$\boldsymbol{S_{AV}}$**:** The average historical **spawning biomass**.

Selectivity ogive: Curve describing the relative vulnerability of fish of different ages or sizes to the fishing gear used.

SFWG: The Shellfish (Science) Working Group.

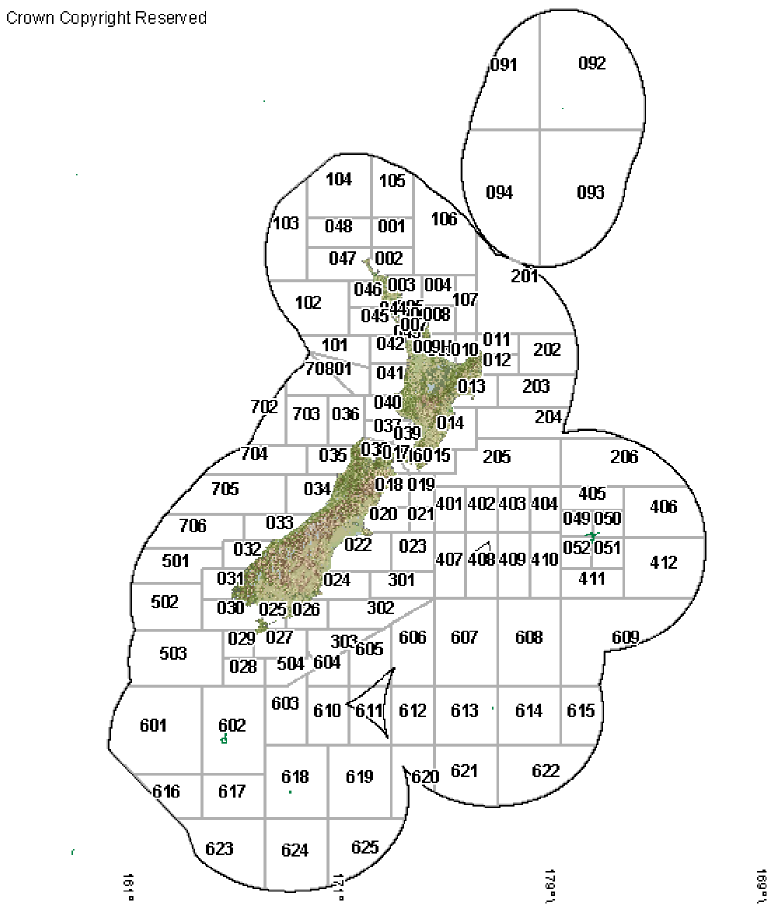
SINSWG: Southern Inshore (Science) Working Group.

Soft Limit: A **biomass** limit below which the requirement for a formal, time-constrained **rebuilding plan** is triggered.

Spawning biomass: The total weight of sexually mature fish in the **stock**. This quantity depends on the abundance of **year classes**, the **exploitation** pattern, the rate of growth, both fishing and **natural mortality rates**, the onset of sexual maturity, and environmental conditions. Same as **mature biomass**.

Spawning (biomass) Per Recruit or Spawning Potential Ratio (SPR): The expected lifetime contribution to the **spawning biomass** for the average recruit to a fishery. For a given exploitation pattern, rate of growth, maturity schedule and **natural mortality**, an **equilibrium** value of SPR can be calculated for any level of fishing mortality. SPR decreases monotonically with increasing fishing mortality.

Statistical area: See the map below for the official **Territorial Sea** and Exclusive Economic Zone (**EEZ**) statistical areas.



Steepness: A parameter of **stock-recruitment relationships** that determines how rapidly, or steeply, it rises from the origin, and therefore how resilient a stock is to rebounding from a depleted state. It equates to the proportion of virgin recruitment that corresponds to 20% $\boldsymbol{B_0}$. A steepness value greater than about 0.9 is considered to be high, whereas one less than about 0.6 is considered to be low. The minimum value is 0.2.

Stock: The term has different meanings. Under the Fisheries Act, it is defined with reference to units for the purpose of fisheries management (Fishstock). On the other hand, a biological stock is a population of a given species that forms a reproductive unit and spawns little if at all with other units. However, there are many uncertainties in defining spatial and temporal geographical boundaries for such biological units that are compatible with established data collection systems. For this reason, the term "stock" is often synonymous with an assessment /management unit, even if there is migration or mixing of some components of the assessment/management unit between areas.

Stock assessment: The analysis of available data to determine stock status, usually through application of statistical and mathematical tools to relevant data in order to obtain a quantitative understanding of the **status** of the **stock** relative to defined management benchmarks or **reference points** (e.g., $\boldsymbol{B_{MSY}}$ and/or $\boldsymbol{F_{MSY}}$).

Stock-recruitment relationship: An equation describing how the expected number of recruits to a stock varies as the **spawning biomass** changes. The most frequently used stock-recruitment relationship is the asymptotic Beverton-Holt equation, in which the expected number of recruits changes very slowly at high levels of spawning biomass.

Stock status: Refers to a determination made, on the basis of **stock assessment** results, about the current condition of the **stock**. Stock status is often expressed relative to management benchmarks and **biological reference points** such as $\boldsymbol{B_{MSY}}$ or $\boldsymbol{B_0}$ or $\boldsymbol{F_{MSY}}$ or $\boldsymbol{F_{\%SPR}}$. For example, the current biomass may be said to be above or below $\boldsymbol{B_{MSY}}$ or to be at some percentage of $\boldsymbol{B_0}$. Similarly, fishing mortality may be above or below $\boldsymbol{F_{MSY}}$ or $\boldsymbol{F_{\%SPR}}$.

Stock structure: (1) Refers to the geographical boundaries of the **stocks** assumed for assessment and management purposes (e.g., albacore tuna may be assumed to comprise two separate **stocks** in the North Pacific and South Pacific), (2) Refers to boundaries that define self-contained **stocks** in a genetic sense, (3) refers to known, inferred or assumed patterns of residence and migration for stocks that mix with one another.

Surplus production: The amount of **biomass** produced by the **stock** (through growth and **recruitment**) over and above that which is required to maintain the [total stock] **biomass** at its current level. If the catch in each year is equal to the surplus production then the biomass will not change.

Sustainability: Pertains to the ability of a fish **stock** to persist in the long term. Because fish **populations** exhibit natural variability, it is not possible to keep all fisheries and **stock** attributes at a constant level simultaneously, thus sustainable fishing does not imply that the fisheries and the **stock** will persist in a constant **equilibrium** state. Because of natural variability, even if $\boldsymbol{F_{MSY}}$ could be achieved exactly each year, **catches** and **stock biomass** will oscillate around their average ***MSY*** and $\boldsymbol{B_{MSY}}$ levels, respectively. In a more general sense, sustainability refers to providing for the needs of the present generation while not compromising the ability of future generations to meet theirs.

TAC: Total Allowable Catch is the sum of the Total Allowable Commercial Catch (**TACC**) and the allowances for customary Māori interests, recreational fisheries interests and other sources of fishing-related mortality that can be taken in a given period, usually a year.

TACC: Total Allowable Commercial Catch is the total regulated commercial catch from a **stock** in a given time period, usually a fishing year.

Target: Generally, a **biomass**, **fishing mortality** or **exploitation rate** level that management actions are designed to achieve with at least a 50% probability.

Threshold: Generally, a **biological reference point** that raises a "red flag" indicating that **biomass** has fallen below the **target**, or **fishing mortality** or **exploitation rate** has increased above its **target**, to the extent that additional management action may be required in order to prevent the stock from declining further and possibly breaching the **soft limit**.

TCEPR: Trawl Catch-Effort Processing Return.

TCER: Trawl Catch-Effort Return.

TLCER: Tuna Longline Catch-Effort Return.

TS: Territorial Sea. A belt of coastal waters extending at most 12 nautical miles (22.2 km; 13.8 mi) from the baseline (usually the mean low-water mark) of a coastal state.

$\boldsymbol{U_{MSY}}$**:** The **exploitation rate** associated with the maximum sustainable yield.

$\boldsymbol{U_{40\%B0}}$**:** The **exploitation rate** associated with a biomass of 40% $\boldsymbol{B_0}$ at equilibrium or on average.

von Bertalanffy equation: An equation describing how fish increase in length as they grow older. The mean length (L) at age a is

$$L = L_\infty(1 - e^{-k(a-t_0)})$$

where L_∞ is the average length of the oldest fish, k is the average growth rate (Brody coefficient) and t_0 is a constant.

Vulnerable biomass: Refers to that portion of a **stock's biomass** that is available to fisheries. Also called **exploitable biomass** or **recruited biomass**.

Year class (cohort): Fish in a **stock** that were born in the same year. Occasionally, a **stock** produces a very small or very large year class which can be pivotal in determining **stock** abundance in later years.

Yield: Catch expressed in terms of weight.

Yield per Recruit (YPR): The expected lifetime **yield** for the average recruit. For a given **exploitation pattern**, rate of growth, and **natural mortality**, an **equilibrium** value of YPR can be calculated for each level of **fishing mortality**. YPR analyses may play an important role in advice for management, particularly as they relate to minimum size controls.

***Z*:** Total mortality rate. The sum of **natural** and **fishing mortality rates**.

Terms of Reference for Fisheries Assessment Working Groups (FAWGs) in 2020

Overall purpose

The purpose of the FAWGs is to assess the status of fish stocks managed within the Quota Management System, as well as other important species of interest to New Zealand. Based on scientific information the FAWGs assess the current status of fish stocks or species relative to MSY-compatible reference points and other relevant indicators of stock status, conduct projections of stock size and status under alternative management scenarios, and review results from relevant research projects. They do not make management recommendations or decisions (this responsibility lies with Fisheries New Zealand fisheries managers and the Minister responsible for fisheries).

Preparatory tasks

1. Prior to the beginning of the main sessions of FAWG meetings (January to May and September to November), Fisheries New Zealand fisheries scientists will produce a list of stocks and issues for which new stock assessments or evaluations are likely to become available prior to the next scheduled sustainability rounds. This list will include stocks for which the fishing industry and others intend to directly purchase scientific analyses. It is therefore incumbent on those purchasing research to inform the relevant FAWG chair of their intentions at least three months prior to the start of the sustainability round. FAWG Chairs will determine the final timetables and agendas for each Working Group.

2. At least six months prior to the main sessions of FAWG meetings, Fisheries New Zealand fisheries managers will alert Fisheries New Zealand science managers and the Fisheries New Zealand Principal Science Advisor to unscheduled special cases for which assessments or evaluations are urgently needed.

Technical objectives

3. To review new research information on stock structure, productivity, abundance and related topics for each fish stock/issue under the purview of individual FAWGs.

4. Where possible, to derive appropriate MSY-compatible reference points[1] for use as reference points for determining stock status, based on the Harvest Strategy Standard for New Zealand Fisheries[2] (the Harvest Strategy Standard).

5. To conduct stock assessments or evaluations for selected fish stocks to determine the status of the stocks relative to MSY-compatible reference points[1] and associated limits, based on the "Guide to Biological Reference Points for Fisheries Assessment Meetings", the Harvest Strategy Standard, and relevant management reference points and performance measures set by fisheries managers.

6. For stocks where the status is unknown, FAWGs should use existing data and analyses to draw logical conclusions about likely future trends in biomass levels and/or fishing mortality (or exploitation) rates if current catches and/or TACs/TACCs are maintained, or if fishers or fisheries managers are considering modifying them in other ways.

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[1] MSY-compatible reference points include those related to stock biomass (i.e., B_{MSY}), fishing mortality (i.e., F_{MSY}) and catch (i.e., MSY itself), as well as analytical and conceptual proxies for each of the three of these quantities.

[2] Link to the Harvest Strategy Standard: https://www.mpi.govt.nz/dmsdocument/728-harvest-strategy-standard-for-new-zealand-fisheries

7. Where appropriate and practical, to conduct projections of likely future stock status using alternative fishing mortality (or exploitation) rates, or catches, or other relevant management actions, based on the Harvest Strategy Standard and input from the FAWG and fisheries managers.

8. For stocks that are deemed to be depleted or collapsed, to develop alternative rebuilding scenarios based on the Harvest Strategy Standard and input from the FAWG and fisheries managers.

9. For fish stocks for which new stock assessments or analyses are not conducted in the current year, to review the existing Fisheries Assessment Plenary report text on the "Status of the Stocks" to determine whether the latest reported stock status summary is still relevant; else to revise the evaluations of stock status based on new data or analyses, or other relevant information.

Working Group reports

10. To include in the Working Group report information on commercial, Māori customary, non-commercial and recreational interests in the stock; as well as all other mortality to that stock caused by fishing, which might need to be allowed for in setting a TAC or TACC. Estimates of recreational harvest will normally be provided by the Marine Amateur Fisheries Working Group (MAFWG).

11. To provide information and advice on other management considerations (e.g., area boundaries, bycatch issues, effects of fishing on habitat, other sources of mortality, and input controls such as mesh sizes and minimum legal sizes) required for specifying sustainability measures. Sections of the Working Group reports related to bycatch and other environmental effects of fishing will be reviewed by the Aquatic Environment Working Group (AEWG) although the relevant FAWG is encouraged to identify to the AEWG Chair any major discrepancies between these sections and their understanding of the operation of relevant fisheries.

12. To summarise the stock assessment methods and results, along with estimates of MSY-compatible references points and other metrics that may be used as benchmarks for assessing stock status.

13. To review, and update if necessary, the "Status of the Stocks" tables in the Fisheries Assessment Plenary report for all stocks under the purview of individual FAWGs (including those for which a full assessment has not been conducted in the current year) based on new data or analyses, or other relevant information.

14. For all important stocks, to complete (and/or update) the Status of Stocks tables using the template provided in the Introductory chapter of the most recent May and November Plenary reports.

15. It is desirable that full agreement amongst technical experts is achieved on the text of the FAWG reports, particularly the "Status of the Stocks" sections, noting that the AEWG will review sections on bycatch and other environmental effects of fishing, and the MAFWG will provide text on recreational harvests. If full agreement amongst technical experts cannot be reached, the Chair will determine how this will be depicted in the FAWG report, will document the extent to which agreement or consensus was achieved, and record and attribute any residual disagreement in the meeting notes.

Working Group input to the Plenary

16. To advise the Fisheries New Zealand Principal Science Advisor about stocks requiring review by the Fisheries Assessment Plenary and those stocks that are not believed to warrant review by the Plenary. The general criteria for determining which stocks should be discussed by the

Plenary are that (i) the assessment is controversial and Working Group members have had difficulty reaching consensus on one or more base cases, or (ii) the assessment is the first for a particular stock or the methodology has been substantially altered since the last assessment, or (iii) new data or analyses have become available that alter the previous assessment, particularly assessments of recent or current stock status, or projections of likely future stock status. Such information could include:

- new or revised estimates of MSY-compatible reference points, recent or current biomass, productivity or yield projections;
- the development of a major trend in the catch or catch per unit effort; or
- any new studies or data that extend understanding of stock structure, fishing patterns, or non-commercial activities, and result in a substantial effect on assessments of stock status.

Membership and Protocols for all Science Working Groups

17. FAWG members are bound by the Membership and Protocols required for all Science Working Group members (see separate document).

Terms of Reference for the Aquatic Environment Working Group (AEWG) in 2020

Overall purpose

For all New Zealand fisheries in the New Zealand TS and EEZ as well as other important fisheries in which New Zealand engages to assess, based on scientific information, the effects of (and risks posed by) fishing on the aquatic environment, including:

- bycatch and unobserved mortality of protected species (e.g., seabirds and marine mammals), fish, and other marine life, and consequent impacts on populations;
- effects on benthic ecosystems, species, and habitat;
- effects on biodiversity, including genetic diversity; and
- changes to ecosystem structure and function from fishing, including trophic effects.

Where appropriate and feasible, such assessments should explore the implications of the effect, including with respect to government standards, other agreed reference points, or other relevant indicators of population or environmental status. Where possible, projections of future status under alternative management scenarios should be made.

AEWG does not make management recommendations or decisions (this responsibility lies with Fisheries New Zealand fisheries managers and the Minister responsible for Fisheries).

Fisheries New Zealand also convenes a Biodiversity Research Advisory Group (BRAG) which has a similar review function to the AEWG. Projects reviewed by BRAG and AEWG have some commonalities in that they relate to aspects of the marine environment. However, the key focus of projects considered by BRAG is on the functionality of the marine ecosystem and its productivity, whereas projects considered by AEWG more commonly focus on the direct effects of fishing.

Preparatory tasks

1. Prior to the beginning of AEWG meetings each year, Fisheries New Zealand fisheries scientists will produce a list of issues for which new assessments or evaluations are likely to become available that year.

2. The Ministry's research planning processes should identify most information needs well in advance but, if urgent issues arise, Fisheries New Zealand staff will alert the relevant AEWG Chair prior to the required meeting of items that could be added to the agenda. AEWG Chairs will determine the final timetables and agendas for meetings.

Technical objectives

3. To review any new research information on fisheries, including risks of impacts, and the relative or absolute sensitivity or susceptibility of potentially affected species, populations, habitats, and systems.

4. To estimate appropriate reference points for determining population, system, or environmental status, noting any draft or published Standards.

5. To conduct environmental assessments or evaluations for selected species, populations, habitats, or systems in order to determine their status relative to appropriate reference points and Standards, where such exist.

6. In addition to determining the status of the species, populations, habitats, and systems relative to reference points, and particularly where the status is unknown, AEWG should explore the potential for using existing data and analyses to draw conclusions about likely future trends in

fishing effects or status if current fishing methods, effort, catches, and catch limits are maintained, or if fishers or fisheries managers are considering modifying them in other ways.

7. Where appropriate and practical, to conduct or request projections of likely future status using alternative management actions, based on input from AEWG, fisheries plan advisers, and fisheries and standards managers, noting any draft or published Standards.

8. For species or populations deemed to be depleted or endangered, to develop ideas for alternative rebuilding scenarios to levels that are likely to ensure long-term viability based on input from AEWG, fisheries managers, noting any draft or published Standards.

9. To review and revise existing environmental and ecosystem consideration sections of Fisheries Assessment Plenary report text based on new data or analyses, or other relevant information.

Working Group input to the Aquatic Environment and Biodiversity Annual Review

10. To include in contributions to the Aquatic Environment and Biodiversity Annual Review (AEBAR) summaries of information on selected issues that may relate to species, populations, habitats, or systems that may be affected by fishing. These contributions are analogous to Working Group reports from the Fisheries Assessment Working Groups.

11. To provide information and scientific advice on management considerations (e.g., area boundaries, bycatch issues, effects of fishing on habitat, other sources of mortality, and input controls such as mesh sizes and minimum legal sizes) that may be relevant for setting sustainability measures.

12. To summarise the assessment methods and results, along with estimates of relevant standards, references points, or other metrics that may be used as benchmarks or to identify risks to the aquatic environment.

13. It is desirable that full agreement among technical experts is achieved on the text of contributions to the AEBAR. If full agreement among technical experts cannot be reached, the Chair will determine how this will be depicted in the AEBAR, will document the extent to which agreement or consensus was achieved, and record and attribute any residual disagreement in the meeting notes.

14. To advise the Fisheries New Zealand Principal Science Advisor and Aquatic Environment manager about issues of particular importance that may require independent review or updating in the AEBAR. The general criterion for determining which issues should be discussed by a wider group or text changed in the AEBAR is that new data or analyses have become available that alter the previous assessment of an issue, particularly assessments of population status or projection results. Such information could include:

    - New or revised estimates of environmental reference points, recent or current population status, trend, or projections;
    - The development of a major trend in bycatch rates or amount;
    - Any new studies or data that extend understanding of population, system, or environmental susceptibility to an effect or its recoverability, fishing patterns, or mitigation measures that have a substantial implications for a population, system, or environment or identify risks associated with fishing activity; and
    - Consistent performance outside accepted reference points or Standards.

Membership and Protocols for all Science Working Groups

15. The AEWG is bound by the same membership and protocols as are other Science Working Groups (see separate document).

Terms of Reference for the Biodiversity Research and Advisory Group (BRAG) in 2020

Overall purpose

Since 2000, the objectives of the Biodiversity Research Programme have been drawn directly from Fisheries New Zealand commitments to Theme 3 of the New Zealand Biodiversity Strategy (NZBS) 2000. Within this framework, the workstreams of the Biodiversity Research Programme have been adapted over time as new issues emerge, to build on synergies with other research programmes and work where biodiversity is under greatest threat from fishing or other anthropogenic activities, within the constraints of the overall purpose of the programme, which are:

> "To improve our understanding of New Zealand marine ecosystems in terms of species diversity, marine habitat diversity, and the processes that lead to healthy ecosystem functioning, and the role that biodiversity has for such key processes" and the NZBS definition of biodiversity (the variability among living organisms from all sources including *inter alia*, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species, and of ecosystem), the science currently commissioned broadly aims to:

- Describe and characterise the distribution and abundance of fauna and flora, as expressed through measures of biodiversity, and improving understanding about the drivers of the spatial and temporal patterns observed;

- Determine the functional role of different organisms or groups of organisms in marine ecosystems, and assess the role of marine biodiversity in mitigating the impacts of anthropogenic disturbance on healthy ecosystem functioning; and

- Identify which components of biodiversity must be protected to ensure the sustainability of a healthy marine ecosystem as well as to meet societal values on biodiversity.

Fisheries New Zealand also convenes an Aquatic Environment Working Group (AEWG) which has a similar review function to BRAG. Projects reviewed by BRAG and AEWG have some commonalities in that they relate to aspects of the marine environment. However, the key focus of projects considered by BRAG is on marine issues related to the functionality of the marine ecosystem and its productivity, whereas projects considered by AEWG are more commonly focused on the direct effects of fishing.

BRAG may identify natural resource management issues that extend beyond fisheries management and make recommendations on priority areas of research that will inform Fisheries New Zealand or other government departments of emerging science results that require the attention of managers, policymakers, and decision-makers in the marine sector. BRAG does not make management recommendations or decisions (this responsibility lies with Fisheries New Zealand fisheries managers and the Minister responsible for Fisheries).

Preparatory tasks

1. Prior to the beginning of BRAG meetings each year, Fisheries New Zealand fisheries scientists will produce a list of issues for which new research projects are likely to be required in the forthcoming financial year. The BRAG Chair will determine the final timetables and agendas.

2. The Ministry's research planning processes should identify most information needs well in advance but, if urgent issues arise, Fisheries New Zealand fisheries managers will alert the Aquatic Environment and Biodiversity Science Manager and the Principal Advisor Fisheries Science at least three months prior to the required meetings where possible.

BRAG technical objectives

3. It is the responsibility of the BRAG to review, discuss, and convey views on the results of marine biodiversity research projects contracted by Fisheries New Zealand. The review process is an evaluation of how existing research results can be built upon to address emerging research issues and needs. It is essentially an evaluation of "what we already know" and how this can be used to obtain "what we need to know”. This information should be used by BRAG to identify gaps in our knowledge and for developing research plans to address these gaps.

4. It is the responsibility of BRAG participants to discuss, evaluate, make recommendations, and convey views on particular research area as required. Individual related projects on a species or fishery or research topic need to be aligned to relevant strategic and policy directions.

5. The recommendations on project proposals for the next financial year will be submitted via the Chair of BRAG to the Principal Science Advisor Fisheries.

6. The Biodiversity Research Programme includes research in New Zealand’s TS, EEZ, Extended Continental Shelf, the South Pacific Region, and the Ross Sea region. There are six scientific work streams as follows:

   - To provide ecological information for a whole-of-systems approach to domestic fisheries management;
   - To develop tools and methods to assess and track the footprint of fisheries related activities on biodiversity and ecosystem functioning;
   - To identify and monitor threats and opportunities for adaptation or mitigation associated with environmental change;
   - To develop the blue-green economy within environmental constraints;
   - To evaluate and safeguard natural capital for future generations; and
   - To progress ecosystem based fisheries management under international obligations.

BRAG input to the Fisheries Assessment Plenary and the Aquatic Environment and Biodiversity Annual Review

7. To contribute to and summarise progress on biodiversity research in the Aquatic Environment and Biodiversity Annual Review. This contribution is analogous to Working Group Reports from the Fisheries Assessment Working Groups.

8. To summarise the assessment methods and results, along with estimates of relevant standards, references points, or other metrics that may be relevant to biodiversity objectives, the Biodiversity Strategy, and international obligations.

9. It is desirable that full agreement among technical experts is achieved on the text of these contributions. If full agreement among technical experts cannot be reached, the Chair will determine how this will be depicted in the Aquatic Environment and Biodiversity Annual Review, will document the extent to which agreement or consensus was achieved, and record and attribute any residual disagreement in the meeting notes.

10. To advise the Principal Science Advisor Fisheries about issues of particular importance that may require review by a Plenary meeting or summarising in the Aquatic Environment and Biodiversity Annual Review. The general criterion for determining which issues should be discussed by a wider group include:

    - Emerging issues, recent or current biodiversity status assessments, trends, or projections;

- The development of a major trend in the marine environment that will impact on marine productivity or ecosystem resilience to stressors; and

- Any new studies or data that impact on international obligations.

Membership and Protocols for all Science Working Groups

11. The BRAG is bound by the same membership and protocols as are other Science Working Groups (see separate document).

Terms of Reference for the Marine Amateur Fisheries Working Group (MAFWG) in 2020

Overall purpose

The purpose of the MAFWG is to assess the harvest of marine amateur fishers from fish stocks managed within or outside the Quota Management System and to review other scientific or research information relevant to the management of marine amateur fisheries. MAFWG does not make management recommendations or decisions; this responsibility lies with Fisheries New Zealand fisheries managers and the Minister responsible for fisheries.

Preparatory tasks

1. It is anticipated that marine amateur fisheries research will focus primarily on the estimation of amateur harvests of fish stocks based on corroborated off-site national surveys conducted about every 5 years. At least six months before any such survey is conducted, Fisheries New Zealand fisheries managers will alert Fisheries New Zealand science managers and the Fisheries New Zealand Principal Science Advisor to their priority stocks for harvest estimation to facilitate good survey design. In years when national surveys are not being conducted, Fisheries New Zealand fisheries managers and fisheries scientists will work closely together to prioritise the meeting of other key information needs in relation to marine amateur fisheries.

Technical objectives

2. To review new research information on the harvest and harvesting patterns of marine amateur fishers using off-site and/or on-site methods, focusing primarily on priority non-commercial and shared stocks or fisheries identified by fisheries managers.

3. To develop methods for making reliable estimates of total catch by fish stock (finfish and shellfish); catch per unit of effort (CPUE); fish lengths and weights within the harvest; daily bag sizes in relation to limits; the spatial and temporal variability of fishing, CPUE, or harvest; and other information likely to inform fisheries management decisions, the development of environmental standards, or the formulation of relevant policy.

Working Group reports

4. In collaboration with relevant Stock Assessment Working Group Chairs, to provide timely and current information on marine amateur harvest for Working Group reports for non-commercial and shared stocks. MAFWG will also periodically review information on marine amateur harvest in Working Group reports to ensure accuracy and currency.

5. As necessary, provide information and advice on other management considerations for marine amateur fisheries (e.g., effects of fishing on habitat, other sources of mortality, and potential input controls such as bag limits, mesh sizes, and minimum legal sizes) required for specifying sustainability measures.

6. It is desirable that full agreement amongst technical experts is achieved on the information provided for Working Group reports on the harvest and other aspects of marine amateur fisheries. If full agreement amongst technical experts cannot be reached, the Chair will determine how this will be depicted in the Working Group report, will document the extent to which agreement or consensus was achieved, and record and attribute any residual disagreement in the meeting notes.

Membership and Protocols for all Science Working Groups

7. MAFWG members are bound by the Membership and Protocols required for all Science Working Group members (see separate document).

Terms of Reference for the Antarctic Working Group (ANTWG) in 2020

Overall purpose

The purpose of the ANTWG is to review science and research information intended for submission to or use by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). CCAMLR is an inter-governmental organisation that is committed to conserving the marine life of the Southern Ocean while allowing rational use of marine resources, including commercial fishing. The CCAMLR Convention requires that management considers the effects of fishing on dependent and associated species as well as on the target species. The area of jurisdiction of the CCAMLR Convention is approximately south of the circumpolar Antarctic Polar Front in the Southern Ocean. Science and research requested or used by CCAMLR may include, *inter alia*, fisheries characterisations, abundance indices, catch-at-age or catch-at-length data, and stock assessment modelling to assess the status of fish stocks managed by CCAMLR; bycatch and unobserved mortality of protected species, fish, and other marine life; effects on biodiversity and benthic biodiversity, species, and habitat; and changes to ecosystem structure and function as a result of fishing, including trophic effects. The ANTWG also undertakes scientific review of documents and papers that may be submitted to the scientific working groups of CCAMLR to aid and inform its management. The ANTWG does not make management recommendations or decisions; these responsibilities lie with CCAMLR's Scientific Committee and the Commission.

Preparatory tasks

1. Prior to the first meeting of the ANTWG each year, the ANTWG Chair will produce a list of stocks/issues for which new stock assessments, evaluations, impact assessments, risk assessments, or other scientific analyses have been requested by the CCAMLR Scientific Committee or the Commission (including its contributing bodies), fishing industry, or other stakeholders. The ANTWG Chair will determine the final timetables and agendas of the working group each year, taking account of the available time and resources.

Technical objectives

2. To review new research information on stock structure, productivity, abundance, and related topics for each fish stock or environmental issue under the purview of the ANTWG.

3. Where possible, to derive yields or reference points requested by CCAMLR's Scientific Committee or Commission related to fish stocks or environmental issues relevant to CCAMLR fisheries.

4. To conduct stock assessments or evaluations for selected stocks to determine the precautionary yields and status of the stocks relative to the requested reference points or, if no such reference points are specified by CCAMLR, MSY-compatible reference points and associated limits, based on the "Guide to Biological Reference Points for Fisheries Assessment Meetings" and New Zealand's Harvest Strategy Standard.

5. For stocks where the status is unknown, the ANTWG should, where possible, use any existing data and analyses to draw conclusions about likely future trends in biomass levels and/or fishing mortality (or exploitation) rates if current catches and/or TACs are maintained, or if fishers or CCAMLR are considering modifying them in other ways.

6. Where requested by the CCAMLR Scientific Committee or Commission, to conduct projections of likely future stock status using alternative fishing mortality (or exploitation) rates or catches and other relevant management actions, based on input from the ANTWG and any guidance from the CCAMLR Scientific Committee or Commission.

7. Where requested by the CCAMLR Scientific Committee or Commission, in relation to specified stocks, to develop and report on alternative rebuilding scenarios.

8. To conduct environmental impact assessments and qualitative or quantitative risk assessments in relation to bycatch species, other species of concern, benthic systems, or vulnerable marine ecosystems to support the work of the CCAMLR Scientific Committee and Commission.

Working Group reports

9. To review, and update if necessary, the "Status of the Stocks" tables in the Fisheries Assessment Plenary report based on new data or analyses, or other relevant information.

10. To complete (and/or update) the Status of Stocks tables using the template provided in the Introductory chapter of the most recent May Plenary report.

11. To review, and update if necessary, the "Antarctic Science" chapter of the Aquatic Environment and Biodiversity Review (AEBAR) based on new data or analyses, or other relevant information.

12. It is desirable that full agreement amongst technical experts is achieved on the text of the ANTWG reports. If full agreement amongst technical experts cannot be reached, the Chair will determine how this will be depicted in the ANTWG report, will document the extent to which agreement or consensus was achieved, and record and attribute any residual disagreement in the meeting notes.

Papers and reports to CCAMLR

13. Papers and reports summarising work reviewed by the ANTWG are generally submitted to CCAMLR's Scientific Committee, and their content varies widely. It is desirable that full agreement amongst technical experts is achieved on the content of such papers or reports, noting that deadlines for submission to CCAMLR may require the Chair to finalise text after a meeting of the ANTWG has considered and resolved scientific issues. If full agreement amongst technical experts cannot be reached, the Chair will determine how this will be depicted in the paper or report to be submitted to CCAMLR. In such cases, the Chair will also document the extent to which agreement or consensus was achieved and record and attribute any residual disagreement in the meeting notes.

Membership and Protocols for all Science Working Groups

14. ANTWG members are bound by the Membership and Protocols required for all Science Working Group members (see separate document).

Terms of Reference for the South Pacific Assessment Working Group (SPACWG) in 2020

Overall purpose

The purpose of the SPACWG is to review science and research information intended for submission to or use by the South Pacific Regional Fisheries Management Organisation (SPRFMO). SPRFMO is an inter-governmental organisation that is committed to the long-term conservation and sustainable use of the fisheries resources of the South Pacific Ocean and, in so doing, safeguarding the marine ecosystems in which the resources occur. The SPRFMO Convention applies to the high seas of the South Pacific. Science and research information requested or used by SPRFMO may include, *inter alia*, fisheries characterisations, abundance indices, catch-at-age or catch-at-length data, and stock assessment modelling to assess the status of fish stocks managed by SPRFMO. Also included will be characterisations, impact assessments, or risk assessments for the environmental effects of fisheries in the SPRFMO Area, particularly regarding vulnerable marine ecosystems (VMEs), and modelling work to assess the trade-offs inherent in, or likely outcomes of, potential management choices. SPACWG does not make management recommendations or decisions; these responsibilities lie with SPRFMO's Scientific Committee, Compliance and Technical Committee, and the Commission.

Preparatory tasks

1. Prior to the first meeting of SPACWG each year, the SPACWG Chair will produce a list of stocks/issues for which new stock assessments, evaluations, impact assessments, or risk assessments have been requested by the SPRFMO Commission (including its contributing bodies) or by fishing industry or other stakeholders. The SPACWG Chair will determine the final timetables and agendas of the working group each year, taking account of the available time and resources.

Technical objectives

2. To review new research information on stock structure, productivity, abundance, and related topics for each fish stock or environmental issue under the purview of SPACWG.

3. Where possible, to derive reference points requested by SPRFMO's Scientific Committee or Commission related to fish stocks or environmental issues relevant to SPRFMO fisheries.

4. To conduct stock assessments or evaluations for selected stocks in order to determine the status of the stocks relative to the requested reference points or, if no such reference points are specified by SPRFMO, MSY-compatible reference points and associated limits, based on the "Guide to Biological Reference Points for Fisheries Assessment Meetings" and New Zealand's Harvest Strategy Standard.

5. For stocks where the status is unknown, SPACWG should, where possible, use any existing data and analyses to draw conclusions about likely future trends in biomass levels and/or fishing mortality (or exploitation) rates if current catches and/or TACs are maintained, or if fishers or SPRFMO are considering modifying them in other ways.

6. Where requested by the SPRFMO Commission or Scientific Committee, to conduct projections of likely future stock status using alternative fishing mortality (or exploitation) rates or catches and other relevant management actions, based on input from the SPACWG and any guidance from the SPRFMO Scientific Committee or Commission.

7. Where requested by the SPRFMO Scientific Committee or Commission, in relation to specified stocks, to develop and report on alternative rebuilding scenarios.

8. To conduct environmental impact assessments and qualitative or quantitative risk assessments in relation to bycatch species, other species of concern, benthic systems, or vulnerable marine ecosystems to support the work of the SPRFMO Scientific Committee and Commission.

Papers and reports to SPRFMO

9. Papers and reports summarising work reviewed by SPACWG are generally submitted to SPRFMO's Scientific Committee, and their content varies widely. It is desirable that full agreement amongst technical experts is achieved on the content of such papers or reports, noting that deadlines for submission to SPRFMO may require the Chair to finalise text after a meeting of SPACWG has considered and resolved scientific issues. If full agreement amongst technical experts cannot be reached, the Chair will determine how this will be depicted in the paper or report to be submitted to SPRFMO. In such cases, the Chair will also document the extent to which agreement or consensus was achieved and record and attribute any residual disagreement in the meeting notes.

Membership and Protocols for all Science Working Groups

10. SPACWG members are bound by the Membership and Protocols required for all Science Working Group members (see separate document).

Terms of Reference for the Statistics, Assessments and Methods Working Group (SAMWG) in 2020

Overall purpose

The purpose of the SAMWG is to review and evaluate statistical methods, stock assessment methods, risk assessment methods, and any other quantitative or qualitative methods used in stock assessments, or research into the environmental effects of fishing, or assessments of marine biodiversity. The SAMWG will:

a) Develop a work programme each year to review and progress statistics, assessments, and methods used by, or suitable for, Fisheries New Zealand purposes; and

b) Review quantitative and qualitative methods, particularly those that are novel, complex, or contentious, referred by the Chairs of other Science Working Groups (SWGs).

The extent to which the SAMWG can fulfil these two purposes will be contingent on the availability of qualified quantitative staff and research providers to undertake and present the necessary analyses. On the basis of its reviews, the SAMWG will make recommendations, formulate guidelines, or suggest future research and provide these to other relevant SWGs or other entities. The SAMWG does not make management recommendations or decisions (this responsibility lies with Fisheries New Zealand fisheries managers and the Minister responsible for fisheries).

Preparatory tasks

1. Prior to the beginning of the financial year, Fisheries New Zealand fisheries scientists will produce a list of projects likely to be progressed in the coming year. This will be conducted in conjunction with the Chairs of other SWGs and will be reviewed periodically with the Chairs throughout the year.

2. The list should also include relevant projects, including those already contracted or undertaken, and those anticipated by stakeholders directly purchasing scientific analyses. It is therefore incumbent on those purchasing research to inform the SAMWG Chair(s) of their intentions, preferably at least three months prior to the start of the financial year.

3. Some research purchased by Fisheries New Zealand fisheries managers may also benefit from review by the SAMWG. Fisheries New Zealand managers should be involved in producing the initial list of projects, and should alert Fisheries New Zealand science managers and the Fisheries New Zealand Principal Science Advisor to unscheduled special cases for which review or evaluation are urgently needed.

4. The SAMWG may have different Fisheries New Zealand chairs for specific topic areas.

5. SAMWG Chair(s) will determine the final timetables and agendas for each Working Group.

Technical objectives

In conjunction with the Chairs of relevant SWGs and fisheries managers, the SAMWG will:

6. Review and evaluate new research information on statistical methods, stock assessment methods, risk assessment methods, and any other quantitative or qualitative methods used in stock assessments, research into the environmental effects of fishing, or assessments of marine biodiversity, as specified in an annual research programme, or in *ad hoc* opportunities or requests throughout the year for such reviews, or as referred by the Chairs of other SWGs or fisheries managers.

7. Review and evaluate new methodologies for determining reference points for stock assessments and risk assessments.

8. Review and evaluate new methodologies for assessing the status of low information stocks or non-target species, or assessing risks to low information stocks or non-target species.

9. Review and evaluate new approaches to developing Management Procedures, Management Strategy Evaluations, and Harvest Control Rules.

10. Review and evaluate new methods for assessing or mitigating the environmental effects of fishing.

11. Review and evaluate novel tools for accessing, querying, analysing, and storing data to solve specific fisheries problems.

Reports produced

12. The SAMWG will make recommendations, formulate guidelines, or suggest future research and provide these to research providers, or to other relevant SWGs, or to other entities. These may be recorded in the records of SAMWG meetings, or written up more formally in Fisheries Research Reports (FARs) or Aquatic Environment and Biodiversity Reports (AEBRs).

13. In general, such recommendations, guidelines, and future research considerations will be made in the form of a report outlining the rationale by which the SAMWG reached its conclusions. Where relevant, the research evaluated by the SAMWG may be published either as a FAR or an AEBR. Alternatively, the report of the SAMWG could be appended to a relevant FAR or AEBR, or provided to relevant entities as a separate, unpublished (but publicly available) short document.

14. It is desirable that full agreement amongst technical experts is achieved on the text of the documents to which the SAMWG contributes. If full agreement amongst technical experts cannot be reached, the Chair will determine how this will be depicted in the SAMWG minutes or other documents, will document the extent to which agreement or consensus was achieved, and record and attribute any residual disagreement in the meeting notes.

Working Group input to the Plenary and AEBAR

15. The SAMWG will contribute appropriate text to the Plenary and AEBAR, as needed, in coordination with the Chairs of other SWGs.

Membership and Protocols for all Science Working Groups

16. SAMWG members are bound by the Membership and Protocols required for all Science Working Group members (see separate document).

Membership and Protocols for all Science Working Groups in 2020

This document summarises the protocols for membership and participation in all Science Working Groups including Fisheries Assessment Working Groups (FAWGs), the Aquaculture Working Group (AQWG), the Aquatic Environment Working Group (AEWG), the Biodiversity Research Advisory Group (BRAG), the Highly Migratory Species Working Group (HMSWG), the South Pacific Working Group (SPACWG), the Antarctic Working Group (ANTWG), and the Marine Amateur Fisheries Working Group (MAFWG).

Working Group chairs

1. Fisheries New Zealand will select and appoint the Chairs for Science Working Groups. The Chair will be a Fisheries New Zealand fisheries or marine scientist who is an active participant in the Working Group, providing technical input, rather than simply being a facilitator. Working Group Chairs will be responsible for:

    - ensuring that Working Group participants are aware of the Terms of Reference for the Working Group, and that the Terms of Reference are adhered to by all participants;
    - setting the rules of engagement, facilitating constructive questioning, and focusing on relevant issues;
    - ensuring that all peer review processes are conducted in accordance with the Research and Science Information Standard for New Zealand Fisheries[3] (the Research Standard), and that research and science information is reviewed by the relevant Working Group against the *P R I O R* principles for science information quality (page 6 in the Research Standard) and the criteria for peer review (pages 12–16 in the Research Standard);
    - requesting and documenting the names and affiliations of participants at each Working Group meeting and ensuring that these are noted in the Working Group meeting notes. Chairs are responsible for managing conflicts of interest (refer to page 15 of the Research Standard) and ensuring that fisheries management or aquaculture implications do not jeopardise the objectivity of the review or result in biased interpretation of results;
    - ensuring that the quality of information that is intended or likely to inform fisheries management or aquaculture decisions, the development of environmental standards, or the formulation of relevant fisheries policy is ranked in accordance with the information ranking guidelines in the Research Standard (page 21–23), and that resulting information quality ranks are appropriately documented in the Fisheries Assessment Plenary and the Aquatic Environment and Biodiversity Annual Review (AEBAR);
    - striving for consensus while ensuring the transparency and integrity of research analyses, results, conclusions, and final reports; and
    - reporting on Working Group recommendations, conclusions, and action items; and ensuring follow-up and communication with the Fisheries New Zealand Principal Science Advisor, relevant Fisheries New Zealand fisheries management or aquaculture staff, and other key stakeholders.

Working Group members

2. Membership of Science Working groups will be open to any participant with the agreement of the Working Group Chair provided that they expect to meet a participation threshold that may vary depending on the Working Group in question. All members are expected to actively

[3] Link to the Research Standard: https://fs.fish.govt.nz/NR/rdonlyres/D1158D67-505F-4B9D-9A87-13E5DE0A3ABC/0/ResearchandScienceInformationStandard2011.pdf

participate in at least two, and preferably considerably more, Working Group meetings during a given year.

3. Working Groups will consist of the following participants:

- Fisheries New Zealand science chair – required;
- research providers – required (may be the primary researcher, or a designated substitute capable of presenting and discussing the agenda item);
- other scientists not conducting the presented research to act in a peer review capacity;
- representatives of relevant Fisheries New Zealand fisheries management or aquaculture teams; and
- any interested party who meets the participation threshold and agrees to the standards of participation below.

4. Working Group participants must commit to:

- participating appropriately in discussions;
- resolving issues;
- following up on agreements and tasks;
- maintaining confidentiality of Working Group discussions and deliberations (unless otherwise agreed in advance, and subject to the constraints of the Official Information Act);
- adopting a constructive approach;
- avoiding repetition of earlier deliberations, particularly where agreement has already been reached;
- facilitating an atmosphere of honesty, openness, and trust;
- respecting the role of the Chair; and
- listening to the views of others, and treating them with respect.

5. Participants in Working Group meetings will be expected to declare their sector affiliations and contractual relationships to the research under review, and to declare any substantial conflicts of interest related to any particular issue or scientific conclusion.

6. Working Group participants must adhere to the requirements of independence, impartiality, and objectivity listed under the Peer Review Criteria in the Research Standard (pages 12–16). It is understood that Working Group participants will often be representing particular sectors and interest groups and may be expressing the views of those groups. However, when participating in the review of science information, representatives are expected to step aside from their sector affiliations and to ensure that individual and sector views do not result in bias in the science information and conclusions.

7. Participants in each Working Group will have access to the corresponding sections of the Science Working Group website including the Working Group papers and other information provided in those sections. Access to Science Working Group websites will generally be restricted to those who have a reasonable expectation of attending at least two meetings of a given Science Working Group each year.

8. Working Group members who do not adhere to the standards of participation (paragraph 4), or who use Working Group papers and related information inappropriately (see paragraph 10), may be requested by the Chair to leave a particular meeting or to refrain from attending one or more future meetings. In more serious instances, members may be removed from the Working

Group membership and denied access to the Working Group website for a specified period of time, or permanently.

Working Group papers and related information

9. Working Group papers will be posted on the Fisheries New Zealand website prior to meetings if they are available. As a general guide, PowerPoint presentations and draft or discussion papers should be available at least two working days before a meeting, and near-final papers should be available at least five working days before a meeting if the Working Group is expected to agree to the paper. However, it is also likely that some papers will be made available for the first time during the meeting due to time constraints. If a paper is not available for sufficient time before the meeting, the Chair may provide for additional time following the meeting for additional comments from Working Group members.

10. Working Group papers are "works in progress" intended to facilitate the discussion of analyses by the Working Groups. They often contain preliminary results that are receiving peer review for the first time and, as such, may contain errors or preliminary analyses that will be superseded by more rigorous work. **For these reasons, no-one may release the papers or any information contained in these papers to external parties. In general, Working Group papers should not be cited.** Exceptions may be made in rare instances by obtaining permission in writing from the Principal Advisor Fisheries Science, and the authors of the paper. It is also anticipated that Working Group participants who are representing others at a particular Working Group meeting or series of such meetings may wish to communicate preliminary results to the people they are representing. Participants, along with recipients of the information, are required to exercise discretion in doing this, and to guard against preliminary results being made public.

11. From time to time, Fisheries New Zealand commissions external reviews of analyses, models, or issues. Terms of Reference for these reviews and the names of external reviewers may be provided to the Working Group for information or feedback. It is extremely important to the proper conduct of these reviews that all contact with the reviewers is through the Chair of the Working Group or the Principal Advisor Fisheries Science. Under no circumstances should Working Group members approach reviewers directly until after the final report of the review has been published.

Working Group meetings

12. Meetings will take place as required, generally January–April and July–November for FAWGs and throughout the year for other Working Groups (AEWG, AQWG, BRAG, HMSWG, SPACWG, ANTWG, and MAFWG).

13. A quorum will be reached when the Chair, the designated presenter, and at least three other technical experts are present. In the absence of a quorum, the Chair may decide to proceed as a sub-group, with outcomes being discussed with the wider Working Group via email or taken forward to the next meeting at which a quorum is formed.

14. The Chair is responsible for deciding, with input from the entire Working Group, but focusing primarily on the technical discussion and the views of technical expert members:

- the quality and acceptability of the information and analyses under review;
- the way forward to address any deficiencies;
- the need for any additional analyses;
- contents of research reports, Working Group reports, and AEBAR chapters;
- choice of best models and sensitivity analyses to be presented; and

- the status of the stocks, or the status/performance in relation to any relevant environmental standards or targets.

15. The Chair is responsible for facilitating a consultative and collaborative discussion.

15. Working Group meetings will be run formally, with agendas pre-circulated, and formal records kept of recommendations, conclusions and action items.

16. A record of recommendations, conclusions, and action items will be posted on the Fisheries New Zealand website after each meeting has taken place.

17. Data upon which analyses presented to the Working Groups are based must be provided to Fisheries New Zealand in the appropriate format and level of detail in a timely manner (i.e., the data must be available and fully-accessible to Fisheries New Zealand; however, data confidentiality concerns mean that some data may not necessarily be made available to Working Group members).

18. Working Group processes will be evaluated periodically, with a view to identify opportunities for improvement. Terms of Reference and the Membership and Protocols may be updated as part of this review.

19. Fisheries New Zealand scientists and science officers will provide administrative support to the Working Groups.

Information Quality Ranking

20. Science Working Groups are required to rank the quality of research and science information that is intended or likely to inform fisheries management or aquaculture decisions, in accordance with the science information quality ranking guidelines in the Research Standard (pages 21–23). Information quality rankings should be documented in Working Group reports and, where appropriate, in Status of Stock summary tables. Note that:

    - Working Groups are not required to rank all research projects and analyses, but key pieces of information that are expected or likely to inform fisheries management or aquaculture decisions, the development of environmental decisions, or the formulation of relevant policy should receive a quality ranking;
    - explanations substantiating the quality rankings will be included in Working Group reports. In particular, the quality shortcomings and concerns for moderate/mixed and low quality information should be documented; and
    - the Chair, working with participants, will determine which pieces of information require a quality ranking. Not all information resulting from a particular research project would be expected to achieve the same quality rank, and different quality ranks may be assigned to different components, conclusions or pieces of information resulting from a particular piece of research.

Record-keeping

21. The overall responsibility for record-keeping rests with the Chair of the Working Group, and includes:

    - keeping notes on recommendations, conclusions, and follow-up actions for all Working Group meetings, and to ensure that these are available to all members of the Working Group and the Principal Advisor Fisheries Science in a timely manner. If full agreement on the recommendations or conclusions cannot readily be reached amongst technical experts, then the Chair will document the extent to which agreement or consensus was achieved and record and attribute any residual disagreement in the meeting notes; and

- compiling a list of generic assessment issues and specific research needs for each stock, species, or environmental issue under the purview of the Working Group, for use in subsequent research planning processes.

Fisheries Assessment Working Groups: Membership 2020

Antarctic Working Group

Convenors: Marine Pomarède and Nathan Walker

Members: Matthew Baird, Stephanie Brown, Jennifer Devine, Alistair Dunn, Jack Fenaughty, Greig Funnell, Simon Hoyle, Leyla Knittweis-Mifsud, Dan MacGibbon, Bradley Moore, Monique Messina, Phillip Neubauer, Richard O'Driscoll, Steve Parker, Matt Pinkerton, Brodie Plum, Darryn Shaw, Andy Smith, Perry Smith, Josh Van Lier, Tim Vaughan-Sanders, Barry Weeber, D'arcy Webber.

Species: Antarctic toothfish

Aquatic Environment Working Group

Convenors: Rich Ford, William Gibson, Marco Milardi, Ben Sharp, and Karen Tunley

Members: Ed Abraham, Owen Anderson, Sonja Austin, Hilary Ayrton, Karen Baird, Suze Baird, Barry Baker, Scott Baker, Joshua Baller, Josh Barclay, Steve Beatson, Katrin Berkenbusch, Tiffany Bock, Laura Boren, Christine Bowden, David Bowden, Erin Breen, Paul Breen, Anthony Brett, Susan Chalmers, Simon Childerhouse, Malcolm Clark, Tom Clark, Katie Clemens-Seely, Deanna Clement, George Clement, Damian Cloeter, Justin Cooke, Igor Debski, Peter Dillingham, Matt Dunn, Charles Edwards, Mark Edwards, Jack Fenaughty, Brit Finucci, David Foster, Malcolm Francis, Allen Frazer, Sharleen Gargiulo, Shane Geange, Mark Geytenbeek, Sharyn Goldstien, Trude Hellesland, Jeremy Helson, Kristina Hillock, Freydis Hjorvarsdottis, Lyndsey Holland, Daniel Kerrigan, Brianna King, Kirstie Knowles, Jo Lambie, Todd Landers, Laws Lawson, Amanda Leathers, Mary Livingston, Carolyn Lundquist, Dave Lundquist, Greg Lydon, Lucy Manning, Darryl MacKenzie, Gemma McGrath, Stefan Meyer, Karen Middlemiss, David Middleton, Jodi Milne, Janice Molloy, Kiri Morgan, Mark Morrison, Rikki Mules, Philip Neubauer, Richard O'Driscoll, Jenny Oliver, Enrique Pardo, Graham Parker, Steve Parker, Darren Parsons, Johanna Pierre, Matt Pinkerton, Trish Rea, Nathan Reid, Yvan Richard, Peter Ritchie, Jim Roberts, Carol Scott, Katherine Short, Liz Slooten, Andy Smith, Paul Starr, John Taunton-Clark, David Thompson, Finlay Thompson, Rob Tilney, Geoff Tingley, Rob Tinkler, Di Tracey, Ian Tuck, Dominic Vallieres, Anton Van Helden, Adam Watson, Shannon Weaver, D'Arcy Webber, Barry Weeber, Richard Wells, Tamar Wells, James Williams, Jeanne Wissing, Oliver Wilson, Andrew Wright, Jingjing Zhang.

Biodiversity Research and Advisory Group (BRAG)

Convenor: Mary Livingston

Members: Teresa A'mar, Owen Anderson, Erik Behrens, Tiffany Bock, David Bowden, Sarah Bury, Malcolm Clark, Damien Cloester, Vonda Cummings, Roberta D'Archino, Moira Decima, Matt Dunn, Pablo Escobar-Flores, Jack Fenaughty, Debbie Freeman, Jonathan Gardner, Sharleen Gargiulo, Shane Geange, William Gibson, Britt Graham, Barb Hayden, Lyndsey Holland, Daniel Kerrigan, Brianna King, Kirstie Knowles, Cliff Law, Amanda Leathers, Daniel Leduc, Carolyn Lundquist, Greg Lydon, Alison MacDiarmid, Marco Milardi, Wendy Nelson, Philip Neubauer, Richard O'Driscoll, Jenny Oliver, Enrique Pardo, Darren Parsons, Matt Pinkerton, Nathan Reid, Jim Roberts, Karen Robinson, Andy Smith, Phil Sutton, Di Tracey, Karen Tunley, Brenton Twist, Ashley Rowden, Richard Wells, Oliver Wilson.

Deepwater Working Group

Convenors: Gretchen Skea and Pamela Mace

Members: John Annala, Sira Ballara, Steve Bishop, Tiffany Bock, George Clement, Patrick Cordue, Ian Doonan, Alistair Dunn, Matt Dunn, Adele Dutilloy, Pablo Escobar-Flores, Jack Fenaughty, David Foster, Charles Heaphy, Lyndsey Holland, Steven Holmes, Peter Horn, Simon Hoyle, Rosemary Hurst, Daniel Kerrigan, Marco Kienzle, Leyla Knittweis, Yoann Ladroit, Adam Langley, Kath Large, Greg Lydon, Dan MacGibbon, Vidette McGregor, Andy McKenzie, Jeremy McKenzie, David Middleton, Richard O'Driscoll, Graham Patchell, Jim Roberts, Tim Ryan, Richard Saunders, Andy Smith, Paul Starr, Rob Tilney, Geoff Tingley, Rob Tinkler, Ian Tuck, Nathan Walker, D'Arcy Webber, Barry Weeber, Richard Wells.

Species:

Alfonsino
Arrow squid
Barracouta (BAR 4,5 & 7)
Black cardinalfish
Black oreo
Blue mackerel (EMA 3&7)
Frostfish (FRO 3 – 9)
Gemfish (SKI 3&7)
Dark ghost shark (GSH 4 – 6)
Pale ghost shark
Hake
Hoki
Jack mackerel (JMA 3&7)
Ling
Lookdown dory
Orange roughy
Redbait
Ribaldo (RIB 3 – 8)
Rubyfish
Sea perch (SPE 3 – 7)
Silver warehou
Smooth oreo
Southern blue whiting
Spiny dogfish (SPD 4&5)
White warehou

Eel Working Group

Convenor: Marc Griffiths

Members: Joshua Baller, Mike Beentjes, Jacques Boubee, Anthony Charsley, Bill Chisholm, Shannan Crowe, Allen Frazer, Tom Hollings, Mike Holmes, Simon Howard, Simon Hoyle, Mark James, John Jameson, Erik Kuijten, Pamela Mace, Michael Martin, Marco Milardi, Duncan Petrie, Alan Riwaka , Dave West, Erica Williams.

Species: Freshwater eels

Marine Amateur Fisheries Working Group

Convenors: Martin Cryer and Gretchen Skea

Members: Sonja Austin, Hilary Ayrton, Marty Bowers, Paul Breen, Tom Clark, Niki Davey, Mark Edwards, Mark Geytenbeek, Alistair Gray, Bruce Hartill, Jake Hore, Andreas Heinemann, Andy Heinemann, John Holdsworth, Peter van Kampen, Graeme McGregor, Andy McKay, Alicia McKinnon, David Middleton, Jesse Rihia, Carol Scott, Paul Starr, Daryl Sykes, John Taunton-Clark, Scott Tindale, D'Arcy Webber, Oliver Wilson, Jeremy Wynne-Jones.

Northern and Southern Inshore Working Groups

Convenor: Marc Griffiths

Members: John Annala, Josh Barclay, Mike Beentjes, Heather Benko, Anthony Brett, Mark Chambers, Bill Chisholm, Tom Clark, Alistair Dunn, Matt Dunn, Dave Foster, Malcolm Francis, Allen Frazer, Mark Geytenbeek, Bruce Hartill, Sonja Hempel, Freya Hjorvarsdottir, John Holdsworth, Rosie Hurst, Briana King, Leyla Knittweis-Mifsud, Pamela Mace, Adam Langley, Laws Lawson, Graeme McGregor, Dan MacGibbon, Jeremy McKenzie, Alicia McKinnon, David Middleton Jodi Milne, Phil Neubauer, Richard O'Driscoll, Steve Parker, Darren Parsons, Nathan Reid, Carol Scott, Bill

Smellie, Paul Starr, Finlay Thompson, Laura Tremblay-Boyer, Kevin Sullivan, Ali Undorf-Lay, John Taunton-Clark, Nathan Walker, Cameron Walsh, Adam Watson, Richard Wells, Tamara Wells, Nikki Wilkinson, Oliver Wilson, Lauren Woon.

Species:

Anchovy	Groper	Ribaldo (RIB 1, 2 & 9)
Barracouta (BAR 1)	Jack mackerel (JMA 1)	Rough skate
Bluenose	John dory	School shark
Blue cod	Kahawai	Sea perch (SPE1,2,8,9)
Blue mackerel (EMA 1&2)	Kingfish	Smooth skate
Blue moki	Leatherjacket	Snapper
Blue warehou	Ling (LIN 1&2)	Spiny dogfish (SPD1,3,7,8)
Butterfish	Parore	Sprats
Elephant fish	Pilchard	Stargazer
Flatfish	Porae	Tarakihi
Gemfish (SKI 1&2)	Red cod	Trevally
Garfish	Red gurnard	Trumpeter
Grey mullet	Red snapper	Yellow-eyed mullet
	Rig	

Shellfish Working Group

Convenors: Marine Pomarède, Martin Cryer, Marco Milardi

Members: John Annala, Michael Arbuckle, Josh Barclay, Mike Beentjes, Roger Belton, Katrin Berkenbusch, Anthony Brett, Des Boyce, Andrew Caddie, Damian Cloeter, Hannah Charan-Dixon, Mike Connolly, Jeremy Cooper, Tony Craig, Paul Creswell, Jack Fenaughty, Allen Frazer, Mark Geytenbeek, Sean Handley, Natalie Karaitiana, Daniel Kerrigan, Doug Loder, Pamela Mace, Craig Marsh, Winnie Matahaere, Tom McCowan, Keith Michael, Bryony Miller, Te Taiawatea Moko-Mead, Phil Neubauer, Isaac Piper, Richard Prosch, Dave Redshaw, Tanith Robb, Phil Ross, Storm Stanley, Fred Te Miha, Michelle Taiaroa McDonald, Laura Tremblay-Boyer, Ian Tuck, Karen Tunley, Peter van Kempen, D'Arcy Webber, Chris West, Lyndsey White, James Williams, Graeme Wright, Tom Wright, Miao Zhang.

Species:

Cockles (COC 1A & 7A)	Horse mussel Kina	Scampi
Deepwater crab	King crab	Sea cucumber
Dredge oysters (OYU 5, OYS 7 & 7C)	Knobbled whelk	Surf clam
Deepwater (king) clam (Geoduc)	Large trough shell	Toheroa
Deepwater tuatua	Paddle crab	Triangle shell
Fine (Silky) dosinia	Paua (PAU 2-7)	Trough shell
Frilled venus shell	Pipi (PPI 1A)	Tuatua
Giant spider crab	Prawn killer	
Green-lipped mussel	Queen scallop	
	Red crab	
	Ringed dosinia	
	Scallop (SCA 1, CS & 7)	

South Pacific Working Group

Convenor: Martin Cryer

Members: Owen Anderson, Tiffany Bock, Malcom Clark, Patrick Cordue, Duncan Currie, Igor Debski, Alistair Dunn, Matt Dunn, Jack Fenaughty, Shane Geange, Lee Georgeson, Peter Horn, Dean Jurasovich, Carolyn Lundquist, Marco Milardi, Richard O'Driscoll, Steve Parker, Roland Pitcher, Brodie Plum, Ashley Rowden, Gretchen Skea, Andy

Smith, Fabrice Stephenson, Karli Thomas, Geoff Tingley, Hamish Tijsen, Te Aomihia Walker, Cath Wallace, Barry Weeber.

Statistics, Assessments and Methods Working Group

Convenor: Pamela Mace

Members: Edward Abraham, John Annala, Paul Breen, Marc Chambers, Martin Cryer, Ian Doonan, Alistair Dunn, Matt Dunn, Adele Dutilloy, Jack Fenaughty, Marc Griffiths, Steven Holmes, Simon Hoyle, Marco Kienzle, Adam Langley, Kath Large, Vidette McGregor, Andy McKenzie, Jeremy McKenzie, David Middleton, Marine Pomarède, Phil Neubauer, Richard O'Driscoll, Nokuthaba Sibanda, Gretchen Skea, Paul Starr, John Taunton-Clark, Geoff Tingley, Ian Tuck, D'Arcy Webber.

Guide to Biological Reference Points for Fisheries Assessment Meetings

The Guide to Biological Reference Points was originally developed by a Stock Assessment Methods Working Group in 1988, with the aim of defining commonly used terms, explaining underlying assumptions, and describing the biological reference points used in fisheries assessment meetings and associated reports. However, this document has not been substantially revised since 1992 and the methods described herein, while still used in several assessments, have been replaced with other approaches in a number of cases. Some of the latter approaches are described in the Harvest Strategy Standard for New Zealand Fisheries and the associated Operational Guidelines, and are being further developed in various Fisheries Assessment Working Groups and the current Stock Assessment Methods Working Group.

Here, methods of estimation appropriate to various circumstances are given for two levels of yield: Maximum Constant Yield (***MCY***) and Current Annual Yield (***CAY***), both of which represent different forms of maximum sustainable yield (***MSY***). The relevance of these to the setting of Total Allowable Catches (TACs) is discussed.

Definitions of *MCY* and *CAY*

The Fisheries Act 1996 defines Total Allowable Catch in terms of maximum sustainable yield (***MSY***). The definitions of the biological reference points, ***MCY*** and ***CAY***, derive from two ways of viewing ***MSY***: a static interpretation and a dynamic interpretation. The former, associated with ***MCY***, is based on the idea of taking the same catch from fisheries year after year. The latter interpretation, from which ***CAY*** is derived, recognises that fish populations fluctuate in size from year to year (for environmental and biological, as well as fisheries, reasons) so that to get the best yield from fisheries it is necessary to alter the catch every year. This leads to the idea of maximum average yield (***MAY***) which is how fisheries scientists generally interpret ***MSY*** (Ricker 1975).

The definitions are:

> ***MCY*** – Maximum Constant Yield
> The maximum constant catch that is estimated to be sustainable, with an acceptable level of risk, at all probable future levels of biomass.

and

> ***CAY*** – Current Annual Yield
> The one-year catch calculated by applying a reference fishing mortality, F_{REF}, to an estimate of the fishable biomass present during the next fishing year. F_{REF} is the level of (instantaneous) fishing mortality that, if applied every year, would, within an acceptable level of risk, maximise the average catch from fisheries.

Note that ***MCY*** is dependent to a certain extent on the current state of the fish stock. If a stock is fished at the ***MCY*** level from a virgin state then over the years its biomass will fluctuate over a range of levels depending on environmental conditions, abundance of predators and prey, etc. For stock sizes within this range the ***MCY*** remains unchanged (though our estimates of it may well be refined). If the current state of the stock is below this range the ***MCY*** will be lower.

The strategy of applying a constant fishing mortality, F_{REF}, from which the ***CAY*** is derived each year is an approximation to a strategy which maximises the average yield over time. For the purposes of this document the ***MAY*** is the long-term average annual catch when the catch each year is the ***CAY***. With perfect knowledge it would be possible to do better by varying the fishing mortality from year to year. Without perfect knowledge, adjusting catch levels by a ***CAY*** strategy as stock size varies is probably the best practical method of maximising average yield. Appropriate values for F_{REF} are discussed below.

What is meant by an “acceptable level of risk” for ***MCY***s and ***CAY***s is intentionally left undefined here. For most stocks our level of knowledge is inadequate to allow a meaningful quantitative assessment of risk. However, we have two qualitative sources of information on risk levels: the experience of fisheries scientists and managers throughout the world, and the results of simulation exercises such as those of Mace (1988a). Information from these sources is incorporated, as much as is possible, in the methods given below for calculating ***MCY*** and ***CAY***.

It is now well known that ***MCY*** is generally less than ***MAY*** (see, e.g., Doubleday 1976, Sissenwine 1978, Mace 1988a). This is because ***CAY*** will be larger than ***MCY*** in the majority of years. However, when fishable biomass becomes low (through overfishing, poor environmental conditions, or a combination of both), ***CAY*** will be less than ***MCY***. This is true even if the estimates of ***CAY*** and ***MCY*** are exact. The following diagram shows the relationships between ***CAY***, ***MCY*** and ***MAY***.

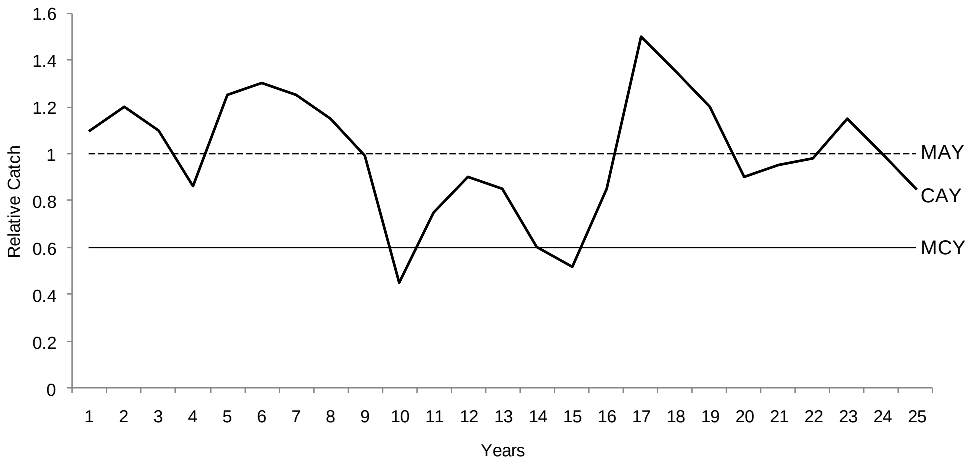

Figure 1: Relationship between *CAY*, *MCY* and *MAY*.

In this example ***CAY*** represents a constant fraction of the fishable biomass, and so (if it is estimated and applied exactly) it will track the fish population exactly. ***MAY*** is the average over time of ***CAY***. The reason ***MCY*** is less than ***MAY*** is that ***MCY*** must be low enough so that the fraction of the population removed does not constitute an unacceptable risk to the future viability of the population. With an ***MCY*** strategy, the fraction of a population that is removed by fishing increases with decreasing stock size. With a ***CAY*** strategy, the fraction removed remains constant. A constant catch strategy at a level equal to the ***MAY***, would involve a high risk at low stock sizes.

Relationship Between *MCY*, *CAY*, TAC and Total Allowable Commercial Catch (TACC)

The TAC covers all mortality to a fish stock caused by human activity, whereas the TACC includes only commercial catch. ***MCY*** and ***CAY*** are reference points used to evaluate whether the current stock size can support the current TAC and/or TACC. It should not be assumed that the TAC and/or TACC will be equal to either one of these yields. There are both legal and practical reasons for this.

Legally, we are bound by the Fisheries Act 1996. In setting or varying any TACC for any quota management stock, ‘the Minister shall have regard to the total allowable catch for that stock and shall allow for –

(a) The following non-commercial fishing interests in that stock, namely –
  (i) Māori customary non-commercial fishing interests; and
  (ii) Recreational interests; and
(b) All other mortality to that stock caused by fishing.

From a practical point of view it must be acknowledged that the concepts of ***MCY*** and ***CAY*** are directly applicable only in idealised management regimes. The ***MCY*** could be used in a regime where a catch level was to be set for once and for all; our system allows changes to be made if, the level is found to be too low or too high.

With a ***CAY*** strategy the yield would probably change every year. Even if there were no legal impediments to following a ***CAY*** strategy, the fishing industry's desire for stability may be a sufficient reason to make TACC changes only when the need is pressing.

Natural and Fishing Mortality

Before describing how to calculate ***MCY*** and ***CAY*** we must discuss natural and fishing mortality, which are used in these calculations. Both types of mortality are expressed as instantaneous rates (thus, over n years a total mortality Z will reduce a population of size B to size Be^{-nZ}, ignoring recruitment and growth). Units for mortalities are 1/year.

Natural mortality

Methods of estimating natural mortality, M, are reviewed by Vetter (1988). When a lack of data rules out more sophisticated methods, M may be estimated by the formula,

$$M = \frac{\log_e(p)}{A}$$

where p is the proportion of the population that reaches age A (or older) in an unexploited stock. p is often set to 0.01, when A is the "maximum age" observed. Other values for p may be chosen dependent on the fishing history of the stock. For example, in an exploited stock the maximum observed age may correspond to a value of p = 0.05, or higher. For a discussion of the method see Hoenig (1983).

Reference Fishing Mortalities

Reference fishing mortalities in widespread use include $F_{0.1}$, F_{MSY}, F_{MAX}, F_{MEY}, and M.

The most common reference fishing mortality used in the calculation of ***CAY*** (and, in some cases, ***MCY***) is $F_{0.1}$ (pronounced `F zero point one'). This is used as a basis for fisheries management decisions throughout the world and is widely believed to produce a high level of yield on a sustainable basis (Mace 1988b). It is estimated from a yield per recruit analysis as the level of fishing mortality at which the slope of the yield-per-recruit curve is 0.1 times the slope at F = 0. If an estimate of $F_{0.1}$ is not available an estimate of M may be substituted.

F_{MAX} , the fishing mortality that produces the maximum yield per recruit. It may be too high as a target fishing mortality because it does not account for recruitment effects (e.g. recruitment declining as stock size is reduced). However, it may be a valid reference point for those fisheries that have histories of sustainable fishing at this level.

F_{MSY}, the fishing mortality corresponding to the deterministic ***MSY***, is another appropriate reference point. F_{MSY} may be estimated from a surplus production model, or a combination of yield per recruit and stock recruitment models.

When economic data are available it may be possible to calculate F_{MEY} the fishing mortality corresponding to the maximum (sustainable) economic yield.

Every reference fishing mortality corresponds to an equilibrium or long-run average stock biomass. This is the biomass which the stock will tend towards or randomly fluctuate around, when the reference fishing mortality is applied constantly. The fluctuations will be caused primarily by variable recruitment. It is necessary to examine the equilibrium stock biomass corresponding to any candidate reference fishing mortality.

A reference fishing mortality which corresponds to a low stock biomass may be undesirable if the low biomass would lead to an unacceptable risk of stock collapse. For fisheries where this applies a lower reference fishing mortality may be appropriate.

Natural Variability Factor

Fish populations are naturally variable in size because of environmental variability and associated fluctuations in the abundance of predators and food. Computer simulations (e.g., Mace 1988a) have shown that, all other things being equal, the ***MCY*** for a stock is inversely related to the degree of natural variability in its abundance. That is, the higher the natural variability, the lower the ***MCY***.

The natural variability factor, ***c***, provides a way of incorporating the natural variability of a stock's biomass into the calculation of ***MCY***. It is used as a multiplying factor in method 5 below. The greater the variability in the stock, the lower is the value of ***c***. Values for ***c*** should be taken from the table below and are based on the estimated mean natural mortality rate of the stock. It is assumed that because a stock with a higher natural mortality will have fewer age-classes it will also suffer greater fluctuations in biomass. The only stocks for which the table should be deviated from are those where there is evidence that recruitment variability is unusually high or unusually low.

Natural mortality rate ***M***	**Natural variability factor** ***c***
<0.05	1.0
0.05-0.15	0.9
0.16-0.25	0.8
0.26-0.35	0.7
>0.35	0.6

Methods of Estimating *MCY*

It should be possible to estimate ***MCY*** for most fish stocks (with varying degrees of confidence). For some stocks, only conservative estimates for ***MCY*** will be obtainable (e.g., some applications of Method 4) and this should be stated. For other stocks it may be impossible to estimate ***MCY***. These stocks include situations in which: the fisheries are very new; catch or effort data are unreliable; strong upwards or downwards trends in catch are not able to be explained by available data (e.g., by trawl survey data or by catch per unit effort data).

When catch data are used in estimating ***MCY*** all catches (commercial, illegal, and non-commercial) should be included if possible. If this is not possible and the excluded catch is thought to be a significant quantity, then this should be stated.

The following examples define ***MCY*** in an operational context with respect to the type, quality and quantity of data available. Knowledge about the accuracy or applicability of the data (e.g., reporting anomalies, atypical catches in anticipation of the introduction of the Quota Management System) should play a part in determining which data sets are to be included in the analysis.

As a general rule it is preferable to apply subjective judgements to input data rather than to the calculated ***MCY***s. For example, rather than saying "with the official catch statistics the ***MCY*** is ***X*** tonnes, but we think this is too high because the catch statistics are wrong" it would be better to say "we believe (for reasons given) that the official statistics are wrong and the true catches were probably such and such, and the ***MCY*** based on these catches is ***Y*** tonnes".

Background information on the rationale behind the following calculation methods can be found in Mace (1988a) and other scientific papers listed at the end of this document.

New fisheries

$$MCY = 0.25F_{0.1}B_0$$

where B_0 is an estimate of virgin recruited biomass. If there are insufficient data to conduct a yield per recruit analysis $F_{0.1}$ should be replaced with an estimate of natural mortality (***M***). Tables 1–3 in Mace (1988b) show that $F_{0.1}$ is usually similar to (or sometimes slightly greater than) ***M***.

It may appear that the estimate of ***MCY*** for new fisheries is overly conservative, particularly when compared to the common approximation to MSY of $\mathbf{0.5}\boldsymbol{MB_0}$ (Gulland 1971). However various authors (including Beddington & Cooke 1983; Getz et al 1987; Mace 1988a) have shown that $\mathbf{0.5}\boldsymbol{MB_0}$ often overestimates ***MSY***, particularly for a constant catch strategy or when recruitment declines with stock size. Moreover it has often been observed that the development of new fisheries (or the rapid expansion of existing fisheries) occurs when stock size is unusually large, and that catches plummet as the accumulated biomass is fished down.

It is preferable to estimate ***MCY*** from a stochastic population model (Method 5), if this is possible. The simulations of Mace (1988a) and Francis (1992) indicate that the appropriate factor to multiply $\boldsymbol{F_{0.1}B_0}$ may be somewhat higher or somewhat lower than **0.25**. This depends primarily on the steepness of the assumed stock recruitment relationship (*see* Mace & Doonan 1988 for a definition of steepness).

New fisheries become developed fisheries once ***F*** has approximated or exceeded ***M*** for several successive years, depending on the lifespan of the species.

2. Developed fisheries with historical estimates of biomass

$$MCY = 0.5F_{0.1}B_{AV}$$

where $\boldsymbol{B_{AV}}$ is the average historical recruited biomass, and fisheries are believed to have been fully exploited (i.e., fishing mortality has been near the level that would produce ***MAY***). This formulation assumes that $\boldsymbol{F_{0.1}}$ approximates the average productivity of a stock.

As in the previous method an estimate of ***M*** can be substituted for $\boldsymbol{F_{0.1}}$ if estimates of $\boldsymbol{F_{0.1}}$ are not available.

3. Developed fisheries with adequate data to fit a population model

$$MCY = {}^{2}/_{3}\,MSY$$

where ***MSY*** is the deterministic maximum equilibrium yield.

This reference point is slightly more conservative than that adopted by several other stock assessment agencies (e.g., ICES, CAFSAC) that use as a reference point the equilibrium yield corresponding to 2/3 of the fishing effort (fishing mortality) associated with the deterministic equilibrium ***MSY***.

If it is possible to estimate ***MSY*** then it is generally possible to estimate ***MCY*** from a stochastic population model (Method 5), which is the preferable method. The simulations of Mace (1988a) and Francis (1992) indicate that the appropriate factor to multiply ***MSY*** varies between about **0.6** and **0.9**. This depends on various parameters of which the steepness of the assumed stock recruitment relationship is the most important.

If the current biomass is less than the level required to sustain a yield of 2/3 ***MSY*** then

$$MCY = {}^{2}/_{3}\,CSP$$

where ***CSP*** is the deterministic current surplus production.

4. Catch data and information about fishing effort (and/or fishing mortality), either qualitative or quantitative, without a surplus production model

$$MCY = cY_{AV}$$

where $\boldsymbol{c}$ is the natural variability factor (defined above) and $\boldsymbol{Y_{AV}}$ is the average catch over an appropriate period.

If the catch data are from a period when the stock was fully exploited (i.e. fishing mortality near the level that would produce $\boldsymbol{MAY}$), then the method should provide a good estimate of $\boldsymbol{MCY}$. In this case, $\boldsymbol{Y_{AV}} = \boldsymbol{MAY}$. If the population was under-exploited the method gives a conservative estimate of $\boldsymbol{MCY}$.

Familiarity with stock demographics and the history of the fisheries is necessary for the determination of an appropriate period on which to base estimates of $\boldsymbol{Y_{AV}}$. The period chosen to perform the averaging will depend on the behaviour of the fishing mortality or fishing effort time series, the prevailing management regime, the behaviour of the catch time series, and the lifespan of the species.

The period should be selected so that it contains no systematic changes in fishing mortality (or fishing effort, if this can be assumed to be proportional to fishing mortality). Note that for species such as orange roughy, where relatively static aggregations are fished, fishing mortality cannot be assumed to be proportional to effort. If catches during the period are constrained by a TACC then it is particularly important that the assumption of no systematic change in fishing mortality be adhered to. The existence of a TACC does not necessarily mean that the catch is constrained by it.

The period chosen should also contain no systematic changes in catch. If the period shows a systematic upward (or downward) trend in catches then the $\boldsymbol{MCY}$ will be under-estimated (over-estimated). It is desirable that the period be equal to at least half the exploited life span of the fish.

5. Sufficient information for a stochastic population model

This is the preferred method for estimating $\boldsymbol{MCY}$ but it is the method requiring the most information. It is the only method that allows some specification of the risk associated with an $\boldsymbol{MCY}$.

The simulations in Mace (1988a) and Breen (1989) provide examples of the type of calculations necessary for this method. A trial and error procedure can be used to find the maximum constant catch that can be taken for a given level of risk. The level of risk may be expressed as the probability of stock collapse within a specified time period. At the moment Fisheries New Zealand has no standards as to how stock collapse should be defined for this purpose, what time period to use, and what probability of collapse is acceptable. These will be developed as experience is gained with this method.

Methods of Estimating *CAY*

It is possible to estimate $\boldsymbol{CAY}$ only when there is adequate stock biomass data. In some instances relative stock biomass indices (e.g., catch per unit effort data) and relative fishing mortality data (e.g., effort data) may be sufficient. $\boldsymbol{CAY}$ calculated by method 1 includes non-commercial catch.

If method 2 is used and it is not possible to include a significant non-commercial catch, then this should be stated.

1. Where there is an estimate of current recruited stock biomass, $\boldsymbol{CAY}$ may be calculated from the appropriate catch equation. Which form of the catch equation should be used will depend on the way fishing mortality occurs during the year. For many fisheries it will be a reasonable approximation to assume that fishing is spread evenly throughout the year so that the Baranov catch equation is appropriate and $\boldsymbol{CAY}$ is given by

$$CAY = \frac{F_{ref}}{F_{ref} + M}(1 - e^{-(F_{ref}+M)})B_{beg}$$

Where B_{BEG} is the projected stock biomass at the beginning of the fishing year for which the ***CAY*** is to be calculated and F_{REF} is the reference fishing mortality described above.

If most of the fishing mortality occurs over a short period each year it may be better to use one of the following equations:

$$CAY = (1 - e^{-F_{ref}})B_{beg}$$

$$CAY = (1 - e^{-F_{ref}})e^{-\frac{M}{2}}B_{beg}$$

$$CAY = (1 - e^{-F_{ref}})e^{-M}B_{beg}$$

where the first equation is used when fishing occurs at the beginning of the fishing year, the second equation when fishing is in the middle of the year, and the third when fishing is at the end of the year.

It is important that the catch equation used to calculate ***CAY*** and the associated assumptions are the same as those used in any model employed to estimate stock biomass or to carry out yield per recruit analyses. Serious bias may result if this criterion is not adhered to. The assumptions and catch equations given here are by no means the only possibilities.

The risk associated with the use of a particular F_{REF} may be estimated using simulations.

2. Where information is limited but the current (possibly unknown) fishing mortality is thought to be near the optimum, there are various "status quo" methods which may be applied. Details are available in Shepherd (1984, 1991) and Pope (1983).

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Guidelines for Status of the Stocks Summary Tables

A new format for Status of the Stocks summaries was developed by the Stock Assessment Methods Working Group over the period February-April 2009. The purpose of this project was to provide more comprehensive and meaningful information for fisheries managers, stakeholders, and other interested parties. Previously, Status of the Stocks summary sections had not reflected the full range of information of relevance to fisheries management contained in the earlier sections of Plenary reports and were of variable utility for evaluating stock status and informing fisheries management decisions.

Status of the Stocks summary tables should be constructed for all stocks except those designated as "nominal"; e.g. those with administrative TACs or TACCs (generally less than 10–20 t) or those for which a commercial or non-commercial development potential has not currently been demonstrated. As of November 2014, there were a total of 292 stocks in this classification. The list of nominal stocks can be found at: https://www.fisheries.govt.nz/dmsdocument/19331-nz-nominal-fish-stocks-2018-report.

In 2012 a number of changes were made to the format for the Status of the Stocks summary tables, primarily for the purpose of implementing the science information quality rankings required by the Research and Science Information Standard for New Zealand Fisheries that was approved in April 2011 (New Zealand Ministry of Fisheries 2011a). At the time, these changes were only applied for Status of Stocks tables updated in 2012. Subsequently, an attempt has been made to revise some of the older tables as well.

In 2013, the format was further modified to require Science Working Groups to make a determination about whether overfishing is occurring, and to further standardise and clarify the requirements for other parts of the table.

It is anticipated that the format of the Status of the Stocks tables will continue to be reviewed, standardised and modified in the future so that it remains relevant to fisheries management and other needs. New formats will be implemented each time stocks are reviewed and as time allows.

The table below provides a template for the Status of the Stocks summaries. The text following the template gives guidance on the contents of most of the fields in the table. Superscript numbers refer to the corresponding numbered paragraph in the following text. Light blue text provides an example of how the table might be completed.

STATUS OF THE STOCKS TEMPLATE[1]

Stock Structure Assumptions[2]
<insert relevant text>

- **Fishstock name**[3]

Stock Status	
Year of Most Recent Assessment	2019
Assessment Runs Presented	Base case model only
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	B_{2019} was estimated to be 50% B_0; Very Likely (> 90%) to be at or above the target
Status in relation to Limits	B_{2019} is Very Unlikely (< 10%) to be below both the soft and hard limits

Status in relation to Overfishing	The fishing intensity in 2014 was Very Unlikely (< 10%) to be above the overfishing threshold [or, Overfishing is Very Unlikely (<10%) to be occurring]

Historical Stock Status Trajectory and Current Status
<insert relevant graphs>

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass reached its lowest point in 2001 and has since consistently increased.
Recent Trend in Fishing Intensity or Proxy	<insert relevant graphs, if available> Fishing intensity reached a peak of F=0.54 in 1999, subsequently declining to less than F=0.2 since 2006.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Recent recruitment (2005–2017) is estimated to be near the long-term average.

Projections and Prognosis	
Stock Projections or Prognosis	Biomass is expected to stay steady over the next 5 years assuming current (2016–17) catch levels.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Very Unlikely (< 10%) Hard Limit: Very Unlikely (< 10%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2019	Next assessment: 2020
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Research time series of abundance indices (trawl and acoustic surveys)	1 – High Quality
	- Proportions at age data from the commercial fisheries and trawl surveys	1 – High Quality
	- Estimates of biological parameters	1 – High Quality
Data not used (rank)	Commercial CPUE	3 – Low Quality: does not track stock biomass
Changes to Model Structure and Assumptions	None since the 2012 assessment	

Major sources of Uncertainty	- The base case model deals with the lack of older fish in commercial catches and surveys by estimating natural mortality at age which results in older fish suffering high natural mortality. However, there is no evidence to validate this outside the model estimates. - Aside from natural mortality, other major sources of uncertainty include stock structure and migration patterns, stock-recruit steepness and natal fidelity assumptions. Uncertainty about the size of recent year classes affects the reliability of stock projections.

Qualifying Comments
The impact of the current young age structure of the population on spawning success is unknown.

Environmental and Ecosystem Considerations	
Observer coverage	Highly variable year to year (from 1.6 to 11.1%), but higher from 2008 onwards.
Non-target fish and invertebrate catch	Blue shark, lancetfish and porbeagle shark are the most commonly non-target fish species caught by the longline fleet (by number), but are rarely retained. Other species, like Rays bream and moonfish are caught more rarely, but are more frequently retained.
Incidental catch of seabirds	Observed capture rates of seabirds was highly variable prior to 2008 due to low levels of observer coverage. This fishery contributes primarily to the risk to Black petrel, Northern Buller's albatross and Gibson's albatross, among other species.
Incidental catch of cetaceans	Between 2002 and 2018, observers recorded one unidentified cetacean, two common dolphin, and one long finned pilot whale captured in this fishery. All of these cetaceans were released alive.
Incidental catch of pinnipeds	Between 2002 and 2018, there were two observed captures of New Zealand fur seals in this fishery. Both were released alive.
Incidental catch of other protected species	Between 2002 and 2018 incidental captures of 17 sea turtles were observed, these were leatherback turtles (10), unidentified turtles (5), green (1) and loggerhead (1) turtles.
Benthic interactions	There are no known benthic interactions for this fishery.

Guidance on preparing the Status of the Stocks summary tables

1. Everything included in the Status of the Stocks summary table should be derived from earlier sections in the Working Group or Plenary report. No new information should be presented in the summary that was not encompassed in the main text of the Working Group or Plenary report.

Stock Structure Assumptions

2. The current assumptions regarding the stock structure and distribution of the stocks being reported on should be briefly summarised. Where the assessed stock distribution differs from the relevant QMA fishstock(s), an explanation must be provided of how the stock relates to the QMA fishstock(s) it includes.

Stock Status

3. One Status of the Stocks summary table should be completed for each assessed stock or stock complex.

4. Management targets for each stock will be established by fisheries managers. Where management targets have not been established, it is suggested that an interim target of 40% B_0, or a related B_{MSY}-compatible target (or $F_{40\%}$, or a related target) should be assumed. In most cases, the soft and hard limits should be set at the default levels specified in the Harvest Strategy Standard (20% B_0 for the soft limit and 10% B_0 for the hard limit). Similarly, the overfishing threshold should be set at F_{MSY}, or a related F_{MSY}-compatible threshold. Overfishing thresholds can be expressed in terms of fishing mortality, exploitation rates, or other valid measures of fishing intensity. When agreed reference points have not been established, stock status may be reported against interim reference points.

5. Reporting stock status against reference points requires Working Group agreement on the model run to use as a base case for the assessment. The preference, wherever possible, is to report on the best estimates from a single base case, or to make a single statement that covers the results from a range of cases. In general, ranges or confidence intervals should not be included in the table. Only where more than one equally plausible model run exists, and agreement cannot be reached on a single base case, should multiple runs be reported. This should still be done simply and concisely (e.g. median results only).

6. Where probabilities are used in qualifying a statement regarding the status of the stock in relation to target, limit, or threshold reference levels, the following probability categories and associated verbal descriptions are to be used (IPCC 2007):

Probability	**Description**
> 99 %	Virtually Certain
> 90 %	Very Likely
> 60 %	Likely
40–60 %	About as Likely as Not
< 40 %	Unlikely
< 10 %	Very Unlikely
< 1 %	Exceptionally Unlikely

   Probability categories and associated descriptions should relate to the probability of being "at or above" biomass targets (or "at or below" fishing intensity targets if these are used), below biomass limits, and above overfishing thresholds. Note, however, that the descriptions and associated probabilities adopted need not correspond exactly to model outputs; rather they should be superimposed with the Working Group's belief about the extent to which the model fully specifies the probabilities. This is particularly relevant for the "Virtually Certain" and "Exceptionally Unlikely" categories, which should be used sparingly.

7. The status in relation to overfishing can be expressed in terms of an explicit overfishing threshold, or it can simply be a statement about the Working Group's belief, based on the evidence at hand, about the likelihood that overfishing is occurring (based on, for example, a stock abundance index exhibiting a pronounced recent increase or decline). The probability rankings in the IPCC (2007) table above should be used. Overfishing thresholds can be considered in terms of fishing mortality rates, exploitation rates, or other valid measures of fishing intensity.

Historical Stock Status Trajectory and Current Status

8. This heading should be changed to reflect the graphs that are available to illustrate trends in biomass or fishing intensity (or proxies) and the current stock or fishery status.

Recent Fishery and Stock Trends

9. Recent stock or fishery trends should be reported in terms of stock size and fishing intensity (or proxies for these), respectively. For full quantitative (Level 1) assessments, median results should be used when reporting biomass. Observed trends should be reported using descriptors

such as increasing, decreasing, stable, or fluctuating without trend. Where it is considered relevant and important to fisheries management, mention could be made of whether the indicator is moving towards or away from a target, limit, threshold, or long term average.

10. Other Abundance Indices: This section is primarily intended for reporting of trends where a Level 2 (partial quantitative) evaluation has been conducted, and appropriate abundance indices (such as standardised CPUE or survey biomass) are available.

11. Other Relevant Indicators or Variables: This section is primarily intended for reporting of trends where only a Level 3 (qualitative) evaluation has been conducted. Potentially useful indicators might include trends in mean size, size or age composition, or recruitment indices. Catch trends vs TACC may be relevant here, provided these are qualified when other factors are known to have influenced the trends.

Projections and Prognosis

12. These sections should be used to report available information on likely future trends in biomass or fishing intensity or related variables under current (or a range of) catch levels over a period of approximately 3–5 years following the last year in the assessment. If a longer period is used, this must be stated.

13. When reporting probabilities of current catches or TACC levels causing declines below limits, the probability rankings in the IPCC (2007) table above should be used. Results should be reported separately (i.e., split into two rows) if the catch and TACC differ appreciably, resulting in differing conclusions for each level of removals, with the level of each specified. The timeframe for the projections should be approximately 3–5 years following the last year in the assessment unless a longer period of time is required by fisheries managers.

Assessment Methodology and Evaluation

14. Assessment type: the envisaged Assessment Levels are:

    1 – Full Quantitative Stock assessment: There is a reliable index of abundance and an assessment indicating status in relation to targets and limits.
    2 – Partial Quantitative Stock Assessment: An evaluation of agreed abundance indices (e.g., standardised CPUE) or other appropriate fisheries indicators (e.g. estimates of F (Z) based on catch-at-age) is available. Indices of abundance or fishing intensity have not been used in a full quantitative stock assessment to estimate stock or fisheries status in relation to reference points.
    3 – Qualitative Evaluation: A fisheries characterisation with evaluation of fisheries trends (e.g., catch, effort, unstandardised CPUE, or length-frequency information) has been conducted but there is no agreed index of abundance.
    4 – Low Information Evaluation: There are only data on catch and TACC, with no other fisheries indicators.

    Management Procedure (MP) updates should be presented in a separate table. In years when an actual assessment is conducted for stocks under MPs, the MP update table should be preceded by a Status of the Stocks summary table.

    Table content will vary for these different assessment levels.

Ranking of Science Information Quality

15. The Research and Science Information Standard for New Zealand Fisheries (2011a) specifies (pages 21–23) that the processes that rank the quality of research and science information used in support of fisheries management decisions will be implemented. The quality ranking system is:

1 – High Quality: information that has been subjected to rigorous science quality assurance and peer review processes as required by this Standard, and substantially meets the key principles for science information quality. Such information can confidently be accorded a high weight in fisheries management decisions. An explanation is not required in the table for high quality information.

2 – Medium or Mixed Quality: information that has been subjected to some level of peer review against the requirements of the Standard and has been found to have some shortcomings with regard to the key principles for science information quality, but is still useful for informing management decisions. Such information should be accompanied by a description of its shortcomings.

3 – Low Quality: information that has been subjected to peer review against the requirements of the Standard but has substantially failed to meet the key principles for science information quality. Such information should be accompanied by a description of its shortcomings and should not be used to inform management decisions.

One of the key purposes of the science information quality ranking system is to inform fisheries managers and stakeholders of those datasets, analyses, or models that are of such poor quality that they should not be used to make fisheries management decisions (i.e. those ranked as "3"). Most other datasets, analyses or models that have been subjected to peer review or staged technical guidance in the Fisheries New Zealand's Science Working Group processes and have been accepted by these processes should be given the highest score (ranked as "1"). Uncertainty, which is inherent in all fisheries science outputs, should not by itself be used as a reason to score down a research output, unless it has not been properly considered or analysed, or if the uncertainty is so large as to render the results and conclusions meaningless (in which case, the Working Group should consider rejecting the output altogether). A ranking of 2 (medium or mixed quality) should only be used where there has been limited or inadequate peer review or the Working Group has mixed views on the validity of the outputs, but believes they are nevertheless of some use to fisheries management.

16. In most cases, the "Data not used" row can be filled in with "N/A"; it is primarily useful for specifying particular datasets that the Working Group considered but did not use in an assessment because they were of low quality and should not be used to inform fisheries management decisions.

Changes to Model Assumptions and Structure

17. The primary purpose of this section is to briefly identify only the most significant model changes that directly resulted in significant changes to results on the status of the stock concerned, and to briefly indicate the main effect of these changes. Details on model changes should be left in the main text of the report.

Qualifying Comments

18. The purpose of the "Qualifying Comments" section is to provide for any necessary explanations to avoid misinterpretation of information presented in the sections above. This section may also be used for brief further explanation considered important to understanding the status of the stock.

Fishery Interactions

19. The "Fishery Interactions" section should be used to simply list QMS bycatch species, non-QMS bycatch species and protected / endangered species interactions.

FOR FURTHER INFORMATION

IPCC (2007) Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. [Core Writing Team, Pachauri, R K; Reisinger, A (eds.)]. IPCC, Geneva, Switzerland, 104 p.

New Zealand Ministry of Fisheries (2008) Harvest Strategy Standard for New Zealand fisheries. 25 p. Available at http://fs.fish.govt.nz/Page.aspx?pk=61&tk=208&se=&sd=Asc&filSC=&filAny=False&filSrc=False&filLoaded=False&filDCG=9&filDC=0&filST=&filYr=0&filAutoRun=1.

New Zealand Ministry of Fisheries (2011a) Research and Science Information Standard for New Zealand Fisheries. 31 p. Available at http://www.fish.govt.nz/en-nz/Publications/Research+and+Science+Information+Standard.htm.

New Zealand Ministry of Fisheries (2011b) Operational Guidelines for New Zealand's Harvest Strategy Standard Revision 1. 78 p. Available at http://fs.fish.govt.nz/Doc/22847/Operational_Guidelines_for_HSS_rev_1_Jun_2011.pdf.ashx.

Fisheries New Zealand

Tini a Tangaroa

New Zealand Government

FNZ management teams and primary species managed

FISHERIES MANAGEMENT - INSHORE

Common name	Code	Stock
Anchovy	ANC	All
Barracouta	BAR	BAR1
Bladder kelp	KBB	All
Blue cod	BCO	All
Blue moki	MOK	All
Blue warehou	WAR	All
Bluenose	BNS	All
Butterfish	BUT	All
Cockle	COC	All
Deepwater (king) clam	PZL	All
Dredge oyster	OYS, OYU	All
Elephantfish	ELE	All
English mackerel	EMA	EMA1, 2
Flatfish	FLA	All
Freshwater eels (NI and SI)	ANG, LFE, SFE	All
Frostfish	FRO	FRO1, 2
Garfish	GAR	All
Gemfish	SKI	SKI1, 2
Ghost shark, dark	GSH	GSH1-3, 7-9
Greenlipped mussel	GLM	All
Grey mullet	GMU	All
Gurnard	GUR	All
Hapuka / bass	HPB	All
Horse mussel	HOR	All
Jack mackerel	JMA	JMA1
John dory	JDO	All
Kahawai	KAH	All
Kina	SUR	All
Kingfish	KIN	All
Knobbed whelk	KWH	All

Common name	Code	Stock
Leatherjacket	LEA	All
Ling	LIN	LIN1, 2
Paddle crab	PAD	All
Parore	PAR	All
Paua	PAU	All
Pilchard	PIL	All
Pipi	PPI	All
Porae	POR	All
Queen scallop	QSC	All
Red cod	RCO	All
Red snapper	RSN	All
Ribaldo	RIB	RIB1, 2, 9
Rig	SPO	All
Rock lobsters (incl. PHC)	CRA, PHC	All
Scallop	SCA	All
School shark	SCH	All
Sea cucumber	SCC	All
Sea perch	SPE	SPE1, 2, 8, 9
Skate, rough and smooth	RSK, SSK	All
Snapper	SNA	All
Spiny dogfish	SPD	SPD1, 3, 7, 8
Sprat	SPR	All
Stargazer	STA	All
Surf clams (all species)	DAN, DSU, MMI, MDI, SAE, PDO, BYA	All
Tarakihi	TAR	All
Trevally	TRE	All
Trumpeter	TRU	All
Tuatua	TUA	All
Yelloweyed mullet	YEM	All

FISHERIES MANAGEMENT - DEEPWATER

Common name	Code	Stock
Alfonsino	BYX	All
Barracouta	BAR	BAR4, 5, 7
Cardinalfish	CDL	All
Deepwater crabs (red crab, king crab, giant spider crab)	CHC, KIC, GSC	All
English mackerel	EMA	EMA3, 7
Frostfish	FRO	FRO3-9
Gemfish	SKI	SKI3, 7
Ghost shark, dark	GSH	GSH4-6
Ghost shark, pale	GSP	All
Hake	HAK	All
Hoki	HOK	All
Jack mackerel	JMA	JMA3, 7
Ling	LIN	LIN3-7
Lookdown dory	LDO	All
Orange roughy	ORH	All
Oreos	SSO, BOE, SOR, WOE, OEO	All
Patagonian toothfish	PTO	All
Prawnkiller	PRK	All
Redbait	RBT	All
Ribaldo	RIB	RIB3-8
Rubyfish	RBY	All
Scampi	SCI	All
Sea perch	SPE	SPE3-7
Silver warehou	SWA	All
Southern blue whiting	SBW	All
Spiny dogfish	SPD	SPD4, 5
Squid	SQU	All
White warehou	WWA	All

FISHERIES MANAGEMENT - HMS

Common name	Code	Stock
*Albacore tuna **	*ALB*	*All*
Bigeye tuna	BIG	All
Blue shark	BWS	All
Mako shark	MAK	All
Moonfish	MOO	All
Pacific bluefin tuna	TOR	All
Porbeagle shark	POS	All
Ray's bream	RBM	All
*Skipjack tuna **	*SKJ*	*All*
Southern bluefin tuna	STN	All
Swordfish	SWO	All
Yellowfin tuna	YFN	All

* *non-QMS species*

INTL POLICY - FISHERIES MGMT

Common name	RFMO
Antarctic toothfish, Patagonian toothfish	CCAMLR
Orange roughy	SPRFMO
Pacific HMS species *	WCPFC
Southern bluefin tuna	CCSBT

Regional Fisheries Management Organisations (RFMOs)

CCAMLR - *Commission for the Conservation of Antarctic Marine Living Resources*

SPRFMO - *South Pacific Regional Fisheries Management Organisation*

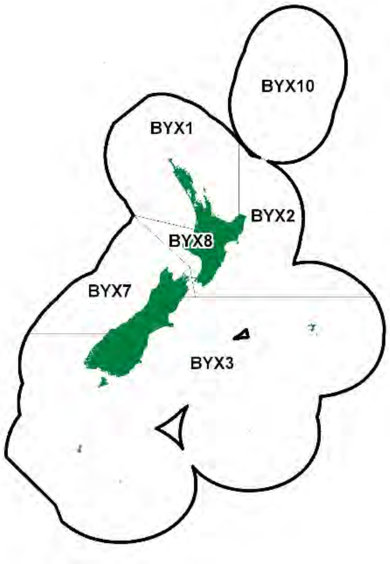
WCPFC - *Western and Central Pacific Fisheries Commission*

CCSBT - *Commission for the Conservation of Southern Bluefin Tuna*

* *primarily ALB, BIG, SKJ, SWO and YFN*

ALFONSINO (BYX)

(*Beryx splendens*, *B. decadactylus*)



1. FISHERY SUMMARY

Alfonsino was introduced into the Quota Management System (QMS) on 1 October 1986. Current allowances, TACCs and TACs are shown in Table 1.

Table 1: Recreational and Customary non-commercial allowances, TACCs and TACs for alfonsino by Fishstock for 2018–19.

Fishstock	Recreational Allowance	Customary non-commercial allowance	TACC	TAC
BYX 1	2	2	300	304
BYX 2	-	-	1 575	1 575
BYX 3	-	-	1 010	1 010
BYX 7	-	-	80.5	80.5
BYX 8	-	-	20	20
BYX 10	-	-	10	10

1.1 Commercial fisheries

Alfonsino has supported a major mid-water target trawl fishery off the east coast of the North Island since 1983 and is a minor bycatch of other trawl fisheries around New Zealand. The original gazetted TACs were based on the 1983–84 landings except for BYX 10 which was administratively set. Recent reported domestic landings and actual TACCs are shown in Table 2, while Figure 1 shows the historical landings and TACC values for the main BYX stocks.

Alfonsino landings in New Zealand consist almost entirely of one species, *Beryx splendens*: the other species, *B. decadactylus*, is thought to make up less than 1% of landings. Before 1983 alfonsino were virtually unfished, but two main fisheries now exist in New Zealand. The first to develop was the lower east coast North Island fishery (BYX 2), which developed in the mid-1980s. The other is the eastern Chatham Rise fishery (BYX 3), which developed in the mid-1990s. Alfonsino are caught throughout the New Zealand EEZ but only in small quantities outside of the east coast North Island and eastern Chatham Rise fisheries.

In BYX 1, alfonsino is mainly caught as a target species by bottom trawl within QMA 1. A smaller amount is taken as bycatch by bottom longline in the bluenose target fishery. The TACC for BYX 1 was increased for the 2001–02 fishing year from 31 t to 300 t when it was included in the adaptive management programme, and allocated 2 t for both customary and other mortality increasing the TAC to a total of 304 t. The new TACC was attained for the first time in 2004–05 and has been undercaught since then.

BYX 2 has historically been the major alfonsino fishery in the New Zealand EEZ. Prior to 1983, alfonsino was virtually an unfished resource. The domestic BYX 2 target fishery was developed during 1981, and was concentrated on the banks and seamount features off the east coast of the North Island, between Gisborne and Cape Palliser. Major fishing grounds included the Palliser Bank, Tuaheni Rise, Ritchie Banks and Paoanui Ridge. In more recent years, the alfonsino catch and effort has decreased from these areas, and an increasing proportion of the annual catch has been taken from the Madden Banks and Motukura Bank. Landings fluctuate around the TACC, which has been set at 1575 t since the 1996-97 fishing year.

In BYX 3 catches of alfonsino were low in the early 1990s and were mainly bycatch of the hoki fishery. The TACC for BYX 3 was increased for the 1987–88 fishing year from 220 t to 1 000 t but annual landings remained low until 1993–94. However, the discovery of new grounds in the mid-1990s saw the rapid development of a target alfonsino fishery, most notably south-east of the Chatham Islands in Statistical Area 051. Annual landings are usually close to 1 000 t, but were 754 t and 807 t in the 2017-18 and 2018-19 fishing years respectively. The vast majority of the BYX 3 alfonsino catch is targeted now, followed by bycatch in fisheries for orange roughy, bluenose, hoki and hake. Catches are made all year round but decrease during the winter months. Catches of alfonsino in the Southland and Sub-Antarctic regions of BYX 3 are negligible.

Catches of alfonsino in BYX 7 are small. They are mainly taken by vessels midwater trawling for spawning hoki in Statistical Areas 034 and 035 in winter. There is essentially no targeting of alfonsino in BYX 7. The TACC was increased from 30 t to 80 t in 1989 but the TACC has never been caught. Annual landings were less than 15 t in the 2017-18 and 2018-19 fishing years.

Landings have been reported from BYX 8 in only a few years. No targeting has ever been reported from this area. All catch has been from midwater trawls targeting jack mackerel and bottom longline targeting bluenose.

Catches of alfonsino from BYX 10 (Kermadec Region) are negligible. Apart from 1 t in 1989, and less than 1 t in each of 1992 and 1993, there have been no reported landings of alfonsino from this area.

Table 2: Reported domestic landings (t) of alfonsino by Fishstock from 1985–86 to 2018–19 and actual TACCs (t) from 1986–87 to 2018–19. QMS data from 1986–present. [Continued on next page].

Fishstock	BYX 1		BYX 2		BYX 3		BYX 7	
FMA (s)	1 & 9		2		3, 4, 5 & 6		7	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1985–86*	11	-	1 454	-	3	-	1	-
1986–87	3	10	1 387	1 510	75	220	4	30
1987–88	8	27	1 252	1 511	101	1 000	2	30
1988–89	6	27	1 588	1 630	64	1 000	4	30
1989–90	24	31	1 496	1 274	147	1 007	21	80
1990–91	17	31	1 459	1 274	202	1 007	26	81
1991–92	7	31	1 368	1 499	264	1 007	2	81
1992–93	6	31	1 649	1 504	113	1 007	12	81
1993–94	7	31	1 688	1 569	275	1 007	31	81
1994–95	11	31	1 670	1 569	482	1 010	59	81
1995–96	11	31	1 868	1 569	961	1 010	66	81
1996–97	39	31	1 854	1 575	983	1 010	77	81
1997–98	14	31	1 652	1 575	1 164	1 010	67	81
1998–99	37	31	1 658	1 575	912	1 010	13	81
1999–00	25	31	1 856	1 575	743	1 010	24	81
2000–01	25	31	1 665	1 575	890	1 010	21	81
2001–02	123	300	1 574	1 575	1 197	1 010	10	81
2002–03	136	300	1 665	1 575	1 118	1 010	7	81
2003–04	219	300	1 468	1 575	884	1 010	11	81
2004–05	300	300	1 669	1 575	1 067	1 010	14	81

Table 2 [Continued]

Fishstock	BYX 1		BYX 2		BYX 3		BYX 7	
FMA (s)	1 & 9		2		3, 4, 5 & 6		7	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2005–06	195	300	1 633	1 575	1 068	1 010	7	81
2006–07	66	300	1 644	1 575	945	1 010	21	81
2007–08	154	300	1 532	1 575	1 030	1 010	32	81
2008–09	172	300	1 589	1 575	895	1 010	18	81
2009–10	185	300	1 643	1 575	1 016	1 010	21	81
2010–11	48	300	1 686	1 575	1 084	1 010	17	81
2011–12	45	300	1 603	1 575	1 037	1 010	14	81
2012–13	22	300	1 605	1 575	1 013	1 010	39	81
2013–14	29	300	1 551	1 575	930	1 010	58	81
2014–15	53	300	1 617	1 575	997	1 010	26	81
2015–16	24	300	1 573	1 575	1 104	1 010	27	81
2016–17	22	300	1 611	1 575	991	1 010	29	81
2017–18	73	300	1 692	1 575	754	1 010	12	81
2018-19	11	300	1538	1575	807	1010	11	81

Fishstock	BYX 10			
FMA (s)	10		Total	
	Landings	TACC	Landings	TACC
1985–86*	0	-	1 469	-
1986–87	0	10	1 470	1 800
1987–88	0	10	1 364	2 598
1988–89	1	10	1 663	2 717
1989–90	0	10	1 688	2 422
1990–91	0	10	1 664	2 423
1991–92	< 1	10	1 641‡	2 648
1992–93	< 1	10	1 780‡	2 653
1993–94	0	10	2 001‡	2 718
1994–95	0	10	2 223‡	2 721
1995–96	0	10	2 906‡	2 721
1996–97	0	10	2 953‡	2 727
1997–98	0	10	2 898‡	2 727
1998–99	0	10	2 624‡	2 727
1999–00	0	10	2 648‡	2 727
2000–01	0	10	2 601‡	2 727
2001–02	0	10	2 904‡	2 925
2002–03	0	10	2 927‡	2 925
2003–04	0	10	2 584‡	2 925
2004–05	0	10	3 052‡	2 925
2005–06	0	10	2 903‡	2 925
2006–07	0	10	2 677‡	2 925
2007–08	0	10	2 748‡	3 000
2008–09	0	10	2 674‡	3 000
2009–10	0	10	2 865‡	3 000
2010–11	0	10	2 836‡	2 996
2011–12	0	10	2 699‡	2 996
2012–13	0	10	2 679‡	2 996
2013–14	0	10	2 568‡	2 996
2014–15	0	10	2 693‡	2 996
2015–16	0	10	2 729‡	2 996
2016–17	0	10	2 653‡	2 996
2017–18	0	10	2 531‡	2 996
2018-19	0	10	2 342‡	2966

*FSU data.
‡ Excludes catches taken outside the New Zealand EEZ.

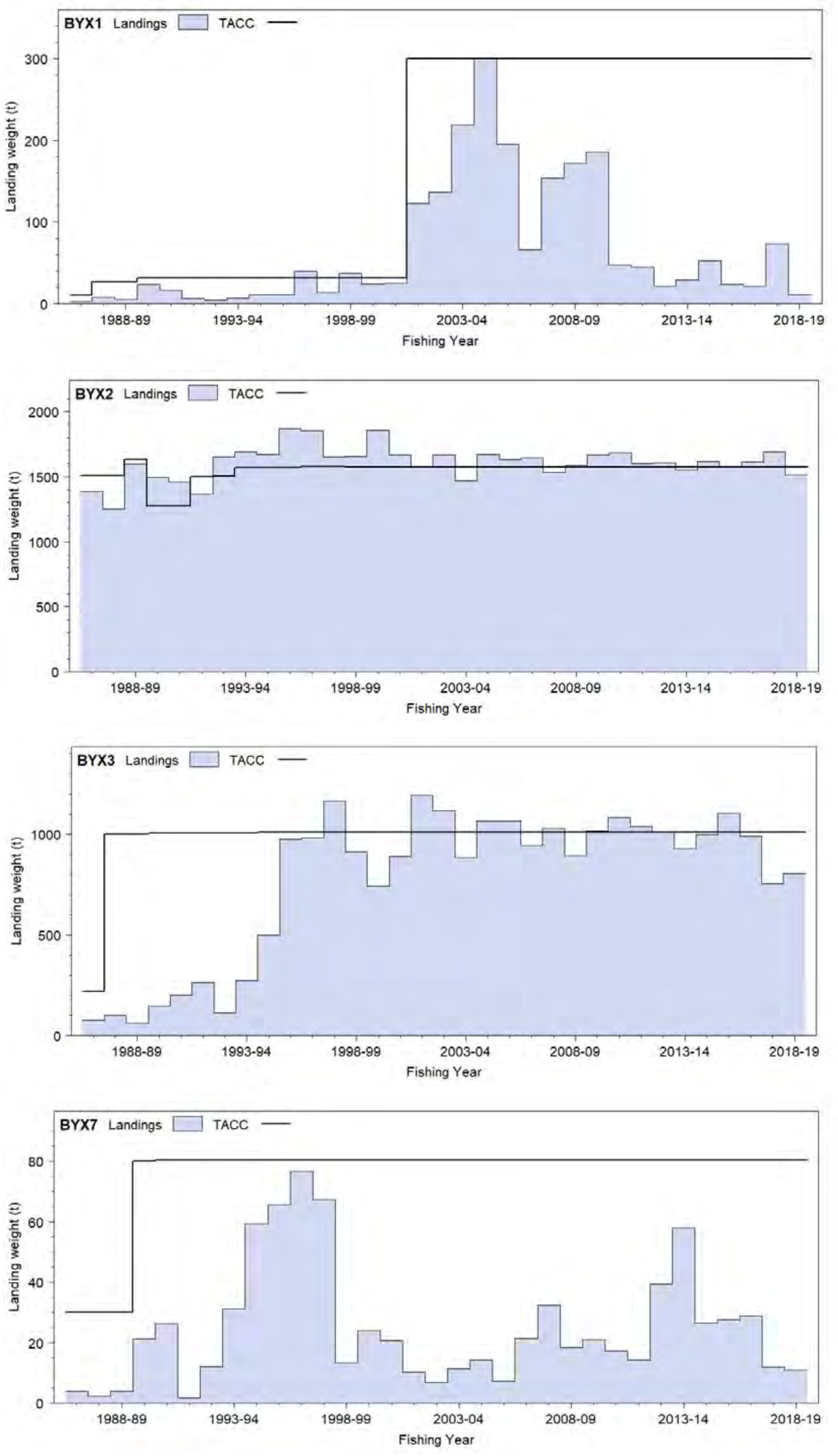


Figure 1: Reported commercial landings and TACC for the four main BYX stocks. Above: BYX 1 (Auckland) BYX 2 (Central East), BYX 3 (South East Coast, South East Chatham Rise, Sub Antarctic, Southland), and BYX 7 (Challenger). Note that these figures do not show data prior to entry into the QMS.

1.2 Recreational fisheries
Occasional catches of alfonsino have been recorded from recreational fishers.

1.3 Customary non-commercial fisheries
No quantitative information on the level of customary non-commercial catch is available.

1.4 Illegal catch
No quantitative information on the level of illegal alfonsino catch is available.

1.5 Other sources of mortality
No qualitative information is available.

2. BIOLOGY

In New Zealand waters, most "alfonsino" landings are alfonsino *B. Splendens*, with landings of the red bream *B. decadactylus* accounting for less than 1% of the catch*.* These species are primarily associated with undersea structures such as the seamounts that occur off the east coast of the North Island and on the Chatham Rise, in depths from 300–600 m. They can be found all around New Zealand waters but occur in greatest numbers along the lower east coast North Island and south-east Chatham Rise. These two areas are essentially where the commercial fisheries for alfonsino in New Zealand are confined.

Alfonsino are widespread in tropical, subtropical and temperate waters from the Atlantic, Pacific, and Indian Oceans (Busakhin 1982). They have been recorded in depths ranging from 10–1200 m but are most commonly found at 200–800 m, on or close to the seabed, often in association with seamounts and other underwater features (Maul 1981, Vinnichenko 1997a, Vinnichenko 1997b).

Stock structure is not currently known for New Zealand alfonsino. Horn & Massey (1989) found substantial differences in length frequency distributions between commercially-caught alfonsino from the Palliser bank compared with those from other locations on the east coast North Island. These differences suggest that there may be some age-specific migration occurring.

It has been suggested that alfonsino could comprise widespread populations in large oceanic eddy systems (Alekseev et al 1986). If New Zealand alfonsino form part of such a system then the east coast North Island may be a vegetative, non-reproductive zone where fish grow and mature before leaving for a possible reproductive zone further east of the mainland (Horn & Massey 1989).

Alfonsino from Japan, northwest of Hawaii, and in the northeast of the Atlantic are known to spawn from August to October (Masuzawa et al 1975, Uchida & Uchihama 1986). In the southeast Atlantic, alfonsino spawn from January to March (Alekseev et al 1986) and from November to February in New Caledonian waters (Lehoday & Grandperrin 1994, Lehoday et al 1997). In New Zealand waters it has been suggested that alfonsino spawn from July to August (Horn & Massey 1989). This was based on observations of fish caught commercially from the lower east coast North Island that were ripening to spawn. However it is not known when and where spawning of alfonsino occurs in New Zealand waters. No running ripe fish were observed in regular samples taken over a 14-month period off the lower Wairarapa coast (Horn & Massey 1989).

Masuzawa et al (1975) estimated that the fecundity of a 40 cm female alfonsino from Japan to be 300 000–500 000 eggs. The fecundity of New Zealand alfonsino however has not been established because a full size range of ripening fish has not been observed (Horn & Massey 1989). Because of this the size and age at maturity cannot be determined precisely for either sex.

Tagging has been unsuccessful for alfonsino (Horn 1989). Being a moderately deepwater fish means that bringing them to the surface is not a viable option due to sudden and usually fatal changes in temperature, light, and particularly pressure. Horn (1989) evaluated the use of detachable hook tags using drop lines to tag alfonsino without bringing them to the surface. Only a small proportion of alfonsino tags were returned by commercial fishermen. This was thought to be due to a combination of low numbers being tagged to begin with (the tagging programme essentially targeted bluenose), low recapture rates, the loss of tags (either before or during capture by commercial fishermen), and possibly low rates of observation by fishermen.

Massey & Horn (1990) examined otoliths from commercially caught alfonsino from various alfonsino fishing grounds of the lower east coast of the North Island (BYX 2) from November 1985 to December 1986. They found evidence that one opaque and one hyaline zone (one 'ring') were formed annually (as did Lehodey & Grandperrin (1996)). They investigated the validity of zone counts by measuring the position of each ring and comparing it to the position of successive ring groups. They calculated the 'marginal index' of each otolith which was defined as the distance from the outer edge of the last hyaline ring to the otolith edge divided by the width of the last complete opaque and hyaline ring. They plotted the mean marginal indices of fish for each month over the study period and found that the index in every fishing ground dropped dramatically from June to December. This drop in mean marginal index meant that for most fish opaque material has started forming in June, and that the hyaline margin is probably laid down from March to May for most fish. Subsequent ageing has also shown the progression of relatively strong year classes between consecutive years of sampling, thus providing further support for the ageing method.

Massey & Horn (1990) observed very few fish younger than three years of age, and believed that full recruitment to the commercial fishery probably occurs at around five years of age. Size-at-sexual maturity is probably about 30 cm fork length (FL) at 4 to 5 years of age. Juvenile fish have been recorded in the pelagic and epipelagic zones in the North Pacific and Indian Oceans. Alfonsino less than 20 cm FL are seldom recorded in New Zealand waters. Differences in length-frequency distributions between fishing grounds off the east coast North Island suggest that some age-specific migration occurs. Fish probably recruit to these grounds at 28–31 cm FL.

Von Bertalanffy growth parameters were derived for alfonsino from BYX 2 by Stocker & Blackwell (1991) (Table 3). They found that females attain a larger size than males and are also larger at corresponding ages. Massey & Horn (1990) presented von Bertalanffy parameters separately by sex for three fishing grounds off lower east coast North Island.

Stocker & Blackwell (1991) used the equation $M = \log_e 100/\text{maximum age}$, where maximum age is the age to which 1% of the population survives in an unexploited stock. Using a maximum age of 20 years, they estimated M for both sexes as 0.23 for BYX 2.

Length-weight relationships are presented in Table 3. Parameters for the Chatham Rise are those reported by O'Driscoll et al (2011) for all fish from the summer Chatham Rise trawl survey time series from 1992–2010.

Table 3: Estimates of biological parameters for alfonsino.

Fishstock						**Estimate**	**Source**
1. Natural mortality (M)							
BYX 2						0.23	Stocker & Blackwell (1991)
2. Weight = a(length)^b (Weight in g, length in cm fork length).							
				Both Sexes			
				a		b	
BYX 2				0.0226		3.018	Stocker & Blackwell (1991)
BYX 3				0.019		3.049	O'Driscoll et al (2011)
3. Von Bertalanffy growth parameters							
	Females			Males			
	L_∞	k	t_0	L_∞	k	t_0	
BYX 2	57.5	0.08	-4.10	51.1	0.11	-3.56	Stocker & Blackwell (1991)

Horn et al (2010) examined stomach contents from *Beryx splendens* caught on three consecutive summer trawl surveys of the Chatham Rise (2005–2007). They found that alfonsino were moderately selective feeders that fed primarily in the mesopelagic layers. The most common prey items were crustaceans and mesopelagic fishes. By mass, the most important were prawns from the genus

Sergestes, followed by the myctophid fish *Lampanyctodes hectoris,* and then prawns from the genus *Pasiphaea.*

Smaller crustaceans such as euphasiids and amphipods are most important in the diet of smaller alfonsino (17–26.5 cm fork length). Larger prawn species and mesopelagic fishes were more important for larger alfonsino (27–42 cm fork length). Horn et al (2010) postulated that they are selective feeders based on the observation that prey items such as squid and salps would be relatively abundant where alfonsino feed on the Chatham Rise, but are rarely taken.

3. STOCKS AND AREAS

No information is available as to whether alfonsino is a single stock in New Zealand waters. Overseas data on alfonsino stock distributions suggest that New Zealand fish could form part of a widely distributed South Pacific stock.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

i) BYX 1

Starr et al (2010) presented CPUE analyses from the bycatch of alfonsino in the east Northland and Bay of Plenty target longline fisheries for bluenose and hapuku. The two series showed no sign of decline up to 2007–08, but the indices were based on only 12% of the BYX catch from the area. The analyses have not been updated, and the catch of BYX has decreased to below 50 t for the last five years.

ii) BYX 2

A biomass index derived from a standardised CPUE (log linear, kg/day) analysis of the target trawl fishery represented by seven core vessels (Blackwell 2000) was calculated for BYX 2. However, the analysis was very uncertain, and the model accounted for only 25% of the variance in catch rates. The results of the standardised analysis were not accepted by the Inshore WG as indices of abundance.

The age composition of the commercial landings in BYX 2 was determined in 1998–99, 1999–00, and 2000–01 and 2002–03, 2003–04 and 2004–05. The commercial catch is dominated by 5–11 year old fish. Without linking age structure to specific fishing grounds the age structure of the catch is unlikely to monitor changes in the population.

iii) BYX 3

The potential to monitor trends in abundance using catch and effort data from the target BYX 3 fishery was investigated by Langley & Walker (2002b). However, it was concluded that the high variation in catch rates, the relatively small number of catch and effort records, and the complex nature of the fishery precluded the development of a reliable CPUE index.

4.2 Biomass estimates

Estimates of current biomass are not available.

4.3 Yield estimates and projections

4.3.1 Other yield estimates and stock assessment factors

Long-term sustainable yield using an $F_{0.1}$ fishing strategy was estimated for BYX 2 using the simulation model with alternative estimates of M. $F_{0.1}$ has been estimated as 0.25 and 0.32 for M = 0.2 and M = 0.23, respectively, for both sexes combined in BYX 2 (Stocker & Blackwell 1991). The biomass at this long-term equilibrium yield is about 35% B_0 and the $F_{0.1}$ yield is about 8–9% B_0.

4.4 Other factors

The most recent assessment for BYX 2 was based upon the historical fishery areas. In recent years the fishery has expanded to new areas not previously fished. Subsequent CPUE analyses have been rejected by Working Groups and it is no longer thought possible to monitor abundance in BYX 2 using trawl CPUE.

Current data on alfonsino movements are inconclusive. It is not known whether the fish on the east coast of the North Island spend some part of their life cycle in other New Zealand waters, or whether the east coast-Chatham Rise region is just one of several pre-reproductive regions. It is possible that the domestic trawl fishery may be exploiting part of a wider South Pacific stock. Catches may be maintained due to the discovery of new grounds. However, the potential for increased catches may be constrained by the availability of BNS 3 quota to cover likely bluenose bycatch.

5. STATUS OF THE STOCKS

Stock Structure Assumptions

No information is available as to whether alfonsino is a single stock in New Zealand fishery waters. Overseas data on alfonsino stock distributions suggest that New Zealand fish could form part of a widely distributed South Pacific stock. In addition to alfonsino (*Beryx splendens*) the BYX Fishstock includes landings of the red bream (*B. decadactylus*), however, red bream makes up less than 1% of the total landings.

BYX 1

Under the adaptive management programme the TACC was increased to 300 t in 2001−02, and catches increased for the next 9 years in the target trawl fishery. However, catches have been below 50 t since 2010–11 as target fishing in this fishery has waned.

BYX 2

Annual landings from 1986 to 2014–15 have remained reasonably stable at or above the level of the TACC. However, as the fishing grounds have extended throughout this time, it is not known if the recent catch levels or the current TACCs are sustainable.

BYX 3

Alfonsino on the Chatham Rise (BYX 3) were lightly fished prior to 1995–96 when catches increased to near the TACC, due to the development of new fishing grounds. Catch has fluctuated around the TACC since then. It is not known if the recent catch levels or the current TACCs are sustainable.

Table 4: Summary of TACCs (t) and reported landings (t) for alfonsino for the most recent fishing year.

Fishstock		FMAs	2017–18 Actual TACC	2017–18 Reported landings
BYX 1	Auckland (East) (West)	1 & 9	300	73
BYX 2	Central (East)	2	1 575	1 692
BYX 3	South-East (Coast) Southland & Sub-Antarctic	3, 4, 5, & 6	1 010	754
BYX 7	Challenger	7	81	12
BYX 8	Central (West)	8	20	<1
BYX 10	Kermadec	10	10	0
Total			2 996	2 531

6. FUTURE RESEARCH CONSIDERATIONS

Neither CPUE nor trawl surveys are likely to provide an index of alfonsino abundance. The best method to determine the status of the stocks and to continue monitoring is likely to be a catch-at-age sampling programme. A large proportion of the alfonsino catch from the two main fisheries is still landed green which would allow for a land-based shed sampling programme for either area, although at-sea observer-based sampling would allow for the detection of any differences in sub-regions within the main fishery areas.

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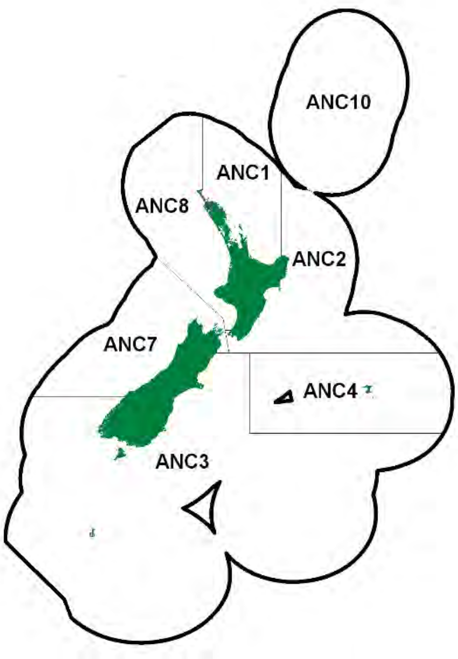
ANCHOVY (ANC)

(*Engraulis australis*)
Kokowhaawhaa



1. FISHERY SUMMARY

Anchovy were introduced into the QMS on 1 October 2002, with allowances, TACCs and TACs in Table 1. These have not changed.

Table 1: Recreational and Customary non-commercial allowances, TACCs and TACs for anchovy by Fishstock.

Fishstock	Recreational Allowance	Customary non-commercial allowance	TACC	TAC
ANC 1	10	5	200	215
ANC 2	10	5	100	115
ANC 3	2	1	50	53
ANC 4	3	2	10	15
ANC 7	10	5	100	115
ANC 8	10	5	100	115
ANC 10	0	0	0	0

1.1 Commercial fisheries

There is no information on catches or landings of anchovy prior to 1990, although sporadic catches were made in some years during exploratory fishing projects for small pelagic species, in the 1960s and 1970s. It is thought that anchovy were caught in most years, but were either not reported, reported as “bait”, or included in the category “mixed species”. Reported annual landings have fluctuated from less than 1 t to 21 t since 1990–91 (Table 2). Under-reporting is likely to have occurred due to misidentification of anchovy in pilchard and other mixed catches, as well as the low value of the species.

Historically most landings have been reported from northeastern New Zealand, ANC 1, with occasional small landings in ANC 3, 7 and 8.

The most consistent (though small) catches have been taken by purse seine. Very few catches have been reported as targeted; most anchovy appear to have been taken as non-target catch in the pilchard fishery. Up to four vessels reported a catch or landing in any one year.

Table 2: Reported catches or landings (t) of anchovy by fishstock from 1990–91 to 2018–19 (prior to 2002–03 reported by FMA). MHR data from 2001–02 - present.

Fishstock	ANC 1	ANC 2	ANC 3	ANC 4	ANC 7	ANC 8	ANC 10	
FMA	1	2	3,5&6	4	7	8&9	10	Total
1990–91†	< 1	0	0	0	< 1	0	0	< 1
1991–92†	1	0	1	0	< 1	0	0	2
1992–93†	21	0	0	0	0	0	0	21
1993–94†	< 1	0	0	0	0	0	0	< 1
1994–95†	< 1	0	0	0	< 1	0	0	< 1
1995–96†	1	0	0	0	0	0	0	1
1996–97†	2	0	0	0	0	0	0	2
1997–98†	1	0	0	0	0	0	0	1
1998–99†	4	0	2	0	0	0	0	6
1999–00†	3	0	0	0	0	0	0	3
2000–01†	10	0	0	0	0	0	0	10
2001–02	7	0	0	0	0	0	0	7
2002–03	8	0	0	0	0	0	0	8
2003–04	4	0	0	0	0	10	0	15
2004–05	< 1	0	0	0	0	12	0	12
2005–06	10	0	0	0	0	< 1	0	10
2006–07	< 1	0	0	0	0	2	0	3
2007–08	< 1	0	0	0	< 1	< 1	0	< 1
2008–09	< 1	0	0	0	< 1	< 1	0	2
2009–10	6	0	0	0	6	0	0	12
2010–11	1	0	< 1	0	< 1	< 1	0	1
2011–12	< 1	0	0	0	0	0	0	< 1
2012–13	0	0	< 1	0	< 1	< 1	0	< 1
2013–14	2	0	<1	0	<1	<1	0	2
2014–15	1	0	<1	0	0	<1	0	<1
2015–16	<1	0	0	0	11	0	0	11
2016–17	<1	0	0	0	5	0	0	5
2017–18	<1	0	0	0	<1	0	0	<1
2018–19	3	<1	<1	0	0	0	0	4

† CELR

1.2 Recreational fisheries
There is no known recreational fishery, but small numbers are caught in small-mesh setnets and beach seines. An estimate of the recreational harvest is not available.

1.3 Customary non-commercial fisheries
An estimate of the customary non-commercial catch is not available.

1.4 Illegal catch
There is no known illegal catch of anchovies.

1.5 Other sources of mortality
Some accidental captures of anchovy by vessels purse seining for other small pelagic species may be discarded if no market is available.

2. BIOLOGY

The single anchovy species, *Engraulis australis*, found in New Zealand also occurs around much of the Australian coast. In New Zealand, it occurs around most of the coastline, but is absent between Banks Peninsula and Foveaux Strait. It is found mostly inshore, particularly in gulfs, bays, harbours, and some large estuaries. In Australia it tends to move seaward in winter, returning closer inshore during spring and the same pattern is likely to occur in New Zealand. Its vertical distribution in the water column is not known, but it seems likely that it occurs at all depths between the surface and the coastal seafloor.

Anchovy are planktivorous, feeding mainly on copepods. They form compact schools, particularly during the warmer months and larger fishes, seabirds, and marine mammals prey heavily upon these schools. Although they generally form single-species schools, anchovies are closely associated with other small pelagic fishes, particularly pilchard and sprats.

The reproductive cycle is not well known. The main spawning season appears to be spring-summer, but in northern regions spawning may occur through much of the year. Spawning grounds extend from shallow water out to mid-shelf. The eggs are pelagic.
No reliable ageing work has been undertaken in New Zealand, but some information is available for this species in Australia where it reaches 16 cm at age 6, and matures at age 1. In northeastern New Zealand, the main size range of anchovy is 8–14 cm, which are likely to be 2–5 year old fish.

There have been no biological studies that are directly relevant to the recognition of separate stocks, or to yield estimates. Consequently no estimates of biological parameters are available. There is extensive international literature on similar species of anchovy, but the relevance of this to the New Zealand species is unknown.

3. STOCKS AND AREAS

No biological information is available on which to make an assessment on whether separate anchovy stocks exist in New Zealand. If spawning is as widespread as the fragmentary accounts suggest and if there is limited migration between regions, there is potential for localised depletion.

Anchovy and pilchard are often caught together. Anchovy fishstock boundaries are fully aligned with those for pilchard.

4. STOCK ASSESSMENT

There have been no stock assessments of New Zealand anchovy.

4.1 Estimates of fishery parameters and abundance
No fishery parameters are available.

4.2 Biomass estimates
No estimates of biomass are available.

4.3 Yield estimates and projections
MCY cannot be determined.

Current biomass cannot be estimated, so *CAY* cannot be determined.

4.4 Other yield estimates and stock assessment results
No information is available.

4.5 Other factors
Ichthyoplankton surveys show anchovy to be locally abundant. However, it is unlikely that the biomass is comparable to the very large stocks of anchovy in some oceans where strong upwelling promotes high productivity. It is more likely that New Zealand anchovy comprise abundant but localised coastal populations.

It is not known whether the biomass of anchovy is stable or variable, but the latter is considered more likely.

In some localities anchovy are a major food source for many fish, seabirds, and marine mammals (e.g., a major component of fur seal diet in May–August at Cape Foulwind). Excessive localised harvesting may disrupt ecosystems.

5. STATUS OF THE STOCKS

No estimates of current biomass are available. At the present level of minimal catches, stocks should be at or close to their natural level. This is nominally a virgin biomass, but not necessarily a stable one. It is not yet possible to estimate a long-term sustainable yield for anchovy.

TACCs and reported landings for the 2017–18 fishing year are summarised in Table 3.

Table 3: Summary of TACCs (t) and reported landings (t) of anchovy for the most recent fishing year.

Fishstock		FMA	2018–19 Actual TACC	2018–19 Reported Landings
ANC 1	Auckland (East)	1	200	<1
ANC 2	Central (East)	2	100	0
ANC 3	South-east (Coast), Southland & sub-Antarctic	3, 5 & 6	50	0
ANC 4	South-east (Chatham)	4	10	0
ANC 7	Challenger	7	100	<1
ANC 8	Central (West), Auckland (West)	8 & 9	100	0
ANC 10	Kermadec	10	0	0
Total			560	<1

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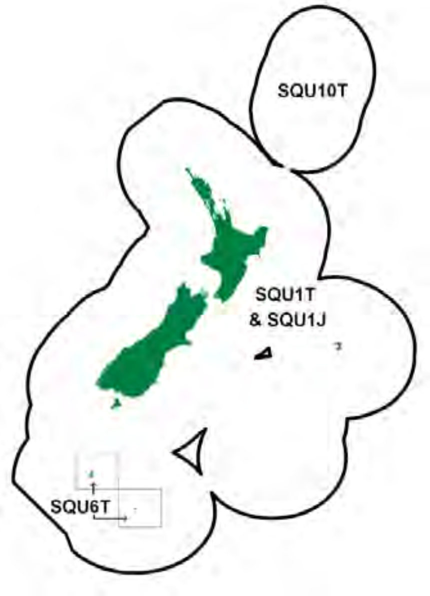
ARROW SQUID (SQU)

(*Nototodarus gouldi*, *N. sloanii*)
Wheketere



1. FISHERY SUMMARY

1.1 Commercial fisheries

The New Zealand arrow squid fishery is based on two related species. *Nototodarus gouldi* is found around mainland New Zealand north of the Subtropical Convergence, whereas *N. sloanii* is found in and to the south of the convergence zone.

Except for the Southern Islands fishery, for which a separate TACC is set, the two species are managed as a single fishery within an overall TACC. The Southern Islands fishery (SQU 6T) is almost entirely a trawl fishery. Although the species (*N. sloanii*) is the same as that found around the south of the South Island, there is evidence to suggest that the Auckland Island shelf stock is different from the mainland stocks. Because the Auckland Island shelf squid are readily accessible to trawlers, and because they can be caught with little finfish bycatch and are therefore an attractive resource for trawlers, a quota has been set separately for the Southern Islands. Total reported landings and TACCs for each stock are shown in Table 1, while historical landings and TACC are depicted in Figure 1.

The New Zealand squid fishery began in the late 1970s and reached a peak in the early 1980s when over 200 squid jigging vessels came to fish in the New Zealand EEZ. The discovery and exploitation of the large squid stocks in the southwest Atlantic substantially increased the supply of squid to the Asian markets causing the price to fall. In the early 1980s, Japanese squid jiggers would fish in New Zealand for a short time before continuing on to the southwest Atlantic. In the late 1980s, the jiggers stopped transit fishing in New Zealand and the number of jiggers fishing declined from over 200 during the 1983–84 fishing year to 5 or fewer vessels from 2006–07. There has been no jig fishery operating since 2016–17. The jig landings in SQU 1J declined from a peak of 53 872 t in 1988–89 to under 1000 t per year by 2012–13. In 2016–17 the TACC was reduced from 50 212 t to 5000 t to reflect these changes within this fishery. Since the 2016–17 fishing year annual landings of less than 1 t have been recorded.

From 1987 to 1998 trawl landings fluctuated between about 30 000–70 000 t, but in SQU 6T the impact of management measures to protect the Hooker's sea lion *(Phocarctos hookeri*) restricted the total catch in some years between 1999 and 2005. Landings have remained below the TACC in SQU 6T since 2004, with only just over 9000 t landed in 2018–19.

Catch and effort data from the SQU 1T fishery show that the catch occurs between December and May, with peak harvest from January to April. The catch has been taken from the Snares shelf on the south coast of the South Island right through to the Mernoo Bank (east coast), but Statistical Area 028 (Snares shelf and Snares Island region) has accounted for over 77% of the total in recent years. Based on Observer data, squid accounts for 67% of the total catch in the target trawl fishery, with bycatch principally of barracouta, jack mackerel, silver warehou and spiny dogfish.

For 2005–06 a 10% in-season increase to the SQU 1T TACC was approved by the Minister of Fisheries. The catch for December–March was 40% higher than the average over the previous eight years and catch rates were double the average, indicating an increased abundance of squid. Previously, in 2003–04, a 30% in-season increase to the TACC was agreed, but catches did not reach the higher limit. In both instances the TACC automatically reverted to the original value at the end of the fishing year. Recent landings have remained below the TACC, with landings recorded during the 2018–19 fishing year (34 212 t) reaching levels last seen in 2007–08 (36 171 t).

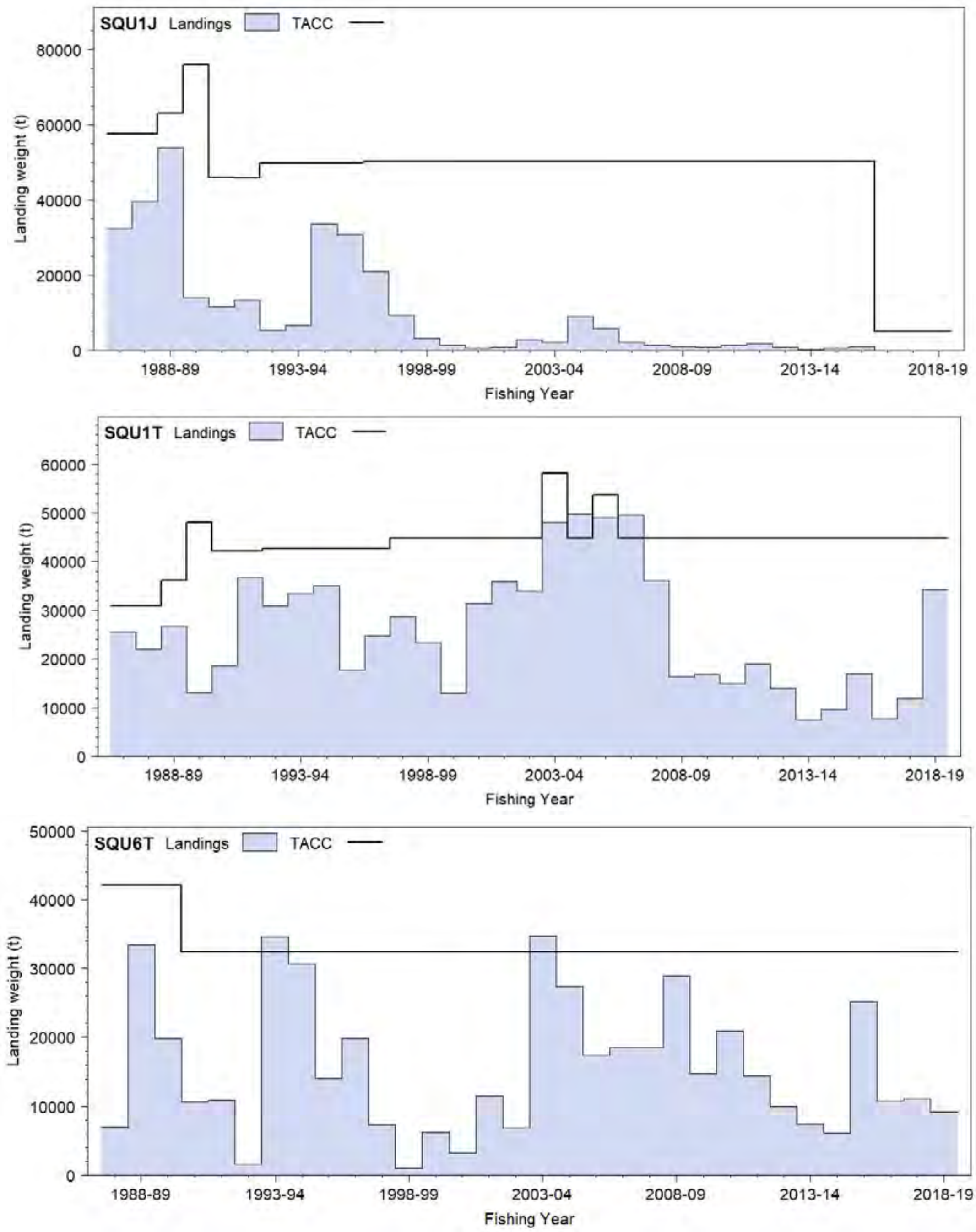


Figure 1: Reported commercial landings and TACC for the three main SQU stocks. Top to bottom: SQU 1J (all waters except 10T and 6T, jigging), SQU 1T (all waters except 10T and 6T, all other methods), and SQU 6T (southern islands, all methods). Note that these figures do not show data prior to entry into the QMS.

Table 1: Reported catches (t) and TACCs (t) of arrow squid from 1986–87 to 2018–19. Source - QMS.

Fishstock	SQU 1J*		SQU 1T*		SQU 6T†		SQU 10T‡		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1986–87	32 394	57 705	25 621	30 962	16 025	32 333	0	10	74 040	121 010
1987–88	40 312	57 705	21 983	30 962	7 021	32 333	0	10	69 316	121 010
1988–89	53 872	62 996	26 825	36 081	33 462	35 933	0	10	114 160	135 080
1989–90	13 895	76 136	13 161	47 986	19 859	42 118	0	10	46 915	166 250
1990–91	11 562	46 087	18 680	42 284	10 658	30 190	0	10	40 900	118 571
1991–92	12 985	45 766	36 653	42 284	10 861	30 190	0	10	60 509	118 571
1992–93	4 865	49 891	30 862	42 615	1 551	30 369	0	10	37 278	122 875
1993–94	6 524	49 891	33 434	42 615	34 534	30 369	0	10	74 492	122 875
1994–95	33 615	49 891	35 017	42 741	30 683	30 369	0	10	99 315	123 011
1995–96	30 805	49 891	17 823	42 741	14 041	30 369	0	10	62 668	123 011
1996–97	20 792	50 212	24 769	42 741	19 843	30 369	0	10	65 403	123 332
1997–98	9 329	50 212	28 687	44 741	7 344	32 369	0	10	45 362	127 332
1998–99	3 240	50 212	23 362	44 741	950	32 369	0	10	27 553	127 332
1999–00	1457	50 212	13 049	44 741	6 241	32 369	0	10	20 747	127 332
2000–01	521	50 212	31 297	44 741	3 254	32 369	< 1	10	35 071	127 332
2001–02	799	50 212	35 872	44 741	11 502	32 369	0	10	48 173	127 332
2002–03	2 896	50 212	33 936	44 741	6 887	32 369	0	10	43 720	127 332
2003–04	2 267	50 212	48 060	#58 163	34 635	32 369	0	10	84 962	127 332
2004–05	8 981	50 212	49 780	44 741	27 314	32 369	0	10	86 075	127 332
2005–06	5 844	50 212	49 149	#49 215	17 425	32 369	0	10	72 418	127 332
2006–07	2 278	50 212	49 495	44 741	18 479	32 369	0	10	70 253	127 332
2007–08	1 371	50 212	36 171	44 741	18 493	32 369	0	10	56 035	127 332
2008–09	1 032	50 212	16 407	44 741	28 872	32 369	0	10	46 311	127 332
2009–10	891	50 212	16 759	44 741	14 786	32 369	0	10	32 436	127 332
2010–11	1 414	50 212	14 957	44 741	20 934	32 369	0	10	37 304	127 332
2011–12	1 811	50 212	18 969	44 741	14 427	32 369	0	10	35 207	127 332
2012–13	741	50 212	13 951	44 741	9 944	32 369	0	10	24 637	127 332
2013–14	167	50 212	7 483	44 741	7 403	32 369	0	10	15 053	127 332
2014–15	513	50 212	9 668	44 741	6 127	32 369	0	10	16 310	127 332
2015–16	937	50 212	17 018	44 741	25 172	32 369	<1	10	43 127	127 332
2016–17	1	5 000	7 735	44 741	10 726	32 369	0	10	18 462	82 120
2017–18	<1	5 000	11 983	44 741	11 086	32 369	<1	10	23 069	82 120
2018–19	0	5 000	34 212	44 741	9 189	32 369	0	10	43 401	82 120

* All areas except Southern Islands and Kermadec.
† Southern Islands.
‡ Kermadec.
\# In season increase of 30% for 2003–04 and 10% for 2005–06

1.2 Recreational fisheries
The amount of arrow squid caught by recreational fishers is not known.

1.3 Customary non-commercial fisheries
No quantitative information is available on the current level of customary non-commercial take.

1.4 Illegal catch
There is no quantitative information available on the level of illegal catch.

1.5 Other sources of mortality
No information is available on other sources of mortality.

2. BIOLOGY

Two species of arrow squid are caught in the New Zealand fishery. Both species are found over the continental shelf in water up to 500 m depth, though they are most prevalent in water less than 300 m depth. Both species are sexually dimorphic, though similar in biology and appearance. Individuals can be identified to species level based on sucker counts on Arm I and differences in the hectocotylized arm of males.

Recent work on the banding of statoliths from *N. sloanii* suggests that the animals live for around one year. Growth is rapid. Modal analysis of research data has shown increases of 3.0–4.5 cm per month for Gould's arrow squid measuring between 10 and 34 cm Dorsal Mantle Length (DML).

Estimated ages suggest that *N. sloanii* hatches in July and August, with spawning occurring in June and July. It also appears that *N. gouldi* may spawn one to two months before *N. sloanii*, although there are some indications that *N. sloanii* spawns at other times of the year. The squid taken by the fishery do not appear to have spawned.

Tagging experiments indicate that arrow squid can travel on average about 1.1 km per day with a range of 0.14–5.6 km per day.

Biological parameters relevant to stock assessment are shown in Table 2.

Table 2: Estimates of biological parameters.

Fishstock		Estimate		Source
1. Weight = a (length)^b (Weight in g, length in cm dorsal length)				
		a	b	
N. gouldi	≤ 12 cm DML	0.0738	2.63	Mattlin et al (1985)
N. sloanii	≥ 12 cm DML	0.029	3	
2. von Bertalanffy growth parameters				
	K	t_0	L_∞	
N. gouldi	2.1–3.6	0	35	Gibson & Jones (1993)
N. sloanii	2.0–2.8	0	35	

3. STOCKS AND AREAS

There are no new data which would alter the stock boundaries given in previous assessment documents. It is assumed that the stock of *N. gouldi* (the northern species) is a single stock, and that *N. sloanii* around the mainland comprises a unit stock for management purposes, although the detailed structure of these stocks is not fully understood. The distribution of the two species is largely geographically separate but those occurring around the mainland are combined for management purposes. The Auckland Islands Shelf stock of *N. sloanii* appears to be different from the mainland stock and is managed separately.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

Tables and text for this section were last updated for the 2020 Fishery Assessment Plenary. A more detailed summary from an issue-by-issue perspective is available in the 2018 Aquatic Environment & Biodiversity Annual Review (Fisheries New Zealand 2019), https://www.mpi.govt.nz/dmsdocument/34854-aquatic-environment-and-biodiversity-annual-review-aebar-2018-a-summary-of-environmental-interactions-between-the-seafood-sector-and-the-aquatic-environment.

4.1 Role in the ecosystem

Arrow squid are short-lived and abundance is highly variable between years (see Biology section). Hurst et al (2012) reviewed the literature and noted that arrow squid are an important part of the diet for many species. Stevens et al (2012) reported that, between 1960 and 2000, squids (including arrow squid) were important in the diet of banded stargazer (59% of non-empty stomachs), bluenose (26%), giant stargazer (34%), gemfish (43%), and hapuku (21%), and arrow squid were specifically recorded in the diets of alfonsino, barracouta, hake, hoki, ling, red cod, red gurnard, sea perch, and southern blue whiting. In a detailed study on the Chatham Rise (Dunn et al 2009), cephalopods were identified as prey of almost all demersal fish species, and arrow squid were identified in the diet of hake, hoki, ling, Ray's bream, shovelnose spiny dogfish, sea perch, smooth skate, giant stargazer and silver warehou, and was a significant component (over 10% prey weight) of the diet of barracouta and spiny dogfish.

Arrow squid have been recorded as important in the diet of marine mammals such as NZ fur seals and New Zealand sea lions, particularly during summer and autumn (Fea et al 1999, Harcourt et al. 2002, Chilvers 2008, Boren 2008) and in the diet of common dolphins (Meynier et al 2008, Stockin 2008). They are also important in the diet of seabirds such as shy albatross in Australia (Hedd & Gales 2001) and Buller's albatross at the Snares and Solander Islands (James & Stahl 2000). Cephalopods in general are important in the diet of a wide range of Australasian albatrosses, petrels and penguins (Marchant & Higgins 2004).

Arrow squid in New Zealand waters have been reported to feed on myctophids, sprats, pilchards, barracouta, euphausiids, mysids, isopods and squid, probably other arrow squid (Yatsu 1986, Uozumi 1998). Uozumi found that the importance of various food items changed between years, and the percentage of empty stomachs was influenced by area, season, size, maturation, and time of day. In Australia, *N. gouldi* was found to feed mostly on pilchard, barracouta, and crustaceans (O'Sullivan & Cullen 1983). Cannibalism was also recorded.

4.2 Bycatch (fish and invertebrate)

Based on models using observer and fisher-reported data, total non-target fish and invertebrate catch in the arrow squid trawl fishery ranged between 8900 and 39 800 t per year between 2002–03 and 2015–16, and has shown a significant decreasing trend since 2005–06 (Anderson & Edwards 2018). Over that time period arrow squid comprised 79% of the total estimated catch recorded by observers in this fishery. Nearly 600 non-target species or species groups were recorded, with QMS species making up most non-target catch (over 85%) in each year. The remainder of the observed catch comprised mainly the QMS fish species barracouta (9.1%), silver warehou (3.3%), and spiny dogfish (1.7%). Invertebrate species made up a much smaller fraction of the bycatch overall (1.3%), but crabs (1.2%), especially the smooth red swimming crab (*Nectocarcinus bennetti*, 0.85%), were frequently caught.

Estimated total annual discards showed a decreasing trend over time, from 16 300 in 2002–03 to about 1500 t in 2013–14 (Anderson & Edwards 2018). QMS species accounted for 44% of discards across all years, followed by non-QMS species (41%), invertebrate species (15%), and arrow squid (8%). Target species discards were relatively low, and annual discards of non-QMS species were overall at a similar level to QMS discards. The species discarded in the greatest amounts were spiny dogfish (80%), redbait (34%), silver dory (87%), and rattails (88%). From 2002–03 to 2015–16, the overall discard fraction value was 0.12, with little trend over time. Discards ranged from 0.05 kg of discarded fish for every 1 kg of arrow squid caught in 2007–08 to 0.43 kg in 2002–03.

Finucci et al (2019) analyzed bycatch trends in deepwater fisheries, including arrow squid trawl, from 1990–91 to 2016–17. They found that the most common bycatch species by weight were barracouta (*Thyrsites atun*, BAR), silver warehou (*Seriolella punctata*, SWA), and spiny dogfish (*Squalus acanthias*, SPD). Moreover, of the 347 fish and invertebrate species caught as bycatch in this fishery and examined in this study, 68 showed a decrease in catch over time (15 were significant) and 81 showed an increase (29 were significant). Species showing the greatest decline were jack mackerels (*Trachurus* spp., JMA), and thresher shark (*Alopias vulpinus*, THR) while species showing the greatest increase were giant spider crab (*Jacquinotia edwardsii*, GSC) and beaked sandfish (*Gonorynchus forsteri* & *G. greyi*, GON). A change in coding between paddle crab (*Ovalipes catharus*, PAD) and smooth red swimming crab (*Nectocarcinus bennetti*, NCB), caused a decline of the former and an increase of the latter in bycatch records.

4.3 Incidental Capture of Protected Species (seabirds, mammals, and protected fish)

For protected species, capture estimates presented here include all animals recovered to the deck (alive, injured or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds struck by a warp but not brought onboard the vessel, Middleton & Abraham 2007).

4.3.1 New Zealand sea lion interactions

The New Zealand sea lion (rāpoka) *Phocarctos hookeri*, is the rarest sea lion in the world. The estimated total population of around 11 800 sea lions in 2015 is classified by the Department of Conservation as 'Nationally Vulnerable' under the New Zealand Threat Classification System (Baker et al 2019). Pup production at the main Auckland Island rookeries showed a steady decline between 1998 and 2009 and has subsequently stabilised (details can be found in the Aquatic Environment and Biodiversity Annual Review, MPI 2017).

Sea lions forage to depths of up to 600 m and overlap with trawling at up to 500 m depth for arrow squid. Sea lions interact with some trawl fisheries which can result in incidental capture and subsequent drowning (Smith & Baird 2005, 2007a & b, Thompson & Abraham 2010a, Thompson & Abraham 2012, Abraham & Thompson 2011, Abraham et al 2016). Since 1988, incidental captures of sea lions have been monitored by government observers on-board an increasing proportion of the fishing fleet.

Since the 2012–13 fishing year, more than 80% of fishing trawls in the SQU 6T fishery have been observed each year.

Efforts to mitigate incidental captures in fisheries have focused on the SQU 6T fishery. From 2017, advice to manage sea lion interactions in this fishery has been developed in consultation with the Squid 6T Operational Plan Technical Advisory Group, including representatives from government and stakeholder groups as well as technical experts and advisors. Under the present Operational Plan, adopted in December 2017, Fisheries New Zealand sets a fishing-related mortality limit (FRML, Table 3) for sea lions in the Auckland Islands squid trawl fishery (SQU 6T) based on estimation of a Population Sustainability Threshold (PST) using a Bayesian population dynamic model (Roberts & Doonan 2016). The PST represents the maximum number of anthropogenic mortalities that the population can sustain while still achieving a defined population objective. For the Auckland Islands sea lion population, the choice of population objective underlying the current PST is as follows: ‘Fisheries mortalities will be limited to ensure that the impacted population is no more than 5% lower than it would otherwise be in the absence of fishing mortality, with 90% confidence, over five years’.

SLEDs were first used on some vessels in the SQU 6T fishing fleet in 2001–02. SLED use increased in subsequent years. The use of SLEDs is not mandatory, but use of a certified SLED is required by the current industry body (the Deepwater Group) and is necessary to receive the ‘Discount Rate’ relative to the tow limit applied by Fisheries New Zealand). For these reasons, from 2006–07 a standardised model Mark 13/3 SLED has been universally employed by all vessels in the SQU 6T fleet. SLED deployment is monitored and audited by Fisheries New Zealand observers.

In 1992, the Ministry adopted a fisheries-related mortality limit (FRML; previously referred to as a maximum allowable level of fisheries-related mortality or MALFiRM) to set an upper limit on the number of New Zealand sea lions that can be incidentally killed each year in the SQU 6T trawl fishery (Chilvers 2008). If this limit is reached, the fishery will be closed for the remainder of the season.

The original ‘MALFiRM’ was calculated using the potential biological removal approach (PBR; Wade 1998) and was used from 1992–93 to 2003–04 (Smith & Baird 2007a). Since 2003–04 the FRML has been translated into a maximum permitted number of tows calculated from assumed interaction and SLED efficacy rates, regardless of the number of observed New Zealand sea lion captures. This approach was taken because since the introduction of SLEDs, observed sea lion captures are no longer a reliable index of the number of sea lions interacting with the net, and there is uncertainty about the survival rate of sea lions exiting the net via the SLED (‘SLED efficacy’); for this reason the number of sea lion deaths from fishery interactions cannot be observed directly. Instead, a management setting meant to approximate the interaction rate, i.e., the ‘Strike Rate’ is set by Fisheries New Zealand and multiplied by a second setting, the ‘Discount Rate’ representing SLED efficacy, to inform a proxy estimate of potential sea lion fatalities per 100 tows. This proxy estimate is then used to set an effort limit on the operation of the fishery, to ensure that estimated sea lion mortalities remain below the FRML.

Since the introduction of SLEDs, observed capture rates have declined substantially and observer coverage has increased in the SQU 6T fishery (Table 4). Subsequently, statistical models formerly used to estimate interaction rates and SLED efficacy rates (Abraham et al 2016) became increasingly uncertain, because these rates are inversely correlated and, since the introduction of SLEDs, are no longer informed by observed captures data. For this reason Fisheries New Zealand no longer estimates interaction rates, and is progressing research to inform the direct estimation of cryptic mortalities (i.e. un-observable deaths) as a function of observed captures.

Observed sea lion captures in the squid fishery on the Stewart Snares shelf are low (less than one observed capture per year), with high observer coverage (Table 5). In choosing management settings for the SQU 6T fishery, the FRML is reduced by 1 to account for one potential sea lion mortality per year occurring in the SQU 6T fishery.

A quantitative risk assessment of all threats to the New Zealand sea lion was undertaken to inform the development of a Threat Management Plan for the species. The risk assessment process used for the development of the TMP aimed to quantify which threats pose most risk to the population, and inform the prioritisation of management actions that would meet the management goals of the TMP. The approach involved the development of demographic models, compilation of data on threats, a risk triage process and detailed modelling of key threats where sufficient data was available. A panel of national and international experts was convened to guide and review the process and provide opinion-based input where data availability was poor. For the Auckland Islands, the greatest risks identified from the triage were; *Klebsiella* disease, commercial trawl fishing, male aggression, trophic effects/prey availability, hookworm disease and wallows.

As the base of the risk assessment, a demographic assessment model were developed for females at the Auckland Islands (which the major squid trawl fishery SQU 6T operates adjacent to), integrating information from mark-recapture observations, pup census and the estimated age distribution of lactating females. Good fits were obtained to all three types of observation and the model structure and parameter estimates appeared to be a good representation of demographic processes that have affected population decline there (primarily low pup survival and low adult survival) (Roberts & Doonan 2016).

Best-estimate projections were undertaken for commercial trawl related mortality, *Klebsiella pneumoniae*-related mortality of pups, trophic effects (food limitation), pups drowning in wallows, male aggression and hookworm mortality and these were compared with the base run – a continuation of demographic rates since 2005 ($\lambda2037 = 0.961$, 95% CI 0.890–1.020). A positive growth rate was obtained only with the alleviation of *Klebsiella* ($\lambda2037 = 1.005$, 95% CI 0.926– 1.069). When assuming the most pessimistic view of cryptic mortality (all interactions resulted in mortality and associated death of pups), alleviating the effects of commercial trawl-related mortality resulted in an increased population growth rate relative to the base run, but did not reverse the declining trend ($\lambda2037 = 0.977$, 95% CI 0.902–1.036). The alleviation of trophic effects (food limitation) had the next greatest effect ($\lambda2037 = 0.974$, 95% CI 0.905–1.038) and all other threats had a minor effect relative to the base run projection (increase in $\lambda2037$ of less than 0.01) (Roberts & Doonan 2016).

Table 3: Fisheries-related mortality limit (FRML) from 1991 to 2018 (♀ = females; numbers in parentheses are FRMLs modified in-season). Direct comparisons among years are not useful because the assumptions underlying the FRML changed over time.

Year	FRML	Discount rate	Management actions
1991–92	16 (♀)		
1992–93	63		
1993–94	63		
1994–95	69		
1995–96	73		Fishery closed by MFish (4 May)
1996–97	79		Fishery closed by MFish (28 Mar)
1997–98	63		Fishery closed by MFish (27 Mar)
1998–99	64		
1999–00	65		Fishery closed by MFish (8 Mar)
2000–01	75		Voluntary withdrawal by industry
2001–02	79		Fishery closed by MFish (13Apr)
2002–03	70		Fishery closed by MFish (29 Mar), overturned by High Court
2003–04	62 (124)	20%	Fishery closed by MFish (22 Mar), overturned by High Court
2004–05	115	20%	Voluntary withdrawal by industry on reaching the FRML
2005–06	97 (150)	20%	FRML increased in mid-March due to abundance of squid
2006–07	93	20%	
2007–08	81	35%	
2008–09	113 (95)	35%	Lower interim limit agreed following decrease in pup numbers
2009–10	76	35%	
2010–11	68	35%	
2011–12	68	35%	
2012–13	68	82%	
2013–14	68	82%	
2014–15	68	82%	
2015–16	68	82%	
2016–17	68	82%	
2017–18	38	75%	

Results from the risk assessment at the Auckland Islands indicated that alleviation of any one threat will not result in an increasing population. Similarly none of the major threats assessed were sufficient alone to explain the observed decline in pup production at the Auckland Islands. Clearly multiple factors were acting on the population, and for management to recover the species a holistic view must be adopted. Further studies will be needed to fully understand, and development management options for some of the key threats, such as trophic effects and *Klebsiella* disease.

Table 4: Annual trawl effort, observer coverage, observed numbers of sea lions captured, observed capture rate (sea lions per 100 trawls), estimated sea lion captures, interactions, and the estimated strike or capture rate (with 95% confidence intervals) for the squid trawl fisheries operating in SQU 6T (Auckland Islands). Estimates are based on methods described in Abraham et al (2016) and available via https://data.dragonfly.co.nz/psc HYPERLINK "http://www.fish.govt.nz/en-nz/Environmental/Seabirds/". **Data for 1995–96 to 2014–15 are based on data version 2019v01.**

			Obs. captures		Est. captures		Est. interactions		Est. Interaction rate	
Year	**Tow**	**% obs.**	**No.**	**Rate**	**Mean**	**95% c.i.**	**Mean**	**95% c.i.**	**Mean**	**95% c.i.**
1995–96	4 468	12.5	13	2.3	130	69–223	129	69–223	2.9	1.5–5
1996–97	3 721	19.8	28	3.8	140	92–208	140	90–211	3.8	2.4–5.7
1997–98	1 442	23.2	15	4.5	59	32–101	59	31–102	4.1	2.1–7.1
1998–99	403	38.7	5	3.2	14	7–26	14	5–27	3.5	1.2–6.7
1999–00	1 206	36.3	25	5.7	69	45–105	69	44–107	5.7	3.6–8.9
2000–01	583	99.1	39	6.7	39	39–40	62	41–85	10.6	7–14.6
2001–02	1 647	34.2	21	3.7	42	29–63	73	44–114	4.4	2.7–6.9
2002–03	1 466	28.4	11	2.6	18	12–28	47	25–79	3.2	1.7–5.4
2003–04	2 594	30.6	16	2	39	26–59	206	104–383	7.9	4–14.8
2004–05	2 693	29.9	9	1.1	30	16–49	167	76–323	6.2	2.8–12
2005–06	2 459	22.4	10	1.8	26	15–43	153	65–306	6.2	2.6–12.4
2006–07	1 317	40.7	7	1.3	15	9–25	93	33–216	7.1	2.5–16.4
2007–08	1 265	46.7	5	0.8	12	6–22	160	24–804	12.6	1.9–63.6
2008–09	1 925	39.6	2	0.3	7	2–15	134	14–672	7	0.7–34.9
2009–10	1 188	25.5	3	1	12	5–26	165	22–818	13.9	1.9–68.9
2010–11	1 583	34.6	0	0	3	0–10	90	5–501	5.7	0.3–31.6
2011–12	1 281	44.6	0	0	2	0–6	60	3–319	4.7	0.2–24.9
2012–13	1 027	86.2	3	0.3	4	3–6	73	8–384	7.1	0.8–37.4
2013–14	737	84.4	2	0.3	2	2–4	47	5–231	6.4	0.7–31.3
2014–15	633	88.3	1	0.2	1	1–3	44	3–236	7	0.5–37.3
2015–16	1 367	92.2	0	0						
2016–17	1 280	70.4	3	0.3						
2017–18	1 137	88.7	2	0.2						

* SLEDs were introduced. ^ SLEDs were standardised and in widespread use.

Table 5: Number of tows by fishing year and observed NZ sea lion captures in squid trawl fisheries on the Stewart-Snares shelf, 2002–03 to 2017–18. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Estimates are based on methods described in Abraham et al (2016) and available via https://data.dragonfly.co.nz/psc. Data for 2002–03 to 2014–15 are based on data version 2019v1.

	Fishing effort			Observed captures		Estimated interactions	
	Tows	**No. obs**	**% obs**	**Captures**	**Rate**	**Mean**	**95% c.i.**
2002–03	3 281	506	15.4	0	0.00	2	0–5
2003–04	4 534	957	21.1	1	0.10	3	1–6
2004–05	5 861	1 582	27.0	3	0.19	6	3–10
2005–06	4 481	537	12.0	1	0.19	3	1–7
2006–07	2 925	706	24.1	1	0.14	2	1–5
2007–08	2 412	866	35.9	0	0.00	1	0–3
2008–09	1 809	532	29.4	0	0.00	1	0–3
2009–10	2 259	765	33.9	1	0.13	2	1–4
2010–11	2 176	685	31.5	0	0.00	1	0–3
2011–12	1 985	801	40.4	0	0.00	1	0–2
2012–13	1 528	1 342	87.8	0	0.00	0	0–1
2013–14	1 222	1 083	88.6	0	0.00	0	0–1
2014–15	1 116	1 047	93.8	1	0.10	0	0–1
2015–16	988	923	93.4	0	0.00		
2016–17	1 116	906	81.2	0	0.00		
2017–18	1 229	1 191	96.9	1	0.08		

4.3.2 New Zealand fur seal interactions

The New Zealand fur seal was classified in 2008 as “Least Concern” by IUCN and in 2010 as “Not Threatened” under the New Zealand Threat Classification System (Baker et al 2019**)**.

Vessels targeting arrow squid incidentally catch fur seals (Baird & Smith 2007a, Smith & Baird 2009, Thompson & Abraham 2010b, Baird 2011, Abraham et al 2016), mostly off the east coast South Island, on the Stewart-Snares shelf, and close to the Auckland Islands. In the 2016–17 fishing year there were 17 observed captures of New Zealand fur seal in squid trawl fisheries. The rate of capture over the period 2002–03 and 2017–18 varied from 0.1 to 1.1 captures per hundred tows without obvious trend (Table 6). Estimated capture rates from Abraham et al (2016) (available via https://data.dragonfly.co.nz/psc) are not reproduced here pending resolution of identified structural issues in the model related to the partition between model strata with contrasting capture rates, resulting in implausibly high estimates of uncertainty despite high observer coverage.

Table 6: Number of tows by fishing year and observed total NZ fur seal captures in squid trawl fisheries, 2002–03 to 2017–18.

		Fishing effort		Observed	
	Tows	**No.**	**%**	**Capture**	**Rate**
2002–03	8 410	1 308	15.6	8	0.61
2003–04	8 336	1 771	21.2	16	0.90
2004–05	10 489	2 512	23.9	15	0.60
2005–06	8 576	1 103	12.9	4	0.36
2006–07	5 905	1 289	21.8	9	0.70
2007–08	4 236	1 459	34.4	6	0.41
2008–09	3 867	1 299	33.6	1	0.08
2009–10	3 789	1 071	28.3	8	0.75
2010–11	4 213	1 263	30.0	8	0.63
2011–12	3 505	1 381	39.4	8	0.58
2012–13	2 644	2 271	85.9	7	0.31
2013–14	2 051	1 789	87.1	10	0.56
2014–15	1 950	1 694	86.9	19	1.12
2015–16	2 895	2 363	81.6	10	0.42
2016–17	2 594	1 926	74.6	17	0.88
2017–18	2 825	2 515	89.0	14	0.56

4.3.3 Seabird interactions

Vessels targeting arrow squid incidentally catch seabirds. Baird (2005a) summarised observed seabird captures in the arrow squid target fishery for the fishing years 1998–99 to 2002–03 and calculated total seabird captures for the areas with adequate observer coverage using ratio based estimations. Baird & Smith (2007b, 2008) summarised observed seabird captures and used both ratio-based and model-based predictions to estimate the total seabird captures for 2003–04, 2004–05 and 2005–06. Abraham & Thompson (2011) summarised captures of protected species and used model and ratio-based predictions of the total seabird captures for 1989–90 and 2008–09.

A consistent modelling framework was developed to estimate the captures for ten species (and species groups), using hierarchical mixed-effects generalised linear models (GLM), fitted using Bayesian methods (Abraham et al 2016, Abraham & Richard 2017, 2018).

In the 2016–17 fishing year there were 261 observed captures of birds in squid trawl fisheries, and 341 estimated captures (95% c.i.: 314–375), with the estimates made using a statistical model (Table 7, Abraham et al 2016). In 2017–18, there were 256 observed captures of seabirds in squid trawl fisheries, and 285 estimated captures (95% c.i.:272–302). (Table 7).

Total estimated seabird captures in squid trawl fisheries varied from 244 to 1348 between 2002–03 and 2017–18 at a rate of 7.6 to 22.7 captures per hundred tows without obvious trend (Table 7). These estimates include all bird species and should be interpreted with caution because trends by species can be masked. The average capture rate in squid trawl fisheries over the last sixteen years is about 13.32 birds per 100 tows, a high rate relative to trawl fisheries for scampi (4.43 birds per 100 tows) and hoki (2.32 birds per 100 tows) over the same years.

Table 7: Number of tows by fishing year and observed and model-estimated total bird captures in squid trawl fisheries, 2002–03 to 2017–18. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Estimates are based on methods described in Abraham et al (2016) and Abraham & Richard (2017, 2018) and are available via https://data.dragonfly.co.nz/psc. Estimates from 2002–03 to 2017–18 are based on data version 2019v1.

		Observed				Estimated	
	Tows	No. obs	% obs	Captures	Rate	Captures	95% c.i.
2002–03	8 410	1 308	15.6	154	11.8	875	706–1080
2003–04	8 336	1 771	21.2	194	11.0	875	723–1059
2004–05	10 489	2 512	23.9	351	14.0	1299	1120–1509
2005–06	8 576	1 103	12.9	195	17.7	1124	907–1396
2006–07	5 904	1 289	21.8	126	9.8	559	451–691
2007–08	4 236	1 459	34.4	162	11.1	442	372–527
2008–09	3 868	1 299	33.6	259	19.9	636	543–745
2009–10	3 788	1 071	28.3	92	8.6	378	305–467
2010–11	4 215	1 263	30.0	142	11.2	548	447–670
2011–12	3 507	1 383	39.4	105	7.6	336	278–403
2012–13	2 644	2 271	85.9	446	19.6	506	483–533
2013–14	2 051	1 789	87.2	206	11.5	242	226–262
2014–15	1 950	1 694	86.9	384	22.7	419	401–442
2015–16	2 895	2 363	81.6	302	12.8	348	329–374
2016–17	2 594	1 926	74.2	261	13.6	341	314–375
2017–18	2 830	2 515	88.9	256	10.2	285	272–302

The squid target fishery contributes to the total risk posed by New Zealand commercial fishing to seabirds. The two species to which the fishery poses the most risk are Southern Buller's albatross and New Zealand white-capped albatross, with this target fishery posing 0.050 and 0.030 of PST respectively (Table 8). Southern Buller's albatross was assessed at high risk and white-capped albatross at medium risk (Richard et al 2020).

Observed seabird captures since 2002–03 have been dominated by four species: white-capped and southern Buller's albatrosses make up 83% and 13% of the albatrosses captured, respectively; and white-chinned petrels and sooty shearwaters make up 56% and 41% of other birds, respectively, the total and fishery risk ratios presented in Table 9. Most captures occur on the Stewart-Snares shelf (63%) or close to the Auckland Islands (36%). These numbers should be regarded as only a general guide on the distribution of captures because observer coverage is not uniform across areas and may not be representative.

Table 8: Risk ratio of seabirds predicted by the level two risk assessment for the squid target trawl fishery and all fisheries included in the level two risk assessment, 2006–07 to 2016–17, showing seabird species with a risk ratio of at least 0.001 of Population Sustainability Threshold, PST (from Richard et al 2020, where full details of the risk assessment approach can be found). The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the PST. The DOC threat classifications are shown (Robertson et al 2017 at http://www.doc.govt.nz/Documents/science-and-technical/nztcs19entire.pdf).

		Risk ratio			
Species name	**PST (mean)**	**Squid target trawl**	**TOTAL**	**Risk category**	**DOC Threat Classification**
Southern Buller's albatross	1 3604	0.050	0.37	High	At Risk: Naturally Uncommon
New Zealand white-capped albatross	10 800	0.030	0.29	Medium	At Risk: Declining
White-chinned petrel	25 8006	0.009	0.07	Low	At Risk: Declining
Salvin's albatross	3 460	0.002	0.65	High	Threatened: Nationally Critical
Northern royal albatross	723	0.001	0.05	Low	At Risk: Naturally Uncommon

Mitigation methods such as streamer (tori) lines, Brady bird bafflers, warp deflectors, and offal management are used in the squid trawl fishery. Warp mitigation was voluntarily introduced from about 2004 and made mandatory in April 2006 (Ministry of Fisheries 2006). The 2006 notice mandated that all trawlers over 28 m in length use a seabird scaring device while trawling (being "paired streamer lines", "bird baffler" or "warp deflector" as defined in the notice). During the 2005–06 fishing year a large trial of mitigation devices was conducted in the squid fishery (Middleton & Abraham 2007).

Eighteen vessels were involved in the trial which used observations of seabird heavily contacting the trawl warps (‘warp strikes’) to quantify the effect of using three mitigation devices; paired streamer/tori lines, four boom bird bafflers and warp scarers. Few warp strikes occurred in the absence of offal discharge. When offal was present the tori lines were most effective at reducing warp strikes. All mitigation devices were more effective for reducing large bird warp strikes than small bird. There were, however, about as many bird strikes on the tori lines as the number of strikes on unmitigated warps. The effect of these strikes has not been assessed (Middleton & Abraham 2007).

The warp capture rate of white-capped albatross (84% of albatross observed caught in this fishery) before warp mitigation was made mandatory at the start of the 2005–06 fishing year was higher than 3 per 100 tows in squid target trawls until the three year period from 2003–04 to 2005–06. Since 2006–07, the warp capture rate has decreased to below 1 per 100 tows. Capture rates from nets has fluctuated over this time period, and now make up the majority (Figure 2).

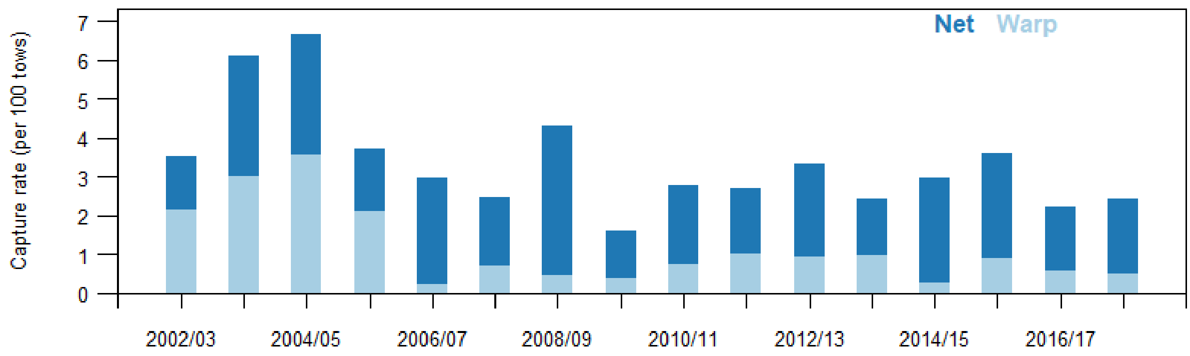


Figure 2: Capture rates of white-capped albatross in squid trawl fisheries for warp and net captures.

4.3.4 Protected fish species interactions

Basking shark

The basking shark (*Cetorhinus maximus*) was classified as “Endangered” by IUCN in 2013 and as “Threatened – Nationally Vulnerable” in 2016, under the New Zealand Threat Classification System (Duffy et al 2018). Basking shark has been a protected species in New Zealand since 2010, under the Wildlife Act 1953, and is also listed in Appendix II of the CITES convention.

Basking sharks are incidentally caught in arrow squid trawls (Francis & Smith 2010). From 2010–11 onwards, fisheries reported catching 36 basking shark individuals (17 of which were reported by fisheries observers from 2013 onwards) in arrow squid fisheries, over more than 22 600 tows. Little is known about the survival of released individuals, but it is assumed to be low. It is not known whether the low numbers of captures in recent decades are a result of different operational methods used by the fleet, a change in regional availability of sharks, or a decline in basking shark abundance (Francis 2017). Of a range of fisheries and environmental factors considered, vessel nationality stood out as a key factor in high catches in the late 1980s and early 1990s (Francis & Sutton, 2012). Research to improve the understanding of the interactions between basking sharks and fisheries was reported in Francis & Sutton (2012) and updated in Francis (2017).

White pointer shark

The white pointer shark (*Carcharodon carcharias*, also known as great white shark) was classified as “Vulnerable” by IUCN in 2019 and as “Threatened – Nationally Endangered” in 2016, under the New Zealand Threat Classification System (Duffy et al 2018).
White sharks were protected in New Zealand waters in 2007, under the Wildlife Act 1953, but they are incidentally caught in commercial and recreational fisheries (Francis & Lyon 2012). Fisheries reported catching a total of 17 white pointer shark individuals in arrow squid trawls since 2016, 3 of which were dead upon capture and the remainder was released alive. Little is known about the survival of released individuals, but it is assumed to be low.

Table 9: Number of observed seabird captures in squid trawl fisheries, 2002–03 to 2016–17, by species and area. The risk category is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Population Sustainability Threshold, PST (from Richard et al 2017, where full details of the risk assessment approach can be found). It is not an estimate of the risk posed by trawl fishing for squid alone

	Risk category	Auckland Islands	Chatham Rise	East Coast South Island	Fiordland	Stewart Snares Shelf	Sub-antarctic	Total
New Zealand white-capped albatross	High	399		3	11	525		938
Southern Buller's albatross	High	46			8	98		152
Salvin's albatross	High	1		4		17	1	23
Southern Royal albatross	Negligible					6		6
Campbell black-browed albatross	Low	1						1
Albatross spp.	-	4				1		5
Black-browed albatross	-	1						1
Buller's albatross	-				1			1
Royal albatross spp.	-					1		1
Total albatrosses		**452**	**0**	**7**	**20**	**648**	**1**	**1128**
White-chinned petrel	Negligible	493				633	2	1128
Sooty shearwater	Negligible	177		22	5	618		822
Antarctic prion	Negligible	34						34
Common diving petrel	Negligible	6				3		9
Cape petrel	Negligible				1	1		2
Fairy prion	Negligible	2						2
Black-bellied storm petrel	Negligible	1						1
Grey petrel	Negligible			1				1
New Zealand white-faced storm petrel	Negligible					1		1
White-headed petrel	Negligible	1						1
mid-sized petrels & shearwaters	-	8				1		9
Giant petrel spp.	-					7		7
Grey-backed storm petrel	-	3						3
Gadfly petrels	-	1						1
Prion spp.	-	1						1
Seabirds	-					1		1
Total other birds		**727**	**0**	**23**	**6**	**1265**	**2**	**2023**

4.4 Benthic interactions

The spatial extent of seabed contact by trawl fishing gear in New Zealand's EEZ and Territorial Sea has been estimated and mapped in numerous studies for trawl fisheries targeting deepwater species (Baird et al 2011, Black et al 2013, Black & Tilney 2015, Black & Tilney 2017, Baird & Wood 2018, and Baird & Mules 2019, 2020b) and species in waters shallower than 250 m (Baird et al. 2015, Baird & Mules 2020a). The most recent assessment of the deepwater trawl footprint was for the period 1989–90 to 2017–18 (Baird & Mules 2020b).

Numbers of bottom-contacting squid trawls used to generate the trawl footprint ranged from about 7000 to 10 000 tows during 1989–90 to 2005–06 and 2000–4000 during 2006–07 to 2015–16 (Baird & Wood 2018). In total, about 168 850 bottom-contacting squid trawls were reported on TCEPRs and TCERs for 1989–90 to 2015–16. The total footprint generated from these tows was estimated at about 40 130 km^2. This footprint represented coverage of 1.0% of the seafloor of the combined EEZ and the Territorial Sea areas; 2.8% of the 'fishable area', that is, the seafloor area open to trawling, in depths of less than 1600 m. For the 2016–17 fishing year, 2592 squid bottom-contacting tows had an estimated footprint of 3715 km^2 which represented coverage of 0.1% of the EEZ and Territorial Sea and 0.3% of the fishable area (Baird & Mules 2019). During 2017–18, the squid trawl footprint was estimated at 3107 km^2, based on 2814 tows, and contacted 0.2% of the fishable area. Overall, for 1989–90 to 2017–18, squid trawls have contacted about 47 486 km^2, with a decreasing trend in the annual footprint from about 8000 km^2 during 1989–90 to 2005–06 to under 4000 km^2 since 2013 (Baird & Mules 2020b).

The overall trawl footprint for squid (1989–90 to 2015–16) covered 8% of the seafloor in waters shallower than 200 m, 8% of 200–400 m seafloor, and 3.5% of the 400–1600 m seafloor (Baird & Wood 2018). In 2016–17, The squid footprint contacted 1%, 1%, and < 0.1% of those depths ranges, respectively, in 2016–17 (Baird & Mules 2019) and < 1%, 1.3%, and < 0.1%, respectively, in 2017–18 (Baird & Mules 2020b). The BOMEC areas with the highest proportion of area covered by the squid footprint were classes E (Stewart-Snares shelf), F (sub-Antarctic island shelves), I (Chatham Rise slope and shelf edge of the east coast South Island), and L (Southern Plateau waters). The 2016–17 arrow squid trawl footprint covered 3% of the 61 000 km^2 of class E, 2% of the 38 608 km^2 of class F, and almost 1% of the 52 224 km^2 of class I (Baird & Mules 2019). In 2017–18, these percentages decreased to 1.7% (class E), 1.0% (class F), 0.7% (class I), and 0.5% (class L) (Baird & Mules 2020b).

Bottom trawling for squid, like trawling for other species, is likely to have effects on benthic community structure and function (e.g., see Rice 2006 for an international review) and there may be consequences for benthic productivity (e.g., Jennings et al 2001, Hermsen et al 2003, Hiddink et al 2006, Reiss et al 2009). These are not considered in detail here but are discussed in the Aquatic Environment and Biodiversity Annual Review 2019 (Fisheries New Zealand 2020).

4.5 Other considerations

A substantial decline in the west coast jig fishery for squid will have reduced any trophic implications of that fishery.

5. STOCK ASSESSMENT

Arrow squid live for one year, spawn once then die. Every squid fishing season is therefore based on what amounts to a new stock. It is not possible to calculate reliable yield estimates from historical catch and effort data for a resource which has not yet hatched, even when including data which are just one year old. Furthermore, because of the short life span and rapid growth of arrow squid, it is not possible to estimate the biomass prior to the fishing season. Moreover, the biomass increases rapidly during the season and then decreases to low levels as the animals spawn and die.

5.1 Estimates of fishery parameters and abundance

No estimates are available.

5.2 Biomass estimates
Biomass estimates are not available for squid.

5.3 Yield estimates and projections
It is not possible to estimate *MCY*.

It is not possible to estimate *CAY*.

5.4 Other yield estimates and stock assessment results
There are no other yield estimates of stock assessment results available for arrow squid.

5.5 Other factors
N. gouldi spawns one to two months before *N. sloanii*. This means that at any given time *N. gouldi* is older and larger than *N. sloanii*. The annual squid jigging fishery begins on *N. gouldii* and at some time during the season the biomass of *N. sloanii* will exceed that of *N. gouldi* and the fleet will move south. If *N. sloanii* are abundant the fleet will remain in the south fishing for *N. sloanii*. If *N. sloanii* are less abundant the fleet will return north and resume fishing *N. gouldi*.

6. STATUS OF THE STOCKS

No estimates of current and reference biomass are available. There is also no proven method at this time to estimate yields from the squid fishery before a fishing season begins based on biomass estimates or CPUE data.

Because squid live for about one year, spawn and then die, and because the fishery is so variable, it is not practical to predict future stock size in advance of the fishing season. As a consequence, it is not possible to estimate a long-term sustainable yield for squid, nor determine if recent catch levels or the current TACC will allow the stock to move towards a size that will support the *MSY*. There will be some years in which economic or other factors will prevent the TACC from being fully taken, while in other years the TACC may be lower than the potential yield. It is not known whether New Zealand squid stocks have ever been stressed through fishing mortality.

TACCs and reported landings for the most recent fishing year are summarised in Table 10.

Table 10: Summary of TACCs (t) and reported landings (t) of arrow squid for the most recent fishing year.

Fishstock	2018–19 Actual TACC	2018–19 Reported landings
SQU 1J	5 000	0
SQU 1T	44 741	34 212
SQU 6T	32 369	9 180
SQU 10T	10	
Total	82 120	43 392

7. FOR FURTHER INFORMATION

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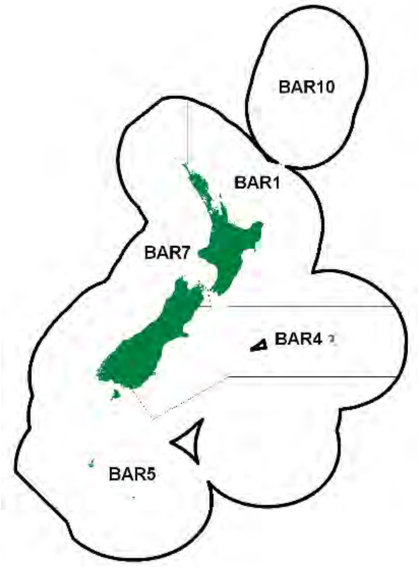
BARRACOUTA (BAR)

(*Thyrsites atun*)
Manga, maka



1. FISHERY SUMMARY

1.1 Commercial fisheries

Barracouta are caught in coastal waters around mainland New Zealand, Snares Islands, and Chatham Islands, down to about 400 m and have been managed under the Quota Management System since 1 October 1986. Historical catch summaries are given in Tables 1 and 2. Landings by New Zealand vessels increased significantly in the late 1960s and total annual landings peaked at about 47 000 t in 1977, with the addition of foreign vessels around New Zealand. Between 1983–84 and 2018–19, landings fluctuated between 18 000 and 30 000 t per annum (Table 3), at an average 25 000 t. Figure 1 shows the historical landings and TACC values for the main BAR stocks.

Table 1: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	BAR 1	BAR 4	BAR 5	BAR 7	Year	BAR 1	BAR 4	BAR 5	BAR 7
1931–32	4	0	0	0	1957	163	0	20	80
1932–33	55	0	0	77	1958	146	0	15	78
1933–34	5	0	1	0	1959	139	0	18	71
1934–35	36	0	0	52	1960	117	0	13	90
1935–36	1	0	0	0	1961	187	0	22	68
1936–37	26	0	0	35	1962	104	0	25	44
1937–38	21	0	0	26	1963	63	0	4	20
1938–39	91	0	22	55	1964	66	0	4	21
1939–40	107	0	27	50	1965	111	0	1	76
1940–41	153	0	53	30	1966	62	0	1	116
1941–42	212	0	86	17	1967	53	0	1	178
1942–43	371	0	151	20	1968	10 113	0	3	1 196
1943–44	192	0	79	7	1969	8 499	0	2	5 756
1944	247	0	97	50	1970	12 984	0	2	3 960
1945	306	0	114	32	1971	11 327	0	191	4 006
1946	391	0	125	63	1972	29 307	2	86	3 487
1947	590	0	213	45	1973	14 856	0	79	4 698
1948	466	0	172	27	1974	23 420	0	106	9 028
1949	425	0	169	40	1975	8 985	0	855	6 257
1950	430	0	153	76	1976	19 124	5	495	6 795
1951	266	0	95	47	1977	69 81	9 095	2 041	33 266
1952	190	0	56	68	1978	6 833	17	1 162	6 918
1953	202	0	41	77	1979	6 474	4 057	3 380	5 263
1954	166	0	35	38	1980	5 649	1 854	7 867	5 146
1955	139	0	14	58	1981	6 993	2 030	8 311	11 141
1956	165	0	16	45	1982	5 393	787	6 909	7 064

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data includes both foreign and domestic landings. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

Table 2: Reported landings (t) by nationality from 1977 to 1987–88.

Fishing	New Zealand		Foreign			Total	
Year	Domestic	Chartered	Japan	Korea	USSR	(FSU)	(QMS)
1977	4 697	0	34 357	8 109	0	47 163	-
1978–79	5 335	58	4 781	2 481	0	12 655	-
1979–80	7 748	6 679	4 339	3 879	47	22 922	-
1980–81	10 058	4 995	4 227	15	60	19 355	-
1981–82	12 055	11 077	2 813	373	0	26 328	-
1982–83	10 814	7 110	1 746	1 888	31	21 589	-
1983–83*	7 763	2 961	803	1 115	0	12 642	-
1983–84	12 390	10 226	1 786	4 355	0	28 757	-
1984–85	7 869	10 425	1 430	5 252	0	24 976	-
1985–86	8 427	7 865	1 371	815	0	18 478	-
1986–87	9 829	13 732	1 575	742	0	25 878	27 660†
1987–88	9 335	12 077	896	609	0	22 971	26 607†

* 6 month changeover in fishing years.
† The discrepancies between QMS and FSU total landings are due to under-reporting to the FSU.

Over 99% of the recorded catch is taken by trawlers. Major target fisheries have been developed on spring spawning aggregations (Chatham Islands, Stewart Island, west coast South Island, and northern and central east coast South Island) as well as on summer feeding aggregations, particularly around the Snares Islands and off the east coast of the South Island. Barracouta also comprise a significant proportion of the bycatch in the west coast North Island jack mackerel fishery, Stewart-Snares shelf squid fishery, and the east coast South Island red cod and tarakihi fisheries.

Landings in BAR 1 have been variable, but the lowest landing of the time series was recorded in 2018–19 (4208 t). The TACC in BAR 5 was increased to 8200 t in 2015–16, and recent landings have fluctuated about the TACC. In BAR 7, 8, 9 the catch limit was exceeded in 2004–05 and 2006–07 (landings nearly reached 15 000 t in 2006–07), but landings have since decreased to well below the TACC and were lower still in 2018–19 (4053 t).

Table 3: Reported landings (t) of barracouta by Fishstock from 1983–84 to 2018–19 and actual TACCs (t) from 1986–87 to 2018–19. QMS data from 1986-present. [Continued on next page]

Fishstock	BAR 1		BAR 4		BAR 5		BAR 7	
FMAs	1, 2, 3		4		5 & 6		7, 8, 9	
	Landings	TACC	Landing	TACC	Landings	TACC	Landings	TACC
1983–84*	7 805	–	1 743	–	11 291	–	7 222	–
1984–85*	5 442	–	1 909	–	12 487	–	4 425	–
1985–86*	5 395	–	1 509	–	6 380	–	4 536	–
1986–87	8 877	8 510	3 084	3 010	7 653	9 010	8 046	10 510
1987–88	9 256	8 837	1 775	3 010	6 457	9 011	9 117	10 603
1988–89	5 838	9 426	946	3 010	5 323	9 011	8 071	10 702
1989–90	9 209	9 841	1 349	3 016	5 960	9 282	7 050	10 925
1990–91	9 401	9 957	1 399	3 016	8 817	9 282	7 138	10 925
1991–92	6 733	9 957	1 156	3 016	6 897	9 282	7 326	10 925
1992–93	9 032	9 969	2 251	3 016	7 019	9 282	10 141	10 925
1993–94	7 299	9 969	606	3 016	3 410	9 282	8 030	10 925
1994–95	10 023	9 969	331	3 016	2 645	9 282	9 345	10 925
1995–96	11 252	9 969	2 234	3 016	4 255	9 282	8 593	10 925
1996–97	11 873	11 000	1 081	3 016	2 839	9 282	10 203	10 925
1997–98	11 543	11 000	1 966	3 016	6 167	9 282	8 717	10 925
1998–99	9 229	11 000	459	3 016	7 302	7 470	4 427	10 925
1999–00	10 032	11 000	1 911	3 016	6 205	7 470	3 288	10 925
2000–01	7 118	11 000	2 122	3 016	6 101	7 470	6 890	10 925
2001–02	6 900	11 000	1 160	3 019	5 883	7 470	7 655	11 173
2002–03	7 595	11 000	573	3 019	7 843	7 470	9 025	11 173
2003–04	5 949	11 000	477	3 019	6 919	7 470	9 114	11 173
2004–05	6 085	11 000	98	3 019	8 593	7 470	12 156	11 173
2005–06	7 030	11 000	687	3 019	9 479	7 470	10 685	11 173
2006–07	5 351	11 000	3 233	3 019	6 334	7 470	14 699	11 173
2007–08	5 987	11 000	2 975	3 019	8 561	7 470	10 451	11 173
2008–09	8 861	11 000	968	3 019	7 659	7 470	8 955	11 173
2009–10	10 635	11 000	1 223	3 019	6 951	7 470	9 642	11 173
2010–11	11 420	11 000	1 190	3 019	8 201	7 470	6 129	11 173
2011–12	9 305	11 000	1 423	3 019	7 071	7 470	8 643	11 173
2012–13	9 740	11 000	706	3 019	7 931	7 470	6 897	11 173
2013–14	11 309	11 000	1 482	3 019	6 886	7 470	6 637	11 173
2014–15	6 902	11 000	3 671	3 019	6 779	7 470	6 974	11 173
2015–16	5 568	11 000	2 893	3 019	7 558	8 200	5 493	11 173
2016–17	9 520	11 000	2 606	3 019	8 916	8 200	7 127	11 173
2017–18	11 110	11 000	2 479	3 019	7 126	8 200	8 356	11 173
2018–19	4 208	11 000	2 016	3 019	8 141	8 200	4 053	11 173

Table 3 Continued: Reported landings (t) of barracouta by Fishstock from 1983–84 to 2018–19 and actual TACCs (t) from 1986–87 to 2018–19. QMS data from 1986-present.

Fishstock	BAR 10			
FMAs	10		Total	
	Landings	TACC	Landings	TACC
1983–84*	0	–	28 061	–
1984–85*	0	–	24 263	–
1985–86*	0	–	17 820	–
1986–87	0	10	27 660	31 050
1987–88	0	10	26 605	31 471
1988–89	0	10	20 178	32 159
1989–90	0	10	23 568	33 073
1990–91	0	10	26 755	33 190
1991–92	0	10	22 212	33 190
1992–93	<1	10	28 443	33 202
1993–94	0	10	19 345	33 202
1994–95	0	10	22 345	33 202
1995–96	0	10	26 334	33 202
1996–97	0	10	25 996	34 233
1997–98	0	10	28 393	34 233
1998–99	0	10	21 417	32 421
1999–00	0	10	21 436	32 421
2000–01	0	10	22 231	32 421
2001–02	0	10	21 598	32 672
2002–03	0	10	25 036	32 672
2003–04	0	10	22 459	32 672
2004–05	0	10	26 919	32 672
2005–06	0	10	27 881	32 672
2006–07	0	10	29 617	32 672
2007–08	0	10	27 968	32 672
2008–09	0	10	26 443	32 672
2009–10	0	10	28 451	32 672
2010–11	0	10	26 937	32 672
2011–12	0	10	26 442	32 672
2012–13	0	10	24 973	32 672
2013–14	0	10	26 313	32 672
2014–15	0	10	24 327	32 672
2015–16	0	10	21 511	33 403
2016–17	0	10	28 169	33 403
2017–18	0	10	29 071	33 403
2018–19	0	10	18 419	33 403

* FSU data.

1.2 Recreational fisheries

Barracouta are commonly encountered by recreational fishers in New Zealand, more frequently in the southern half of BAR 7 and BAR 1. Barracouta are typically harvested as bait for other fishing rather than for consumption. They are predominantly taken on rod and reel (97.9%) with a small proportion taken by net methods (1.7%). The catch is taken predominantly from boat (95.5%) with a small proportion from land based fishers (4.5%).

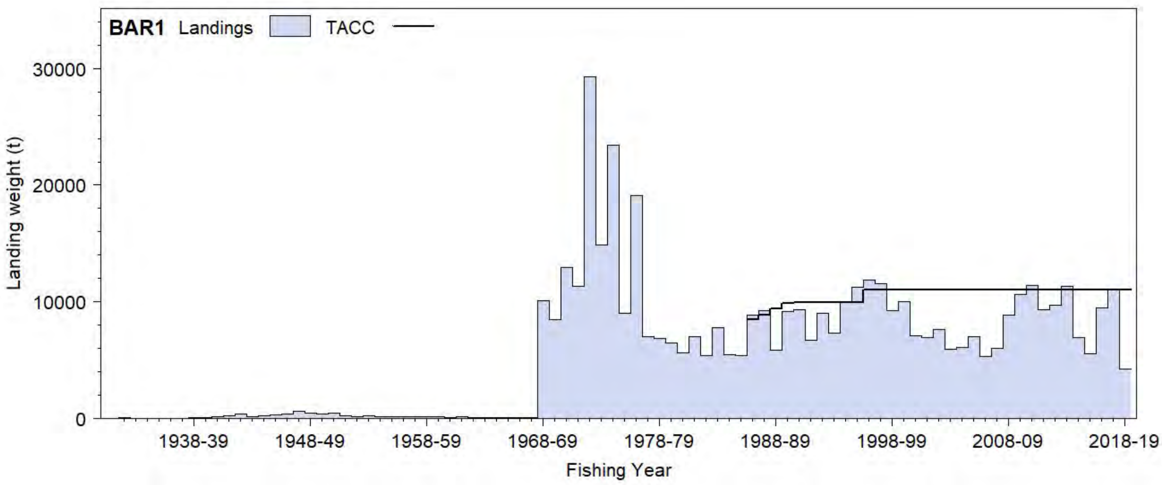


Figure 1: Reported commercial landings and TACC for the four main BAR stocks. BAR 1, [Continued on next page]

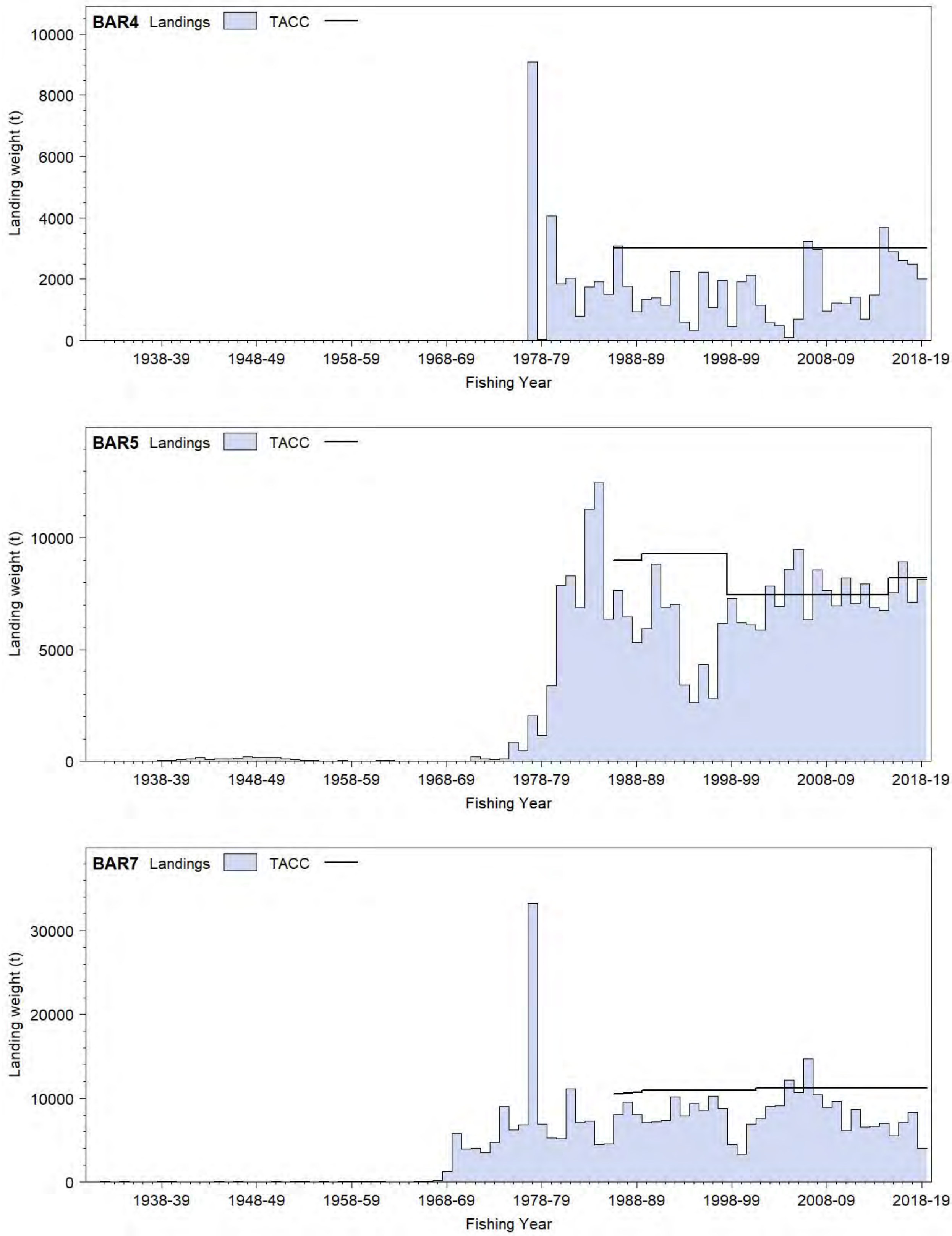


Figure 1: [Continued] Reported commercial landings and TACC for the four main BAR stocks. From top to bottom: BAR 4 (Chatham Rise), BAR 5 (Southland), and BAR 7 (Challenger).

1.2.1 Management controls
The main method used to manage recreational harvests of barracouta is daily bag limits. General spatial and method restrictions also apply. Fishers can take up to 30 barracouta as part of their combined daily bag limit in the Fiordland and Southland Fishery Management Areas. There is currently no bag limit in place in the other Fishery Management Areas.

1.2.2 Estimates of recreational harvest
There are two broad approaches to estimating recreational fisheries harvest: the use of onsite or access point methods where fishers are surveyed or counted at the point of fishing or access to their fishing activity; and offsite methods where some form of post-event interview and/or diary are used to collect data from fishers.

The first estimates of recreational harvest for barracouta were calculated using an offsite approach, the offsite regional telephone and diary survey approach. Estimates for 1996 came from a national telephone and diary survey (Bradford 1998). Another national telephone and diary survey was carried out in 2000 (Boyd & Reilly 2002). The harvest estimates provided by these telephone diary surveys (Table 4) are no longer considered reliable.

In response to the cost and scale challenges associated with onsite methods, in particular the difficulties in sampling other than trailer boat fisheries, offsite approaches to estimating recreational fisheries harvest have been revisited. This led to the development and implementation of a national panel survey for the 2011–12 fishing year (Wynne-Jones et al 2014). The panel survey used face-to-face interviews of a random sample of New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and catch information collected in standardised phone interviews. The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly comparable results (Wynne-Jones et al 2019). Recreational catch estimates from the two national panel surveys are given in Table 4. Note that national panel survey estimates do not include recreational harvest taken under s111 general approvals.

1.3 Customary non-commercial fisheries
Quantitative information on the current level of customary non-commercial take is not available.

1.4 Illegal catch
Quantitative information on the level of illegal catch is not available.

1.5 Other sources of mortality
There may have been considerable amounts of barracouta discarded prior to the QMS, either because of quota restrictions under the deepwater policy, low value, or undesirable small size fish. There is also likely to be some mortality associated with escapement from trawl nets. Some discarding may also have occurred in BAR 1 because of the lack of quota availability and the high deemed value in relation to the low value of the fish.

2. BIOLOGY

Barracouta spawn mainly in late-winter/spring (August–September) off the east and west coasts of both of the main islands, and in late spring (November–December) in Southland and in the Chatham Islands. Some spawning activity may also extend into summer/autumn, with recent observer data indicating spawning off the east coast South Island during September to December (Baird 2016). Sexual maturity is reached at about 50–60 cm fork length (FL) at about 2–3 years of age.

Juvenile barracouta have been recorded from inshore areas (less than 100 m) all around New Zealand and the Chatham Islands, although they appear to be less common off the west coast of the South Island. Adult fish are found down to about 400 m depth. Tagging experiments indicated that mature fish from the east coast South Island waters migrate after June to northern waters off the east coast North Island to spawn during August–September; research survey results and commercial fishing patterns show some consistency with this movement (see Hurst et al 2012).

Table 4: Recreational harvest estimates for barracouta stocks. Early surveys were carried out in different years in the regions: South in 1991–92, Central in 1992–93, and North in 1993–94 (Teirney et al 1997). The estimated Fishstock harvest is indicative in these surveys and made by combining estimates from the different years. Some early survey harvests are presented as a range to reflect the considerable uncertainty in the estimates. The telephone/diary surveys ran from December to November but are denoted by the January calendar year. The national panel surveys ran through the October to September fishing year but are denoted by the January calendar year. Mean weights of 2.14 kg and 2.40 kg were used for the 2011–12 and 2017–18 national panel surveys respectively.

					Total
Fishstock		Survey	Number	CV	Survey harvest (*t*)
BAR 1	1992	South	27 000	47%	30–90
BAR 7	1992	South	2 100	44%	–
BAR 1	1993	Central	17 000	22%	25–35
BAR 7	1993	Central	15 600	24%	25–35
BAR 1	1996	National	68 000	8%	160–190
BAR 7	1996	National	74 000	15%	160–220
BAR 1	2000	National	156 000	35%	182 –377
BAR 5	2000	National	2 000	51%	2–7
BAR 7	2000	National	35 000	28%	68–120
BAR 1	2012	Panel survey	22 244	27%	47.7
BAR 5	2012	Panel survey	666	51%	1.4
BAR 7	2012	Panel survey	16 743	23%	35.9
BAR 1	2018	Panel survey	11 845	22%	28.4
BAR 5	2018	Panel survey	648	61%	1.6
BAR 7	2018	Panel survey	6 088	21%	14.6

No age data are available for the period prior to the onset of commercial fishing, which developed rapidly from 1968. Ageing studies carried out in the mid-1970s showed that the maximum age rarely exceeded 10 years.

M was estimated using the equation $M = \log_e 100/\text{maximum age}$, where maximum age is the age to which 1% of the population survives in an unexploited stock. Using 10 years for the maximum age suggests an *M* of up to 0.46. The effect of fishing on age structure prior to the mid-1970s is unknown, but *M* is unlikely to be less than 0.3, which has been assumed in previous stock assessments.

Biological parameters relevant to the stock assessment are shown in Table 5.

Table 5: Estimates of biological parameters.

Fishstock	**Estimate**	**Source**
1. Natural mortality (*M*)		Hurst (unpub. data)
All-both sexes	Less than 0.46 *M* = 0.30 considered best estimate for all areas for both sexes	

2. Weight = a(length)^b (Weight in g, length in cm fork length).

	Females		Males		
	a	b	a	b	
BAR 4	0.0074	2.94	0.0117	2.82	Hurst & Bagley (1992)
BAR 5	0.0075	2090	0.0075	2.90	Hurst & Bagley (1992)

3. Von Bertalanffy growth parameters

	Both sexes				
	K	t_0	L_∞		Grant et al (1978)
Tasmania	0.45	0.166	91.17	(unconstrained)	
	0.42	-0.25	91.01	(constrained, t_0 fixed)	
Southland	0.336	-0.35	81.1	Male	Horn (2002)
	0.259	-0.60	89.3	Female	Horn (2002)

3. STOCKS AND AREAS

There are thought to be at least four main stocks, based on known spawning locations and movements. Stock boundaries are not well understood, but the Chatham Islands stock is probably separate. There may be some overlap between mainland stock management areas as currently defined from analysis of tagging data, commercial fishery data, biological data (i.e., length frequencies, otoliths, parasites, spawning areas, and seasons) and from seasonal relative biomass estimates. In particular, it appears that there is considerable overlap of Southland fish with other areas, probably the west coast of the South Island and possibly the east coast as well. However, there are not enough data at this stage to alter the existing stock boundaries.

4. STOCK ASSESSMENT

There are no stock assessments available for any barracouta stocks and TACCs have remained constant in all stocks since 2001–02. Hurst et al (2012) provided a comprehensive characterisation of all barracouta stocks and provided CPUE indices for BAR 1 (east coast South Island), BAR 7 (west coast South Island), and BAR 5 for 1989–90 to 2007–08. McGregor (2013) characterised the fisheries and estimated CPUE indices for the fisheries on the WCNI and WCSI (BAR 7) and the southern Snares fishery (BAR 5). Baird (2016) provided indices for 1989–90 to 2013–14 for the ECNI and ECSI parts of BAR 1. Marsh & McGregor (2017) updated CPUE indices for BAR 5 to 2015. Ballara and Holmes (in press) updated the characterisation and CPUE indices from 1989–90 to 2017–18 for WCSI and WCNI (BAR 7) and developed a CPUE index for the ‘Chatham East’ area of BAR 4; no index for ‘Chatham Rise West’ was possible because effort was too sporadic.

A time series of trawl surveys was carried out in the Southland area (QMA 5) in February–March from 1993 to 1996 using *Tangaroa* (Table 6). Trawl surveys on the east and west coasts of the South Island in autumn using *Kaharoa* may help interpretation of trends in biomass around the South Island. The long time series of trawl surveys on the Chatham Rise (deeper than 200 m) and Sub-Antarctic (deeper than 300 m) using *Tangaroa* are not considered to adequately survey the preferred depth range of barracouta.

4.1 BAR 1 Auckland (E), Central (E), South-East (Coast)

4.1.1 Estimates of fishery parameters and abundance

The results from trawl surveys carried out during the mid 1980s (sometimes from a variety of different vessels) were used to provide an approximate estimate of minimum absolute biomass. This approach required an assumption about catchability to convert the trawl survey catches to estimates of absolute biomass. This method is now considered obsolete and the estimates of absolute biomass have not been included.

4.1.2 Biomass estimates

There is no trawl survey series for BAR 1 off the east coast of the North Island. The trawl survey information discussed below is for the east coast of the South Island.

The ECSI winter surveys from 1991 to 1996 in 30–400 m were replaced by summer trawl surveys (1996–97 to 2000–01) which also included the 10–30 m depth range, but these were discontinued after the fifth in the annual time series because of the extreme fluctuations in catchability between surveys (Francis et al 2001). The winter surveys were reinstated in 2007 and this time included additional 10–30 m strata in an attempt to index elephant fish and red gurnard which were added to the list of target species. Only the 2007, 2012, 2014, 2016, and 2018 surveys provide full coverage of the 10–30 m depth range.

The 2014 barracouta biomass estimate was the highest recorded in the east coast South Island winter trawl survey time series core strata (30–400 m). Biomass in the east coast South Island winter trawl survey time series core strata steadily increased until 2014 when it was more than four-fold larger than the average biomass of the early 1990s, before a 57% decline in 2016 (Table 6, Figure 2). Biomass increased for the most recent (2018) survey and is close to the time series mean of 22 176 t. Biomass in the 10–30 m depth range accounted for 6% of the total biomass (core plus shallow, 10–400 m) but has at times accounted for up to 15% of the total biomass, indicating that shallow strata should continue to be monitored for this species.

A comparison of the pre-recruit and recruited biomass (where recruited fish are over 60 cm long) for the ECSI winter survey, based on the core strata, is shown in Figure 3. During the 1991–93 surveys, the pre-recruit and recruited estimates were similar, but in 1994 and 1996 most of the total biomass was from recruited fish. For the renewed series, from 2007, the main increase has come from the recruited fish, with significantly higher biomass for recruited fish compared with pre-recruits in the 2009 and 2012 surveys. The 2014 survey indicated an increase in the pre-recruit biomass, although the uncertainty around this estimate is high, and in 2016 both recruited and pre-recruited biomass declined substantially. In 2018 both recruited and precrecruited fish have increased in abundance, with recruited fish accounting for most of the total biomass.

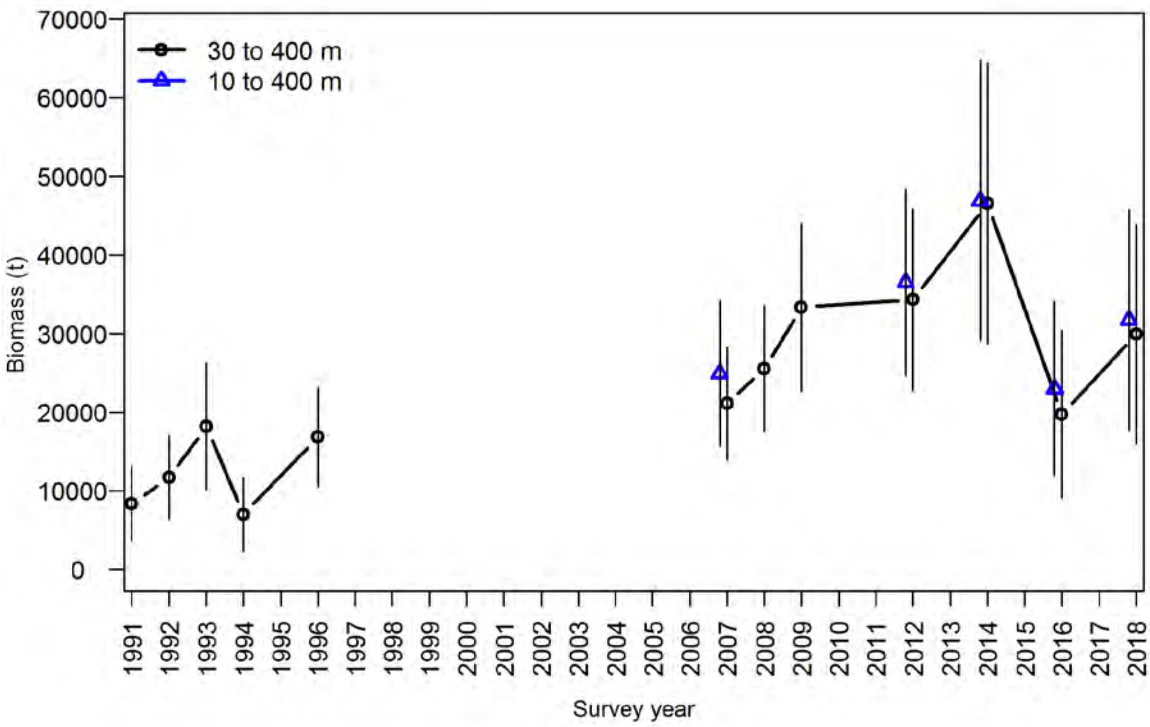


Figure 2: Barracouta total biomass and 95% confidence intervals for the all ECSI winter surveys in core strata (30–400 m), and core plus shallow strata (10–400 m) in 2007, 2012, 2014, 2016, and 2018.

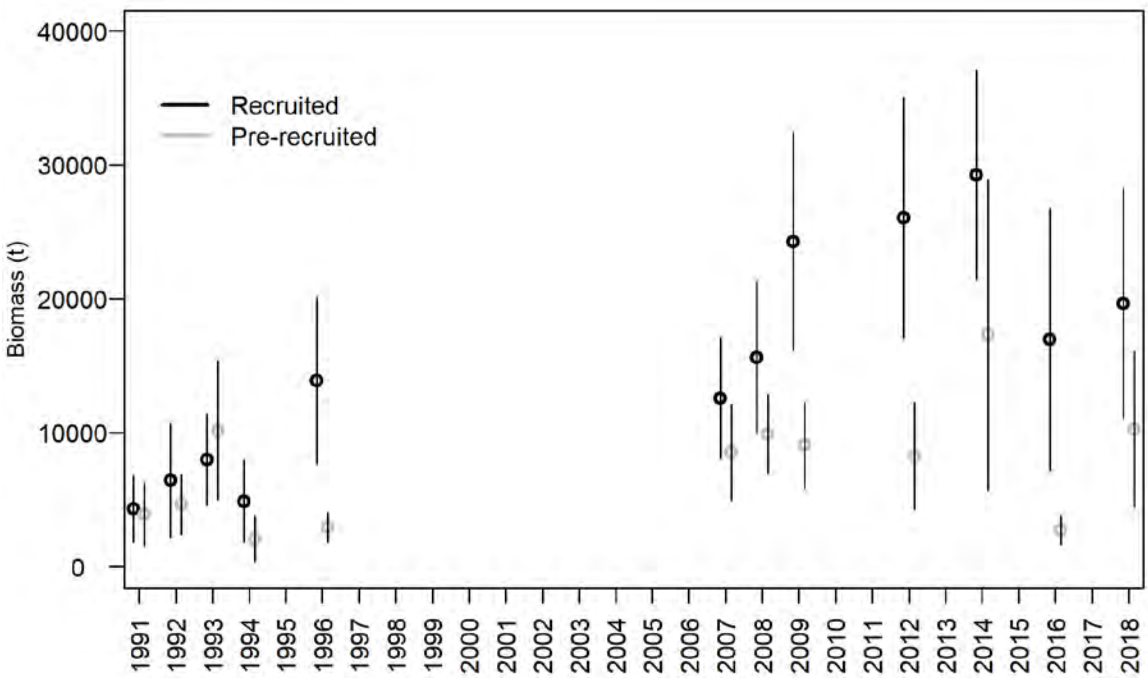


Figure 3: Barracouta pre-recruit and recruited biomass estimates and associated confidence intervals from the ECSI winter trawl survey core strata (30–400 m). Recruited fish were defined as fish over 60 cm fork length.

4.1.3 Length frequency distributions

The length distributions from the east coast South Island winter trawl survey show at least three clear pre-recruit modes at about 20 cm, 35 cm, and 50 cm (combined males, females, and unsexed) consistent with ages of 0+, 1+, and 2+ (Figure 4). Length frequency distributions are consistent among the surveys, showing the presence of the pre-recruited cohorts, with indications that these could be tracked through time (modal progression) (Beentjes et al 2015, 2016). The addition of the 10–30 m depth range does not change the shape of the length distributions (not shown in Figure 4). The 0+ mode in 2018 is the strongest in the time series (Figure 4).

Table 6: Relative biomass indices (t) and coefficients of variation (CV) for barracouta for east coast South Island (ECSI) - winter, east coast North Island (ECNI), west coast South Island (WCSI) and Southland survey areas. Biomass estimates for ECSI in 1991 have been adjusted to allow for non-sampled strata (7 & 9 equivalent to current strata 13, 16 and 17). – , not measured; NA, not applicable.

Region	Fishstock	Year	Trip number	Total Biomass estimate	CV (%)	Total Biomass estimate	CV (%)
ECSI (winter)	BAR 1				30–400 m		10–400 m
		1991	KAH9105	8 361	29	–	–
		1992	KAH9205	11 672	23	–	–
		1993	KAH9306	18 197	22	–	–
		1994	KAH9406	6 965	34	–	–
		1996	KAH9608	16 848	19	–	–
		2007	KAH0705	21 132	17	24 939	19
		2008	KAH0806	25 544	16	–	–
		2009	KAH0905	33 360	16	–	–
		2012	KAH1207	34 325	17	36 526	16
		2014	KAH1402	46 563	19	46 903	19
		2016	KAH1605	19 708	27	23 007	24
		2018	KAH1803	29 917	23	31 723	22
ECNI	BAR 1	1993	KAH9304	2 673	15	–	–
		1994	KAH9402	8 433	33	–	–
		1995	KAH9502	2 103	29	–	–
		1996	KAH9602	2 495	23	–	–
WCSI	BAR 7	1992	KAH9203	2 478	14	–	–
		1994	KAH9404	5 298	16	–	–
		1995	KAH9504	4 480	13	–	–
		1997	KAH9701	2 993	19	–	–
		2000	KAH0004	1 787	11	–	–
		2003	KAH0304	4 485	20	–	–
		2005	KAH0503	2 763	13	–	–
		2013	KAH1305	3 423	16	–	–
		2015	KAH1503	2 662	21	–	–
		2017	KAH1703	4 153	30	–	–
		2019	KAH1902	2 568	15	–	–
Southland	BAR 5	1993	TAN9301	11 587	18	–	–
		1994	TAN9402	6 151	20	–	–
		1995	TAN9502	4 539	17	–	–
		1996	TAN9604	7 693	19	–	–

4.1.4 CPUE indices

Two sets of standardised CPUE indices were derived for BAR 1: one for the northern waters off the east coast of the North Island (ECNI) and one for the east coast South Island, ECSI (Baird 2016). Each set had three CPUE series defined by form type: a merged CELR/TCER day-level model for 1989–90 to 2013–14; a TCER tow-level model for 2007–08 to 2013–14; and a TCEPR tow-level model for 1989–90 to 2013–14. All ECNI series were rejected by the Working Group because of shifts in targeting through time, high inter-annual variability, and unacceptably low levels of data. Thus, the following sections on CPUE pertain to the ECSI waters only.

Three standardised CPUE series for the east coast South Island part of BAR 1 were prepared, as outlined above, using data from 1989–90 to 2013–14, with each series based on the catch of barracouta in bottom trawl fisheries defined by different target species, including barracouta (Baird 2016). Two CPUE series were rejected by the Southern Inshore (SINS) Working Group: the CPUE index based on the TCEPR data (targeting barracouta, red cod, and arrow squid), primarily because of inter-annual inconsistencies in the underlying catch and effort data; and the short TCER series with only seven years of data.

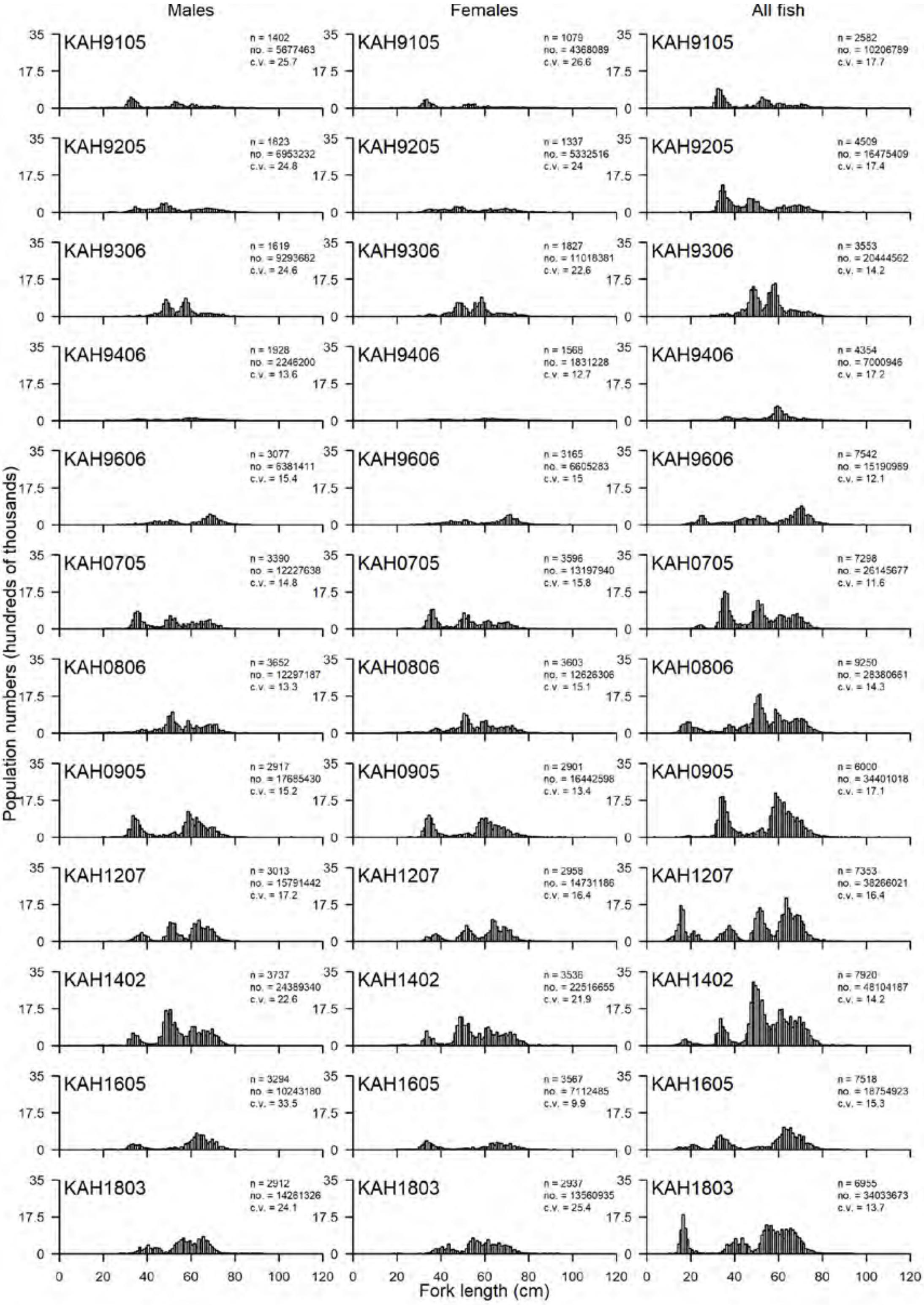


Figure 4: Scaled length frequency distributions for barracouta in core strata (30–400 m) for the ECSI winter surveys. n, number of fish measured; no., core strata population estimates; c.v., coefficient of variation.

The SINS Working Group accepted the combined index (delta lognormal model) series based on the 1989–90 to 2013–14 daily data from CELR and TCER forms (bottom trawls targeting barracouta, red cod, and tarakihi) as an index of abundance for BAR 1. This series has been updated to include data up to 2017 and combines the daily data from CELR, TCER, and TCEPR forms from vessels < 28m

(Figure 5). After a peak period during 1996–97 and 1997–98, there was a period of relatively lower CPUE from 1998–99 to 2008–09, followed by an increase up to 2012–13, to a level similar to the earlier peak. In the following two years, the indices dropped to about the series mean. Subsequently, there was an increase and in 2016–17 the index was similar to that seen in 2013–14. The TCER tow-level CPUE series, for which additional explanatory variables were incorporated into the model, was similar to the CELR/TCER/TCEPR day-level series for the overlapping period (2007–08 to 2016–17). Figure 6 provides a comparison of the ECSI indices with the ECSI winter trawl survey indices. The increase in abundance measured by the trawl survey for 2007 onwards follows a similar trajectory to that for the ECSI CELR/TCER/TCEPR indices.

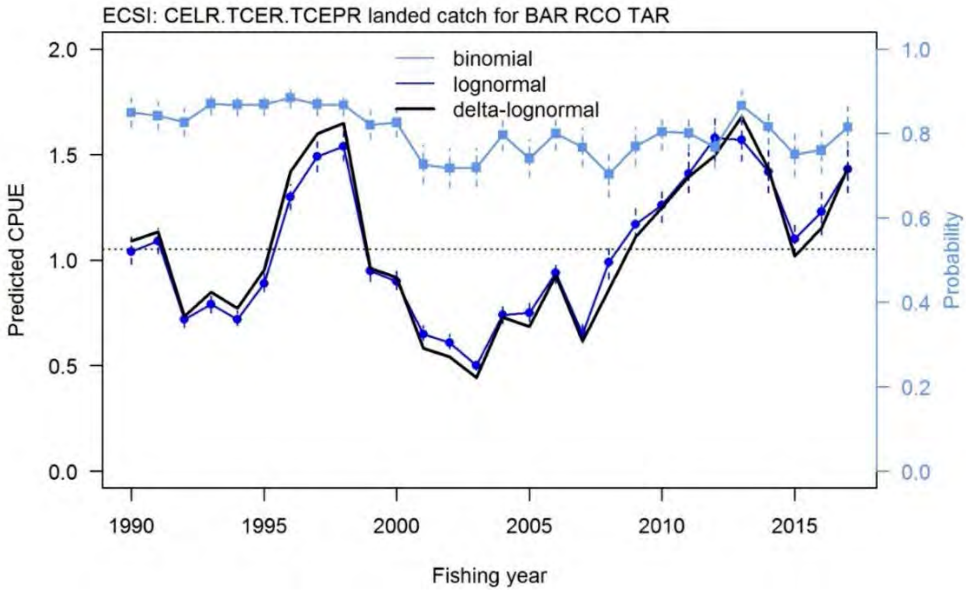


Figure 5: East coast South Island part of BAR 1 CPUE indices from the standardised lognormal, binomial, and the combined (delta lognormal) models, based on the merged day-level CELR, TCER, and small vessel (< 28m) TCEPR data for 1989–90 to 2016–17.

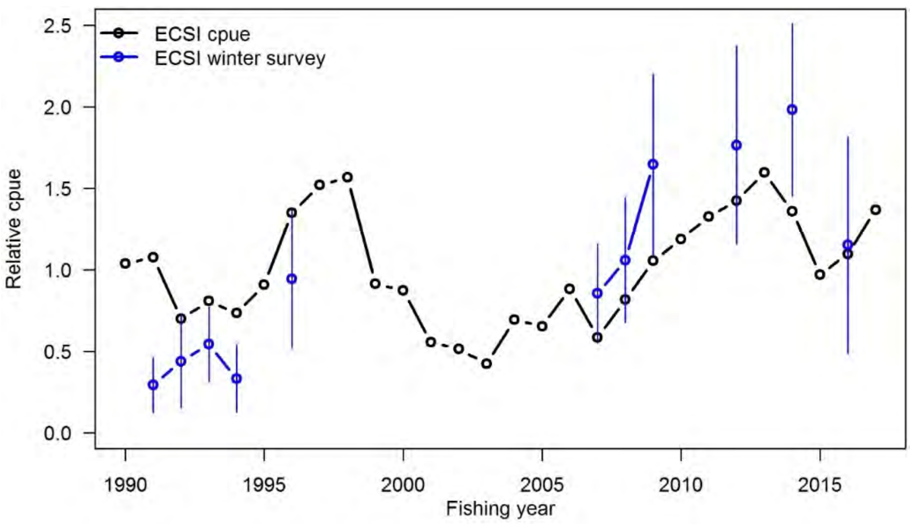


Figure 6: Comparison of the BAR 1 ECSI delta-lognormal CPUE series for 1990–2017 and the recruited biomass (and associated variance) from the ECSI winter trawl survey series from 1991–2016. The recruited biomass is based on fish over 60 cm fork length. Each series has been standardised to the mean for concurrent years.

Future research considerations

Review of the ECSI trawl survey for monitoring abundance of barracouta off the east coast of the South Island. This review should included an investigation of the timing of the survey in relation to a possible seasonal northward migration of barracouta off the east coast of the South Island.

4.2 BAR 4 Chatham Rise

Ballara & Holmes (in press) separated the Chatham Rise into East and West fisheries based on a longitudinal split at 180.5°. A series of standardised combined (delta lognormal model) CPUE indices based on TCEPR and ERS-trawl data was derived for BAR 4 for the Chatham Rise East fishery (Figure 7). The CPUE series is flat. Indices derived from the *Tangaroa* Chatham Rise trawl survey from trawls within the East fishery area are very noisy, and there are years with no barracouta catch or no surveys towards the end of the time series, so is not possible to make a meaningful comparison between the two series. For Chatham Rise West fishing effort was too sporadic to run a CPUE analysis because there was less than 10 t catch per year in most years since 2002.

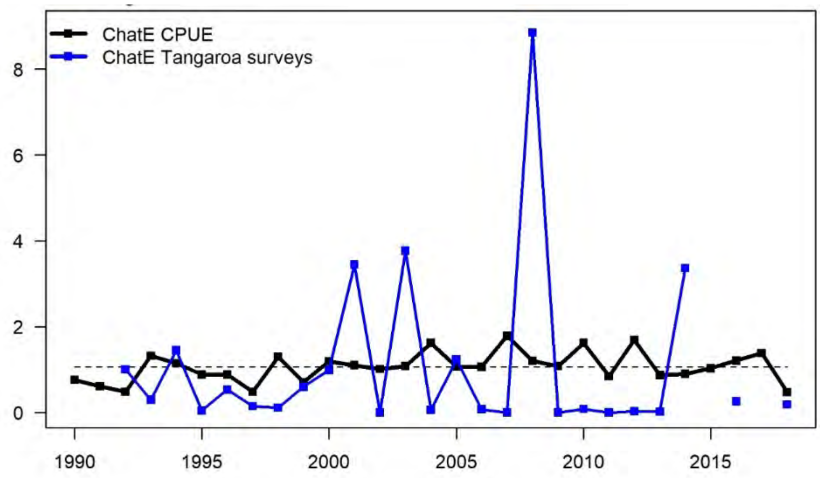


Figure 7: Comparison of Chatham Rise East CPUE standardised indices (scaled to mean 1) for CPUE indices and *Tangaroa* survey indices for the Chatham Rise East area. ChatE CPUE: Unmerged tow level TCEPR and ERS-trawl Oct–Sep. Trawl survey is based on fishing year.

4.3 BAR 5 Southland, Sub-Antarctic

4.3.1 CPUE indices

Marsh & McGregor (2017) used unmerged (tow level) data to fit CPUE indices for barracouta to various target fisheries in the BAR 5 region. The WG agreed that the CPUE from the SQU target fshery in Statistical Area 028 was the best series of abundance indices for BAR 5. An alternative CPUE index based on the target BAR and WAR tows was suggested as a sensitivity run. Both series show high catch rates since 2007. The base case CPUE declines from 1990 to 1995, then increases and decreases again until 2007, but after 2007 the index increases and remains high through to 2015 (Figure 8). The alternative series increases fom 1995 to 2007 and then oscillates at high catch rates through to 2015 (Figure 9). The current stock status is unknown, due to the lack of a quantitive assessment for this stock.

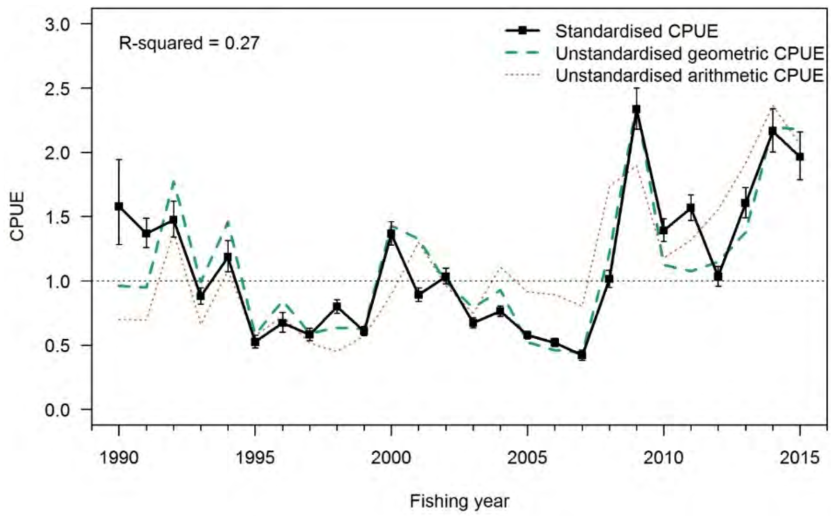


Figure 8 : Base case BAR 5 CPUE Model: CPUE indices for barracouta from SQU target tows in Statistical Area 028 (1990–2015).

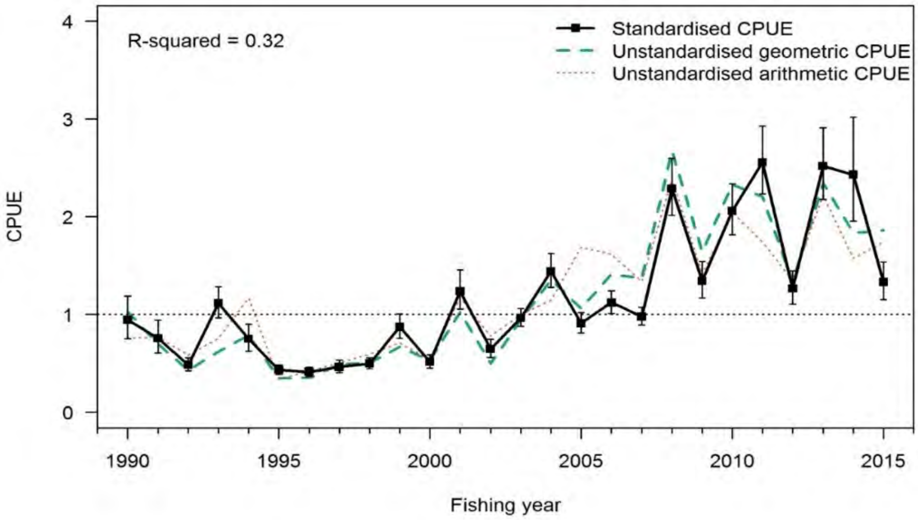


Figure 9 : Alternative BAR 5 CPUE Model: CPUE indices for barracouta from BAR and WAR target tows (1990–2015).

4.4 BAR 7 Challenger, Central (W) Auckland (W)

4.4.1 Survey indices

Barracouta are a common catch of the west coast South Island (WCSI) inshore trawl surveys, with most tows containing barracouta. The biomass has varied almost three-fold during the time series but has not shown any consistent trend (Figure 10). More biomass has always come from the west coast strata compared with Tasman Bay and Golden Bay. Stevenson (2007) reviewed the WCSI time series up to 2007 and believed that the survey likely monitors juvenile and adult abundance of barracouta. The survey covers almost all of the species depth range, CVs are relatively precise, and biomass and length frequencies are reasonably consistent across years.

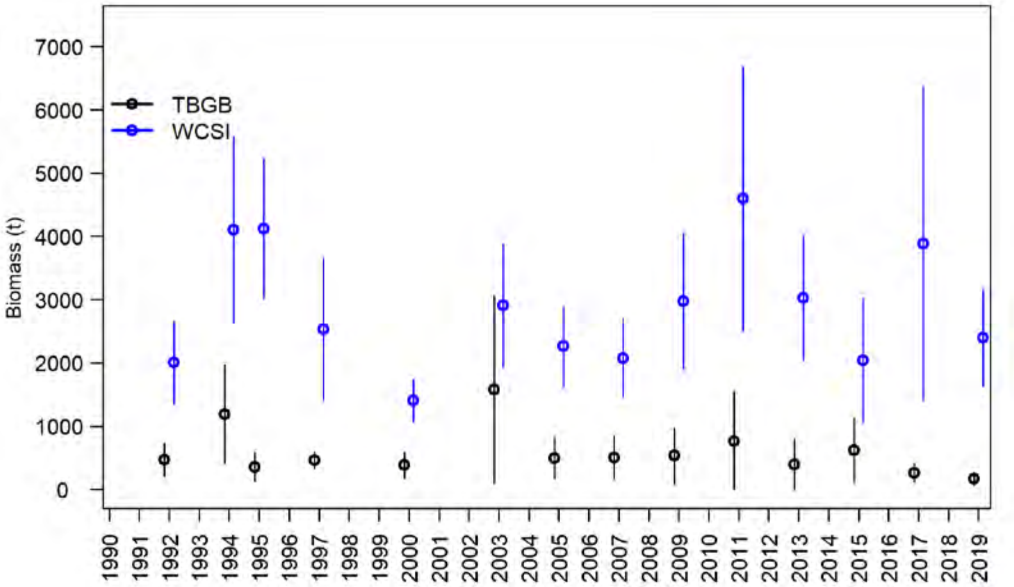


Figure 10: Barracouta biomass estimates from the WCSI inshore trawl survey core strata (20–400 m) for west coast strata and Tasman & Golden Bays.

4.4.2 Length frequency distributions

There are distinct length modes that can be tracked through time in the WCSI time series (Figure 11). In most years that have a strong 0+ mode (centred around 20 cm), a large proportion of these fish were from the Tasman Bay and Golden Bay (TBGB) region, but in some years (e.g., 2000 and 2013) this small mode was almost entirely made up of fish from the west coast.

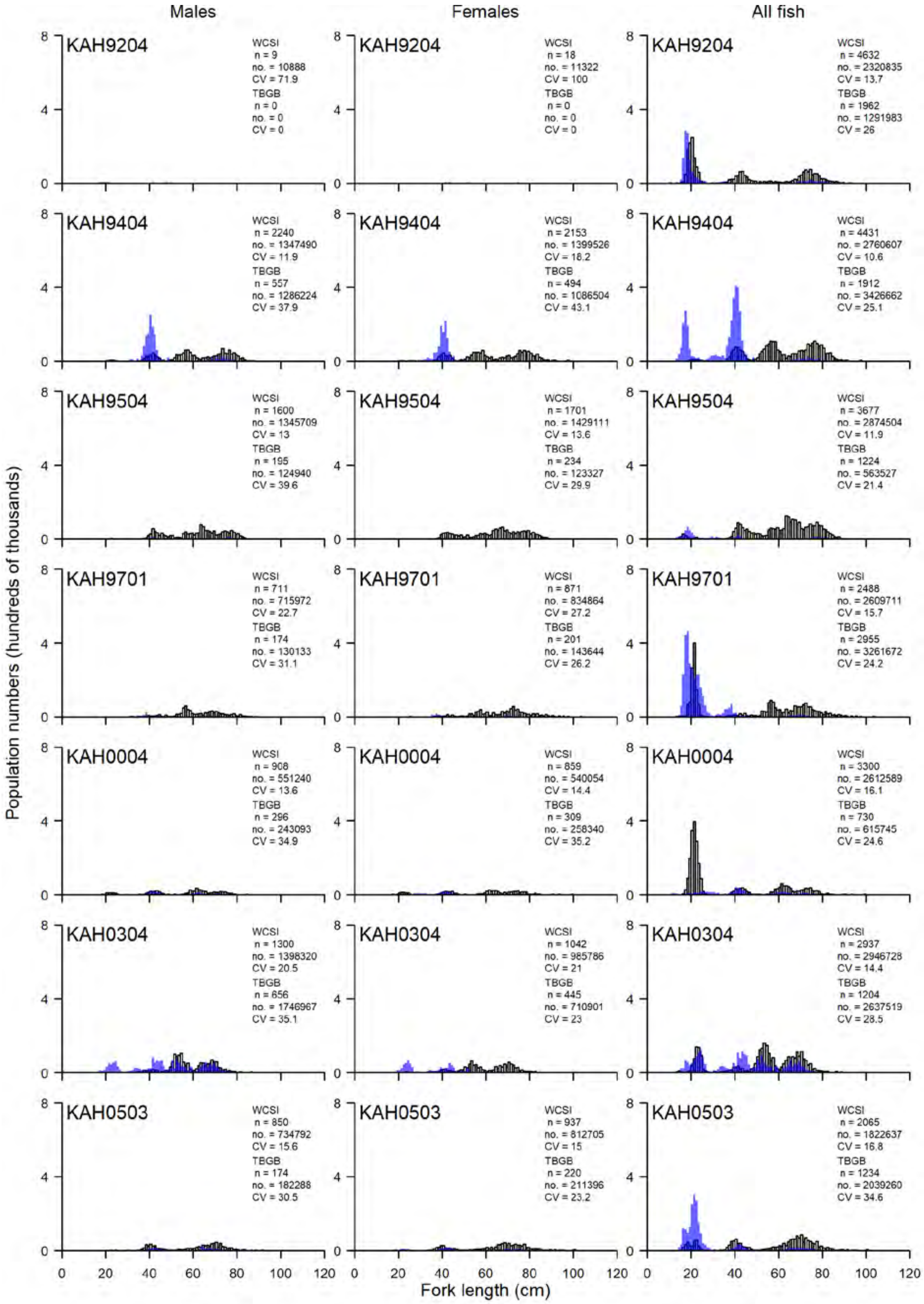


Figure 11: Length frequencies of barracouta from the WCSI (WCSI and TBGB) from *Kaharoa* (KAH) surveys, 1992-2005. Blue: TBGB; black: WCSI. The first two digits of the voyage code refer to the survey year.

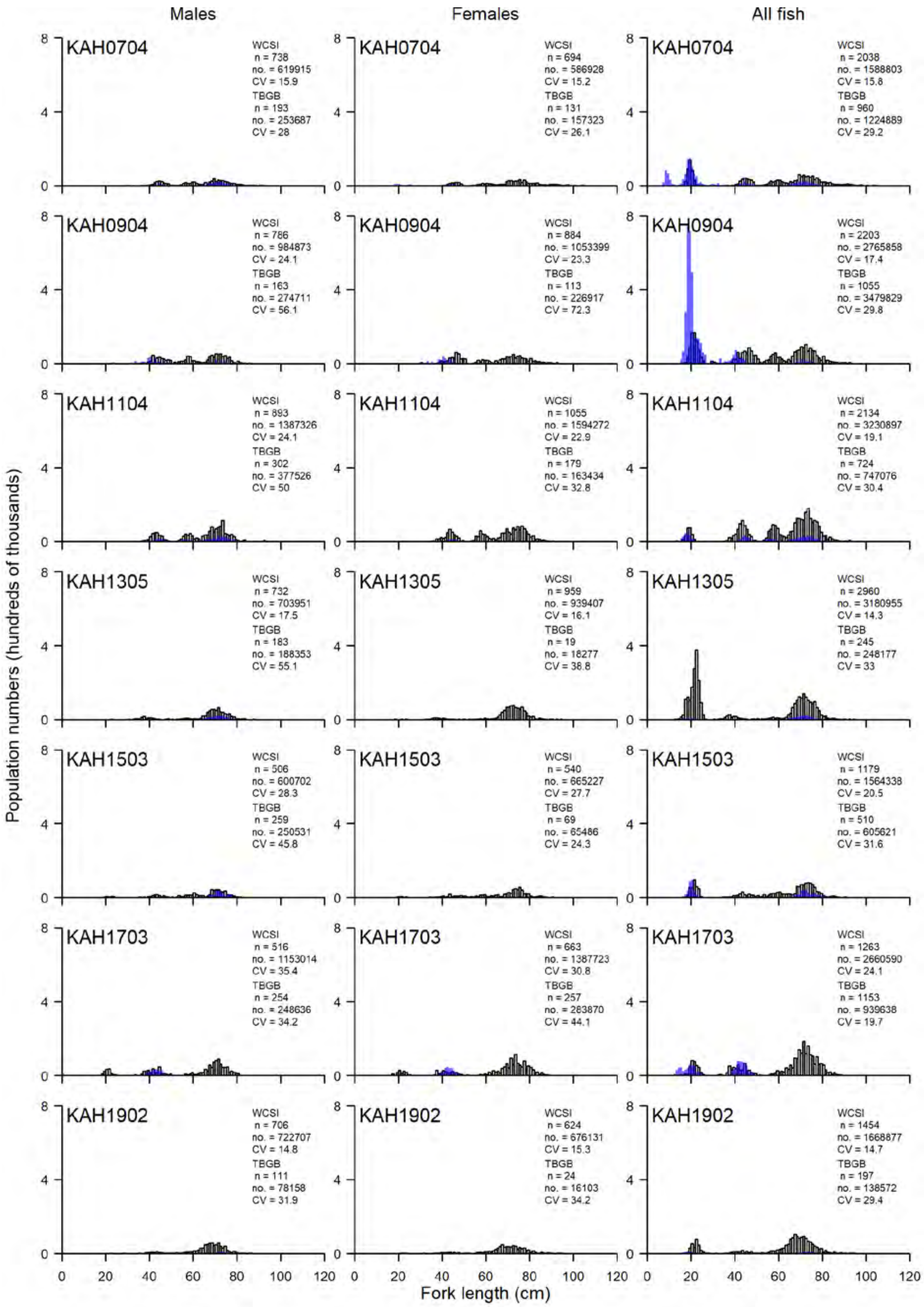


Figure 11: Length frequencies of barracouta from the WCSI (WCSI and TBGB) from *Kaharoa* (KAH) surveys, 2007-2019. Blue: TBGB; black: WCSI. The first two digits of the voyage code refer to the survey year.

4.4.3 CPUE indices

Ballara & Holmes (in press) separated fisheries on the WCNI and WCSI. For WCNI, CPUE trends depended on the selection of input data. The model using tow-level TCEPR/ERS-trawl data (model 1) and the model using merged trip level TCEPR, TCER, CELR, and ERS-trawl (model 3) gave opposing long-term trends. The model using TCER data (model 2) showed the same pattern as model 3 between 2008–13, but then showed an increase in CPUE not seen from model 3, and opposite in direction to model 1. The TBGB *Kaharoa* trawl survey index shows large spikes in 1994 and 2003, and there is little agreement between the survey and any of the estimated CPUE indices. However, the survey in TBGB catches predominantly juveniles (Figure 12). There is a general rising trend in standardised CPUE up to 2010 and a subsequent decline (Figure 12). The DWWG considered that the TCEPR/ERS-trawl tow level CPUE were the best data to monitor this stock.

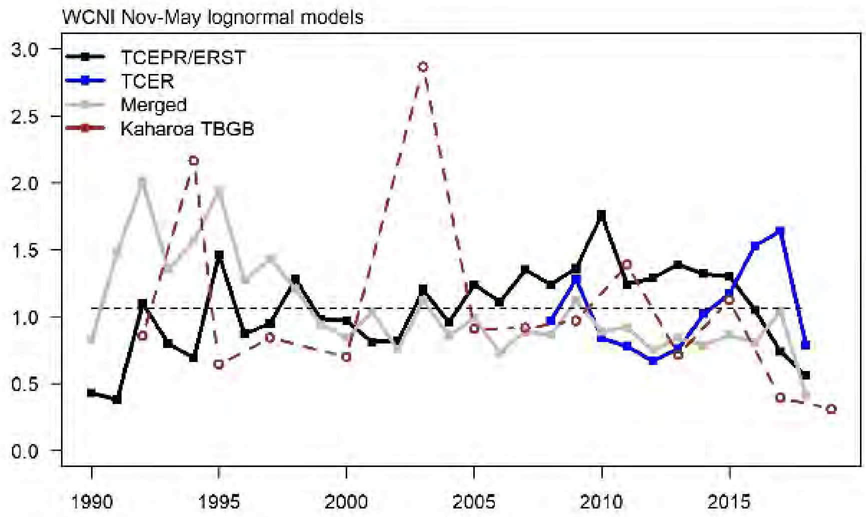


Figure 12: Comparison of WCNI CPUE indices (scaled to mean 1) for CPUE indices and *Kaharoa* survey indices for Tasman Bay, Golden Bay area. TCEPR/ERST:TCEPR and ERS-trawl tow level Nov–May (model 1); TCER: TCER tow level Nov–May (model 2); Merged: TCEPR, TCER, CELR, ERS-trawl trip level Nov-May (model 3). Trawl survey is based on fishing year.

CPUE indices for the WCSI fishery (from either tow- or trip-level models) were similar to the WCSI *Kaharoa* trawl survey series (Figure 13) and showed no long-term trend. The CPUE models were based on data from November–May, and the trawl survey takes place in April–May, the non-spawning season.

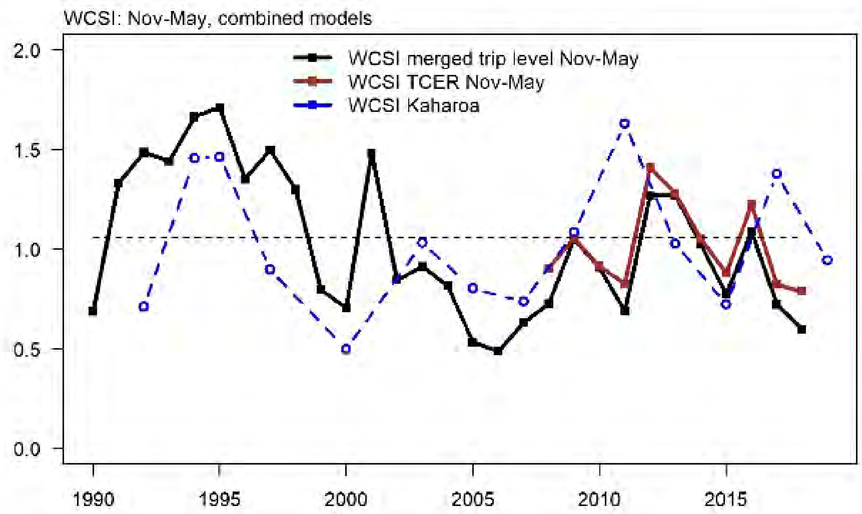


Figure 13: Comparison of WCSI CPUE indices (scaled to mean 1) and and *Kaharoa* survey indices for the WCSI area. TCER: TCER tow level Nov–May (model 2); Merged: TCEPR, TCER, CELR, ERS-trawl trip level Nov–May (model 3). Trawl survey is based on fishing year.

4.4 Yield estimates and projections
No estimates of biomass are available for any of the barracouta stocks.

4.5 Other factors
Barracouta are part of the shelf (30–300 m) mixed fishery and are usually the dominant species in these depths around the South Island (except perhaps in good red cod years in the Canterbury Bight). Any increase or decrease in barracouta quotas will have overflow effects onto bycatch species. The economics of targeting on barracouta is probably affected by its availability relative to other more preferred species and this will, in turn, affect fishing patterns.

An analysis of trends in biomass of the Southland fishery suggests that recruitment may have been relatively low in the years after 1989 and that biomass may have declined between surveys by the *Shinkai Maru* (1981 and 1986) and the *Tangaroa* (annually 1993 to 1996). The scale of decline appeared to be greater than could be explained by different catching efficiencies of the two vessels.

4.6 Future research considerations
Recognising that CPUE will probably not provide a reliable relative abundance indicator for barracouta in isolation, and with the goal of developing a quantitative stock assessment in the future, the data collection needs for barracouta are as follows:

1. Development of age-based stock assessments for BAR 5 and BAR 7, incorporating inshore trawl survey biomass indices (and potentially survey length frequencies), commercial CPUE, and catch-at-age. Alternatively, length-based assessments could be attempted if no catch-at-age data are available.
2. Further investigation of stock relationships, focusing on the possible inter-relationship between BAR 5 with BAR 7 and BAR 1
3. Optimised otolith sampling and development of catch-at-age for BAR 5 and BAR 7 (focusing on the main fisheries areas off WCSI and WCNI, and South).

5. STATUS OF THE STOCKS

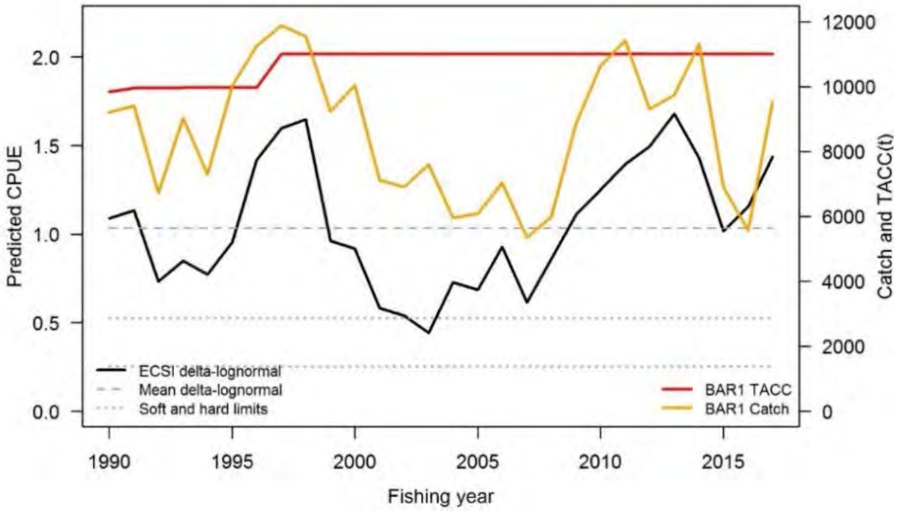
- **BAR 1**

The current uinderstanding of the BAR 1 stock is that adult barracouta undertake an annual northward migration from the east coast of the South Island to spawn off the east coast of the North Island during July/August–September (see Hurst et al 2012). For the purposes of this analysis barracouta in BAR 1 are assumed to comprise a single stock.

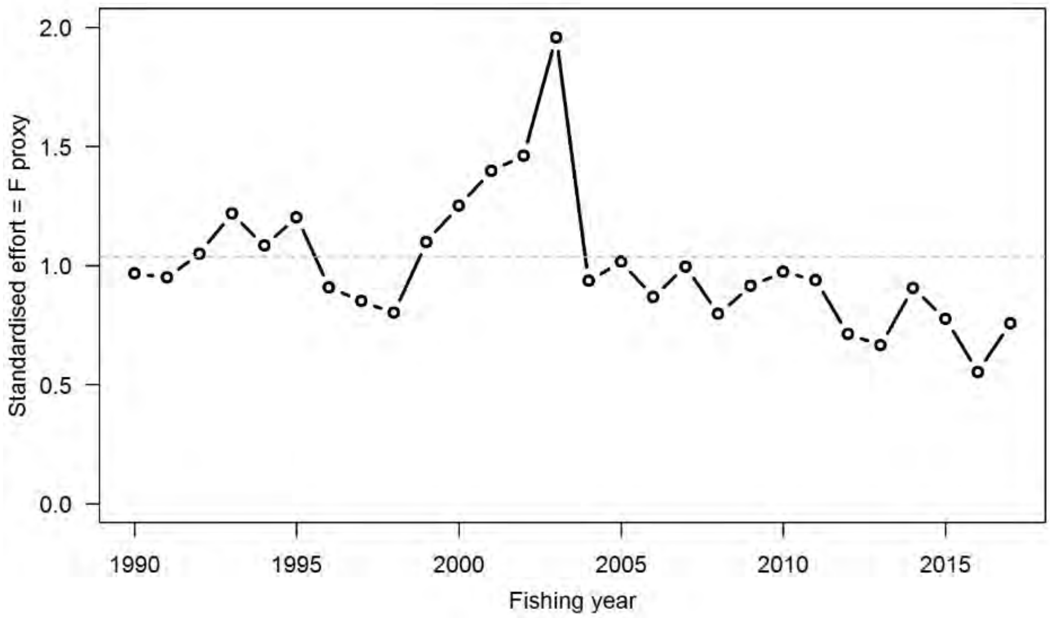
Stock Status	
Year of Most Recent Assessment	2018
Assessment Runs Presented	BAR 1 ECSI CELR/TCER/small vessel TCEPR day-level series (target species BAR, RCO, TAR)
Reference Points	Interim Target: B_{MSY}-compatible proxy based on CPUE (average from 1989–90 to 2013–14 of the BAR 1 ECSI CELR/TCER/TCEPR model as defined by Baird (2018)) Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: F_{MSY} (assumed)
Status in relation to Target	Likely (> 60%) to be at or above the target
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring

Historical Stock Status Trajectory and Current Status

CPUE, Catch and TACC Trajectories



Comparison of the ECSI CPUE series with the trajectories of catch (BAR 1 (QMR/MHR)) and TACCs from 1989–90 to 2016–17. Compare with the trawl survey trajectory shown in Figure 6.



Annual relative exploitation rate (catch/CPUE) for barracouta ECSI. The dotted line represents mean relative exploitation rate for the reference period.

Fishery and Stock Trends	
Recent trend in Biomass or Proxy	The BAR 1 CPUE series increased steeply from 2002–03 to a peak in 2012–13, dropped to the series mean in 2014–15, then increased.
Recent trend in Fishing Mortality or Proxy	Relative exploitation rate has declined gradually since 2005, and has been below the series mean (target) since 2012.
Other Abundance Indices	The winter ECSI trawl survey series for recruited fish has a trend that is similar to the BAR 1 CPUE index, with a peak in 2014 and a subsequent drop in 2016
Trends in Other Relevant Indicator or Variables	Recent landings (2008–09 to 2013–14) are at a similar level to those recorded during 1994–95 to 1999–2000.

Projections and Prognosis	
Stock Projections or Prognosis	Low pre-recruit biomass from the 2016 ECSI trawl survey suggests biomass may decline
Probability of Current Catch or TACC causing Biomass to remain below or decline below Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Unlikely (< 40%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE series	
Assessment Dates	Latest assessment: 2016	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data - Trawl survey biomass indices and associated length frequencies	1 – High Quality 1 – High Quality (used as supporting information)
Data not used (rank)	- TCEPR CPUE Series (ECSI) - Standardised CPUE series (ECNI) - Summer ECSI trawl survey data	3 – Low Quality: few vessels and highly variable CPUE 3 – Low Quality: insufficient data and high interannual variability 3 – Low Quality: variable catchability between years
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
-

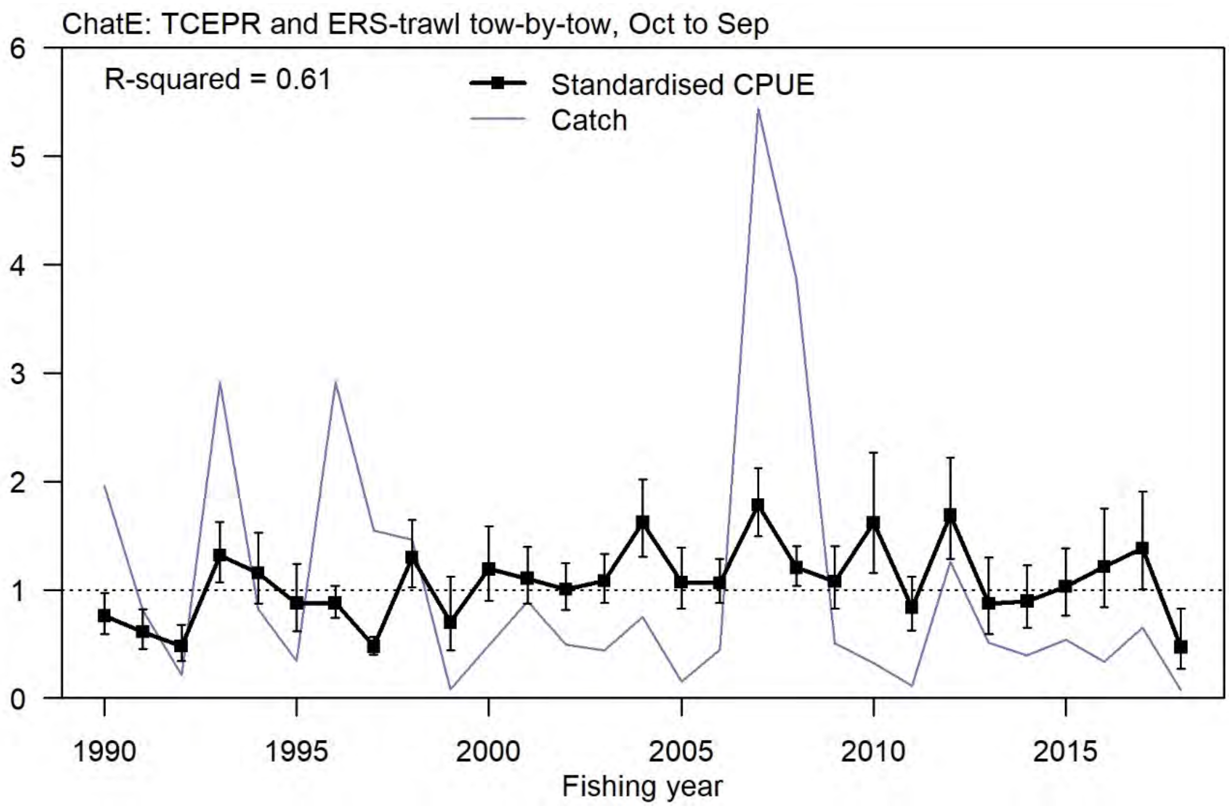
Fishery Interactions
Barracouta in the ECSI part of BAR 1 are taken as bycatch by inshore bottom trawl fisheries targeting, amongst others, red cod and tarakihi, and red cod and arrow squid by deepwater vessels. ECSI bycatch also comes from midwater effort targeting jack mackerels. In the ECNI part of BAR 1, most barracouta bycatch is from tarakihi and red gurnard effort; currently, there is little targeting of barracouta in this area. The trawl fishery in the ECSI area is subject to management measures designed to reduce interactions with endemic Hector’s dolphins and seabirds. There is also a risk of incidental capture of sea lions from Otago Peninsula south.

- **BAR 4 (East Chatham Rise only)**

The relationships between the stock taken in this fishery and other barracouta stocks is uncertain.

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised CPUE Chatham East
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Comparison of Chatham Rise East CPUE standardized indices (scaled to mean 1) for CPUE indices for the Chatham Rise East area. ChatE CPUE: Unmerged tow level TCEPR and ERS-trawl Oct–Sep.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The CPUE series is flat.
Recent Trend in Fishing Intensity or Proxy	-
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE	
Assessment Dates	Latest assessment: 2020	Next assessment: 2021
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	Commercial CPUE (East)	2 – Medium or mixed Quality: the highly variable nature of this fishery makes interpretation of standardised CPUE difficult
Data not used (rank)	*Tangaroa* Chatham Rise trawl survey	3 – Low Quality: high interannual variability, doesn't cover depth range of species
Changes to Model Structure and Assumptions	-	
Major sources of Uncertainty	-	

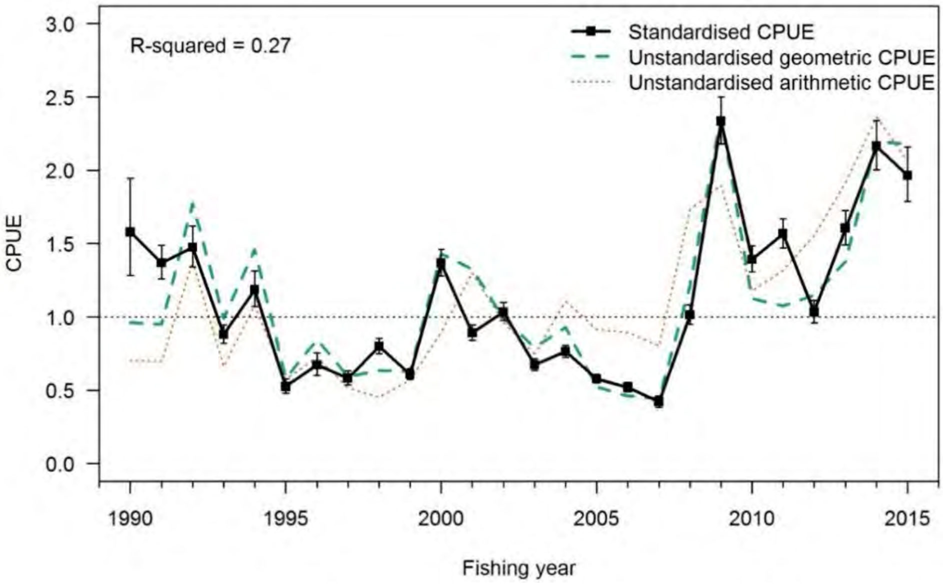
Qualifying Comments
-

Fishery Interactions
Barracouta from Chatham Rise East are caught sporadically all year, but mainly in May-June and/or December-January, by bottom or midwater trawls targeting barracouta.

- **BAR 5**

The relationship between these southern fisheries and the WCSI is uncertain.

Stock Status	
Year of Most Recent Assessment	2017
Assessment Runs Presented	Standardised CPUE Sub-Antarctic (tow level)
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	Unknown
Status in relation to Limits	B_{2015} is Very Unlikely (< 10%) to be below both the soft and hard limits
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status

BAR 5 CPUE Model: CPUE indices for barracouta from SQU target tows in statistical area 028 (1990–2015).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	-
Recent Trend in Fishing Intensity or Proxy	-
Other Abundance Indices	CPUE has remained at a high level since 2008 despite catches at or above the TACC.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Very Unlikely (< 10%) Hard Limit: Very Unlikely (< 10%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment.	
Assessment Method	Standardised CPUE	
Assessment Dates	Latest assessment: 2016	Next assessment: 2021
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Commercial CPUE	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major sources of Uncertainty		

Qualifying Comments
None

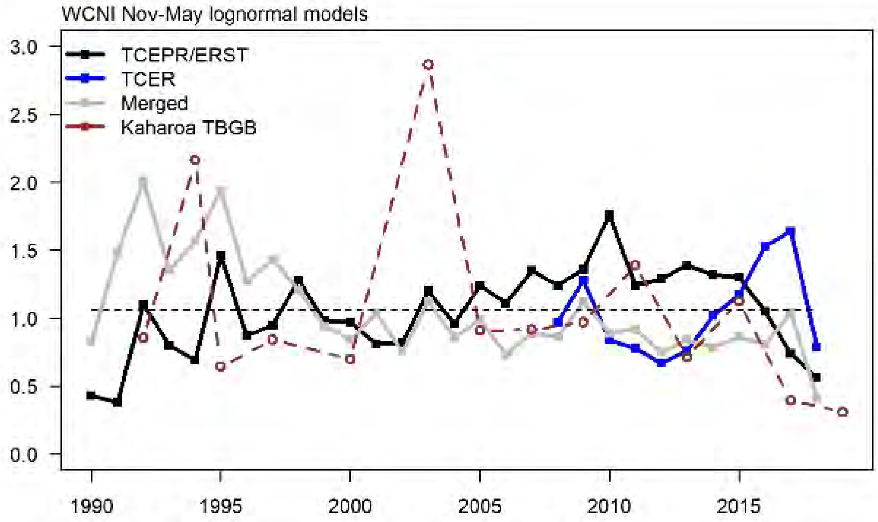
Fishery Interactions
Barracouta are taken as a target species in BAR 5 and also as by-catch in the squid and warehou target fisheries.

- **BAR 7**

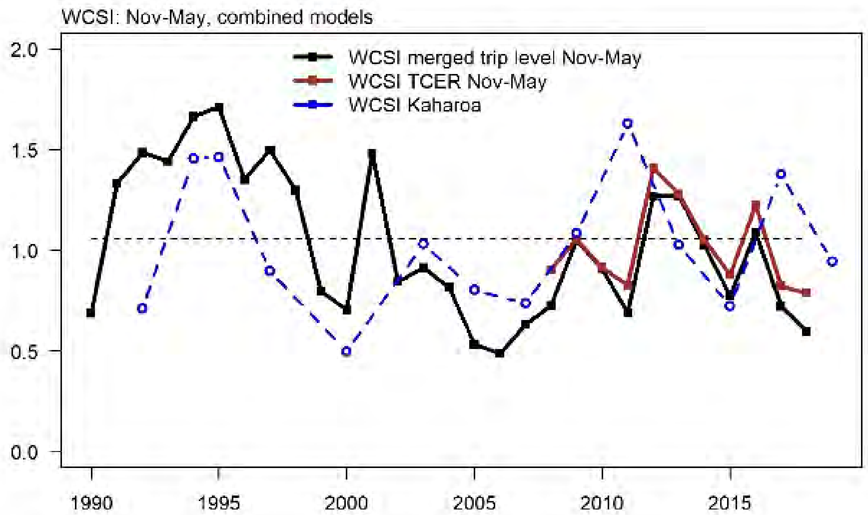
The relationship between the WCSI and the fisheries in BAR 5 is uncertain.

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised CPUE (tow level)
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Comparison of WCNI CPUE indices (scaled to mean 1) for CPUE indices and *Kaharoa* survey indices for Tasman Bay, Golden Bay area. TCEPR/ERST: TCEPR and ERS-trawl tow level Nov–May (model 1); TCER: TCER tow level Nov–May (model 2); Merged: TCEPR, TCER, CELR, ERS-trawl trip level Nov-May (model 3). Trawl survey is based on fishing year.



Comparison of WCSI CPUE indices (scaled to mean 1) and and *Kaharoa* survey indices for the WCSI area. TCER: TCER tow level Nov–May (model 2); Merged: TCEPR, TCER, CELR, ERS-trawl trip level Nov-May (model 3). Trawl survey is based on fishing year.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	On the WCSI, CPUE is fluctuating with no clear trend. On the WCNI, CPUE has declined since 2010.
Recent Trend in Fishing Intensity or Proxy	-
Other Abundance Indices	The estimated biomass has varied almost three-fold during the *Kaharoa* WCSI time series but has not shown any consistent trend
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE	
Assessment Dates	Latest assessment: 2020	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Commercial CPUE - *Kaharoa* WCSI trawl survey biomass indices and associated length frequencies	1 – High Quality 1 – High Quality (used as supporting information)
Data not used (rank)	WCSI *Tangaroa* survey	3- Low Quality: doesn't cover appropriate depth range
Changes to Model Structure and Assumptions	-	
Major sources of Uncertainty	-	

Qualifying Comments
Potential stock movement between FMA 5 and FMA 7 (or FMA 3) is unresolved. It is possible barracouta from other areas move into WCSI to spawn in winter.

Fishery Interactions
Barracouta in BAR 7 are taken both as a target on the WCSI and as bycatch in the WCNI jack mackerel and WCSI hoki fisheries.

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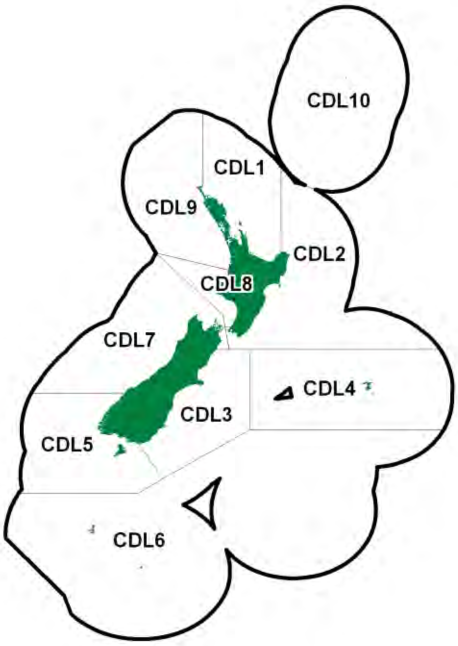
BLACK CARDINALFISH (CDL)

(*Epigonus telescopus*)
Akiwa



1. FISHERY SUMMARY

Black cardinalfish was introduced into the QMS on 1 October 1998 and quotas were set for QMAs 2–8. Quotas for QMAs 1 and 9 were subsequently set for 1999–00. TACCs were increased from 1 October 2006 in CDL 4 t to 66 t and in CDL 5 t to 22 t. In these stocks landings were above the TACC for a number of years and the TACCs were increased to the average of the previous eight years plus an additional 10%. From 1 October 2009 the TACC was reduced in CDL 2 to 1620 t, then reduced to 1020 t in 2010–11, and further reduced to 440 t in 2011–12. CDL 1 and CDL 2 have other mortality allocations of 120 t and 20 t respectively (Table 1).

Table 1: TACs (t), TACCs (t) and allowances (t) for black cardinalfish.

Fishstock	Recreational allowance	Customary non-commercial allowance	Other sources of mortality	TACC	TAC
CDL 1	0	0	120	1 200	1 320
CDL 2	0	0	20	440	460
CDL 3	0	0	–	196	196
CDL 4	0	0	–	66	66
CDL 5	0	–	–	22	22
CDL 6	0	0	–	1	1
CDL 7	0	0	–	39	39
CDL 8	0	0	–	0	0
CDL 9	0	0	–	4	4
CDL 10	0	0	–	0	0
Total	0	0	219	1 968	2 108

1.1 Commercial fisheries

Several species of *Epigonus* are widely distributed in New Zealand waters, but only black cardinalfish (*E. telescopus*) reaches a marketable size and is found in commercial concentrations. It occurs throughout the New Zealand EEZ at depths of 300–1100 m, mostly in very mobile schools up to 150 m off the bottom over hills and rough ground. Black cardinalfish have been caught since 1981 by research and commercial vessels, initially as a bycatch of target trawling for other high value species. The preferred depth range of schools (600–900 m) overlaps the upper end of the depth range of orange roughy and the lower end of alfonsino and bluenose. The exploitation of these species from 1986 resulted in the development of the major cardinalfish fishery in QMA 2.

It is primarily sold domestically due to the short freezer life of fillets. The species has a section of dark flesh under the lateral line that has caused problems with overseas marketing. The fillets can be tainted if this flesh is not removed quickly.

Landings for 1998–99 to 2008–09 are from QMR totals following introduction of the species into the QMS for 1998–99. For the 1982–83 to 1985–86 fishing years, the best estimate of landings was the sum of the FSU Inshore and FSU Deepwater (i.e., FSU Total) catch returns. For 1986–87 to 1988–89 the best estimate was taken as the greater value of either the FSU Total or the LFRR. From the 1989–90 fishing year, the best estimate was taken as the higher of either the LFRR or the sum of the CLR and CELR Landed data.

The best estimate of total landings was split between the nine QMAs and ET (outside the EEZ) based on FSU and QMS data (Table 2). For FSU data (1982–83 to 1987–88 fishing years), catch where area was unknown was prorated to QMAs according to the catch level where area was reported. For QMS data (1988–89 to 1994–95 fishing years), catch by area in CELR Landed and CLR reports were scaled to equal the best estimate of the total catch. Commercial landings of black cardinalfish have been made in QMAs 1–9 and outside the EEZ (ET).

In most years since 1982 more than 65% of black cardinalfish landings were from the east coast of the North Island (QMA 2). The large increase in landings from this area in 1986–87 was associated with the development of the orange roughy fishery around the Ritchie Banks and Tuaheni High, and an increase in targeted fishing to establish a catch history when it was anticipated to become a quota species. The relatively large landings in 1990–91 were a combination of bycatch from the orange roughy fishery and target fishing for black cardinalfish. Landings from the Bay of Plenty (QMA 1) peaked at 2001 t in the fishing year 1996–97, but have remained well below the TACC since, with < 50 t of annual landings being recorded since 2014–15. Between 1991–92 and 2008–09 occasional catches were taken from outside the EEZ on the northern Challenger Plateau and the Lord Howe Rise. Figure 1 shows the historical landings and TACC values for the main CDL stocks.

1.2 Recreational fisheries
Recreational fishing for black cardinalfish is negligible.

1.3 Customary non-commercial fisheries
The level of this fishery is believed to be negligible.

1.4 Illegal catch
No information is available about illegal catch.

Table 2: Reported landings (t) of black cardinalfish by QMA and fishing year (1 October to 30 September) from 1982–83 to 2018–19. The data in this table have been updated from that published in the 1998 Plenary Report by using the data through to 1996–97 in table 32 on p. 262 of the "Review of Sustainability Measures and Other Management Controls for the 1998–99 Fishing Year - Final Advice Paper" dated 6 August 1998. Data for 1997–98 based on catch and effort returns, since 1998–99 on QMR records. [Continued on next page]

	QMA 1		QMA 2		QMA 3		QMA 4		QMA 5		QMA 6	
Year	Catch	TACC	Catch	TACC	Catch	TACC	Catch	TACC	Catch	TACC	Catch	TACC
1982–83	–	–	76	–	< 1	–	< 1	–	–	–	–	–
1983–84	–	–	212	–	7	–	< 1	–	–	–	–	–
1984–85	< 1	–	189	–	341	–	< 1	–	–	–	–	–
1985–86	< 1	–	238	–	50	–	3	–	2	–	–	–
1986–87	1	–	1 738	–	72	–	2	–	< 1	–	< 1	–
1987–88	3	–	1 556	–	28	–	1	–	3	–	–	–
1988–89	305	–	1 434	–	57	–	4	–	–	–	–	–
1989–90	613	–	1 718	–	20	–	18	–	–	–	–	–
1990–91	233	–	3 473	–	598	–	1	–	4	–	–	–
1991–92	7	–	1 652	–	146	–	3	–	< 1	–	2	–
1992–93	23	–	1 550	–	519	–	2	–	< 1	–	–	–
1993–94	364	–	2 310	–	277	–	10	–	5	–	–	–
1994–95	1 162	–	2 207	–	51	–	7	–	1	–	< 1	–
1995–96	1 418	–	2 621	–	57	–	4	–	10	–	–	–
1996–97	2 001	–	1 910	–	100	–	7	–	–	–	–	–

Table 2: [Continued]

	QMA 1		QMA 2		QMA 3		QMA 4		QMA 5		QMA 6	
Year	**Catch**	**TACC**	**Catch**	**TACC**	**Catch**	**TACC**	**Catch**	**TACC**	**Catch**	**TACC**	**Catch**	**TACC**
1997–98	995	–	1 176	–	40	–	351	–	–	–	–	–
1998–99	24	–	1 268	2 223	181	196	41	5	–	2	< 1	1
1999–00	980	1 200	2 158	2 223	215	196	36	5	< 1	2	< 1	1
2000–01	294	1 200	1 135	2 223	99	196	35	5	74	2	< 1	1
2001–02	455	1 200	1 693	2 223	146	196	29	5	18	2	< 1	1
2002–03	583	1 200	1 845	2 223	172	196	80	5	9	2	< 1	1
2003–04	481	1 200	966	2 223	96	196	148	5	27	2	< 1	1
2004–05	267	1 200	1 102	2 223	43	196	49	5	15	2	< 1	1
2005–06	643	1 200	2 153	2 223	50	196	53	5	< 1	2	< 1	1
2006–07	415	1 200	1 692	2 223	66	196	31	66	10	22	< 1	1
2007–08	202	1 200	861	2 223	7	196	23	66	20	22	< 1	1
2008–09	197	1 200	1 135	2 223	52	196	58	66	11	22	< 1	1
2009–10	49	1 200	1 046	1 620	45	196	15	66	3	22	< 1	1
2010–11	84	1 200	736	1 020	17	196	19	66	5	22	< 1	1
2011–12	148	1 200	376	440	79	196	44	66	93	22	< 1	1
2012–13	35	1 200	470	440	40	196	10	66	14	22	1	1
2013–14	160	1 200	282	440	68	196	11	66	19	22	< 1	1
2014–15	21	1 200	408	440	209	196	18	66	4	22	< 1	1
2015–16	35	1 200	299	440	136	196	30	66	15	22	1	1
2016–17	12	1 200	369	440	101	196	22	66	87	22	2	1
2017–18	2	1 200	236	440	131	196	13	66	6	22	1	1
2018–19	40	1 200	372	440	177	196	13	66	87	22	< 1	1

	QMA 7		QMA 8		QMA 9		Total (EEZ)		ET	Total
Year	**Catch**	**TACC**	**Catch**	**TACC**	**Catch**	**TACC**	**Catch**	**TACC**	**Catch**	**Catch**
1982–83	< 1	–	–	–	–	–	78	–	–	78
1983–84	< 1	–	–	–	–	–	220	–	–	220
1984–85	1	–	–	–	–	–	532	–	–	532
1985–86	< 1	–	–	–	45	–	292	–	–	292
1986–87	< 1	–	–	–	–	–	1 814	–	–	1 814
1987–88	2	–	< 1	–	< 1	–	1 638	–	–	1 638
1988–89	2	–	–	–	–	–	1 798	–	2	1 800
1989–90	15	–	–	–	–	–	2 385	–	< 1	2 385
1990–91	1	–	< 1	–	–	–	4 311	–	–	4 311
1991–92	11	–	–	–	–	–	1 821	–	17	1 838
1992–93	2	–	–	–	–	–	2 096	–	270	2 366
1993–94	6	–	–	–	–	–	2 972	–	829	3 801
1994–95	51	–	–	–	< 1	–	3 479	–	231	3 710
1995–96	26	–	–	–	–	–	4 150	–	340	4 490
1996–97	27	–	–	–	–	–	4 045	–	522	4 567
1997–98	76	–	–	–	108	–	2 338	–	405	2 743
1998–99	16	39	< 1	0	< 1	–	1 531	3 670	390	1 921
1999–00	27	39	0	0	< 1	4	3 415	3 670	962	4 377
2000–01	2	39	0	0	3	4	1 642	3 670	571	2 213
2001–02	3	39	0	0	5	4	2 349	3 670	490	2 839
2002–03	27	39	0	0	5	4	2 721	3 670	275	2 996
2003–04	2	39	0	0	6	4	1 727	3 670	58	1 785
2004–05	2	39	0	0	1	4	1 479	3 670	204	1 683
2005–06	1	39	0	0	2	4	2 901	3 670	44	2 945
2006–07	1	39	0	0	1	4	2 216	3 751	2	2 218
2007–08	2	39	< 1	0	19	4	1 134	3 751	1	1 135
2008–09	1	39	0	0	2	4	1 456	3 751	17	1 474
2009–10	< 1	39	0	0	5	4	1 163	3 148	–	–
2010–11	< 1	39	0	0	1	4	863	2 548	–	–
2011–12	< 1	39	0	0	< 1	4	742	1 968	–	–
2012–13	2	39	0	0	4	4	576	1 968	–	–
2013–14	1	39	0	0	< 1	4	542	1 968	–	–
2014–15	5	39	0	0	1	4	665	1 968	–	–
2015–16	3	39	0	0	2	4	522	1 968	–	–
2016–17	5	39	0	0	1	4	599	1 968	–	–
2017–18	11	39	0	0	1	4	401	1 968	–	–
2018–19	6	39	0	0	2	4	696	1968	–	–

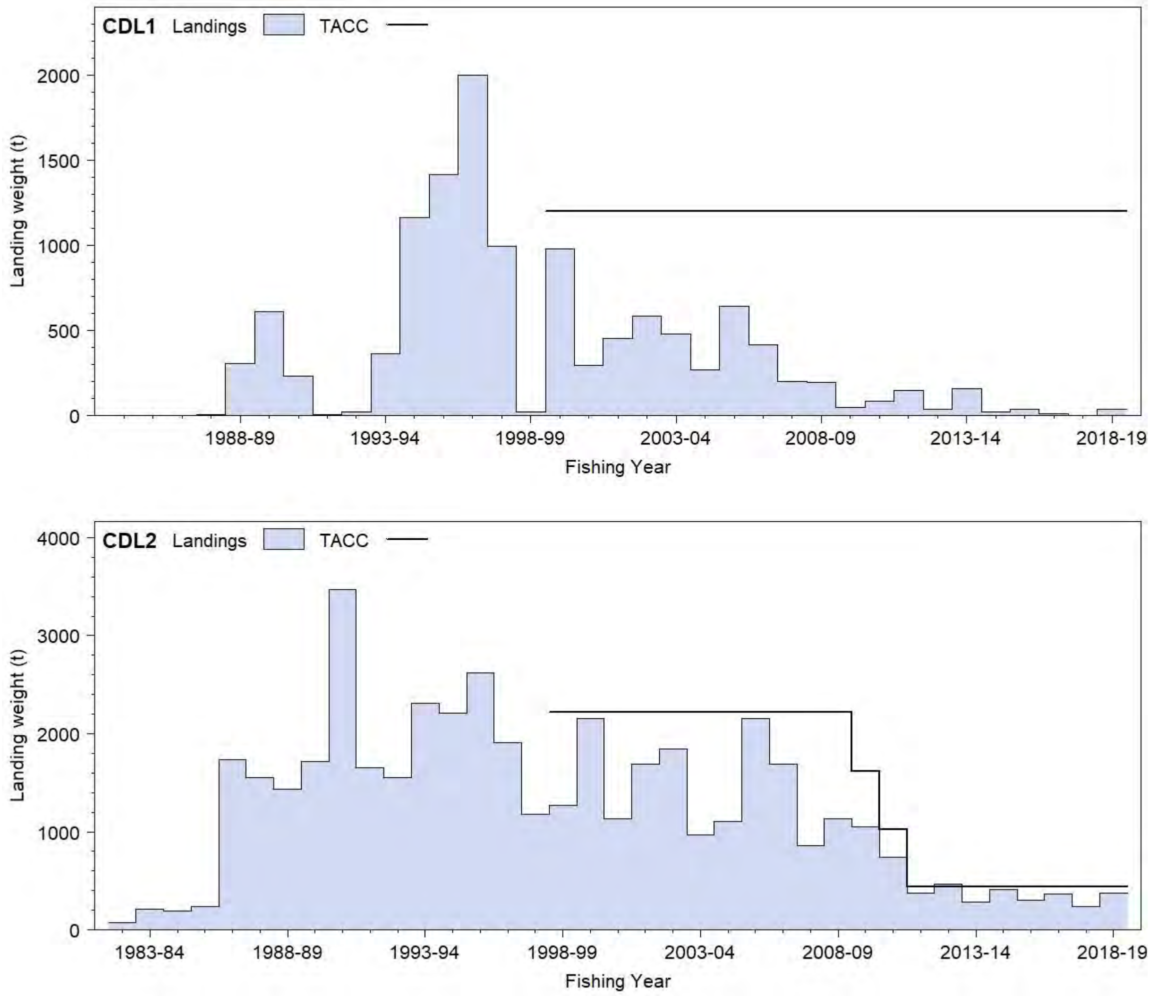


Figure 1: Reported commercial landings and TACC for the two main CDL stocks. CDL 1 (Auckland East) and CDL 2 (Central East).

1.5 Other sources of mortality

There has been a history of catch overruns (unreported catch) from loss of fish through burst nets, and the discarding at sea of this species while target fishing for higher value species. In the assessment presented here, the total removals were assumed to exceed reported catches by the overrun percentages in Table 3 (Dunn 2009). All yield estimates make an allowance for the current estimated level of overrun of 10%.

Table 3: Catch overruns (%) for CDL 2 by year.

Year	Overrun	Year	Over-run
1982–83	100	1991–92	30
1983–84	100	1992–93	30
1984–85	100	1993–94	30
1985–86	100	1994–95	20
1986–87	50	1995–96	20
1987–88	50	1996–97	20
1988–89	50	1997–98	20
1989–90	50	1998–99 and	10
1990–91	50	subsequently	–

2. BIOLOGY

The average size of black cardinalfish landed by the commercial fishery is about 50–60 cm fork length (FL). Length frequency distributions from research surveys are unimodal with a peak at 55–65 cm FL. They reach a maximum length of about 75 cm FL. Otolith readings from 722 fish from

QMA 2 have been validated using radiometric and bomb radiocarbon methods and indicated that this species is relatively slow-growing and long-lived (Andrews & Tracey 2007, Neil et al 2008). Maximum ages of over 100 years were reported, with the bulk of the commercial catch being between 35 and 55 years of age. The validation indicated that fish aged over 60 years tended to be under-aged, by up to 30%. This bias would be likely to have little impact on the estimated growth parameters, but would influence the estimate of natural mortality (*M*). Life history parameters are given below in Table 4.

Table 4: Life history parameters for black cardinalfish. All estimates are for CDL 2, except the length-weight parameters which are for CDL 2–4.

Fishstock	Estimate	Source
1. Natural mortality (*M*)	0.034*	(Tracey et al 2000)
Age at recruitment (A_r)	unknown	
Gradual recruitment (A_m)	unknown	
Age at full recruitment	45	(Tracey et al 2000)
Age at maturity (A_s)	35	(Field & Clark 2001)
Gradual maturity (S_m)	13	(Field & Clark 2001)

2. Weight = a(length)^b (weight in g, fork length in cm).

	Both sexes		
	a	b	
	0.113	2.528	Dunn (2009)

3. Von Bertalanffy growth parameters (Tracey et al 2000)

Both sexes			Female			Male		
L_∞	k	t_0	L_∞	k	t_0	L_∞	K	t_0
70.8	0.034	-6.32	70.9	0.038	-4.62	67.8	0.034	-8.39

* Because of uncertainties in ageing and *M*, the Deepwater Fisheries Assessment Working Group used a range of *M*s in the assessments.

The reproductive biology of black cardinalfish is not well known (Dunn 2009). Indications from research survey and Observer Programme data are that spawning may occur between November and July. Spawning locations have been identified in CDL 1, CDL 2, CDL 7, CDL 9, and outside the EEZ on the northern Challenger Plateau, Lord Howe Rise, and West Norfolk Ridge. A probit analysis of maturity at length indicated that fish became sexually mature at around 50 cm length, at an age of approximately 35 years (Field & Clark 2001). Maturity was also inferred to be between ages 26 and 44 years (mean 33 years) from changes in $\delta^{13}C$ in otoliths (Neil et al 2008).

Juveniles are thought to be mesopelagic until they reach a length of about 12 cm (5 years of age), after which they become primarily demersal (Neil et al 2008). Larger juveniles have been caught in bottom trawls at depths of 400–700 m, extending into deeper water as they grow, with adult fish caught primarily at 800–1000 m (Dunn 2009). Prey items from research trawl samples include mesopelagic fish, natant decapod prawns, and octopus.

Elevated levels of mercury (Hg) have been recorded in a sample of black cardinalfish from the Bay of Plenty (Tracey 1993).

3. STOCKS AND AREAS

The stock boundaries and number of black cardinalfish stocks in New Zealand are unknown. There are no data on genetics, or known movements of black cardinalfish which indicate possible stock boundaries.

There is evidence that spawning occurs in CDL 1, CDL 2, CDL 7, and CDL 9 and outside the EEZ (e.g., North Challenger, Lord Howe, and West Norfolk Ridge). In CDL 2, three geographically close spawning locations have been identified: Tuaheni High, Ritchie Bank, and Rockgarden (Dunn 2009). Juveniles of less than 30 cm have been infrequently identified in CDL 2 and more frequently found on the northern flanks of the Chatham Rise, which is south of the spawning grounds in CDL 2. No spawning grounds have been identified on the Chatham Rise, where adult fish are relatively rare.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the 2020 Fishery Assessment Plenary. A more detailed summary from an issue-by-issue perspective is available in the 2018 Aquatic Environment & Biodiversity Annual Review (Fisheries New Zealand 2019, https://www.mpi.govt.nz/dmsdocument/34854-aquatic-environment-and-biodiversity-annual-review-aebar-2018-a-summary-of-environmental-interactions-between-the-seafood-sector-and-the-aquatic-environment).

4.1 Role in the ecosystem

Black cardinalfish is a part of the mid slope demersal fish assemblage identified by Francis et al (2002). It is widely distributed with a range centred on a depth of about 750 m and latitude about 39.4° S (i.e., central and northern New Zealand). It occupies depths intermediate between the shallower southern community dominated by hoki (about 620 m, 49.5° S) and the deeper southern black oreo (about 930 m, 45.5° S) and smooth oreo (about 1090 m, 44.6° S), and the deeper centrally located orange roughy (about 1090 m, 41.2° S) (Francis et al 2002). The role in the ecosystem is not well understood; and nor are the effects on the ecosystem of removing about an average of 2300 t of black cardinalfish per year between 1986–87 and 2010–11 from the New Zealand EEZ, mostly from the east coast of the North Island.

4.1.1 Trophic interactions

No detailed feeding studies for black cardinalfish have been documented for New Zealand waters. Prey items observed during research surveys in New Zealand waters include mesopelagic fish, particularly lighthouse fish (*Phosichthys argenteus*), natant decapod prawns, and cephalopods (Tracey 1993). Predators of black cardinalfish are not documented but predation is expected to vary with fish development.

4.1.2 Ecosystem indicators

Tuck et al (2009, 2014) used data from the Sub-Antarctic and Chatham Rise middle-depth trawl surveys to derive indicators of fish diversity, size, and trophic level. However, fishing for cardinalfish occurs mostly deeper than the depth range of these surveys and is only a small component of fishing in the areas considered by Tuck et al (2009, 2014).

4.2 Bycatch (fish and invertebrates)

Incidental catch and discards have not been estimated for the black cardinalfish target fishery. Anderson et al (2017) summarised the bycatch and discards from the target orange roughy and oreo trawl fisheries from 2000–01 to 2014–15. The bycatch of these fisheries may be similar to that of the cardinalfish fishery, although both occur somewhat deeper than cardinalfish and oreo fisheries are found further to the south.

4.3 Incidental capture of protected species (seabirds, mammals, and protected fish)

For protected species, capture estimates presented here include all animals recovered to the deck (alive, injured, or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds struck by a warp but not brought onboard the vessel, Middleton & Abraham 2007).

4.3.1 Seabird interactions

Annual observed seabird capture rates ranged from 0 to 0.9 per 100 tows in orange roughy, oreo, and cardinalfish trawl fisheries between 2002–03 and 2017–18 (Baird 2001, 2004a, 2004b, 2005, Abraham & Thompson 2009, Abraham et al 2009, Abraham & Thompson 2011, Abraham et al 2016, Table 5). Capture rates have fluctuated without obvious trend at this low level. In the 2016–17 fishing year there were 2 observed captures of seabirds and 4 observed captures of seabirds in 2017–18 in orange roughy, oreo, and cardinalfish trawl fisheries at a rates of 0.2 and 0.4 (respectively) seabirds per 100 observed tows (Table 5, Abraham et al 2016). The average capture rate in deepwater trawl fisheries (including orange roughy, oreo, and cardinalfish) for the period from 2002–03 to 2017–18 is about 0.31 birds per 100 tows, a very low rate relative to other New Zealand trawl fisheries; e.g., for scampi (4.43 birds per 100 tows) and squid (13.79 birds per 100 tows) over the same years.

Table 5: Number of tows by fishing year and observed seabird captures in orange roughy, oreo, and cardinalfish trawl fisheries, 2002–03 to 2017–18. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Estimates are based on methods described by Abraham et al (2016) and Abraham & Richard (2017, 2018) and available via https://data.dragonfly.co.nz/psc. Estimates from 2002–03 to 2017–18 are based on data version 2019v1.

Fishing	Fishing effort			Observed captures		Estimated captures	
year	Tows	No. obs	% obs	Captures	Rate	Mean	95% c.i.
2002–03	8 870	1 382	15.6	0	0.0	34	20–52
2003–04	8 007	1 262	15.8	3	0.2	32	19–47
2004–05	8 427	1 619	19.2	7	0.4	43	28–62
2005–06	8 291	1 359	16.4	8	0.6	39	25–55
2006–07	7 379	2 324	31.5	1	0.0	20	10–31
2007–08	6 731	2 811	41.8	7	0.2	23	14–33
2008–09	6 133	2 372	38.7	7	0.3	23	15–34
2009–10	6 012	2 132	35.5	19	0.9	35	27–46
2010–11	4 177	1 205	28.8	1	0.1	16	8–26
2011–12	3 655	923	25.3	2	0.2	12	6–21
2012–13	3 099	346	11.2	2	0.6	14	7–23
2013–14	3 608	434	12.0	2	0.5	16	8–26
2014–15	3 818	978	25.6	0	0.0	14	6–23
2015–16	4 084	1 421	34.8	4	0.3	14	8–22
2016–17	3 967	1 226	30.9	2	0.2	13	6–21
2017–18	3 748	903	24.1	4	0.4	16	9–25

Table 6: Number of observed seabird captures in orange roughy, oreo, and cardinalfish fisheries, 2002–03 to 2017–18, by species and area. The risk category is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Population Sustainability Thresholds, PST (from Richard et al 2017, where full details of the risk assessment approach can be found). It is not an estimate of the risk posed by fishing for black cardinalfish. These data are available via https://data.dragonfly.co.nz/psc, based on data version 2019v1.

Species	Risk Category	Chatham Rise	East coast South Island	Fiordland	Sub-Antarctic	Stewart-Snares shelf	West coast South Island	Total
Salvin's albatross	High	11	4	0	3	0	0	18
Southern Buller's albatross	High	3	0	1	0	0	0	4
Chatham Island albatross	Medium	7	0	0	1	0	0	8
New Zealand white-capped albatross	Medium	4	0	0	0	0	2	6
Gibson's albatross	High	1	0	0	0	0	0	1
Antipodean albatross	Medium	1	0	0	0	0	0	1
Northern royal albatross	Low	1	0	0	0	0	0	1
Southern royal albatross	Negligible	1	0	0	0	0	0	1
Albatrosses	–	1	2	0	0	0	0	3
Total albatrosses	–	30	6	1	4	0	2	43
Northern giant petrel	Medium	1	0	0	0	0	0	1
White-chinned petrel	Low	2	1	0	0	0	0	4
Grey petrel	Negligible	1	0	0	1	0	0	2
Sooty shearwater	Negligible	0	3	0	0	0	1	4
Common diving petrel	Negligible	2	0	0	0	0	0	2
White-faced storm petrels	Negligible	3	0	0	0	0	0	3
Cape petrel	–	8	1	0	0	0	0	9
Petrels, prions, and shearwaters	–	0	0	0	1	0	0	1
Total other birds	–	17	5	0	2	1	1	26

Salvin's albatross was the most frequently captured albatross (50% of observed albatross captures) but eight different albatross species have been observed captured since 2002–03. Cape petrels were the most frequently captured other taxon (35% of observed captures of taxa other than albatross, Table 6). Seabird captures in the orange roughy, oreo, and cardinalfish fisheries have been observed mostly around the Chatham Rise and off the east coast South Island. These numbers should be regarded as only a general guide on the distribution of captures because the observer coverage is not uniform across areas and may not be representative.

The deepwater trawl fisheries (including the cardinalfish target fishery) contribute to the total risk posed by New Zealand commercial fishing to seabirds (see Table 7). The two species to which the fishery poses the most risk are Chatham Island albatross and Salvin's albatross, with this suite of fisheries posing 0.06 and 0.022 of Population Sustainability Threshold (PST) (Table 7). Chatham Island albatross is assessed as at medium risk and Salvin's albatross as at high risk (Richard et al 2020).

Mitigation methods such as streamer (tori) lines, Brady bird bafflers, warp deflectors, and offal management are used in the orange roughy, oreo, and cardinalfish trawl fisheries. Warp mitigation was voluntarily introduced from about 2004 and made mandatory in April 2006 (Department of Internal Affairs 2006). The 2006 notice mandated that all trawlers over 28 m in length use a seabird scaring device while trawling (being "paired streamer lines", "bird baffler" or "warp deflector" as defined in the notice).

Table 7: Risk ratio of seabirds predicted by the level two risk assessment for the cardinalfish and all fisheries included in the level two risk assessment, 2006–07 to 2016–17, showing seabird species with a risk ratio of at least 0.001 of PST (from Richard et al 2020, where full details of the risk assessment approach can be found). The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the PST. The DOC threat classifications are shown (Robertson et al 2017 at http://www.doc.govt.nz/documents/science-and-technical/nztcs19entire.pdf).

	PST	Risk ratio			
Species name	**(mean)**	**DPW Risk Ratio***	**Total**	**Risk category**	**DOC Threat Classification**
Chatham Island albatross	428	0.0602	0.28	Medium	At Risk: Naturally Uncommon
Salvin's albatross	3 460	0.0223	0.65	High	Threatened: Nationally Critical
Northern giant petrel	337	0.0052	0.15	Medium	At Risk: Naturally Uncommon
Northern Buller's albatross	1 640	0.0024	0.26	Medium	At Risk: Naturally Uncommon
Black petrel	447	0.0024	1.23	Very high	Threatened: Nationally Vulnerable
Antipodean albatross	369	0.002	0.17	Medium	Threatened: Nationally Critical
Gibson's albatross	497	0.0016	0.31	High	Threatened: Nationally Critical
Northern royal albatross	723	0.0013	0.05	Low	At Risk: Naturally Uncommon
Flesh-footed shearwater	1 450	0.0007	0.49	High	Threatened: Nationally Vulnerable
Southern Buller's albatross	1 360	0.0006	0.37	High	At Risk: Naturally Uncommon
Grey petrel	5 460	0.0003	0.03	Negligible	At Risk: Naturally Uncommon
Common diving petrel	137 000	0.0001	< 0.01	Negligible	At Risk: Relict
New Zealand white-faced storm petrel	331 000	0.0001	0.00	Negligible	At Risk: Relict
New Zealand white-capped albatross	10 800	0.0001	0.29	Medium	At Risk: Declining
Buller's shearwater	56 200	0	0.00	Negligible	At Risk: Naturally Uncommon
Westland petrel	351	0	0.54	High	At Risk: Naturally Uncommon
Sooty shearwater	622 000	0	0.00	Negligible	At Risk: Declining
Hutton's shearwater	14 900	0	0.00	Negligible	At Risk: Declining
Otago shag	283	0	0.13	Medium	Threatened: Nationally Vulnerable
White-headed petrel	34 400	0	0.00	Negligible	Not Threatened

* DPW Risk Ratio from Richard et al 2017.

4.4 Benthic interactions

The spatial extent of seabed contact by trawl fishing gear in New Zealand's EEZ and Territorial Sea has been estimated and mapped in numerous studies for trawl fisheries targeting deepwater species (Baird et al 2011, Black et al 2013, Black & Tilney 2015, Black & Tilney 2017, Baird & Wood 2018, and Baird & Mules 2019, 2020b) and species in waters shallower than 250 m (Baird et al. 2015, Baird & Mules 2020a). The most recent assessment of the deepwater trawl footprint was for the period 1989–90 to 2017–18 (Baird & Mules 2020b).

The Tier 2 species black cardinalfish is part of the deepwater fishery complex that includes orange roughy and oreo species. During 1989–90 to 2017–18, about 15 600 black cardinalfish bottom trawls were reported. These data show a gradual increase in tows a year to a relatively stable period during 1995–96 to 2006–07 (about 700–1100 tows annually), then a period of steady decline from 2007–08 onwards to a low of 82 tows in 2017–18 (Baird & Mules 2020b). The annual trawl footprint from these tows increased to a peak of about 400 km^2 in 1998–99 and 1999–2000, ranged between 114 and 262 km^2 during 2000–01 and 2010–11, then declined steadily to 35 km^2 in 2017–18 (Baird & Mules 2020b). In total, the 1989–90 to 2017–18 footprint contacted 2211.3 km^2 of the seafloor which equates to 0.05% of the EEZ and Territorial Sea and 0.16% of the fishable area (the seafloor area in depths shallower than 1600 m that are open to fishing).

Trawling for orange roughy, oreo, and cardinalfish, like trawling for other species, is likely to have effects on benthic community structure and function (e.g., Rice 2006) and there may be consequences for benthic productivity (e.g., Jennings et al 2001, Hermsen et al 2003, Hiddink et al 2006, Reiss et al 2009). These consequences are not considered in detail here but are discussed in the Aquatic Environment and Biodiversity Annual Review 2019 (Fisheries New Zealand 2020).

4.5 Other considerations

4.5.1. Spawning disruption

Fishing during spawning may disrupt spawning activity or success. Morgan et al (1999) concluded that Atlantic cod (*Gadus morhua*) "exposed to a chronic stressor are able to spawn successfully, but there appears to be a negative impact of this stress on their reproductive output, particularly through the production of abnormal larvae". Morgan et al. (1997) also reported that "Following passage of the trawl, a 300-m-wide "hole" in the [cod spawning] aggregation spanned the trawl track. Disturbance was detected for 77 min after passage of the trawl." There is no research on the disruption of spawning black cardinalfish by fishing in New Zealand. Spawning of this species appears to occur between February and July, peaking in April, and catches of black cardinalfish occur throughout the year (Dunn 2005).

4.5.2 Genetic effects

Fishing or environmental changes (including those caused by climate change or pollution) could alter the genetic composition or diversity of a species. There are no known studies of the genetic diversity of cardinalfish from New Zealand. Genetic studies for stock discrimination are reported under "stocks and areas".

4.5.3 Habitat of particular significance to fisheries management

Habitat of particular significance for fisheries management (HPSFM) does not have a policy definition (Ministry for Primary Industries 2012). O'Driscoll et al (2003) reported spawning black cardinalfish mostly from around the North Island, but higher catch rates of juveniles on the northwest Chatham Rise and Puysegur area (O'Driscoll et al 2003). In both areas, sample sizes were small so these distributions should be treated with caution. It is not known if there are any direct linkages between the congregation of cardinalfish around features and the corals found on those features. Bottom trawling for cardinalfish has the potential to affect features of the habitat that could qualify as habitat of particular significance to fisheries management.

5. STOCK ASSESSMENT

A stock assessment for CDL 2–4 was completed in 2009. No assessments have been made for stocks in other areas. For the purposes of stock assessment, it has been assumed that black cardinalfish on the east coast North Island (CDL 2) are from the same stock as fish on the north Chatham Rise (CDL 3 and CDL 4).

5.1 Assessment inputs

The assessment inputs for CDL 2–4 were two CPUE indices (Table 8), catches adjusted by overruns (Table 9), and length frequency and maturity at length samples (Dunn 2009). The CPUE indices were derived from catch and effort data for fisheries focused on and around specific hill features in CDL 2 (Dunn & Bian 2009) with no overrun included. Although the CPUE indices accounted for a substantial proportion of the total catch (65–77%), the spatial extent of the fisheries was small compared with the overall area believed to be occupied by the stock. As a result, the indices may reflect local abundance, but it is less certain that they reflect overall stock biomass. The CPUE was split into two indices, before and after 1 October 1998, because of a change in reported fishing patterns in the late 1990s. This may have been caused, at least in part, by the introduction of the black cardinalfish TACC. The growth parameters used in the assessment are presented in Table 4. Length frequency samples were available for eight years between 1989–90 and 2007–08 from at-sea and market sampling. Maturity was input as the proportions mature at length from samples collected during research trawl surveys of the east coast North Island in 2001 and 2003.

Table 8: Standardised CPUE indices, and their calculated CVs, as used in the stock assessment.

Fishing year	Index a	CV (%)	Index b	CV (%)
1990–91	1.00	46	–	–
1991–92	0.73	43	–	–
1992–93	0.87	42	–	–
1993–94	0.58	46	–	–
1994–95	0.41	45	–	–
1995–96	0.26	39	–	–
1996–97	0.51	42	–	–
1997–98	0.29	47	–	–
1998–99	–	–	1.00	37
1999–00	–	–	0.57	32
2000–01	–	–	0.39	36
2001–02	–	–	0.50	35
2002–03	–	–	0.30	33
2003–04	–	–	0.26	38
2004–05	–	–	0.23	35
2005–06	–	–	0.34	34
2006–07	–	–	0.27	35
2007–08	–	–	0.17	37

Table 9: Estimated catches calculated by summing the CDL 2–4 catches from Table 2 (column 2), and increasing them by the overrun values in Table 3 (column 3), with the combined TACC for CDL 2–4 (column 4).

Year	Reported catch	Catch including overruns	TACC
1982–83	76	152	–
1983–84	219	438	–
1984–85	530	1 060	–
1985–86	291	582	–
1986–87	1 812	2 718	–
1987–88	1 585	2 378	–
1988–89	1 495	2 243	–
1989–90	1 756	2 634	–
1990–91	4 072	6 108	–
1991–92	1 801	2 341	–
1992–93	2 071	2 692	–
1993–94	2 597	3 376	–
1994–95	2 265	2 718	–
1995–96	2 682	3 218	–
1996–97	2 017	2 420	–
1997–98	1 567	1 880	–
1998–99	1 490	1 639	2 424
1999–00	2 409	2 650	2 424
2000–01	1 269	1 396	2 424
2001–02	1 868	2 055	2 424
2002–03	2 097	2 307	2 424
2003–04	1 210	1 331	2 424
2004–05	1 194	1 313	2 424
2005–06	2 256	2 482	2 424
2006–07	1 789	1 968	2 485
2007–08	891	980	2 485

5.2 Model structure and runs

Stock assessments were performed using the stock assessment program CASAL (Bull et al 2002) to estimate virgin and current biomass (Dunn 2009). Preliminary model runs were completed using all of the observational data. The key assumptions of the final model runs were:

- The biomass information in the data is primarily contained in the CPUE indices. Therefore, a two-step approach was used to produce the final model runs. In the final runs, selectivity and maturity were fixed at estimates from the preliminary runs and the length frequency and maturity data were not fitted. This ensured that any biomass signal from the length frequency data, potentially caused by errors in estimated growth and selectivity, did not dominate the signal from the CPUE trends.

- For runs assuming an *M* of 0.027, the selectivity and maturity estimates were similar; therefore the two were estimated separately in final runs.
- The base case with *M* set at 0.04 and vulnerability set equal to the MCMC median of maturity was considered to be the most credible.
- Runs where maturity and selectivity were estimated separately resulted in selectivity curves displaced to the right of the maturity ogive for $M = 0.04$ and $M = 0.06$, resulting in a proportion of the spawning stock not being available to the fishery (called "cryptic biomass"). The Deepwater Fisheries Assessment Working Group considered that it was unlikely that there existed mature biomass that was not vulnerable to the fishery, and the WG agreed that the age of vulnerability should be fixed to the age at maturity for the base case and for the case with $M = 0.06$. The WG agreed to present a sensitivity model run using $M = 0.04$ and with separately estimated maturity and selectivity to explore the implications of this scenario.

Four model runs are therefore presented, two with selectivity assumed to be the same as maturity and *M* assumed to be either 0.06 or 0.04, and two with selectivity and maturity fitted as separate ogives and *M* assumed to be 0.04 or 0.027 (Table 10).

Table 10: Four alternative assumptions to the stock assessment.

Model	***M***	**Selectivity**
Base	0.04	Equal to MCMC median maturity
Mat&sel	0.04	Estimated separately
*M*0.027	0.027	Estimated separately
*M*0.06	0.06	Equal to MCMC median maturity

The model was fitted using Bayesian estimation and partitioned the population by age (age-groups used were 1–90, with a plus group). The model assumed a single sex, with growth modelled using the von Bertalanffy growth function. The stock was considered to reside in a single area and have a single maturation episode, with maturation modelled by a logistic ogive which was estimated in preliminary model runs. Selectivity of the fishery was assumed to be equal to maturity, or modelled by a logistic ogive estimated in preliminary model runs. The catch equation used was the instantaneous mortality equation from Bull et al (2002), whereby half the natural mortality was applied, followed by the fishing mortality, then the remaining natural mortality. Deterministic recruitment was assumed. A Bayesian estimation procedure was used with a penalty function included to discourage the model from allowing the stock biomass to drop below a level at which the historical catch could not have been taken. Lognormal errors, with known (sampling error) CVs were assumed for the CPUE. In preliminary model runs, an additional process error was estimated and added to the length frequency distributions. Binomial errors were assumed for the proportions mature at length. The final model runs estimated virgin biomass, B_0, and two catchabilities. Confidence intervals were calculated from a posterior distribution of the model parameters, which was estimated using a Markov chain Monte Carlo technique.

5.3 Biomass estimates

Biomass estimates depended on the assumed *M*, with the *M*0.027 run resulting in a larger and less productive stock, and the *M*0.06 run in a smaller and more productive stock (Table 11, Figure 2). Estimates of current biomass were lowest in the Base case.

The Mat&sel run estimated cryptic spawning stock biomass, where vulnerability to the fishery took place after maturity, such that a median of 86% and 62% of the mature biomass was vulnerable to the fishery at virgin and 2009 biomass levels, respectively. It is unclear whether cryptic biomass could occur for black cardinalfish, and it is possible that this result is an artefact generated from the model assumptions. Cryptic biomass was not estimated when maturity and selectivity were estimated separately and *M* was assumed to be 0.027, and in sensitivity runs the level of cryptic biomass was found to increase as *M* increased. The wide confidence intervals reflect the uncertainty in the model, which was fitted to only relative biomass indices having relatively high CVs (see Table 8).

Table 11: Biomass estimates (medians rounded to the nearest 100 t, with 95% confidence intervals in parentheses) for the four model runs. $B_{CURRENT}$ is the mid-year biomass in 2009. $p(B_{2009} < 0.1\ B_0)$ is the probability of the mature biomass in 2009 being less than 10% of the virgin mature biomass (B_0). $p(B_{2009} < 0.2\ B_0)$ is the probability of the mature biomass in 2009 being less than 20% of the virgin mature biomass (B_0).

Run	B_0 (t)	$B_{CURRENT}$(t)	$\%B_0$	$p(B_{2009} < 0.1\ B_0)$	$p(B_{2009} < 0.2\ B_0)$
Base	36 800 (32 800–95 400)	4 400 (1 900–60 400)	11.9 (5.9–63.3)	0.41	0.70
Mat&sel	40 800 (35 600–96 700)	7 300 (3 500–61 300)	17.8 (9.9–63.5)	0.13	0.56
*M*0.027	45 100 (39 500–93 500)	6 100 (2 000–53 000)	13.6 (5.0–56.6)	0.32	0.69
*M*0.06	33 800 (25 500–10 700)	8 200 (2 400–82 800)	24.2 (9.6–74.9)	0.16	0.43

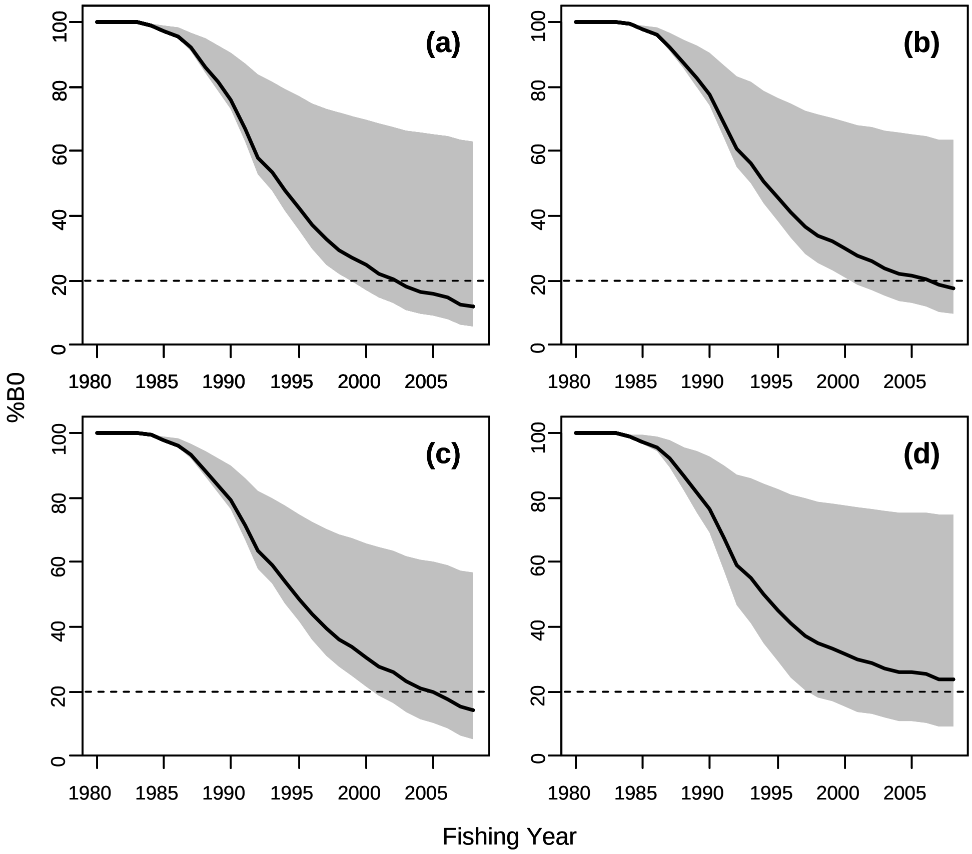


Figure 2: Estimated biomass trajectories (solid line) and 95% confidence intervals (shaded area) for the model runs (a) Base, (b) Mat&sel, (c) *M*0.027, (d) *M*0.06. The horizontal broken line indicates 20% B_0.

5.4 Sensitivity analyses

Several sensitivity analyses were conducted (reported in more detail by Dunn 2009). The assessment was found to be relatively insensitive to the assumed catch overruns. When overruns were either assumed to be zero, or were doubled for the period before 1998–99 (before the TACC was introduced), the mature stock in 2009 was estimated to be slightly less depleted compared with the Base case, at 13.5% (5.9–67.0%) B_0, and 12.2% (5.5–58.3%) B_0, respectively.

5.5 5-year projection results

Forward projections were carried out over a 5-year period using a range of constant catch options. A catch level of 180 t is approximately the level associated with $F = M$, a catch of 890 t is approximately the current (2007–08) catch and a catch of 2490 t is approximately the current (2007–08) TACC. In all projections overrun of 10% was assumed for future catches. For each catch option, three measures of fishery performance were calculated. The first one, $\%B_0$, is the median biomass in 2009 as a percentage of B_0. The second one, $P_{0.1}$, is the probability that the biomass at the end of the 5-year period is less than $10\%B_0$. The third, $P_{0.2}$, is the probability that the biomass at the end of the 5-year period is less than 20% B_0. At high future catches the biomass may be reduced to such a low level that the catch is unlikely to be able to be taken (assumed to occur when the exploitation rate exceeds 0.9). This is indicated as *P*(no catch).

All projections indicate that the biomass would increase for all catch levels near or below the 2008–09 catch (890 t) and would continue to decline at catch levels of 1200 t in all runs except $M = 0.06$, where it would remain about the same (Table 12). In all runs the biomass would decline at catch levels equal to the current TACC (2490 t), and there was a 38–71% probability the biomass would decline to a level where the catch could not be taken.

Table 12: Results from forward projections to 2013 for the model runs. $P_{0.1}$ is the probability of the mature biomass in 2013 being less than 10% of the virgin mature biomass (B_0). $P_{0.2}$ is the probability of the mature biomass in 2013 being less than 20% of the virgin mature biomass (B_0). *P*(no catch) is the probability that the catch could not be taken, which is assumed to occur if the exploitation rate exceeds 90%. Current (2007–08) values of %B_0 are shown for each run in parentheses next to the measure. 95% confidence intervals are shown for the %B_0 estimates in 2013. A catch of 180 t is approximately *M* times the current biomass, 890 t is the current catch, and 2490 t is the current TACC.

		Future catch (t)					
Run	**Measure**	**0**	**180**	**530**	**890**	**1200**	**2490**
Base	%B_0 (11.9)	17.6	16.5	14.3	12.6	10.2	5.2
		(8.5–67.4)	(7.01–66.0)	(5.3–63.9)	(3.6–62.7)	(2.9–62.6)	(2.7–56.2)
	$P_{0.1}$	0.11	0.19	0.30	0.40	0.49	0.70
	$P_{0.2}$	0.57	0.60	0.65	0.71	0.74	0.83
	P(no catch)	0	0	0	0	0	0.38
Mat&sel	%B_0 (17.8)	24.5	23.6	20.4	18.6	16.2	9.5
		(14.0–68.8)	(12.9–67.8)	(10.2–65.5)	(8.0–63.4)	(6.5–61.7)	(5.5–57.8)
	$P_{0.1}$	0.00	0.00	0.06	0.14	0.22	0.53
	$P_{0.2}$	0.35	0.38	0.49	0.55	0.61	0.75
	P(no catch)	0	0	0	0	0	0.42
*M*0.027	%B_0 (13.6)	17.9	16.7	14.3	12.0	10.0	4.3
		(7.1–59.4)	(6.2–59.1)	(4.5–56.7)	(2.9–56.5)	(2.2–55.0)	(2.0–50.1)
	$P_{0.1}$	0.14	0.19	0.28	0.40	0.49	0.71
	$P_{0.2}$	0.57	0.60	0.67	0.71	0.75	0.84
	P(no catch)	0	0	0	0	0	0.41
*M*0.06	%B_0 (24.2)	33.6	31.4	29.8	26.3	24.6	17.4
		(13.0–80.2)	(12.5–79.2)	(10.6 –77.5)	(8.3–77.2)	(6.7–75.7)	(4.8–71.2)
	$P_{0.1}$	0.02	0.33	0.07	0.15	0.17	0.35
	$P_{0.2}$	0.27	0.29	0.35	0.40	0.42	0.54
	P(no catch)	0	0	0	0	0	0.71

5.6 Updated characterisation and CPUE analyses

A characterisation and CPUE analyses were conducted using catch and effort data to the end of the 2013–14 fishing year (Bentley & MacGibbon 2016). Catch and effort data were examined in each of nine “zones” which encompassed groups of underwater features where the majority of the cardinalfish catch has been taken: North Colville (NC), Mercury-Colville (MC), White Island (WI), East Cape (EC), Tuaheni High (TH), Richie-Rockgarden (RR), Madden (MD), Wairarapa (WA), and Kaikoura (KK). Within these zones, only tows in the depth range 470–980m (the 2.5th and 97.5th percentiles of the distribution of cardinalfish catch by depth) were considered when characterising effort and performing CPUE analyses.

Catches in each zone have generally declined or remained stable. In CDL 1, most of the catch has come from the Mercury-Colville zone since the early 2000s. In CDL 2, concurrent with a reduction in the TACC, catches have declined in the East Cape, Tuaheni High, and Richie-Rockgarden zones since 2010. In these zones, as in CDL 1, most of the cardinalfish is taken in target tows. In contrast, catches in the Wairarapa and Kaikoura zones have remained relatively constant during this period. In these southern two zones a greater proportion of the cardinalfish catch is taken as bycatch from tows that are targeting species other than cardinalfish and orange roughy. There was no evidence of substantial movement of fishing effort between features within zones.

A CPUE analysis was done using data from all nine zones and year effects estimated for each zone. This suggested that the CPUE trends in all zones were generally similar but that the Wairarapa and Kaikoura zones exhibited a flatter trend since 2000. On this basis, a final CPUE standardisation was done with separate year effects estimated for three regions North (zones North Colville, Mercury-Colville, and White Island; i.e., CDL 1), Central (zones East Cape, Tuaheni High, Richie-Rockgarden, and Madden; i.e., CDL 2 except for Wairarapa) and South (zones Wairarapa and Kaikoura). This standardisation model has the advantage over separate models for each region of using all the available data to estimate vessel coefficients.

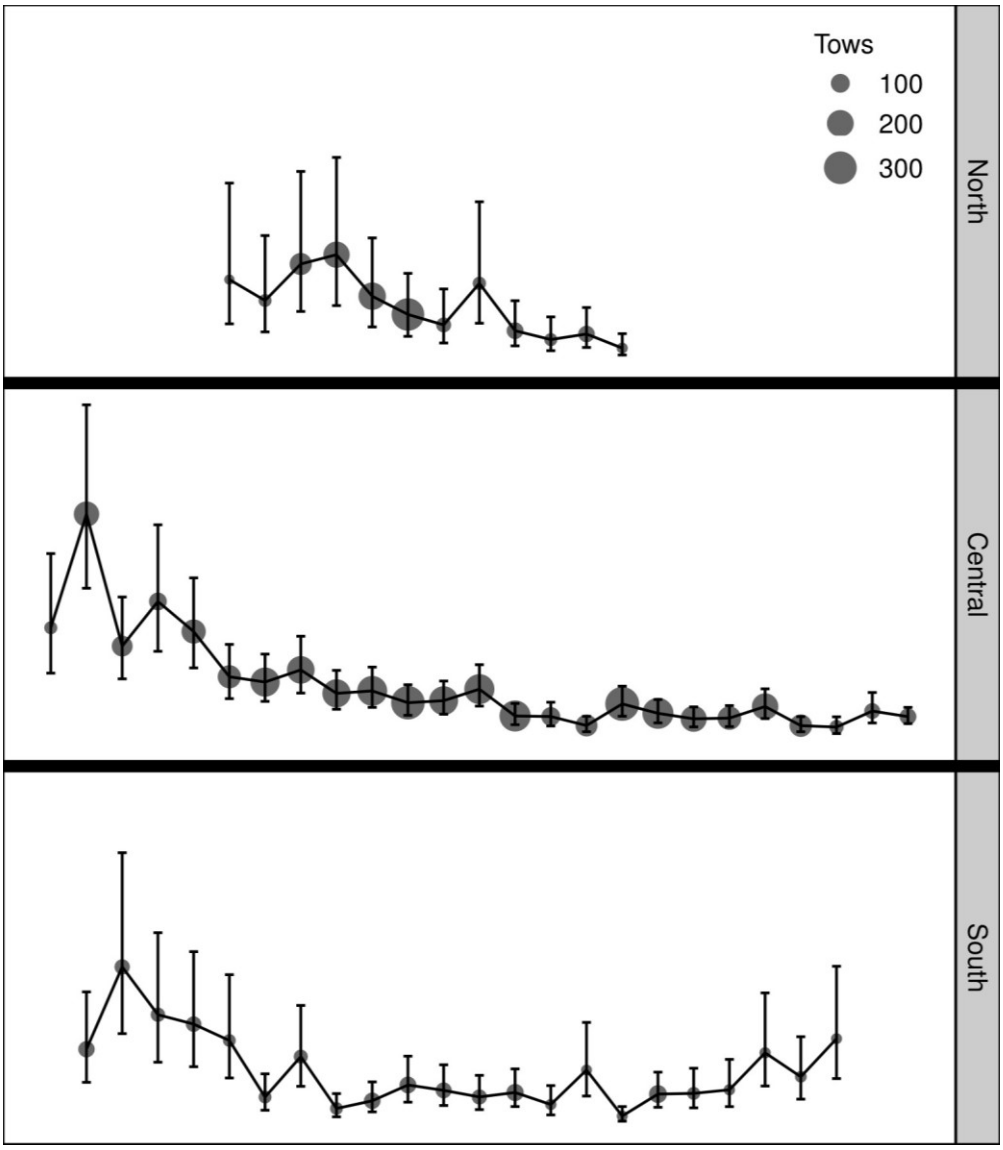


Figure 3: CPUE indices by region (see text for definitions of regions). Region/year combinations with less than 30 tows are not shown. Error bars indicate ± one standard error. Fishing years are indicated by the later calendar year.

6. STATUS OF THE STOCKS

Stock Structure Assumptions

The stock boundaries and number of black cardinalfish stocks in New Zealand is unknown. There are no data on genetics, or known movements of black cardinalfish which indicate possible stock boundaries.

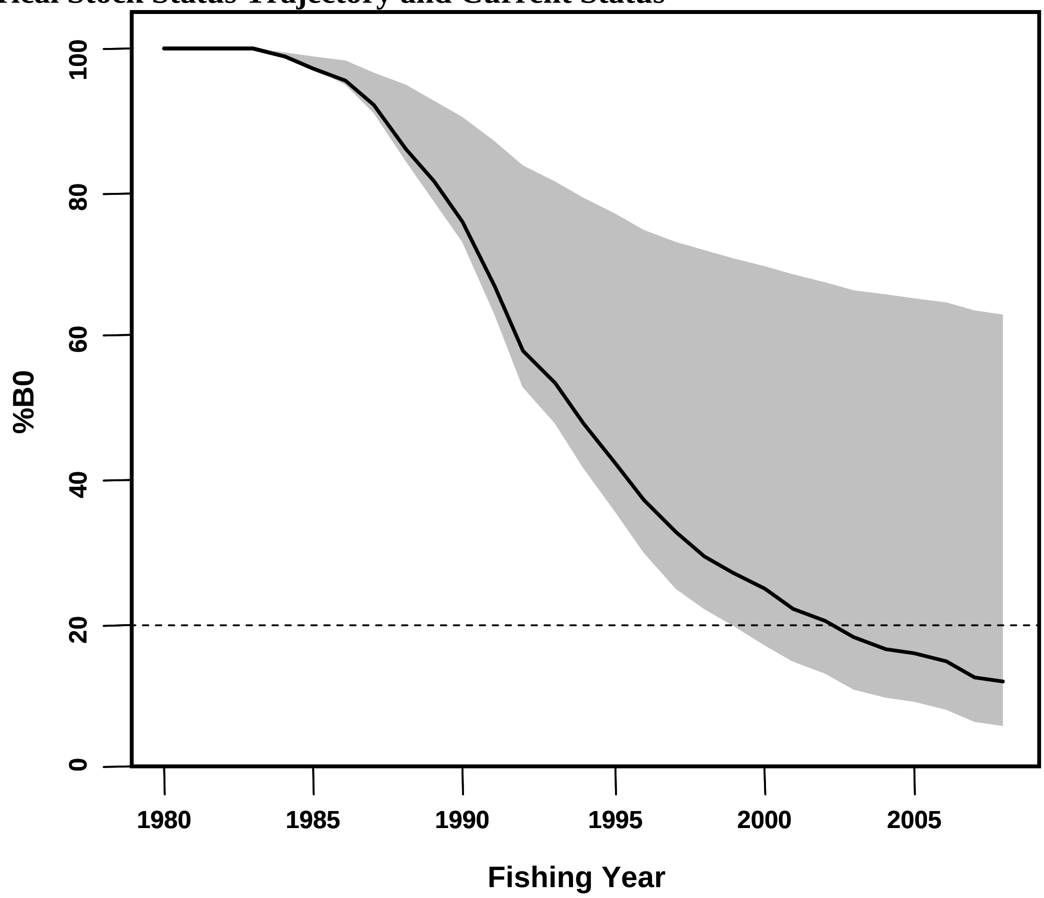
There is evidence that a spawning stock exists in CDL 2, with three geographically close spawning locations identified, on Tuaheni High, Ritchie Bank, and Rockgarden (Dunn 2009). Juveniles of less than 30 cm have been infrequently identified in CDL 2, and more frequently found on the northern flanks of the Chatham Rise, which is south of the spawning grounds in CDL 2. No spawning grounds have been identified on the Chatham Rise, where adult fish are relatively rare.

For the purposes of stock assessment, it has been assumed that black cardinalfish on the east coast North Island (CDL 2) are from the same stock as fish on the north Chatham Rise (CDL 3 and CDL 4).

CDL 2, 3 & 4

Stock Status	
Year of Most Recent Assessment	2009 full assessment 2014 CPUE updated
Assessment Runs Presented	One base case and three sensitivity runs Base case: M = 0.04; selectivity equal to maturity Sensitivity runs: various combinations of M and assumptions about the relationship between maturity and selectivity, considered to be less reliable than the base case
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $U_{40\%}$
Status in relation to Target	Very Unlikely (< 10%) to be at or above the target
Status in relation to Limits	Base case: B_{2009} was estimated to be 12% B_0; Likely (> 60%) to be below the Soft Limit and About as Likely as Not (40–60%) to be below the Hard Limit. Other model runs: The range of B_{2009} was estimated to be 14–24% B_0; About as Likely as Not (40–60%) or Likely (> 60%) to be below the Soft Limit and Unlikely (< 40%) to be below the Hard Limit.
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Estimated biomass trajectories (solid line) and 95% confidence intervals (shaded area) for the base case. The horizontal broken line indicates 20% B_0

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE has been flat since 2008
Recent Trend in Fishing Intensity or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Model projections indicate that the biomass will increase at catch levels near or below the 2007–08 level but will decline sharply at catch levels equal to the TACC.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Likely (> 60%) Hard Limit: About as Likely as Not (40–60%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Soft Limit: Likely (> 60%) Hard Limit: Likely (> 60%)

Assessment Methodology and Evaluation		
Assessment Type	2009 Level 1: Full Quantitative Stock Assessment 2014 Level 2: Partial Quantitative Stock Assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2009	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Two commercial catch-per-unit-effort (CPUE) series from the trawl fishery up to 2008 - Estimates of biological parameters	1 – High Quality 1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	First accepted assessment for these stocks	
Major sources of Uncertainty	Major sources of uncertainty include the representativeness of the CPUE data, the relationship between CPUE and abundance, the assumption that recruitment has been constant throughout the history of the fishery, estimates of growth and natural mortality and the catch history.	

Qualifying Comments
The TACC was reduced from 2 223 t in 3 stages to the level of 440 t in 2010–11. This level was the maximum annual catch required to rebuild the CDL 2 stock to 30%B_0 within the 24 year period specified in the Harvest Strategy Standard (twice T_{min}). CPUE since 2008 has been flat.

Fishery Interactions
Black cardinalfish is part of the deepwater trawl fishery complex that includes orange roughy and oreo species. Bycatch has not been characterised for the cardinalfish fishery, but is likely to be similar to that of orange roughy and oreo. Incidental captures of protected seabird species have been reported. Bottom trawling for cardinalfish is likely to have effects on benthic community structure and function.

Other QMAs

There is no information on the status of cardinalfish stocks in other QMAs.

TACCs and reported landings for the 2018–19 fishing year are summarised in Table 13.

Table 13: Summary of TACCs (t) and reported landings (t) for black cardinalfish for the most recent fishing year.

Fishstock	QMA	FMA	2018–19 Actual TACC	2018–19 Reported landings
CDL 1	Auckland (East)	1	1 200	40
CDL 2	Central (East)	2	440	372
CDL 3	South-east (Coast)	3	196	177
CDL 4	South-east (Chatham)	4	66	13
CDL 5	Southland	5	22	87
CDL 6	Sub-Antarctic	6	1	1
CDL 7	Challenger	7	39	6
CDL 8	Central (West)	8	0	0
CDL 9	Auckland (West)	9	4	4
CDL 10	Kermadec	10	0	0
Total			1 968	696

7. FOR FURTHER INFORMATION

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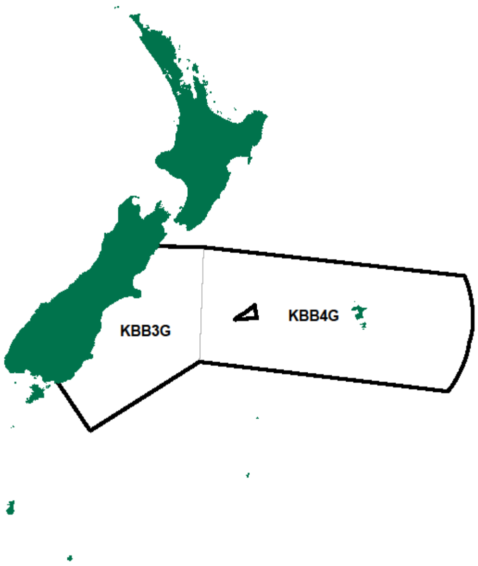
BLADDER KELP ATTACHED (KBB G)

(Macrocystis pyrifera)



1. FISHERY SUMMARY

Attached bladder kelp (KBB G) was introduced into the Quota Management System (QMS) on 1 October 2010, within FMA 3 and FMA 4 only which have the reporting codes KBB 3G and KBB 4G, respectively. The Total Allowable Catch (TAC), commercial, recreational, customary, and other mortality allowances issued to KBB G on entering the QMS remain unchanged and are presented in Table 1 and Figure 1.

Bladder kelp, like all other large seaweeds, occurs in one of three states: attached (growing on the substrate), free-floating, and beach-cast. The attached growing state of bladder kelp is the only state managed under the QMS. Fisheries New Zealand will continue to monitor the use of beach-cast and free-floating seaweeds in FMAs 3 and 4 and will reconsider introducing these states into the QMS if sustainability and utilisation risks are identified in the future. Separate codes refer to beach-cast bladder kelp in FMA 3 (KBB 3B) and free-floating bladder kelp in FMA 3 and 4 (KBB 3F and KBB 4F). Unless explicitly stated, this section refers to only attached bladder kelp.

Table 1: Total Allowable Catch (TAC, t), Total Allowable Commercial Catches (TACC, t), customary non-commercial (t), recreational (t), and other mortality allowances (t) for attached bladder kelp on entering the QMS on 1 October 2010.

Fishstock	TAC	TACC	Customary non-commercial	Recreational	Other Mortality
KBB 3G	1 238	1 237	0.1	0.1	1
KBB 4G	274	273	0.1	0.1	

1.1 Commercial fisheries

Bladder kelp has been used as a dietary supplement, fertiliser, cultivation for bio-remediation purposes, as well as abalone and sea urchin feed (Buschmann et al 2006, Gutierrez et al 2006). There is current research evaluating the utilisation of bladder kelp as feed for other aquaculture species such as shrimps (Buschmann et al 2006, Cruz-Suárez et al 2009), as well as an evaluation as a possible feedstock for conversion into ethanol for biofuel use (Wargacki et al 2012). Because of the growing demand for bladder kelp, Fisheries New Zealand considered that the bladder kelp resource requires active management to ensure its sustainable use, and that management under the QMS was the most appropriate mechanism. The fishing year for commercial harvest of KBB G is 1 October to 30 September, and catch is measured in greenweight (tonnes).

Restrictions on New Zealand harvests of KBB G have been based on the Californian fishery (where the majority of research into harvesting effects has been conducted) and modified to take into account differences between California and New Zealand. These differences include reduced nutrients in New Zealand waters, the shallower depth at which KBB G is harvested in New Zealand, and the lack of information on New Zealand stocks.

The single restriction on KBB G harvest, implemented on introduction to the QMS on 1 October 2010, is a maximum cutting depth of 1.2 m.

Harvest of KBB G mainly occurs in QMA 3 and has varied since 2001–02 from 3 t to 105 t. Landings of KBB G in QMA 4 are minimal, with a total of only 2.49 t reported in the last 18 years (Table 2).

Table 2: Reported landings for KBB G in greenweight (t) by fishing year. Blank cells indicate nil catches. Values above and below the horizontal line represent historic landings prior to QMS introduction and landings post QMS introduction, respectively. * Pre 2010 landings in KBB 3G include a combination of beach-cast, free-floating and attached bladder kelp. Pre 2010 landings in KBB 4G may include a combination of free-floating and attached bladder kelp. Post 2010, the reported landings are for attached bladder kelp only.

Fishing Year	KBB 3G	KBB 4G
2001–02	104.50*	0.37*
2002–03	37.00*	
2003–04	7.53*	
2004–05	17.90*	
2005–06	2.82*	
2006–07	8.35*	
2007–08	6.43*	2.10*
2008–09	63.50*	
2009–10	28.37*	
2010–11	53.34	
2011–12	34.25	
2012–13	5.00	
2013–14	94.00	0.00
2014–15	62.00	0.02
2015–16	30.54	0.00
2016–17	41.77	0.00
2017–18	40.81	0.00
2018–19	67.24	0.00

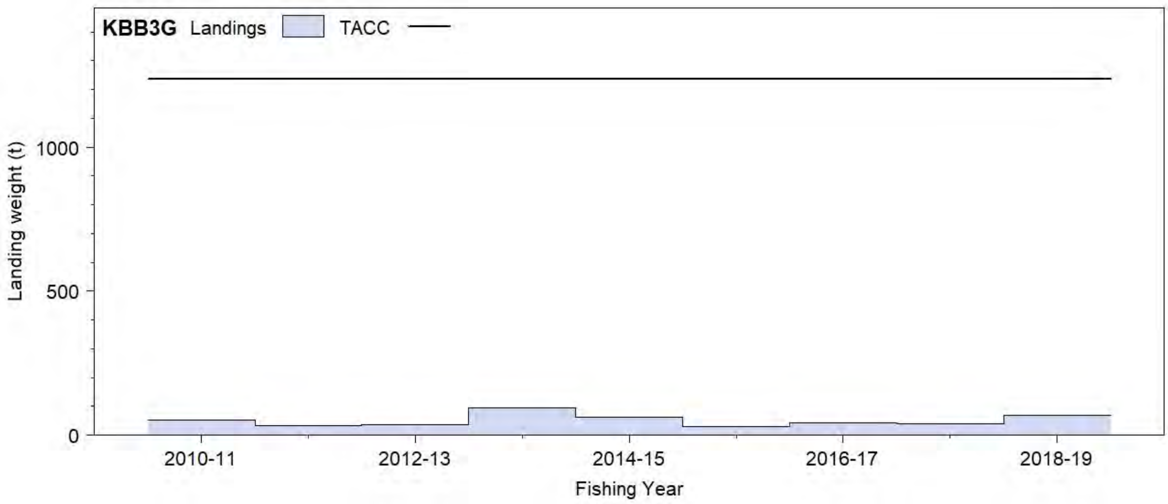


Figure 1: Reported commercial landings and TACC for KBB 3G (east coast, South Island). Note that this figure does not show data prior to entry into the QMS.

1.2 Recreational fisheries

There is no quantitative estimate of recreational harvest of bladder kelp at this time, although it is assumed to be restricted to the collection of beach-cast seaweed for composting. Consequently, recreational harvest of attached bladder kelp is assumed to be negligible.

1.3 Customary non-commercial fisheries

The customary harvest of bladder kelp is currently unrestricted. There is no quantitative information on the extent of customary harvest of attached bladder kelp (or any other state) in FMAs 3 and 4; however, the customary harvest of attached bladder kelp is likely to be negligible.

1.4 Illegal catch

There is some qualitative data to suggest illegal, unreported, unregulated activity in this Fishery.

1.5 Other sources of mortality

Hydrographic factors (e.g., tidal surge, nutrient limitation, temperature, and salinity stress) and biological processes have been demonstrated to result in significant mortality of bladder kelp in the southern hemisphere (Buschmann et al 2004, 2006). Californian and Chilean studies have shown that grazing by sea urchins can result in the detachment of adult plants and their removal from the population (Dayton 1985a, Tegner et al 1995), and/or the removal of recruits and juvenile plants (Dean & Jacobsen 1984, Dean et al 1988, Vásquez et al 2006). In Chile, infestations of bladder kelp holdfasts by crustaceans (e.g., amphipods and isopods) may increase mortality by decreasing attachment strength (Ojeda & Santelices 1984). Due to their large size and high drag, adult bladder kelp are vulnerable to removal by high water motion (Dayton et al 1984, Seymour et al 1989, Schiel et al 1995, Fyfe & Israel 1996, Graham et al 1997, Fyfe et al 1999), which is considered the primary agent of mortality. In 1994, Fyfe et al (1999) found that winter storms extensively removed floating surface canopies at Pleasant River (north of Dunedin), and that by February 1995, 50% of surface canopies had reformed. High seasonal and year-to-year variability in wave intensity and plant biomass results in high intra- and inter-annual variability in mortality. In California, uprooted plants may become entangled with attached plants, increasing drag and the likelihood of detachment, which may result in a 'snowball effect' capable of clearing large swaths in the local population (Dayton et al 1984). For example, Seymour et al (1989) observed that mortality of bladder kelp in California due to storm-induced plant detachment and entangled was as great as 94%. Graham et al (1997) observed that bladder kelp holdfast growth in California decreased significantly along a gradient of increasing wave exposure, possibly due to greater disturbance to the bladder kelp surface canopy, which reduces holdfast growth (Barilotti et al 1985, McCleneghan & Houk 1985). Thus, increased water motion and decreased holdfast strength can act in combination to decrease plant survival.

Sedimentation can also increase bladder kelp mortality – movement of bottom sediments can scour or bury bladder kelp spores and recruits, and the resuspension of sediments can reduce the amount of light reaching sub-canopy algae, preventing the attachment and development of spores, and inhibiting the growth of bladder kelp recruits (Dean & Jacobson 1984, Pirker 2002).

Over large spatial scales, elevated temperature also appears to be a major influence on bladder kelp mortality and is likely to limit the northern distribution of bladder kelp within New Zealand (Hay 1990). For example, Hay (1990) described an apparent retraction of the distribution of bladder kelp within Cook Strait since 1942, presumably due to increasing surface water temperatures. Cavanaugh et al (2011) compared changes in canopy biomass with oceanographic and climatic data in California. They revealed that winter losses of regional kelp canopy biomass were positively correlated with significant wave height, whereas spring recoveries were negatively correlated with sea surface temperature. On inter-annual timescales, regional kelp-canopy biomass lagged the variations in wave height and sea surface temperatures by 3 years, indicating that these factors affect cycles of kelp recruitment and mortality. The dynamics of kelp biomass in exposed regions were related to wave disturbance, whereas kelp dynamics in sheltered regions tracked sea surface temperatures more closely.

Although wave disturbance and sea surface temperature appear to be the predominant sources of bladder kelp mortality, there are no quantitative estimates for these sources of mortality available for New Zealand. Further, the relevance of results from studies conducted outside New Zealand may be limited due to differences in hydrographic environment between New Zealand and other locations.

2. BIOLOGY

Historically, two species of bladder kelp, *Macrocystis pyrifera* (Linnaeus) C.Agardh and *M. integrifolia* Bory, were reported from both Northern and Southern Hemispheres, and *M. angustifolia* Bory and *M. laevis* Hay were reported from the Southern Hemisphere. However, *M. angustifolia, M. integrifolia,* and *M. laevis* are currently regarded as taxonomic synonyms of *M. pyrifera* (Graham et al 2007, Demes et al 2009). Therefore, for the clarity within this document, the four previously recognised species are simply referred to as bladder kelp, *Macrocystis pyrifera.*

Bladder kelp is globally widespread. It is found in the Atlantic Islands (Baardseth 1941, Chamberlain 1965); North America from Alaska to California, Baja, and Mexico (e.g., Carr 1994, Graham et al 2007, Cavanaugh et al 2011); Central America (Taylor 1945); South America from Peru to Chile, Argentina, and Uruguay (e.g., Vásquez et al 2006, Thiel et al 2007, Macaya & Zuccarello 2010); the Indian Ocean (Silva et al 1996); Tasmania (Cribb 1954, Womersley 1987); the Antarctic and the sub-Antarctic islands (Ricker 1987, John et al 1994); and New Zealand (Hay 1990, Fyfe & Israel 1996, Brown et al 1997, Hepburn et al 2007).

In New Zealand, bladder kelp has a broad latitudinal distribution, occurring in the southern North Island, the South Island, as well as Stewart, Chatham, Bounty, Antipodes, Auckland, and Campbell islands (Chapman & Chapman 1980, Adams 1994, Hurd & Pilditch 2011, Harper et al 2012). Bladder kelp does not persist in New Zealand waters where maximum temperatures exceed 18–19° C for several days (Hay 1990). The northern limit of bladder kelp is between Castlepoint and Cape Turnagain on the east coast of the North Island, and Kapiti Island on the west coast of the North Island, and appears to correspond to the Southland current, which brings cool nutrient-rich water north from the south (Hay 1990). The distribution of bladder kelp is generally patchy, and there is both seasonal and inter-annual variation in abundance (Hay 1990, Pirker et al 2000).

Bladder kelp can grow up to 45 m long in New Zealand and occurs in water 3–20 m deep. Where the bottom is rocky and affords places for it to anchor, bladder kelp grows in extensive kelp beds with large floating canopies and frequently forms colonies or large populations in calm bays, harbours, or in sheltered offshore waters. It can tolerate a wide range of water motion in New Zealand, including areas where tidal currents reach 5–7 knots (Hay 1990). Smaller plants can be found in shallow pools and channels.

Bladder kelp is a large perennial kelp. Individuals persist for up to 5 years in California (North 1994). The life history progresses from planktonic zoospores (less than 3 days longevity) to microscopic benthic gametophytes (7–30 days longevity) and finally macroscopic benthic sporophytes (the large plants visible along the coast) (Figure 2). Adult sporophytes typically consist of numerous vegetative fronds that arise from longitudinal splits in meristem tissue (undifferentiated plant tissue which gives rise to new cells) located just above the holdfast. Vegetative fronds consist of a stipe (stem) terminating in an apical meristem (the primary point of growth at the tip of a frond) which gives rise to new vegetative blades as the frond develops (Figure 2). Blades are attached to the stipe by a single pneumatocyst (gas bladder), which provides buoyancy to the frond. Continued elongation of the stipe, combined with the production of new blades by the apical meristem, results in elongation of the frond and increases in the number of blades. Fronds continue to grow after reaching the surface, forming canopies (Figure 2). Finally, meristem activity ceases in the apical blade and a terminal blade is formed. In California, frond elongation has been observed occurring at a rate of up to 30 cm per day, making bladder kelp one of the fastest growing organisms on earth. Reproductive blades (called sporophylls) are clustered above the holdfast, forming from the lowermost two to six blades on each frond (Figure 2). Sporophylls develop reproductive sporangia (spores) that are densely packed in sori (a cluster of sporangia) on the surface of the sporophylls. Californian studies have shown spores within sporangia take about 14 days to mature, with a mean residence time of about 30 days (Tugwell & Branch 1989). Each sporangium releases numerous mature zoospores that develop into gametophytes (North 1986).

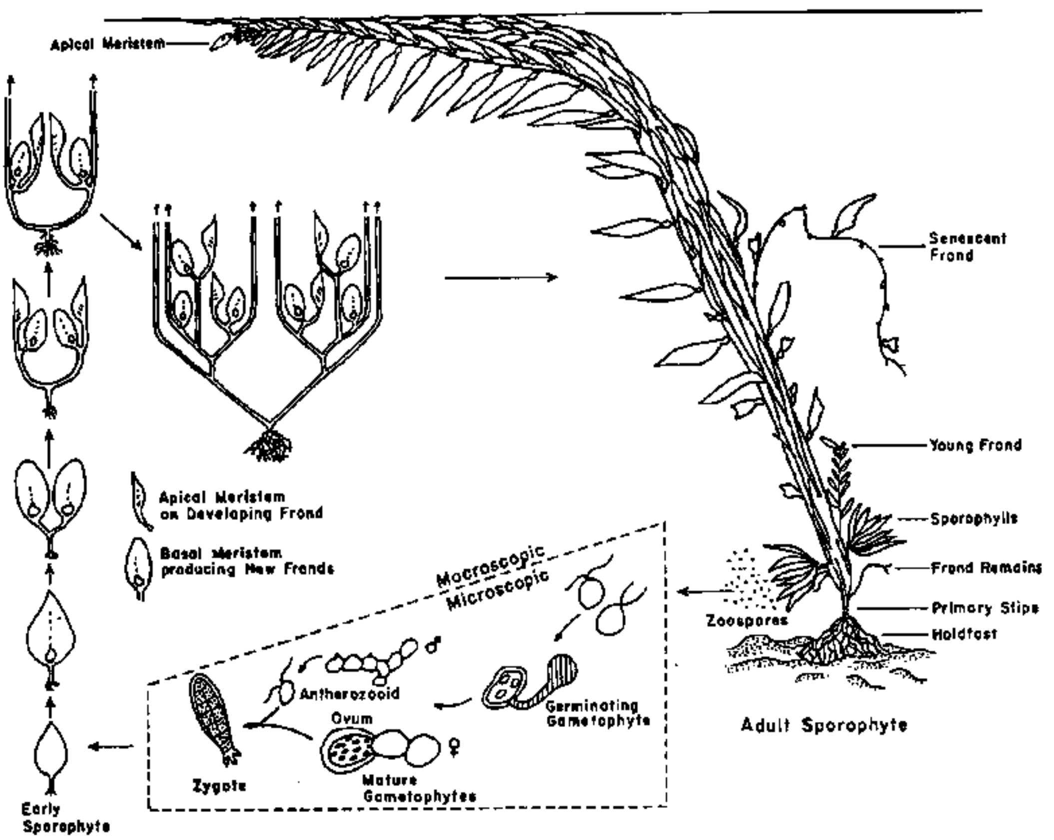


Figure 2: Diagram of the bladder kelp life cycle showing (left side) development of the young diploid sporophyte, increasing frond numbers through production of basal and apical meristematic blades; (right side) growth habit of an adult diploid sporophyte about two years old, standing in 10 m of water depth, and liberating haploid zoospores; (below centre) development of haploid gametophytes from settled zoospores, proceeding to gametogenesis, and fertilisation yielding the zygote and, thence, a diploid embryonic sporophyte. From North (1986).

A floating surface canopy consisting of numerous vegetative fronds characterises adult plants. In California, the floating surface canopy comprises 33–50% of total plant biomass and produces approximately 95% of organic production (Towle & Pearse 1973). Unlike other perennial kelp genera, bladder kelp has limited nutrient and photosynphate storage capabilities, which in New Zealand is about 2 weeks (Brown et al 1997); consequently, growth by young fronds, reproductive material, holdfasts, and other tissues near the base of the plant is supported by translocation of photosynphates from the canopy, which follows a source-sink relationship (North 1986). Mature canopy tissue exports both upward to the apical meristem at the frond apex, and downward to sporophylls, meristem tissue, holdfasts, and into apical regions of juvenile fronds (Schmitz & Lobban 1976, Lobban 1978, Manley 1984). The ability of bladder kelp to translocate photosynphates allows it to grow in dense aggregations with overlapping canopies that effectively shade out competitors on the bottom, yet support rapid growth by young fronds, sporophylls, holdfasts, and other tissues near the base of the plant.

The reliance on surface fronds for translocated photosynphate, combined with their vulnerability to disturbance, results in considerable spatial and temporal variability in bladder kelp productivity and size. For example, Graham et al (1997), observed that bladder kelp holdfast growth in California decreased significantly along a gradient of increasing wave exposure, possibly due to greater disturbance to the bladder kelp surface canopy. Similarly, Miller & Geibel (1973) and McCleneghan & Houk (1985) observed reduced holdfast growth in bladder kelp following the experimental removal of surface canopies in California. Reed (1987) demonstrated that a 75% thinning of vegetative fronds in California led to an approximate 75% decrease in the generation of reproductive blades. Graham (2002) identified shifts in the reproductive condition of Californian bladder kelp from fertile to completely sterile in response to episodic, sub-lethal frond grazing by amphipods. This change in reproductive condition occurred despite relatively constant sporophyll biomass. Finally, in a New Zealand study, Geange (2014) identified an apparent trade-off between vegetative growth and the generation of reproductive sporophylls. Relative to controls, the removal of surface canopies did not result in decreased frond generation, despite an 86%

reduction in the generation of reproductive blades. Geange (2014) also found that 89% of plants became completely sterile 50 days after canopy removal, with effects persisting for up to 83 days.

Growth of bladder kelp in New Zealand appears to be seasonal, with autumn and winter growth rates in 1988 in Otago Harbour having been estimated at approximately 1–20 mm per day (table 3, Brown et al 1997). Brown et al (1997) identified a seasonal pattern of blade relative growth rate (RGR) in Otago Harbour, where blade RGRs during 1986–87 were similar year-round, except for summer when lower rates were recorded. Brown et al (1997) concluded that sufficiently high irradiance levels and seawater nutrient concentrations support relatively constant growth throughout most of the year, but that growth was nutrient-limited during summer months when seawater nitrate levels decline. In a study on Stewart Island, Hepburn et al (2007) found that exposure to waves increased nitrogen uptake, modifying the seasonal pattern of growth by ameliorating the negative effect of low seawater nitrogen concentrations during summer.

Table 3: Growth parameters for KKB G canopy (> 2.25 m) and submerged fronds at Aquarium Point, Otago Harbour during autumn (March/April/May) and winter (June/July/August) 1988. From Brown et al (1997).

Growth parameter	Frond type	
	Canopy	Submerged
Frond-elongation rate		
autumn	1.9 cm d^{-1}	1.2 cm d^{-1}
winter	2.0 cm d^{-1}	1.3 cm d^{-1}
Relative frond-elongation rate		
autumn	0.0065 d^{-1}	0.008 d^{-1}
winter	0.0066 d^{-1}	0.013 d^{-1}
Node-initiation rate		
autumn	0.33 nodes d^{-1}	0.28 nodes d^{-1}
winter	0.30 nodes d^{-1}	0.30 nodes d^{-1}
Relative node-initiation rate		
autumn	0.0047 d^{-1}	0.0064 d^{-1}
winter	0.0044 d^{-1}	0.0089 d^{-1}
Net blade-elongation rate		
autumn	9.4 cm d^{-1}	5.4 cm d^{-1}
winter	12.8 cm d^{-1}	12.1 cm d^{-1}
Elongation rate of immature blades		
autumn	0.22 cm d^{-1}	0.08 cm d^{-1}
winter	0.21 cm d^{-1}	0.10 cm d^{-1}
Relative elongation rate of immature blades		
autumn	0.038 d^{-1}	0.001 d^{-1}
winter	0.036 d^{-1}	0.001 d^{-1}

3. STOCKS AND AREAS

In New Zealand, patches of bladder kelp are typically small and discrete, usually less than 100 m^2, although large beds (less than 1 km^2) are found along the North Otago coast (Fyfe et al 1999). Although there are currently no data evaluating stock structure for bladder kelp in New Zealand, Alberto et al (2010, 2011) found low, but significant, genetic differentiation over a 70 km stretch of coast in the Santa Barbara Channel in southern California. In a New Zealand context, where stands of bladder kelp are small and discrete, these results suggest that stocks may display strong spatial structuring; however, these results should be viewed with caution because current regimes in the Santa Barbara Channel are strongly unidirectional.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was reviewed by the Aquatic Environment Working Group for the May 2013 Fishery Assessment Plenary.

4.1 Role in the ecosystem

Forests of bladder kelp are amongst the most productive marine communities in temperate waters. They act as keystone species, altering the abiotic environment and providing vast amounts of energy and highly structured three-dimensional habitat (Foster & Schiel 1985, Graham 2004, Graham et al 2008). In California, bladder kelp has been identified as altering abiotic and biotic conditions by dampening water motion (Jackson & Winant 1983, Jackson 1998), altering sedimentation (North 1971), shading the sea floor (Reed & Foster 1984, Edwards 1998, Dayton et al 1999, Clark et al 2004), scrubbing nutrients from the water column (Jackson 1977, 1998), stabilising substrata (North 1971), and providing physical habitat for organisms both above and below the benthic boundary layer (Foster & Schiel 1985).

There are three primary components to the provisioning of habitat by attached bladder kelp: the holdfast, the midwater fronds, and the surface canopy (Foster & Schiel 1985). Studies from California, Canada, Chile, the Sub-Antarctic, and Tasmania have shown that a highly diverse assemblage of organisms colonises each of these three components. Holdfasts are primarily colonised by algae and invertebrates and encrusted with bryozoans and sponges. The midwater fronds and surface canopies are host to a variety of sessile and mobile invertebrates (e.g., amphipods, top snails, and turban snails), encrusting bryozoans, and hydroids. Juvenile and adult fishes may also associate with midwater and canopy fronds, although kelp-fish associations in New Zealand appear to be weaker than those reported in California.

Although the following associations are not exclusive, the major species associated with bladder kelp forests in New Zealand include: (i) understory brown algae, *Ecklonia radiata*, *Carpophyllum flexuosum*, *Marginariella boryana*, and *Cystophora platylobium*; (ii) a rich fauna of sessile invertebrates, including *Callana* spp*., Calliostoma granti*, *Cookia sulcata*, *Evechinus chloroticus, Haliotis iris*, *Trochus* spp.; and (iii) fishes, including *Notolabrus celidotus*, *N. cinctus*, *Odax pullus*, and *Parika scaber* (Pirker et al 2000, Shears & Babcock 2007). Of these species, *Ecklonia radiate*, *Evechinus chloroticus* (kina), and *Haliotis iris* (pāua) have significant recreational value.

A significant proportion of annual kelp production becomes free-floating and beach-cast in response to storm events, seasonal mortality, or ageing. Bladder kelp continues to provide habitat resources after detachment from the substratum. Studies from California, Chile, Macquarie Island, South Georgia, and Tasmania, have shown that holdfasts, midwater fronds, and canopies can retain epifaunal fishes and mobile and sessile invertebrates when drifting long distances, and play an important role in the dispersal of invertebrates and fishes (Edgar 1987; Vásquez 1993; Helmuth et al 1994; Hobday 2000a, 2000b, 2000c; Smith 2002; Macaya et al 2005; Thiel & Gutow 2005a, 2005b). Mature free-floating individuals may also be important in the connectivity of bladder kelp populations and may explain low genetic diversity of bladder kelp over large geographic extents in the south eastern Pacific (Thiel et al 2007, Macaya & Zuccarello 2010).

The beach-cast state is either washed back into the sea over subsequent tidal cycles or remains in the beach environment; New Zealand and Californian studies demonstrate that it is incorporated into physical beach processes, or into the terrestrial or marine food webs through consumption and decomposition (Inglis 1989, Lastra et al 2008). In New Zealand, beach-cast material supports a diverse ecology of organisms through nutrient cycling and decomposition, including various micro- and macro-fauna (Inglis 1989, Marsden 1991) and, if washed up high enough on the beach, can aid sand dune formation.

4.2 Incidental catch (fish and invertebrates)

Small scale harvesting experiments carried out in Akaroa Harbour showed that harvesting canopy biomass had no measurable effect on bladder kelp and the dominant understorey species (Pirker et al 2000).

4.3 Incidental catch (marine mammals, seabirds, and protected fish)

None known.

4.4. Benthic interactions

None known.

4.5 Other considerations

None known.

5. STOCK ASSESSMENT

Currently there is insufficient information on canopy area and density to allow for a stock assessment for KBB G. Furthermore, due to large temporal and spatial variation in bladder kelp growth, estimates of biomass should be looked at conservatively when applying regional scale management.

Large spatial and temporal fluctuations in biomass within and between individual kelp forests necessitates the need for initial annual stock assessments of targeted beds to determine credible biomass and sustainable yield information to ensure long-term sustainability (Pirker et al 2000). A combination of aerial photography and *in situ* measurements provide an easy method for assessing canopy biomass (Fyfe & Israel 1996, Fyfe et al 1999, Pirker et al 2000).

5.1 Estimates of fishery parameters and abundance

No estimates of fishery parameters or abundance are available at present.

5.2 Biomass Estimates

Maximum biomass occurs in winter (Cummack 1981, Pirker et al 2000). Growth rates and peaks in biomass can vary significantly over very short distances (i.e., kilometres) and temporal scales (i.e., seasonally) in response to changes in currents, light, nutrient levels, and other environmental factors. Fyfe et al (1999) found that the wet biomass of closed canopy at Pleasant River in KBB 3 fluctuated from an estimated 10 639 g m^{-2} (SE = 1566) in November 1995 to 3761 g m^{-2} (SE = 1237) in November 1996. Pirker et al (2000) noted that marked differences exist in the demography of bladder kelp at a spatial scale of only a few kilometres – and that beds decline and regenerate at different times. Because of the apparent rapid spatio-temporal fluctuations in biomass, the status of KBB 3G and KBB 4G biomass is unknown and unable to be reliably estimated using best available information. Therefore, Fisheries New Zealand was unable to ascertain whether the current biomass of both attached bladder kelp stocks is stable, increasing, or decreasing.

There is some limited information on past harvestable bladder kelp biomass and potential yield at three sites in Akaroa Harbour (Wainui, Ohinepaka, and Mat White Bays: located in KBB 3G) where Pirker et al (2000) estimated a combined annual harvestable canopy biomass of 377 tonnes for 1999. Further, Pirker et al (2000) concluded that at Akaroa Harbour sites no one forest was capable of supporting the removal of consistent amounts of canopy, although two harvests could be sustained per year – one in late spring/early summer just prior to frond senescence, and then another cut in late autumn/early winter. However, this estimate should be treated with caution – the survey provides only seasonal point estimates of harvestable biomass during the time the survey was conducted, with the 1999 estimate being the highest. Further, the 1999 estimate does not provide an indication of biomass at a QMA level.

There is also some limited information on the location of bladder kelp beds throughout KBB 3, although the biomass of floating surface canopies is unknown. In November 1995, Fyfe et al (1999) used aerial photography to quantify whole plant biomass (surface canopies and subsurface fronds) of bladder kelp forests at Pleasant River. They estimated 42 ha of closed bladder kelp canopy and 43 ha of broken canopy, with a combined biomass of 7900 tonnes (± 1300). Shears & Babcock (2007) also provide a per square metre biomass estimates for entire bladder kelp plants from 247 sites within 43 locations across the North Island and South Island between 1999 and 2005 (Figure 3). About 12.1% of sites surveyed had bladder kelp, with a mean ash free dry weight (AFDW) biomass of 5.43 g m^{-2}. In KBB 3, biomass of attached bladder kelp ranged between 0.8 g AFDW m^{-2} (± 0.5, Fiordland) and 374 g AFDW m^{-2} (Banks Peninsula, figure 25, Shears & Babcock 2007). Again, estimates from these studies should be treated with caution because they only provide point estimates of biomass (estimates are not of harvestable biomass), and they do not provide estimates of biomass at the QMA level.

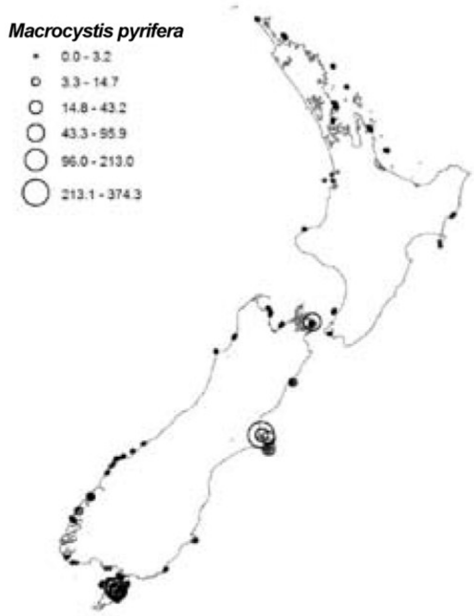


Figure 3: Mean biomass (g ash free dry weight m^{-2}) of attached bladder kelp at all sites, averaged across 4 depth. From Shears & Babcock (2007).

5.3 Yield estimates and projections
MCY cannot be estimated because absolute biomass has not been estimated.

CAY cannot be estimated.

5.4 Other yield estimates and stock assessment results
No information is available.

5.5 Other factors
It is not known whether the biomass of bladder kelp is stable or variable, but the latter is considered more likely.

6. STATUS OF THE STOCKS

KBB 3G

Stock Structure Assumptions
No information is currently available to determine biological stocks for bladder kelp. Therefore, where quota has been allocated this has been to existing fishery management areas (3 and 4).

Stock Status	
Year of Most Recent Assessment	1995 and 1999
Assessment Runs Presented	Survey biomass from different parts of KBB 3
Reference Points	Interim Target: 40% B_0 Interim Soft Limit: 20% B_0 Interim Hard Limit: 10% B_0 Interim Overfishing threshold: F_{MSY}
Status in relation to Target	Due to the relatively low levels of exploitation it is likely that all stocks are still effectively in a virgin state, therefore they are Very Likely (> 90%) to be at or above the target.
Status in relation to Limits	Very Unlikely (< 10%) to be below the soft and hard limits
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status
-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Intensity or Proxy	Fishing is light in KBB 3G averaging 37 t since 2001–02.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below, or to decline below, Limits	Current catches are Very Unlikely (< 10%) to cause declines below soft or hard limits
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Current catches are Very Unlikely (< 10%) to cause overfishing to continue or commence

Assessment Methodology and Evaluation		
Assessment Type	Level 2 Partial quantitative stock assessment	
Assessment Method	Ground-truthed remote sensing biomass surveys	
Assessment Dates	Latest assessment: 1999 and 1995 (in different areas of KBB 3)	Next assessment: Unknown
Overall assessment quality rank	1-High quality: it is very likely that fishing is light and having little impact	
Main data inputs (rank)	Biomass surveys	2 - Medium or mixed quality as surveys only cover part of the range and are dated
Data not used (rank)	-	-
Changes to Model Structure and Assumptions	-	-
Major Sources of Uncertainty	-	-

Qualifying Comments
There are large temporal and spatial fluctuations in biomass within and between beds; therefore, biomass estimates should be utilised conservatively.

Fishery Interactions
Bladder kelp plays an important role in structuring habitats and providing beach-cast material, but harvesting the canopy biomass has no known measurable effect on associated or dependent species.

KBB 4G

Stock Structure Assumptions
No information is currently available to determine biological stocks for bladder kelp. Therefore where quota has been allocated this has been to existing fishery management areas (3 and 4).

Stock Status	
Year of Most Recent Assessment	None
Assessment Runs Presented	None
Reference Points	Interim Target: 40% B_0 Interim Soft Limit: 20% B_0 Interim Hard Limit: 10% B_0

	Interim Overfishing threshold: F_{MSY}
Status in relation to Target	Due to the relatively low levels of exploitation it is likely that all stocks are still effectively in a virgin state, therefore they are Very Likely (> 90%) to be at or above the target
Status in relation to Limits	Very Unlikely (< 10%) to be below the soft and hard limits
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status
-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Intensity or Proxy	Fishing is very light in KBB 4G with less than 3 t reported since 2001–02.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below, or to decline below, Limits	Current catches are Very Unlikely (< 10%) to cause declines below soft or hard limits
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Current catches are Very Unlikely (< 10%) to cause overfishing to continue or commence

Assessment Methodology and Evaluation		
Assessment Type	-	
Assessment Method	-	
Assessment Dates	-	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs (rank)	-	-
Data not used (rank)	-	-
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
There are large temporal and spatial fluctuations in biomass within and between beds; therefore, any biomass estimates in the future should be utilised conservatively.

Fishery Interactions
Bladder kelp plays an important role in structuring habitats and providing beach-cast material, but harvesting the canopy biomass has no known measurable effect on associated or dependent species.

7. RESEARCH NEEDS

Future high priority research areas include: (i) updated (or new in the case of KBB 4G) biomass surveys; (ii) an evaluation of stock structure and inter-stock genetic differentiation; and (iii) quantitative estimates for different sources of mortality.

8. FOR FURTHER INFORMATION

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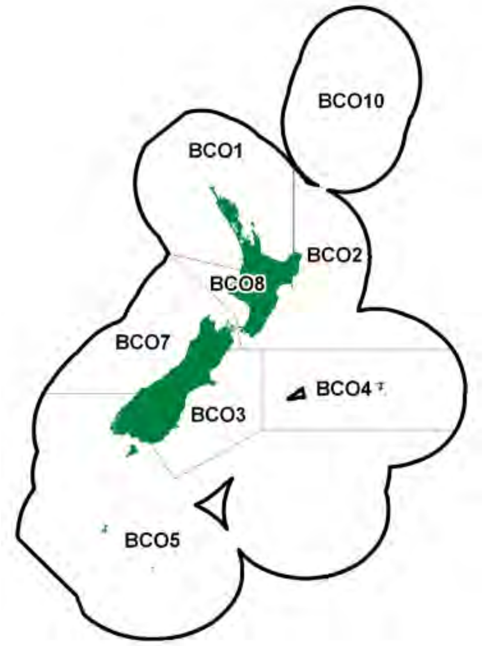
BLUE COD (BCO)

(Parapercis colias)
Rawaru



1. FISHERY SUMMARY

Allowances, TACCs, and TACs are shown in Table 1.

Table 1: Recreational and Customary non-commercial allowances (t), other mortality (t), TACCs (t), and TACs (t) for blue cod by Fishstock.

Fishstock	Recreational Allowance	Customary non-commercial allowance	Other mortality	TACC	TAC
BCO 1	2	2	–	46	46
BCO 2	–	–	–	10	10
BCO 3	–	–	–	163	163
BCO 4	–	–	–	759	759
BCO 5	191	2	20	1 239	1 452
BCO 7	–	–	–	70	20
BCO 8	188	2	2	34	226
BCO 10	–	–	–	10	10

1.1 Commercial fisheries

Blue cod is predominantly an inshore domestic fishery with very little deepwater catch. The major commercial blue cod fisheries in New Zealand are off Southland and the Chatham Islands, with smaller but regionally significant fisheries off Otago, Canterbury, the Marlborough Sounds, and Wanganui.

The fishery has had a long history. National landings of up to 2400 t were reported in the 1930s and landings of over 1500 t were sustained for many years in the 1950s and 1960s (see Table 2). Fluctuations in annual landings since the 1930s can be attributed to World War II, the subsequent market for frozen blue cod for a short period of time, and then the development of the rock lobster fishery. Annual landings of blue cod also vary with the success of the rock lobster season. Traditionally many blue cod fishers were primarily rock lobster fishers. Therefore, the amount of effort in the blue cod fishery tended to depend on the success of the rock lobster season, with weather conditions in Southland affecting the number of ‘fishable’ days.

The commercial catch from the BCO 5 fishery is almost exclusively taken by the target cod pot fishery operating within Foveaux Strait and around Stewart Island (Statistical Areas 025, 027, 029, and 030). Similarly, the BCO 3 commercial catch is dominated by the target pot fishery, although blue cod is also taken as a small bycatch of the inshore trawl fisheries operating within BCO 3. Most of the catch from BCO 3 is taken in the southern area of the Fishstock (Statistical Area 024). Catches from BCO 3 and 5 peak during autumn and winter and the seasonal nature of the fishery is influenced by the operation of the associated rock lobster fishery.

Total landings averaged 574 t in the 1970s before building up to 1546 t in 1985, the year before the QMS was implemented. Landings then declined up to 1989, but have since increased, coinciding with a change in the main fishing method from hand-lines to cod pots. Historical landings are shown in Table 2, recent reported landings are shown in Table 3, and Figure 1 shows the historical landings and TACC values for the five main BCO fish stocks.

During the fishing years 1994–95 to 2017–18, total landings exceeded 2000 t annually, peaking at 2501 t in 2003–04. In 2018–19 landings dropped to 1844 t. Historically, the largest catches of blue cod have been taken in BCO 5 (1556 t in fishing year 2003–04). The total landings from this fishery remained relatively stable from 1982 to 1993 and subsequently increased to approach the level of the TACC in 1995–96. Landings have been declining since 2003–04, and the TACC was lowered to 1239 t in 2011–12. In 2018–19, less than 1000 t of landings were recorded for the first time since 1991–92.

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	BCO 1	BCO 2	BCO 3	BCO 4	Year	BCO 5	BCO 7	BCO 8
1931–32	29	0	55	148	1931–32	719	4	4
1932–33	12	0	59	111	1932–33	726	1	5
1933–34	24	5	26	1 055	1933–34	792	3	2
1934–35	17	5	23	1 306	1934–35	1057	0	4
1935–36	18	23	34	1 197	1935–36	284	44	2
1936–37	3	7	27	755	1936–37	113	61	0
1937–38	2	8	31	793	1937–38	172	81	0
1938–39	2	3	19	686	1938–39	94	57	0
1939–40	1	4	33	715	1939–40	135	68	0
1940–41	3	7	39	320	1940–41	177	72	0
1941–42	2	5	30	189	1941–42	128	54	0
1942–43	3	5	20	204	1942–43	139	65	0
1943–44	4	12	31	212	1943–44	221	80	0
1944	3	10	38	216	1944	552	88	0
1945	8	6	45	102	1945	634	109	0
1946	11	9	43	175	1946	715	116	2
1947	8	22	81	278	1947	955	153	1
1948	7	24	74	623	1948	852	88	2
1949	37	6	98	390	1949	929	82	3
1950	5	5	66	485	1950	1005	94	1
1951	4	9	51	494	1951	873	74	2
1952	5	7	53	543	1952	889	95	3
1953	7	20	62	682	1953	414	114	2
1954	5	9	84	603	1954	385	112	2
1955	4	8	83	355	1955	405	79	3
1956	1	7	86	636	1956	656	77	2
1957	2	5	63	1185	1957	581	61	2
1958	2	4	57	892	1958	542	71	2
1959	1	2	51	1158	1959	492	71	1
1960	1	4	48	903	1960	757	65	2
1961	1	2	43	871	1961	590	55	3
1962	1	9	37	550	1962	668	65	3
1963	1	12	46	633	1963	621	60	4
1964	1	107	83	495	1964	462	70	3
1965	1	18	55	742	1965	296	59	2
1966	1	395	35	13	1966	337	79	6
1967	1	437	34	0	1967	518	74	5
1968	1	312	69	0	1968	494	105	2
1969	6	232	92	8	1969	361	60	1
1970	0	402	70	39	1970	432	70	8
1971	1	105	81	36	1971	375	44	2
1972	0	137	60	3	1972	194	63	1
1973	1	127	65	4	1973	571	68	11
1974	0	67	61	1	1974	486	61	16
1975	0	5	42	2	1975	232	58	14
1976	0	103	72	17	1976	254	58	17
1977	2	3	21	46	1977	208	87	19
1978	0	9	49	14	1978	197	104	12
1979	0	17	74	13	1979	217	98	16
1980	1	1	89	1	1980	403	62	18
1981	1	2	69	40	1981	494	79	23
1982	7	0	62	13	1982	356	68	34

Table 3: Reported landings (t) of blue cod by Fishstock from 1983 to 2018–19 and actual TACCs (t) from 1986–87 to 2018–19. QMS data from 1986-present. FSU data 1983–1986.

Fishstock	BCO 1		BCO 2		BCO 3		BCO 4		BCO 5	
FMA (s)	1 & 9		2		3		4		5 & 6	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983*	23	–	4	–	81	–	192	–	626	–
1984*	39	–	6	–	74	–	273	–	798	–
1985*	21	–	3	–	55	–	274	–	954	–
1986*	19	–	2	–	82	–	337	–	844	–
1986–87	8	30	1	10	84	120	417	600	812	1 190
1987–88	9	40	1	10	148	140	204	647	938	1 355
1988–89	8	42	1	10	136	142	279	647	776	1 447
1989–90	10	45	1	10	121	151	358	749	928	1 491
1990–91	12	45	< 1	10	144	154	409	757	1 096	1 491
1991–92	10	45	1	10	135	154	378	757	873	1 536
1992–93	12	45	4	10	171	156	445	757	1 029	1 536
1993–94	14	45	2	10	142	162	474	757	1 132	1 536
1994–95	13	45	1	10	155	162	565	757	1 218	1 536
1995–96	11	45	2	10	158	162	464	757	1 503	1 536
1996–97	13	45	2	10	156	162	423	757	1 326	1 536
1997–98	16	45	4	10	163	162	575	757	1 364	1 536
1998–99	12	45	2	10	150	162	499	757	1 470	1 536
1999–00	14	45	2	10	168	162	490	757	1 357	1 536
2000–01	15	45	2	10	154	162	627	757	1 470	1 536
2001–02	12	46	2	10	138	163	648	759	1 477	1 548
2002–03	11	46	4	10	169	163	724	759	1 497	1 548
2003–04	9	46	4	10	167	163	710	759	1 556	1 548
2004–05	9	46	5	10	183	163	731	759	1 473	1 548
2005–06	7	46	1	10	183	163	580	759	1 346	1 548
2006–07	6	46	4	10	177	163	747	759	1 382	1 548
2007–08	6	46	3	10	167	163	779	759	1 277	1 548
2008–09	7	46	8	10	158	163	787	759	1 391	1 548
2009–10	8	46	7	10	171	163	691	759	1 210	1 548
2010–11	7	46	8	10	183	163	781	759	1 296	1 548
2011–12	6	46	8	10	166	163	753	759	1 215	1 239
2012–13	9	46	7	10	170	163	739	759	1 207	1 239
2013–14	9	46	8	10	159	163	720	759	1 208	1 239
2014–15	11	46	7	10	175	163	796	759	1 132	1 239
2015–16	9	46	6	10	169	163	758	759	1 099	1 239
2016–17	12	46	10	10	170	163	741	759	1 152	1 239
2017–18	8	46	12	10	174	163	752	759	1 027	1 239
2018–19	9	46	9	10	177	163	744	759	827	1 239

Fishstock	BCO 7		BCO 8		BCO 10			
FMA (s)	7		8		10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983*	91	–	53	–	0	–	1 070	–
1984*	129	–	56	–	0	–	1 375	–
1985*	169	–	70	–	0	–	1 546	–
1986*	83	–	42	–	0	–	1 409	–
1986–87	79	110	22	60	0	10	1 422	2 130
1987–88	78	126	44	72	0	10	1 420	2 400
1988–89	66	131	32	72	0	10	1 298	2 501
1989–90	75	136	34	74	0	10	1 527	2 666
1990–91	63	136	28	74	0	10	1 752	2 667
1991–92	57	136	25	74	0	10	1 480	2 722
1992–93	85	136	32	74	0	10	1 777	2 724
1993–94	67	95	21	74	0	10	1 852	2 689
1994–95	113	95	24	74	0	10	2 089	2 689
1995–96	65	70	31	74	0	10	2 234	2 664
1996–97	71	70	38	74	0	10	2 029	2 664
1997–98	60	70	15	74	0	10	2 197	2 664
1998–99	52	70	35	74	0	10	2 220	2 664
1999–00	28	70	30	74	0	10	2 089	2 664
2000–01	26	70	22	74	0	10	2 316	2 664
2001–02	30	70	17	74	0	10	2 319	2 680
2002–03	39	70	13	74	0	10	2 457	2 680
2003–04	45	70	10	74	0	10	2 501	2 680
2004–05	44	50	7	74	0	10	2 452	2 680
2005–06	50	70	20	74	0	10	2 184	2 680
2006–07	69	70	34	74	0	10	2 413	2 680
2007–08	59	70	22	74	0	10	2 313	2 680
2008–09	58	70	18	74	0	10	2 427	2 680
2009–10	59	70	16	74	0	10	2 162	2 680
2010–11	51	70	16	74	0	10	2 342	2 681
2011–12	54	70	10	34	0	10	2 214	2 332
2012–13	71	70	12	34	0	10	2 215	2 332
2013–14	58	70	12	34	0	10	2 174	2 332
2014–15	68	70	8	34	0	10	2 198	2 332
2015–16	60	70	4	34	0	10	2 096	2 332
2016–17	65	70	5	34	0	10	2 155	2 332
2017–18	71	70	4	34	0	10	2 049	2 332
2018–19	64	70	14	34	0	10	1 844	2 332

Table 4: Reported total New Zealand landings (t) of blue cod for the calendar years 1970 to 1983. Sources MAF and FSU data.

Year	Landings
1970	1 022
1971	644
1972	459
1973	846
1974	696
1975	356
1976	524
1977	383
1978	378
1979	437
1980	536
1981	696
1982	539
1983	1 135

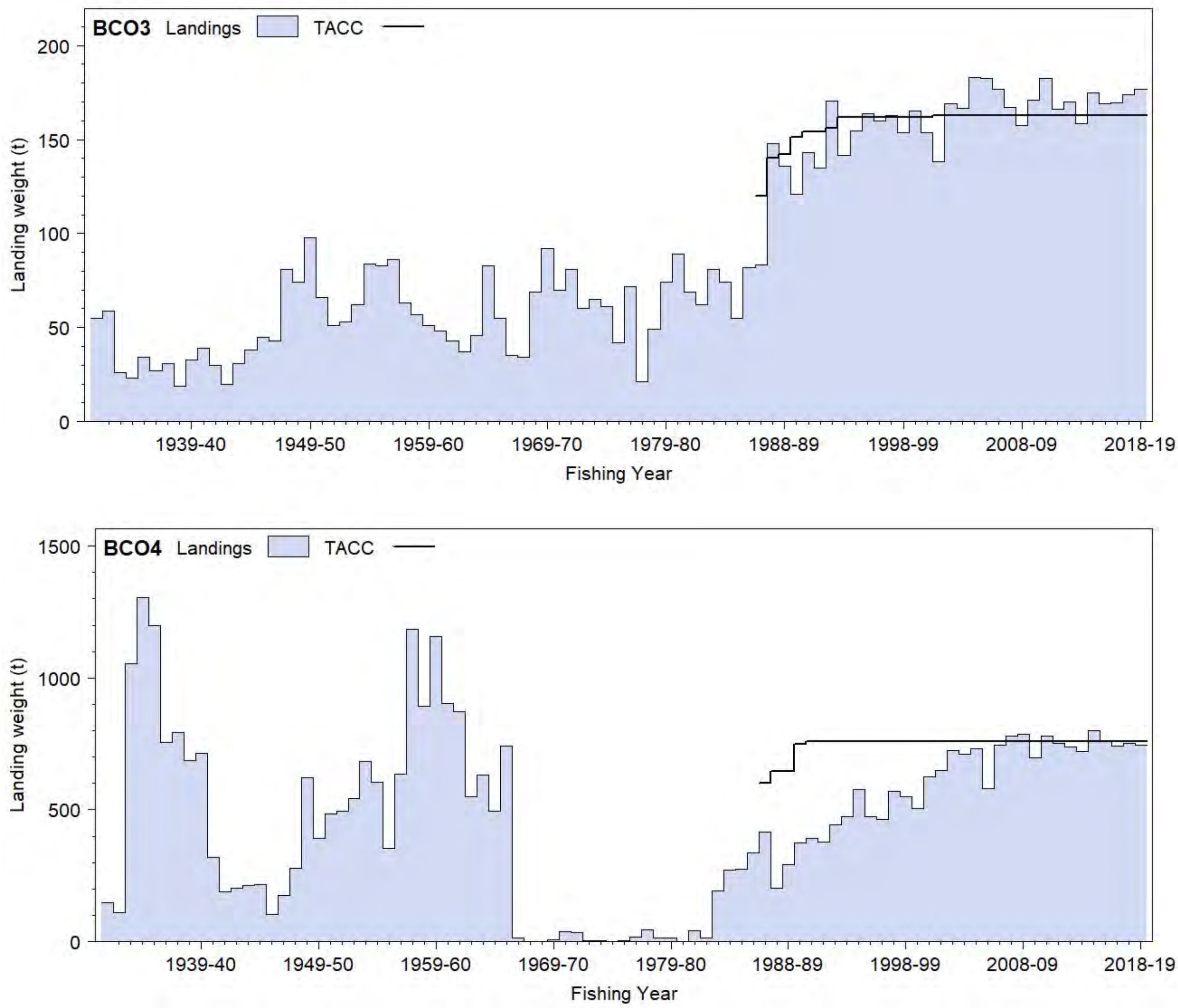


Figure 1: Reported commercial landings and TACC for the five main BCO stocks. From top: BCO 3 (South East Coast) and BCO 4 (South East Chatham Rise) [Continued on next page].

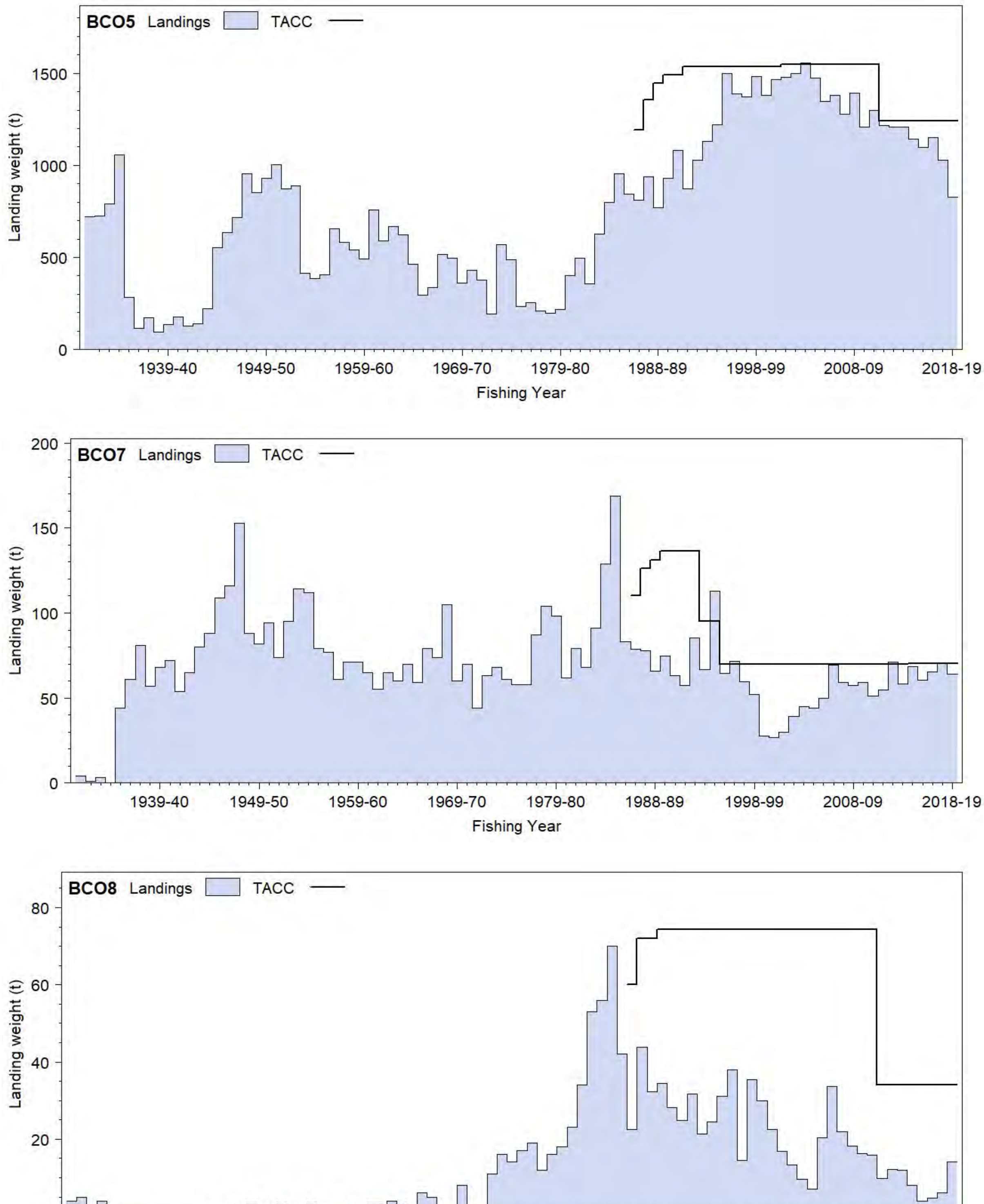


Figure 1 [Continued]: Reported commercial landings and TACC for the five main BCO stocks. From top: BCO 5 (Southland), BCO 7 (Challenger), and BCO 8 (Central Egmont).

1.2 Recreational fisheries

Blue cod are generally the most important recreational finfish in Marlborough, Otago, Canterbury, Southland, and the Chatham Islands. Blue cod are taken predominantly by line fishing, but also by longlining, set netting, potting, and spearfishing. The current allowances within the TAC for each Fishstock are shown in Table 1.

1.2.1 Management controls

The main methods used to manage recreational harvests of blue cod are minimum legal size limits (MLS), method restrictions, and daily bag limits. Daily bag limits are specified as either blue cod specific (DL) or a combined species limit (CDL). The main management controls have changed over time and vary by Fishstock (Table 5). In addition there have been temporary and seasonal closures in the Marlborough Sounds and several Fiordland Sounds.

Table 5: Changes to minimum legal size (MLS in cm), blue cod specific daily bag limit (DL) and combined species daily bag limit (CDL) by Fishstock from 1986 to present. Slot = slot limit (legal size range). * DS = Doubtful Sounds, TS = Thompson's Sound, BS = Bradshaw Sound. ** C = inner sounds closed. # excluding Challenger East. ^bag limit of 6 inside Te Whaka ā Te Wera Mātaitai Reserve.

Fishstock	BCO 1		BCO 2		BCO 3		BCO3		BCO3		BCO 4	
Area	Auckland		Central (East)		South East (Otago)		North Canterbury		Kaikoura Marine Area		South East (Chatham Is.)	
	MLS	CDL	MLS	CDL	MLS	CDL	MLS	DL	MLS	DL	MLS	CDL
1986	30	30	30	30	30	30	30	30	N/A	N/A	30	30
1993	33	20	33	20	30	30	30	30	N/A	N/A	30	30
1994	33	20	33	20	30	30	30	30	N/A	N/A	30	30
2001	33	20	33	20	30	30	30	10	N/A	N/A	30	30
2008	30	20	33	20	30	30	30	10	N/A	N/A	30	30
2014	30	20	33	20	30	30	30	10	33	6	30	30
2017	30	20	33	20	30	30	30	10	33	6	30	30

Fishstock	BCO5		BCO5		BCO 5		BCO5		BCO 7		BCO7	
Area	Southland & Fiordland (External)		Paterson Inlet ^		Fiordland internal (excl. DS, TS, BS*)		DS, TS, BS*		Challenger West & South		Challenger East (incl. Marlborough Sounds)	
	MLS	CDL	MLS	DL	MLS	DL	MLS	DL	MLS	DL	MLS	DL
1986	30	30	30	30	33	20	33	20	30	30	30	12
1993	33	30	33	30	33	20	33	20	33	20	33	10
1994	33	30	33	15	33	20	33	20	33	20	28	6
2001	33	30	33	15	33	20	33	20	33	20	28	6
2003	33	30	33	15	33	20	33	20	33	20	30	3
2005	33	30	33	15	33	20	C*	C*	33	20	30	3
2008	33	30	33	15	33	20	C*	C*	33	20	C**	C**
2011	33	30	33	15	33	20	C*	C*	33	20	#SLOT 30–35	2
2014	33	20	33	15	33	20	C*	C*	33	20	#SLOT 30–35	2
2015	33	20	33	15	33	3	33	1	33	20	33	2
2017	33	20	33	15	33	3	33	1	33	20	33	2

Fishstock	BCO8		BCO10	
Area	Central (West)		Kermadec	
	MLS	DL	MLS	CDL
1986	30	30	30	30
1993	33	20	33	20
2014	33	10	33	20
2017	33	10	33	20

During 1992–93, the national minimum legal size (MLS) for blue cod increased from 30 cm to 33 cm for both amateur and commercial fishers, with the exception of BCO 3 and BCO 4 (South East management area). However, this was amended to 30 cm in 2008 for BCO 1, in response to a management review of blue cod in the area. Additionally, the Marlborough Sounds Area (part of BCO 7) had several MLS amendments between 1993 and 2015 including a closure in the inner sounds followed by a slot limit of 30–35 cm in response to differing management approaches in the Marlborough Sounds. In 2014, the Kaikoura Marine Area in BCO 3 was established and the MLS of blue cod in this area was set at 33 cm.

The recreational daily bag limit (DL) has remained unchanged since 1993 in BCO 1, BCO 2, BCO 3 (South East Otago area), BCO 4, BCO 7 (Challenger West and South area), and BCO 10. In 2001, the recreational daily bag limit (DL) was reduced to 10 in the North Canterbury area (BCO 3). In 2014, the DL was set at 6 in the newly established Kaikoura Marine Area (BCO 3), and the DL was reduced to 20 in Southland and the external waters of the Fiordland marine area (BCO 5). Before these changes, the DL in Paterson's Inlet (BCO 5) was reduced from 30 to 15 in 1994. In 2005, new commercial and recreational rules were introduced to the internal waters of the Fiordland Marine Area and Doubtful Sound, Thompson's Sound, and Bradshaw Sound were closed to all blue cod fishing for 10 years. The closure was lifted in 2015 to recreational blue cod fishing and the new DL within Doubtful Sound was set at 1. The DL for the Challenger East area (BCO 7) has reduced five-fold from 10 to 2 since 1993 in response to differing management regimes in the area. In 2014, the DL in BCO 8 was reduced from 20 to 10.

1.2.2 Estimates of recreational harvest

Recreational harvest estimates are given in Table 6. There are two broad approaches to estimating recreational fisheries harvest: the use of onsite or access point methods where fishers are surveyed or counted at the point of fishing or access to their fishing activity; and, offsite methods where some form of post-event interview and/or diary are used to collect data from fishers.

The first estimates of recreational harvest for blue cod were calculated using an offsite approach, the offsite regional telephone and diary survey approach: MAF Fisheries South (1991–92), Central (1992–93), and North (1993–94) regions (Teirney et al 1997). Estimates for 1996 came from a national telephone and diary survey (Bradford 1998). Another national telephone and diary survey was carried out in 2000 (Boyd & Reilly 2002) and a rolling replacement of diarists in 2001 (Boyd et al 2004) allowed estimates for a further year (population scaling ratios and mean weights were not re-estimated in 2001).

The harvest estimates provided by these telephone diary surveys are no longer considered reliable for various reasons. With the early telephone/diary method, fishers were recruited to fill in diaries by way of a telephone survey that also estimates the proportion of the population that is eligible (likely to fish). A "soft refusal" bias in the eligibility proportion arises if interviewees who do not wish to co-operate falsely state that they never fish. The proportion of eligible fishers in the population (and, hence, the harvest) is thereby under-estimated. Pilot studies for the 2000 telephone/diary survey suggested that this effect could occur when recreational fishing was established as the subject of the interview at the outset. Another equally serious cause of bias in telephone/diary surveys was that diarists who did not immediately record their day's harvest after a trip sometimes overstated their harvest or the number of trips made. There is some indirect evidence that this may have occurred in all the telephone/diary surveys (Wright et al 2004).

The recreational harvest estimates provided by the 2000 and 2001 telephone diary surveys are thought to be implausibly high, which led to the development of an alternative maximum count aerial-access onsite method that provides a more direct means of estimating recreational harvests for suitable fisheries. The maximum count aerial-access approach combines data collected concurrently from two sources: a creel survey of recreational fishers returning to a subsample of ramps throughout the day; and an aerial survey count of vessels observed to be fishing at the approximate time of peak fishing effort on the same day. The ratio of the aerial count in a particular area to the number of interviewed parties who claimed to have fished in that area at the time of the overflight was used to scale up harvests observed at surveyed ramps, to estimate harvest taken by all fishers returning to all ramps. The methodology is further described by Hartill et al (2007).

This aerial-access method was first employed, optimised for SNA, in the Hauraki Gulf in 2003–04. It was then extended to survey the wider SNA 1 fishery in 2004–05 and to other areas (SNA 8) and other species, including blue cod in BCO 7 in 2005–06 (Davey et al 2008). The estimates for BCO 7 in 2005–06 may not be accurate for two reasons. A large proportion of the fishing effort observed during aerial surveys of the outer Marlborough Sounds was from launches and other vessels that would not have returned to the surveyed boat ramps, because they would have returned to other access points and often on following days. A significant proportion of the boats fishing in the inner Marlborough Sounds may also have returned to a bach/crib rather than a surveyed ramp. For both these situations it was therefore necessary to assume that the catch and effort of these boats would have been the same as that reported by boats returning to surveyed boat ramps on the same day, which may not have been the case. A repeat aerial-access survey was conducted in BCO 7 over the 2015–16 fishing year (Hartill et al 2017) and this was considered by the Marine Amateur Fisheries Working Group to be more reliable than the initial survey because a greater number of days were surveyed in this year, and a pilot survey was undertaken to determine where boats fishing in the inner Marlborough Sounds had originated from, which led to interviews being conducted at two extra high traffic ramps in this area. The recreational harvest from BCO 7 in 2015–16 was about half that in 2005–06 (Table 6), almost with all of the decrease being in the Marlborough Sounds.

In response to the cost and scale challenges associated with onsite methods, in particular the difficulties in sampling other than trailer boat fisheries, offsite approaches to estimating recreational fisheries harvest have been revisited. This led to the implementation of a national panel survey during the 2011–12 fishing year. The panel survey used face-to-face interviews of a random sample of 30 390 New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and harvest information collected in standardised phone interviews. The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly comparable results (Wynne-Jones et al 2019). Recreational catch estimates from the two national panel surveys are given in Table 6. Note that national panel survey estimates do not include recreational harvest taken under s111 general approvals.

Table 6: Recreational harvest estimates for blue cod stocks. The telephone/diary surveys and aerial-access survey ran from December to November but are denoted by the January calendar year. The national panel surveys ran through October to September fishing years but are denoted by the January calendar year. Mean fish weights were obtained from boat ramp surveys (for the telephone/diary and panel survey harvest estimates).

Stock	Year	Method	Number of fish	Total weight (t)	CV
BCO 1	1996	Telephone/diary	34 000	17	0.11
	2000	Telephone/diary	37 000	23	0.31
	2012	Panel survey	17 463	1	0.20
	2018	Panel survey	13 276	6	0.18
BCO 2	1996	Telephone/diary	145 000	81	0.13
	2000	Telephone/diary	187 000	161	0.25
	2012	Panel survey	53 618	26	0.19
	2018	Panel survey	48 140	28	0.26
BCO 3	1996	Telephone/diary	217 000	151	0.11
	2000	Telephone/diary	1 026 000	752	0.29
	2012	Panel survey	212 184	101	0.20
	2018	Panel survey	202 765	99	0.18
BCO 5	1996	Telephone/diary	171 000	139	0.12
	2000	Telephone/diary	326 000	229	0.28
	2012	Panel survey	72 328	44	0.24
	2018	Panel survey	139 176	67	0.20
BCO 7	1996	Telephone/diary	356 000	239	0.09
	2000	Telephone/diary	542 000	288	0.20
	2006	Aerial-access	-	149	0.16
	2012	Panel survey	176 152	77	0.17
	2016	Aerial-access	-	75	0.15
	2018	Panel survey	129 038	63	0.12
BCO 8	1996	Telephone/diary	159 000	79	0.12
	2000	Telephone/diary	232 000	188	0.32
	2012	Panel survey	88 980	48	0.36
	2018	Panel survey	62 539	31	0.20

1.2.3 Charter vessel harvest

The national marine diary survey of recreational fishing from charter vessels in 1997–98 found blue cod to be the second most frequently landed species nationally and the most frequently landed species in the South Island. Results indicated that recreational harvests from charter vessels (Table 7) follow the same pattern as overall recreational harvest (Table 6). The estimated recreational harvests from charter vessels in BCO 7 exceeded the 1997–98 TACC and the commercial landings in QMA 7.

Table 7: Results of a national marine diary survey of recreational fishers from charter vessels, 1997–98 (November 1997 to October 1998).*

Fishstock	Number caught	CV	Estimated landings (number of fish killed)	Point E estimate (t)
BCO 1	430	0.18	2 500	2.4
BCO 2	34	0.50	300	0.2
BCO 3	17 272	0.29	72 000	58
BCO 5	16 750	0.36	63 000	51
BCO 7	32 026	0.13	110 000	76
BCO 8	2	–	–	0

*Estimated number of blue cod harvested by recreational fishers on charter vessels by Fishstock and the corresponding harvest tonnage. The mean weights used to convert numbers to harvest weight were considered the best available at the time (James & Unwin 2000).

1.3 Customary non-commercial fisheries

No quantitative data on historical or current blue cod customary non-commercial catch are available. However, bones found in middens show that blue cod was a significant species in the traditional Maori take of pre-European times.

1.4 Illegal catch

No quantitative data on the levels of illegal blue cod catch are available.

1.5 Other sources of mortality

Blue cod have in the past been used for bait within the rock lobster fishery. Pots are either set specifically to target blue cod or have a bycatch of blue cod that is used for bait. However, these fish are frequently not recorded and the quantity of blue cod used as bait cannot be accurately determined.

Cod pots covered in 38 mm mesh frequently catch undersized blue cod. It has been estimated that in Southland, 65% of blue cod caught in these pots are less than 33 cm. When returned, the mortality of these fish can be high due to predation by mollymawks following commercial boats. It is estimated by the fishing industry that up to 50% of returned fish can be taken. To reduce the problem of predation of returned undersized fish, a minimum 48 mm mesh size was introduced to BCO 5 in 1994. However, no mesh size restrictions exist in any other area. An experiment conducted by Glen Carbines on commercial vessels in 2015 to quantify the reduction in undersized blue cod caught in pots with the alternative mesh size showed that almost all retained undersized fish were dead when returned to the water. Even though blue cod are not subject to barotrauma, because they have no swim bladders, the high mortality was the result of undersized blue cod being returned once the catch had been processed.

Recreational line fishing often results in the harvest of undersized blue cod. The survival of these has been shown to be a factor of hook size. A small scale experiment showed that returned undersized fish caught with small hooks (size 1/0) experience 25% mortality, whereas those caught with large hooks (size 6/0) appear to have little or no mortality (Carbines 1999).

2. BIOLOGY

Blue cod is a bottom-dwelling species endemic to New Zealand. Although distributed throughout New Zealand near foul ground to a depth of 150 m, they are more abundant south of Cook Strait and around the Chatham Islands. Growth may be influenced by a range of factors, including sex, habitat quality, and fishing pressure relative to location (Carbines 2004a). Size-at-sexual maturity also varies according to location. In Northland, maturity is reached at 10–19 cm total length (TL) at an age of 2 years, whereas in the Marlborough Sounds it is reached at 21–26 cm TL at 3–6 years. In Southland, the fish become mature at 26–28 cm TL, at an age of 4–5 years. Blue cod have also been shown to be protogynous hermaphrodites, with individuals over a large length range changing sex from female to male (Carbines 1998). Validated age estimates using otoliths have shown that blue cod males grow faster and are larger than females (Walsh 2017). The maximum recorded age for this species is about 32 years.

An *M* of 0.17 was based on the empirical age distribution from the offshore Banks Peninsula survey in 2016, because these fish were aged using the blue cod age determination protocol. The *M* estimate is based on the 1% tail of the distribution, which was 27 years, not the maximum age. The default *M* for blue cod was changed from 0.14 to 0.17 in April 2019 following the recommendation of the Inshore Working Group. All spawner-per-recruit ratio (SPR) analyses carried out using 0.14 will need to be recalculated.

Blue cod have an annual reproductive cycle with an extended spawning season during late winter and spring. Spawning has been reported within inshore and mid-shelf waters. It is also likely that spawning occurs in outer-shelf waters. Ripe blue cod are also found in all areas fished commercially by blue cod fishers during the spawning season. Batch fecundity was estimated by Beer et al (2013). Eggs are pelagic for about five days after spawning, and the larvae are pelagic for about five more days before settling onto the seabed. Juveniles (less than about 10 cm TL) are not caught by commercial potting or lining, and therefore blue cod are not vulnerable to the main commercial fishing methods until they are mature. Recreational methods do catch juveniles, but since this species does not have a swim bladder, the survival of these fish is good if they are caught using large hooks (6/0)(which do not result in gut hooking) and returned to the sea quickly (Carbines 1999).

Tagging experiments carried out in the Marlborough Sounds in the 1940s and 1970s suggested that most blue cod remained in the same area for extended periods. A more recent tagging experiment carried out in Foveaux Strait (Carbines 2001) showed that although some blue cod moved as far as 156 km, 60% travelled less than 1 km. A similar pattern was found in Dusky Sound where four fish moved over 20 km but 65% had moved less than 1 km (Carbines & McKenzie 2004). The larger movements observed during this study were generally eastwards into the fiord. The inner half of the fiord was found to drain the outer strata and had 100% residency.

Biological parameters relevant to stock assessment are shown in Table 8.

Table 8: Estimates of biological parameters for blue cod. These estimates are survey specific and reflect varying exploitation histories and environmental conditions. Only von Bertalanffy growth parameters derived from otoliths aged using the Age Determination Protocol for Blue Cod (Walsh 2017) are included in this table.

Fishstock	**Estimate**	**Source**
1. Natural mortality (M)		
All	0.17	Doonan et al (2020)

2. Von Bertalanffy growth parameters

	Females			Males			
Survey/year	L_∞	K	t_0	L_∞	k	t_0	
Dusky Sound (2014)	46.7	0.129	-1.8	50.3	0.222	0.638	Beentjes & Page (2016)
Kaikoura (2015)	40.7	0.174	-1.12	52.3	0.171	-0.27	Beentjes & Page (2017)
Banks Peninsula (2016)	50.2	0.116	-2.07	58.7	0.134	-1.21	Beentjes & Fenwick (2017)
Marlborough Sounds (2017)	32.2	0.52	0.83	39.9	0.37	0.69	Beentjes et al (2018)
Paterson Inlet	40.0	0.20	-4.31	46.8	0.21	0.215	Beentjes & Miller 2020

3. Weight = a(length)^b (Weight in g, length in cm total length).

Area			a	b	R^2	
Kaikoura	2011	Male	0.011793	3.09246	0.97	Carbines & Haist (2012b)
	2011	Female	0.007042	3.23949	0.95	
Motunau	2012	Male	0.01490	3.03796	0.98	Carbines & Haist (2012b)
	2012	Female	0.01384	3.05982	0.97	
Banks Peninsula	2012	Male	0.019138	2.98181	0.98	Carbines & Haist (2012a)
	2012	Female	0.016939	3.02644	0.96	
North Otago	2013	Male	0.01093	3.10941	0.98	Carbines & Haist (2014b)
	2013	Female	0.012023	3.09201	0.97	
South Otago	2013	Male	0.008472	3.19011	0.99	Carbines & Haist (2014c)
	2013	Female	0.008617	3.1863	0.99	
Fiordland	2002	Male	0.007825	3.1727	0.97	Carbines & Beentjes (2003)
(Dusky Sound)	2002	Female	0.00506	3.2988	0.98	
Stewart Island	2010	Male	0.00663	3.2469	0.98	Carbines & Haist (2014a)
(Paterson Inlet)	2010	Female	0.00663	3.2469	0.98	

The preliminary results of a mitochondrial DNA analysis (Smith 2012) suggest that the Chatham Island blue cod are likely to be genetically distinct from mainland New Zealand. Over larger distances the mainland New Zealand blue cod appear to show a pattern of Isolation-by-Distance or continuous genetic change among populations.

3. STOCKS AND AREAS

The FMAs are used as a basis for Fishstocks, except FMAs 5 and 6, and FMAs 1 and 9, which have been combined. The choice of these boundaries was based on a general review of the distribution and relative abundance of blue cod within the fishery.

There are no data that would alter the current stock boundaries. However, tagging experiments suggest that blue cod populations may be geographically isolated from each other, and there may be several distinct populations within each management area (particularly those occurring in sounds and inlets).

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

4.1.1 South Island blue cod potting surveys

Potting surveys are used to monitor blue cod populations supporting nine important recreational fisheries around the South Island (Figure 2). Surveys are generally carried out every four years and are used to monitor relative abundance, size, age, and sex structure of the nine geographically separate blue cod populations. The surveys also provide an estimate of fishing mortality (*F*), and associated spawner-per-recruit ratios.

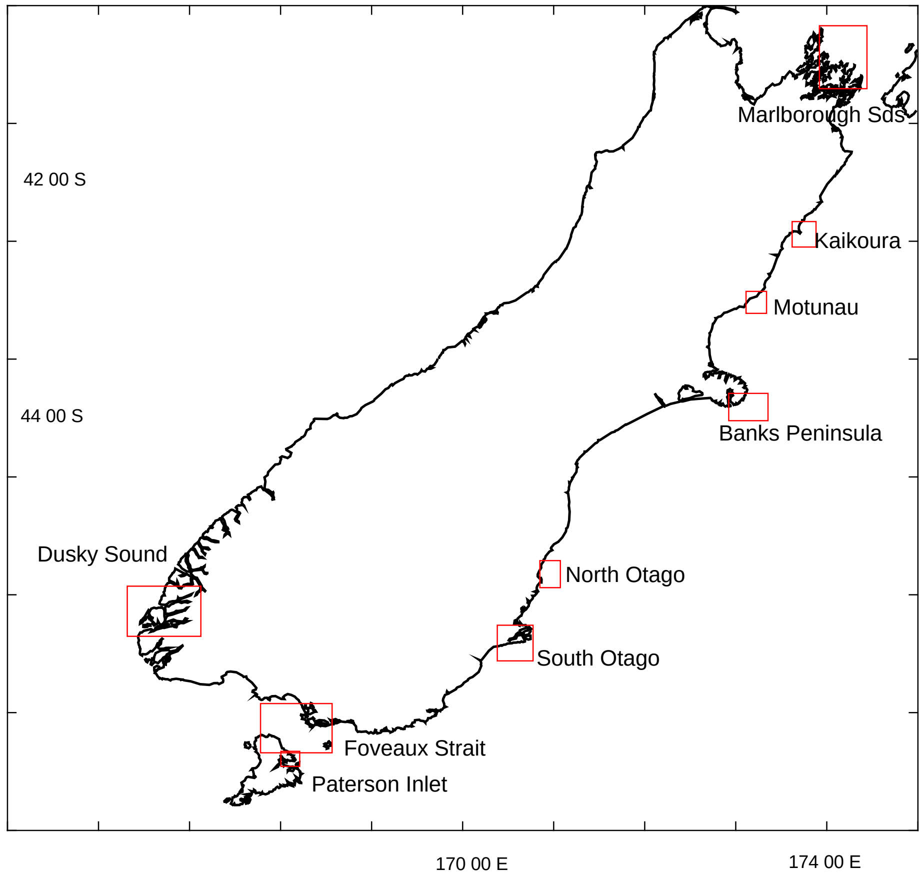


Figure 2: Map showing the nine South Island blue cod potting survey locations.

Marlborough Sounds

In 1995, a fishery-independent survey using standardised cod pots at fixed stations provided catch rate estimates for recruited blue cod in Queen Charlotte Sound and outer Pelorus Sound. In 1996 a second potting survey covered all of Pelorus Sound as well as the east coast of D'Urville Island (Blackwell 1997, 1998). A 2001 survey (Blackwell 2002) included Queen Charlotte Sound, Pelorus Sound, and east D'Urville, and a survey in 2004 covered the same areas as 2001 but was expanded to include west D'Urville and Separation Point (Blackwell 2005). In 2007, the surveyed area was the same as 2004 except that Separation Point was dropped. In 2008 a standalone survey of a Cook Strait stratum was carried out and in 2010 the Cook Strait stratum was added to the surveyed area along with those strata used in 2007 (Beentjes & Carbines 2012). A new survey in 2013 used the same strata as 2010 (Beentjes et al 2014). The 2001 to 2008 surveys were reanalysed as part of the 2010 survey so that they were consistent with methods used for recent surveys (Beentjes & Carbines 2012). The 1995 and 1996 surveys, similarly, have been reanalysed as part of the 2013 survey analyses (Beentjes et al 2014). All surveys before 2010 used fixed sites which were selected randomly from a wider list of fixed sites within a given stratum. These fixed locations are available to be used repeatedly on subsequent surveys in that area (Beentjes & Francis 2011). In 2010, experimental random sites were trialled in selected strata. Random sites may have any location (single latitude and longitude) and are generated randomly within each stratum. In 2013 and 2017 (Beentjes et al 2017, Beentjes et al 2018), full random and full fixed site surveys were conducted concurrently. Of the three random-site surveys only the last two are (2013 and 2017) are comparable.

Throughout the fixed-site surveys, catch rates of total blue cod (all sizes) have tended to be highest around D'Urville Island, lowest in Cook Strait, and similar between Queen Charlotte Sound and Pelorus Sound (Figure 3, Table 9). In Queen Charlotte Sound catch rates progressively declined from 2.1 to 1.1 kg pot^{-1} (CV range 16 to 26%) between 1995 and 2007 before increasing markedly in 2010 to 1.75 kg pot^{-1} (Figure 3). From October 2008 to April 2011, the inner sounds were closed to recreational blue cod fishing and the 2010 potting survey increased abundance in Queen Charlotte Sound is attributed to the closure. In Pelorus Sound, total blue cod catch rates declined from 2.4 to 1.1 kg pot^{-1} (CV range 7 to 19%) over the same period, then increased again in 2010, to 2.9 kg pot^{-1} (Figure 3). Pelorus Sound showed a similar trend in catch rates to Queen Charlotte Sound, dropping markedly from 1996 to 2007 and increasing again in 2010 after two years of closure. In April 2011, a seasonal opening with a "slot" limit (which allowed the take of blue cod between 30 and 35 cm) was introduced for the Marlborough Sounds Management Area, an area that includes inner and outer Queen Charlotte Sound and Pelorus Sound and east D'Urville.

The 2013 survey was carried out two years after the slot limit had been in place, with total blue cod catch rates for both Queen Charlotte Sound and Pelorus Sound declining compared with 2010 rates, but remaining higher than 2001 to 2007 for Pelorus Sound when the fishery was open, and about the same magnitude as pre-closure for Queen Charlotte Sound (Figure 3). In the D'Urville Island strata, which have been fished continuously over the same period, catch rates for total blue cod between 2004 and 2013 have been stable, ranging from 3.9 to 4.44 kg pot^{-1} (CV range 8 to 18%) (Figure 3). D'Urville was not closed to fishing in October 2008, but the east side of the island was included in the management area where the "slot limit" has been applicable since April 2011. Cook Strait has three comparable random-site surveys (2010, 2013, and 2017) with the first survey in 2008 being a fixed-site survey which was not comparable. Total blue cod catch rates from the Cook Strait random surveys ranged from 0.7 to 1.1 kg pot^{-1} with no trend (Table 9). There were no closures or slot limit management measures for Cook Strait. The proportion of the total biomass within the "slot limit" (30–35 cm) in 2013 was 45%, 49%, and 49% for QCH, PEL, and DUR regions respectively, and proportions of biomass above the "slot limit" were 26%, 25%, and 22%, respectively. Sex ratios have been dominated by males in all regions over all surveys (Table 9). The 2017 survey took place 2 years after the "slot limit" was removed and in the Marlborough Sounds Area the MLS was increased to 33 cm. In 2017, catch rates from the fixed-site survey in Queen Charlotte Sound were similar to those in 2013, in Pelorus Sound they were similar to 2010, and at D'Urville Island they were about 40% higher than in 2013 (Figure 3, Table 9).

The random-site surveys in 2013 and 2017 generally have lower catch rates than fixed-site surveys, and, although the patterns among strata in each region are similar, they do not show the same overall trends as fixed sites by region (Table 9, Figure 3). In Queen Charlotte Sound survey biomass increased markedly, whereas for Pelorus Sound and D'Urville Island there are no significant changes. Cook Strait random-site catch rates show no significant difference from 2010 to 2017. The overall Marlborough Sounds catch rates from 2004 onward (where survey strata are consistent among surveys) indicates that blue cod were more abundant in 2017 than any of the previous years (Figure 3). It is the intention to transition to random-site surveys and conducting both fixed- and random-site surveys allows comparison of catch rates, length and age composition, and sex ratios between survey designs in the interim. The next survey in the time series will use only a random-site design.

A random-site survey of Long Island Marine Reserve in 2017, in which all fish were returned alive (unsexed), had mean catch rates of all blue cod of 8.76 kg pot^{-1} (CV of 15%), substantially higher than adjacent fished strata in Queen Charlotte Sound (Table 9). In addition, the mean size was 3.2 cm greater in the marine reserve and length frequency distributions were bimodal in contrast to the unimodal distributions from adjacent strata in Queen Charlotte Sound.

Growth rates and age compositions were similar for 2013 and 2017. Fixed-site survey Chapman-Robson total mortality estimates (Z) for age at recruitment of 6 years were very close at 0.51 in 2013 and 0.53 in 2017 (Table 10). Spawner-per-recruit ratios ($F_{SPR\%}$), however, differed substantially and were 25% in 2013 and 39% in 2017 (the Fisheries New Zealand target is $F_{45\%}$). The difference was primarily a result of having different selectivity ages to the fishery because the MLS increased from 30 cm in 2013 to 33 cm in 2017, and hence these ratios cannot be validly compared. Similarly, random-site survey Chapman-Robson total mortality estimates (Z) for age at recruitment of 6 years were very close at 0.46 in 2013 and 0.52 in 2017 (Table 10). Spawner-per-recruit ratios ($F_{SPR\%}$) also differed substantially and were 27% in 2013 and 39% in 2017 for the same reasons.

Banks Peninsula

There have been five fixed-site blue cod potting surveys off Banks Peninsula (2002, 2005, 2008, 2012, and 2016), split into geographically separate inshore and offshore areas (Beentjes & Carbines 2003, 2006, 2009; Carbines & Haist 2017; Beentjes & Fenwick 2017). In 2012 and 2016 concurrent random-site potting surveys were also carried out and these are intended to replace fixed-site surveys because the random surveys provide a more reliable indicator of stock status.

The most recent fixed-site inshore survey in 2016 recorded catch rates of 1.26 kg pot^{-1} (CV 12%), a sex ratio of 67% male, estimated fishing mortality (F) of 1.73 and associated spawner-per-recruit ratio of 4.7% (Table 11). Corresponding values for the 2016 inshore random site survey were 0.53 kg pot^{-1} (CV 22%), 81% male, F = 2.1 and a spawner-per-recruit ratio of 4.3%. For both fixed and random site surveys, the level of exploitation of Banks Peninsula inshore blue cod stocks in 2016 greatly exceeded the Fisheries New Zealand F_{MSY} target reference point of $F_{45\%SPR}$. The very high estimate of total mortality, truncated age composition, strongly skewed sex ratio toward males and extremely low spawner-per-recruit ratio, indicates that the Banks Peninsula inshore blue cod population is heavily overfished. Further, as nearly all females and most males currently caught will be of sub-legal size (less than 30 cm), there is also likely to be significant mortality through catch and return of undersize fish. For the five inshore fixed site surveys there were no trends in survey abundance, length distribution, mean length, or sex ratio. A strong juvenile mode in 2016 can be expected to contribute to increased abundance in about three years when these blue cod recruit to the fishery at 30 cm.

The most recent fixed site offshore survey in 2016 had catch rates of 5.6 kg pot^{-1} (CV 14%), sex ratio of 65% male, estimated fishing mortality (F) of 0.12, and associated spawner-per-recruit ratio of 40.7% (Table 11). Corresponding values for the 2016 offshore random site survey values were 5.08 kg pot^{-1} (CV 19%), 57% male, F = 0.05, and a spawner-per-recruit ratio of 64.3%. For both fixed- and random-site surveys the level of exploitation (F) of Banks Peninsula offshore blue cod stocks in 2016 is close to or less than the Fisheries New Zealand F_{MSY} target reference point of $F_{45\%SPR}$. The offshore blue cod population, in contrast to inshore, have high catch rates, a wide size range of both males and females, a more balanced sex ratio, and spawner-per-recruit ratio above the target, indicating that they are not overfished. For the five offshore fixed-site surveys there were no trends in survey abundance, length distribution, mean length, or sex ratio.

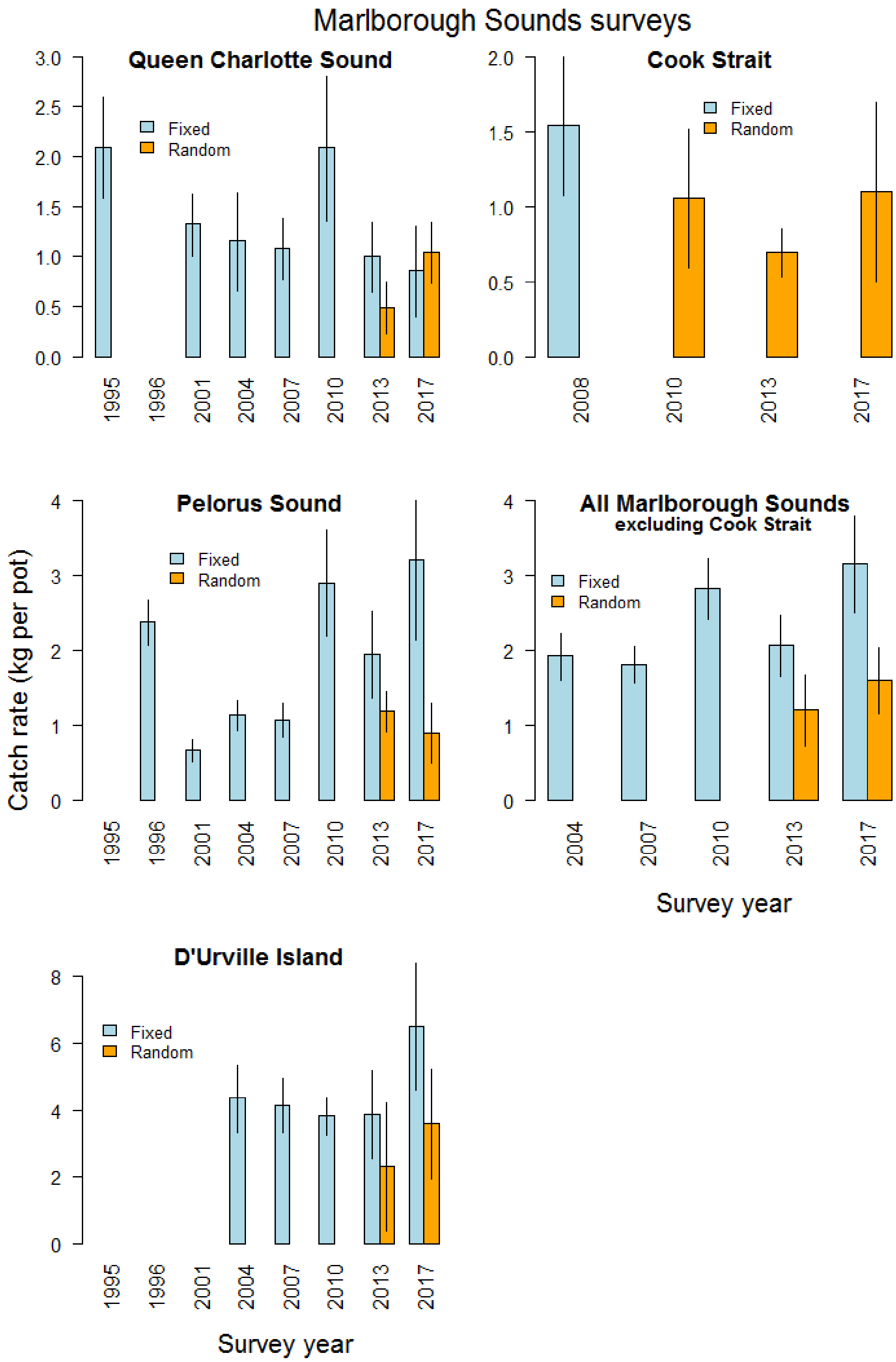


Figure 3: Marlborough Sounds fixed-site and random-site potting survey catch rates of all blue cod by survey year for each region and overall for the Marlborough Sounds. Error bars are 95% confidence intervals. There were no complete fixed-site surveys in Queen Charlotte Sound in 1996, Pelorus Sound in 1996, and D'Urville Island from 1995 to 2001. For the overall Marlborough Sounds plot, the 2004 and 2007 fixed-site surveys exclude Separation Point, and the random-site surveys exclude Cook Strait, hence the strata are consistent among the surveys for fixed and random site surveys.

Table 9: Summary statistics from standardised blue cod fixed-site and random-site potting surveys in the Marlborough Sounds up to 2017 by region. Mean length and sex ratios are derived from the scaled population length distributions. Results for each region are shown only for surveys where strata have remained the same throughout the time series and results are for all blue cod. For the overall Marlborough Sounds (All MS), the 2004 and 2007 fixed-site surveys exclude Separation Point, and the random-site surveys exclude Cook Strait, hence the strata are consistent among the surveys for fixed and random site surveys. QCH, Queen Charlotte Sound; PEL, Pelorus Sound; DUR, D'Urville; CKST, Cook Strait; LIMR, Long Island Marine Reserve; All MS, all Marlborough Sounds

			Mean length (cm)			CPUE (kg pot^{-1})		Sex ratio
Region/strat	Year	Site type	Male	Female	unsexed	Overall	range (CV)	(% male)
QCH	1995	Fixed	31.0	28.0		2.1	0.74–2.91 (12%)	59%
	1996	–	–	–		–	–	–
	2001	Fixed	28.5	24.3		1.33	0.58–1.69(12%)	61%
	2004	Fixed	27.9	24.2		1.16	0.35–2.01(22%)	51%
	2007	Fixed	29.8	25.7		1.09	0.00–2.60(15%)	69%
	2010	Fixed	33.2	29.0		2.09	0.60–2.56(18%)	71%
	2013	Fixed	31.7	29.8		1.0	0.32–1.12 (18%)	62%
		Random	32.1	30.3		0.49	0.22–1.07 (27%)	66%
	2017	Fixed	32.2	29.6		0.86	0.18–1.95 (27.3%)	72%
		Random	32.5	30.7		1.04	0.11–1.94 (15%)	73%
QCH/LIMR	2017	Random	–	–	35.2	8.76	8.76 (14%)	–
PEL	1995	–	–	–		–	–	–
	1996	Fixed	29.8	26.2		2.4	1.00–3.30 (7%)	70%
	2001	Fixed	27.8	22.2		0.67	0.19–1.46(12%)	64%
	2004	Fixed	28.2	23.5		0.96	0.20–2.70(11%)	66%
	2007	Fixed	29.2	24.5		1.07	0.28–3.24(11%)	77%
	2010	Fixed	32.8	28.3		2.9	1.60–3.86(13%)	87%
	2013	Fixed	31.3	27.2		1.95	3.30–4.94(15%)	89%
		Random	33.3	30.1		1.18	0.18–3.96 (12%)	77%
	2017	Fixed	32.0	29.5		3.20	0.11–10.1 (17%)	86%
		Random	32.4	29.8		0.90	0.07–2.77 (23%)	90%
DUR	1995	–	–	–		–	–	–
	1996	–	–	–		–	–	–
	2001	–	–	–		–	–	–
	2004	Fixed	30.7	27.8		4.23	3.75–4.67(11%)	50%
	2007	Fixed	32.2	29.5		4.15	2.92–5.49(10%)	71%
	2010	Fixed	31.3	28.7		3.82	2.15–5.64(8%)	64%
	2013	Fixed	31.7	29.4		3.88	3.37–4.44(18%)	70%
		Random	32.8	29.9		2.31	1.42–3.28(43%)	57%
	2017	Fixed	32.9	30.6		6.52	4.50–8.70 (15%)	61%
		Random	32.6	30.6		3.59	2.90–4.30 (24%)	65%
CKST	2008	Fixed	31.9	26.4		1.50	0.30–4.20(15%)	88%
	2010	Random	30.5	25.6		1.06	0.11–1.74(22%)	84%
	2013	Random	31.7	28.4		0.70	0.14–1.62(12%)	83%
	2017	Random	32.3	28.2		1.10	0.08–2.67(28%)	87%
All MS	2004	Fixed	29.1	25.9		1.92	0.37–4.67 (8%)	54
	2007	Fixed	30.7	27.2		1.81	0.00–5.48 (7%)	72
	2010	Fixed	32.5	28.7		2.83	0.60–5.64 (7%)	75
	2013	Fixed	31.5	29.1		2.68	0.31–4.44 (10%)	76
		Random	32.9	30.0		1.20	0.22–3.96 (21%)	66
	2017	Fixed	32.4	30.2		3.15	0.11–8.73 (10%)	72
		Random	32.5	30.6		1.59	0.06–4.32 (14%)	72

Table 10: Mortality parameters (*Z*, *F*, and *M*) and spawner-per-recruit ($F_{SPR\%}$) estimates for blue cod from the 2013 and 2017 Marlborough Sounds fixed-site and random-site potting surveys for all regions combined. *F*, fishing mortality; *M*, natural mortality; *Z*, total mortality; Age at recruitment = 6 years equivalent to age at which females reach MLS of 30 cm in 2013, and males and females combined reach MLS of 33 cm in 2017. Otoliths from both surveys were aged using the Age Determination Protocol for blue cod (Walsh 2017). CIs, 95% confidence intervals.

Survey	Region	Site type	*M*	*Z* (CIs)	*F*	$F_{\%SPR}$
2013	All regions combined	Fixed	0.14	0.56 (0.40–0.74)	0.42	$F_{25.5\%}$
2017			0.14	0.53 (0.38–0.72)	0.39	$F_{39.0\%}$
2013	All regions combined	Random	0.14	0.53 (0.38–70	0.39	$F_{26.7\%}$
2017			0.14	0.52 (0.37–0.69)	0.38	$F_{39.4\%}$

North Canterbury

Kaikoura

There have been four fixed-site blue cod potting surveys off Kaikoura (2004, 2007, 2011, and 2015), (Carbines & Beentjes 2006a, 2009; Carbines & Haist 2018a; Beentjes & Page 2017). In 2011 and 2015 concurrent random-site potting surveys were also carried out and these are intended to replace fixed-site surveys. Subsequently a solely random-site survey was carried out in 2017, earlier than the standard four-year cycle, to assess the impact of the November 2016 earthquake (Beentjes & Page 2018). Random surveys provide a more reliable indicator of stock status and will be used in future.

The most recent random-site survey in 2017 recorded catch rates of 1.9 kg pot^{-1} (CV 16%), sex ratio of 45% male, and mean lengths of 28.4 cm and 28.6 cm for males and females respectively (Table 11). For the four fixed-site surveys, catch rates increased nearly two-fold from 2004 to 2007, and then declined in both 2011 and 2015, and catch rates from the last were the lowest of all four surveys (Table 11, Figure 4). For the three random-site surveys there was no trend in relative abundance. The sex ratio for all blue cod was close to parity for all surveys (fixed and random), with the exception of the 2015 fixed-site survey where two-thirds of the blue cod were male (Table 11).

Ageing is currently only valid for the 2015 and 2017 surveys (i.e., compliant with the blue cod age determination protocol, Walsh 2017). Strong age classes at three and five years were apparent in 2017 for both sexes, and progression of age classes from 2015 to 2017 was evident. Length frequency distributions and mean lengths were similar among the three random-site surveys with any differences due to the strong recruitment of mainly juvenile male blue cod in 2015, progressing through to strong modes in 2017. In 2015 the random-site survey spawner-biomass-per-recruit ratio was 58% indicating that the level of exploitation (*F*) of Kaikoura blue cod stocks was below the F_{MSY} target reference point of $F_{45\%SPR}$ (underexploited) (Table 11). However, in 2017 the random-site survey spawner-biomass-per-recruit ratio was 34%, indicating that the level of exploitation (*F*) of Kaikoura blue cod stocks was above the F_{MSY} target reference point of $F_{45\%SPR}$ (over-exploited).

Motunau

There have been four fixed-site blue cod potting surveys off Motunau (2005, 2008, 2012, and 2016), (Carbines & Beentjes 2006a, 2009; Carbines & Haist 2018a; Beentjes & Sutton 2017). In 2012 and 2016 concurrent random-site potting surveys were also carried out and these are intended to replace fixed-site surveys in the future because the random surveys provide a more reliable indicator of stock status.

The most recent fixed site survey in 2016 had catch rates of 3.3 kg pot^{-1} (CV 13%), sex ratio of 76% male, estimated fishing mortality (*F*) of 0.62, and associated spawner-per-recruit ratio of 19% (Table 11). Corresponding values for 2016 random site survey were 2.5 kg pot^{-1} (CV 27%), 76% male, $F = 0.61$, and a spawner-per-recruit ratio of 19.2%. For both fixed- and random-site surveys, the level of exploitation of Motunau blue cod stocks in 2016 was greater than the Fisheries New Zealand F_{MSY} target reference point of $F_{45\%SPR}$.

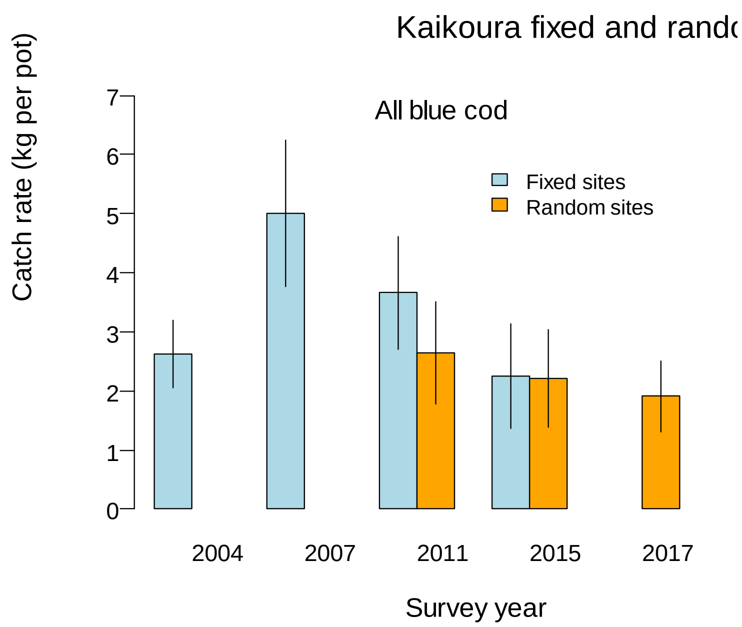


Figure 4: **Kaikoura fixed-site and random-site potting survey catch rates of all blue cod by survey year. Error bars are 95% confidence intervals.**

For the four fixed-site surveys, catch rates decreased markedly in 2008 and then again in 2016 with a three-fold decline between 2005 and 2016 (Table 11). Overall blue cod mean size steadily declined from 2005 to 2016, with the biggest decreases in 2016. The sex ratio for all blue cod was around 75% male for all fixed-site surveys with no trend. A strong juvenile mode in 2015 can be expected to contribute to increased abundance in about three to four years when these blue cod recruit to the fishery at 30 cm. Blue cod abundance and mean size off Motunau has declined and spatial distribution contracted over the eleven years from 2005 to 2016. The very high estimate of total mortality, truncated age composition, strongly skewed sex ratio toward males, and a spawner-per-recruit ratio less than half the target indicates that the blue cod population off Motunau was over-exploited in 2016. Further, as nearly all females and most males currently caught will be of sub-legal size (less than 30 cm), there is also likely to be significant mortality through catch and return of undersize fish.

North Otago

There have been four fixed-site blue cod potting surveys (2005, 2009, 2013, and 2018), and two random-site surveys off north Otago (2013 and 2018) (Beentjes & Fenwick 2019a). Random-site potting surveys are intended to replace fixed-site surveys, because they provide a more reliable indicator of abundance. The most recent random-site survey in 2018 recorded catch rates of 2.35 kg pot^{-1} (CV 18%), sex ratio of 87% male, and mean lengths of 30.2 cm and 26.7 cm for males and females respectively (Table 12, Figure 5).

For the four fixed-site surveys, catch rate was similar in 2005 and 2009, but in 2013 there was a decline with no overlap in the confidence intervals, and catch rates remained low in 2018. (Table 12, Figure 5). There are only two random-site surveys in the time series, but relative abundance showed a similar decline between 2013 and 2018 with no overlap in the confidence intervals. The sex ratio for all fixed-site surveys was 72–76% male for all blue cod with no trend, and 75–87% for the two random sites (Table 12). A preponderance of males is thought indicate high fishing intensity. The fixed-site scaled length frequency distribution shapes were similar for the 2005 and 2009, but changed in 2013 and again in 2018 with the latter having relatively fewer larger fish than earlier surveys. For the two random-site surveys the length frequency distributions were similar between years, but overall blue cod were slightly smaller in 2018 than 2013. Ageing is currently only valid for the 2018 survey (i.e., compliant with the blue cod age determination protocol, Walsh 2017) and showed strong modes at three, five, and eight years for both sexes, but particularly for males. The

2018 random-site survey spawner-biomass-per-recruit ratio was 23%, indicating that the level of exploitation (F) of north Otago blue cod stocks was above the F_{MSY} target reference point of $F_{45\%SPR}$, in 2018 (over-exploited) (Table 12).

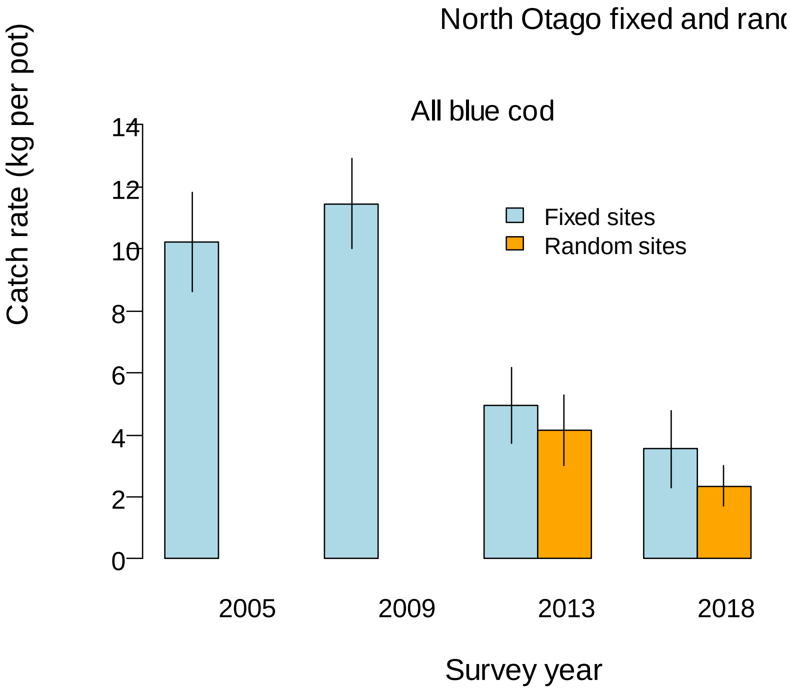


Figure 5: **North Otago fixed-site and random-site potting survey catch rates of all blue cod by survey year. Error bars are 95% confidence intervals. Surveys after 2005 include a new stratum (stratum 6).**

South Otago

There has been one fixed-site blue cod potting survey (2010), and three random-site surveys off south Otago (2010, 2013, and 2018) (Beentjes & Fenwick 2019b). The random-site surveys in 2013 and 2018 replaced fixed-site surveys. Random surveys provide a more reliable indicator of stock status and will be used solely in future south Otago. The first survey in 2010 was designed to compare fixed- and random-site potting survey designs and used only three of the six strata (Beentjes & Carbines 2011), with catch rates in fixed sites double that from random sites (Table 12, Figure 6). The most recent random-site survey in 2018 had catch rates of 1.52 kg pot^{-1} (CV 28%), a sex ratio of 68% male, and mean lengths of 29.0 cm and 24.9 cm for males and females, respectively (Table 12, Figure 6). There was a four-fold drop in catch rates between 2013 and 2018 random-site full strata surveys with no overlap in the confidence intervals, and this was largely mirrored in the three strata survey.

The sex ratio has varied from 60–70% male with no trend (Table 12) – a preponderance of males indicating high fishing pressure. The scaled length frequency distribution shapes for the random-site full strata surveys differed with 2013 having a strong juvenile mode and relatively more larger fish than 2018. Ageing is currently only valid for the 2018 survey (i.e., compliant with the blue cod age determination protocol, Walsh 2017) and showed strong modes at three, five, and eight years for both sexes, but particularly for males. This age structure mirrored that in north Otago in 2018. The 2018 random-site survey spawner-biomass-per-recruit ratio was 25%, indicating that the level of exploitation (F) of south Otago blue cod stocks was above the F_{MSY} target reference point of $F_{45\%SPR}$, in 2018 (over-exploited) (Table 12).

Foveaux Strait

There have been three random-site surveys in Foveaux Strait (2010, 2014, and 2018) (Beentjes et al 2019). The most recent random-site survey in 2018 had catch rates of 5.66 kg pot^{-1} (CV 20%), sex ratio of 51% male, and mean lengths of 30.6 cm and 28.4 cm for males and females respectively (Table 13, Figure 7). There is no clear trend in catch rates over the time series. Catch rates in Foveaux Strait, as of 2018, are the highest of all South Island surveys.

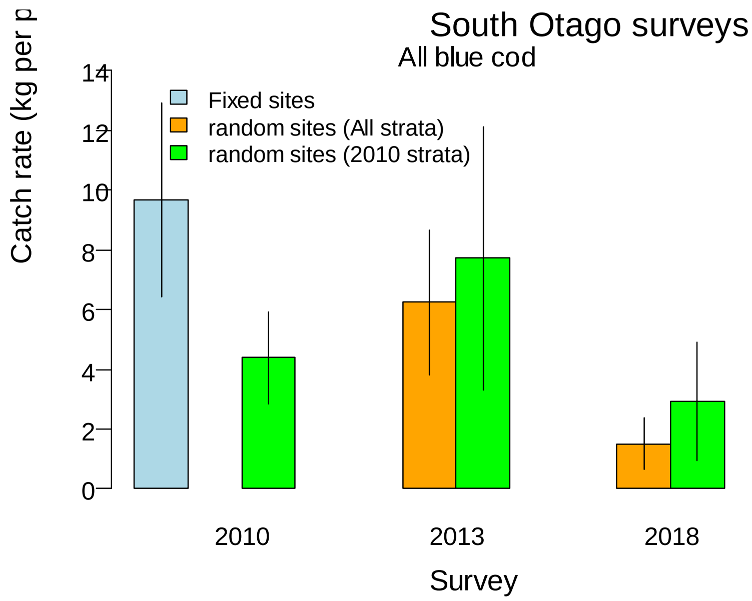


Figure 6: **South Otago fixed-site and random-site potting survey catch rates of all blue cod by survey year. Error bars are 95% confidence intervals. The 2010 survey used three strata, and subsequent surveys used 6 strata. Catch rates are also shown for the three strata used in 2010 for the random-site surveys.**

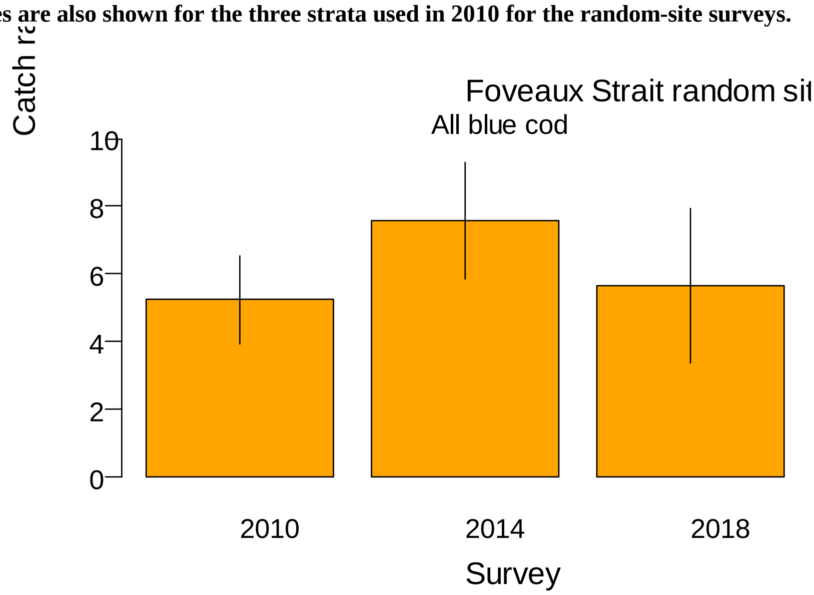


Figure 7: **Foveaux Strait random-site potting survey catch rates of all blue cod by survey year. Error bars are 95% confidence intervals.**

The sex ratio has varied from 47–51% male with no trend (Table 13). The scaled length frequency distributions and mean length of all blue cod were remarkably similar for all three surveys. Ageing is valid for all three surveys (i.e., compliant with the blue cod age determination protocol, Walsh 2017). The age structure of both males and females was generally similar among the three surveys with minor differences in the strength of some cohorts. The spawner-biomass-per-recruit ratios were 27%, 28%, and 22%, for 2010, 2014, and 2018 respectively, indicating that the level of exploitation (F) of Foveaux Strait blue cod stocks was above the F_{MSY} target reference point of $F_{45\%SPR}$, in all three surveys (over-exploited) (Table 13). However, a cautious approach should be taken in interpreting SPR estimates when so few age classes are included in the recruited population.

Paterson Inlet

There have been three fixed-site (2006, 2010, 2014), and three random-site blue cod potting surveys in Paterson Inlet (2010, 2014, and 2018) (Carbines 2007, Carbines & Haist 2014a, 2018, Beentjes & Miller 2020). Random-site potting surveys have replaced fixed-site surveys because they provide a more reliable indicator of abundance. All surveys have included the Ulva Island Marine Reserve as an additional stratum but all results in this report exclude the marine reserve. The most recent random-site survey in 2018 recorded catch rates of 1.5 kg pot^{-1} (CV 18%), sex ratio of 67% male, mean lengths of 29.6 cm for males and 27.2 cm for females, and mean ages of 5.3 years males and 6.1 years for females. Neither the fixed-site nor random-site survey time series show any clear indications of a change in relative abundance, size, or sex ratio, although there was a large increase in abundance between 2010 and 2014 for the random site series (Figure 8). More random-site surveys are required before trends can be reliably identified. Ageing is only valid for the 2018 random-site survey, which is compliant with the blue cod age determination protocol (Walsh 2017). In 2018, using a default *M* of 0.17, estimated fishing mortality (*F*) was 0.08, and the associated spawner biomass-per-recruit ratio (SPR) was 68% (95% confidence interval 49–100%) (Table 13). The point estimates of *Z*, *F*, and SPR in 2018 should be treated with caution because the traditional catch curve did not follow the ideal straight-line descending limb, suggesting that the assumption of constant recruitment had been violated.

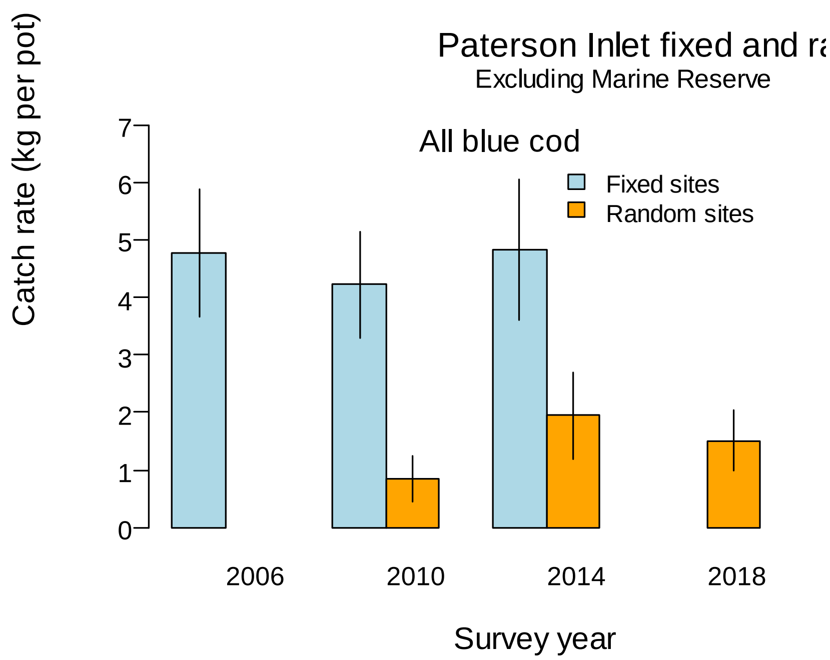


Figure 8: **Paterson Inlet random-site potting survey catch rates of all blue cod by survey year. Error bars are 95% confidence intervals.**

Dusky Sound

Three blue cod potting surveys have been carried out in the Dusky Sound. The surveys in 2002 and 2008 were both fixed-site surveys, whereas in 2014, independent fixed-site and random-site surveys were carried out concurrently.

In 2002 the overall mean catch rates for all blue cod from fixed sites were 2.65 kg pot^{-1} (CV = 9.2%) and 1.81 kg pot^{-1} for recruited blue cod ≥ 33 cm (CV = 8.7%). Catch rates were highest on the open coast (i.e., at the entrance to the Sound; Carbines & Beentjes 2003). The 2008 fixed site survey catch rates were 4.2 kg pot^{-1} (CV = 5.8%) for all blue cod and 3.15 kg pot^{-1} (CV = 5.9%) for recruited blue cod, considerably higher than in 2002 and again highest catch rates were in the open coast stratum (Carbines & Beentjes 2011a). In 2014 the fixed-site catch rates had declined to 3.22 kg pot^{-1} (CV = 11.9%) and 2.35 kg pot^{-1} (CV = 11.9%), respectively, with highest catch rates on the open coast. The 2014 random site catch rates were less than from fixed sites and were 2.61 kg pot^{-1} (CV = 8.6%) for all blue cod and 1.92 kg pot^{-1} (CV = 9.6%) for recruited blue cod, also with catch rates highest on the open coast (Beentjes & Page 2017). Overall scaled length and age distributions were similar between the fixed- and random-site surveys but the sex ratio favoured females in fixed sites (39% male) and was close to parity in random sites (52% male). Fixed site surveys may not be suitable for monitoring the Dusky Sound blue cod population, but at least one more dual fixed- and random-site survey is required before moving exclusively to random-site surveys.

Total mortality (*Z*) for blue cod from the 2014 random site survey was estimated at 0.25 with spawner-biomass-per-recruit (full recruitment at 8 years for females) estimated at $F_{49\%}$. Mortality estimates from the 2002 and 2008 surveys should not be used due to a recent change in the age determination protocol for blue cod.

Table 11: Summary statistics from standardised blue cod potting surveys of the northeast coast of the South Island (BCO 3). CPUE – catch per unit effort (kg.pot^{-1}); CV – coefficient of variation; Mean length is from population scaled length. All surveys from these three areas were reanalysed and reported in Beentjes & Page (2017) Beentjes & Sutton (2017), and Beentjes & Fenwick (2017), respectively. –, no valid ageing.

	Mean length (cm)		Survey	CPUE stratum range (CV) are	Sex ratio	$F_{\%SPR}$
Area/Year	Female	Male	(kg pot^{-1})	(kg pot^{-1})	% male	
North Canterbury						
Kaikoura						
2004 (fixed sites)	30.3	32.5	2.62	0.60–7.97 (11.1%)	48.7%	–
2007 (fixed sites)	29.8	32.5	5.0	1.91–20.45 (12.6%)	48.1%	–
2011 (fixed sites)	27.5	29.1	3.66	2.14–11.44 (13.3%)	53.0%	–
2011 (random sites)	28.5	29.5	2.64	0.61–8.22 (16.7%)	46.8%	–
2015 (fixed sites)	25.9	27.0	2.25	1.58–5.07 (20.2%)	66.3%	–
2015 (random sites)	29.0	30.0	2.21	0.48–9.41 (18.9%)	51.7%	58%
2017 (random sites)	28.6	28.4	1.9	0.00–6.92 (15.9)	44.8%	34%
Motunau						
2005 (fixed sites)	25.7	29.6	10.2	8.7–15.4 (11.4%)	76.6%	
2008 (fixed sites)	25.2	29.3	5.5	4.1–8.9 (16.1%)	77.9%	
2012 (fixed sites)	24.6	29.1	5.55	4.43–8.70 (11.8%)	71.9%	
2012 (random sites)	23.5	28.2	3.01	1.81–6.95 (19.5%)	72.1%	
2016 (fixed sites)	22.4	25.8	3.32	2.94–4.66 (12.7%)	75.5%	
2016 (random sites)	22.2	26.5	2.48	1.10–7.24 (26.8%)	76.3%	
Banks Peninsula						
Inshore						
2002	25.4	28.3	1.12	0.04–2.61 (23.2%)	67.9%	
2005	27.2	32.7	2.78	1.02–4.16 (12.2%)	74.2%	
2008	25.5	29.8	1.08	0.07–2.30 (17.8%)	70.2%	
2012 (fixed sites)	24.7	28.8	1.35	0.60–1.88 (12.4%)	67.2%	
2012 (random sites)	22.8	27.3	1.23	0.33–2.89 (16.6%)	66.1%	
2016 (fixed sites)	23.2	26.5	1.26	0.57–2.12 (11.8%)	67.5%	
2016 (random sites)	23.8	26.1	0.53	0.09–0.94 (22.2%)	81.3%	
Offshore						
2002	36.6	37.6	3.39	2.04–4.74 (19.9%)	41.8%	
2005	37.4	41.2	6.48	5.68–7.27 (9.4%)	57.2%	
2008	35.6	41.8	4.48	3.13–5.80 (13.8%)	49.8%	
2012 (fixed sites)	33.5	37.4	4.88	3.49–6.28 (17.0%)	55.9%	
2012 (random sites)	34.1	39.3	3.77	3.69–4.09 (36.2%)	59.0%	
2016 (fixed sites)	33.6	36.8	5.6	5.09–6.10 (14.1%)	65.2%	
2016 (random sites)	36.1	41.3	5.08	5.21–4.54 (19.5%)	57.5%	

Table 12: Summary statistics from standardised blue cod potting surveys carried out in the southeast coast of the South Island (BCO 3). CPUE – catch per unit effort (kg pot^{-1}); CV – coefficient of variation; Mean length, are from population scaled length. All north Otago survey outputs from Beentjes & Fenwick (2019a). South Otago survey 2010 outputs from Beentjes (2012) and subsequent surveys from Beentjes & Fenwick (2019b). *, no stratum 6 in 2005; **, only strata 1, 3, and 6 surveyed in 2010; –, no valid ageing.

	Mean length (cm)		Survey CPUE		Sex ratio	$F_{\%SPR}$
Area/Year	**Female**	**Male**	**(kg pot^{-1})**	**CPUE range (CV)**	**(% male)**	
North Otago						
2005(fixed sites)*	27.8	32.8	10.2	7.49–14.5 (7.9%)	72.5	–
2009 (fixed sites)	27.4	32.3	11.5	6.21–19.88 (6.6%)	73.1	–
2013 (fixed sites)	27.5	31.7	5.0	2.72–8.07 (12.6%)	75.9	–
2013 (random sites)	27.5	30.7	4.2	0.94–7.46 (13.9%)	67.8	–
2018 (fixed sites)	26.3	30.4	3.55	2.24–5.30 (17.7%)	84.9	23%
2018 (random sites)	26.7	30.2	2.35	0.33–4.12 (14.3%)	87.0	23%
South Otago						
2010 (fixed sites)**	29.4	33.6	9.7	3.3–16.9 (17.1%)	74.5	–
2010 (random sites)**	23.7	29.0	4.4	1.2–6.0 (17.8%)	66.9	–
2013 (random sites)	25.5	31.9	6.2	0.8–7.4 (19.9%)	57.4	–
2018 (random sites)	24.9	29.0	1.52	0.17–3.79 (28.5%)	68.4	25%

Table 13: Summary statistics from standardised blue cod potting surveys carried out in the south and southwest coast of the South Island (BCO 5). $F_{\%SPR}$ estimated for age at full recruitment and M = 0.14 except Paterson Inlet where M is 0.17. Mean length, mean age, and sex ratios are from population scaled length and age. Foveaux Strait survey - all results from Beentjes et al (2019); Paterson Inlet survey excludes Ulva Island Marine Reserve –all results from Carbines (2007), Carbines & Haist (2014a), Carbines & Haist (2018), Beentjes & Miller (2020); Dusky Sound excludes Five Fingers Marine Reserve – all results from Carbines & Beentjes (2003), (2011a) and Beentjes & Page (2016). Only mean ages and $F_{\%SPR}$ based on otoliths aged with the Age Determination Protocol (Walsh 2017) are included in this table. CPUE, catch per unit effort (kg pot^{-1}); CV, coefficient of variation.

	Mean length (cm)		Mean age (years)		CPUE	CPUE range (CV)	Sex ratio % male	$F_{\%SPR}$
Area/Year	**Female**	**Male**	**Female**	**Male**	**(kg pot^{-1})**	**or set-based***	**(MWCV around age)**	
Foveaux Strait								
2010 (random sites)	27.7	30.4	5.8	5.2	5.25	0.81 – 14.14	47.2%	26.9%
2014 (random sites)	27.7	30.3	6.0	4.9	7.57	3.16 – 16.22	48.0%	27.6%
2018 (random sites)	28.4	30.6	6.8	5.7	5.7	1.47–8.40 (20.5%)	50.7%	21.8%
Paterson Inlet								
2006 (fixed sites)	26.9	32.8			4.8	1.47 – 8.42 (11.9%)	55.5%	
2010 (fixed sites)	27.5	32.2			4.2	1.5 – 6.6 (11.1%)	75.1%	
2010 (random sites)	25.9	29.0			0.82	0.23 – 1.4 (24.1%)	61.5%	
2014 (fixed sites)	26.9	32.3			4.8	1.05 – 7.66 (12.9%)	75.3%	
2014 (random sites)	27.0	29.9			1.94	0.44 – 2.73 (19.9%)	67.5%	
2018 (random sites)	27.2	29.6	6.1	5.3	1.51	0.59–2.72 (17.7%)	67.0%	68%
Dusky Sound								
2002 (fixed sites)	29.9	34.7			2.95	1.29–8.43 (10.8%)		
2008 (fixed sites)	32.2	37.9			4.20	2.49 – 8.13 (5.8%)		
2014 (fixed sites)	32.6	35.2	8.1	6.9	3.22	1.87–9.2 (11.9%)		48.3%
2014 (random sites)	32.3	33.8	8.2	6.5	2.61	2.04–4.99 (8.6%)		49.0%

4.1.2 Trawl survey estimates
Relative abundance indices from trawl surveys are available for BCO 3, BCO 5, and BCO 7, but these have not been used because of the high variance and concerns that this method may not appropriately sample blue cod populations.

4.1.3 CPUE Analyses

BCO 3
A standardised CPUE analysis was conducted in 2019 on the target blue cod potting fishery operating in BCO 3. This fishery accounted for two-thirds of the total BCO 3 landings in the 29 years from 1989–90 to 2017–18, predominantly in the two southernmost BCO 3 Statistical Areas: 024 and 026. Together these two areas represented about 90% of the total target blue cod potting fishery over the same 29 years (Figure 9). As found in the previous analyses, there was misreporting of RCO 3 landings as BCO 3, probably due to data entry errors (Starr & Kendrick 2010). This problem was again resolved before undertaking the CPUE analysis.

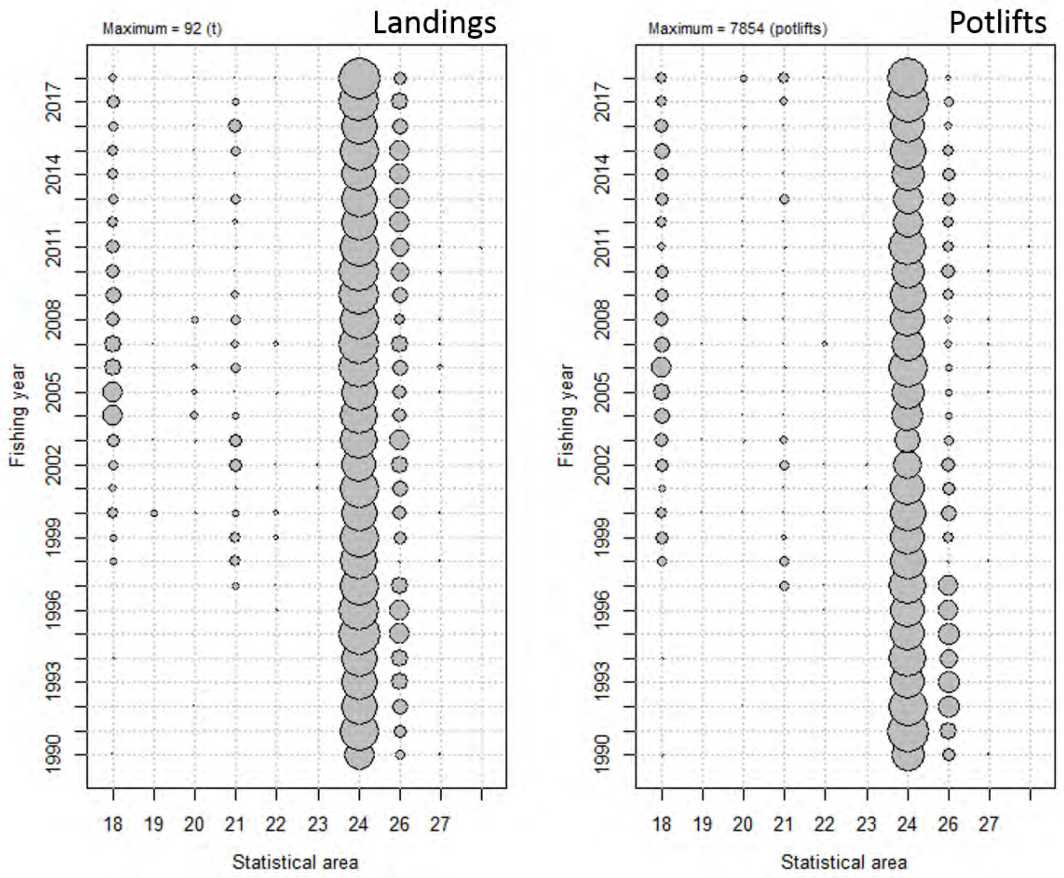


Figure 9: Distribution of landings and number of potlifts for the cod potting method by statistical area and fishing year from trips which landed BCO 3. Circles are proportional within each panel: [landings] largest circle = 92 t in 2011 for 024; [number potlifts] largest circle = 7854 pots in 2006 for 024 (Large et al in prep.).

The effort data were matched with the landing data at the trip level and the "trip-stratum" stratification inherent in the CELR data was maintained. The 2019 analysis used only data from Statistical Areas 024 and 026. The CPUE analysis was confined to a set of core vessels which had participated consistently in the fishery for a reasonably long period (5 trips in 3 years), resulting in keeping 61 vessels representing 94% of the landings. The explanatory variables offered to the model included fishing year (forced), month, vessel, statistical area, number of pots lifted in a day and number of days fishing in the record. A log-logistic model (as used in the 2015 analysis) based on successful catch records was used because there were too few unsuccessful fishing events to justify pursuing a binomial model.

The log-logistic standardised model for BCO 3 (Figure 10) fluctuated without trend with the final data point close to the series mean. In the 2015 analysis, a model using estimated catches instead of scaled landings showed a similar trend up to 2012–13, when the series based on landed catch increased more rapidly than the estimated catch series. The Southern Inshore Working Group agreed in 2015 that the series based on landed catch was more reliable and consistent with other CPUE analyses done for the working group.

During 2002–03 to 2017–18, commercial catches in BCO 3 exceeded the TACC by 5%. The bulk of the total BCO 3 commercial catch (72%) was taken from Statistical Areas 024 and 026 (along with about 90% of the CPUE data). The CPUE series shown in Figure 10 is representative of the southern portion of BCO 3 (Statistical Areas 024 and 026) and is not applicable to those parts of BCO 3 north of Statistical Area 024.

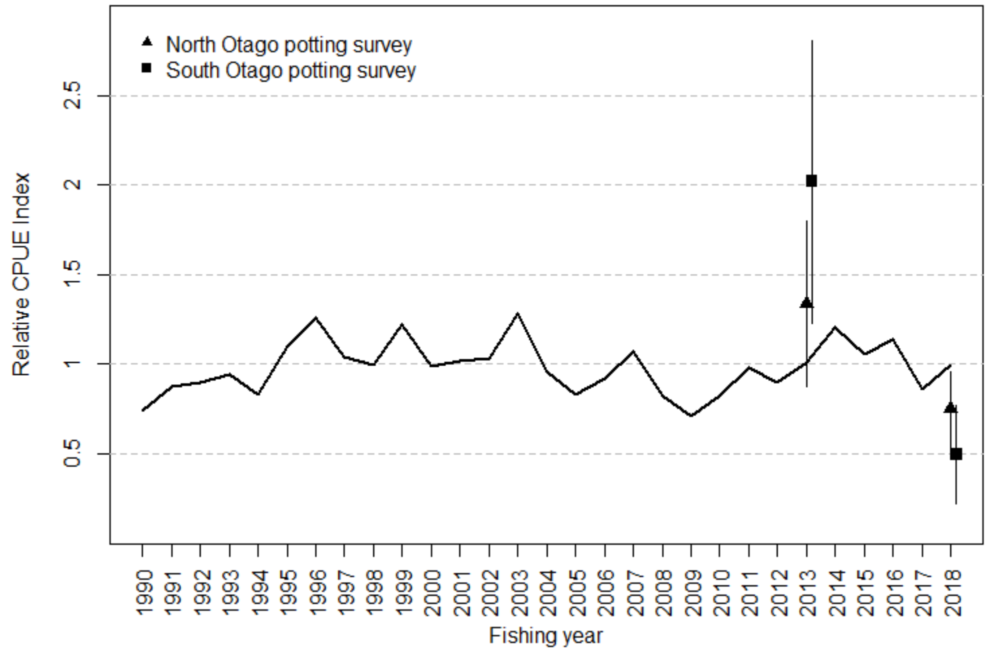


Figure 10: Comparison of BCO 3 standardised series (1989–90 to 2017–18) based on landed green weight catch data and the 2013 and 2018 observations from the North Otago and South Otago potting surveys conducted at random sites over all strata (Large et al in prep.). (Each relative series is scaled so that the geometric mean equals 1.0 from 2013 to 2018.)

Establishing B_{MSY} compatible reference points

The Working Group accepted the mean CPUE from the target BCO cod potting series for the period 1994–95 to 2003–04 as the B_{MSY}-compatible proxy for BCO 3. This period was chosen because catches and CPUE were stable without trend and apparent productivity was good. This period was also used to determine average fishing intensity compatible with the selected B_{MSY}-compatible proxy. The Working Group accepted the default Harvest Strategy Standard definitions for the Soft and Hard Limits at one-half and one-quarter the target, respectively.

4.3 BCO 4

The cod potting fishery in BCO 4 is entirely targeted on blue cod and reported on the daily CELR form. The spatial resolution of the catch effort data is therefore defined by general statistical area, and by day (or part of a day). CPUE was standardised for the cod pot fishery operating in Statistical Areas 049 to 052 (Large et al in prep.). The analysis was based on a Weibull model of positive allocated landed catches from a core fleet of vessels. This methodology follows that used in the previous CPUE standardisation (Bentley & Kendrick in prep). Detailed examination of model residuals and the distribution of catch per vessel day suggested that the Weibull distribution provided a better fit to the data than the lognormal distribution and other alternative distributions. The previous analysis found that there appears to have been a change in the underlying frequency distribution of catch categories in the late 1990s, which may be a result of several factors, including changes in the fleet composition, fishing methods, and/or reporting practices. Consequently, the indices for the fishing years up to, and including, 1996–97 are considered to be less reliable and may not be comparable with the indices from the latter part of the series. The working group considered that the current CPUE standardisation should only include analysis of the fishing years from 1997–98.

Overall, the annual indices from the standardisation model have fluctuated without trend since the late 1990s (Figure 11).

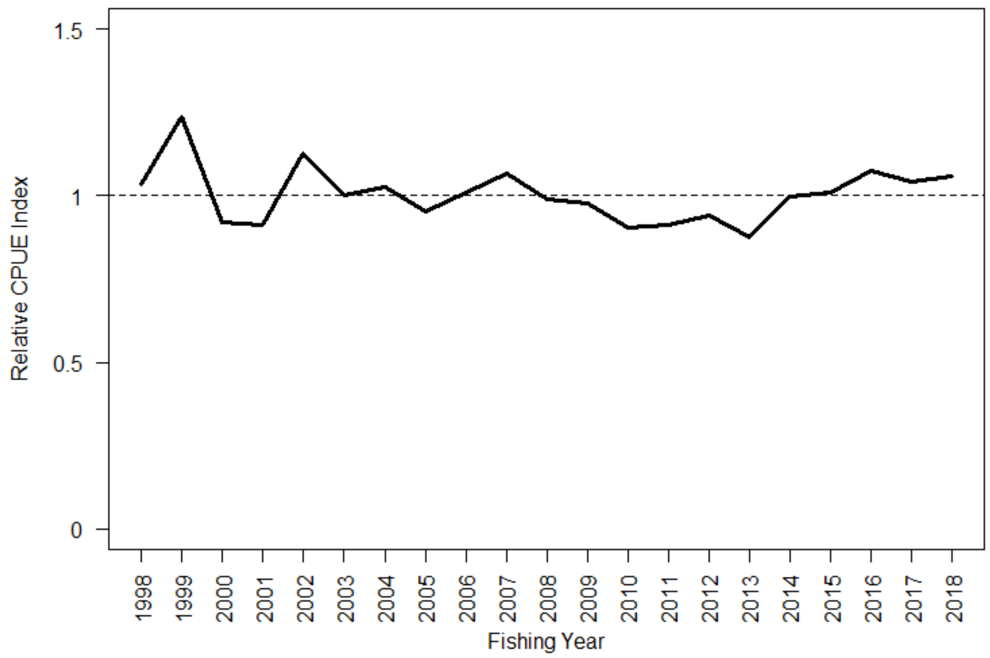


Figure 11: Standardised CPUE index for BCO 4 based on records of positive BCO catch by core vessels, 1997–98 to 2017–18 (Large et al in prep.).

4.4 BCO 5 (Southland)

The first fully quantitative stock assessment for blue cod in BCO 5 was carried out in 2013 (Haist et al 2013). A custom-built length-based model, which used Bayesian estimation, was fitted separately to data from Statistical Areas 025, 027, and 030. A second stock assessment was completed in 2019, but it switched to an age-based Bayesian model and the assessment was conducted using NIWA's CASAL2 assessment package. Again, the model was fitted separately to data from Statistical Areas 025, 027, and 030.

4.4.1 Methods

4.4.1.1 Model structure

The stock assessment model was aged-based with the population partitioned into six categories: male and female combined with three growth morphs. The growth morphs were fast, medium, and slow growth. Each morph had a normal length distribution at each age and they were constrained to combine into a normal length distribution-at-age with the same spread of length-at-age as observed in potting survey catches. Because fish cannot unambiguously be assigned to any one growth morph, observed data for each morph are not available. The pot fishery operates under a legal minimum size (MLS) and the morph construct helps the model "remember" length distributional changes as a cohort grows past the MLS; i.e., once a cohort is completely recruited into the fishery, its length distribution is asymmetrical.

There are three fisheries: commercial line, commercial pot, and recreational line. Each fishery was modelled with a selectivity ogive and a retention ogive (Table 14), so catch data were a function of the selectivity ogive and landings data were a function of the product of selectivity and retention ogives. There were three time blocks for the pot fishery selectivity: pre-1994, 1994 to 2017, and 2018 onwards. These periods mirror the changes in regulations starting with the change in MLS (30 to 33 cm) in 1994, and the change in commercial pot mesh sizes in 2018. Discard mortality was assumed for fish that were caught but not landed.

Spawning stock biomass (SSB) is measured as the total mature biomass. A Beverton-Holt stock recruitment relationship was assumed. The CV of recruitment residuals was fixed at 0.6 and the steepness was assumed to be 0.75. Recruitment residuals were estimated for 1980 to 2014. Fish recruited to the model at age 1+ with 50% of fish recruiting as females. The populations were initialised at unexploited equilibrium conditions in 1900.

The informed prior distributions for model parameters are given in Table 15. Other parameters had uniform priors.

Table 14: Model selectivity and retention ogives by fishery, their parametric form, and parameter values if fixed or data fitted in the model to inform their estimation. AF is age frequency data; LF is length frequency data.

Ogives	Type	Parameters if fixed or data to inform
Selectivity		
Commercial line fishery	Logistic	50% selected at 280 mm; 95% selected at 305 mm
Commercial pot fishery ≤ 1993	Logistic	Mesh size trial LF
Commercial pot fishery 1994–2017	Logistic	Logbook sampling LF
Commercial pot fishery ≥ 2018	Logistic	2015 pot experiment & commercial AF
Recreational fishery	Logistic	Recreational catch LF
Survey	Logistic	Survey AF
Retention		
Commercial line fishery	Knife-edge	MLS (300 mm)
Commercial pot fishery ≤ 1993	Knife-edge	MLS (300 mm)
Commercial pot fishery 1994–2017	Knife-edge	MLS (330 mm)
Commercial pot fishery ≥ 2018	Knife-edge	MLS (330 mm)
Recreational fishery ≤ 1993	Knife-edge	MLS (300 mm)
Recreational fishery ≥ 1994	Knife-edge	MLS (330 mm)

Table 15: Assumed informed prior distributions for model parameters.

Model parameters	Distribution	Parameters/ bounds
Recruitment variation	Lognormal	CV: 0.60

As a sensitivity, sex change was modelled as a dynamic process, with the proportion of females transitioning to males as a function of age. Since there was little indication from the pot survey age data that sex change was occurring in the mature population, it was concluded that sex change probably occurred in the period before maturation. The sex ratio for mature fish was assumed to be 1:1.

4.4.1.2 Data

Separate data sets were compiled and analysed for Statistical Areas 025, 027, and 030. The data available for each of these areas differs, and little data were available for the remainder of the BCO 5 Statistical Areas. Data for Statistical Areas 025, 027, and 030, when combined, represent 92% of the recent commercial fishery landings. The general categories of data used in the stock assessment models included: landings, fishery length frequency data (LF), fishery and survey age frequency data (AF), abundance indices from standardised CPUE (all areas) and from fishery independent potting surveys (Statistical Area 025 only), and biological information on natural mortality, growth, and maturation.

Historical time series of BCO 5 landings were constructed for three gear types: commercial hand line fishing, commercial pot fishing, and recreational line fishing. Additionally, non-reported blue cod catch used as bait in the CRA 8 rock lobster fishery was estimated and included with the commercial landings, and customary catch estimates were included with the recreational harvest. The constructed catch history prior to 2012 was the same as that used in the 2013 stock assessment (Haist et al 2013), and is presented in Figure 12.

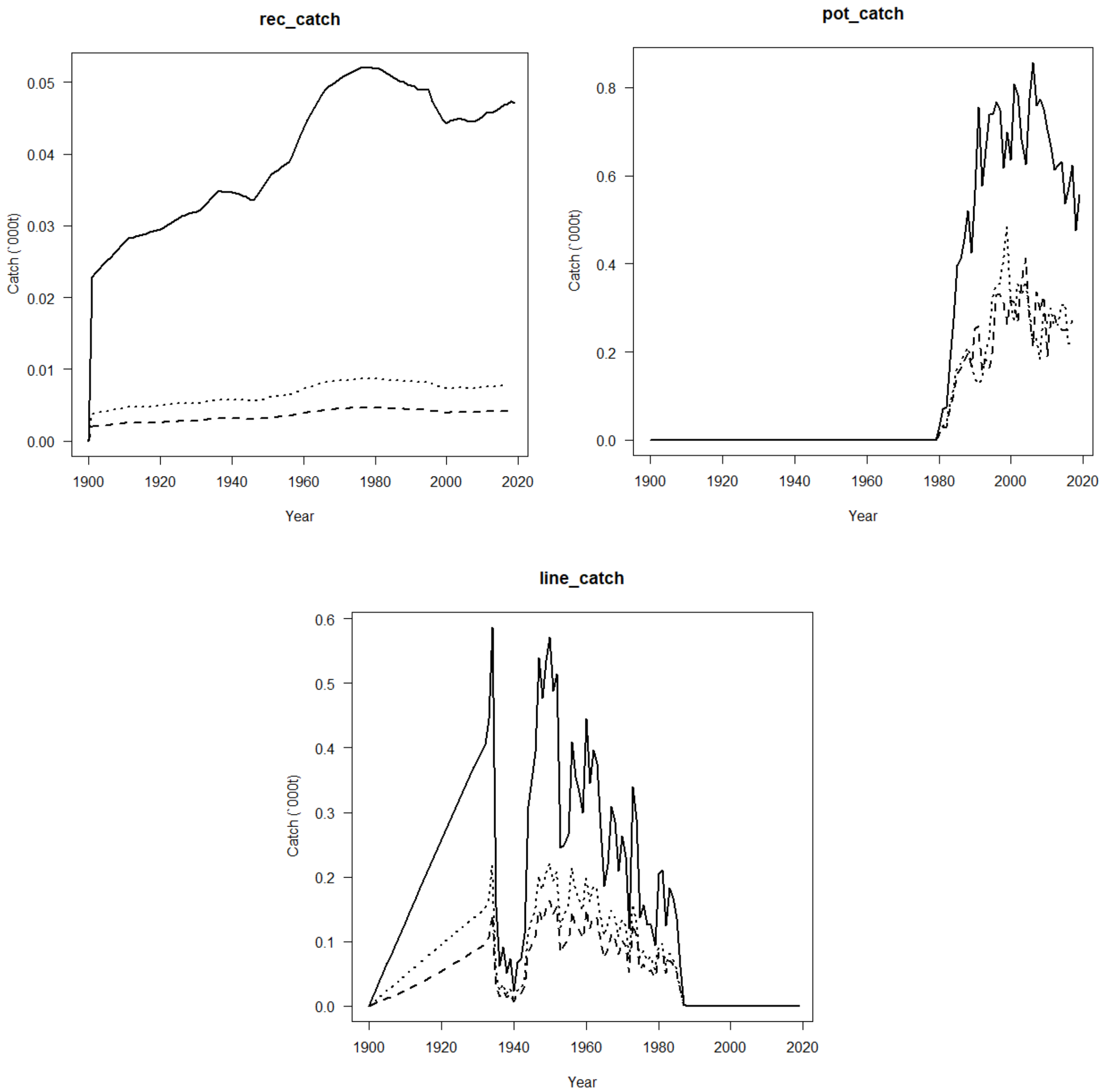


Figure 12: Constructed catch history used in the assessments by fishery and Statistical Areas 025 (solid line), 027 (dashed line), & 030 (dotted line).

Commercial landings data were available from 1931 (Warren et al 1997) and these were linearly decreased back to 1900, when the fishery was assumed to begin. The 1989–90 to 2011–12 average proportion of the total BCO 5 catch in each Statistical Area was used to prorate the earlier landings estimates to Statistical Area. A time series of non-reported blue cod used as bait in the rock lobster fishery was developed based on a 1985 diary study (Warren et al 1997), in conjunction with CRA 8 rock lobster landings.

A time series of recreational blue cod harvest was developed based on the 1991–92 and 1996 diary survey estimates of BCO 5 recreational catch. The average blue cod catch per Southland resident was estimated from the survey data and, assuming a constant per capita catch rate, was extrapolated to a time series using Southland District population census data.

Commercial fishery LF data were collected through a commercial fishers' logbook project and a shed sampling project from 2009–2011. The shed sampling was sex-specific whereas the logbook sampling was not. Mean size of fish from the shed samples were smaller than those from the logbook programme (for Statistical Areas 025 and 027; there were not shed samples from Statistical Area 030), due to these data being from the last catch of the day, which was likely to be from inshore waters close to the sheds (so the fish would not spoil), where exploitation rates were higher. The logbook LF data were fitted to model predictions of the commercial catch size distribution for 2010, and as a sensitivity, the logbook LFs were replaced by the shed LFs.

Recreational fishery LFs were obtained from a 2009–10 study of the Southland recreational blue cod fishery (Davey & Hartill 2011). This study included a boat ramp survey (Bluff, Riverton/Colac Bay, and Halfmoon Bay) and a logbook survey of charter and recreational vessels. Blue cod measured through the boat ramp programme were assumed to represent the landings, and fish measured through the logbook programme were assumed to represent the catch. Only the logbook data were fitted in the model.

Length frequency data from a blue cod mesh-size selectivity study, conducted by MAF in 1986 at Bluff and Stewart Island, were available. The LF from pots fitted with the then-standard 38 mm mesh were assumed to represent the size composition of the BCO 5 commercial pot fishery catch before the 1994 pot regulation changes. In preparation for a further change in mesh size regulations in 2018, different mesh sizes were trialled at various sites close to land in 2015 (Glen Carbines, pers. comm.). The data for the new mesh sizes were fitted to the 2018 size frequency. Both experiments did not catch a representative sample of the larger fish given the restricted range of sites used. Consequently, the model was fitted to just the left hand limb (LHS), since its use was for catch selectivity estimation.

Length frequency data were also available from random stratified potting surveys conducted in Statistical Areas 025 and 030 in 2010, 2014, and 2018. These surveys also provide age frequency (AF) data by sex.

There are two stock abundance estimates: fishery-based standardised CPUE estimates (Table 16), and pot survey estimates of abundance.

The data fitted in the models for each Statistical Area are shown in Table 17, and the assumed error structure of each data series is shown in Table 18.

Table 16: Standardised CPUE indices for Statistical Areas 025, 027, and 030, for fishing years 1990–2018.

Fishing Year	Area 025	Area 027	Area 030	Fishing Year	Area 025	Area 027	Area 030
1990	1.01	0.59	1.04	2005	1.32	1.25	1.24
1991	0.81	0.62	0.97	2006	1.26	1.18	1.27
1992	0.79	0.66	1	2007	1.09	0.96	1.14
1993	0.8	0.85	0.89	2008	1.02	0.88	0.95
1994	0.81	0.61	0.65	2009	1.03	0.88	1.04
1995	0.84	0.91	0.69	2010	0.9	0.82	1.01
1996	0.97	1.07	0.7	2011	0.98	1.01	0.86
1997	1.08	1.24	1.15	2012	0.98	0.98	0.81
1998	1.06	1.13	1.2	2013	0.96	0.92	0.91
1999	0.96	1.11	1.32	2014	1	0.84	0.96
2000	1.12	1.32	1.13	2015	0.93	0.92	0.96
2001	1.23	1.65	1.18	2016	0.92	0.97	0.85
2002	1.31	1.75	1.35	2017	0.92	1.01	0.89
2003	1.27	1.51	1.35	2018	0.76	0.9	0.82
2004	1.23	1.63	1.23				

Table 17: Data series fitted in the stock assessments for Statistical Areas 025, 027, and 030. AF is age frequency data; LF is length frequency data.

Data type	Series	Area 025	Area 027	Area 030
AF data				
	Survey	✓	–	–
	Pot fishery	✓	✓	✓
LF data:				
	Logbook	✓	✓	✓
	Mesh selectivity trials (1986)	data common to all areas		
	Recreational catch	data common to all areas		
	Mesh selectivity trials (2015)	data common to all areas		
Abundance Index:	CPUE	✓	✓	✓
	Survey	✓	–	–

Table 18: Assumed distributions for data fitted in the models. AF is age frequency data; LF is length frequency data. N is effective sample size.

Data type	Distribution	Parameters
Survey abundance	Lognormal	CV: 0.20
Survey AF	Multinomial	N: 100
Pot fishery AF 2018	Multinomial	N: 100
2019	Multinomial	N: 5
CPUE	Lognormal	CV: 0.10
Logbook LF	Multinomial	N: 100
Mesh size trials LF (1986)	Multinomial	N: 20
Mesh size trials LF (2015)	Multinomial	N: 20
Recreational catch LF	Multinomial	N: 100
Ages	Off-by-one, binominal	P: 0.086
Sensitivities		
Shed samples LF	Multinomial	N: 100

4.4.1.3 Further assumptions

Age data to estimate sex-specific von Bertalanffy growth parameters were available from the random-stratified potting surveys and the commercial AFs. The same growth model was assumed for all areas. For males, the L_∞ parameter was not well estimated because data were sparse at L_∞ due to fishing pressure. Male L_∞ was therefore estimated within the model. The potting surveys also had maturity data which gave maturity as logistic with A_{50} of 4.1 y and A_{50to95} of 2.47 y for both sexes.

4.4.1.4 Biomass estimates

The assessment was conducted in two steps. First, a set of initial exploratory model runs was carried out generating point estimates (MPD runs, which nominally estimate the mode of each posterior distribution). The purpose of the MPD runs was to decide which sets of assumptions should be carried forward to the final runs and to quantify the sensitivities of the MPD to the assumptions used. The final runs were fully Bayesian, estimating posterior distributions for all quantities of interest. The base-case model run consisted of separate stock assessments for Statistical Areas 025, 027, and 030, with the results combined to provide results for BCO 5. Natural mortality was fixed at 0.17.

The MPD $B_{CURRENT}$ ($\%B_0$) for the base case was estimated at 31.2%. When M was set at 0.15, $B_{CURRENT}$ was 29.4%, and when M was set to 0.19, it was 33.1%. The largest change occurred when the LF data from the logbook programme were replaced with that from the shed sampling programme; this reduced $B_{CURRENT}$ to 23.9%. The latter was considered unlikely, because the shed length data have a lower proportion of large fish than that from the logbook data because of the differences in the way the fish were sampled. The logbook length data were preferred by the working group. Other sensitivities model runs included:

Sensitivity	$B_{CURRENT}$ (% B_0)
Commercial discard mortality of 50%	31.6
Sex change in model (also single growth path)	32.0
Single growth path	31.6
Single stock assessment	33.0

Bayesian posterior distributions were estimated for the base-case model using a Markov chain Monte Carlo (MCMC) approach. For each run a chain of 1 million was completed and the chains thinned to produce a posterior sample of 1000. BCO 5 summary statistics are calculated by summing across Statistical Areas 025, 027, and 030, and BCO 5 catch is calculated assuming these areas account for 92% of the BCO 5 stock. The model estimates are summarised in Table 19 (estimates of spawning biomass), Figure 13 (biomass trajectories), and Figure 14 (recruitment trajectories).

Table 19: Estimates of BCO 5 unfished spawning stock biomass and current spawning stock biomass as a percentage of the unfished level for the final runs (medians of marginal posterior distributions, with 95% confidence intervals in parentheses). B_0 is calculated assuming Areas 025, 027 and 030 represent 92% of the BCO 5 blue cod stock.

Run	B_0 **(000 t)**	$B_{CURRENT}$ **(%** B_0**)**
base	21(20,23)	36 (31,41)

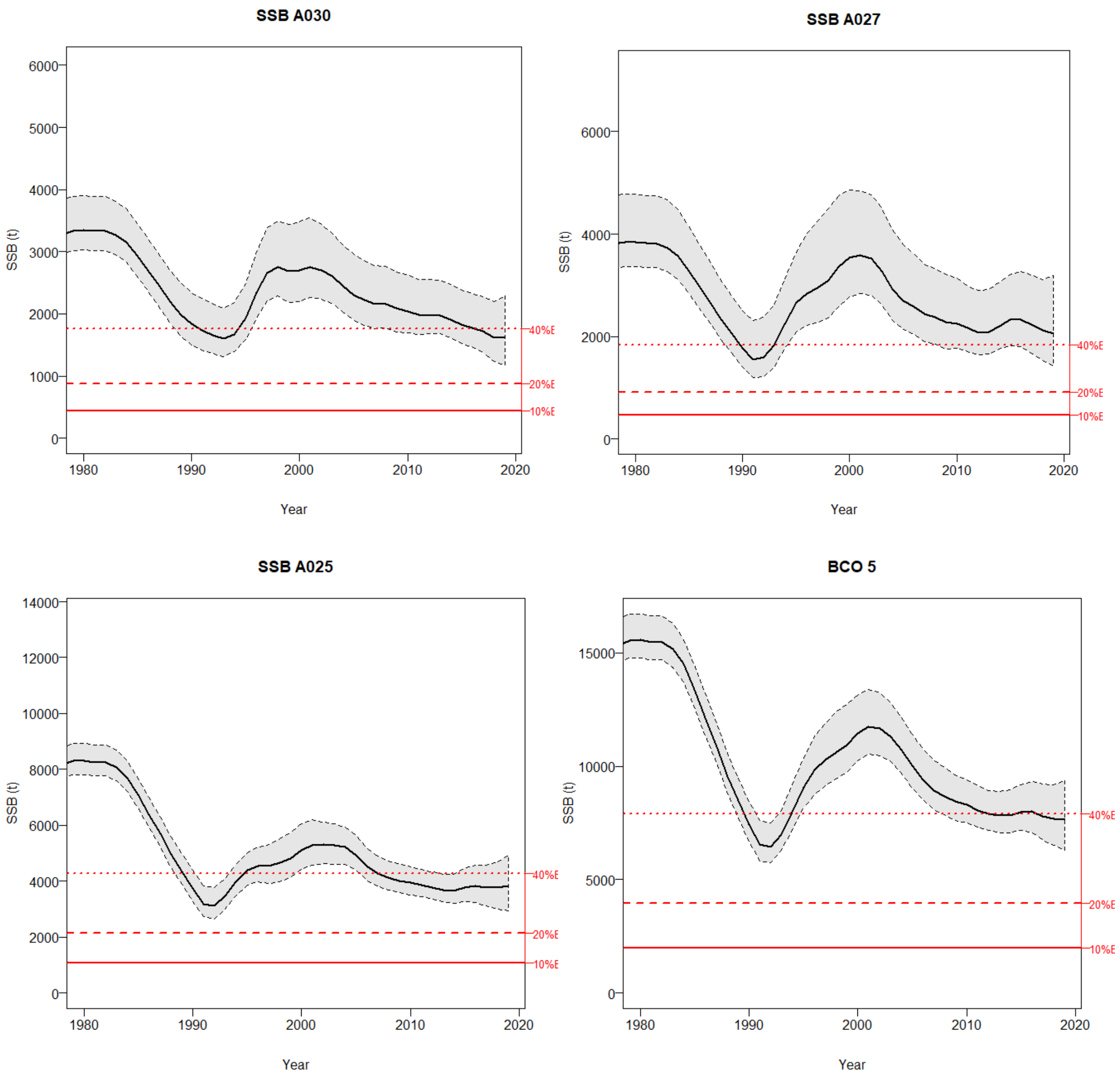


Figure 13: Median estimates of spawning biomass for Statistical Areas 025, 027, and 030, and the three areas combined, for the base-case model runs, 1980–2019.

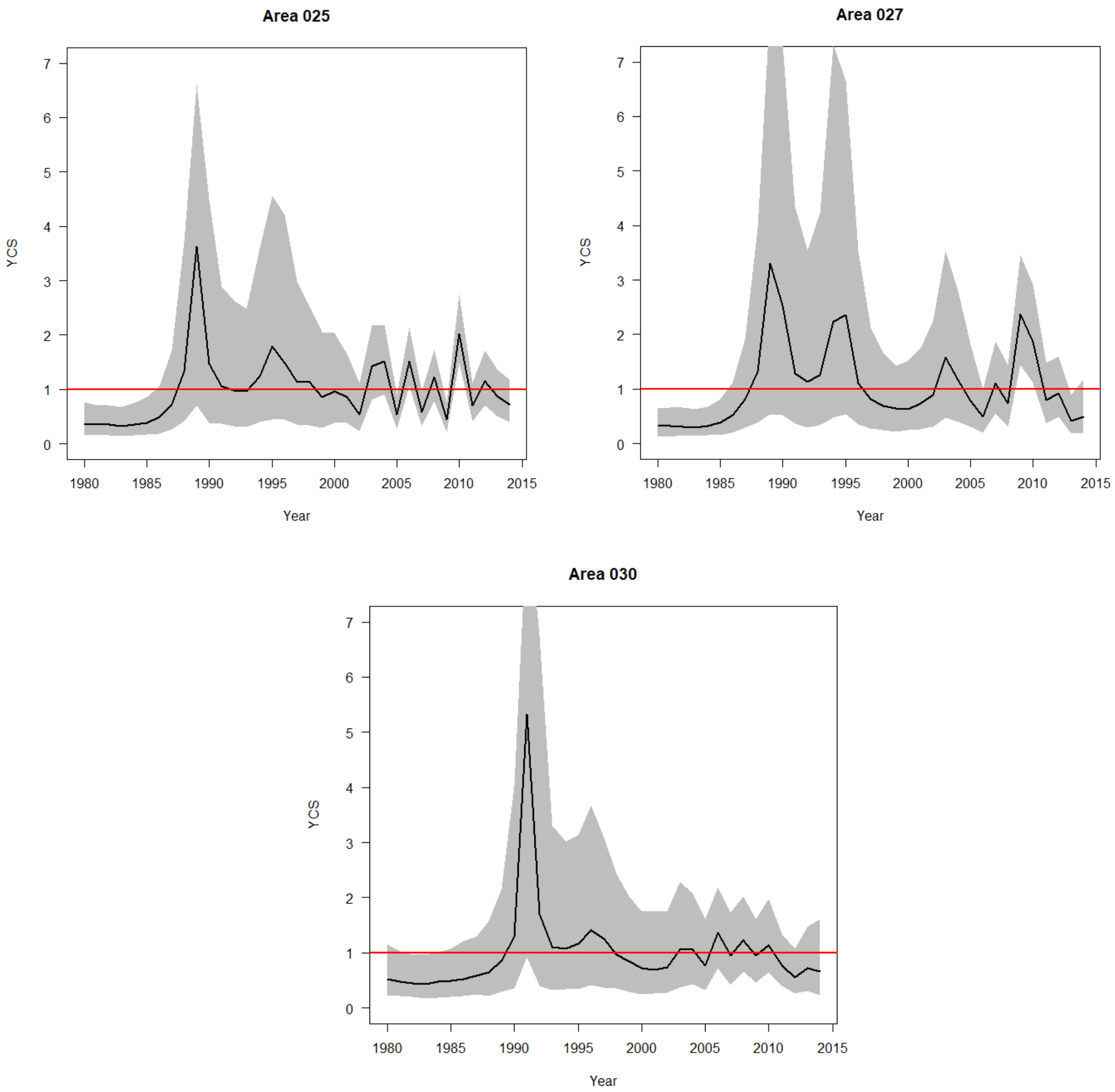


Figure 14: Year Class Strength (YCS) from the base-case runs for Statistical Areas 025, 027, and 030, for 1980–2014. Medians are shown by the black line and the shaded areas show the 95% range limits.

4.4.1.5 Yield estimates and projections

Ten-year stock projections were conducted for the three statistical areas at constant catch levels, with summary statistics calculated at the end of 5 and 10 years. These are based on the MCMC results.

In the stock assessment, the 2018–19 commercial catch level was set at the average of the years (2015–16, 2016–17, and 2017–18). This level of catch was also used in projections based on current catch for the years 2019–20 onwards, and the 2018–19 catch was recalculated based on returns-to-date (as of 8 November 2019) of 804.8 t, which was allocated to the assessment areas based on their fraction of catch to the total. An alternative catch scenario was simulated with commercial catch reduced by 20%.

Recruitment was simulated by randomly re-sampling (with replacement) from the 2005–14 recruitment deviates, applied to the stock-recruitment relationship. Summary statistics were calculated for the BCO 5 QMA by summing B_0 and projected biomass estimates across the three statistical areas.

The projections indicate that under the assumptions of commercial catch at current levels and recruitment at recent levels, the BCO 5 biomass is likely to decline gradually over the next 10 years

(Figure 15). Although the spawning stock sex ratio is variable among the sensitivity trials, by 2013 and through the projection period, the sex ratio remains relatively constant (Table 20).

The probabilities of the projected spawning stock biomass (2018 and 2023) being below the hard limit of 10% B_0, the soft limit of 20% B_0 or above the target of 40% B_0, are presented in Table 21, for the base case model with recent recruitment for the sensitivity runs with recent recruitment and commercial catch at current levels and with a reduction of 20%. With catches at current levels, the probability of the stock being less than either the soft or hard limit over the next five years is negligible.

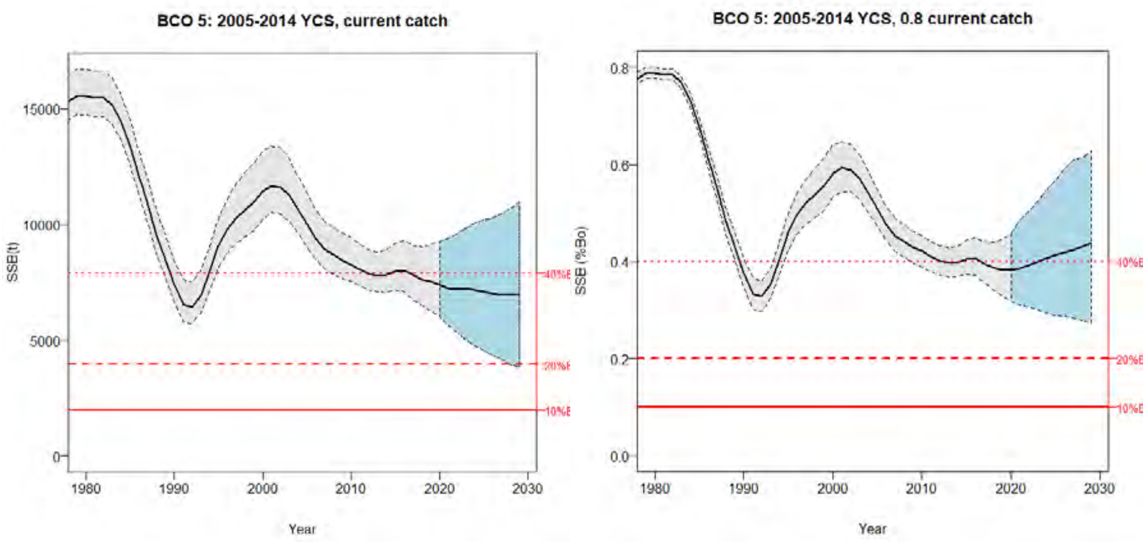


Figure 15: Projected BCO 5 spawning biomass (%B_0) assuming recent recruitment and catch at current levels and at 80% of current levels for the base case run. Median estimates are shown as solid lines and 95% confidence intervals as shaded polygons. Projections start in 2020.

Table 21: Probabilities of SSB being below B_0 reference levels in 2019, 2024, and 2029 at alternative catch levels for the base-case projections.

Run	**Base**		
Recruitment	**Recent**	**Recent**	**Recent**
Catch Level	TACC	Current	0.8·Current
$P(B_{2019} < 0.1\,B_0)$	NA	0	0
$P(B_{2019} < 0.2\,B_0)$	NA	0	0
$P(B_{2019} >= 0.4\,B_0)$	NA	0.279	0.269
5 year projection			
$P(B_{2024} < 0.1\,B_0)$	NA	0	0
$P(B_{2024} < 0.2\,B_0)$	NA	0.004	0
$P(B_{2024} >= 0.4\,B_0)$	NA	0.286	0.535
10 year projection			
$P(B_{2029} < 0.1\,B_0)$	NA	0	0
$P(B_{2029} < 0.2\,B_0)$	NA	0.024	0.001
$P(B_{2029} >= 0.4\,B_0)$	NA	0.301	0.69

4.5 Other factors

Blue cod fishing patterns have been strongly influenced by the development and subsequent fluctuations in the rock lobster fishery, especially in the Chatham Islands, Southland, and Otago. Once a labour intensive hand-line fishery, blue cod are now taken mostly by cod pots. The fishery had decreased in the past; however, with the advent of cod pots it rapidly redeveloped. Anecdotal information from recreational fishers suggests that there is local depletion in some parts of BCO 3, BCO 5, and BCO 7 where fishing has been concentrated. Blue cod abundance (Carbines & Cole

2009), catch (Cranfield et al 2001), and productivity (Jiang & Carbines 2002, Carbines et al 2004) may also be affected by disturbance of benthic habitat.

4.6 Future research considerations

<u>BCO 5</u>

- Further examine the potting survey data to determine spatial structuring (e.g., using GAM surfaces).
- Try to find otoliths from early surveys or experiments and re-read using current protocols.
- Re-age otoliths from other early surveys in lightly fished areas to provide a better estimate of *M*.
- More commercial length and age data by area would be useful for determining spatial differences in size structure and growth; obtain and examine market grading data for this purpose.
- Consider interviewing fishers to ascertain changes in fishing behaviour that might affect the relationship between the CPUE indices and abundance.
- Use a wider range of values of *M* in sensitivities.
- Use empirical data for maturity rather than a logistic.
- Conduct alternative runs to better understand the behaviour of the model; e.g., start estimating year classes earlier than 1980 to see how this affects early recruitments and the early part of the biomass trajectory; remove the age composition data to determine their relative influence.

5. STATUS OF THE STOCKS

For BCO 1 and 8 recent commercial catch levels are considered sustainable. The status of the remaining fish stocks is summarised below.

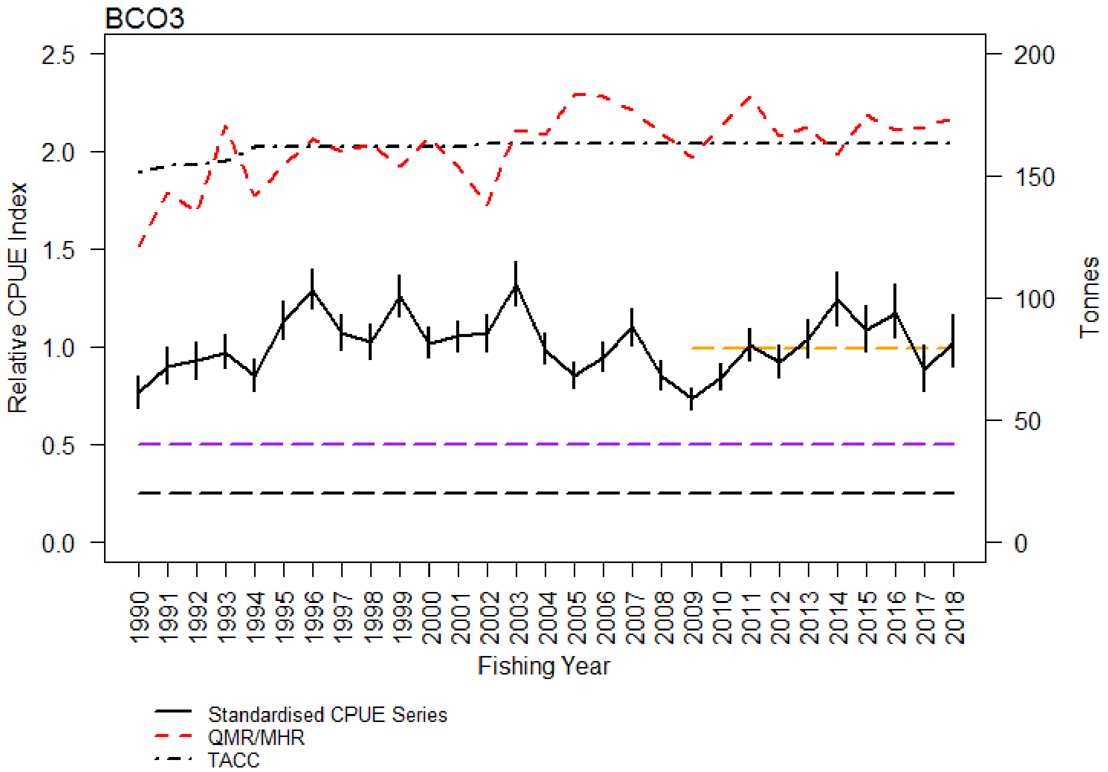
- **BCO 3 (Statistical Areas 024 and 026)**

Stock Structure Assumptions

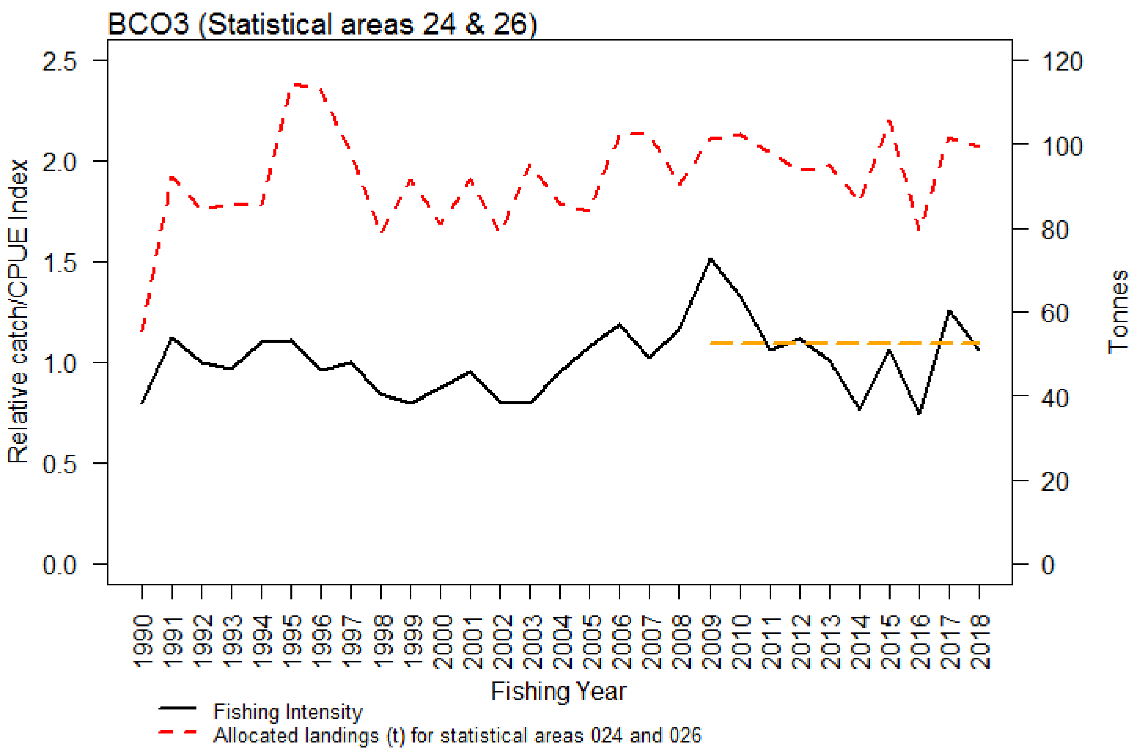
Tagging experiments suggest that blue cod populations may be isolated from each other and there may be several distinct populations within management areas. For the purposes of this summary, BCO 3 is split into two sub-areas along the Statistical Area 022/024 boundary: Statistical Areas 18, 20 and 22 (Northern); and 24 and 26 (Southern). There were insufficient data to produce a standardised CPUE series for the northern sub-area.

Stock Status	
Year of Most Recent Assessment	2019 (CPUE analysis)
Assessment Runs Presented	Standardised CPUE index based on landed catch of BCO target pot fishery
Reference Points	Target: B_{MSY} proxy based on mean CPUE for the period – 1998–99 to 2017–18 Soft Limit: 50% B_{MSY} Proxy Hard Limit: 25% B_{MSY} Proxy Overfishing Threshold: F_{MSY} proxy based on mean relative exploitation rate for the period 1998–99 to 2017–18
Status in relation to Target	About as Likely as Not (40–60%) to be at or above
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Overfishing is About as Likely as Not (40–60 %) to be occurring

Historical Stock Status Trajectory and Current Status



Cod-potting CPUE index (CP-landed), along with catches and TACC for BCO 3. Also plotted are the QMR/MHR landings and the BCO 3 TACC. The orange line represents the interim B_{MSY} proxy of mean CPUE from 2009–2018. The purple line is the interim Soft Limit=0.5*[B_{MSY} proxy] and the grey line is the interim Hard Limit=0.25*[B_{MSY} proxy].



Relative Fishing Intensity (catch/CPUE) for BCO 3 based on the standardised CPUE series and the sum of the allocated landings for statistical areas 024 and 026. Horizontal orange line represents the mean 2003–2014 fishing intensity associated with the interim B_{MSY} proxy.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass has declined during the last five years with the 2017–18 index near the series mean.
Recent Trend in Fishing Intensity or Proxy	Relative exploitation has fluctuated without trend since 2011–12, and the 2017–18 level was at the overfishing threshold.
Other Abundance Indices	The North Otago and South Otago potting surveys each have two annual indices based on the random survey design. The declines in abundance since 2013 were similar to the CPUE series for the North Otago survey, but much steeper for the North Otago survey.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	At current catches biomass is likely to remain stable. Current catch has exceeded the TACC in 14 of the last 16 years (beginning 1999-2000).
Probability of Current Catch or TACC causing decline Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Very Unlikely (< 10%)
Probability of Current Catch causing Overfishing to continue or to commence	About as Likely as Not (40–60%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE analysis of a target cod-potting fishery	
Main data inputs	Catch and effort data derived from the MPI catch reporting data	
Period of Assessment	Latest assessment: 2019	Next assessment: 2023
Overall Assessment Quality	1 – High Quality	
Main Data Inputs (Rank)	- Catch and effort data	1 – High Quality
Data not used	- North and South Otago potting surveys	1 – High Quality: Monitors abundance in restricted survey areas supporting local recreational fisheries.
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
As the bulk of the commercial catch (72%) is taken from Statistical Areas 024 and 026, both CPUE and catch trends for BCO 3 are strongly influenced by catches in these areas. A June 2009 change in regulations governing commercial pots (change from 38 mm mesh to 48 mm square grids) will have affected CPUE indices and comparison of trends before and after this date. The impact of this regulation change is unknown.

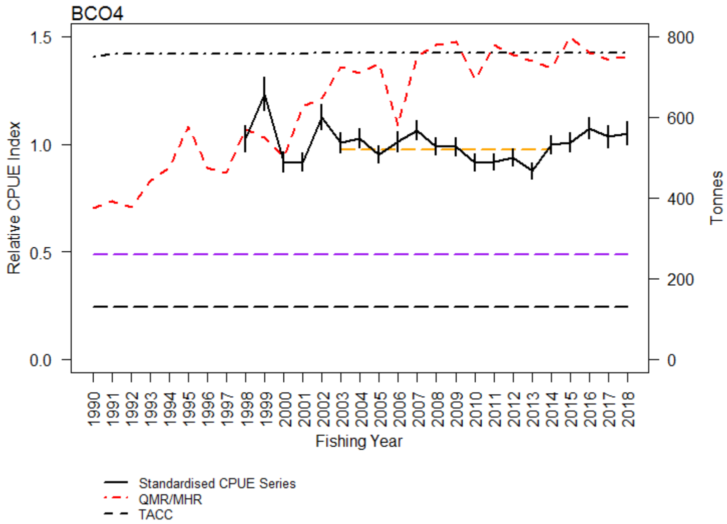
Fishery Interactions
Over two thirds of BCO 3 commercial catches are taken in a target cod-potting fishery which has very little interaction with other species. Most of the remaining BCO 3 catch is taken in the inshore bottom trawl fishery operating on the east coast of the South Island, largely directed at flatfish, red cod and tarakihi.

- **BCO 4**

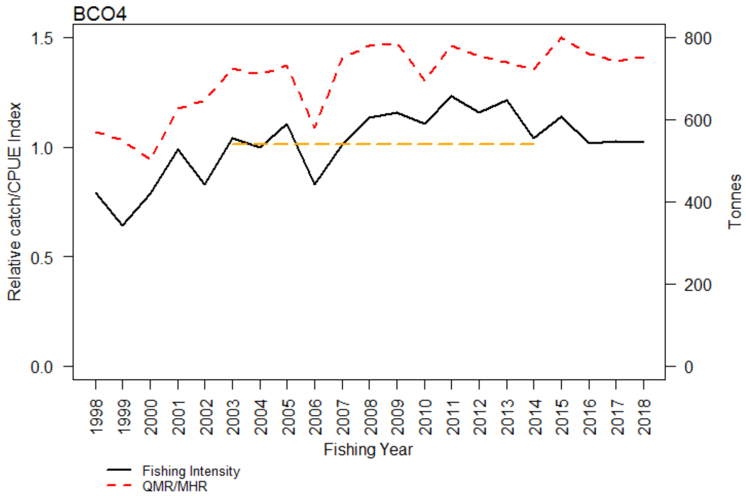
Stock Structure Assumptions
For the purposes of this summary BCO 4 is considered to be a single management unit.

Stock Status	
Year of Most Recent Assessment	2019
Assessment Runs Presented	CPUE index based on landed catch
Reference Points	Interim Target: B_{MSY} proxy based on mean CPUE for the period 2002–03 to 2013–14 (a period with high yield when both catch and CPUE were stable) Soft Limit: 50% B_{MSY} proxy Hard Limit: 25% B_{MSY} proxy Overfishing threshold: F_{MSY} proxy based on mean relative exploitation rate for the period 2002–03 to 2013–14
Status in relation to Target	Likely (> 60%) to be at or above the target
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	About as Likely as Not (40–60 %) to be occurring

Historical Stock Status Trajectory and Current Status



BCO 4 standardised CPUE series for 1998–2018. Also plotted are the QMR/MHR landings and the BCO 4 TACC. The orange line represents the B_{MSY} proxy of mean CPUE from 2003–2014. The purple line is the Soft Limit=0.5*[B_{MSY} proxy] and the grey line is the Hard Limit=0.25*[B_{MSY} proxy].



BCO 4 fishing intensity (=catch/CPUE) plot based on the standardised CPUE series from 1997-98 to 2017-18 and the QMR/MHR landings. Horizontal orange line represents the mean 2003–2014 fishing intensity associated with the interim B_{MSY} proxy.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE has fluctuated without trend since 1997–98.
Recent Trend in Fishing Intensity or Proxy	Relative exploitation rate has declined since 2010–11 and in 2017–18 was near the overfishing threshold.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	The current catch and TACC are Unlikely (< 40%) to cause the stock to decline
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Very Unlikely (< 10%) Hard Limit: Very Unlikely (< 10%)
Probability of Current Catch or TACC causing overfishing to continue or to commence	-

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Fishery characterisation and standardised CPUE analysis	
Assessment Dates	Latest assessment: 2019	Next assessment: 2023
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and Effort 1997–98 to 2017–18	1 – High Quality
Data not used (rank)	- Catch and Effort 1989–90 to 1996–97	2 – Moderate or mixed Quality: compromised by changes in fleet composition and reporting practices
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
-
Fishery Interactions
The catch is almost entirely taken by target cod potting and there is little interaction with other species.

- **BCO 5**

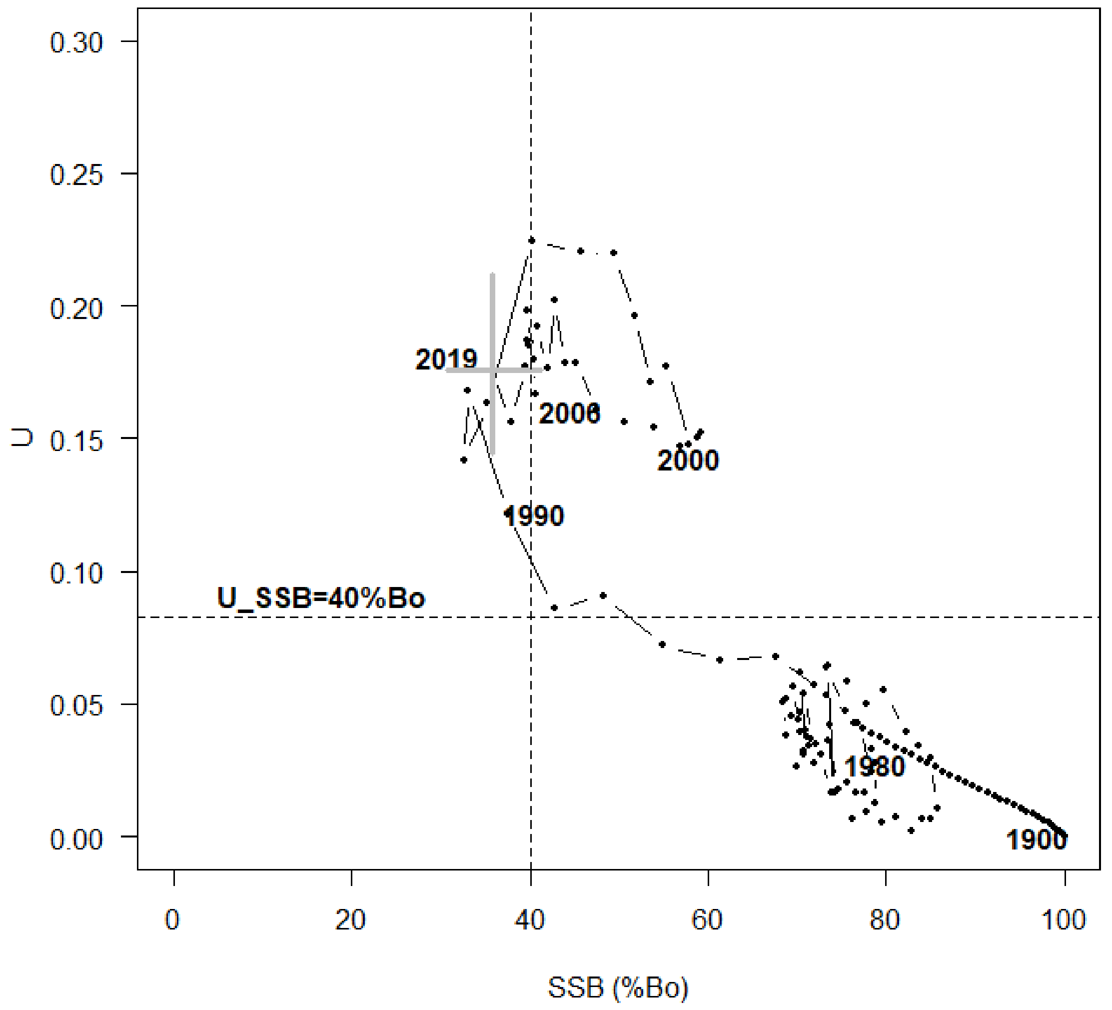
Stock Structure Assumptions

Tagging experiments suggest that blue cod populations may be isolated from each other and there may be several distinct populations within management areas. For the purposes of this summary, blue cod in Statistical Areas 025, 027 and 030 of BCO 5 are treated as a unit stock. Dusky Sound and Paterson Inlet are assumed to contain discreet populations of BCO, which are monitored with potting surveys.

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	One base case model
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $U_{40\%SB}$
Status in relation to Target	B_{2019} was estimated to be 36% B_0; and is Unlikely (< 40%) to be at or above the Management Target

Status in relation to Limits	B_{2019} is Very Unlikely (< 10%) to be below the Soft Limit and Exceptionally Unlikely (< 1%) to be below the Hard Limit
Status in relation to Overfishing	Overfishing is Likely (> 60%) to be occurring

Historical Stock Status Trajectory and Current Status



Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass has been decreasing since about 2000.
Recent Trend in Fishing Intensity or Proxy	The exploitation rate has been above the target since 1990.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	BCO 5 biomass is expected to decline over the next 5 to 10 years at current catch levels.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	For current catch in the next 3-5 years: Soft Limit: Very Unlikely (< 10%) Hard Limit: Very Unlikely (< 10%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	The current catch (average of 2015/16 – 2017/18), which is lower than the TACC, is Likely (> 60%) to cause overfishing to continue.

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Age-based model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2020	Next assessment: 2024
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- CPUE time series	1 – High Quality
	- Proportions at length and age from commercial catch for 2017-18 and 2018-19	1 – High Quality
	-Proportions at length from commercial catch for 2010	2 – Medium or Mixed Quality: sampling potentially unrepresentative
	- Relative biomass and proportions at length and age from potting surveys	1 – High Quality
	- Estimates of biological parameters	1 – High Quality
	- Potting survey abundance estimates	1 – High Quality
Data not used (rank)	Shed sampling LF by sex; only used in a sensitivity	3 – Low Quality: sampling potentially unrepresentative of the overall population
Changes to Model Structure and Assumptions	- Changed from length-based to age-based model - Maturity ogive age-based - M assumed to be 0.17 instead of 0.14 - No sex change assumed in base case	
Major Sources of Uncertainty	- Year classes prior to 2000 - Lack of adequate catch at age data - Lack of contrast in age data and CPUE - Relationship between abundance and sex change dynamics	

Qualifying Comments
There have been potential changes in fisher behaviour that are not captured in the assessment; for example, changes in responses to new pot mesh sizes, and changes in areas fished (local versus long-distance). Also, anecdotal information suggests some fishers have modified their fishing behaviour to maintain catch rates in a manner that cannot be standardised. Specifically, they move pots after each lift instead of re-setting them in the same place. It is not known to what degree this behaviour was adopted by core fleets in each statistical area, but this behaviour may have biased high recent CPUE, thereby masking declines in abundance.

Fishery Interactions
Historically, significant quantities of blue cod, taken by potting, were used as bait in the commercial rock lobster fishery. Since 1996, reporting of blue cod used for bait is mandatory and included as part of the commercial catch reporting. Some blue cod are landed as bycatch in rock lobster pots and oyster dredges.

- **BCO 7 - Marlborough Sounds only**

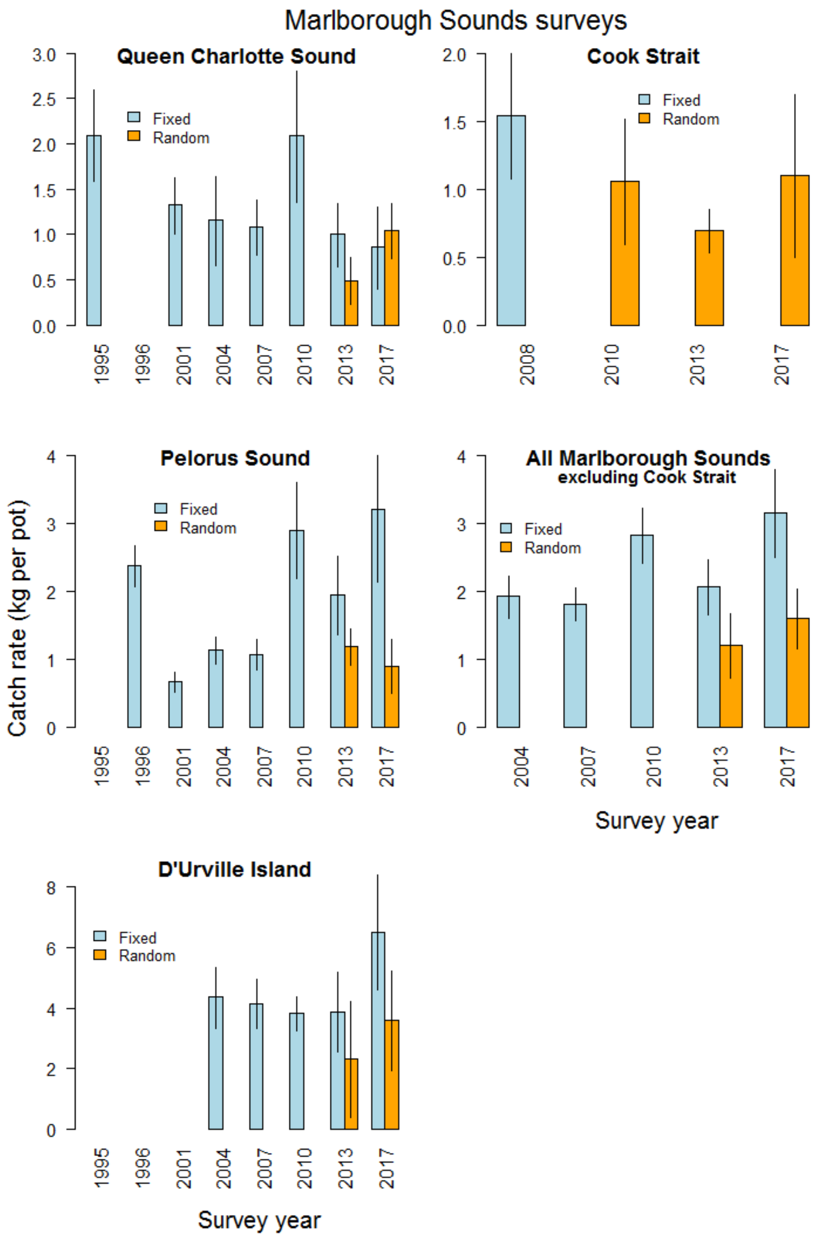
Stock Structure Assumptions

For the purposes of this summary BCO - Marlborough Sounds is considered to be a single management unit.

Stock Status	
Year of Most Recent Assessment	2018

Assessment Runs Presented	Catch rates from the fixed and random site Marlborough Sounds potting surveys
Reference Points	Target1: B_{MSY}-compatible proxy based on the Marlborough Sounds potting survey (to be determined) Target 2: $F_{SB45\%}$ ($F_{SB45\%}$ = 0.26). Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{SB45\%}$
Status in relation to Target	*F* is Unlikely (< 40%) to be at or below the target
Status in relation to Limits	Unknown
Status in relation to Overfishing	Overfishing is Likely (> 60%) to be occurring

Historical Stock Status Trajectory and Current Status



Marlborough Sounds fixed-site and random-site potting survey catch rates of all blue cod by survey year for each region and overall for the Marlborough Sounds. Error bars are 95% confidence intervals. There were no complete fixed-site surveys in QCH in 1996, PEL in 1996, and DUR from 1995 to 2001. For the overall Marlborough Sounds plot, the 2004 and 2007 fixed-site surveys exclude Separation Point, and the random-site surveys exclude Cook Strait, hence the strata are consistent among the surveys for fixed and random site surveys.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The Marlborough Sounds fixed site potting survey indices of abundance increased markedly in 2010 in the Queen Charlotte Sound and Pelorus regions following the closure of the fishery in the inner sounds in 2008 (QCH, PEL). The survey indices were stable in the D'Urville region where the fishery remained open (DUR). The QCH and PEL fisheries were reopened to a limited size range of blue cod (slot limit) in April 2011 and the estimated 2013 survey abundance in those regions declined, but no change was observed in DUR. In 2017, abundance in QCH was not different to 2013, whereas for PEL and DUR abundance was the highest of any of the surveys. The overall Marlborough Sounds catch rates from 2004 onward (where survey strata are consistent among surveys) indicates that blue cod were more abundant in 2017 than any of the previous surveys. Cook Strait random-site surveys show no trend in abundance from 2010 to 2017. There are only two random site surveys for the other regions (2013 and 2017), not enough to comment on trends.
Recent Trend in Fishing Mortality or Proxy	Regulatory changes to the recreational fishery (e.g. fishery closures, changes to MLS and daily bag limits) are likely to have resulted in a reduction in fishing mortality up to April 2011, after which mortality increased with the re-opening of the fishery. Fishing mortality was at least twice natural mortality for the random and fixed site surveys in 2017, and the spawning biomass per recruit ratio was 39% (i.e. lower than the target of 45%).
Other Abundance Indices	The mean length of catches taken during the 2010 blue cod potting survey (following the closure) tended to be larger than those observed in previous surveys and this has generally been maintained in 2013 and 2017.
Trends in Other Relevant Indicators or Variables	- Sex ratio is strongly skewed in favour of males. For Marlborough Sounds overall, the percent male from random sites surveys in 2013 was 66%, and in 2017 it was 72% (Table 9). - Blue cod catch rates were about 10-fold higher, and length about 5 cm larger overall in the Long Island Marine Reserve (head of QCH) compared to adjacent fished strata in Queen Charlotte Sound. This is a strong indication that fishing pressure has reduced the size and abundance of blue cod in the Marlborough Sounds.

Projections and Prognosis	
Stock Projections or Prognosis	Biomass is expected to increase under current management controls.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing overfishing to continue or to commence	Current catches are Likely (> 60%) to cause overfishing to continue.

Assessment Methodology and Evaluation		
Assessment Type	2 - Partial Quantitative Stock Assessment	
Assessment Method	Fishery-independent potting survey. Fixed and random sites in QCH, PEL, DUR, and random sites in CKST.	
Assessment Dates	Latest assessment: 2018	Next assessment: 2022
Overall assessment quality rank	2 – Medium or Mixed Quality: mortality estimates compromised by	

	regulation changes	
Main data inputs (rank)	- Potting survey catch rates from fixed and random site surveys. - Length and age composition of catches from random and fixed site potting surveys in 2017	1 – High Quality 1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Uncertainty in the estimate of M - Frequent regulatory changes for this fishery are likely to have resulted in inconsistent fishing mortality over the lifetime of recent cohorts. - The predominance of males suggests fishing mortality may be higher than estimated. - Trends for random and fixed site surveys between 2013 and 2017 were contradictory in some areas. Random site surveys are believed to be better indicators of population abundance.	

Qualifying Comments
The survey has been transitioning from a fixed-site to a random-site stratified potting survey. The 2010 survey comprised a full fixed-site survey along with a partial random-site survey in selected strata, whereas 2013 and 2017 included full fixed and full random site surveys carried out simultaneously. The next survey will be based on random sites only.

Fishery Interactions
Most of the BCO catch is taken by recreational fishers using line methods. There is a reasonably high catch of associated species in this fishery, such as spotted and other wrasses as well as other targeted species such as tarakihi. Most of the commercial catch is taken by potting and has little bycatch.

Table 22: Summary of yields (t), TACCs (t), and reported landings (t) for blue cod from the most recent fishing year.

Fishstocks	QMA	FMA	2018–19 Actual TACC	2018–19 Reported landings
BCO 1	Auckland	1 & 9	46	8
BCO 2	Central (East)	2	10	9
BCO 3	South-East (Coast)	3	163	177
BCO 4	South-East (Chatham Rise)	4	759	744
BCO 5	Southland and Sub-Antarctic	5 & 6	1 239	827
BCO 7	Challenger	7	70	64
BCO 8	Central (Egmont)	8	34	14
BCO 10	Kermadecs	10	10	0
Total			2 332	1 844

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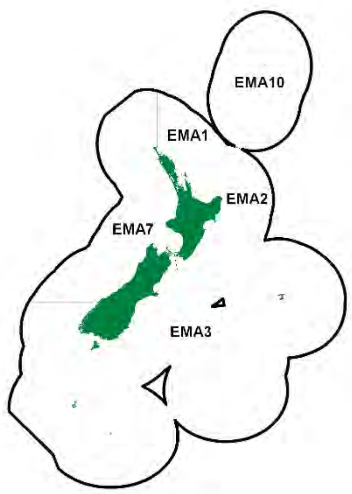
BLUE MACKEREL (EMA)

(*Scomber australasicus*)
Tawatawa



1. FISHERY SUMMARY

Blue mackerel were introduced into the QMS on 1 October 2002. Since then allowances, TACCs and TACs (Table 1) have not changed.

Table 1: Recreational and Customary non-commercial allowances, TACCs and TACs for blue mackerel by Fishstock.

Fishstock	Recreational Allowance	Customary Non-Commercial Allowance	TACC	TAC
EMA 1	40	20	7 630	7 690
EMA 2	5	2	180	187
EMA 3	1	1	390	392
EMA 7	1	1	3 350	3 352
EMA 10	0	0	0	0
Total	47	24	11 550	11 621

1.1 Commercial fisheries

Blue mackerel are taken by a variety of methods but for most of these methods the catches are very low. The largest and most consistent catches have been from the target purse seine fishery in EMA 1, 2 and 7, and as non-target catch in the jack mackerel mid-water trawl fishery in EMA 7. Most catch is taken north of latitude 43° S (Kaikoura). Historical estimated and recent reported blue mackerel landings and TACCs are shown in Tables 2 and 3, while Figure 1 shows the historical landings and TACC values for these three main stocks. Since 1983–84 the catch of blue mackerel in New Zealand waters has grown substantially (Table 3), primarily in the purse seine fishery in EMA 1, and have averaged about 10 000 t annually since 1990–91.

Most blue mackerel purse seine catch comes from the Bay of Plenty (BoP) and East Northland, where it is primarily taken between July and December. Purse seine fishing effort on blue mackerel has been strongly influenced by the availability and market value of other pelagic species, particularly skipjack tuna and kahawai, with effort increasing as limits have been placed on the purse seine catch of kahawai. The purse seine fishery has accounted for more than 97% of annual EMA 1 landings since at least 1990, and about 90% of this was targeted (Ballara 2016).

Total blue mackerel landings peaked in 1991–92 at more than 15 000 t, of which 60–70% was taken by purse seine. More recently, commercial landings of over 12 500 t were taken in 2000–01 (13 100 t) and 2004–05 (12 750 t), with the highest landings recorded in EMA 1 and EMA 7. EMA 1 landings exceeded the TACC in 2004–05, 2006–07, 2009–10, 2011–12, 2014–15, and 2017-18. The 2004–05, 2005–06, and 2008–09 EMA 7 landings also exceeded the TACC. EMA 7 landings have fluctuated in recent years, with the lowest landings since the mid-1980s recorded in 2016-17 (625 t) and landings increasing to just below the TACC in 2017-18 (3 254 t). Landings from EMA 2 and 3 have been below the TACCs since the early to mid-1990s; they are mainly bycatch from purse seines (EMA 2) and trawlers (EMA 3).

The blue mackerel catch from EMA 7 is now principally non-target catch from the jack mackerel mid-water trawl fishery. Highest catches are taken during June, July and October in areas 034 and 035 on the WCSI and areas 041 and 801 further north (WCNI). Fishing has shifted from south to north in the last decade. Since the late 1990s, a fleet of Ukrainian vessels has taken most of the catch in the JMA 7 target fishery and these vessels have taken the EMA as bycatch. Since 2004, 0–11% of the EMA 7 catch has been taken annually by purse seine, down from an average of about 25% between 1991 and 2003.

A number of factors have been identified that can influence landing volumes in the blue mackerel fisheries. In the purse seine fishery, blue mackerel has become the second most preferred species because of decreased TACCs on kahawai. Skipjack tuna is the preferred species and blue mackerel will not be targeted once the skipjack season has begun in late-spring, early summer. Thus, early arrival of skipjack can result in reduced volumes of blue mackerel being landed.

Management of company quota is complicated by the relative timing of the fishing season and the fishing year and this, along with the timing of the main market, may influence whether the blue mackerel TACC can all be taken in a particular year. The fishing season usually begins in about July–August, runs through to the end-beginning of subsequent fishing years, and finishes in about November. The main market for purse seined blue mackerel takes up to 80% of the catch and requires premium fish to be available from early spring. To meet the demands of this market and to minimise the costs of storing fish from the previous season, fishing companies must carry over some proportion of their quota for a given year until fish become available the following season. If availability is delayed until after October 1, only 10% of the total quota can then be carried over into the new fishing year.

Because blue mackerel is taken principally as bycatch in the jack mackerel TCEPR target fishery in JMA 7, factors influencing the targeting of jack mackerel also affect blue mackerel landings. Other bycatch species taken in this fishery include barracouta, gurnard, John dory, kingfish, and snapper, and, although non-availability of ACE is unlikely to be constraining in the first three of these, the same is not true of kingfish and snapper. Fishing company spokespersons have stated that known hotspots of snapper are avoided. Other factors in this fishery include strategies to avoid the catch of marine mammals, and a code of practice operates in which gear is not deployed between 2 a.m. and 4 a.m. It is unknown whether this affects total landing volumes.

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	EMA 1	EMA 2	EMA 3	EMA 7	Year	EMA 1	EMA 2	EMA 3	EMA 7
1931–32	0	0	0	0	1957	0	0	0	0
1932–33	0	0	0	0	1958	0	0	0	0
1933–34	0	0	0	0	1959	0	0	0	0
1934–35	0	0	0	0	1960	0	0	0	0
1935–36	0	0	0	0	1961	0	0	0	0
1936–37	0	0	0	0	1962	0	0	0	0
1937–38	0	0	0	0	1963	0	0	0	0
1938–39	0	0	0	0	1964	0	0	0	0
1939–40	0	0	0	0	1965	0	0	0	0
1940–41	0	0	0	0	1966	0	0	0	0
1941–42	0	0	0	0	1967	0	0	0	0
1942–43	0	0	0	0	1968	0	0	0	0
1943–44	0	0	0	0	1969	0	0	0	0
1944	0	0	0	0	1970	0	0	0	0
1945	0	0	0	0	1971	0	0	0	0
1946	0	0	0	0	1972	0	0	0	0
1947	0	0	0	0	1973	0	0	0	0
1948	0	0	0	0	1974	38	8	0	6
1949	0	0	0	0	1975	10	0	0	2
1950	0	0	0	0	1976	50	49	0	0
1951	0	0	0	0	1977	34	135	0	0
1952	0	0	0	0	1978	14	55	0	128
1953	0	0	0	0	1979	185	31	0	317
1954	0	0	0	0	1980	752	32	0	407
1955	0	0	0	0	1981	459	49	0	1363
1956	0	0	0	0	1982	305	0	0	791

Notes
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data includes both foreign and domestic landings.

Table 3: Reported landings (t) of blue mackerel by QMA, and where area was unspecified (Unsp.), from 1983–84 to 2018–19. CELR data from 1986–87 to 2000–01. MHR data from 2001–02 to present.

	QMA						
Fishing year	1	2	3	7	10#	Unsp	Total
1983–84*	480	259	44	245	0	1	1 028
1984–85*	565	222	18	865	0	73	1 743
1985–86*	618	30	190	408	0	51	1 296
1986–87	1 431	7	424	489	0	49	2 399
1987–88	2 641	168	864	1 896	0	58	5 625
1988–89	1 580	< 1	1 141	1 021	0	469	4 211
1989–90	2 158	76	518	1 492	0	< 1	4 245
1990–91	5 783	94	478	3 004	0	0	9 358
1991–92	10 926	530	65	3 607	0	0	15 128
1992–93	10 684	309	133	1 880	0	0	13 006
1993–94	4 178	218	223	1 402	5	0	6 025
1994–95	6 734	94	154	1 804	10	149	8 944
1995–96	4 170	119	173	1 218	0	1	5 680
1996–97	6 754	78	340	2 537	0	< 1	9 708
1997–98	4 595	122	78	2 310	0	< 1	7 104
1998–99	4 505	186	62	8 756	0	4	13 519
1999–00	3 602	73	3	3 169	0	0	6 847
2000–01	9 738	113	6	3 278	0	< 1	13 134
2001–02	6 368	177	49	5 101	0	0	11 694
2002–03	7 609	115	88	3 563	0	0	11 375
2003–04	6 523	149	1	2 701	0	0	9 373
2004–05	7 920	9	< 1	4 817	0	0	12 746
2005–06	6 713	13	133	3 784	0	0	10 643
2006–07	7 815	133	42	2 698	0	0	10 688
2007–08	5 926	6	122	2 929	0	0	8 982
2008–09	3 147	2	88	3 503	0	0	6 740
2009–10	8 539	3	14	3 260	0	0	11 816
2010–11	6 630	2	9	1 996	0	0	8 638
2011–12	8 080	2	28	2 707	0	0	10 817
2012–13	7 213	3	100	2 401	0	0	9 716
2013–14	6 860	4	29	1 200	0	0	8 092
2014–15	8 134	16	87	892	0	0	9 129
2015–16	7 226	18	27	761	0	0	8 033
2016–17	7 551	83	126	625	0	0	8 385
2017–18	7 988	112	46	3 254	0	0	11 400
2018–19	7 630	12	32	2 626	0	0	10 300

* FSU data, # Landings reported from QMA 10 are probably attributable to Statistical Area 010 in the Bay of Plenty (i.e., QMA 1).

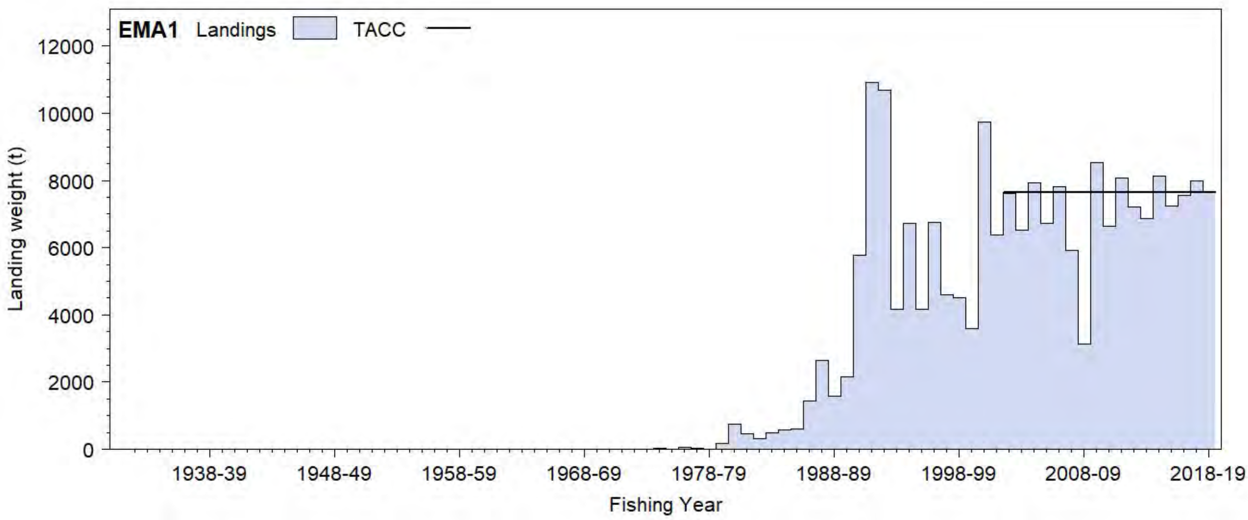
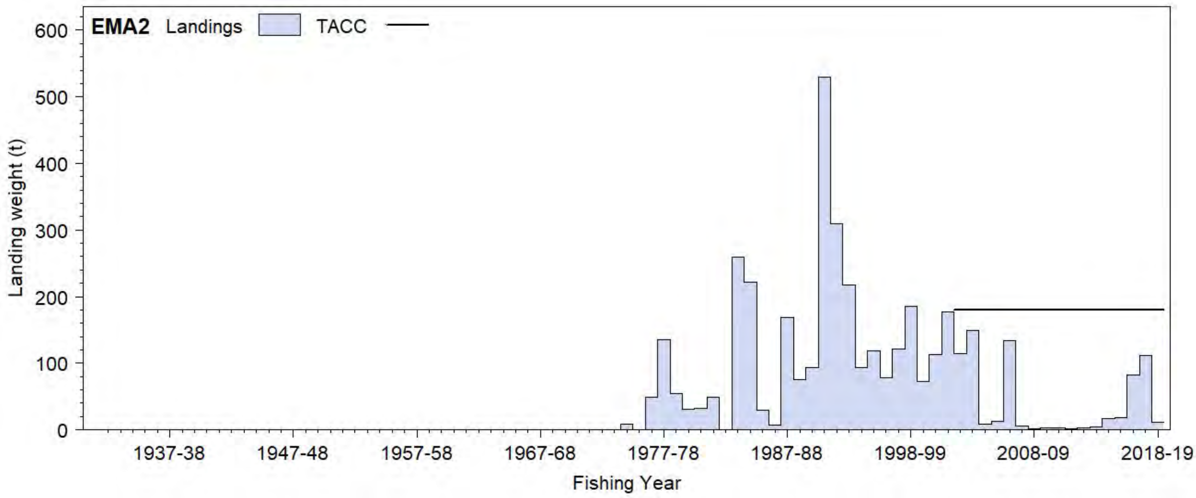


Figure 1: Reported commercial landings and TACC for the three main EMA stocks. EMA 1 (Auckland East) [Continued on next page]



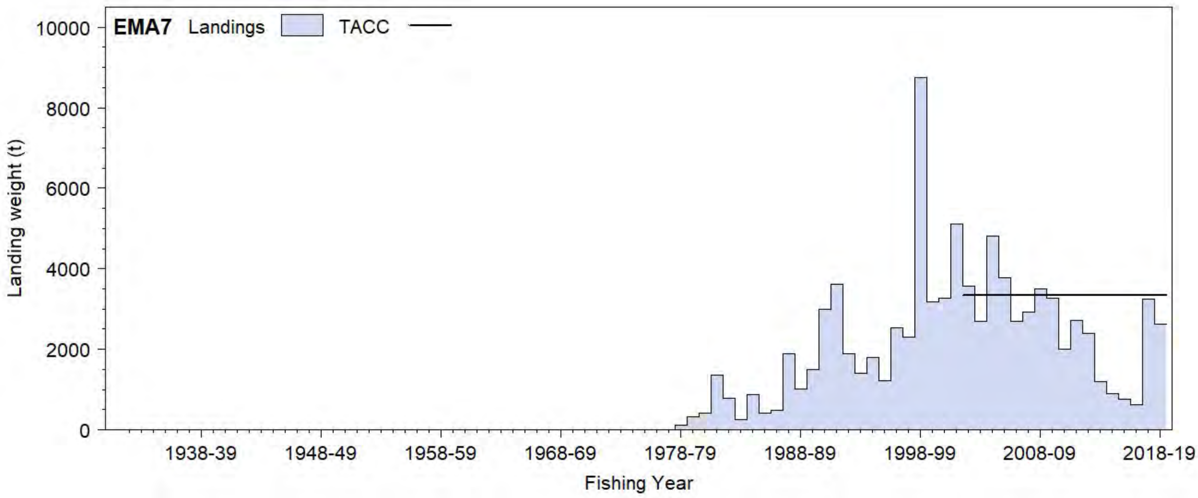


Figure 1[Continued]: Reported commercial landings and TACC for the three main EMA stocks. From top: EMA 2 (Central East), and EMA 7 (Challenger to Auckland West).

1.2 Recreational fisheries

Blue mackerel does not rate highly as a recreational target species although it is popular as bait. There is some uncertainty with all recreational harvest estimates for blue mackerel and there is some confusion between blue and jack mackerels in the recreational data.

Recreational catch in the northern region (EMA 1) was estimated at 114 000 fish by a diary survey in 1993–94 (Bradford 1996), 47 000 fish in a national recreational survey in 1996 (Bradford 1998), 84 000 fish (CV 42%) in the 2000 survey (Boyd & Reilly 2005) and 58 000 fish (CV 27%) in the 2001 survey (Boyd et al 2004). The surveys suggest a harvest of 35–90 t per year for EMA 1, insignificant in the context of the commercial catch. Estimates from other areas are very low (between 500 and 3000 fish) and are likely to be insignificant in the context of the commercial catch.

The harvest estimates provided by telephone-diary surveys between 1993 and 2001 are no longer considered reliable for various reasons. A Recreational Technical Working Group concluded that these harvest estimates should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries. In response to these problems and the cost and scale challenges associated with onsite methods, a National Panel Survey was conducted for the first time throughout the 2011–12 fishing year. The panel survey used face-to-face interviews of a random sample of 30 390 New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and harvest information collected in standardised phone interviews. The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly comparable results (Wynne-Jones et al 2019). Recreational catch estimates from the two national panel surveys are given in Table 4. Note that national panel survey estimates do not include recreational harvest taken under s111 general approvals.

Table 4: Recreational harvest estimates for blue mackerel stocks (Wynne-Jones et al 2014, 2019). Mean fish weights were obtained from boat ramp surveys (Hartill & Davey 2015, Davey et al 2019).

Stock	Year	Method	Number of fish	Total weight (t)	CV
EMA 1	2011/12	Panel survey	18 438	19.2	0.36
	2017/18	Panel survey	15 036	17.3	0.50
EMA 2	2011/12	Panel survey	3 346	3.5	-
	2017/18	Panel survey	1 209	1.3	0.69
EMA 7	2011/12	Panel survey	11 194	11.6	0.42
	2017/18	Panel survey	4 375	4.5	0.45

1.3 Customary non-commercial fisheries
Quantitative information on the current level of customary non-commercial catch is not available.

1.4 Illegal catch
There is no known illegal catch of blue mackerel.

1.5 Other sources of mortality
There is no information on other sources of mortality.

2. BIOLOGY

The geographical distribution and habitat of blue mackerel vary with life history stage. Juvenile and immature blue mackerel are northerly in their distribution, having been recorded from commercial and research catches around the North Island and into Golden and Tasman Bay at the top of the South Island.

By contrast, adults have been recorded around both the North and South Islands to Stewart Island and across the Chatham Rise almost to the Chatham Islands. Sporadic catches of small numbers of yearling blue mackerel have been made by bottom trawl in shallow waters.

The distribution of blue mackerel at the surface is seasonal and differs from its known geographical range. During summer, surface schools are found in Northland, BoP, South Taranaki Bight, and Kaikoura, but they disappear during winter, when only occasional individuals are found in Northland and the BoP. A possible corollary to this winter disappearance comes from the peak in bycatch of blue mackerel in the winter jack mackerel mid-water trawl fishery in EMA 7. This suggests an increased partitioning of the population in deeper water at this time of the year, reflecting an observed behavioural characteristic of the related Atlantic species, *Scomber scombrus*. Summaries from aerial sightings data show that blue mackerel can be found in mixed schools with jack mackerel (*Trachurus* spp.), kahawai (*Arripis trutta*), skipjack tuna (*Katsuwonus pelamis*) and trevally (*Pseudocaranx dentex*), and that its appearance in mixed schools varies seasonally.

Blue mackerel are serial spawners, releasing eggs in batches over several months. Based on gonad condition, sexual maturity for both sexes of blue mackerel taken in the Great Australian Bight between January 1979 and December 1980 was estimated to be about 28 cm FL, which translates to an age of about 2 years. Eggs are pelagic and development rate is dependent on temperature. In plankton surveys, blue mackerel eggs have been found from North Cape to East Cape, with highest concentrations from Northland, the Hauraki Gulf, and the Western BoP. Eggs have been described throughout the Hauraki Gulf from November to the end of January, at surface temperatures in the range 15–23°C. Individuals in spent or spawning condition have been taken in a few tows off Tasman Bay and Taranaki, in EMA 7 and in the BoP in EMA 1.

Age and growth studies suggest a difference in the age structures of catches taken in the BoP (New Zealand, EMA 1) and New South Wales (Australia). For fish from the New South Wales study, a peak was found at 1 year that accounted for more than 55% of the fish sampled, with a maximum age of 7 yr. The BoP results show a much broader distribution, with a maximum age of 24 yr, and a mode in the data around 8 to 10 yr. Growth parameters estimated in the BoP study are given in Table 5. Following a quantitative test of competing growth models in the BoP study, no evidence was found of statistically significant differences in growth between the sexes in BoP blue mackerel.

Australian studies may underestimate the ages of larger, older blue mackerel in their catch. The Australian method for estimating blue mackerel ages is based on reading otoliths whole in oil, whereas the New Zealand method is based on otolith thin-sections (Marriott & Manning 2011). Results from the New South Wales study referred to above, suggest that blue mackerel 25–40 cm fork length may be 3–7 years old. Using the New Zealand method, fish in this length range could be as old as 16 years. Australian scientists, reading whole otoliths, may be missing opaque zones near the margin, which are visible in sectioned otoliths.

Table 5: Von Bertalanffy growth parameters for Bay of Plenty (EMA 1) blue mackerel (Manning et al 2006).

	Males	**Females**	**Both sexes**
L_∞	52.49	53.10	52.79
K	0.15	0.15	0.15
t_0	-3.29	-3.18	-3.19
Age range	1.8–21.9	1.8–21.9	1.8–21.9
N	240	269	509

Although Australian scientists have validated the timing of the first opaque zone in blue mackerel otoliths, their results do not cover the complete life history defined using either the Australian or New Zealand method. A study attempting to validate the New Zealand age estimation method using lead-radium dating indicated that blue mackerel in New Zealand are a relatively long lived small pelagic species, living to at least 17 to 49 years, with the real age most likely nearer the lower value (Marriott et al 2010). While this range of age estimates is less than desirable for the validation of the growth zone counting method for this species, the findings are consistent with the New Zealand method where otolith ageing studies from commercial catches have blue mackerel living to at least 24 years.

Instantaneous natural mortality (*M*) for male and female fish was estimated using Hoenig's method (Morrison et al 2001a). Based on age estimates from otoliths collected during the mid 1980s when fishing pressure was presumably light, natural mortality estimates of 0.22 for males and 0.20 for females were derived.

In New Zealand, the diet of blue mackerel has been described as zooplankton, which consists mainly of copepods, but also includes larval crustaceans and molluscs, fish eggs and fish larvae. Feeding involves both filtering of the water and active pursuit of prey, with blue mackerel able to take much smaller animals than, for example, kahawai can.

3. STOCKS AND AREAS

Sampling of eggs, larvae, and spawning blue mackerel indicate at least three spawning centres for this species: Northland-Hauraki Gulf; Western BoP; and South Taranaki Bight. Nothing is known of migratory patterns or the fidelity of fish to a particular spawning area. Examination of mitochondrial DNA shows no geographical structuring between New Zealand and Australian fish. Meristic characters show significant regional differentiation within New Zealand fisheries waters and, combined with parasite marker information, Smith et al (2005) sub-divided blue mackerel into at least three stocks in New Zealand fisheries waters: EMA 1, EMA 2, and EMA 7. No information is currently available on the stock affinity of fish in EMA 3.

4. STOCK ASSESSMENT

4.1 EMA 1

4.1.1 Estimates of fishery parameters and abundance

Analysis of aerial sightings data for east Northland (part of EMA 1) from 1985–86 to 2002–03 found no apparent trends in abundance, apart from a peak off east Northland in 1991–92 for both the number of schools and the estimated tonnage, and a further strong signal for the number of schools and the estimated tonnage from 2000–01 to 2002–03.

Using market and catch sampling data collected from 2002 to 2005, estimated numbers-at-length and numbers-at-age were calculated based on all available groomed length and length-at-age data (Manning et al 2007). These were done separately by sex and scaled to estimates of the total catch from the purse seine fishery. Results showed that the EMA 1 purse seine fishery was composed of fish between 2–21 years of age, although most were between 5 and 15 years.

4.2. EMA 7

4.2.1 Estimates of fishery parameters and abundance

A standardised CPUE analysis for EMA 7 was carried out using TCEPR tow by tow data from the mid-water trawl jack mackerel target fishery up to 2013–14 in which blue mackerel form a significant and important bycatch (Ballara 2016). The initial dataset comprised tows that targeted jack mackerel with blue mackerel caught as bycatch. Tows that targeted blue mackerel were not considered as they constituted a small amount of catch and effort (about 30 tows each year for the last 10 years by all vessels) and they were confined to a few areas in the fishery and were directed at large sub-surface schools of blue mackerel. Tows that targeted jack mackerel but did not report any blue mackerel catch were also excluded. The data used for the CPUE analyses consisted of catch and effort by core vessels that targeted jack mackerel; core vessels were those participating in the fishery for five or more years, and reporting at least 20 tows per vessel-year. Estimates of relative year effects were obtained using a forward stepwise multiple regression method, where the data were fitted using binomial-lognormal model structure.

Separate standardisations were carried out to two subgroups of core vessels corresponding to an early and late period of the data series respectively. CPUE indices were developed for the early time series from 1989–90 to 1997–98 using catch and effort by 12 core vessels and the late time series from 1996–97 to 2013–14 using catch and effort by 7 core vessels (Table 6). The residual deviance explained was 33% for the early time series and 35% for the late time series. For both data series, the main terms selected by the models are statistical area, vessel, and month.

The early time series increased from 1990 to 1992, and was then relatively constant to 1998. The late time series declined steadily from 1997 to about 2005, and has been relatively constant since then (although the three most recent years produced the lowest indices from this series). Similar trends were also apparent for the later series analysed separately by WCSI and WCNI areas (Figure 2). The series from 2000 onwards shows a decline of more than 50%.

The WG concluded that standardised CPUE series based on the blue mackerel bycatch in the WCNI and WCSI jack mackerel trawl fishery appears to provide reliable indices of abundance.

Using market and catch sampling data collected from 2002 to 2005, estimated numbers-at-length and numbers-at-age were calculated based on all available groomed length and length-at-age data (Manning et al 2007). These were done separately by sex and scaled to estimates of the total catch from the purse seine and the trawl fisheries. Results showed that the EMA 7 purse seine fishery was composed of fish between 2–24 years of age, although most were between 5 and 15 years. Catch-at-age in the EMA 7 mid-water trawl TCEPR bycatch (jack mackerel target) fishery also showed a wide range, with fish between 2–24 years represented, and small peaks evident between 10 and 11 years in both sexes. These results were generally consistent with those from previous years, although relatively low numbers of small fish in the sampled fisheries were noted.

Table 6: Standardised lognormal CPUE catch/hr indices for the core West coast TCEPR tow-by-tow target JMA data indices for fishing years 1990–2014. The Standardised CPUE indices for the early series is from 1990 to 1998 (from Fu & Taylor 2011) and for the late series from 1997 to 2014 (Ballara 2016).

Year	Indices	CV	Indices	CV
1990	0.67	0.20	–	–
1991	0.87	0.10	–	–
1992	1.24	0.11	–	–
1993	1.01	0.13	–	–
1994	0.99	0.09	–	–
1995	1.05	0.07	–	–
1996	0.87	0.11	–	–
1997	1.34	0.08	2.27	0.09
1998	1.13	0.08	1.99	0.07
1999	–	–	2.22	0.05
2000	–	–	2.03	0.05
2001	–	–	1.66	0.05
2002	–	–	1.73	0.04
2003	–	–	1.17	0.05
2004	–	–	0.80	0.04
2005	–	–	0.70	0.04
2006	–	–	0.86	0.04
2007	–	–	0.60	0.04
2008	–	–	0.69	0.04
2009	–	–	0.84	0.04
2010	–	–	0.71	0.04
2011	–	–	0.75	0.04
2012	–	–	0.55	0.05
2013	–	–	0.57	0.05
2014	–	–	0.52	0.06

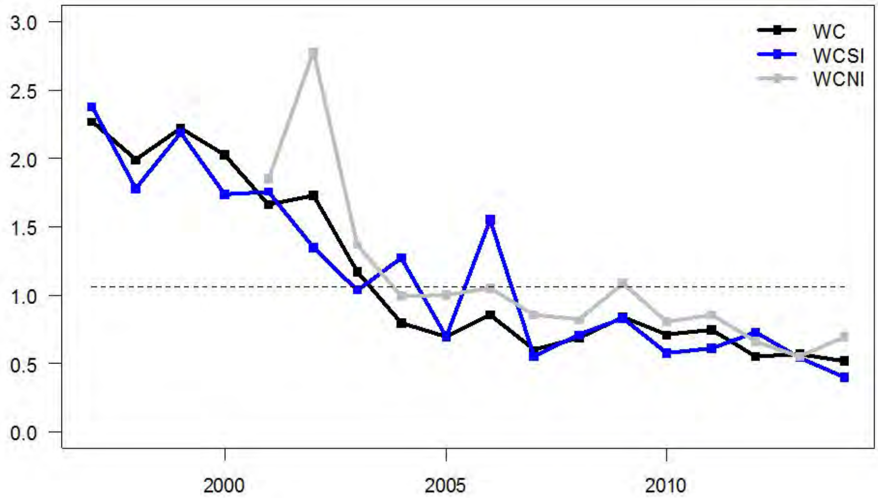


Figure 2: Blue mackerel CPUE for 1997–2014 for West coast (WC); WCSI, and WCNI. Indices have been standardised to have a mean of one.

4.3 Biomass estimates

No estimates of biomass are available for any blue mackerel stocks.

4.4 Other factors

Catch sampling in the period from 2002 to 2005 indicated that catch-at-length and catch-at-age is relatively stable between years in EMA 1. Although total mortality in EMA 1 is poorly understood, the relatively stable age-length composition between years and the number of year-classes that compose the catch-at-age within fishing years, suggested that blue mackerel may be capable of sustaining the catch levels at that time in EMA 1.

5. STATUS OF THE STOCKS

Based on studies of stock structure within New Zealand waters blue mackerel may be sub-divided into at least three stocks: EMA 1, EMA 2, and EMA 7. No information is currently available on the stock affinity of fish in EMA 3.

Little is known about the status of blue mackerel stocks and no estimates of current and reference biomass, or yield, are available for any blue mackerel area.

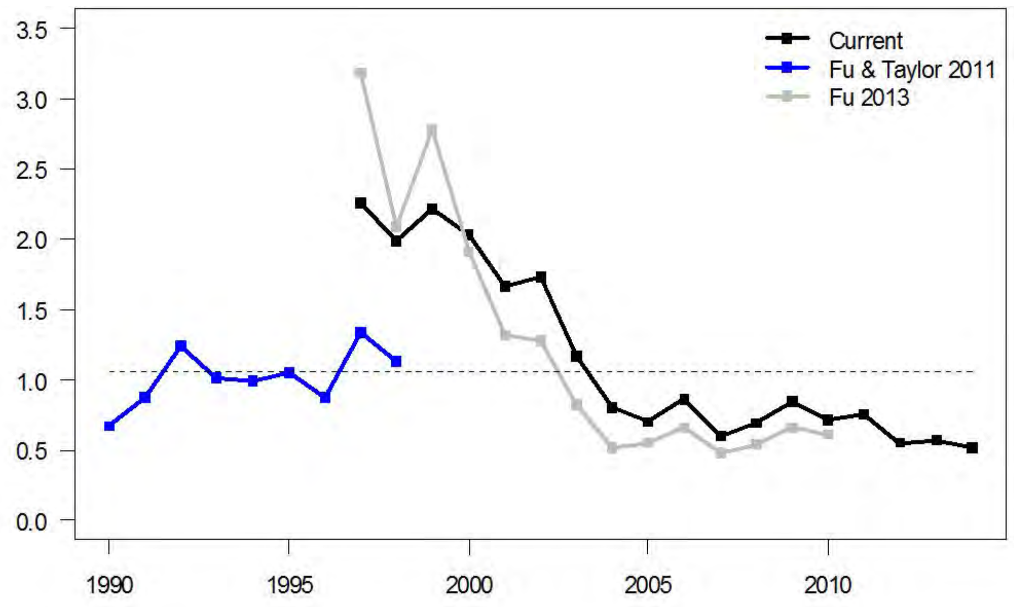
- **EMA 1**

For EMA 1, the stability of the age composition data and the large number of age classes that comprise the catches suggests that blue mackerel may be capable of sustaining current commercial fishing mortality, at least in the short-term.

- **EMA 7**

Stock Status	
Year of Most Recent Assessment	2016
Assessment Runs Presented	Standardised trawl CPUE
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



West coast blue mackerel CPUE: Comparison of indices for the TCEPR tow-by-tow datasets for fishing years 1990–2014 , current analysis with CPUE indices from Fu (2013) and Fu & Taylor (2011). Indices have been standardised to have a mean of one.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE has continued to decline since 2009
Recent Trend in Fishing Intensity or Proxy	

Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Broad age structure of the trawl catch (2004–05) did not support a large decrease in biomass from 1999 to 2005 as suggested by the CPUE series

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE from the jack mackerel target fishery WCSI and WCNI	
Assessment Dates	Latest assessment: 2016	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Standardised CPUE - Proportions at age data from the commercial trawl fishery	1 – High Quality 1 – High Quality
Data not used (rank)		
Changes to Model Structure and Assumptions	-	
Major sources of Uncertainty	-	

Qualifying Comments
The decline in CPUE from 1999 to 2005 was not consistent with the broad range of ages in the trawl catch. However, no recent age data are available.

Fishery Interactions
There is a small target fishery for blue mackerel on the WCNI but the bulk of the catch is taken as bycatch in the jack mackerel mid-water trawl fishery on the WCSI and WCNI, which has issues with bycatch of kingfish and snapper. Incidental interactions and associated mortality of common dolphins occur in the jack mackerel fishery. Interactions with other species are currently being characterised.

Table 7: Summary of reported landings (*t*) and TACCs by QMA for the most recent fishing year.

Fishstock	FMA	2018–19 TACC	2018–19 Reported Landings
EMA 1	1	7 630	7 630
EMA 2	2	180	12
EMA 3	3–6	390	32
EMA 7	7–9	3 350	2 626
EMA 10	10	0	0
TOTAL		11 550	10 300

6. FOR FURTHER INFORMATION

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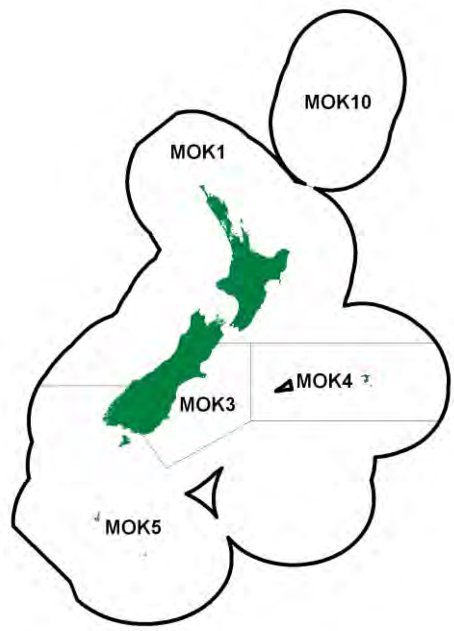
BLUE MOKI (MOK)

(*Latridopsis ciliaris*)
Moki



1. FISHERY SUMMARY

1.1 Commercial fisheries

Most blue moki landings are taken by set net or trawl off the east coast between the Bay of Plenty (BoP) and Kaikoura, although small quantities are taken in most New Zealand coastal waters. Although the proportions of the total commercial landings taken by set net and trawl have varied over time, set netting has been the predominant method, accounting for 50–60% of the annual catch during 1989–90 to 2011–12. The proportion of the catch taken by set net declined in the more recent years (to 2015–16) and catches by the two methods were at about parity during this period.

Reported landings and TACCs are given in Tables 1 and 2, and an historical record of landings and TACC values for the two main MOK stocks are depicted in Figure 1. Landings of blue moki peaked in 1970 and 1979 at about 960 t. Blue moki stocks appeared to have been seriously depleted by fishing prior to 1975 and this resulted in the sum of allocated ITQs being markedly less than the sum of the catch histories.

Table 1: Total reported landings (t) of blue moki from 1979 to 1985–86.

Year	1979*	1980*	1981*	1982*	1983†	1983–84†	1984–85†	1985–86†
Landings	957	919	812	502	602	766	642	636

*MAF data.
†FSU data.

Total annual landings of blue moki were substantially constrained when it was introduced into the QMS. In MOK 1, landings increased as the TACC was progressively increased. Since the TACC was set at 400 t (1995–96) landings have fluctuated around the TACC, which was subsequently increased to 403 t in 2001–02.

Landings from MOK 3 increased from the mid-2000s and exceeded the TACC of 127 t from 2010–11. The TACC was increased to 160 t in 2014–15, and landings have fluctuated around the TACC since. The combined MOK 1 and 3 catch fluctuated around 500 t per annum during 1994–95 to 2009–10. Since then annual landings have been about 550 t and peaked at over 600 t in 2017–18.

Annual landings from MOK 4 and 5 are generally < 10 t.

Table 2: Reported landings (t) and actual TACCs (t) of blue moki by Fishstock from 1986–87 to 2018–19. Source: QMS data. MOK 10 is not tabulated; no landings have ever been reported from MOK 10.

Fishstock	MOK 1		MOK 3		MOK 4		MOK 5			
FMA (s)	1,2,7,8,9		3		4		5 & 6		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1986–87	109	130	52	60	0	20	3	40	164	260
1987–88	183	142	95	62	0	20	2	40	280	274
1988–89	134	151	121	64	0	20	3	40	258	285
1989–90	202	156	89	65	11	25	1	43	303	299
1990–91	264	157	93	71	1	25	2	43	360	306
1991–92	285	157	66	71	2	25	2	43	355	306
1992–93	289	157	94	122	1	25	4	43	388	358
1993–94	374	200	102	126	4	25	5	43	485	404
1994–95	418	200	90	126	< 1	25	3	43	511	404
1995–96	435	400	91	126	1	25	3	43	530	604
1996–97	408	400	66	126	2	25	3	43	479	604
1997–98	416	400	78	126	3	25	2	43	500	604
1998–99	468	400	78	126	< 1	25	4	43	551	604
1999–00	381	400	56	126	1	25	5	43	443	604
2000–01	420	400	67	126	5	25	6	43	499	604
2001–02	365	403	77	127	8	25	2	44	451	608
2002–03	380	403	87	127	2	25	6	44	475	608
2003–04	372	403	60	127	2	25	6	44	440	608
2004–05	418	403	70	127	3	25	11	44	502	608
2005–06	408	403	69	127	1	25	5	44	483	608
2006–07	402	403	90	127	< 1	25	11	44	504	608
2007–08	401	403	125	127	< 1	25	8	44	533	608
2008–09	413	403	103	127	1	25	8	44	525	608
2009–10	386	403	129	127	< 1	25	6	44	521	608
2010–11	421	403	144	127	< 1	25	10	44	574	608
2011–12	427	403	137	127	< 1	25	6	44	571	608
2012–13	385	403	159	127	< 1	25	5	44	549	608
2013–14	393	403	134	127	<1	25	7	44	535	608
2014–15	376	403	146	160	<1	25	6	44	529	631
2015–16	395	403	183	160	<1	25	8	44	587	631
2016–17	387	403	162	160	<1	25	7	44	556	631
2017–18	435	403	178	160	<1	25	7	44	620	631
2018–19	389	403	149	160	<1	25	5	44	543	631

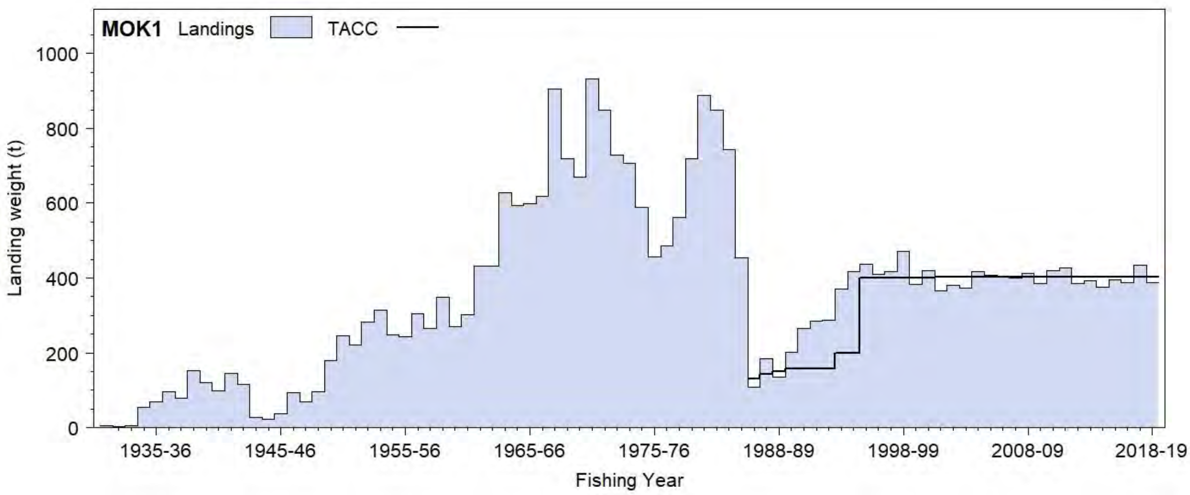


Figure 1: Reported commercial landings and TACC for the two main MOK stocks: MOK 1 (Auckland, Central, and Challenger). Note: these figures do not show data prior to entry into the QMS. [Continued on next page]

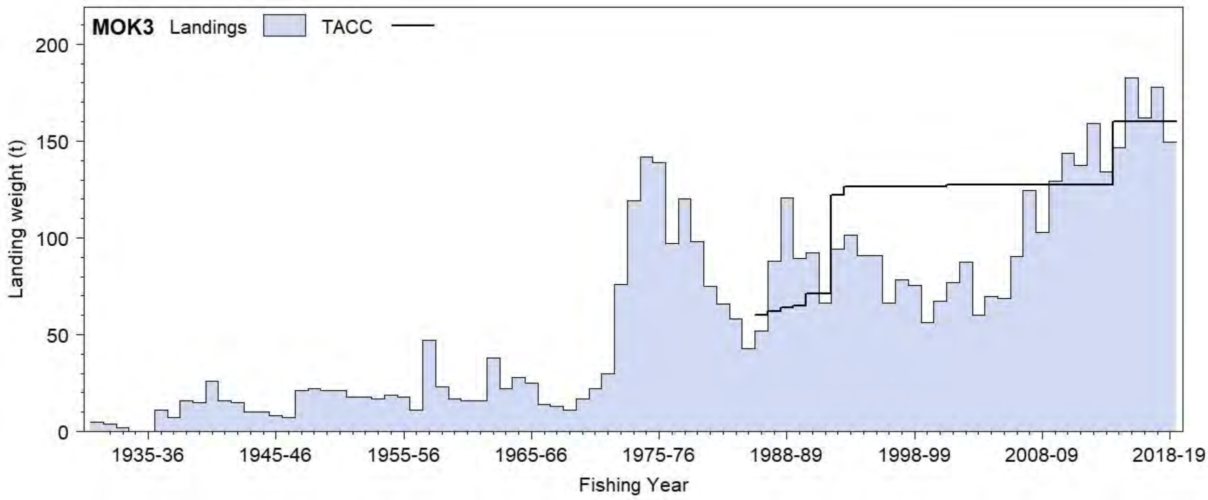


Figure 1 [Continued]: Reported commercial landings and TACC for the two main MOK stocks: MOK 3 (South East Coast). Note: these figures do not show data prior to entry into the QMS.

1.2 Recreational fisheries

Popular with recreational fishers, blue moki are taken by beach anglers, set netting, and spearfishing. Annual estimates of recreational harvest were obtained from diary surveys in 1991–94, 1996, and 1999–2000 (Tables 3a & 3b).

Table 3a: Estimated number and weight of blue moki harvested by recreational fishers by Fishstock and survey. Surveys were carried out in different years in the MAF Fisheries regions: South in 1991–92, Central in 1992–93, and North in 1993–94 (Teirney et al 1997).

Fishstock	Survey	Number	CV(%)	Survey harvest (t)
MOK 1	North	6 000	-	5–15
MOK 1	Central	38 000	28	40–80
MOK 1	South	2 000	-	0–5
MOK 3	South	31 000	33	40–70
MOK 5	South	7000	33	5–15

Table 3b: Estimates of annual number and weight of blue moki harvested by recreational fishers from national diary surveys in 1996 (Bradford 1998) and Dec 1999–Nov 2000 (Boyd & Reilly 2005). The mean weights used to convert numbers to catch weight are considered the best available estimates. Estimated harvest is also presented as a range to reflect the uncertainty in the point estimates.

Fishstock	Number caught	CV	Estimated harvest range (t)	Point estimate (t)
				1996
MOK 1	63 000	14	80–110	93
MOK 3	16 000	18	20–30	24
MOK 5	9 000	–	–	–
				1999–2000
MOK 1	81 000	37	82–180	131
MOK 3	36 000	32	36–70	53
MOK 5	38 000	89	7–115	61

The harvest estimates provided by telephone/diary surveys between 1993 and 2001 are no longer considered reliable for various reasons. A Recreational Technical Working Group concluded that these harvest estimates should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries. In response to these problems and the cost and scale challenges associated with onsite methods, a National Panel Survey was conducted for the first time throughout the 2011–12 fishing year (Wynne-Jones et al 2014). The panel survey used face-to-face interviews of a random sample of 30 390 New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and harvest information collected in standardised phone interviews. The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly comparable results (Wynne-Jones et al 2019). Recreational catch estimates from the two national panel surveys are given in Table 4. Note that national panel survey estimates do not include recreational harvest taken under s111 general approvals.

Table 4: Recreational harvest estimates for blue moki stocks (Wynne-Jones et al 2014, 2019). Mean fish weights were obtained from boat ramp surveys (Hartill & Davey 2015 and Davey et al 2019).

Stock	Year	Method	Number of fish	Total weight (t)	CV
MOK 1	2011–12	Panel survey	21 945	44.5	0.31
	2017–18	Panel survey	16 598	32.6	0.26
MOK 3	2011–12	Panel survey	5 739	11.6	0.53
	2017–18	Panel survey	8 324	16.3	0.29
MOK 5	2011–12	Panel survey	243	0.5	1.02
	2017–18	Panel survey	7 018	13.8	0.58

1.3 Customary non-commercial fisheries

A traditional Maori fishery exists in some areas, particularly the eastern Bay of Plenty and East Cape regions. No quantitative information is available on the level of customary non-commercial catch.

Iwi in the Cape Runaway area have a strong view that blue moki are of special significance in the history and life of the community. They believe that blue moki come to spawn in the waters around Cape Runaway and there are traditional fishing grounds, where in earlier years fishing took place in accordance with customary practices. In addition, these local Iwi consider the taking of blue moki by nets in this area to be culturally offensive.

Since September 1996, fishing by the methods of trawling, Danish seining, and set netting has been prohibited at all times within a two nautical mile wide coastal band beginning at the high water mark and extending from Cape Runaway to a stream tributary at Oruiti Beach. Note this is not a legal description, for full details please refer to the Fisheries Act (Auckland and Kermadec Areas Commercial Fishing Regulations 1986, Amendment No. 13).

1.4 Illegal catch

No quantitative estimates are available.

1.5 Other sources of mortality

Some blue moki caught for use as rock lobster bait have not been reported. Although little information is available, this practice appears to have been most common around Stewart Island and the Chatham Islands and may have accounted for about 45 t and 60 t from Stewart Island and Chatham Islands, respectively, in the past. The use of blue moki as bait has not been considered in the determination of *MCY*.

2. BIOLOGY

Blue moki grow rapidly at first, attaining sexual maturity at 40 cm fork length (FL) at 5–6 years of age. Growth then slows, and fish of 60 cm FL are 10–20 years old. Fish over 80 cm FL and 43 years old have been recorded (Manning et al 2009).

Many adults take part in an annual migration between Kaikoura and East Cape. The migration begins off Kaikoura in late April–May as fish move northwards. Spawning takes place in August–September in the Mahia Peninsula to East Cape region (the only known spawning ground), with the fish then returning south towards Kaikoura. The larval phase for blue moki lasts about 6 months.

Juvenile blue moki are found inshore, usually around rocky reefs, whereas most adults school offshore over mainly open bottom. Some adults do not join the adult schools but remain around reefs.

Biological parameters relevant to the stock assessment are shown in Table 5.

Table 5: Estimates of biological parameters for blue moki.

Fishstock				Estimate	Source
1. Natural mortality (*M*)					
All areas				0.14	Francis (1981b)
For maximum observed age of 33 yr.					
MOK 1				0.10	Manning et al (2009)
For maximum observed age of 44 yr.					
2. Weight = a(length)^b (Weight in g, length in cm fork length).					
	Both sexes				
	a	b			
All areas	0.055	2.713			Francis (1979)
3. von Bertalanffy growth parameters					
	Both sexes				
	L_∞	k	t_0		
All areas	66.95	0.208	-0.029		Francis (pers. comm.)

The estimate of natural mortality, given a maximum age of 43 years and using the equation $M = \log_e 100$/maximum age, is 0.1. Note that the maximum age for this calculation is meant to be the maximum age that 1% of the unfished population will reach, however, as this is not known, the maximum observed age was used here.

3. STOCKS AND AREAS

There are no new data which would alter the stock boundaries given in previous assessment documents.

Blue moki forms one stock around the North Island and the South Island north of Banks Peninsula. No information is available to indicate stock affiliations of blue moki in other areas (southern South Island and Chatham Rise) so these fish are currently divided into three Fishstocks.

4. STOCK ASSESSMENT

4.1 Estimates of fishing mortality

Estimates of total mortality (*Z*) for MOK 1 were obtained from catch curve analysis of catch sampling data collected during 2004–05 and 2005–06. Samples were taken from both the target set net fishery and from bycatch from the TAR 2 trawl fishery. When data were pooled across the two years, sexes and fishing methods, *Z* estimates ranged from 0.11 to 0.14, depending on assumed age-at-full recruitment (ages 4–12 years were tested). Assuming a value of natural mortality of 0.10 (based on a maximum age of 44 years), this suggests that recent fishing mortality is likely to be in the range of about 0.01 to 0.04. The Working Group considered that the most plausible age-at-full recruitment was 8 years. The estimate of Z and the bootstrapped 95% confidence intervals were 0.14 (0.12–0.16), giving rise to an *F* estimate of 0.04 (0.02–0.06). These estimates are well below the current assumed value of natural mortality (Manning et al 2009).

4.2 CPUE analyses

In 2017, a summary of the recent trends in catch from the MOK 1 and MOK 3 fisheries was presented to the Southern Inshore Fishery Assessment Working Group (Langley 2018). The analysis identified three main fisheries catching blue moki:

1. The bottom trawl fishery operating within the Gisborne-Mahia area (Statistical Area 013) throughout the year.
2. The target blue moki set net fishery operating between East Cape and Wairarapa (Statistical Areas 014–015) primarily during May–October.
3. The Kaikoura set net fishery (Statistical Area 018) operating during May–June and October.

For each fishery, a standardised CPUE analysis was conducted for 1989–90 to 2015–16. All three CPUE analyses modelled the positive catch of blue moki assuming a lognormal error structure, and the CPUE analysis of the tarakihi bottom trawl fishery (BT-TAR2-North) also modelled the presence of blue moki in the catch and derived delta-lognormal CPUE indices (Figure 2).

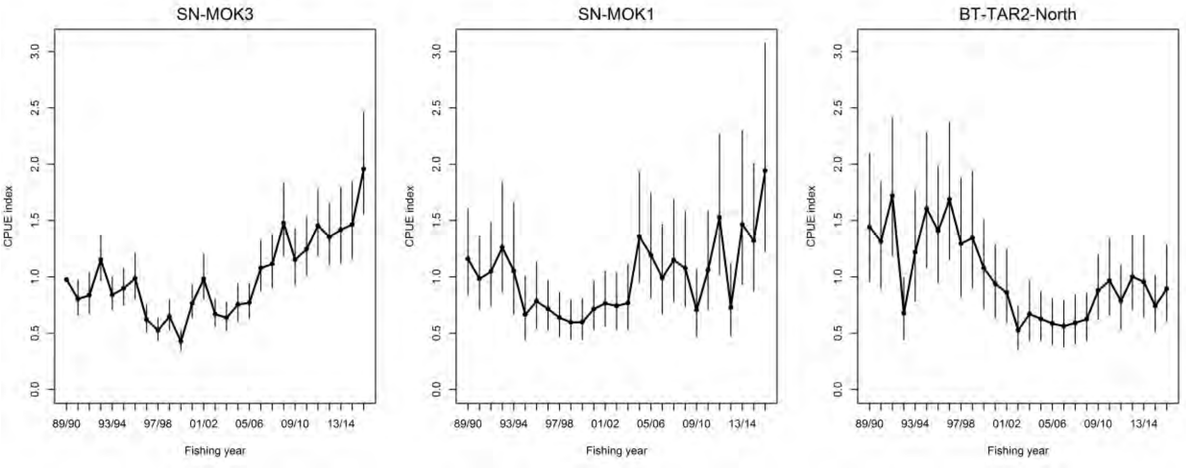


Figure 2: CPUE indices and 95% confidence intervals from the three main MOK 1 and MOK 3 fisheries.

The SN-MOK3 CPUE indices increased from a relatively low level in 1996–97 to 1999–2000 to reach the highest level of the time series in 2015–16. The SN-MOK1 CPUE indices increased during the same period although the CPUE indices are considerably more variable among years and are less well determined than the SN-MOK3 CPUE indices. The higher variability in the SN-MOK1 indices appears to be related to the inter-annual variation in the operation of the fishery (between Statistical Areas) and limited continuity in the core set of vessels participating in the fishery.

The SINSWG rejected the SN-MOK1 and SN-MOK3 CPUE indices as monitoring tools which could be used to determine stock status against Harvest Standard reference points, for the following reasons:

1. High inter-annual variation in the CPUE indices due to the low precision of CPUE indices derived from limited catch-effort data sets from these small fisheries and/or inter-annual variation in the catchability (availability) of migrating fish.
2. Possible hyperstability as a result of fishing directed at dense schools of migrating fish.

The WG nevertheless agreed that the SN-MOK1 and SN-MOK3 CPUE indices were likely to be broadly indicative of trends in abundance.

The two sets of SN CPUE indices are considered to represent the component (or components) of the blue moki stock migrating northward prior to spawning and then returning southward following spawning. These CPUE indices indicate that there has been a general increase in the abundance of adult blue moki within MOK 3 and the southern area of MOK 1 from the late 1990s. This is consistent with the estimates of total mortality derived from the population age structure in 2005–06 that indicated that fishing mortality on the adult population was less than natural mortality (*M*).

The BT-TAR2-North CPUE indices contrast the trend in the CPUE indices from the two set net fisheries. The BT-TAR2-North CPUE indices declined from 1996–97 to 2002–03 and remained at a relatively low level during 2002–03 to 2008–09. The index increased in 2009–10 and remained at about that level during 2010–11 to 2015–16. These recent indices are at a level considerably lower than the indices from 1989–90 to 1996–97 (with the exception of the low 1992–93 index).

The BT-TAR2-North CPUE indices are considered to predominantly comprise a component of the blue moki stock that remains in the Gisborne-Mahia area throughout the year. The trawl catch is probably comprises both immature and mature blue moki, although limited sampling of this component of the stock was conducted during the catch sampling programme. The SINSWG considered that the BT-TAR2-North CPUE series potentially provides an index of abundance for the resident portion of the population, but did not provide a monitoring tool for the entire population.

The contrasting trends in the CPUE indices (SN-MOK1 and SN-MOK3 versus BT-TAR-North) are indicative of differences in the stock dynamics (recruitment and/or exploitation) in the two components of the stock (resident and migrating). It was not considered feasible to amalgamate the three sets of CPUE indices to derive a composite set of abundance indices for the MOK 1&3 stock because the relative proportion of the stock biomass monitored by each CPUE series is unknown. Thus, the utility of the CPUE series is limited to the monitoring each component of the stock separately.

4.3 Biomass estimates

Estimates of current and reference biomass are not available.

4.4 Yield estimates and projections

MCY for all Fishstocks combined was estimated using the equation, $MCY = cY_{AV}$ (Method 4). The national catch, and probably effort, over the period 1961–86 varied considerably (annual landings ranged from 450 to 957 t with an average value of 705 t). However, no clear trend in landings over that period is apparent. The value of c was set equal to 0.9 based on the estimate of $M = 0.14$.

$$MCY = 0.9 * 705 \text{ t} = 635 \text{ t}$$

The level of risk to the stock by harvesting the population at the estimated *MCY* value cannot be determined.

Yield estimates for blue moki have been made using reported commercial landings data only and therefore apply specifically to the commercial fishery. Blue moki have been caught and used as bait and not reported. Therefore, the *MCY* estimates are likely to be conservative.

No estimate of *CAY* is available for blue moki stocks.

4.5 Other factors

CPUE data from the 1970s for the main northern blue moki stock indicated that the stock had declined to a level low enough to make recruitment failure a real concern. The 1986–87 TAC was set at a level considered low enough to enable some stock rebuilding.

Blue moki forms one stock around the North Island and the east coast of the South Island north of Banks Peninsula. As other stock boundaries are unknown, any interdependence is uncertain. If only one stock exists, then blue moki from the southern waters may be moving north and rebuilding the heavily exploited northern population.

5. STATUS OF THE STOCKS

Stock Structure Assumptions

Blue moki forms one stock around the North Island and the South Island north of Banks Peninsula. The bulk of the commercial catch is taken off the east coast between Banks Peninsula and East Cape, suggesting that this is where most of the blue moki stock resides.

MOK 1&3

Stock Status	
Year of Most Recent Assessment	2017
Assessment Runs Presented	2008 – Catch-at-age 2017 – Three CPUE series

Reference Points	Target: Not established but $F = M$ assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: Not established but $F = M$ assumed
Status in relation to Target	F is Very Likely (> 90%) to be below M
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unknown
Status in relation to overfishing	F is Very Unlikely (< 10%) to be above M

Historical Stock Status Trajectory and Current Status	-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Catch curve analysis from catch sampling the migratory adult population (2004–05 and 2005–06) indicated that total mortality was low, with fishing mortality well below natural mortality. The general increase in CPUE from the SN-MOK1 and SN-MOK3 fisheries suggests that the biomass of migratory adults has increased since then.
Recent Trend in Fishing Intensity or Proxy	Low estimates of fishing mortality in 2005–06 and stable catches over the previous 14 years suggest that fishing mortality had been low for more than two decades. Recent increases in CPUE suggest that adult biomass has increased since the catch-at-age study, and together with constant catch suggests that fishing mortality remains below the target.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	CPUE indices from three fisheries are not considered to be sufficiently reliable to represent abundance indices for the stock. Rather, the indices are considered to be indicative of general trends in abundance for components of the stock. The SN-MOK1 and SN-MOK3 CPUE indices indicate that there has been a general increase in the abundance of adult blue moki within MOK 3 and the southern area of MOK 1 from the late 1990s. By contrast the BT-TAR2N series suggests that resident MOK in the northern part of FMA2 (Mahia Peninsula) declined to the mid-2000s and then increased to 2010–11, after which it fluctuated without trend at a level approximately half of that in the early 1990s.

Projections and Prognosis	
Stock Projections or Prognosis	If catches remain at current levels then fishing mortality should remain below the target.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Fishing mortality was estimated to be below the target fishing mortality level (M) in the mid-2000s. Since then, there has been a general increase in stock abundance of the migrating adult component of the stock (as indicated by the CPUE trends). It is therefore Unlikely (< 10%) that fishing mortality will exceeds the overfishing threshold at current catch levels.

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative stock assessment	
Assessment Method	Estimates of total mortality using Chapman-Robson estimator	
Assessment Dates	Latest assessment: 2017	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Age structure of setnet and trawl catches of blue moki made between Kaikoura and East Cape in 2004–05 and 2005–06	1 – High Quality
	-Instantaneous rate of natural mortality (*M*) of 0.10 based on a maximum age of 44 years	2 – Medium or Mixed Quality: uncertainty in estimate of M
	-CPUE indices for migrant components of the stock (SN-MOK1 and SN-MOK3 CPUE)	2 – Medium or Mixed Quality: may not be fully representative
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	Uncertainty in the estimate of *M* Reliability of CPUE indices as indices of stock abundance.	

Qualifying Comments
-
Fishery Interactions
Interactions with other species are currently being characterised.

Yields and reported landings are summarised in Table 6.

Table 6: Summary of yields (t), TACCs (t), and reported landings (t) for blue moki for the most recent fishing year.

Fishstock	QMA	*MCY*	2018–19 Actual TACC	2018–19 Reported landings
MOK 1	Auckland (East) (West), Central (East) (West), Challenger 1, 2, 7, 8 & 9	-	403	389
MOK 3	South East (Coast) 3	-	160	149
MOK 4	South East (Chatham) 4	-	25	< 1
MOK 5	Southland, Sub-Antarctic 5 & 6	-	44	5
MOK 10	Kermadec 10	-	10	0
Total		635	631	543

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BLUE WAREHOU (WAR)

(Seriolella brama)
Warehou

1. FISHERY SUMMARY

1.1 Commercial fisheries

Blue (or common) warehou are caught in coastal waters of the South Island and lower North Island down to depths of about 400 m. Annual landings were generally less than 100 t up to the early 1960s, increased to about 1000 t by the early 1970s, and peaked at 4387 t in 1983–84 before declining steadily through to 1988–89 (Table 2). Figure 1 shows the historical landings and TACC values for the main WAR stocks.

The decline was most notable in WAR 3, from which most of the catch is recorded. A TACC reduction for WAR 3, from 3357 to 2528 t, was approved for the 1990–91 fishing year. In 1990–91, total catch increased substantially. The largest increase was in WAR 3 and catches in this area exceeded 2000 t for the following three years. There is no direct correlation between WAR 3 catches and fluctuations in effort in the Snares squid fishery where blue warehou is mostly taken as bycatch. In 1996–97, total catch increased again to 1990–91 levels and total catch has been maintained at this level since. Increased catches in WAR 2, 3 and 7 contributed to the increased total catch.

Until the mid 1980s, the main domestic fishing method used to catch blue warehou was gill-netting. The majority of the landings are now taken as a bycatch from trawling. Bull & Kendrick (2006) describe the commercial fishery from 1989–90 to 2002–03.

Catches have fluctuated in most stocks but overall the total landings have increased. In 2002–03, total reported landings of blue warehou were the highest on record, with catches in WAR 3 exceeding the TACC by 983 t. From 2002–03 to 2006–07 catches in WAR 3 were well above the TACC as fishers landed catches well in excess of ACE holdings and paid deemed values for the overcatch. From 1 October 2007 the deemed values were increased to $0.90 per kg for WAR 3 and WAR 7 stocks and differential rates were also introduced. The differential rate applied to all catch over 110% of ACE holding at which point the deemed value rate increased to $2 per kg. The effect of these measures was seen immediately in 2007–08 as fishing without ACE was reduced and catch fell well below the TACC in WAR 3. Landings subsequently increased again and exceeded the TACC slightly in 2009-10 and 2014-15. In all other areas landings are below the TACCs.

Table 2: Reported landings (t) of blue warehou by Fishstock 1983–84 to 2018–19 and actual TACCs (t) from 1986–87 to 2018–19. QMS data from 1986–present. [Continued on next page.]

Fishstock		WAR 1		WAR 2		WAR 3		WAR 7
FMA		1 & 9		2		3, 4, 5 & 6		7
	Landings	TACC	Landings	TACC	Landings	TACC	Landings‡	TACC
1983–84*	13	-	346	-	3 222	-	702	-
1984–85*	5	-	278	-	1 313	-	478	-
1985–86*	15	-	185	-	1 584	-	955	-
1986–87	7	30	190	480	1 330	3 210	780	910
1987–88	7	41	204	560	976	3 223	685	962
1988–89	12	41	177	563	672	3 348	561	969
1989–90	17	41	201	570	814	3 357	607	1 047
1990–91	14	41	250	570	2 097	2 528	758	1 117
1991–92	25	41	235	570	2 514	2 528	1 001	1 117
1992–93	15	41	199	578	2 310	2 530	539	1 120
1993–94	16	41	233	578	688	2 530	436	1 120
1994–95	15	41	203	578	1 274	2 530	468	1 120
1995–96	32	41	368	578	1 573	2 530	756	1 120
1996–97	24	41	563	578	1 814	2 531	1 428	1 120
1997–98	20	41	402	578	2 328	2 531	860	1 120
1998–99	15	41	503	578	1 978	2 531	1 075	1 120
1999–00	9	41	422	578	2 761	2 531	1 147	1 120
2000–01	12	41	388	578	1 620	2 531	1 572	1 120
2001–02	7	41	294	578	1 614	2 531	1 046	1 120
2002–03	5	41	429	578	3 514	2 531	961	1 120
2003–04	6	41	392	578	3 539	2 531	755	1 120
2004–05	6	41	402	578	2 963	2 531	756	1 120
2005–06	4	41	293	578	3 505	2 531	691	1 120
2006–07	4	41	235	578	3 326	2 531	823	1 120
2007–08	7	41	198	578	684	2 531	569	1 120
2008–09	9	41	210	578	2 021	2 531	733	1 120
2009–10	6	41	204	578	2 601	2 531	414	1 120
2010–11	11	41	102	578	2 086	2 531	633	1 120
2011–12	13	41	131	578	2 425	2 531	714	1 120
2012–13	8	41	172	578	1 847	2 531	632	1 120
2013–14	17	41	153	578	1 819	2 531	551	1 120
2014–15	24	41	123	578	2 674	2 531	823	1 120
2015–16	5	41	167	578	1 861	2 531	764	1 120
2016–17	14	41	143	578	2 357	2 531	875	1 120
2017–18	13	41	88	578	1 468	2 531	772	1 120
2018–19	7	41	45	578	2 063	2 531	764	1 120

Fishstock		WAR 8		WAR 10		
FMA		8		10		Total
	Landings	TACC	Landings	TACC	Landings	TACC
1983–84*	104	-	0	-	4 387	-
1984–85*	91	-	0	-	2 165	-
1985–86*	43	-	0	-	2 782	-
1986–87	40	210	0	10	2 347	4 850
1987–88	43	218	0	10	1 915	5 014
1988–89	44	231	0	10	1 466	5 162
1989–90	57	233	0	10	1 696	5 459
1990–91	113	233	0	10	3 232	4 499
1991–92	132	233	<1	10	3 905	4 499
1992–93	152	233	<1	10	3 215	4 512
1993–94	126	233	0	10	1 500	4 512
1994–95	114	233	0	10	2 074	4 512
1995–96	186	233	0	10	2 913	4 512
1996–97	161	233	0	10	3 990	4 513
1997–98	111	233	0	10	3 720	4 513
1998–99	168	233	0	10	3 739	4 513
1999–00	116	233	0	10	4 455	4 513
2000–01	143	233	0	10	3 735	4 513
2001–02	146	233	0	10	3 107	4 513
2002–03	192	233	0	10	5 101	4 513
2003–04	129	233	0	10	4 821	4 513
2004–05	157	233	0	10	4 284	4 513
2005–06	76	233	0	10	4 569	4 513
2006–07	59	233	0	10	4 448	4 513
2007–08	72	233	0	10	1 530	4 513
2008–09	146	233	0	10	3 119	4 513
2009–10	159	233	0	10	3 384	4 513
2010–11	92	233	0	10	2 924	4 512

Table 2 [Continued]

Fishstock	WAR 8		WAR 10			
FMA		8		10		Total
	Landings	TACC	Landings	TACC	Landings	TACC
2011–12	97	233	0	10	3 381	4 512
2012–13	111	233	0	10	2 770	4 512
2013–14	161	233	0	10	2 701	4 512
2014–15	69	233	0	10	3 713	4 512
2015–16	95	233	0	10	2 891	4 512
2016–17	59	233	0	10	3 448	4 512
2017–18	134	233	0	10	2 476	4 512
2018–19	50	233	0	10	2 929	4 512

* FSU data.

‡ Includes landings from unknown areas before 1986–87.

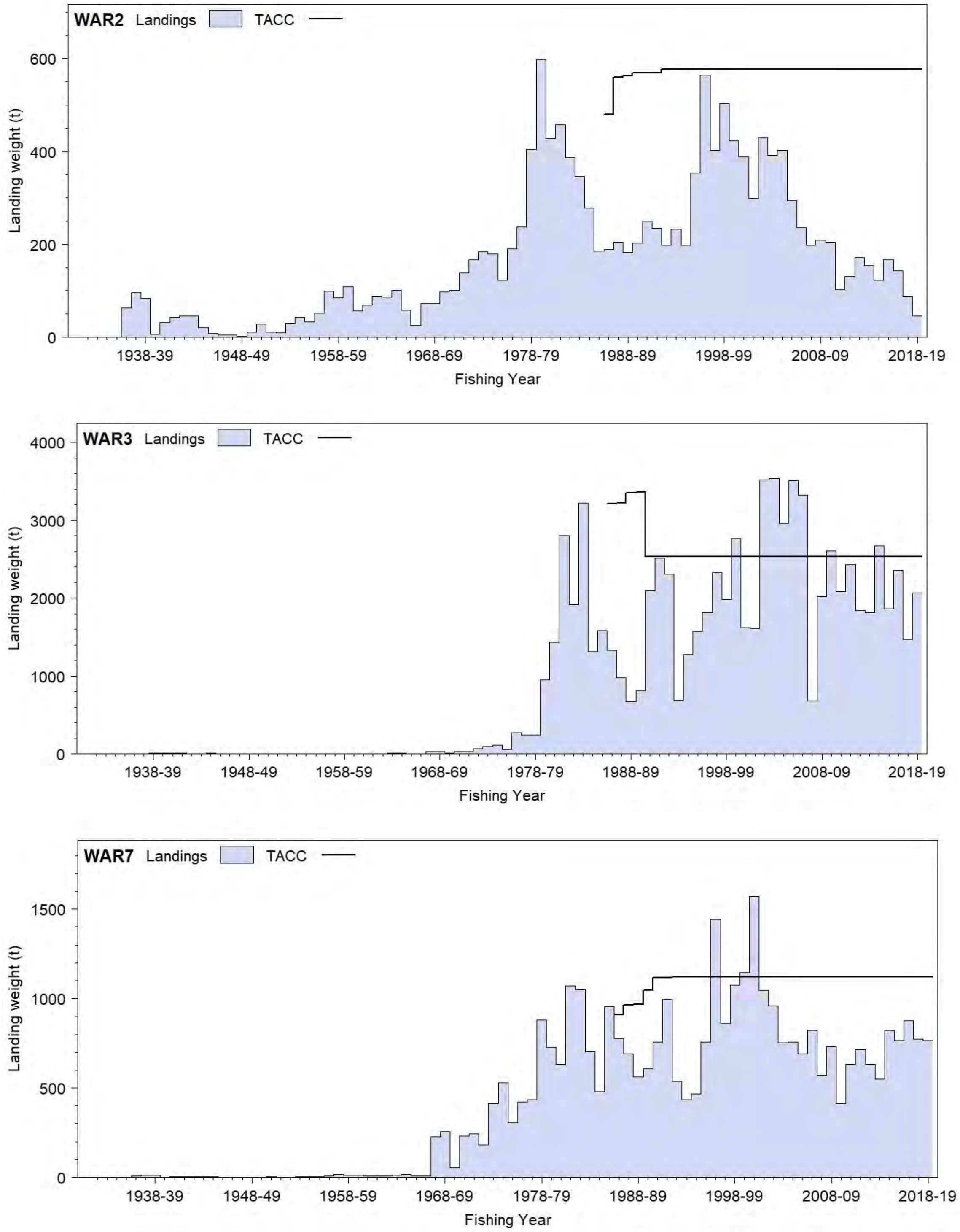

Figure 1: Reported commercial landings and TACC for the four main WAR stocks. WAR 2 (Central East), WAR 3 (South East Coast) and WAR 7 (Challenger) [Continued on next page].

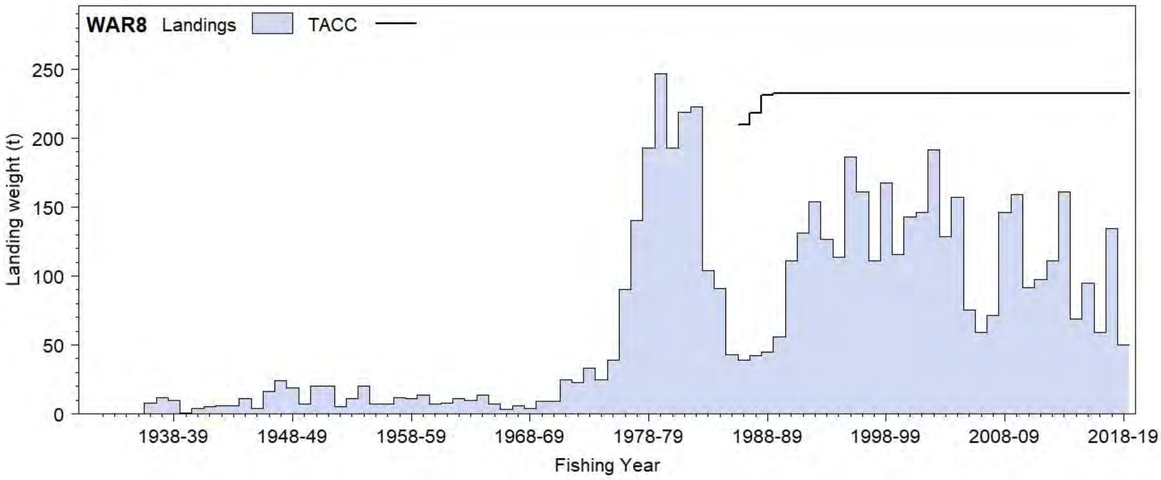

Figure 1 [Continued]: Reported commercial landings and TACC for the four main WAR stocks. WAR 8 (Central Egmont).

1.2 Recreational fisheries

Estimates of recreational catch in the MAF Fisheries Central and South regions are shown in Table 3. Surveys in the North region in 1993–94 indicated that blue warehou were not caught in substantial quantities.

Table 3: Estimated harvest (t) of blue warehou by recreational fishers. Surveys were carried out in the MAF Fisheries Southern region in 1991–92 and in the Central region in 1992–93.

Fishstock	Survey	Estimated harvest	CV
1991–92			
WAR 3	Southern	10–20	-
1992–93			
WAR 2	Central	10.0	0.62
WAR 7	Central	1.7	0.65
WAR 8	Central	0.6	1.02

Blue warehou harvest estimates from the 1996 national survey were; WAR 2, 7000 fish; WAR 3, 3000 fish and WAR 7, 1000 fish. There are locally important fisheries which will not have been adequately sampled by these surveys.

The harvest estimates provided by telephone-diary surveys between 1993 and 2001 are no longer considered reliable for various reasons. A Recreational Technical Working Group concluded that these harvest estimates should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries. In response to these problems and the cost and scale challenges associated with onsite methods, a National Panel Survey was conducted for the first time throughout the 2011–12 fishing year. The panel survey used face-to-face interviews of a random sample of 30 390 New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and harvest information collected in standardised phone interviews. The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly comparable results (Wynne-Jones et al 2019). Recreational catch estimates from the two national panel surveys are given in Table 4 in numbers of fish (insufficient data are available to convert these numbers to catch weight). Note that national panel survey estimates do not include recreational harvest taken under s111 general approvals.

Table 4: Recreational harvest estimates for blue warehou stocks (Wynne-Jones et al 2014, 2019). Insufficient data on fish weights were obtained from boat ramp surveys to convert numbers caught to tonnes.

Stock	Year	Method	Number of fish	Total weight (t)	CV
WAR 2	2011/12	Panel survey	1 485	-	-
	2017/18	Panel survey	265	-	1.00
WAR 3	2011/12	Panel survey	483	-	-
	2017/18	Panel survey	206	-	1.00
WAR 8	2011/12	Panel survey	0	-	-
	2017/18	Panel survey	568	-	0.72

1.3 Customary non-commercial fisheries
No quantitative information is available on the current level of customary non-commercial take.

1.4 Illegal catch
No quantitative information is available on the level of illegal catch.

1.5 Other sources of mortality
No information is available on other sources of mortality.

2. BIOLOGY

Blue warehou average 40–60 cm fork length (FL) and reach a maximum of about 75 cm. Validated ageing of blue warehou shows rapid growth up to the time of first spawning (about 4–5 years), but negligible growth after about 10 years. Female blue warehou grow significantly faster and reach a larger size than males. Maximum recorded ages are 22 years for males, and 21 years for females. The best estimate of M is now considered to be 0.24 (Bagley et al 1998).

Blue warehou feed on a wide variety of prey, mainly salps but also euphausiids, krill, crabs and small squid.

Known spawning areas include the west coast of the South Island (in August–September), Kaikoura (in March, April, May), Southland (in November), and Hawke Bay (in September). Eggs are found in the surface plankton and juvenile fish are believed to occur in inshore areas.

The seasonal pattern of landings suggest that there is a coastal migration of blue warehou. There is a winter/spring fishery for blue warehou at New Plymouth and north Wairarapa, a summer fishery with a small autumn peak at Wellington and a summer/autumn fishery along the east coast South Island. The west coast South Island has a fishery in August/September which picks up again in summer. There is a summer fishery in Tasman Bay.

Biological parameters relevant to the stock assessment are shown in Table 5.

Table 5: Estimates of biological parameters for blue warehou.

Fishstock	Estimate	Source
1. Natural mortality (M)		
WAR 3	0.24	Bagley et al (1998)

2. Weight = a(length)^b (Weight in g, length in cm total length).

	Females		Males		Source
	a	b	a	b	
WAR 3	0.016	3.07	0.015	3.09	Bagley et al (1998)

3. Von Bertalanffy growth parameters

	Females			Males			Source
	L_∞	k	t_0	L_∞	k	t_0	
WAR 3	66.3	0.209	-0.79	63.8	0.241	-0.46	Bagley et al (1998)
	Both Sexes						
WAR 1, 2, 7, 8 (part)	65.5	0.169	-1.35				Jones (1994)
WAR 8 (New Plymouth)	57.7	0.314	0.02				Jones (1994)

3. STOCKS AND AREAS

No definite stock boundaries are known; however, Bagley et al (1998), after considering known spawning grounds and seasonal fishing patterns, suggested that there may be four stocks:

i. A southern population, mainly off Southland but perhaps extending into the Canterbury Bight. The main spawning time is November in inshore waters east and west of Stewart Island.
ii. A central eastern population, located on the northeast coast of the South Island and south east coast of the North Island (including Wellington), spawning mainly in the northern area in winter/early spring and also in autumn off Kaikoura.
iii. A south western population which spawns on the west coast of the South Island in winter.
iv. A north western population which may spawn off New Plymouth in winter/spring.

The proposed stock structure is tentative and there may be overlap between stocks. The available age and length frequency data are insufficient to compare by area and tagging studies have been minimal (about 150 fish tagged) with no returns.

For modelling WAR 3, the area on the east coast of the South Island south of Banks Peninsula including Southland was assumed to be a single stock. Movement between the west coast of the South Island and Southland is possible but there was no evidence for this from Southland seasonal trawl surveys. Also, the existence of two spawning periods, from August to September off the west coast of the South Island and from November to December in Southland, suggests two separate stocks.

4. STOCK ASSESSMENT

4.1 Estimation of fishery parameters and abundance

Biomass estimates are available from a number of early trawl surveys (Table 6) but the CVs are rather high for the *Shinkai Maru* data. From the age data from the *Tangaroa* Southland trawl surveys (1993–96) it appears that these surveys did not sample the population consistently, as apparently strong year classes did not follow through the time series of surveys.

Table 6: Trawl survey biomass indices (t) and coefficients of variation (CV) for recruited blue warehou.

Fishstock	Area	Vessel	Trip code	Date	Biomass (*t*)	CV (%)
WAR 3	Southland	*Shinkai Maru*	SHI8101	Jan–Mar 81	2 100	43
			SHI8201	Mar–May 82	800	62
			SHI8302	Apr–83	4 700	72
			SHI8601	Jun–86	2 000	59
WAR 3	Southland	*Tangaroa*	TAN9301	Feb–Mar 93	2 297	36
			TAN9402	Feb–Mar 94	1 629	38
			TAN9502	Feb–Mar 95	1 103	38
			TAN9604	Feb–Mar 96	1 615	40

4.2 Biomass estimates

Estimates of current and reference biomass are not available for any blue warehou Fishstocks.

4.3 Yield estimates and projections

MCY was estimated using the equation $MCY = cY_{AV}$ (Method 4) for all stocks. The value of c was set equal to 0.8 based on the revised estimate of M = 0.24 from the validated ageing work completed in 1997.

Auckland, Central (East) (WAR 1 and 2)

Average landings into Wellington over the period 1977 to 1983 were relatively stable at 300 t. Landings along the east coast of the North Island have shown large fluctuations. At Gisborne landings increased from 2 t in 1978 to 140 t in 1979 before declining to 2 t again in 1983. In Napier landings fluctuated from 1 t in 1960 to 87 t in 1972, decreased to less than 20 t in 1975 before peaking at 123 t in 1978 and then declining to 30–40 t. Y_{AV} for Central (East) (FMA 2) was estimated as 300–350 t.

$$\begin{aligned} MCY &= 0.8 \times (300\text{–}350\ t) \\ &= 240\text{–}280\ t \end{aligned}$$

South-east (south of Banks Peninsula), Southland, and Sub-Antarctic (WAR 3)
The catches from 1983–84 to 1985–86 were considered to be a sustainable level of catch. Y_{AV} = 2040 t

$$MCY = 0.8 \times 2040\ t$$
$$= 1630\ t$$

Challenger (WAR 7)
The catches from 1983–84 to 1985–86 were considered to be a sustainable level of catch. Y_{AV} = 710 t.

$$MCY = 0.8 \times 710\ t$$
$$= 570\ t$$

Central (West) (WAR 8)
The average domestic landings in the Central (West) zone from 1977 to 1983 were 70 t, and the average (declining) catch over 1983–84 to 1985–86 was 79 t. An *MCY* of 80 t is suggested for this area. New Plymouth has a peak seasonal catch in July, the season extending from June to September.

$$MCY = 80\ t$$

The level of risk to the stock by harvesting the population at the estimated *MCY* value cannot be determined.

CAY cannot be estimated because of the lack of current biomass estimates.

4.4 Factors modifying yield estimates
No information available.

5. STATUS OF THE STOCKS

Estimates of reference and current biomass are not available.

For all Fishstocks, it is not known if recent landings or TACCs are at levels which will allow the stocks to move towards a size that will support the maximum sustainable yield.

From 2002–03 to 2006–07 catches in WAR 3 were well above the TACC as fishers landed catches well in excess of ACE holdings. Deemed values were increased from 1 October 2007 and landings in WAR 3 in 2007–08 were much reduced to 684 t, well below the current TACC. WAR 3 landings have since increased to more than 2000 t.

Yield estimates, TACCs and reported landings for the 2017–18 fishing year are summarised in Table 7.

Table 7: Summary of yield estimates (t), TACCs (t) and reported landings (t) for blue warehou for the most recent fishing year.

Fishstock		FMAs	*MCY*	2017–18 Actual TACC	2017–18 Reported Landings
WAR 1	Auckland (East) (West)	1 & 9	240–280	41	13
WAR 2	Central (East)	2		578	88
WAR 3	South-east (Coast) (Chatham), Southland & Sub-Antarctic	3,4,5 & 6	1 630	2 531	1 468
WAR 7	Challenger	7	570	1 120	772
WAR 8	Central West)	8	80	233	134
WAR 10	Kermadecs	10	0	10	0
Total				4 512	2 476

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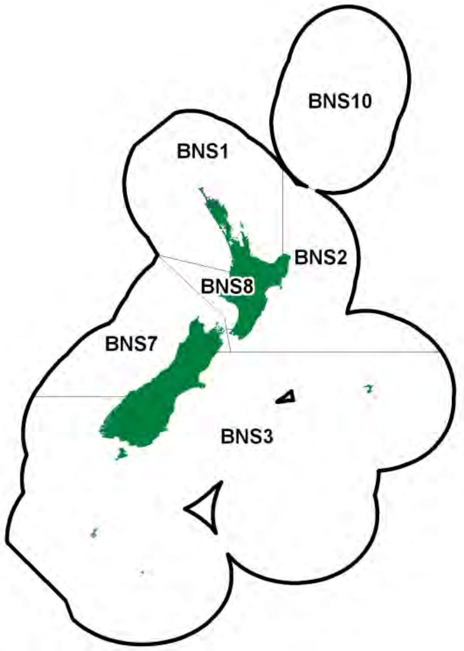
BLUENOSE (BNS)

(Hyperoglyphe antarctica)
Matiri



1. FISHERY SUMMARY

Bluenose were introduced into the QMS on 1 October 1986. A Total Allowable Catch (TAC) was set under the provisions of the 1983 Fisheries Act, initially at 1350 t. In 2010 new TACs were set for all BNS stocks along with recreational allowances, customary non-commercial allowances, and allowances for other sources of mortality. All current allowances, TACCs, and TACs can be found in Table 1.

Table 1: Recreational and customary non-commercial allowances, TACCs, and TACs by Fishstock (t) for bluenose.

Fishstock	Recreational allowance	Customary allowance	Other mortality	TACC	TAC
BNS 1	15	2	8	230	251
BNS 2	25	2	9	247	279
BNS 3	18	2	3	93	114
BNS 7	3	2	2	34	40
BNS 8	2	1	1	16	20
BNS 10	–	–	–	10	10

1.1 Commercial fisheries

Bluenose have been landed since the 1930s, although the target line fishery for bluenose only developed in the late 1970s, with the trawl fishery off the lower east coast of the North Island developing after 1983, initially as a bycatch of the alfonsino fishery (Horn 1988a). The largest domestic bluenose fisheries occur in BNS 1 and 2. Historically, catches in BNS 2 were predominately taken in the target alfonsino and bluenose trawl fisheries, but have been primarily taken by target bottom longline fishing in recent years. There is a target line fishery for bluenose in the Bay of Plenty and off Northland (both BNS 1). Target line fisheries for bluenose also exist off the west coast of the South Island (BNS 7) and the central west coast of the North Island (BNS 8). Bluenose in BNS 7 are also taken as bycatch in the hoki trawl and ling line fisheries. The BNS 3 fishery is focused on the eastern Chatham Rise where bottom longline catches were historically a bycatch of ling and hapuku target fisheries. Target bluenose lining has predominated since 2003–04. There has been a consistent bycatch of bluenose in the alfonsino target bottom trawl fishery and bluenose have been targeted sporadically in a midwater trawl fishery in BNS 3 since the early 2000s. The bottom trawl fishery in BNS 3 has diminished. A small amount of target set net fishing for bluenose occurred in the Bay of Plenty until 1999 and again since 2012. Target bluenose set net fishing also occurs sporadically in the

Wairarapa region of BNS 2. Set net catches off the east coast of the South Island have been a mix of target and bycatch in ling and hapuku target sets.

Reported landings and TACCs since 1981 are given in Table 2, and the historical landings and TACC for the main BNS stocks are depicted in Figure 1.

Table 2: Reported landings (t) of bluenose by Fishstock from 1981 to 2018–19 and actual TACCs (t) from 1986–87 to 2018–19. QMS data from 1986-present. [Continued on next page]

Fish stock	BNS 1		BNS 2		BNS 3		BNS 7		BNS 8	
FMA (s)	1 & 9		2		3, 4, 5 & 6		7		8	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1981*	146		101		36		12		–	
1982*	246		170		46		22		–	
1983†	250		352		51		47		1	
1984†	464		810		81		30		1	
1985†	432		745		73		26		1	
1986†	440		1 009		33		53		1	
1986–87	286	450	953	660	93	150	71	60	1	20
1987–88	405	528	653	661	101	166	104	62	1	22
1988–89	480	530	692	768	90	167	135	69	13	22
1989–90	535	632	766	833	132	174	105	94	3	22
1990–91	696	705	812	833	184	175	72	96	5	22
1991–92	765	705	919	839	240	175	62	96	5	22
1992–93	787	705	1 151	842	224	350	120	97	24	22
1993–94	615	705	1 288	849	311	350	79	97	27	22
1994–95	706	705	1 028	849	389	357	83	150	79	100
1995–96	675	705	953	849	513	357	140	150	70	100
1996–97	966	1 000	1 100	873	540	357	145	150	86	100
1997–98	1 020	1 000	929	873	444	357	123	150	67	100
1998–99	868	1 000	1 002	873	729	357	128	150	46	100
1999–00	860	1 000	1 136	873	566	357	114	150	55	100
2000–01	890	1 000	1 097	873	633	357	87	150	14	100
2001–02	954	1 000	1 010	873	+733	+925	70	150	17	100
2002–03	1 051	1 000	933	873	+876	+925	76	150	66	100
2003–04	1 030	1 000	933	873	915	925	117	150	96	100
2004–05	870	1 000	1 162	1 048	844	925	94	150	42	100
2005–06	699	1 000	1 136	1 048	536	925	84	150	20	100
2006–07	742	1 000	957	1 048	511	925	164	150	50	100
2007–08	585	1 000	1 055	1 048	660	925	145	150	53	100
2008–09	627	786	864	902	444	505	80	89	31	43
2009–10	665	786	845	902	419	505	94	89	36	43
2010–11	623	786	560	902	411	505	75	89	27	43
2011–12	417	571	431	629	256	248	94	89	20	43
2012–13	368	400	449	438	245	171	53	62	26	29
2013–14	382	400	435	438	248	171	60	62	28	29
2014–15	407	400	441	438	175	171	61	62	20	29
2015–16	344	400	386	438	172	171	52	62	7	29
2016–17	304	327	299	358	156	140	51	51	13	24
2017–18	208	230	267	247	139	93	38	34	4	16
2018–19	236	230	295	247	105	93	37	34	4	16

Fish stock	BNS 10			
FMA (s)	10		Total	
	Landings	TACC	Landings	TACC
1981*	0		295	
1982*	0		484	
1983†	0		701	
1984†	0		1 386	
1985†	0		1 277	
1986†	0		1 536	
1986–87	7	10	1 411	1 350
1987–88	10	10	1 274	1 449
1988–89	10	10	1 420	1 566
1989–90	0	10	1 541	1 765
1990–91	#12	#10	1 781	1 831
1991–92	#40	#10	2 031	1 837
1992–93	#29	#10	2 335	2 016
1993–94	#3	#10	2 323	2 023
1994–95	0	10	2 285	2 161
1995–96	0	10	2 351	2 161
1996–97	#9	#10	2 846	2 480
1997–98	#30	#10	2 613	2 480
1998–99	#2	#10	2 775	2 480
1999–00	#0	#10	2 731	2 480
2000–01	#0	#10	2 721	2 480
2001–02	#0	#10	2 784	3 048
2002–03	0	10	3 002	3 058
2003–04	0	10	3 091	3 058
2004–05	0	10	3 012	3 233
2005–06	0	10	2 475	3 233

Table 2 [Continued]

Fish stock	BNS 10			
FMA (s)	10		Total	
	Landings	TACC	Landings	TACC
2006–07	0	10	2 425	3 233
2007–08	0	10	2 498	3 233
2008–09	0	10	2 046	2 335
2009–10	0	10	2 059	2 335
2010–11	0	10	1 696	2 335
2011–12	0	10	1 218	1 590
2012–13	0	10	1 142	1 110
2013–14	0	10	1 190	1 110
2014–15	0	10	1 104	1 110
2015–16	0	10	960	1 110
2016–17	0	10	823	910
2017–18	0	10	656	630
2018–19	0	10	671	630

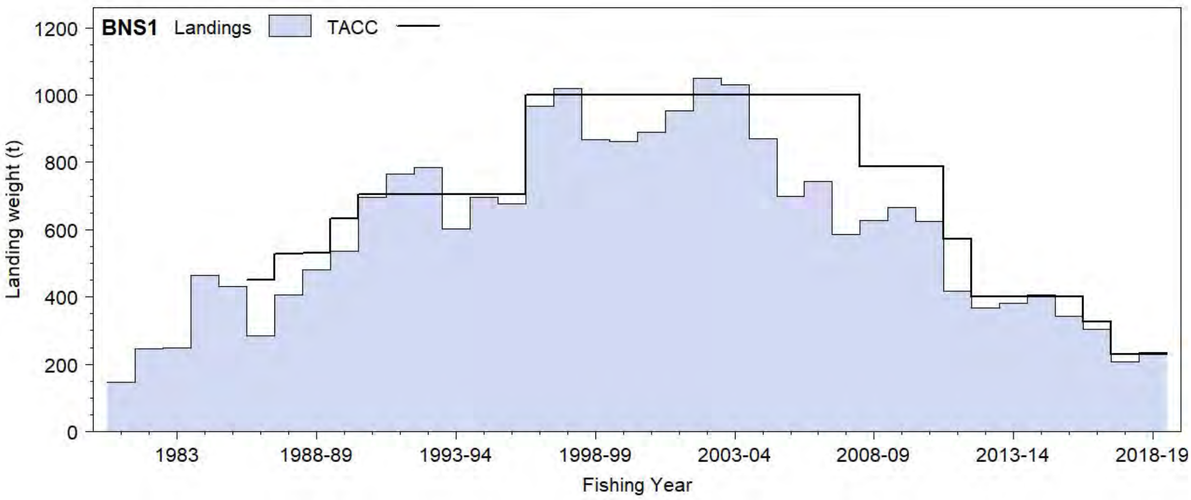
* MAF data, † FSU data, # Includes exploratory catches in excess of the TAC, + An additional transitional 250 t of ACE was provided to Chatham Islands fishers, resulting in an effective commercial catch limit of 1175 t in 2001–02 and 2002–03.

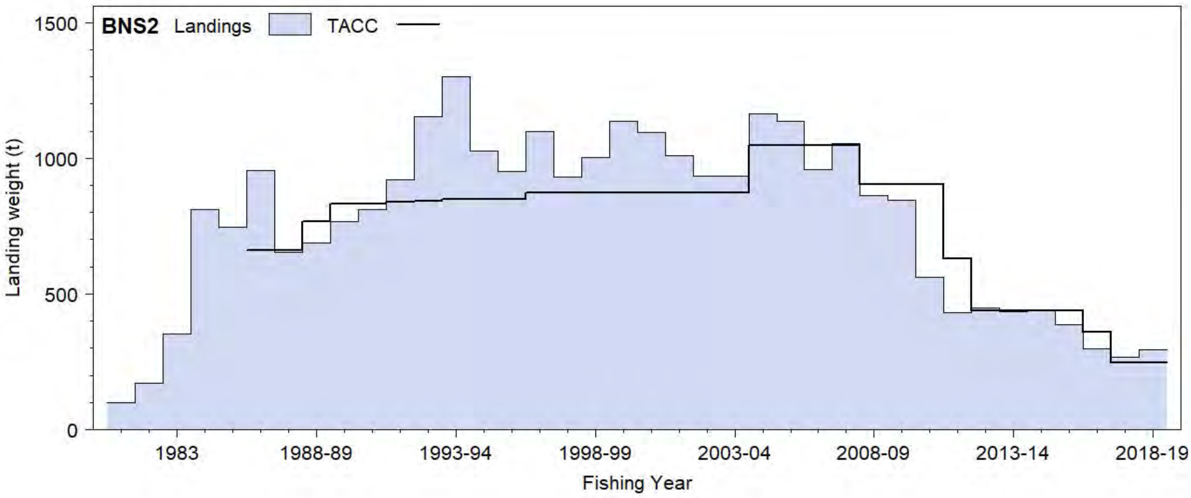
Bluenose landings prior to 1981 were poorly reported, with bluenose sometimes being recorded as bonita, or mixed with hapuku/bass/groper, and foreign licensed and charter catches in the 1970s included bluenose catches as warehou and butterfish. Landings before 1986–87 have been grouped by statistical areas which approximate the current QMAs.

TACCs were first established for bluenose upon introduction to the QMS in 1986–87, with TACCs for all bluenose stocks totalling 1350 t. From 1992 to 2009 all bluenose fishstocks were included, for at least some of the time, in Adaptive Management Programmes (AMPs). BNS 3 was the first stock to enter an AMP in October 1992, with a TACC increase from 175 t to 350 t. This was further increased within the AMP to 925 t in October 2001, plus an additional transitional 250 t of ACE provided to Chatham Islands fishers in 2001–02 and 2002–03 only. BNS 7 (TACC increase from 97 t to 150 t) and BNS 8 (TACC increase from 22 t to 100 t) entered AMPs in October 1994. BNS 1, the second largest bluenose fishery, entered an AMP in October 1996, with a TACC increase from 705 t to 1000 t. BNS 2, the largest bluenose fishery, was the most recent entry into an AMP in October 2004, with a TACC increase from 873 t to 1048 t. TACCs for all bluenose stocks were reduced on 1 October 2008: 786 t (BNS 1), 902 t (BNS 2), 505 t (BNS 3), 89 t (BNS 7), and 43 t (BNS 8). AMP programmes were terminated on 30 September 2009.

Under a rebuild plan following the 2011 stock assessment, there have been further phased reductions to TACCs for bluenose stocks. On 1 October 2011, TACCs were reduced to: 571 t (BNS 1), 629 t (BNS 2), and 248 t (BNS 3); BNS 7 and BNS 8 were not reduced at that time. On 1 October 2012, TACCs were further reduced for all bluenose stocks to: 400 t (BNS 1), 438 t (BNS 2), 171 t (BNS 3), 62 t (BNS 7), and 29 t (BNS 8). The 2011 rebuild plan included a third phase of TACC reductions. For the 2016–17 fishing year, the Minister reduced the combined TACCs for bluenose stocks by 205 t as a further step towards ensuring the rebuild. He did not take stronger action because he wanted to provide the opportunity for a management procedure to be developed. As from October 2017, following the assessment being updated to include information up to the end of the 2015–16 year, the Minister noted that the stocks remained in a depleted state and he did not want to delay the rebuild any longer. Consequently, he reduced the TACCs for all BNS stocks further to ensure that BNS stocks rebuild towards the target at an appropriate rate consistent with the HSS guidelines.

As a result of the TACC increases under AMPs, the combined total TACC for all bluenose stocks increased from an initial 1350 t in 1986–87 to 3233 t by 2004–05. Reductions followed with the total TACC set to 1110 t by 2012–13, to 910 t in 2016–17, and finally to 630 t in 2017–18. Catch performance against the TACC has varied, with the combined TACC being under-caught by an average 9% (average landings 1504 t / year) over 1987–88 to 1990–91, over-caught by an average 11% (average landings 2501 t / year) over 1991–92 to 2000–01, and under-caught by an average 19% (average landings 2180 t / year) from 2004–05 to 2011–12. More recently landings have fluctuated around the combined TACC, over-caught by an average of just 1% from 2012–13 to 2018–19.





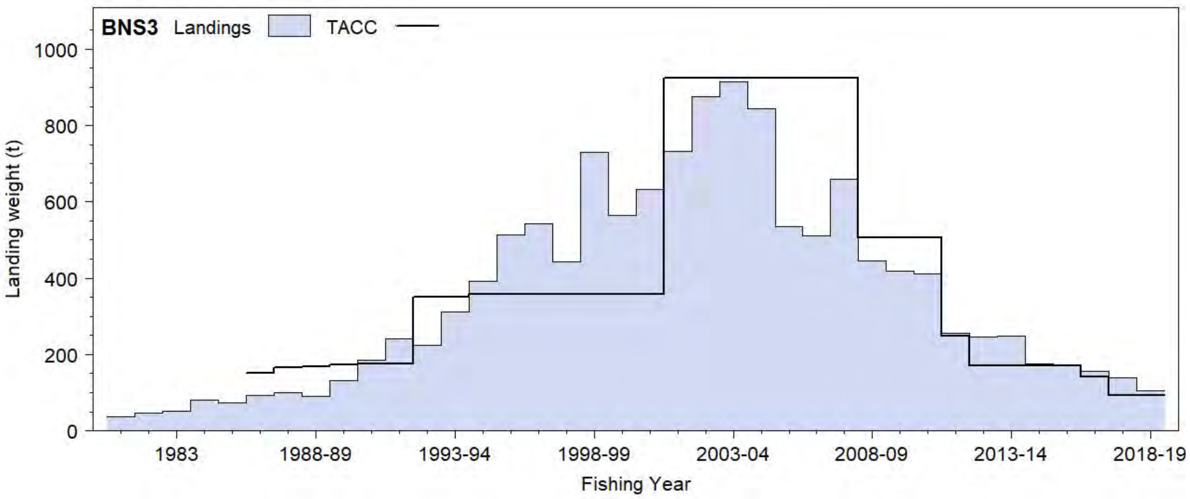
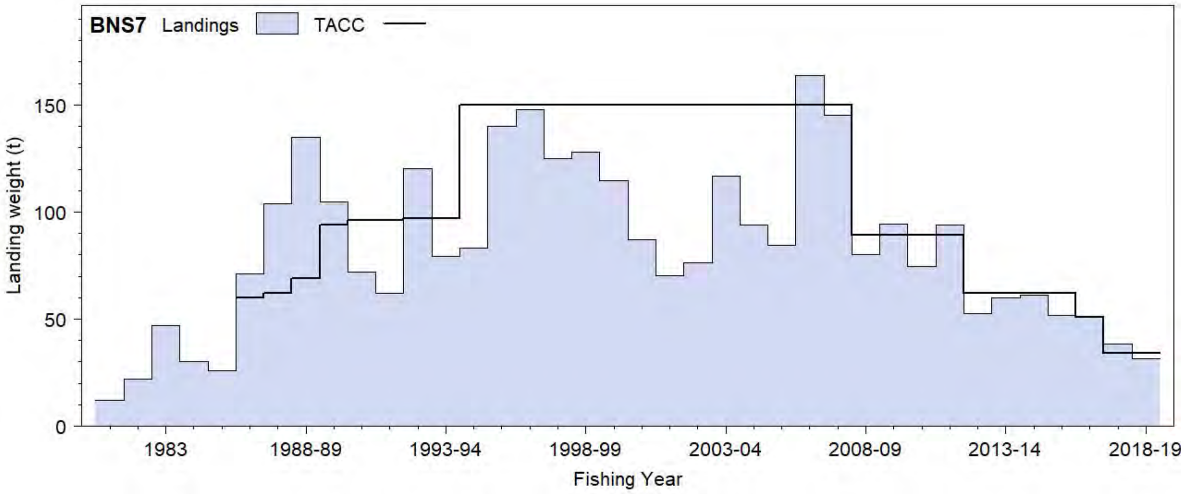


Figure 1: Reported commercial landings and TACC for the five main BNS stocks. BNS 1 (Auckland East), BNS 2 (Central East), BNS 3 (South East Coast) [Continued on next page]



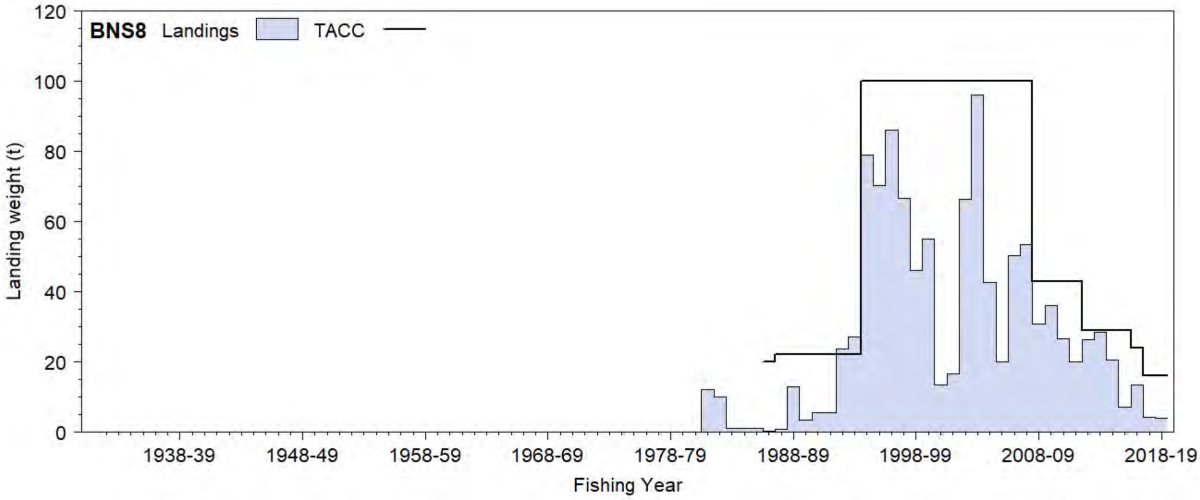


Figure 1: [Continued] Reported commercial landings and TACC for the five main BNS stocks. BNS 7 (Challenger), BNS 8 (Central Egmont).

1.2 Recreational fisheries

Bluenose is targeted by recreational fishers around deep offshore reefs. They are caught using line fishing methods, predominantly on rod and reel with some longline catch. The allowances within the TAC for each Fishstock are given in Table 1.

1.2.1 Management controls

From 2012 onwards the catch limit for recreational fishers in all areas has been up to 5 bluenose per person per day as part of their multi-species (combined) individual daily bag limit.

1.2.2 Estimates of recreational harvest

There are two broad approaches to estimating recreational fisheries harvest: the use of onsite or access point methods where fishers are surveyed or counted at the point of fishing or access to their fishing activity; and, offsite methods where some form of post-event interview and/or diary are used to collect data from fishers.

The first estimates of recreational harvest for bluenose were calculated using an offsite approach, the offsite regional telephone and diary surveys. Estimates for 1996 came from a national telephone and diary survey (Bradford 1998). Another national telephone and diary survey was carried out in 2000 (Boyd & Reilly 2002) and a rolling replacement of diarists in 2001 (Boyd & Reilly 2004) allowed estimates for a further year (population scaling ratios and mean weights were not re-estimated in 2001). The annual recreational catch of BNS 1 was estimated from diary surveys to be 2000 fish in 1993–94 (Teirney et al 1997), 5000 fish in 1996 (Bradford 1998) and 11 000 fish in 1999–00 (Boyd &

Reilly 2004). The harvest estimates provided by these telephone/diary surveys are no longer considered reliable.
A new national panel survey was developed, and implemented in the 2011–12 fishing year (Wynne-Jones et al 2014). The panel survey used face-to-face interviews of a random sample of New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and catch information collected in standardised phone interviews. The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly comparable results (Wynne-Jones et al 2019). Recreational catch estimates from the two national panel surveys are given in Table 3. Note that national panel survey estimates do not include recreational harvest taken under s111 general approvals.

Table 3: Recreational harvest estimates for bluenose stocks (Wynne-Jones et al 2014, 2019). Mean fish weights were obtained from boat ramp surveys; for bluenose the value used was 4.473 kg (Hartill & Davey 2015).

Stock	Year	Method	Number of fish	Total weight (t)	CV
BNS 1	2011–12	Panel survey	6 287	28.15	0.40
	2017–18	Panel survey	7 571	36.45	0.29
BNS 2	2011–12	Panel survey	444	1.99	0.48
	2017–18	Panel survey	1 298	6.12	0.43
BNS 3	2011–12	Panel survey	461	2.05	0.92
	2017–18	Panel survey	405	1.91	0.60
BNS 7	2011–12	Panel survey	456	2.02	1.00
	2017–18	Panel survey	355	1.67	0.60
BNS 8	2011–12	Panel survey	137	0.61	1.03
	2017–18	Panel survey	0	0	–

The recreational surveys indicate that the recreational harvest of bluenose is relatively small in areas other than BNS 1. There are some locally important fisheries which will not have been adequately sampled by the national panel survey.

1.3 Customary non-commercial fishing
No quantitative information on the level of customary non-commercial take is available.

1.4 Illegal catch
No quantitative information on the level of illegal catch is available.

1.5 Other sources of mortality
There have been reports of depredation by orca on bluenose caught by line fisheries.

2. BIOLOGY

Depth distribution
The depth distribution of bluenose extends from near-surface waters to about 1200 m. Research trawl surveys record their main depth range as 250–750 m, with a peak at 300–400 m, and they regularly occur to about 800 m (Anderson et al 1998). Commercial catches recorded in logbook programmes implemented for some of the bluenose stocks under AMPs, and catch-effort data for these fisheries, confirm that bluenose catches range in depth from less than 100 m to about 1000 m, depending on target species, but with a peak around 400 m for bluenose targeted fishing by any method.

The depth distribution of bluenose changes with size, with small juveniles known to occur at the surface under floating objects (Last et al 1993, Duffy et al 2000). Larger juveniles probably live in coastal and oceanic pelagic waters for one or two years. Fish 40–70 cm in length are caught between 200 m and 600 m, whereas larger fish, particularly those larger than 80 cm, are more often caught deeper than 600 m. A sequential move to deeper waters as bluenose grow has been confirmed by analysis of the stable radio-isotope ratios in otolith sections. Oxygen isotope ($\delta^{18}O$) ratios of bluenose otolith cores confirm residence of juvenile fish within surface waters. Changes in oxygen isotope ratios across otolith sections indicate changes in preferred mean depth with age of each fish (Horn et al 2008). That study hypothesised that the larger adults may be distributed below usually fished depths on underwater topographic features, but potentially available to fisheries as a result of regular vertical feeding migrations. The largest adults appear to reside in 700–1000 m; i.e., deeper than where most trawl or longline fishing for bluenose occurs. However, adult bluenose are also known to associate closely with underwater topographic features (hills and seamounts). Bluenose may undertake diurnal migrations into shallower depths to feed.

Age, growth, and natural mortality

Recent ageing validation work by Horn et al (2008, 2010) substantially revised estimates of maximum age and size at maturity for bluenose which were previously considered to be moderately fast growing (Horn 1988b). Radiocarbon (^{14}C) levels in core micro-samples from otoliths that had been aged using zone counts were compared with a bomb-radiocarbon reference curve which provided independent estimates of the age of the fish.

Horn & Sutton (2010) estimated a maximum age of 71 years for bluenose from line fisheries in BNS 1. This maximum age is consistent with the maximum age of 85 years estimated for the closely related barrelfish (*Hyperoglyphe perciformis*) in the western North Atlantic, also determined, in part, using the bomb chronometer method (Filer & Sedberry 2008). Previous under-estimates of bluenose ages appear to have resulted from the incorrect interpretation of paired, fine ‘split rings’ as single growth zones, when they probably represent two separate growth zones. Horn & Sutton (2010) concluded *M* for bluenose would likely be in the range 0.09–0.15, based on 1% of the unfished population living to 30–50 years. However, they also noted that the true *M* for bluenose could be even lower than 0.09 given that the maximum recorded age was 71 years, and that old bluenose may be poorly sampled by the line fishery.

Horn & Sutton (2011) recorded a maximum age of 76 years for bluenose from trawl fisheries in BNS 2 and estimated total mortality (*Z*) to be in the range 0.11–0.26. Because bluenose had been only lightly exploited before the samples were taken (1984–86), these estimates of *Z* could be considered as reasonable proxies for natural mortality (*M*) because *F* would be very small. However, the *Z* estimates at the high end of the range are clearly inappropriate as *M* values for a species with a maximum age in excess of 50 years. Because of problems in obtaining a representative age sample of the population, Horn & Sutton (2011) favoured *M* estimation methods based simply on observed longevity. They concluded that a plausible range for *M* would be 0.07 to 0.14, with 0.10 as the best point estimate.

Previous stock assessments assumed an *M* of 0.08 as the best point estimate. From the range of estimates resulting from ageing, the Working Group concluded that *M* for bluenose was unlikely to be greater than 0.1. The *M* assumed in historical stock assessments was consequently 0.06, 0.08, or 0.1.

Little is known about the reproductive biology of bluenose. Maturity ogives derived from aged bluenose caught in BNS 1 from January to May indicated that ages at 50% maturity were about 15 and 17 years for males and females, respectively (Horn & Sutton 2011). Data from commercial logbook programmes implemented under AMPs indicate that bluenose sampled in QMAs 1, 3, 7, and 8 mature at between 60 cm and 65 cm. Analysis of gonad maturity stage proportions for bluenose sampled by Fisheries New Zealand observers and commercial logbook programmes, primarily in BNS 1, 7, and 8, indicate that spawning takes place over an extended period but peaks from February to April annually. No distinct spawning grounds have been described for bluenose in New Zealand waters. Most reproductively active fish have been sampled from locations in the Bay of Plenty, and in smaller numbers from several locations around the North Island, from northwest of Taranaki to East Cape, and off the south west coast of the South Island (Dutilloy et al., in prep.).

Maturity and reproduction

Biological parameters relevant to stock assessment are summarised in Table 4.

3. STOCKS AND AREAS

Stock boundaries are unknown, but similarity in trends in catch and CPUE across fisheries occurring in each of the five New Zealand BNS QMAs suggests the possibility that there may be a single BNS stock across all these areas, or of some close relationship between stocks in these QMAs. Tagging studies have shown that bluenose are capable of extensive migration, i.e., from the Wairarapa coast to Kaikoura, Bay of Plenty, and North Cape (Horn 2003). There is a possibility that the long period of relatively stable CPUE observations in the face of increasing catches before the period of decline may be evidence of hyper-stability caused by the replenishment of adult stocks on specific areas or features. Increases in BNS targeting in some areas, and increasing catches, could have exceeded the replenishment rate and caused the rapid and synchronous declines observed from about 2001–02 to 2011–12. Alternatively, there could be a simultaneous drop in recruitment due to coincident environmental factors. An environmental mechanism simultaneously affecting availability or catchability of BNS across all QMAs is considered to be less likely than the possibility of a single stock, or of correlated recruitment across sub-stocks in the various areas.

Table 4: Estimates of biological parameters for bluenose.

Fishstock						**Estimate**	**Source**
1. Natural mortality (M)							
BNS						0.07–0.14	Horn & Sutton (2011)
2. Weight = a(length)^b (Weight in g, length in cm fork length).							
						Both sexes	
BNS 2				a = 0.00963		b = 3.173	Horn (1988a)
3. Von Bertalanffy growth parameters							
			Females			Males	
	K	t_0	L_∞	K	t_0	L_∞	
BNS 2	0.071	-0.5	92.5	0.125	-0.5	72.2	Horn et al (2010)
3. Age at maturity (50%)							
			Females			Males	
a_{50} (a_{to95})			17 (11)			15 (6)	Horn & Sutton (2011)

Analyses of length samples from research surveys and commercial catches indicated the smallest bluenose (predominantly juveniles) had been caught in relatively shallow water (< 445 m) off the east coast of central and northern New Zealand, from Chatham Rise to East Northland, and the largest bluenose were caught off the south of the South Island and in the more northern parts of BNS 1 and in BNS 10 (Dutilloy et al in prep). Bottom longlines caught both the largest, and smallest, fish observed. Particle tracking studies, assuming that juvenile bluenose drift passively in ocean surface currents for the first year of life, suggested juveniles from spawning locations on both coasts of the North Island would accumulate on the east coast of central and northern New Zealand (Dutilloy et al in prep). Particles released off the west and south coasts of the South Island were predominantly retained in that area. Genetic analyses for the allied species hapuku (*Polyprion oxygeneios*) found differences between fish from the west of the South Island and those from around the North Island and east of the South Island (Lane et al 2016). CPUE models offered alternative spatial areas (to explain variability in bottom longline catch rates) accepted the nine relatively fine-scale areas identified by Bentley (Bentley unpublished), but rejected other splits including separation of the west and south coast of the South Island from the rest of New Zealand (Dutilloy et al in prep). A single stock of bluenose around New Zealand remains most likely, although division into two stocks, separating the west and south coast of the South Island from the rest of New Zealand, remains possible.

4. STOCK ASSESSMENT

The first fully quantitative stock assessment modelling for bluenose was carried out in 2011. Models were implemented in the general purpose Bayesian stock assessment program CASAL (Bull et al 2009). This assessment was updated in 2016, using standardised CPUE series and catch histories to 2014–15 (Bentley unpublished). Methods for modelling CPUE were revised in 2014 (see section 4.5).

A new assessment was attempted in 2019, but was not accepted as of May 2019 by either the Working Group or the Plenary due to the need for further work to be undertaken, primarily to resolve the issue of strong patterns in the residuals for the composition data, and apparent fine-scale spatial and temporal heterogeneity in size and age distributions of catches. Additional analyses will be conducted based on Working Group and Plenary recommendations (see section 5. Future Research Considerations).

4.1 Methods

Model structure

The 2011 assessment model (Cordue & Pomarède 2012) assumed a single New Zealand stock of bluenose, partitioned into two sexes, with 80 age groups (1–80 years with a plus group), and without maturity in the partition. The model has a single time step, single area, two year-round fisheries (line and trawl), and mid-fishing-year spawning. The stock was assumed to be at B_0 in 1935. The maximum allowable exploitation rate in each fishery was set to 60%.

Data

The catch history in the model starts in 1936 when some bluenose were landed as groper or hapuku. The main uncertainty in the catch history is the foreign catch just prior to the implementation of the EEZ in 1978. Foreign vessels recorded bluenose catch within mixed species groups, typically as part of a general warehou category. Catch data in the early 1980s were used to estimate the likely proportion of bluenose within a mixed warehou and bluenose group. Where possible, this was done on an area-specific basis and the proportions were applied to the pre-EEZ mixed species catches. Due to the uncertainties in species attributions mentioned above, alternative bluenose proportions were used to construct three alternative catch histories: low, mid, and high (Figure 2, Table 5).

The catch histories for the line and trawl fisheries from 1989–90 to 2006–07 were derived from the bluenose characterisations conducted for the 2008 AMP review. From 2007–08 onwards, the total recorded catch was split between line and trawl fisheries in roughly the same proportion as the catches from the 2006–07 year. The 2009–10 catch was rounded down to provide the assumed total catch in 2010–11. Recreational and illegal catch were assumed to be zero.

Two CPUE indices were fitted as indices of abundance, one for line and one for trawl fisheries (Figure 3). CVs of 20% were assumed for each year. This assumption incorporates some process error because the estimated CVs for the CPUE indices are unrealistically low (as is typical for indices estimated using a GLM approach).

Table 5: The three alternative catch (t) histories used in the BNS model runs. Trawl catch prior to 1970 was assumed to be zero. [Continued next page]

	Line				Line				Trawl		
Year	**Low**	**Mid**	**High**	**Year**	**Low**	**Mid**	**High**	**Year**	**Low**	**Mid**	**High**
1936	0	75	150	1963	0	59	119				
1937	0	75	150	1964	0	66	133				
1938	0	75	150	1965	0	64	128				
1939	0	75	150	1966	0	61	123				
1940	0	56	112	1967	0	65	129				
1941	0	50	100	1968	0	57	113				
1942	0	50	100	1969	0	55	111				
1943	0	50	100	1970	0	70	140	1970	0	0	0
1944	0	50	100	1971	0	69	138	1971	0	0	0
1945	0	50	100	1972	0	59	118	1972	0	45	78
1946	0	69	138	1973	0	63	126	1973	0	42	72
1947	0	75	150	1974	0	69	137	1974	0	68	117
1948	0	81	162	1975	111	182	252	1975	0	116	204
1949	0	95	189	1976	618	692	767	1976	0	112	211
1950	0	89	177	1977	821	913	1 004	1977	0	385	1 505
1951	0	74	147	1978	1	81	161	1978	0	0	0
1952	0	71	142	1979	9	92	176	1979	0	0	0
1953	0	70	141	1980	15	98	180	1980	0	0	0
1954	0	69	137	1981	235	300	365	1981	0	0	0
1955	0	66	132	1982	469	511	554	1982	0	0	0
1956	0	69	138	1983	730	755	780	1983	0	0	0
1957	0	69	138	1984	951	956	962	1984	324	324	324
1958	0	75	149	1985	1 013	1 013	1 013	1985	372	372	372
1959	0	68	137	1986	982	982	982	1986	605	605	605
1960	0	62	124	1987	744	744	744	1987	667	667	667
1961	0	60	121	1988	752	752	752	1988	522	522	522
1962	0	59	118	1989	797	797	797	1989	623	623	623

Table 5 [Continued]

	For all three catch histories	
Year	**Trawl**	**Line**
1990	763	777
1991	577	1 192
1992	549	1 414
1993	733	1 573
1994	860	1 459
1995	904	1 382
1996	811	1 503
1997	1 060	1 765
1998	779	1 728
1999	904	1 871
2000	1 022	1 712
2001	1 082	1 638
2002	1 345	1 443
2003	1 331	1 671
2004	957	2 133
2005	1 114	1 900
2006	710	1 765
2007	424	2 001
2008	500	2 000
2009	300	1 746
2010	300	1 759
2011	300	1 700

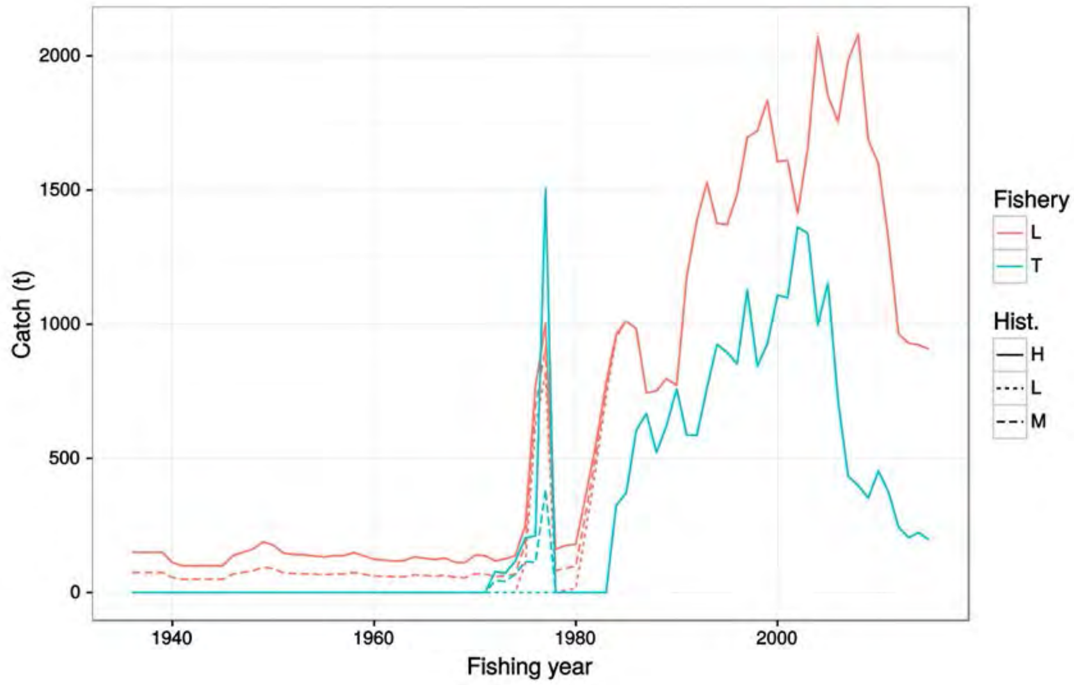


Figure 2: The three alternative catch histories used in BNS model runs.

Logbook and observer length samples were used to construct annual length frequencies for the line and trawl fisheries for each year when there were more than 500 fish measured (Line: 1993–2008; Trawl: 1995–2004). For each sample, the length frequency was scaled to the numbers of fish in the sampled catch. Catch-weighted samples were then combined with no further scaling or stratification.

Two age frequencies were fitted in each run: one from trawl caught fish on the Palliser Bank, for the single fishing year 1985–86, and one for line caught fish in the Bay of Plenty and East Northland, combined across areas for the fishing year 2000–01.

Fixed and estimated parameters

In the final assessment runs, year class strengths (YCSs) were assumed deterministic and only B_0 (uniform-log prior), the nuisance qs (for the two CPUE time series; uniform-log priors), the fishing selectivities (both double normal, uniform priors), and the CV of length at age (uniform prior) were estimated. Natural mortality (M) and steepness (h) were varied (see MPD runs below).

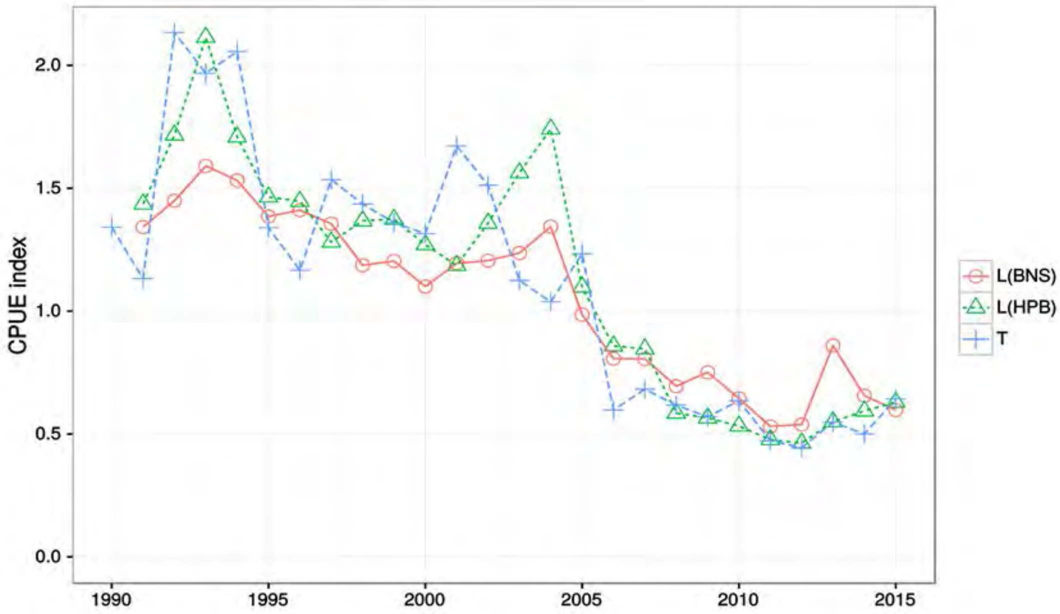


Figure 3: The line and trawl CPUE indices fitted in the 2016 BNS assessment model runs. Also presented is the CPUE series based on longline effort targeting groper (HPB).

Fixed parameters were assigned the following values.

	Male	Female	Source
Length-weight (cm, g)			
a	0.00963	0.00963	See Table 4
b	3.173	3.173	
von Bertalanffy growth			
t_0	–0.5	–0.5	Horn et al 2010
L_∞	72.2	92.5	
k	0.125	0.071	
Maturity (logistic)			
a_{50}	15	17	Horn & Sutton 2010
$a_{95} - a_{50}$	5	10	Horn & Sutton 2010

Assessment runs

Initial assessment runs indicated that the assessment was sensitive to the assumed catch history, natural mortality, and stock-recruitment steepness. As a result the working group agreed to present results from a "grid" of MPD runs. The final set of 18 runs consisted of all combinations of catch history: low, mid, high

- *M*: 0.06, 0.08, 0.10
  h: 0.75, 0.90

The *M* values cover what the working group considered a plausible range. The default assumption of $h = 0.75$ was adopted, and $h = 0.90$ was included as a sensitivity.

Iterative re-weighting was used to determine weights for the run with mid catch, $M = 0.08$ and $h = 0.75$. The CVs were unaltered from the initial assumption of 20%. These CVs and the sample sizes, determined from the re-weighting, were fixed for all other runs. Convergence was checked for two runs (mid catch and mid *M*, with h = 0.75 and $h = 0.90$). An MCMC run was also conducted for mid catch and mid *M* with $h = 0.75$. This was to check that the MPD estimates were not substantially different from the medians of the posterior distributions for B_0 and stock status. Because all runs had the same simple model structure, MCMCs were not conducted for other runs.

4.2 Results

The fishing selectivities for both trawl and line were estimated to be domed. However, the shapes of the fishing selectivities, especially for the line fishery, were confounded with *M* (Figure 4). The CV of length at age was estimated at 6% for all of the runs.

The fits to the CPUE indices were consistent with the assumed CVs of 20%. However, for both time series, a poor residual pattern was apparent, especially for the line CPUE (Figure 5). The line CPUE is flatter than the predicted values from 1990 to 2004, and then steeper than the predictions from 2005 to 2010.

The trawl and line fisheries showed different trends in exploitation rates, with the trawl fishery peaking from 2002 to 2005 and the line fishery increasing from 1980 to 2011 (Figure 6).

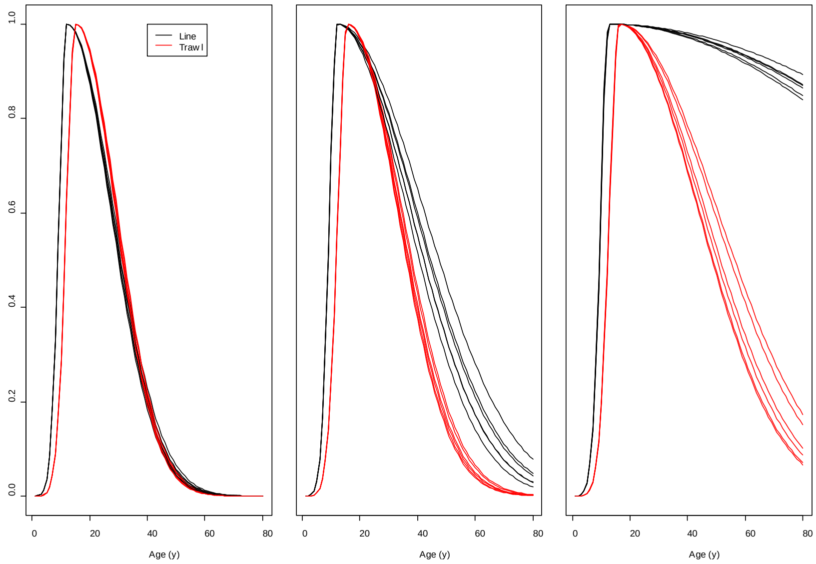


Figure 4: Estimated fishing selectivities for the trawl and line fisheries for the final 18 MPD runs in the 2011 assessment. Each plot shows the results for six runs with the same value of *M* (which increases from 0.06 to 0.08 to 0.10 from left to right in the three plots).

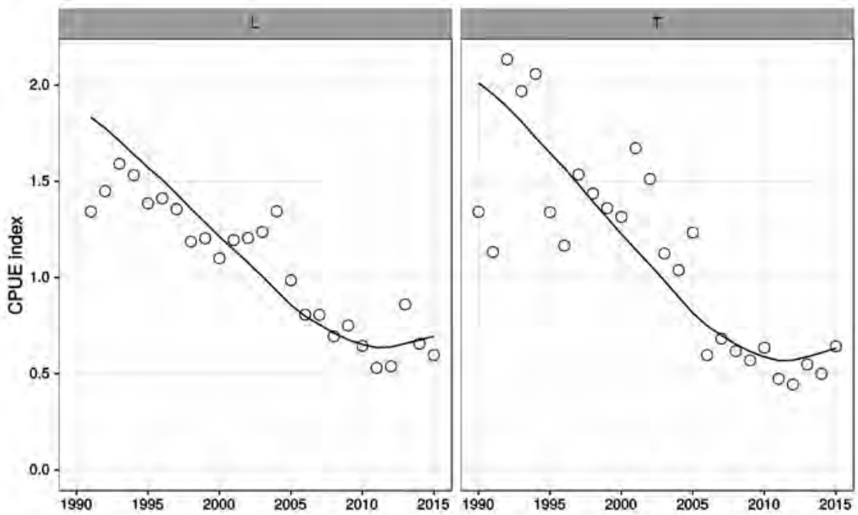


Figure 5: The model fits to the line and trawl CPUE for the run with mid catch, mid *M*, and *h* = 0.75. The fits for the other runs were almost identical.

The differences between the biomass trajectories from the 18 assessment runs are driven by the value of *M* (Figures 7 & 8) with estimates of B_0 ranging from just over 30 000 t at an *M* of 0.1 to around 60 000 t with an M of 0.06.

Biomass trajectories, as a proportion of B_0, all show a continuous decline in female spawner biomass from the late 1980s to 2011, followed by a levelling off or slight increase to 2016, depending on model run (Figure 8). The runs presented are in two groups with regard to current stock status. The 6 runs with M = 0.06 are above 20% B_0 whereas the 12 runs with M = 0.08 or M = 0.10 are below 20% B_0 (Figure 8, Table 6). These results should not be interpreted as there being a 66% probability that the stock is below 20% B_0. It is the range of the results that is important. The proportion of runs above or below 20% B_0 can be altered by including additional runs at different M values.

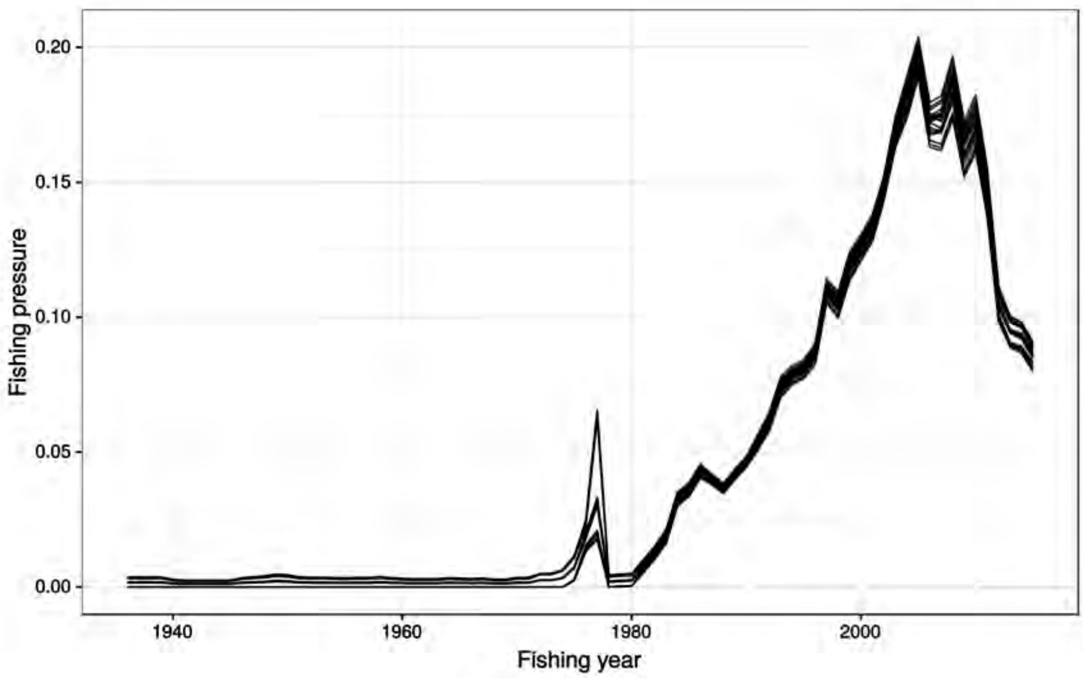


Figure 6: Trends in fishing pressure (the maximum proportion of fish taken from any age class) for the line fishery for each of the assessment runs.

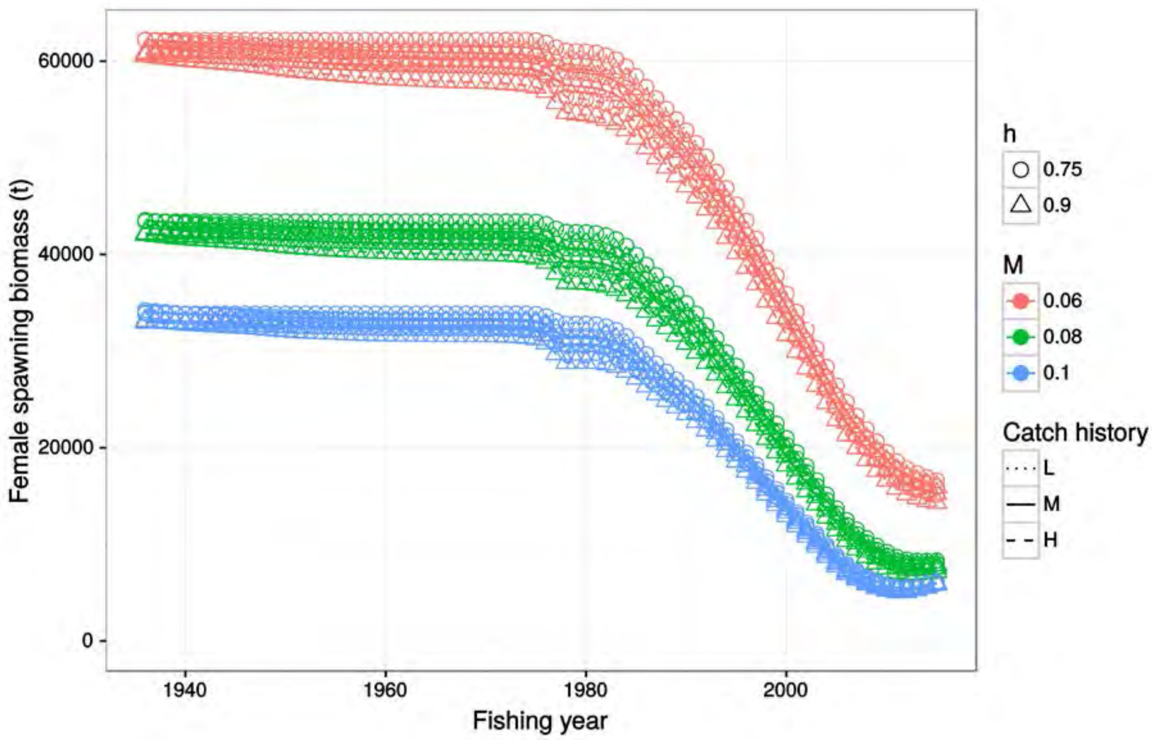


Figure 7: Biomass trajectories (t) for the final set of 18 MPD runs.

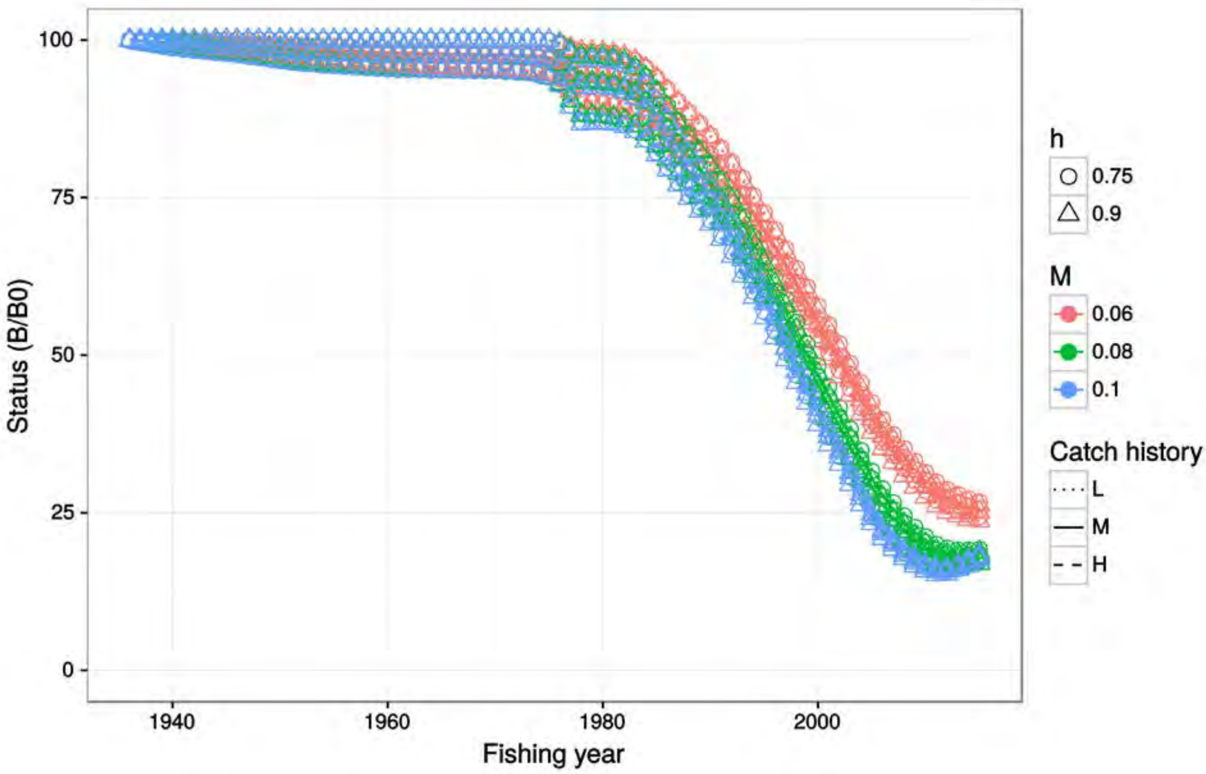


Figure 8: Biomass trajectories (proportion of B_0) for the final set of 18 MPD runs.

Table 6: Estimates of B_0, B_{2015}, and stock status (B_{2015}/B_0) for the final 18 runs. The range is given for the 6 runs at each value of *M*. B_0 and B_{2015} are mid-spawning season (after half the annual catch has been removed).

M	B_0 (000 *t*)	B_{2015} (000 *t*)	B_{2015}/B_0
0.06	60–62	14–17	0.24–0.27
0.08	42–44	7.2–8.3	0.17–0.19
0.10	33–34	5.9–6.1	0.17–0.18

4.3 Projections

Deterministic projections to 2050 were carried out as part of the 2011 and 2016 assessments, maintaining the 2009–10 ratio between catches from the line and trawl fisheries. For a stock below the soft limit of 20% B_0, the time required for SSB to rebuild to 40% B_0 with no future catch is called T_{min}. Although the point estimates for some runs with low *M* are above 20% B_0, the time required to rebuild to 40% B_0 was calculated for each run and is denoted as T_{min}. The estimates of T_{min} were established using the 2011 assessment range from 10 to 13 years (Table 7). Catches at the level of the 2015–16 TACC were predicted (2016 assessment) to cause the stock to increase, but not nearly fast enough to attain the biomass target within the rebuild time frame (Figure 9).The maximum constant catches estimated by the 2016 assessment that allow a rebuild to 40% B_0 within twice the 2011 T_{min} (the maximum rebuilding time under the Harvest Strategy Standard) range from 600–840 t (Table 8).

4.4 Other factors

This assessment relies on standardised catch per unit effort as an index of abundance. Members of the fishing industry have noted that bluenose fisheries have undergone a number of changes not all of which are adequately captured in the statutory catch and effort data. These include changes in quota holdings, company structures and vessel operators, and subtle shifts in fishing practice. The effect of increasing the number of hooks per line set and per day was investigated by identifying vessels that had changed their practice over time. The CPUE analysis was repeated without these vessels and the resulting standardised indices were very similar to those derived from the full dataset (Starr 2011).

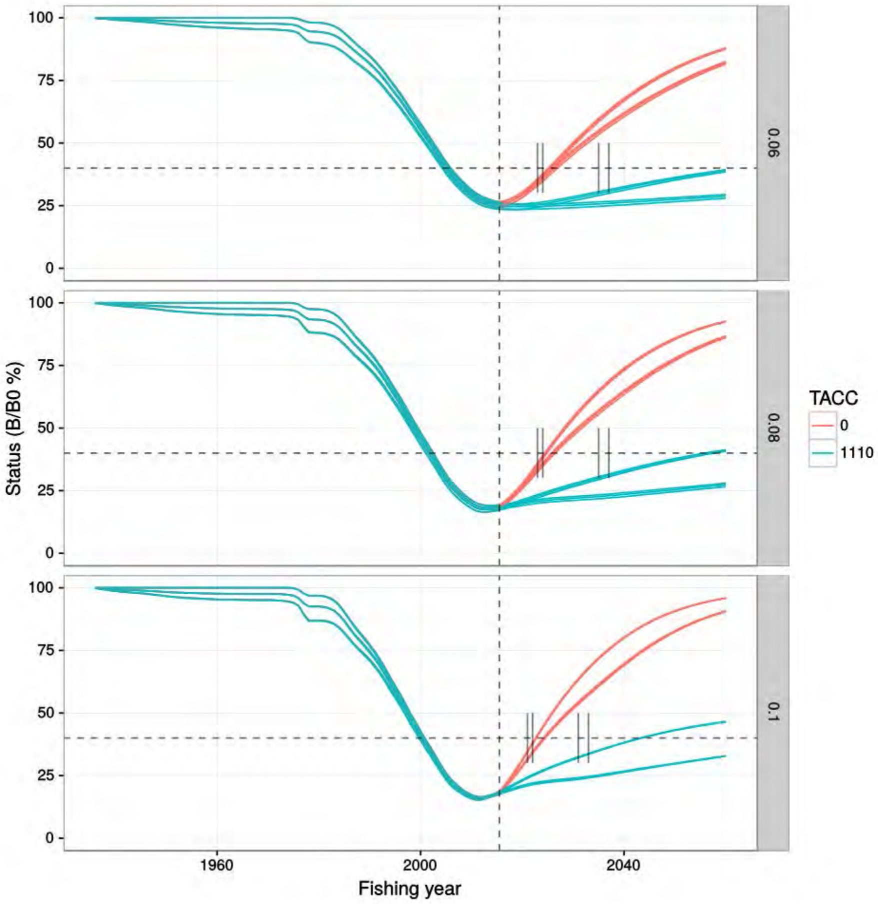


Figure 9: Projected SSB at different catch levels from the 2016 run with alternative levels of *M* and *h and catch histories*. The short vertical lines around 40% B_0 mark 2011 + T_{min} and 2011 + 2 T_{min}.

Table 7: The number of years before SSB reaches 40% B_0 when no future catch is taken (2011 Assessment). The duration, in a whole number of years, is defined as "T_{min}" and is shown for the six runs with the mid catch and combinations of *M* and *h*.

	h	
M	**0.75**	**0.90**
0.06	13	12
0.08	13	12
0.10	11	10

Table 8: The maximum constant catch (t) from 2016 that allows SSB to rebuild to at least 40% B_0 within twice T_{min} beginning in 2011 for the six runs with mid catch.

	h	
M	**0.75**	**0.90**
0.06	620	740
0.08	600	800
0.10	600	840

Prior to 2008, CPUE was not considered to be a reliable indicator of abundance of bluenose. However, in 2008, close coincidence observed in declining trends in most trawl and line CPUE indices in recent years increased confidence in their value as indices of abundance. Standardised CPUE series, based on data from six fisheries spanning most major fisheries taking BNS in the New Zealand EEZ, declined an average of 64% over the period 2001–02 to 2006–07.

More complex spatial structuring of bluenose populations, such as the replenishment of the population on fished features from a wider stock pool, is also plausible and may imply a non-linear relationship between CPUE and abundance. However, preliminary modelling exploring a non-linear relationship between longline CPUE and abundance did not improve the fit to the CPUE indices. In addition, previous studies for orange roughy found estimation of the non-linear parameter to be substantially inaccurate in the absence of absolute biomass information (A. Hicks, unpublished).

Catch-at-age data are limited, but suggest that the composition of catches can vary significantly on small spatial and temporal scales. The available catch-at-age data are insufficient to allow reasonable estimation of variation in year class strengths.

4.5 Updated standardised CPUE indices

The approach to standardising CPUE indices for bluenose was reassessed in 2014 and the key indices were updated in 2016. For the line CPUE, effort and estimated catch data were summarised for every unique combination of vessel, date, and statistical area. This reduced the higher resolution catch effort records (from LTCER and LCER forms) to lower resolution data compatible with records from the earlier CELR forms. The trawl CPUE used the higher resolution tow by tow data (from TCEPR and TCER forms) at their original resolution.

In 2014, separate CPUE indices were estimated for line fisheries targeting BNS, HPB, and LIN because the high resolution data provide evidence of spatial separation in these fisheries, and they target differing depth ranges and achieve markedly different catch compositions. The BNS target line CPUE index was selected as the primary line index. The trawl CPUE index included both BT and MW trawling and BNS and BYX target tows.

The primary BLL.BNS standardisation used a Weibull error distribution and model selection retained fishing year, vessel, hooks, and statistical area as explanatory variables. The influence of hook numbers was examined in detail to ensure that changes in reporting and fleet composition were dealt with appropriately in the standardisation.

Nine zones were defined, as groupings of statistical areas, which better separated the bluenose fisheries than the QMA boundaries. An amalgamated national line index was estimated by weighting the zone indices by the number of 0.1 degree cells they contained that accounted for 95% of the nationwide bluenose catch. These cells were used as a proxy for bluenose habitat.

Zone indices were calculated by fitting a zone × year interaction (Figure 10). In general the individual zone indices show the same pattern as the overall index, with the exception of the southwest zone which has a much flatter index.

The BNS target LL CPUE declined to a low point in 2011–12, increased markedly in 2012–13, but then dropped to a point in 2014–15 that remained above the 2011–12 nadir. The BNS trawl series (BNS and BYX target) had very similar overall trend to the LL series, but with general increase after the 2011–12 nadir (Figure 3). The LL BNS CPUE series based on HPB targeted effort had a similar trend to the BNS+BYX trawl series, with a gradual increase after the 2011–12 nadir, suggesting that BNS biomass had slowly increased since 2011–12, and that the spike in the BNS target LL series was probably disproportionate to abundance. All three series (BNS-BLL, HPB-BLL, and BNS/BYX-BT/MW all have the same relative position in 2014–15.

Detailed analyses were undertaken of catch rates at the level of discrete spatial areas (“features”). No obvious, consistent changes in the distribution of catch/effort by feature since 2007–08 were apparent and there was general consistency among feature CPUE indices within a zone.

4.6 Management procedure evaluation

Four classes of management procedure were evaluated for the New Zealand bluenose fishery using the 2011 assessment as the basis for the operating model (Bentley & Middleton 2015). Evaluations were done using alternative operating model scenarios including re-estimating parameters using updated catch per unit effort (CPUE) series and different recruitment assumptions.

The management procedure evaluation focused on procedures that work to maintain a stock rebuild trajectory and demonstrated that use of a management procedure to adjust catches provided for higher catches, for a given rebuild criterion, than maintaining a constant catch. After initial presentation of results to stakeholders, the “Trajectory Status Adjustment Restricted” (TSAR) class of management procedure (MP) became the focus for further evaluations and refinements. The TSAR class is based on a predefined CPUE trajectory with changes made to the total allowable commercial catch (TACC) when the smoothed CPUE index deviates from the defined trajectory.

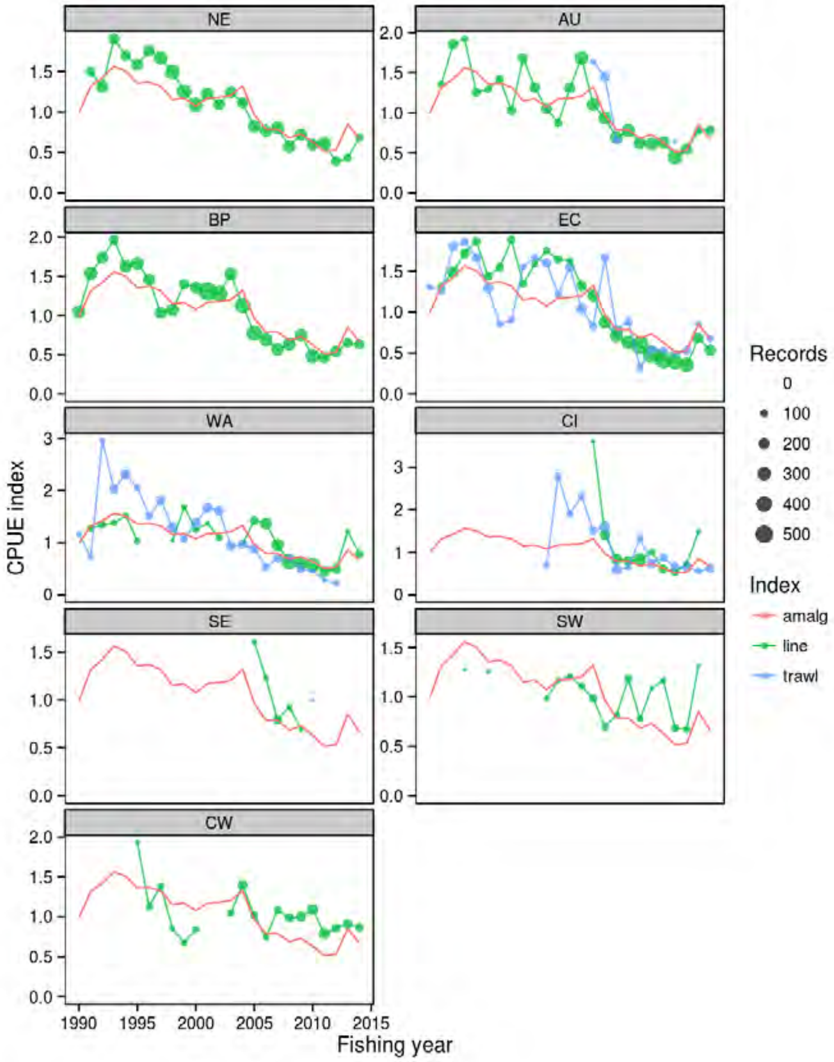


Figure 10: Zone-year indices for the line and trawl indices with the amalgamated national line index shown for reference. Zone-year combinations with less than 30 records are not shown.

One of the performance statistics which MPs were evaluated against was the time taken to rebuild to 40% B_0, using 25 years as an acceptance threshold (approximately two times *Tmin*). Most of the TSAR instances evaluated failed to meet the 25 years to 40% B_0 rebuild criterion, but often by only a small margin.

5. FUTURE RESEARCH CONSIDERATIONS

- Use fishery-specific CPUE indices in the stock assessment model, rather than a combined area index, and/or re-examine the method used for area weighting.
- Revisit assumptions about historical catches, including the potential for under-reporting by trawlers in Area 2 in the 1990s. Include the agreed historical catches in the Plenary tables and graphs.
- Incorporate estimated recreational catches in the assessment model.
- Examine the data sources for biological samples as recorded in the SeaFIC Data Management System (SFDMS) databases to understand the relationship of the AMP data within the wider SFDMS database. Ensure that double-counting has not occurred.
- Review all available biological data to create a repository of validated information.
- If data on numbers of bluenose by mean weight sold by Licenced Fish Receivers (‘packing data’) are used as a model input, they should be used as weights rather than converting them to lengths.
- Examine the spatial and temporal structure of the packing data.

- Create an age determination protocol, including creating a reference set of otoliths with agreed ages, to ensure that BNS ageing remains consistent over time.
- Develop otolith sampling programmes to a) obtain representative samples for estimating recruitment strength and b) develop a growth function from data covering a wider range of ages and areas.
- Review the composition data and CPUE indices to determine whether the nine areas used in previous assessments are appropriate with respect to selectivity patterns.
- Evaluate alternative error assumptions for the CPUE indices, including the Weibull distribution for positive catches and the delta Weibull for all catches.

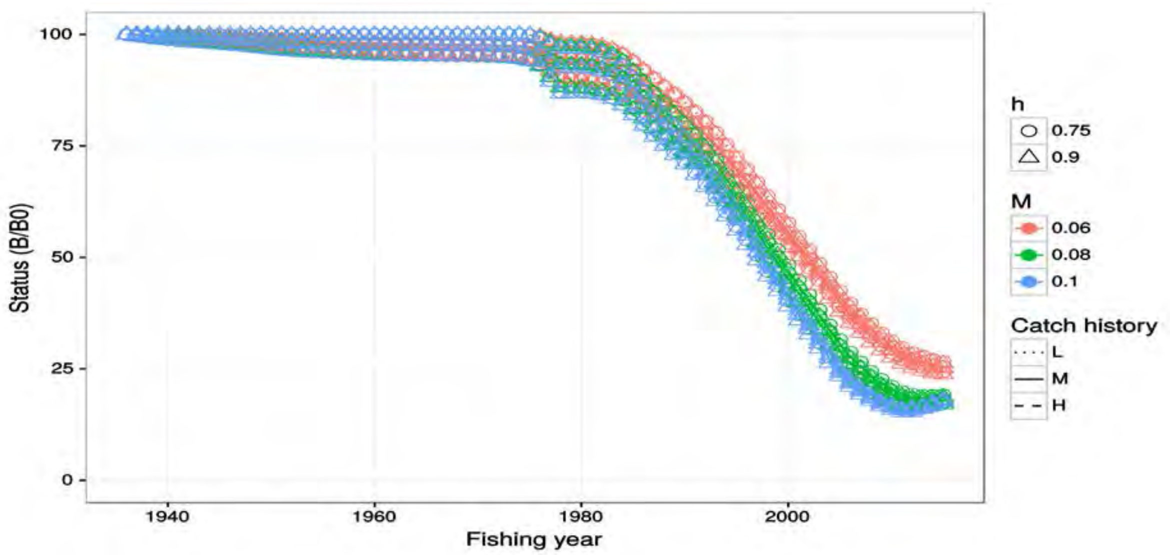
6. STATUS OF THE STOCKS

Stock Structure Assumptions
The assessment presented here assumes that bluenose in New Zealand waters comprise a single biological stock.

BNS 1, BNS 2, BNS 3, BNS 7, BNS 8, BNS 10

Stock Status	
Year of Most Recent Assessment	2016 An update of this assessment is incomplete as of May 2019
Assessment runs presented	Eighteen MPD runs exploring a plausible range of catch history, natural mortality rate, and stock-recruitment steepness
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: Not defined
Status in relation to Target	Unlikely (< 40%) to be at or above the target.
Status in relation to Limits	About as Likely as Not (40–60%) to be below the Soft Limit Unlikely (< 40%) to be below the Hard Limit
Status in relation to Overfishing	-

Historical Stock Status Trajectory and Current Status



Spawning stock biomass trajectories (percentage of B_0) for the 2016 set of 18 MPD runs.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The MPD estimates of stock size in 2016 ranged from 17–27%

	B_0. Biomass was estimated to have declined continuously from the 1980s to 2011 and then to have either levelled off or increased slightly. Biomass has been below the 40% B_0 target since around 2000.
Recent Trend in Fishing Mortality or Proxy	Exploitation rates were estimated to have increased from 1980 as the stock declined. In 2011 exploitation rates in the trawl fishery were estimated to have declined since 2005, but remained high in the line fishery. Reduced TACCs since 2011 have resulted in substantially reduced catches and a reduction in exploitation rates.
Other Abundance Indices	A second BLL index based on bycatch of bluenose in the HPB LL fishery had a trend that was very similar to the Trawl index
Trends in Other Relevant Indicator or Variables	-
Stock Projections or Prognosis	Deterministic projections in 2011 with M = 0.08 and h = 0.75 predicted that stock abundance would decline to below the hard limit within the next 20 years (from 2010) under 2010 catch levels. The time to rebuild (T_{min}) to the target (40% B_0) under zero catches ranged from 10 to 13 years, depending on model assumptions. Within the range of model runs explored, the maximum constant catch (EEZ wide) implemented in 2016 that would rebuild the stock to the target within twice T_{min} (beginning in 2011) was 600–620 t for h = 0.75 and 740–840 t for h = 0.9. A rebuilding plan to reduce catches and rebuild the stock to target levels within twice T_{min} was developed. The TACC was incrementally reduced in 2011, 2012, 2016 and 2017.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Very Unlikely (< 10%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment (2011)	
Assessment Method	Age-structured CASAL model with MPD estimation over a range of plausible catch histories, natural mortality rates and steepness.	
Assessment Dates	Latest assessment: 2016	Next assessment: 2021
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- CPUE indices derived from statutory catch and effort reporting - Length frequency data from sampling conducted under the Adaptive Management Programme, and from observer data - One age frequency distribution for each of the trawl and line fisheries	1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	The longline CPUE index for the 2016 assessment is based only on BNS target fishing rather than BNS, HPB and LIN target sets (used in the 2011 assessment), and combined indices by zone weighted by a habitat proxy.	
Major Sources of Uncertainty	- Stock structure and spatial dynamics are uncertain. - The assessment assumes that CPUE indexes abundance. - Natural mortality is uncertain; the plausible range considered	

	affects the estimate of current status, and is confounded with the estimated fishery selectivities. - Method specific selectivities are considered constant across areas. - Deterministic recruitment is assumed; variations in year class strengths are not estimated. - Catches are known and the catch history is complete.
Qualifying Comments	
Alternative plausible stock hypotheses have not been explored.	

Fishery Interactions
Bluenose is taken in conjunction with alfonsino in target midwater trawl fisheries directed at the latter species and in target bluenose bottom trawl fisheries. These fisheries are frequently associated with undersea features. Bluenose is also taken by target bottom longline fisheries throughout the New Zealand EEZ. Other commercially important species taken when longlining for bluenose are ling, hapuku and bass. Incidental captures of seabirds occur in the bottom longline and setnet fisheries, including black petrel in FMA 1 and 2, that are ranked as at very high risk in the Seabird Risk Assessment.[1] Interactions with other species are currently being characterised.

7. FOR FURTHER INFORMATION

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[1] The risk was defined as the ratio of the estimated annual number of fatalities of birds due to bycatch in fisheries to the Potential Biological Removal (PBR), which is an estimate of the number of seabirds that may be killed without causing the population to decline below half the carrying capacity. Richard and Abraham (2013).

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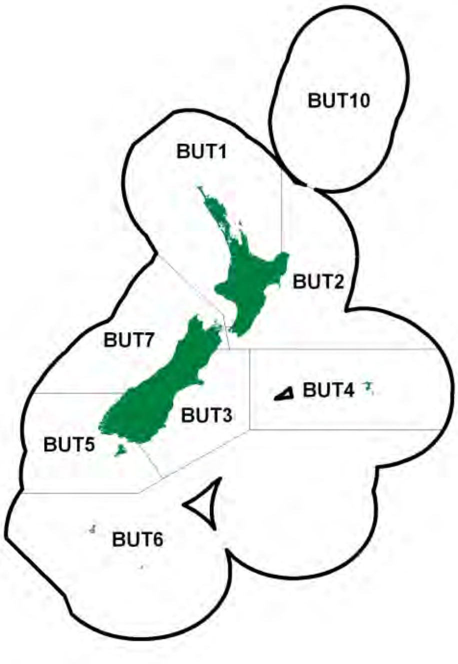
BUTTERFISH (BUT)

(*Odax pullus*)
Marari



1. FISHERY SUMMARY

Butterfish was introduced into the QMS in 1 October 2002 with allowances, TACCs and TACs as follows (Table 1).

Table 1: Summary of recreational and customary non-commercial allowances, TACs, and TACCs.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	TACC	Other Mortality	TAC
BUT 1	10	10	3	1	24
BUT 2	80	80	63	2	225
BUT 3	65	65	3	1	134
BUT 4	4	4	10	0	18
BUT 5	10	10	45	1	66
BUT 6	0	0	0	0	0
BUT 7	15	15	38	1	69
BUT 10	0	0	0	0	0
TOTAL	184	184	162	6	537

1.1 Commercial fisheries

Butterfish is targeted by setnets in shallow coastal waters, principally around kelp-beds. The main fishery is centred on Cook Strait, between Tasman Bay, Castlepoint, and Kaikoura. There is also a smaller fishery around Stewart Island. A minimum setnet mesh size of 108 mm and a minimum fish size of 35 cm apply to commercial and recreational fishers; additional regional netting restrictions may also apply.

Hector’s dolphin setnet closure areas were introduced on 1 October 2008 as part of the implementation of a Hector’s and Maui dolphin Threat Management Plan. On 18 March 2011 the Minister decided to provide an exemption to the setnet prohibition on the East Coast South Island to allow commercial fishers targeting butterfish to use setnets in a defined area at the top of the East Coast South Island.

In line with the acceptable risk of mortality associated with butterfish fishing by commercial fisheries at the top of the East Coast of the South Island, given the type of fishing gear they use and the size of the area and the numbers of Hector’s dolphins, recreational fishers are also allowed to target butterfish by method of set net from 1 January–30 April (inclusive). Set netting can only be undertaken if fishers stay with their nets at all times, the net is set no more than 200 m from the shore and it does not exceed 60 m in length.

Table 2: Reported domestic landings (t) and TACCs of butterfish by Fishstock from 2001–02 to 2018–19.

Fishstock	BUT 1		BUT 2		BUT 3		BUT 4		BUT 5	
FMA	1,8&9		2		3		4		5	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2001–02	0.7	3	64	63	0.4	3	13	10	19	45
2002–03	2.0	3	58.2	63	2.8	3	4.0	10	34.6	45
2003–04	1.4	3	52.6	63	2.1	3	2.6	10	42.6	45
2004–05	1.5	3	62.9	63	2.4	3	5.3	10	35.4	45
2005–06	2.9	3	44.5	63	1.8	3	0.1	10	21.8	45
2006–07	2.4	3	55.5	63	1.8	3	0.1	10	30.1	45
2007–08	1.0	3	46.3	63	2.0	3	0	10	35.9	45
2008–09	2.1	3	55.5	63	0.6	3	0.6	10	36.9	45
2009–10	2.5	3	45.3	63	< 0.1	3	0.2	10	33.3	45
2010–11	3.1	3	42.4	63	0.1	3	0.2	10	47.0	45
2011–12	2.7	3	48.3	63	< 0.1	3	0.8	10	46.3	45
2012–13	2.1	3	53.8	63	0	3	0.1	10	34.5	45
2013–14	3.0	3	42.0	63	<1	3	<1	10	33.3	45
2014–15	2	3	36.3	63	<1	3	0	10	37.1	45
2015–16	1.4	3	38.1	63	<1	3	0	10	35.2	45
2016–17	2.8	3	44.4	63	<1	3	0	10	48.9	45
2017–18	2.4	3	47.3	63	0.7	3	0	10	36.2	45
2018-19	1.6	3	48.0	63	< 0.1	3	0	10	37.1	45

Fishstock	BUT 6		BUT 7		BUT 10			
FMA (s)	6		7		10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACCs
2001–02	0	0	25	38	0	0	121	162
2002–03	0	0	28.5	38	0	0	130.1	162
2003–04	0	0	24.8	38	0	0	126.1	162
2004–05	0	0	24.5	38	0	0	132.0	162
2005–06	0	0	23.7	38	0	0	94.8	162
2006–07	0	0	26.9	38	0	0	116.8	162
2007–08	0	0	29.4	38	0	0	114.6	162
2008–09	0	0	26.3	38	0	0	122.0	162
2009–10	0	0	16.5	38	0	0	97.9	162
2010–11	0	0	23.3	38	0	0	116.2	162
2011–12	0	0	21.4	38	0	0	119.5	162
2012–13	0	0	19.9	38	0	0	110.4	162
2013–14	0	0	16.7	38	0	0	95.1	162
2014–15	0	0	21.8	38	0	0	97.1	162
2015–16	0	0	19.3	38	0	0	94.5	162
2016–17	0	0	18.2	38	0	0	114.3	162
2017–18	0	0	18.7	38	0	0	102.9	162
2018–19	0	0	24.2	38	0	0	110.8	162

Total reported landings from 1982–83 to 2000–01 ranged between 105 and 193 t. Butterfish was introduced into the QMS in 2002. Reported landings and TACCs are given in Table 2, while Figure 1 shows the historical landings and TACC values for the main BUT stocks.

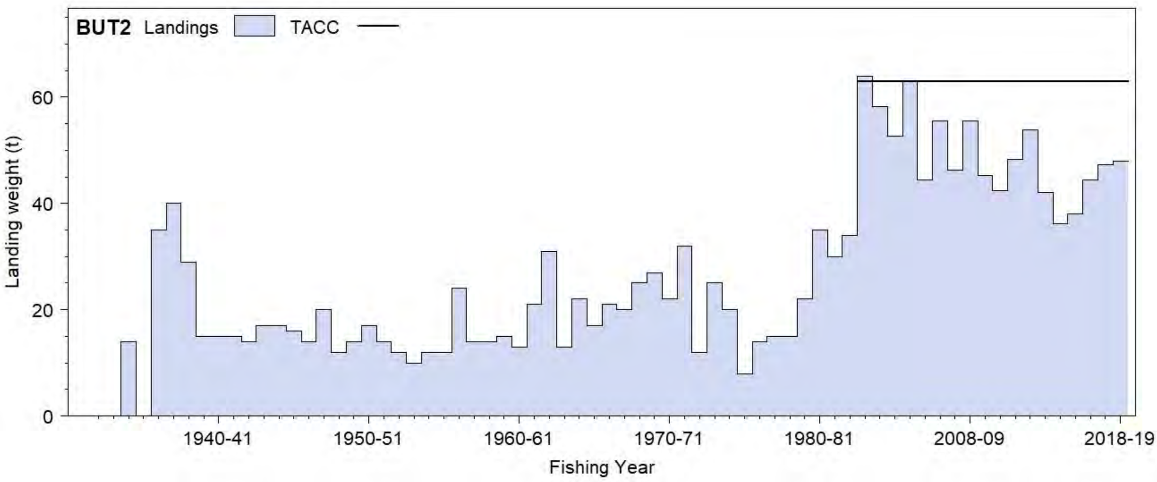


Figure 1: Reported commercial landings and TACC for the four main BUT stocks: BUT 2 (Central East). [Continued on next page]

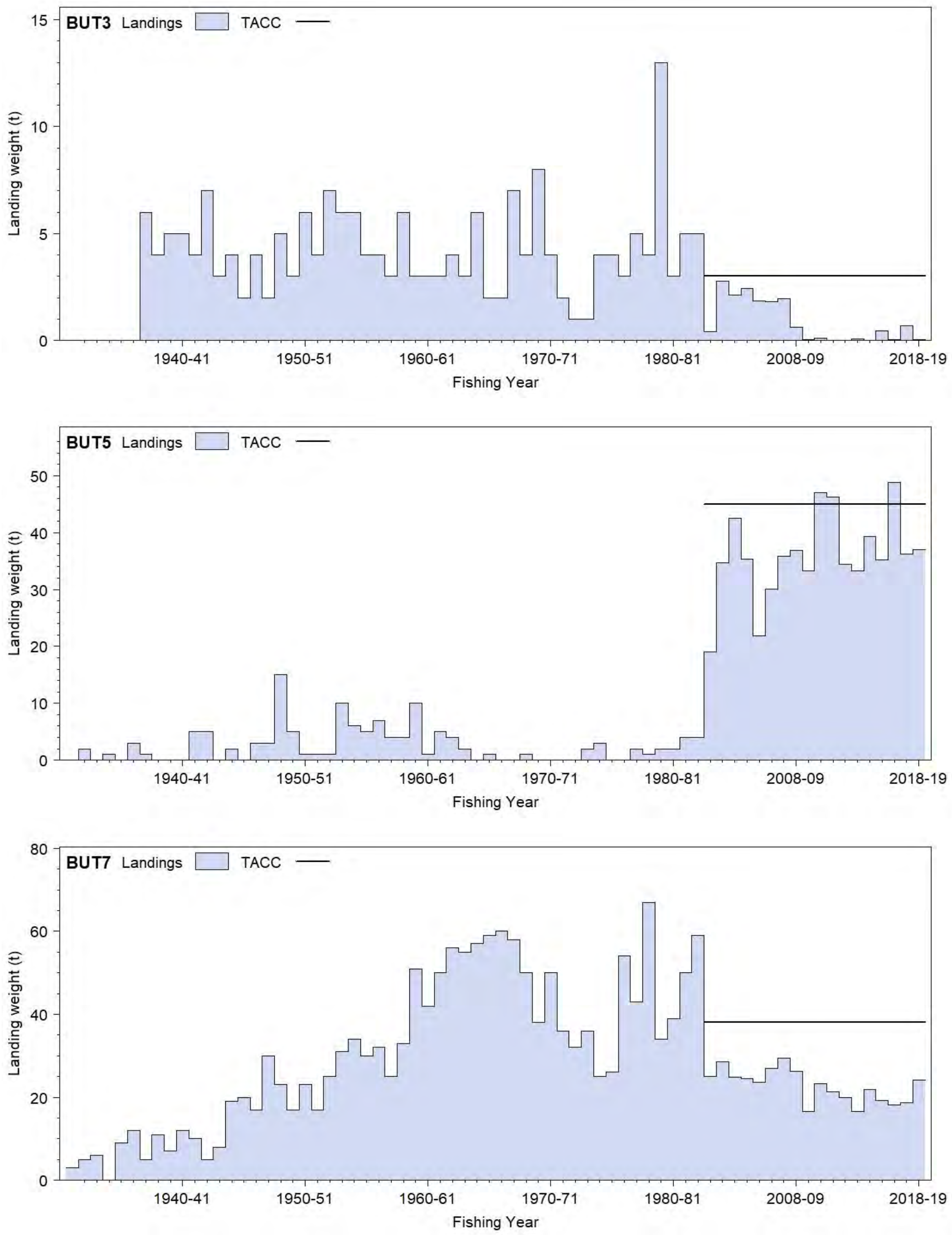


Figure 1 [Continued]: Reported commercial landings and TACC for the four main BUT stocks. From top, BUT 3 (South east coast), BUT 5 (Southland) and BUT 7 (Challenger).

From 2001-02 to 2018-19 total annual landings have averaged 112 t, with the highest proportion of landings being recorded for BUT 2, 5, and 7. Landings have consistently been below the TACC in all QMAs except for BUT 5, where landings slightly above the TACC of 45 t were recorded in 2010-11, 2011-12, and 2016-17.

1.2 Recreational fisheries

Butterfish is a popular recreational catch, and is taken mainly by setnet and spear. Recreational daily bag limits were set at 30 fish in 1986, but subsequently reduced to 20 for Northern and Central and Challenger (1995), and 15 for South (1993). Survey estimates indicate that the recreational catches appear to be of similar magnitude to those of the commercial fisheries in QMAs 1, 2, 5 and 7, and substantially higher in QMA 3 (Tables 3a and 3b).

Table 3a: Estimated recreational harvest of butterfish by QMA and survey.

QMA	Survey	Number caught	Survey harvest (t)	Fishstock harvest (t)
				1991–92
QMA 7	South	6 000	10	
QMA 7	South	4 000	5	15
QMA 3	South	36 000	65	65
QMA 5	South	8 000	10	10
				1993–93
QMA 2	Central	61 000	80	80
				1993–94
QMA 1 + 9	North	9 000	10	10
TOTAL		124 000		180

*Surveys were in different years: South 1991–92; Central 1992–93: and North 1993–94 (Teirney et al 1997). Many of these estimates have high CVs, and the estimate of total harvest is a guide only because of the different survey years. Line-caught 'butterfish' in QMA 3 and QMA 5 are excluded because of apparent species misidentification; these survey totals should be slightly higher.

Table 3b: Estimated number and weight of butterfish harvested by recreational fishers by Fishstock and survey. Surveys were carried out nationally in 1999–2000 (Boyd & Reilly 2002).

Fishstock	Survey	Number	CV%	Survey harvest (t)
BUT 1	National	1 000	71	< 1–3
BUT 2	National	23 000	39	16–36
BUT 3	National	45 000	47	27–76
BUT 5	National	17 000	42	11–27
BUT 7	National	18 000	41	12–29
BUT 8	National	1 000	100	0–2

The harvest estimates provided by telephone-diary surveys between 1993 and 2001 are no longer considered reliable for various reasons. A Recreational Technical Working Group concluded that these harvest estimates should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries. In response to these problems and the cost and scale challenges associated with onsite methods, a National Panel Survey was conducted for the first time throughout the 2011–12 fishing year. The panel survey used face-to-face interviews of a random sample of 30 390 New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and harvest information collected in standardised phone interviews. The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly comparable results (Wynne-Jones et al 2019). Recreational catch estimates from the two national panel surveys are given in Table 4. Note that national panel survey estimates do not include recreational harvest taken under s111 general approvals.

Table 4: Recreational harvest estimates for butterfish stocks (Wynne-Jones et al 2014, 2019). Mean fish weights were obtained from boat ramp surveys (Hartill & Davey 2015, Davey et al 2019).

Stock	Year	Method	Number of fish	Total weight (t)	CV
BUT 1	2011/12	Panel survey	27 488	29.4	0.64
	2017/18	Panel survey	13 769	14.5	0.30
BUT 2	2011/12	Panel survey	13 892	15.6	0.33
	2017/18	Panel survey	20 478	25.8	0.30
BUT 3	2011/12	Panel survey	13 637	15.3	0.42
	2017/18	Panel survey	15 217	19.2	0.40
BUT 5	2011/12	Panel survey	188	0.2	0.74
	2017/18	Panel survey	8 411	10.6	0.65
BUT 7	2011/12	Panel survey	14 625	16.4	0.94
	2017/18	Panel survey	9 615	12.1	0.61

1.3 Customary non-commercial fisheries
There is no quantitative information on the current level of customary non-commercial catch.

1.4 Illegal catch
Because this is a localised small-scale fishery, some sales from fishers directly to retailers may have gone unreported, but no quantitative estimate of this are available.

1.5 Other sources of mortality
There is no quantitative information on other sources of mortality. In the past butterfish has been used as rock lobster bait and not reported.

2. BIOLOGY

Butterfish are endemic to New Zealand, and occur from North Cape to the Snares Islands. The species is also reported from the Chatham, Bounty and Antipodes Islands. Butterfish are more common from Cook Strait southwards. They inhabit rocky coastlines, and are commonly found among seaweed beds in moderately turbulent water. Their main depth range is 0–20 m. They occur shallower (to 10 m) in the north than in Cook Strait (to 20 m) and in southern waters they can be found as deep as 40 m.

Adult butterfish average 45–55 cm (FL) in length. Their maximum size is approximately 70 cm. Length/weight data are not available for whole fish, but as an interim measure a length/gutted weight relationship is given in Table 5.

Butterfish are almost exclusively herbivorous, feeding on several of the larger seaweeds. The diet of butterfish varies regionally and is largely determined by the species composition of the local seaweed beds. Feeding activity is greatest early in the day, and the tidal state controls the accessibility of intertidal seaweeds; fish were found to feed more actively in summer than winter (Trip 2009).

Fish were aged using sectioned sagittal otoliths, validated using daily growth (Trip 2009). Growth varies with latitude due to temperature difference, and local ecological factors such as diet and fish density.

Trip (2009) found that size and age differ significantly with latitude. Environmental temperature is the primary driver underlying the difference in life histories across latitudes, and affects growth rate, size-at-age and longevity. Butterfish living in colder temperatures (higher latitudes) grow slower, live longer, attain a greater average size and delay the onset of maturity (Trip 2009). Butterfish in Hauraki Gulf (BUT 1) reach 70% of their mean asymptotic size by the age of two, and have reached 90% of their maximum size by age 4. In the southern areas butterfish grow slower and reach a maximum size at about 75 % of their life span. The maximum age ranged from 11 years in the north (Hauraki Gulf) to 19 years in the south (Stewart Island) (Trip 2009). There are no significant differences in growth rates or mean adult body size between sexes, yet with the exception of the Hauraki Gulf, the oldest and largest fish (FL) sampled in all areas were females (Trip 2009).

Table 5: Estimates of biological parameters for butterfish.

Fishstock							**Estimate**	**Source**
1. Natural mortality (*M*)								
Cook Strait							0.30–0.45	Paul et al (2000)
2. Weight = a(length)^b (Weight in g, length in cm fork length).								
	Females		Males		Juvenile			
	a	b	a	b	a	b		
Cook Strait	67.699	1 947.8	67.034	1 885.9	21.205	362.28		Ritchie (1969)
Hauraki Gulf								
Stewart Is.								
Linear regression, b = constant. Weight is gutted weight.								
3. von Bertalanffy growth parameters								
			Both sexes					
			K	t_0	L_∞			
Cook Strait			0.23	-1.7	51.8			Paul et al (2000)
Hauraki Gulf			0.517	-0.23	457.36			Trip (2009)

Butterfish start life as female, some, but not all, undergo sex change where an estimated 50% of mature females develop into males. The size at sex change ranges between 37 to 45 cm FL. The length at which sex change occurs does not seem to differ between geographical areas, but age-at-sex change varies geographically. The mean age-at-sex change was found to be significantly lower in warmer latitudes, 2.5 yrs at the Hauraki Gulf, in comparison to 7 years old at Stewart Island. At D'Urville Island, in-between the two, fish changed sex at 5 years old (Trip 2009).

In the warm waters of the north females mature early and of the samples collected in the Hauraki Gulf 95% of females are sexually mature by two years old (29.7 cm FL). Females sampled at Stewart Island show delayed maturity with only 50% mature at an average age of four (25.2 cm FL) (Trip 2009).

The depth distribution of butterfish differs by size and sex. Juveniles (less than 30 cm) occur in the shallow weed beds (less than 15 m) and (outside the breeding season) males occur in deeper waters than females. Consequently, sex ratios vary with locality, but females often outnumber males.

In the North the spawning season occurs between July and November, with a peak in August. The spawning season extends from July to March in Cook Strait, peaking in September and October. In southern New Zealand the spawning season appears to be shorter (August to January, peaking in October–January).

3. STOCKS AND AREAS

There is no clear information on whether biologically distinct stocks occur, although there is some evidence of regional variation in meristic characters which suggests some separation of populations. The time larval butterfish spend in the plankton before settling out into the adult habitats as postlarvae is relatively short, a factor that may cause a high level of stock separation around coastal New Zealand. The only information on movement relates to feeding behaviour involving small-scale movements within seaweed beds. There is no information on movement along the coastline within a weed-bed habitat, or potentially longer migration between such habitats separated by open coast. However, the latter seems unlikely on any substantial scale, and as a result butterfish populations are probably quite localised. Butterfish populations at offshore islands (Chatham, Antipodes, Bounties, and Snares), have not been studied but may be distinct from the mainland population(s) simply because of their isolation.

4. STOCK ASSESSMENT

A yield per recruit analysis was undertaken in 1997 (Paul et al 2000). This report derived new estimates of growth and natural mortality from the Cook Strait which were incorporated into this analysis. Stock status was not determined by this analysis.

4.1 Estimates of fishery parameters and abundance
No information is available.

4.2 Biomass estimates
No information is available.

4.3 Yield estimates and projections
The method *MCY* = *cYav* (Method 4) was evaluated. However, this method was rejected due to a lack of reliable information on changes in fishing effort and/or mortality over the history of the fishery. *MCY* for butterfish cannot be determined.

CAY cannot be determined.

4.4 Other yield estimates and stock assessment results

A study of setnet mesh selectivity in relation to the current legal minimum fish size showed that 108 mm mesh retained few undersized fish (immature). This provides a level of protection to butterfish stocks and their recruitment. A yield per recruit analysis showed that a modest yield increase could be obtained by using a smaller mesh and taking younger (2–3 year old) fish. However, this theoretical gain would be counter-balanced by the capture of relatively more juveniles and young females, and almost certainly a higher bycatch of other reef fishes. Butterfish populations are susceptible to localised depletion.

5. STATUS OF THE STOCKS

No estimates of current and reference biomass are available. It is not known whether recent catch levels will allow the stock to move towards B_{MSY}.

Reported landings and TACCs are summarised in Table 6.

Table 6: Summary of reported landings (t) and TACCs by QMA for the most recent fishing year.

Fishstock		FMA	2018–19 Actual TACC	2018–19 Reported landings
BUT 1	Auckland (East)(West), Central (West)	1,8&9	3	1.6
BUT 2	Central (East)	2	63	48.0
BUT 3	South-east coast	3	3	0.04
BUT 4	Chatham	4	10	0
BUT 5	Southland	5	45	37.1
BUT 6	Sub-Antarctic	6	0	0
BUT 7	Challenger	7	38	24.2
BUT 10	Kermadec	10	0	0
TOTAL			162	110.8

6. FOR FURTHER INFORMATION

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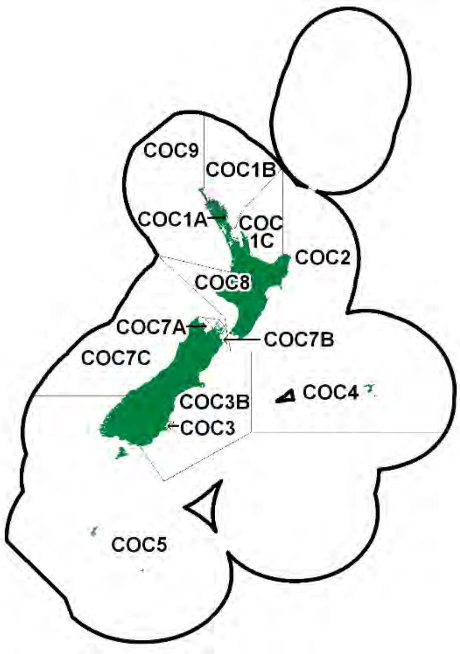
COCKLES (COC)

(*Austrovenus stutchburyi*)
Tuangi



1. INTRODUCTION

Cockles are important shellfish both commercially and for non-commercial fishers.

Since 1992, Fisheries New Zealand or its predecessors has commissioned biomass surveys for cockles and pipi in the northern North Island on beaches where there is known recreational and customary fishing pressure. The objective of the surveys is to determine the distribution, abundance and size frequency of cockles and pipi on selected beaches in the Auckland Fisheries Management Area. Over the years, a total of 35 beaches have been monitored. On average, 12 beaches are sampled each year. The last survey was conducted in 2019 (see Berkenbusch & Neubauer, 2019). All of the 2018–19 survey sites contained notable cockle populations, and data from the field sampling were sufficient to provide cockle population estimates with relatively low uncertainty, i.e., with a CV of less than 20%. Seven of the sites had relatively high population densities, where estimates exceeded 400 individuals per square metre, with four sites with particularly high density estimates (1997 per m^2 in Ngunguru estuary in Northland, 1229 per m^2 in Whangapoua harbour in Coromandel, 1091 per m^2 in Mangawhai harbour in Northland and 1047 per m^2 in Whangamata harbour in Coromandel). In contrast, the lowest density estimate was Ruakaka estuary in Northland, where cockles occurred at an estimated 88 per m^2.

1.1 Commercial fisheries

Commercial picking of cockles, *Austrovenus stutchburyi*, is carried out on Snake Bank, Whangarei Harbour (FMA 1), Papanui and Waitati Inlets, Otago (FMA 3) and Pakawau Beach, Ferry Point and Tapu Bay in Tasman and Golden Bays (FMA 7). Cockles have also been commercially harvested from Otago Harbour since August 2009 under a special permit. Subsequently, since November 2018, two substantial beds within the Otago Harbour (Bed 1 and Bed 2) have been open for commercial harvest. Cockles were introduced into the QMS on 1 October 2002. The fishing year runs from 1 October until September 30 and catches are measured in greenweight for all stocks. There is no minimum legal size for commercial or non-commercial fishers for cockles in any stock. Cockles are managed under Schedule 6 of the Fisheries Act for all stocks listed in Table 1, which allows cockles to be returned to where they were taken as soon as practicable after the cockle is taken as long as the cockle is likely to survive.

For assessment purposes, individual reports on the largest fisheries have been produced separately:

1. Snake Bank, Whangarei Harbour, in COC 1A.
2. Papanui Inlet, Waitati Inlet, and Otago Harbour, Otago Peninsula in COC 3.
3. Tasman and Golden Bays in COC 7A.

The landings, by stock, of these cockle fisheries are dominated by catch from COC 3 (Figure 1). Landings from COC 3 have been relatively stable since 2002–03; by contrast landings from COC 1A and COC 7A have generally declined over that time period. However, it should be noted that since 2009, COC 3 has had access to additional substantial stocks within Otago Harbour.

Information on cockles that applies to all stocks is included below rather than being repeated in the reports for each fishery.

New Zealand operates a mandatory shellfish quality assurance programme for all bivalve shellfish commercial growing or harvesting areas for human consumption. Shellfish caught outside this programme can only be sold for bait. This programme is based on international best practice and managed by Food Safety New Zealand in cooperation with the District Health Board Public Health Units and the shellfish industry[1] and is summarised below. Before any area can be used to grow or harvest bivalve shellfish, public health officials survey both the water catchment area to identify any potential pollution issues and microbiologically sampling water and shellfish over at least a 12-month period, so all seasonal influences are explored. This information is evaluated and, if suitable, the area classified and listed by Food Safety New Zealand for harvest. There is then a requirement for regular monitoring of the water and shellfish flesh to verify levels of microbiological and chemical contaminants. Management measures stemming from this testing include closure after rainfall, to deal with microbiological contamination from runoff. Natural marine biotoxins can also cause health risks, therefore testing for these also occur at regular intervals. If toxins are detected above the permissible level the harvest areas are closed until the levels fall below the permissible level. Products are also traceable so that the source and time of harvest can always be identified in case of contamination.

Table 1: TACC, Recreational, customary and other sources of mortality allowances and TAC (t) for all cockle stocks.

Code	Description	TACC	Recreational allowance	Customary allowance	Other sources of mortality	TAC
COC 1A	Whangarei Harbour	346	25	25	4	400
COC 1B	East Northland	0	22	22	2	46
COC 1C	Hauraki Gulf and Bay of Plenty	5	32	32	3	72
COC 2	Central	0	2	2	1	5
COC 3	Otago	1 470	10	10	10	1 500
COC 3B	Part South East Coast	1	27	27	3	58
COC 4	South East (Chatham Rise)	0	1	1	1	3
COC 5	Southland and Sub-Antarctic	2	2	2	1	7
COC 7A	Nelson Bays	1 390	85	25	10	1 510
COC 7B	Marlborough	0	5	5	0	10
COC 7C	Part Challenger	0	3	3	1	7
COC 8	Central (Egmont)	0	1	1	1	3
COC 9	Auckland (West)	0	6	6	1	13

1.2 Recreational fisheries

Cockles are taken by recreational fishers in many areas of New Zealand. The recreational fishery is harvested entirely by hand digging. Relatively large cockles are preferred.

Estimates of recreational harvest of cockles at the FMA level are available. Early estimates of the amateur cockle harvest are available from telephone-diary survey in 1992–93 (Teirney et al 1997), 1996 (Bradford 1998), and 2000 (Boyd & Reilly 2002). Harvest weights were estimated assuming a mean weight of 25 g per cockle (for cockles over 30 mm).

[1]For full details of this programme, refer to the Animal Products (Regulated Control Scheme-Bivalve Molluscan Shellfish) Regulations 2006 and the Animal Products (Specifications for Bivalve Molluscan Shellfish) Notice 2006 (both referred to as the BMSRCS), at: http://www.nzfsa.govt.nz/industry/sectors/seafood/bms/page-01.htm

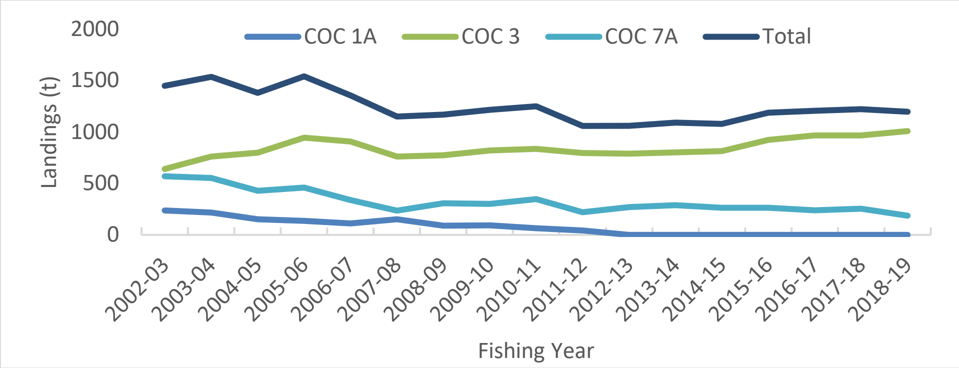


Figure 1: Commercial landings and the sum total (black line) of the three main commercial COC stocks throughout time. Note that this figure does not show data prior to entry into the QMS.

The harvest estimates provided by telephone-diary surveys between 1993 and 2001 are no longer considered reliable for various reasons. A Recreational Technical Working Group concluded that these harvest estimates should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries. In response to these problems and the cost and scale challenges associated with onsite methods, a National Panel Survey was conducted for the first time throughout the 2011–12 fishing year (Wynne-Jones et al 2014). The panel survey used face-to-face interviews of a random sample of 30 390 New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and harvest information collected in standardised phone interviews. A repeat of the National Panel Survey was conducted over the 2017–18 October fishing year (Wynne-Jones et al 2019). Results are given in Table 2.

Table 2: Estimated numbers of cockles harvested by recreational fishers in each FMA for the 2017–18 fishing year, and the corresponding harvest weight based on an assumed mean weight of 25 g.

Stock	Harvest (number of cockles)	CV (%)	Harvest (kg)
COC 1A	-	-	-
COC 1B	17221	0.69	430.53
COC 1C	164297	0.52	4107.42
COC 2	1492	0.80	37.30
COC 3, 3B	94885	0.40	2372.12
COC 3	8475	0.67	211.86
COC 5	6761	1.00	169.03
COC 7A	23176	0.41	579.41
COC 7B	1601	0.59	40.03
COC 7C	-	-	-
COC 8	-	-	-
COC 9	22337	0.77	558.44

Details for COC 1A, COC 3 and COC 7A can be found in the respective Working Group reports.

The Umupuia Beach cockle fishery is popular with recreational and customary fishers. In 2006, Ngāi Tai placed a traditional rāhui (closure) on taking cockles from the beach in recognition of the depletion caused by past fishing pressure. The traditional rāhui has been supported by a series of temporary closures since 2008. The closure was extended for another two years by the Minister in November 2018.

1.3 Customary non-commercial fisheries

In common with many other intertidal shellfish, cockles are very important to Maori as a traditional food. Limited quantitative information on the level of customary take is available from Fisheries New Zealand (Table 3). These numbers are likely to be an underestimate of customary harvest as only the catch in numbers and kilograms are reported in the table below. Details are provided in the respective Working Group reports.

Table 3: Fisheries New Zealand records of customary harvest of cockles (reported as weight (kg) and numbers), since 2000–01. – no data.

		Weight (kg)		Numbers	
Stock	Fishing year	Approved	Harvested	Approved	Harvested
COC 1B	2008–09	120	120	450	450
	2009–10	440	440	–	–
	2010–11	340	340	–	–
	2011–12	400	400	–	–
	2012–13	280	280	–	–
COC 1C	2005–06	65	45	2 000	0
	2006–07	3 680	3 680	–	–
	2007–08	465	260	–	–
	2008–09	260	120	–	–
	2009–10	20	20	–	–
	2014–15	25	25	–	–
COC 2	2009–10	–	–	1 200	980
COC 3	2000–01	–	–	400	400
	2001–02	–	–	37	37
	2002–03	–	–	1 200	1 200
	2006–07	100	100	9 100	7 580
	2007–08	–	–	500	500
	2008–09	–	–	24 496	23 865
	2009–10	–	–	4 750	4 750
	2010–11	–	–	19 500	19 500
	2011–12	30	28	10 600	10 600
	2013–14	–	–	2 300	2 100
	2015–16	80	80	9 610	9 510
	2016–17	–	–	5 500	5 240
	2017–18	–	–	4 950	4 800
COC 3B	2006–07	–	–	156	156
	2007–08	–	–	5 000	5 000
	2008–09	–	–	1 250	750
	2011–12	–	–	500	340
	2015–16	–	–	500	100
	2017–18	–	–	2 250	1 433
	2018–19	–	–	1 500	1 356
COC 7C	2006–07	120	120	–	–
COC 9	2009–10	20	20	–	–
	2012–13	145	145	–	–
	2013–14	270	270	–	–
	2014–15	250	250	–	–

1.4 Illegal catch
No quantitative information on the level of illegal catch is available.

1.5 Other sources of mortality
No quantitative information is available on the magnitude of other sources of mortality. Harvesting implements, such as brooms, rakes, “hand-sorters”, bedsprings and “quickfeeds” may cause some incidental mortality, particularly of small cockles, but this proposition has not been scientifically investigated. High-grading is often practiced with smaller sized clams being returned to the beds, potentially causing stress and related mortality, however no research has substantiated this.

2. BIOLOGY

The cockle, *Austrovenus stutchburyi*, formerly known as *Chione stutchburyi*, is a shallow-burrowing suspension feeder of the family Veneridae. It is found in soft mud to fine sand on protected beaches and enclosed shores around the North and South Islands, Stewart Island, the Chatham Islands and the Auckland Islands (Morton & Miller 1973, Spencer et al 2002). Suspension feeders such as *A. stutchburyi* tend to be more abundant in sediments with a larger grain size. Cockles have been shown to be most abundant in sediments of below 12 percent mud in two separate studies (Thrush et al 2003, Anderson 2008). They are also common in eelgrass (e.g., *Zostera* sp.), which often co-occurs with sand flats.

Cockles are found from the lowest high water neap tide mark to the lowest part of the shore. Larcombe (1971) suggested that the upper limit is found where submergence is only 3.5 hours per day. *A. stutchburyi* is often a dominant species and densities as high as 4500 per m^2 have been reported in some areas. In Pauatahanui Inlet the cockle biomass was estimated at 80% (5000 t) of the total intertidal biomass in 1976 (Richardson et al 1979). Calculations based on laboratory measurements of filtration rates suggested that cockles over 35 mm shell length were capable of filtering 1.1×10^6 m^3 of water or enough to filter all the water in Papanui Inlet every two tidal cycles (Pawson 2004).

Sexes are separate and the sex ratio is usually close to 1:1. Size at maturity has been estimated at about 18 mm shell length (Larcombe 1971). Spawning extends over spring and summer, and fertilisation is followed by a planktonic larval stage lasting about three weeks. Significant depression of larval settlement has been recorded for areas of otherwise suitable substrate from which all live cockles have been removed. This suggests the presence of some conditioning factor.

Work on Snake Bank also showed moderate differences among years in the level of recruitment of juveniles to the population. The variability of recruitment was estimated as $\sigma_R = 0.41$ using all available data (1983–1996) but as $\sigma_R = 0.31$ using data only from those years since the fishery has been considered to be fully developed (1991–96). Given the variability of most shellfish populations and the shortness of the time series, this is probably an underestimate of the real variability of recruitment in the Snake Bank population.

Small cockles grow faster than large cockles, but overall, maximum growth occurs on the first of January, and a period of no growth occurs at the beginning of July (Tuck & Williams 2012). Growth is slower in the higher tidal ranges and in high density beds. Significant increases in growth rates have been observed for individuals remaining in areas that have been ‘thinned out’ by simulated harvesting. Tagging work at Pakawau beach also highlighted the variability in growth that can occur within a beach (Osborne 2010).

Growth parameters and length weight relationships are listed in Table 4 (Stewart 2008, Williams et al 2009, Osborne 2010). However, considerable variability in growth has been seen in all three QMAs over time. At Snake bank (1A) growth to 30 mm has been estimated as taking between 2 and 5 years in separate studies (Martin 1984, Cryer 1997). Additional tagging work on Snake Bank from 2001 to 2010 showed that on average, cockles reach maturity (18 mm; Larcombe 1971) in their second year of growth, and recruit to harvestable size (about 28 mm SL) in about 3 to 4 years, although these results showed great variability in growth rate (tabulated in table 8, Tuck & Williams 2012). At Pakawau beach (7A) K has varied between 0.36 and 0.41 and L_∞ between 47 and 49mm (Osborne 1992, 1999). The work of Breen et al (1999) in Papanui and Waitati Inlets, Purakanui and Otago Harbour showed no significant growth after one year and modes in the length frequency distributions did not shift when measured over four sampling periods within a year. They concluded that it was unlikely that average growth is really as slow as the results indicated, but there may be high inter-annual variability in growth.

Quite extensive movements of juveniles have been documented, but individuals over 25 mm shell length remain largely sessile, moving only in response to disturbance.

Given that cockles recruit to the spawning biomass at about 18 mm shell length, but do not recruit to commercial or non-commercial fisheries until closer to 30 mm shell length, there is some protection for the stock against egg overfishing, especially as the Snake Bank and Papanui and Waitati Inlet stocks are probably not isolated as far as recruitment of juveniles is concerned. However, this generality should be treated with some caution, given that some population of adults seems to be required to stimulate settlement of spat.

Natural mortality arises from a number of sources. Birds are a major predator of cockles (up to about 23 mm shell length). Other predators include crabs and whelks. Cockles are also killed after being smothered by sediments shifted during storms or strong tides. A mass mortality that killed an estimated 56–63% of all cockles and 80–84% of cockles over 30 mm in shell length (Fisheries New Zealand unpublished data) has been reported from sites within the Whangateau harbour (north of Auckland). This mortality was attributed to a potential weakening of cockles due to heat stress then mortality from a coccidian parasite and a mycobacterium[2]. Sediments, both suspended and deposited, both impact upon cockle fitness or survival, with terrestrial sediments having greater effects than marine sediments (Gibbs & Hewitt 2004). Increasing suspended sediment concentrations have induced increased physiological stress, decreased reproductive status and decreased juvenile growth rates (Nicholls et al 2003, Gibbs & Hewitt 2004). Sediment deposition has also been shown to negatively impact upon densities of cockles (Lohrer et al 2004). The sum of these effects is seen in the distribution of cockles which decline in abundance across a number of sites with increasing mud content in the sediments, either above zero or 11% mud content, depending upon the study (Thrush et al 2003, Anderson 2008).

Experimental work on Snake Bank led to estimates of absolute mortality of 17–30% per annum, instantaneous natural mortality (*M*) of 0.19–0.35, with a midpoint of $M = 0.28$. The estimated mortality rates for cockles of over 30 mm shell length were slightly greater at 19–37% per annum, (*M* of 0.21–0.46 with a midpoint of 0.33). This higher estimate was caused by relatively high mortality rates for cockles of over 35 mm shell length and, as these are now uncommon in the population, $M = 0.30$ (range 0.20–0.40) has been assumed for yield calculations across all three stocks (Table 4). Tagging (both notch and individual numbered tags) has been ongoing on Mair Bank from 2001 to 2009 and the last recoveries occurred in 2010 (Tuck & Williams 2012). Annualised mortality estimates (*M)* (averaged over 3, 6 and 9 month recoveries) were 0.356 and 0.465 from studies in 2008 and 2009.

Table 4: Biological parameters used for cockle assessments for different stocks. SL = shell length, within area 7A, P = Pakawau, FP = Ferry Point, TBR = Tapu Bay/Riwaka.

	1A	**3**	**7A**
1. Natural mortality (*M*)	0.3	0.3	0.3
2. Weight (grams)	= a(shell length)^b	= a(shell length) + b	= a(shell length)^b
a	0.00014	0.7211	P = 0.000018, FP = 0.0002, TBR = 0.00015
b	3.29	11.55	P = 3.78, FP = 3.153, TBR = 3.249
3. von Bertalanffy growth parameters			Not used instead growth = a(Ln(age in years))+b
K	0.26	0.326	a = 11.452
L_∞ (mm)	35	40.95	b = 16.425
SL at recruitment to the fishery (mm)	28	28	30

3. STOCKS AND AREAS

Little is known of the stock boundaries of cockles. Given the planktonic larval phase, many populations may receive spat fall from other nearby populations and may, in turn, provide spat for these other areas. In the absence of more detailed knowledge, each commercial fishery area is managed as a discrete population.

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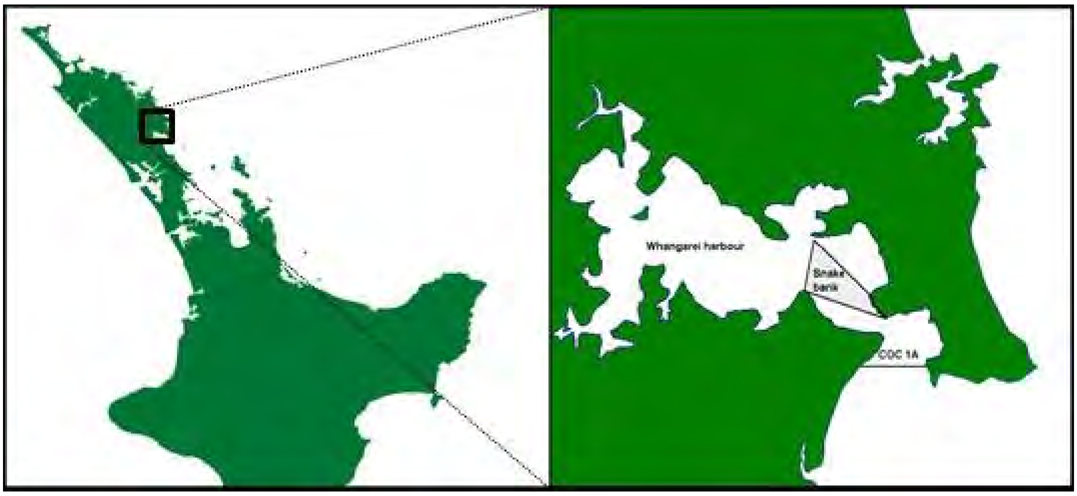
COCKLES (COC 1A) Snake Bank (Whangarei Harbour)

(*Austrovenus stutchburyi*)
Tuangi



1. FISHERY SUMMARY

COC 1A was introduced to the QMS in October 2002 with a TAC of 400 t, comprising a TACC of 346 t, customary and recreational allowances of 25 t each, and an allowance of 4 t for other fishing related mortality. These limits have remained unchanged since.

1.1 Commercial fisheries

Snake Bank is not the only cockle bed in Whangarei Harbour, but it is the only bed allowed for commercial fishing. Commercial fishers are restricted to hand gathering, but they routinely use simple implements such as “hand sorters” to separate cockles of desirable size from smaller animals and silt. There are several other cockle beds in the harbour, some on the mainland and some on other sandbanks, notably MacDonald Bank. Fishing on these other beds should be exclusively non-commercial.

Commercial picking in Whangarei Harbour began in the early 1980s and was then undertaken year round, with no particular seasonality. Catch statistics (Table 1) are unreliable before 1986, although it is thought that over 150 t of Snake Bank cockles were exported in 1982. There was probably some under reporting of landings before 1986, and this may have continued since. Effort and catch information for this fishery has not been adequately reported by all permit holders in the past, and there are problems interpreting the information that is available. Landed weights reported on CELRs only summed to between 52 and 91% of weights reported on LFRRs during the years 1989–90 to 1992–93. CPUE data are available but have not yet been analysed for this fishery.

Before entry of this stock to the QMS there were eight permit holders, each allowed a maximum of 200 kg (greenweight) per day by hand-gathering. If all permit holders took their quota every day a maximum of 584 t could be taken in a 365 day year. Reported landings of less than 130 t before 1988–89 rose to 537 t in 1991–92 (about 92% of the theoretical maximum). Landings for the 1992–93 fishing year were much reduced (about 316 t) following an extended closure for biotoxin contamination. Landings averaged 462 t between 1993–94 and 2000–01. Landings have decreased substantially since COC 1A entered the QMS (average of 108 t). Due to low biomass, the fishery closed in November 2012 and has remained closed since.

The low catch in the last few years before the closure may partly reflect reduced effort on the bank because of temporary fishery closures during incidents of sewage and stormwater overflows which adversely affected harbour water quality. The fishery was closed for these reasons for 101, 96, 167 and

96 days for the 2006–07, 2007–08, 2008–09 and 2009–10 fishing years, respectively[1]. Figure 1 shows the commercial landings and TACC values of COC 1A since 1986.

Table 1: Reported commercial landings and catch limits (t greenweight) of cockles from Snake Bank since 1986–87 (from QMR/MHR records)*. Before COC 1A entered the QMS, the fishery was restricted by daily catch limits which summed to 584 t in a 365 day year, but there was no explicit annual restriction. A TACC of 346 t was established in October 2002 when COC 1A entered the QMS.

Fishing year	Landings (t)	Limit (t)	Fishing year	Landings (t)	Limit (t)
1986–87	114	584	2002–03	237	346
1987–88	128	584	2003–04	218	346
1988–89	255	584	2004–05	151	346
1989–90	426	584	2005–06	137	346
1990–91	396	584	2006–07	111	346
1991–92	537	584	2007–08	151	346
1992–93	316	584	2008–09	88	346
1993–94	**566	584	2009–10	93	346
1994–95	501	584	2010–11	64	346
1995–96	495	584	2011–12	43	346
1996–97	457	584	2012–13	0	346
1997–98	439	584	2013–14	0	346
1998–99	472	584	2014–15	0	346
1999–00	505	584	2015–16	0	346
2000–01	423	584	2016–17	0	346
2001–02	405	584	2017–18	0	346
			2018–19	0	346

*Before COC 1A entered the QMS, the fishery was restricted by daily catch limits which summed to 584 t in a 365 day year, but there was no explicit annual restriction. A TACC of 346 t was established in October 2002 when COC 1A entered the QMS. ** The figure of 566 t for 1993–94 may be unreliable.

The mean length of the commercial harvest was about 29.5 mm; cockles smaller than 25 mm were less attractive to both commercial and non-commercial fishers.

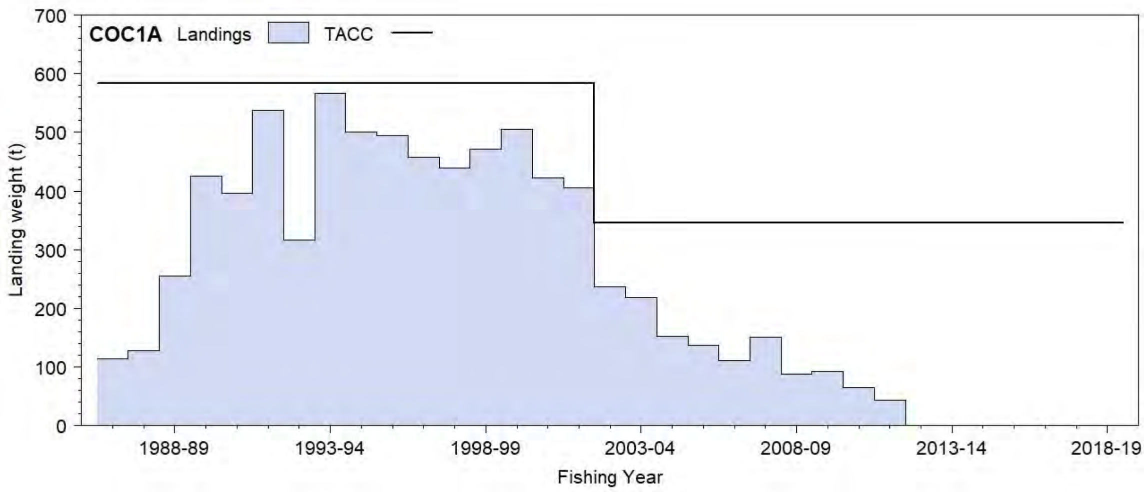


Figure 1: Reported commercial landings and TACC for COC 1A (Whangarei Harbour).

1.2 Recreational fisheries

The recreational fishery is harvested entirely by hand digging, and large cockles (30 mm shell length or greater) are preferred. No recreational harvest estimates specific to the Snake Bank fishery are available.

History of the estimates of recreational catch is provided in the introductory COC Working Group report. Estimated numbers of cockles harvested by recreational fishers in QMA 1 are provided in Table 2.

1.3 Customary fisheries

In common with many other intertidal shellfish, cockles are very important to Maori as a traditional food. The MFish customary catch database contained no records of Maori customary harvest of cockles from COC 1A. Patuharakeke gazetted their rohe moana which covers the southern shoreline of the

[1] Statistics supplied by New Zealand Food Safety Authority in Whangarei.

Whangarei harbour in 2009. Reporting of customary permits is now required. However, a full understanding of Maori customary take will not occur until such time as all iwi operate under the Fisheries (Kaimoana Customary Fishing) Regulations 1998.

Table 2: Estimated numbers of cockles harvested by recreational fishers in QMA 1, and the corresponding harvest tonnage based on an assumed mean weight of 25 g. Figures were extracted from telephone-diary surveys in 1993–94, 1996, 1999–00, and 2000–01 and the National Panel Survey in 2011–12 and 2017–18.

Survey	Numbers	CV (%)	Tonnes	Reference
1993–94	2 140 000	18	55	Bradford (1997)
1996	569 000	18	14	Bradford (1998)
1999–00	2 357 000	24	59	Boyd & Reilly (2002)
2000–01	2 327 000	27	58	Boyd et al (2004)
2011–12	299 765	68	7	Wynne-Jones et al (2014)
2017–18	0	0	0	Wynne-Jones et al (2019)

1.4 Illegal catch

Anecdotal evidence suggests that there was a significant illegal catch from Snake Bank in the 1990s, with some fishers greatly exceeding their catch limits. Commercial landings, therefore, may have been under-reported. There is also good evidence that illegal commercial gathering has occurred on MacDonald Bank on a reasonable scale in the past, which could have resulted in some over-reporting of catch from Snake Bank in some years. However, no quantitative information on the level of illegal catch is available.

1.5 Other sources of mortality

For further information on other sources of mortality, please refer to the introductory COC Working Group report.

Table 3: Estimates of fishery parameters.

Population and years	Estimate	Source
1. Estimated Fishing Mortality (F_{est}, recruited size classes only)		
Snake Bank, 1991–92	1.55	Cryer (1997)
Snake Bank, 1992–93	0.62	Cryer (1997)
Snake Bank, 1995–96	0.50	Cryer (1997)
Snake Bank, 1991–96	0.89	Cryer (1997)
2. Reference Fishing Mortality (F_{ref}, recruited size classes only)		
Snake Bank, $F_{0.1}$	0.41	Cryer (1997)
Snake Bank, F_{max}	0.62	Cryer (1997)
Snake Bank, $F_{50\%}$	4.52	Cryer (1997)
3. Total Instantaneous Mortality (Z, all size classes)		
Snake Bank, 1992–93	0.46	Cryer & Holdsworth (1993)

4. Exploitation rate percentage (≥ 30 mm shell length)

Year*	%
1991	71
1992	41
1995	34
1996	57
1998	54
1999	38
2000	74
2001	93
2002	51
2003	21
2004	28
2005	14
2006	14
2007	11
2008	8
2009	11
2012	0
2013	0

* Exploitation rate is only given in years when biomass surveys were completed and catch reporting was considered reliable (apart from in 2012 and 2013 where no catch was reported, therefore exploitation rate percentage must be zero.

2. BIOLOGY

Biological parameters used in this assessment are presented in the general cockle section.

3. STOCKS AND AREAS

This is covered in the general cockle section.

4. STOCK ASSESSMENT

Stock assessment for Snake Bank cockles has been conducted periodically using absolute biomass surveys, yield per recruit (YPR), and spawning stock biomass per recruit (SSBPR) modelling. The stock assessments were used to estimate *CAY* and *MCY*. A length-based stock assessment model was developed for cockles but was not successful.

4.1 Estimates of fishery parameters and abundance

Estimated and reference fishing mortality rates, estimates of total mortality and exploitation rate are available for Snake Bank (Table 3, Figure 2). Exploitation rate in 2012 and 2013 was 0% and had generally had a downward trend since 1991 (70%) with the exception of a large peak around 2001 (93%). Exploitation rate is likely to be overestimated in the calculation below as the size of cockles commercially harvested is believed to have decreased from over 30 mm to over 28 mm shell length over time.

4.2 Biomass estimates

Biomass estimates for the Snake Bank cockle population from 1982–96 were made using grid surveys. Surveys done from 1998 used a stratified random approach (Table 4, Figure 3). The data given here differ from those in reports before 1997 because the assumptions made when estimating biomass have changed. The surveys conducted in 1985 and 1991 did not cover the whole area of the bank, and results from these surveys have been corrected in the table by assuming that the cockle population occupied the same area of the bank in these years as it did in 1982 (the first and largest survey). It has been further assumed for the estimation of variance for the grid based surveys that samples have been taken at random from the bank, although variance estimators not requiring this assumption gave very similar results in 1995 and 1996. The post 1997 surveys also incorporated a large area of low density cockles not included in previous surveys, although this adds only a small tonnage of biomass to the total figure. In 1998 and 2000, biomass surveys were undertaken at MacDonald Bank using a stratified random approach (Table 5). Cryer et al (2003) reported biomass estimates for several locations in Whangarei Harbour in 2002, including a new MacDonald Bank stratum (Table 5). Northland Regional Council completed a survey in 2014 but only reported total biomass (Griffiths & Eyre 2014), this is included as it gives a recent indication of biomass in the absence of commercial fishing.

Virgin biomass, B_0, is assumed to be equal to the estimated biomass of cockles above a certain shell length in 1982. For example, if a length at recruitment of 30 mm or more was used then a biomass of 2340 t resulted. This biomass was estimated using length frequency distributions, a length weight regression, and a direct estimate of the biomass of cockles ≥ 35 mm shell length in 1982 (1 825 t).

Between the start of the commercial fishery in 1982 and the survey in 1992, there was a consistent decline in the biomass of large cockles (≥ 30 mm shell length) on Snake Bank. The biomass of these large individuals declined to 33% of its virgin level in 1991. A decrease in the proportion and biomass of large, old individuals can be expected with the development of a commercial fishery. The biomass of mature cockles has fluctuated since then without trend between 63 and 19% of virgin levels. The recruited biomass is likely to be underestimated in the calculation below as the size of cockles commercially harvested is believed to have decreased from over 30 mm to over 28 mm shell length over time. There was no survey that has allowed calculation of percent B_0 since 2009.

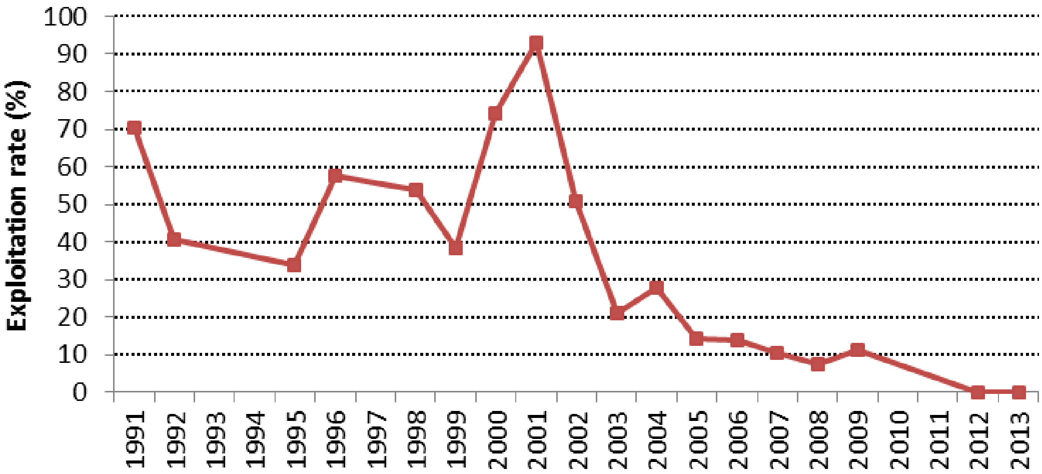


Figure 2: Exploitation rate (≥ 30 mm shell length).

Table 4: Estimates of biomass (t) of cockles on Snake Bank for surveys (*n*, number of stations) between 1982 and 2015. Biomass estimates for the ≥ 18 mm shell length component and those marked with an asterisk (*) were made using length frequency distributions and length-weight regressions, the other size fractions were generated by direct weighing of samples. Two alternative estimates are presented for 1988 because the survey was abandoned part-way through, "a" assuming the distribution of biomass in 1988 was the same as in 1991, and "b" assuming the distribution in 1988 was the same as in 1985. The 2001 result comes from the second of two surveys, the first having produced unacceptably imprecise results. The 2007 and 2008 results differ slightly from those reported previously because they were estimated using an analytical approach more consistent with that used in other years. The column "%$B_{recruited}$" compares the biomass in the ≥ 30 mm SL to the defined B_0 for that size (22 340 t in 1982).

Year	*n*	Total		≥18 mm SL		≥ 30 mm SL		≥ 35 mm SL		% $B_{recruited}$
		Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV	
1982	199	2 556	-	-	-	*2 340	-	1 825	~ 0.10	100
1983	187	2 509	-	2460	0.06	*2 188	-	1 700	~ 0.10	94
1985	136	2 009	0.08	1360	0.07	1 662	0.08	1 174	~ 0.10	71
1988 a	53	-	-	-	-	1 140	> 0.15	-	-	-
1988 b	53	-	-	-	-	744	> 0.15	-	-	-
1991	158	1 447	0.09	1069	0.08	761	0.10	197	0.12	33
1992	191	1 642	0.08	1355	0.07	780	0.08	172	0.11	33
1995	181	2 480	0.07	2380	0.07	1 478	0.07	317	0.12	63
1996	193	1 755	0.07	-	-	796	0.08	157	0.11	34
1998	53	2 401	0.18	-	-	880	0.17	114	0.20	38
1999	47	3 486	0.12	2645	0.11	1 321	0.14	194	0.32	56
2000	50	1 906	0.23	2609	0.18	570	0.25	89	0.32	24
2001	51	1 405	0.17	1382	0.17	435	0.17	40	0.29	19
2002	53	1 618	0.14			466	0.19	44	0.29	20
2003	60	2 597	0.11	2385	0.31	1 030	0.12	121	0.14	44
2004	65	1 910	0.15	1096	0.14	546	0.14	59	0.22	23
2005	57	2 592	0.18	2035	0.15	967	0.20	111	0.20	41
2006	57	2 412	0.13	2039	0.13	792	0.13	103	0.20	34
2007	73	2 883	0.13	2681	0.13	1 434	0.15	329	0.42	61
2008	70	2 510	0.10	-	-	1 165	0.11	193	0.43	50
2009	75	1 686	0.15	-	-	815	0.13	88	0.19	35
2014	63	1 794	0.14							

4.3 Yield estimates and projections

A range of sizes are taken commercially, selectivity seems to vary between years and *MCY* estimates are sensitive to the assumed size at recruitment to the fishery (Table 6). These are presented over time for two different shellfish lengths at recruitment into the fishery (when available), 30 mm the historic size at recruitment, and 28 mm the more recently accepted size at recruitment (Table 7). All of these estimates include commercial and all non-commercial catch.

As fishing is conducted year round on Snake Bank, the Baranov catch equation is appropriate (Method 1, see Plenary introduction). This approach assumes that, between the start of the fishing year and when the biomass survey is started, productivity and catch cancel each other. The estimate includes non-commercial catch.

A range of sizes are taken commercially, selectivity seems to vary between years and *CAY* estimates are sensitive to the assumed size at recruitment to the fishery (Table 6). The level of risk to the stock by harvesting the population at the estimated *CAY* value cannot be determined.

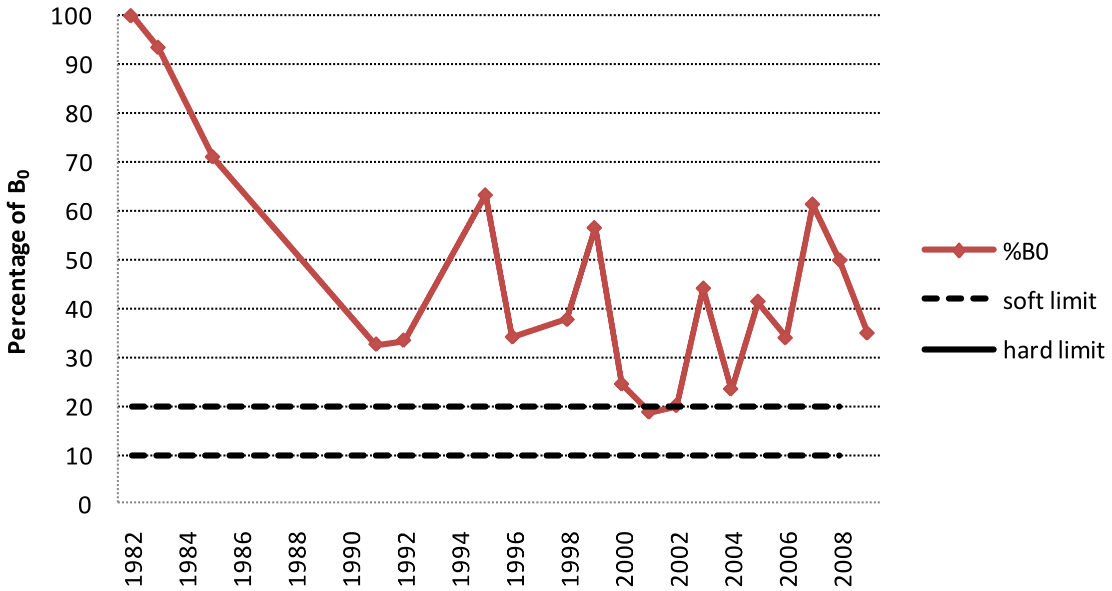


Figure 3: Recruited biomass (≥30 mm shell length) over time as a percentage of B_0 in relation to the hard and soft limits.

Table 5: Biomass estimates (t) and approximate CVs by shell length size classes for cockles on MacDonald Bank. *n* = the number of samples in the survey.

Year	*n*	Total		< 30 mm SL		≥ 30 mm SL		≥ 35 mm SL	
		Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV
1998	33	6 939	0.19	5 261	0.18	1 678	0.31	128	0.41
2000	30	6 037	0.28	4 899	0.29	1 137	0.30	34	0.37
2002	24	2 548	0.12	2 010	0.14	538	0.36	61	0.46

Table 6: Sensitivity of biomass and *CAY* estimates to shell length at recruitment (L_{RECR}) for Snake Bank cockles.

L_{recr} (mm)	Rationale	B_{av} (1991–2009) (t)	B_{curr}(2009) (t)	*M*	$F_{0.1}$	*MCY* (t)	*CAY* (t)
25	Smallest in catch	1 877	1 596	0.3	0.34	385	401
28	Fisher selectivity	1 409	1 265	0.3	0.38	289	349
30	Historical assumption	890	815	0.3	0.41	182	239
35	Largest cockles	145	88	0.3	1.00	30	49

4.4 Other yield estimates and stock assessment results

$F_{0.1}$ was estimated using a yield per recruit (*YPR*) model using quarterly (rather than the more usual annual) increments and critical sizes (rather than ages) for recruitment to the spawning stock and to the fishery. The following input information was used: growth rate parameters from a MULTIFAN analysis of 1991–96 length frequencies; an estimate of $M = 0.30$ (range 0.20–0.40) from a tagging study in 1984; length weight data from 1992, 1995 and 1996 combined; size at maturity of 18 mm; and size at recruitment of 30 mm from an analysis of fisher selectivity. For the base case analysis, $F_{0.1} = 0.41$. Estimates were neither sensitive to the length weight regression used, nor to the value of *M* chosen ($F_{0.1}$ = 0.38–0.45 for M = 0.20–0.40), but were more sensitive to the assumed length at recruitment ($F_{0.1} = 0.34$ for $L_{recr} = 25$ mm).

4.5 Other factors

Biomass and yield estimates will differ for different sizes of recruitment. Maori and recreational fishers prefer cockles of 30 mm shell length and greater whereas commercial fishers currently prefer cockles of 25 mm and greater. Therefore, yield has been estimated for sizes of recruitment between 25 and 30 mm. As cockles become sexually mature at around 18 mm, using a size of recruitment between 25 mm and 30 mm should provide some protection against egg overfishing under most circumstances. However, using the smaller size of recruitment to estimate yield will confer a greater risk of overfishing.

Table 7: *MCY* and *CAY* estimates (t) for different shell lengths at recruitment (L_{RECR}). *MCY* is calculated using the equation for developing fisheries prior to 1995 and developed fisheries after 1995. A value for 2010 is not shown as no survey was completed in COC 1A in 2010. Year labels as given in Table 4.

Year	*MCY* ≥28 mm SL	*MCY* ≥ 30mm SL	*CAY* ≥ 28 mm SL	*CAY* ≥ 30mm SL
1982		240		687
1983		240		642
1985		240		488
1988 a		240		335
1988 b		240		218
1991		240		223
1992		240		229
1995		206		434
1996		196		234
1998		192		258
1999		206		388
2000		193		167
2001		180		128
2002		171		137
2003	269	175	255	302
2004		169		160
2005	238	171	389	284
2006	254	171	329	233
2007	243	179	516	421
2008	293	183	584	342
2009	268	182	349	239

As the Snake Bank cockle population may receive spat from spawnings in other parts of Whangarei Harbour, it may not be realistic to assume that the Snake Bank stock is discrete and that reduced egg production (as a result of heavy fishing mortality on medium and large sized individuals) would necessarily lead to recruitment overfishing. Spawning stock biomass per recruit (SSBPR) analysis suggests that $F_{50\%} > F_{max} > F_{0.1}$ ($F_{50\%}$ is that fishing mortality which would lead to egg production from the population at equilibrium being half of egg production from the virgin stock), except where the size at recruitment is reduced to 25 mm. Substantial reduction of egg production is therefore unlikely if fishing mortality is restrained to within $F_{0.1}$ or F_{max}, and the fishery concentrates on cockles over 30 mm in length.

However, it has been demonstrated for this bank that recruitment of juvenile cockles can be reduced by the removal of a large proportion of adult cockles from a given area of substrate. Conversely, there did not seem to be heavy recruitment to the population during the years when adult biomass was close to virgin (1982–85). This would suggest that there is some optimal level of adult biomass to facilitate recruitment, although its value is not known. It would appear prudent, therefore, to exercise some caution in reducing the biomass of adult cockles. If adult biomass is driven too low, then recruitment overfishing of this population could still occur despite high levels of egg production. In addition, sporadic recruitment of juveniles will probably lead to a fluctuating biomass, suggesting that a *CAY* approach may be more appropriate than a constant catch approach.

A length-based stock assessment model developed in 2000 allowed for more of the natural variability of the system to be incorporated in the stock assessment. This first model did not adequately capture the detail of cockle dynamics. Further work in 2002 (McKenzie et al 2003) did not resolve all of these problems and substantial conflict remained in the model. Additional information on growth and the length frequency of cockles taken by the fishery was collected in 2003 and 2004 and updated in the model. Several additions and enhancements to the model were also made in an attempt to resolve the above-mentioned conflict (Cryer et al 2004, Watson et al 2005). As a result, the model showed an improved fit to the observed data. However, there still remained some conflict, primarily relating to annual variability in the growth increment data, in which only two years of observations were available (2002 and 2004). This was thought to be due to the existence of annual variability in recruitment, and possibly mortality, which are presently not explicitly modelled. Watson et al (2005) therefore concluded that no further development of the model should be undertaken for three to five years, and that resources be concentrated more on data collection, and in particular, growth and recruitment data. Consequently, a tag-recapture experiment was started in March 2005, and additional large samples of cockles have been notch-tagged and released annually from 2005 to 2010. Tagged individuals were recovered and measured on a quarterly basis, and preliminary results suggested there may be strong seasonal variability in growth.

Although the Shellfish Working Group considered that the development of a length-based stock assessment model would be of considerable benefit to the stock assessment, the problems with the model were such that the current approach used to estimate yield for this fishery that had been agreed to by the Shellfish Fishery Assessment Working Group since 1992, would remain.

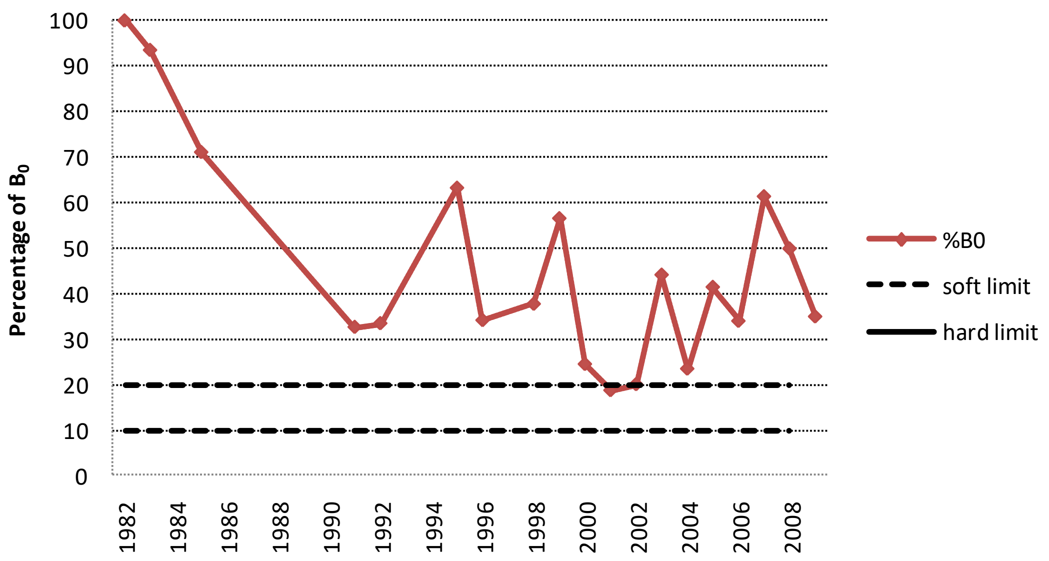
5. STATUS OF THE STOCKS

Stock structure assumptions
Snake bank is assumed to be a single stock.

COC 1A

Stock Status	
Year of Most Recent Assessment	2009
Assessment Runs Presented	Survey biomass estimate for ≥ 30 mm shell length
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing Threshold: -
Status in relation to Target	Unknown in 2018-19 as the available information in too out of date to inform stock status (more recent stock assessment was more than 10 years ago and commercial fishing closed in 2012).
Status in relation to Limits	Unknown in 2018-19 as the available information in too out of date to inform stock status (more recent stock assessment was more than 10 years ago and commercial fishing closed in 2012).

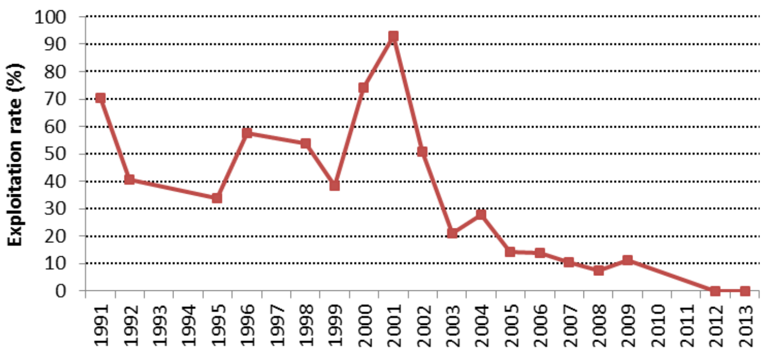
Historical Stock Status Trajectory and Current Status



Recruited biomass (≥ 30 mm shell length) over time as a percentage of B_0 in relation to the hard and soft limits.

The current status is unknown (more recent stock assessment was more than 10 years ago and commercial fishing closed in 2012).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The stock status in 2009 was at 35% of B_0. Commercial fishing closed in 2012.
Recent Trend in Fishing Mortality or Proxy	Exploitation rate (≥ 30 mm shell length) generally trended downward from 1991 (70%) until 2012 (0%), with the exception of a large peak in rate around 2001 (up to 93%). Commercial fishing closed in 2012.

	
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	The commercial fishery has been closed since 2012.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	-

Assessment Methodology and Evaluation		
Assessment Type	Level 2: Partial quantitative stock assessment	
Assessment Method	Absolute biomass estimates from quadrant surveys	
Assessment Dates	Latest assessment: 2009	Next assessment: Unknown
Overall assessment quality rank		
Main data inputs (rank)	- Abundance - Length frequency	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major sources of Uncertainty	- The estimate of B_0 was from 1982 and is not necessarily a good estimate of average unfished biomass. - Maturity at length.	

Qualifying Comments
Water quality issues have influenced the amount of time when cockles can be harvested from the bank in the past, e.g. the fishery was closed for 96 days in the 2009–10 year due to poor water quality.

Fishery Interactions
Interactions with other species are currently being characterised.

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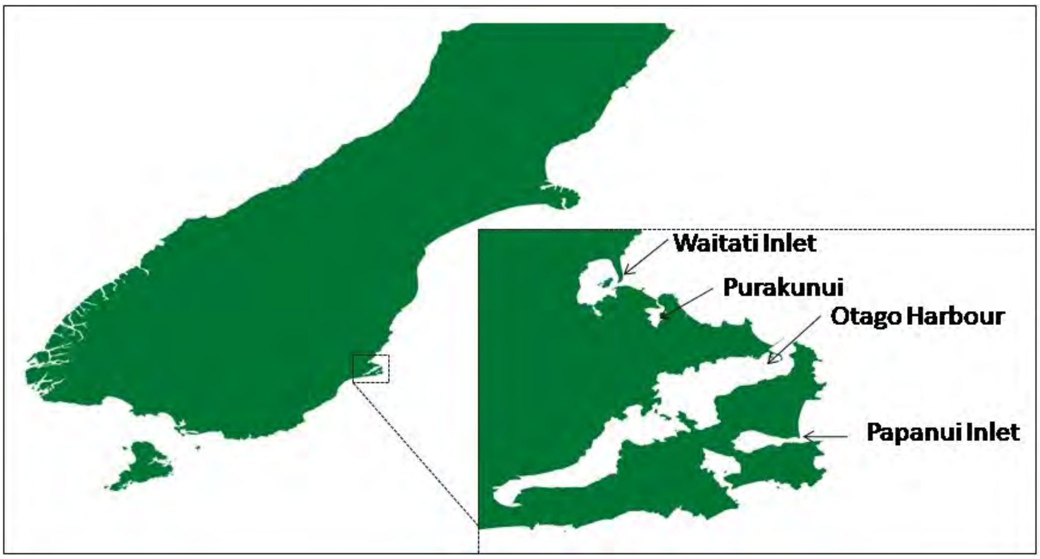
COCKLES (COC 3) Otago Peninsula

(*Austrovenus stutchburyi*)
Tuaki



1. FISHERY SUMMARY

COC 3 was introduced into the Quota Management System in October 2002 with a TAC of 1500 t, comprising a customary allowance of 10 t, a recreational allowance of 10 t, an allowance for other fishing related mortality of 10 t, and a TACC of 1470 t. Historical catch limits are shown in Table 1.

1.1 Commercial fisheries

Cockles are present at various locations around the Otago Peninsula but are only commercially fished from Papanui Inlet, Waitati Inlet, and Otago Harbour.

Commercial fishing in Papanui and Waitati Inlets began in 1983. A limit of 104 t was in effect for Papanui and Waitati Inlets combined from 1986–87 until 1991–92 (Table 1). From 1992–93 to 1998–99, separate catch limits were set for each inlet: 90 t for Papanui Inlet and 252 t for Waitati Inlet. In April 2000, based on new CAY estimates (Breen 1999) for each area, the catch limits were increased to 427 t for Papanui Inlet and 746 t for Waitati Inlet. In 2002 when cockles entered the QMS spatial restrictions upon harvest within COC 3 were removed.

From August 2009 until 31 January 2017, cockles were taken from Otago Harbour under a special permit in order to investigate the ecosystem effects of commercial cockle harvesting in this location (Table 1). This permit stated no explicit limit to the tonnage able to be taken but delimited the area where harvest would be taken. Subsequently, in November 2018, regulation 10 of the Fisheries (South-East Area Commercial Fishing) Regulations 1986 closing Otago Harbour to commercial shellfish harvest was amended to allow harvest from two beds corresponding to sanitation areas 1804 (Port Chalmers) and 1805 (Sawyers Bay).

Total landings have remained below the TACC since 2002–03, with the highest landings since the beginning of the time series recorded in 2018–19 (1008 t) (Table 1, Figure 1).

In 1992, 35 mm shell length was the minimum size for commercial cockles. However, commercial fishers currently target the favoured market size of 28 mm or more.

Table 1: Reported landings (t) of cockles from Papanui and Waitati Inlets, Otago harbour (by each sanitation area and overall) and the entire FMA, since 1986–87 based on Licensed Fish Receiver Returns (LFRR). Catch splits are provided by Southern Clams Ltd. N/A = Not Applicable.

	Papanui Inlet		Waitati Inlet		Otago Harbour catch (t)			Total	
Year	catch (t)	limit (t)	catch (t)	limit (t)	Sanitation area, 1804	Sanitation area, 1804	Total	catch (t)	limit (t)
1986–87	14	–	–	–			–	14	104
1987–88	8	–	–	–			–	8	104
1988–89	5	–	–	–			–	5	104
1989–90	25	–	–	–			–	25	104
1990–91	90	–	16	–			–	106	104
1991–92	90	–	14	–			–	104	104
1992–93	90	90	92	252			–	182	342
1993–94	90	90	109	252			–	199	342
1994–95	90	90	252	252			–	342	342
1995–96	90	90	252	252			–	342	342
1996–97	90	90	252	252			–	342	342
1997–98	90	90	252	252			–	342	342
1998–99	90	90	293	252			–	383	342
1999–00	118	427	434	746			–	552	1 273
2000–01	90	427	606	746			–	696	1 273
2001–02	49	N/A	591	N/A			–	640	1 273
2002–03	52	N/A	717	N/A			–	767	1 470
2003–04	73	N/A	689	N/A			–	762	1 470
2004–05	91	N/A	709	N/A			–	800	1 470
2005–06	68	N/A	870	N/A			–	943	1 470
2006–07	0*	N/A	907	N/A			–	907	1 470
2007–08	–	N/A	760	N/A			–	760	1 470
2008–09	–	N/A	751	N/A	2	21	24	775	1 470
2009–10	–	N/A	379	N/A	188	253	441	820	1 470
2010–11	–	N/A	240	N/A	567	30	596	836	1 470
2011–12	–	N/A	358	N/A	153	284	437	795	1 470
2012–13	–	N/A	403	N/A	98	290	387	790	1 470
2013–14	–	N/A	438	N/A	201	161	362	800	1 470
2014–15	–	N/A	466	N/A	90	259	349	815	1 470
2015–16	–	N/A	453	N/A	193	276	469	923	1 470
2016–17	–	N/A	825	N/A	44	94	138	967	1 470
2017–18	48	N/A	906	N/A	0	0	0	954	1 470
2018–19	27	N/A	153	N/A	348	480	828	1 008	1 470

*No catches have been taken from Papanui Inlet between 2006–07 and 2016–17 because of water quality problems.

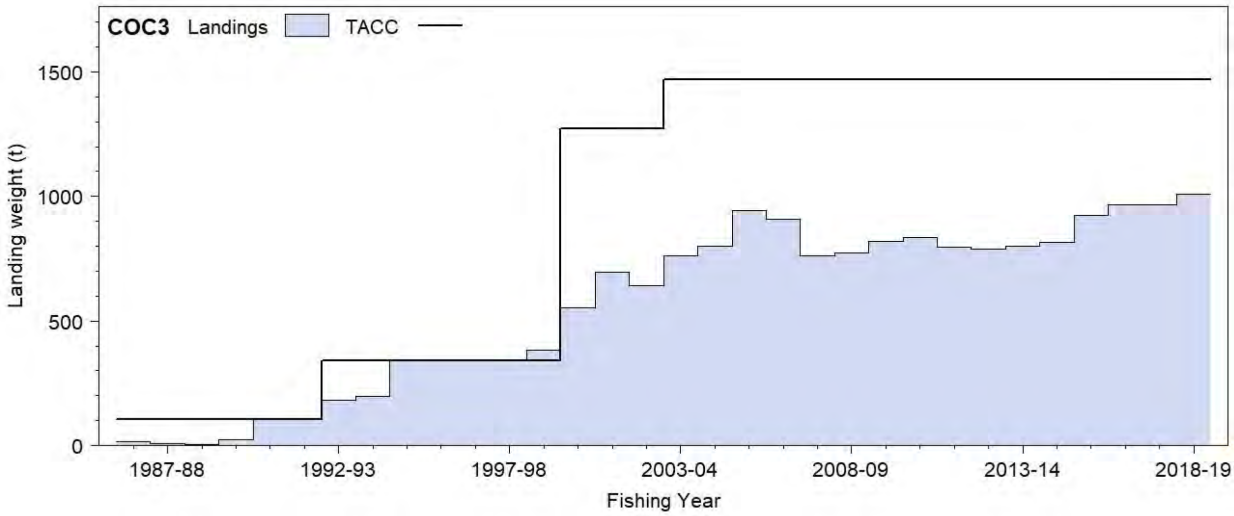


Figure 1: Reported commercial landings and TACC for COC 3 (Otago).

1.2 Recreational fisheries

Cockles are taken by recreational fishers in many areas of New Zealand. The recreational fishery is harvested entirely by hand digging.

No recreational harvest estimates specific to the COC 3 commercial fishery areas are available. History of the estimates of recreational catch is provided in the introductory COC Working Group report. Estimated numbers of cockles harvested by recreational fishers in QMA 3 are provided in Table 2.

Table 2: Estimated numbers of cockles harvested by recreational fishers in QMA 3, and the corresponding harvest tonnage based on an assumed mean weight of 25 g. Figures were extracted from telephone-diary survey in 1993–94, 1996 and 1999–00, and from the National Panel Survey in 2011–12 and 2017–18.

Survey	Numbers	% CV	Tonnes	Reference
1993–94 South	106 000	51	2.7	Teirney et al (1997)
1996	144 000	–	3.6	Bradford (1998)
1999–00	1 476 000	45	36.9	Boyd & Reilly (2002)
2011–12	300 158	67	7.5	Wynne-Jones et al (2014)
2017–18	103 359		2.6	Wynne-Jones et al (2019)

1.3 Customary non-commercial fisheries

Many intertidal bivalves, including cockles, are very important to Maori as traditional food, particularly to Huirapa and Otakou Maori in the Otago area. Tangata tiaki issue customary harvest permits for cockles in Otago. The number and kilograms of cockles harvested under customary permits is given in Table 3, and is likely to be an underestimate of customary harvest. It is understood that local customary fishers generally utilise the daily amateur bag for their customary needs.

Table 3: Fisheries New Zealand records of customary harvest of cockles (reported as weight (kg) and numbers), since 2000–01. – no data.

	Weight (kg)		Numbers	
Fishing year	Approved	Harvested	Approved	Harvested
2000–01	–	–	400	400
2001–02	–	–	37	37
2002–03	–	–	1 200	1 200
2003–04	–	–	–	–
2004–05	–	–	–	–
2005–06	–	–	–	–
2006–07	100	100	9 100	7 580
2007–08	–	–	500	500
2008–09	–	–	24 496	23 865
2009–10	–	–	4 750	4 750
2010–11	–	–	19 500	19 500
2011–12	30	28	10 600	10 600
2012–13	–	–	–	–
2013–14	–	–	2 300	2 100
2014–15	–	–	–	–
2015–16	80	80	9 610	9 510
2016–17	–	–	5 500	5 240
2017–18	–	–	–	–
2018–19	–	–	–	–

On 1 October 2010, on the recommendation of the Taiāpure Committee, the Minister of Fisheries introduced new regulations for the East Otago Taiāpure[1]. These included a new amateur daily bag limit of 50 for shellfish, including cockles, and a ban on the commercial take of cockles from any part of the Taiāpure, except for the existing sanitation areas within Waitati Inlet. The new regulations reflect the Committee's concern about fishing pressure on shellfish stocks, including cockles, within the Taiāpure.

A long-running time series of surveys suggest that there are no sustainability concerns for cockles within the Taiāpure. However, they do indicate a shift in some beds towards smaller size classes of cockle. The Committee hopes that reducing the bag limit and limiting the spatial extent of commercial harvest will lead to an increase in the number of large cockles.

[1] The Kati Huirapa Runanga ki Puketeraki application for a taiāpure-local fishery was gazetted as the East Otago Taiāpure-Local Fishery in 1999. A management committee, made up of representatives from the Runanga and various recreational, environmental, commercial, community and scientific groups, was appointed in 2001.

The Ōtākou Mataitai Reserve was established over the outer Otago Harbour in 2016 in recognition of the importance of this area as a traditional customary food source.

1.4 Illegal catch

There is qualitative data to suggest illegal, unreported, unregulated (IUU) activity in this Fishery.

1.5 Other sources of mortality

For further information on other sources of mortality, please refer to the introductory COC Working Group report.

Other mortality sources would include predation from oystercatchers (Haematopus ostralegus) and other wading birds, and sediment burial via landslips or shifting sediments (Stephenson, 1981).

2. BIOLOGY

Biological parameters used in this assessment are presented in the general cockle section.

3. STOCKS AND AREAS

Each inlet is assumed to be an independent fishery within the stock.

4 STOCK ASSESSMENT

Stock assessments for Papanui Inlet and Waitati Inlet have been conducted using absolute biomass surveys, yield-per-recruit analyses, and Method 1 for estimating CAY (See Introduction chapter of Plenary). From a 1998/99 survey, Breen et al. (1999) also estimated biomasses and yields and size composition for clams in Papanui Inlet and Waitati Inlet as well as five beds within Otago Harbour (Harwood, Aramoana, Port Chalmers, Sawyers Bay, and St Leonards), and Purakanui Inlet. Stewart (2006, 2008a) estimated biomass and yields for Papanui and Waitati Inlets in 2004 and Waitati Inlet in 2007. Similarly, Jiang et al estimated biomass and yields for Papanui and Waitati Inlets in 2011 (Jiang et al 2011). Stewart (2017) also estimated the size structure and biomass for clams in part of Sanitation areas 1804 and 1805 in Otago Harbour in January 2007, 2012 and 2017. Miller & Black (2019) calculated MCY and CAY for the recruited biomass of commercial beds in Waitati Inlet using Method 1 and yield per recruit (YPR) values calculated by previous surveys. In 2020 the five Otago Harbour beds were resurveyed providing estimates of biomass and size composition (Beentjes 2020). Sanitation area 1804 includes the Port Chalmers bed, and Sanitation area 1805 the Sawyers Bay bed.

4.1 Estimates of fishery parameters and abundance

A project to estimate growth and mortality in Papanui and Waitati Inlets, Purakanui and Otago Harbour was undertaken in the late 1990s. Notched clams did not exhibit significant growth when recovered after one year, and modes in the length frequency distributions did not shift when measured over four sampling periods within a year (Breen et al 1999).

Yield-per-recruit modelling has been conducted for Papanui and Waitati inlets separately (Stewart 2006, 2008a, Jiang et al 2011, Miller & Black 2019) and for Otago harbour (Stewart 2017). The most recent parameters used in this modelling are detailed in table 2 of the cockle introductory section. Estimates of $F_{0.1}$ from these studies are given in Table 4. The exploitation rate has never exceeded 13% for Waitati, Papanui Inlet and Otago harbour sanitation areas (beds 1804 and 1805 combined and individually) (Table 5, Figure 2).

Table 4: Estimates of fishery parameters (recruitment to this fishery is at ≥28 mm)

M	$F_{0.1}$ 2004	$F_{0.1}$ 2007		$F_{0.1}$ 2011	$F_{0.1}$ 2017	$F_{0.1}$ 2019
			Waitati	Papanui	Otago harbour	Waitati
0.2	0.2321	0.2899	0.2600	0.2900	0.2899	0.2899
0.3	0.3412	0.3863	0.3900	0.4400	0.3863	0.3863
0.4	0.4767	0.5537	0.5300	0.6000	0.5537	0.5537

Table 5: Exploitation rate % as calculated by commercial landings divided by biomass (≥30 mm) from Papanui Inlet (whole inlet), Waitati Inlet (whole inlet) and Otago Harbour Sanitation areas (beds 1804 and 1805 combined)*.

Year	Papanui Inlet	Waitati Inlet	Otago Harbour		
			Sanitation areas combined	Sanitation area, 1804	Sanitation area, 1805
1998	2	3			
2002	1	8			
2004	2	9			
2007		13	0	0	0
2011	0	2	5	4	7
2017			2	1	4
2019		3			

* This measure is likely to overestimate exploitation as harvest occurs down to a size limit of 28 mm.

4.2 Biomass estimates

Biomass surveys have been undertaken periodically in COC 3 since 1984. The methods for the calculation of biomass have changed over time[2] which means that comparison of biomass values between times of different calculation methodologies should be conducted cautiously.

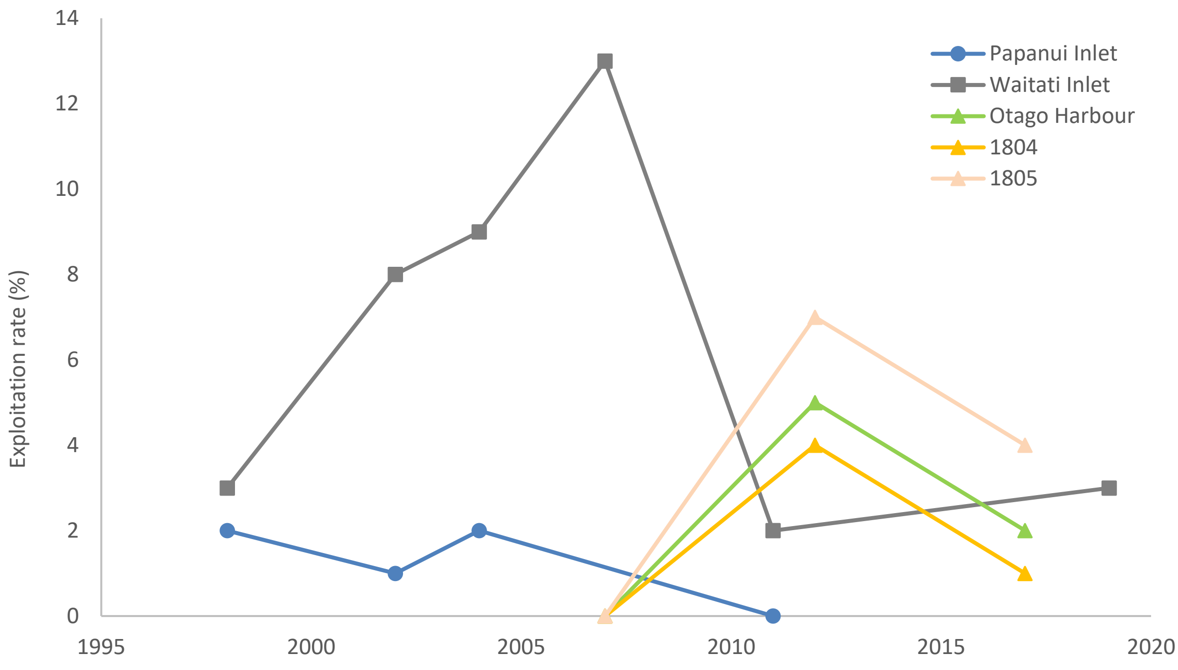


Figure 2: Exploitation rate (%) as calculated by commercial landings divided by biomass (≥30 mm) from Papanui Inlet (whole inlet), Waitati Inlet (whole inlet) and Otago Harbour Sanitation areas (beds 1804 and 1805 combined). Note: This measure is likely to overestimate exploitation as harvest occurs down to a size limit of 28 mm.

The spawning stock biomass (19 mm or more, shell length) was stable around the level of virgin biomass in Waitati Inlet until 2007 and has increased since (Table 6, Figure 3). In Papanui Inlet the

[2] Wildish (1984a and b) and Stewart et al (1992) separated cockles by sieving into three size classes. Breen et al (1999) measured random samples of cockles from each inlet to calculate length-weight relationships. The first method only allows estimation of biomass from predetermined size classes. By calculating size structure of populations using length to weight data, a more flexible approach is allowed where data can be matched to current commercial needs as well as to future survey results. The 1998 survey used random samples from each inlet to calculate length to weight relationships (Breen et al 1999). This method was once again used in the 2002 survey (Wing et al 2002). In the 2004 and 2007 surveys random samples from each shellfish bed were weighed and their longest axis measured (Stewart 2006, 2008a). These data were then used to generate length to weight relationships. The 2017 survey replicated the method used in the 2004 and 2007 surveys. The 2020 survey of Otago Harbour followed the methods of Breen et al. 1999 (Beentjes 2020).

spawning stock biomass (19 mm or more shell length) showed a trend of gradual decline from 1984 until 2011, when it was at 73% of virgin biomass. No commercial harvesting has occurred in Papanui Inlet since 2006–07. The recruited biomass (30 mm or more shell length) in the sanitation areas (beds 1804 and 1805) in Otago Harbour decreased before the start of harvesting in 2008 and has decreased more since then (to 60% of virgin biomass). A new survey was conducted in January 2017. From 164 stations at bed 1804 and 176 stations at bed 1805 the total clam biomass for each bed was estimated to be 4549 tonnes for 1804 and 4829 tonnes for 1805.

Table 6: Survey biomass estimates (B in tonnes) and ±95% confidence intervals (CI) from COC 3*.

Size classes	**>2 to 18 mm (juveniles)**		**19 – 34 mm (adults)**		**≥30 mm**		**≥35 mm**		**Total (t)**	
	B	**±95% CI**	**B**	**±95% CI**	**B**	**±95% CI**	**B**	**±95% CI**	**B**	**±95% CI**
Papanui Inlet										
1984	65		3 705				2 370		**6 140**	
1992	139	± 41	3 721	± 852			1 706	± 635	**5 567**	**± 1 058**
1998	33	± 11	3 435	± 645	3 990	± 1 115	2 231	± 708	**5 699**	**± 1 154**
2002 (total inlet)	17	± 1.7	1 970	± 192	3 860	± 365	2 579	± 252	**4 565**	**± 424**
2002 (Commercial area)	8	± 1.2	888	± 111			1731	± 210	**2 628**	**± 305**
2004 (total inlet)	36	± 2.2	2 415	± 151	3 677	± 367	2 301	± 273	**4 752**	**± 425**
2004 (Commercial area)	13	± 1.3	825	± 88	2 420	± 271	1 847	± 208	**2 685**	**± 298**
2011 (total inlet)	8	± 1.4	1 400	± 168	4 025	± 542	3 048	± 429	**4 457**	**± 601**
2011 (Commercial area)	4		401				1 508		**1 913**	
Waitati Inlet**										
1984	619		7 614				3 844		**12 080**	
1992	1 210	± 115	5 198	± 363			4 620	± 596	**11 027**	**± 707**
1998	304	± 63	8 519	± 1 241	7 235	± 1 625	4 381	± 1 335	**13 204**	**± 1 947**
2002 (total inlet)	153	± 20	6 653	± 652	7 183	± 463	4 298	± 298	**11 103**	**± 848**
2002 (Commercial area)	26	± 1.8	2 622	± 168			3 630	± 260	**6 278**	**± 410**
2004 (total inlet)	257	± 14	7 272	± 403	7 993	± 720	4 535	± 508	**12 064**	**± 925**
2004 (Commercial area)	77	± 4	2 735	± 129	5 612	± 681	3 872	± 384	**6 685**	**± 517**
2007 (total inlet)	335	± 26	4 507	± 347*[3]	7 106	± 548	3 941	± 462	**11 948**	**± 921**
2007 (Commercial area)	102	± 7.5	1 284	± 95*[3]	4 726	± 352			**6 112**	**± 456**
2011 (total inlet)	220	± 14	7 348	± 501	11 441	± 946	6 323	± 643	**13 892**	**± 1 149**
2011 (Commercial area)	48		2 846		6 881		5 114		**8 008**	
2019 (total inlet)	885	± 67	5 403	± 369*[3]	7 875	± 601			**14 162**	**± 1 082**
2019 (Commercial area)	105	±7	1 677	± 109*[3]	4 535	± 294			**6 317**	**± 410**
Purakunui Inlet										
1998					1 825					
Otago Harbour										
1998					32 975					
2020					20 606				**22 978**	
Otago Harbour Sanitation area, 1804										
1998					8 091**[4]					
2007	208	± 15	472	± 35	5 473	± 402			**6 153**	**± 452**
2012	155	± 19	348	± 44	4 183	± 497			**4 686**	**± 560**
2017	312	± 42.35	148	± 20	4 100	± 554			**4 550**	**± 616**
2020					3 675**[4]	± 1 374			**3 715*[4]**	**± 1 386**
Otago Harbour Sanitation area, 1805										
1998					5 546**[4]					
2007	375	± 41	3 387	± 367	3 526	± 382			**7 288**	**± 790**
2012	385	± 46	2 016	± 241	4 078	± 472			**6 479**	**± 764**
2017	1 106	± 201	1 465	± 271	2 258	± 416			**4 829**	**± 888**
2020					4 384**[4]	± 978			**5 353*[4]**	**± 1 165**

*Wildish 1984a; Stewart et al 1992; Breen et al 1999; Wing et al 2002; Stewart, 2006; Stewart 2008a (table 4.1.5), Stewart 2008b; Jiang et al 2011; Stewart 2013, Stewart 2017, Beentjes 2020. Area of current commercial beds, Papanui Inlet = 815 811 m^2. **Area of current commercial beds, Waitati Inlet = 943 986 m^2. *[3] = this value is only for ≥19 mm to <30 mm cockles. *[4] The surveys of Breen et al 1999 and Beentjes 2020 covered a larger extent of these beds than the three subsequent surveys in 2007–08, 2012 and 2017.

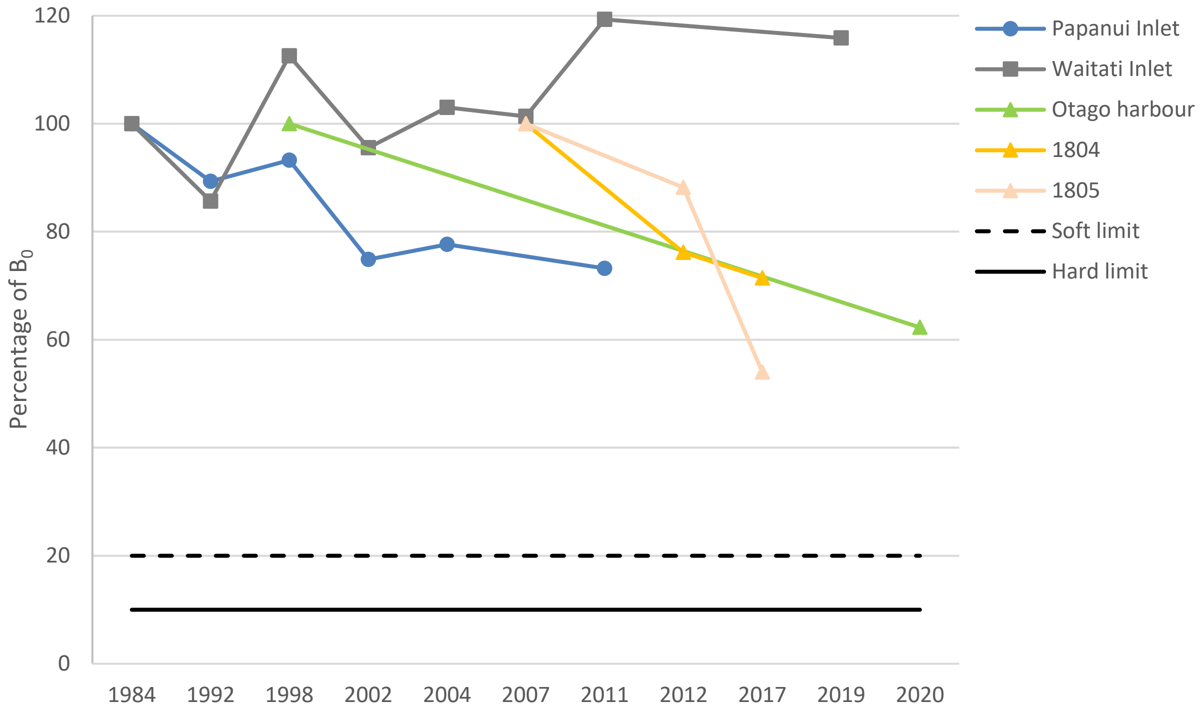


Figure 3: Biomass as a proportion of B_0. For Papanui Inlet, Waitati Inlet, and the two sanitation areas (1804 and 1805) this is estimated for biomass ≥ 19mm. For Otago harbour, the estimates are for biomass ≥ 30 mm. For the 2020 Otago harbour survey, the biomass of the additional bed (Te Rauone, 69 t) was removed so the 1998 and 2020 surveys could be compared. Virgin biomass was taken as biomass estimated during the first survey for each area. Note: No catch has been taken from Papanui Inlet between 2006–07 and 2016–17.

4.4 Other factors

Commercial, customary and recreational fishers target different sized cockles. Biomass and yield estimates will differ for different sizes of recruitment to the fishery. Maori and recreational fishers prefer larger cockles (45 mm shell length and greater) whereas commercial fishers currently prefer cockles of around 28–34 mm. Commercial fishers currently target cockles 28 mm or more, therefore 28 mm is used as the effective minimum size in yield calculations; however, these estimates do not consider multiple fisheries preferring different sized cockles. Depending on the management approach taken in the future in COC 3, the appropriateness of the current methods to estimate yield may need to be reviewed.

The yield estimates use information from yield-per-recruit analyses that assume constant recruitment and constant growth and mortality rates. Yield estimates will be improved when growth, mortality and recruitment variation are better known.

As cockles become sexually mature at around 18 mm, using a size of recruitment of 30 mm should provide some protection against egg overfishing under most circumstances. Certainly the increase in the biomass of small cockles (2 to 18 mm) seen in both inlets in 2004 suggests that the very poor recruitment observed by Wing et al (2002) may have been due to natural variability, and supports the conjecture that significant recruitment might occur only sporadically in the Otago fishery, as suggested by John Jillett (*pers. comm.)* and Breen et al (1999). The possibility that fishing has an effect on recruitment remains an unknown.

In other cockle fisheries it has been shown that recruitment of juvenile cockles can be reduced by the removal of a large proportion of adult cockles from a given area of substrate. This would suggest that there is some optimal level of adult biomass to facilitate recruitment, although its value is not known. To date it has not been determined whether the cockles being targeted by commercial harvesting in the Otago fishery comprise the bulk of the spawning stock or if disturbance of the cockle beds is influencing settlement.

The distribution of very small size classes (2 to 10 mm) across the various beds is variable and no consistent differences exist for this size of shellfish between commercial and non-commercial beds (Stewart 2008a). A comparison of the size/frequency histograms with fishing history for each bed would be a worthwhile exercise and may reveal more. The fact that the relationship between spawning stock and recruitment in this fishery is poorly understood remains a concern.

The effects of the illegal catch, the Maori traditional catch and incidental handling mortality are unknown, although illegal catch is thought to be insignificant. The impacts of the recreational fishery are probably minor compared with those from the commercial fishery.

Table 8: *CAY* estimates (*t*) for COC 3. WI = Waitati Inlet, PI = Papanui Inlet, WIc and PIc are estimates for commercial areas only, B_{beg} = Projected biomass at the beginning of the fishing year. References: (a) Breen et al 1999, (b) Wing et al 2002, (c) Stewart 2006, (d) Stewart 2008a, (e) Jiang et al 2011 and (f) Miller & Black 2019.

				WI		WIc		PI		PIc		
Year	***M***	$F_{0.1}$	**≥ SL (mm)**	B_{beg}	***CAY***	B_{beg}	***CAY***	B_{beg}	***CAY***	B_{beg}	***CAY***	**Reference**
1999	0.2	0.258	30	7 235	1 498			3 990	826			(a)
1999	0.3	0.357	30	7 235	1 848			3 990	1 019			(a)
1999	0.4	0.457	30	7 235	2 221			3 990	1 225			(a)
2002	0.2	0.2017	30	7 183	1 193	5 364	891	3 860	641	2 322	386	(b)
2002	0.3	0.3015	30	7 183	1 627	5 364	1 215	3 860	874	2 322	526	(b)
2002	0.4	0.3956	30	7 183	1 960	5 364	1 464	3 860	1 053	2 322	634	(b)
2004	0.2	0.2321	30	9 399	1 771	6 081	1 146	4 119	776	2 454	462	(c)
2004	0.3	0.3412	30	9 399	2 367	6 081	1 532	4 119	1 038	2 454	618	(c)
2004	0.4	0.4767	30	9 399	2 984	6 081	1 930	4 119	1 308	2 454	779	(c)
2007	0.2	0.2899	28	8 378	1 920	5 261	1 206					(d)
2007	0.3	0.3863	28	8 378	2 342	5 261	1 471					(d)
2007	0.4	0.5537	28	8 378	2 990	5 261	1 878					(d)
2007	0.2	0.2899	30	7 106	1 629	4 725	1 083					(d)
2007	0.3	0.3863	30	7 106	1 986	4 725	1 321					(d)
2007	0.4	0.5537	30	7 106	2 536	4 725	1 686					(d)
2011	0.2	0.26	30	11 441	2 385	6 881	1 434					(e)
2011	0.3	0.39	30	11 441	3 223	6 881	1 938					(e)
2011	0.4	0.53	30	11 441	3 948	6 881	2 374					(e)
2011	0.2	0.29	30					4 026	923	1 784	409	(e)
2011	0.3	0.44	30					4 026	1 252	1 784	555	(e)
2011	0.4	0.60	30					4 026	1 527	1 784	677	(e)
2019	0.2	0.2899	28	9 330	2 138	5 089	1 166					(f)
2019	0.3	0.3863	28	9 330	2 608	5 089	1 423					(f)
2019	0.4	0.5537	28	9 330	3 330	5 089	1 816					(f)

5. STATUS OF THE STOCKS

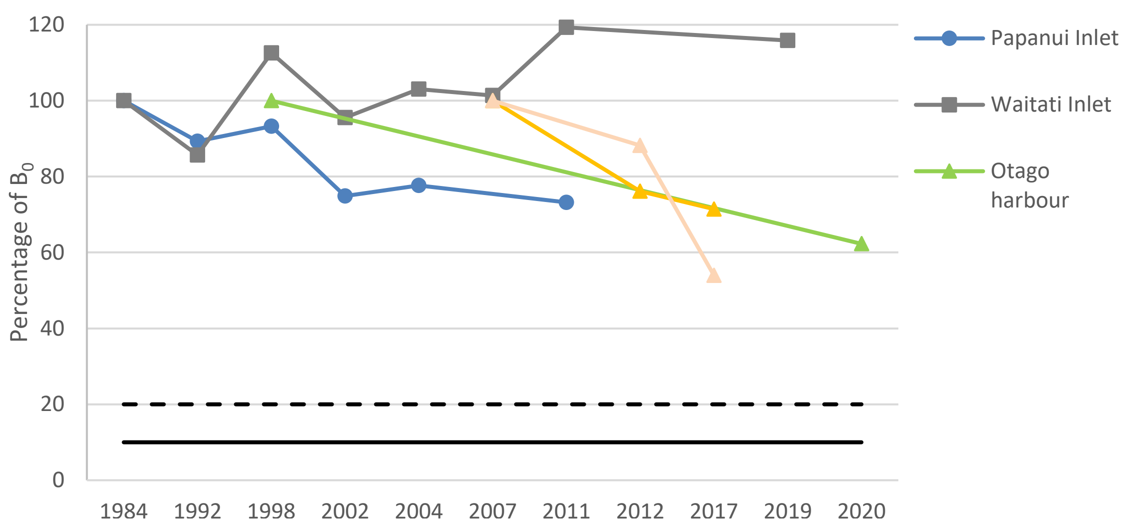
Stock structure assumptions

Each inlet is assessed separately.

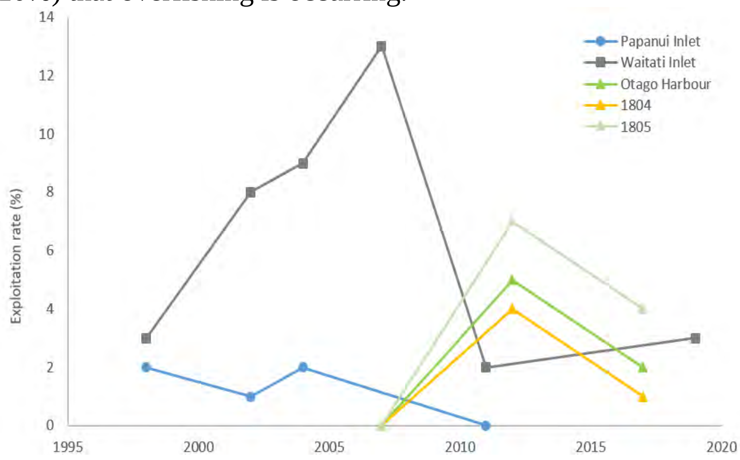
- **COC 3**

Stock Status	
Year of Most Recent Assessment	2020 - Otago harbour
Assessment Runs Presented	Survey biomass estimate for ≥ 19 mm shell length
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: Not defined
Status in relation to Target	Likely (> 60%) to be at or above the target
Status in relation to Limits	For Papanui Inlet, Waitati Inlet, Otago harbour and each sanitation area (1804 and 1805): Very Unlikely (< 10%) to be below both soft and hard limits
Status in relation to overfishing	Exploitation rate has never exceeded 13% at any of the harvested sites. It is Very Unlikely (< 10%) that overfishing is occurring.

Historical Stock Status Trajectory and Current Status



Biomass as a proportion of *B_0*. For Papanui Inlet, Waitati Inlet, and the two sanitation areas (1804 and 1805); this is estimated for the biomass ≥ 19 mm. For Otago harbour, the estimates are for biomass ≥ 30 mm. For the 2020 Otago harbour survey, the biomass of the additional bed (Te Rauone, 69 t) was removed so the 1998 and 2020 surveys would be comparable. Virgin biomass was assumed as the biomass estimated during the first survey for each area. Note: No catch was taken from Papanui Inlet between 2006–07 and 2016-17.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The biomass at Waitati Inlet has been stable or increasing and has never decreased below 85% B_0. At Papanui Inlet, biomass generally decreased to approximately 70% of B_0 in 2004 but little commercial catch has come out of this inlet since. In Otago Harbour, recruited biomass has shown a declining trend in the commercially fished Sanitation bed 1804 (54% decline from 1999 to 2020), whereas in Sanitation bed 1805 it has been variable but stable from 1999 to 2020. The three other non-commercial beds in Otago Harbour showed declines of between 26% –65% between 1999 and 2020.
Recent Trend in Fishing Intensity or Proxy	Exploitation rate has never exceeded 13% at any of the harvested sites, and even the 13% rate was a single-year event that subsequently declined considerably. It is Very Unlikely (< 10%) that overfishing is occurring.  **Exploitation rate (%) as calculated by commercial landings divided by biomass (≥30 mm) from Papanui Inlet (whole inlet), Waitati Inlet (whole inlet) and Otago Harbour Sanitation areas (beds 1804 and 1805 combined).**
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Fishing at recent levels is Very Unlikely (< 10%) to cause declines below soft or hard limits
Probability of Current Catch or TACC causing Overfishing to continue or to commence	-

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Assessment Dates	Latest assessment: 2020	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs (rank)	- Abundance - Length frequency	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
For Papanui Inlet, the classification of this area changed from Conditionally Approved to Restricted on 9 June 2009. The Restricted classification allows for harvesting to take place under the following conditions: by a special permit as required for relaying, for depuration or for harvest treatment.

Fishery Interactions
Harvesting had a severe but short lived impact on macroinfaunal community structure and no change in sediment structure was found after harvesting (Irwin 2004). Overall, adverse effects from harvesting at the current level appear to be no more than minor and of a transitory nature (Stewart 2017).

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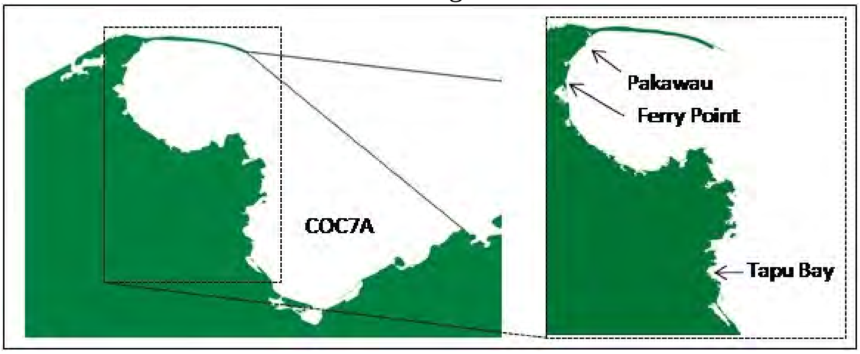
COCKLES (COC 7A) Tasman and Golden Bays

(*Austrovenus stutchburyi*)
Tuangi



1. FISHERY SUMMARY

COC 7A was introduced into the Quota Management System in October 2002 with a TAC of 1 510 t; comprising a customary allowance of 25 t, a recreational allowance of 85 t, an allowance for other fishing related mortality of 10 t, and a TACC of 1 390 t. These limits have remained unchanged since.

1.1 Commercial fisheries

Commercial harvesting at Pakawau Beach in Golden Bay began in 1984, but with significant landings taken only since 1986. Harvesting at Pakawau Beach has occurred every year since 1984. Cockles have also been taken commercially from Tapu Bay-Riwaka (in Tasman Bay) since 1992–93, and Ferry Point (in Golden Bay) since 1998–99. Catch statistics (Table 1) derived from company records and QMS returns reveal a peak in recorded landings in 1997-98 to 2003-04 (average of 496 t landed annually). After 2004 landings declined, and in 2018-19 one of the lowest records since the beginning of the time series was recorded (187 t). All commercial landings have been taken by mechanical harvester. Historical landings and TACC for this stock are depicted in Figure 1.

Table 1: Reported landings (t) of cockles from all commercially harvested areas in COC 7A/7B. Landings from 1983–84 to 1991–92 are based on company records. [Continued next page].

Fishing Year	Total Landings	TACC
1983–84	2	225
1984–85	38	225
1985–86	174	225
1986–87	230	225
1987–88	224	225
1988–89	265	300
1989–90	368	300
1990–91	535	300
1991–92	298	300
1992–93	300	336
1993–94	440	336
1994–95	326	336
1995–96	329	336
1996–97	325	336
1997–98	513	949
1998–99	552	1 130
1999–00	752	1 130
2000–01	731	1 134
2001–02	556	1 134
2002–03	569	1 390
2003–04	553	1 390
2004–05	428	1 390
2005–06	460	1 390
2006–07	337	1 390
2007–08	237	1 390
2008–09	307	1 390
2009–10	301	1 390
2010–11	348	1 390
2011–12	220	1 390
2012–13	269	1 390
2013–14	290	1 390
2014–15	263	1 390
2015–16	263	1 390

Table 1 [Continued]

Fishing Year	Total Landings	TACC
2016–17	238	1 390
2017–18	254	1 390
2018–19	187	1 390

Each of the three areas has a specific catch limit, within the COC7A TACC, which has varied over time:

- At Pakawau Beach, the fishery operated up to October 1988 under a special permit constraining annual landings to 225 t. From 1988–89 to 1997–98, the fishery operated under a commercial permit allowing an annual catch of 300 t. In 1997–98, the fishery was re-assessed and a catch limit of 913 t was set based on a *CAY* harvest strategy. This level of harvest was changed to 760 t from the 1998–99 fishing year and then 764 t for the 2000–01 fishing year. The harvest is taken from an area of about 500 ha.
- The Ferry Point fishery, initiated in 1998–99, has an annual allowable catch of 334 t based on an *MCY* harvest strategy. The harvested area is about 40 ha. Reportedly, the area has not been fished since 2004.
- The Tapu Bay-Riwaka fishery, which was developed in 1990–91, has operated under a commercial permit limiting catches to 36 t annually. This fishery has been only lightly harvested owing largely to water quality issues and the area from which catches have been taken is probably less than 100 ha.

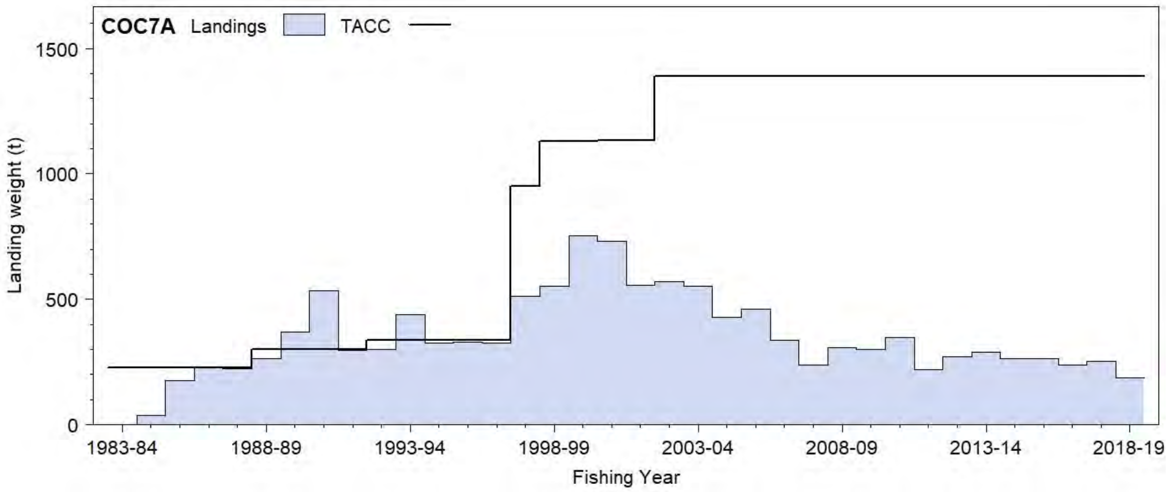


Figure 1: Total reported landings and TACC for COC 7A (Nelson Bays) since 1983-84.

1.2 Recreational fisheries

Cockles are taken by recreational fishers, generally using hand digging. The catch limit is currently 150 cockles per person per day. Relatively large cockles (i.e., shell length over 30 mm) are generally preferred. Specific areas for recreational fishing are set aside from the commercial fishery by regulation and these include the area north of Ferry Point opposite Totara Ave and the area of Tapu Bay itself north of the fishery.

No estimates of recreational harvest of cockles from COC 7A are available. History of the estimates of recreational catch and their reliability is provided in the introductory COC Working Group report. Estimated numbers of cockles harvested by recreational fishers in QMA 7 are provided in Table 2. The estimate for 2011–12 is lower than expected, potentially because of the number of toxic algal blooms in that year.

Table 2: Estimated numbers of cockles harvested by recreational fishers in QMA 7, and the corresponding harvest tonnage based on an assumed mean weight of 25 g. Figures were extracted from telephone-diary survey in 1993–94, 1996 and 1999-00, and from the National Panel Survey in 2011–12 and 2017-18.

Survey	Numbers	CV	Tonnes	Reference
1993–94	166 000	-	4	Teirney et al (1997)
1996	325 000	-	8	Bradford (1998)
1999-00	499 000	-	12.5	Boyd & Reilly (2002)
2011–12	78 751	0.45	2	Wynne-Jones et al (2014)
2017–18	23 176	0.41	0.6	Wynne-Jones et al (2019)

1.3 Customary non-commercial fisheries

Cockles are an important Maori traditional food, but no quantitative information on the level of customary take in COC 7A/7B is available. However, Kaitiaki are now in place in many areas and estimates of customary harvest can be expected to improve.

1.4 Illegal catch

No quantitative information on the level of illegal catch is available.

1.5 Other sources of mortality

The extent of any other sources of mortality is unknown. Incidences of unexplained large-scale die-off in localised areas have been noted (e.g., at Pakawau Beach and Ferry Point in 1999). Mortality of unrecruited cockles during the mechanical harvesting process was found to be very low (Bull 1984), and disturbance and mortality of other invertebrates in the harvested areas is slight (Wilson et al 1988).

For further information on other sources of mortality, please refer to the introductory COC Working Group report.

2. BIOLOGY

All references to "shell length" in this report refer to the maximum linear dimension of the shell (in an anterior-posterior axis). General cockle biology has been summarised in the Cockle Introduction Working Group report. Some aspects of biology with particular relevance to COC 7A follow.

Estimates of growth and mortality have been made for cockles from Pakawau Beach (Osborne 1992, 1999, 2010), and the two early studies are summarised in Table 3. The 1992 investigation used a Walford plot of tag recapture data (Bull 1984), and measured growth after about 18 months on translocated cockles, to produce the growth parameters. A MIX analysis of the scaled length-frequency distribution from the 1992 survey enabled calculation of the proportional reduction of the 4+ and 5+ age classes to produce estimates of instantaneous natural mortality, *M* (after removal of estimated fishing mortality, *F*).

The 1999 investigation used a MIX analysis of length-frequency data from two strata in comparable surveys in 1997, 1998 and 1999 to estimate mean lengths (and proportion in the population) of the first 8 year classes. Von Bertalanffy parameters were estimated for each survey. Mean natural mortality rates were estimated (for age classes 4–7) between 1997 and 1998, and 1998 and 1999.

Table 3: Estimates of biological parameters.

Population & years			Estimate	Source
1. Natural mortality (*M*)				
Pakawau Beach (1992)			0.45 for 4+; 0.30 for 5+	Osborne (1992, 1999)
Pakawau Beach (1998)			0.4	Osborne (1999)
Pakawau Beach (1999)			0.52	Osborne (1999)
2. Weight = a (shell length)^b (weight in g, shell length in mm)				
		a	b	
Pakawau Beach (1992)		0.000017	3.78	Osborne (1992)
Ferry Point (1996)		0.00020	3.153	Forrest & Asher (1997)
Tapu Bay-Riwaka (1991)		0.000150	3.249	Stark & Asher (1991)
3. von Bertalanffy growth parameters				
	K	t_0	*L*	
Pakawau Beach (1984–92)	0.36	0.3	49	Osborne (1992)
Pakawau Beach (1997)	0.38	0.68	48.3	Osborne (1999)
Pakawau Beach (1998)	0.4	0.68	47.4	Osborne (1999)
Pakawau Beach (1999)	0.41	0.66	47	Osborne (1999)

It was acknowledged that none of the MIX analyses converged, but the results presented were the best available fits (Osborne 1992, 1999). However, all four analyses produced very similar von Bertalanffy parameters. There is a trend of a reducing L_∞ and increasing *K* over the period 1992–1999, which might be expected as a result of fishing. In 2009 growth was modelled by the equation y = 11.452Ln(x) +

16.425, where y is shell width and x is age in years, this equation is only applicable to individuals 23–55 mm in shell width.

3. STOCKS AND AREAS

Little is known of the stock boundaries of cockles. The planktonic larval phase of this shellfish has a duration of about three weeks, so dispersal of larvae to and from a particular site could be considerable. Cockles are known to be abundant and widely distributed throughout Golden and Tasman Bays, and although nothing is known about larval dispersion patterns, cockles in these areas are likely to comprise a single stock. However, in the absence of any detailed information on stocks, the three currently fished sites in COC 7A are all managed as one stock.

4. STOCK ASSESSMENT

This report summarizes estimates of absolute biomass and yields for exploited and unexploited cockle populations in Tasman and Golden Bays. Stock assessments have been conducted using absolute biomass surveys, yield-per-recruit analyses, Methods 1 and 2 for estimating *MCY*, and Method 1 for estimating *CAY* (Ministry of Fisheries 2010).

Recruited cockles are considered to be those with a shell length of 30 mm or greater. This is the minimum size of cockles generally retained by the mechanical harvesters used in the COC 7A fishery. Where possible, estimates of yields from surveys are based on recruited biomass not occurring in areas of eel grass (*Zostera*), as the disturbance of these *Zostera* beds by mechanical harvesters has detrimental effects on intertidal ecology.

4.1 Estimates of fishery parameters and abundance

None available.

4.2 Biomass estimates

Biomass estimates from surveys are available for the three commercially fished areas and three other sites.

On Pakawau Beach, the surveys done in 1992 and 1997–2008 used a stratified random approach (Table 4, Figure 2). An additional southern stratum was added to the survey area in 1997 after legal definition of the fishery area, accounting for the greater survey area relative to 1992. The surveys in 1984 and 1988 covered smaller areas still. The survey area was reduced further in 2008 and 2014 to remove areas that were observed to be consistently unsuitable habitat for cockles or cockle harvesting (sand banks, soft mud and *Zostera* areas). The eight comparable surveys show total and recruited biomass to have fluctuated with no consistent trend, but the lowest value in this time series was recorded in 2014. In addition to recruited biomass (>30mm size), and vulnerable biomass (outside *Zostera* beds), reference biomass levels used for MCY calculation this year and in previous years are shown in Table 4.

Estimates of biomass are available for Tapu Bay-Riwaka in 1991 using a fixed transect approach (Stark & Asher 1991) and Ferry Point in 1996 using a stratified random approach (Forrest & Asher 1997). Both these surveys were conducted about two years prior to the commencement of commercial harvesting in those areas. The cockle resource on three other beaches in Golden Bay was assessed using stratified random surveys in 1993 (Osborne & Seager 1994). Since then both Riwaka and Ferry Point have been surveyed in 2004 and 2008 using stratified random survey designs. Results from all these surveys are listed in Table 5 and shown in Figure 2. The biomass at Riwaka and Ferry Point have generally decreased over time.

Table 4: Estimates of biomass with 95% confidence intervals where available for Pakawau Beach. Values are recruited (>30mm) and vulnerable biomass (not occurring in *Zostera* beds) and reference levels of biomass used for calculating MCY (B_0 virgin biomass, B_{av} average biomass). In 2014 vulnerable biomass was calculated differently (see Osborne 2014 for details).

	Recruited biomass				Vulnerable biomass				Assessed reference levels		
	Area	tonnes	95 % CI	CV	Area	tonnes	95 % CI	CV	B_0	B_{av}	95 % CI
1984	326	4604	1562	-	-	-	-	-	-	-	-
1988	510	5640	-	-	-	-	-	-	-	-	-
1992	588	6784	929			3586	612	8.7	3293	-	-
1997	642	7796	1628	10.7	275	3723	1331	18.2	-	3655	134
1998	642	6768	1221	9.0	317	3412	827	12.4	-	3574	176
1999	642	7502	1294	8.8	246	3058	727	12.1	-	3445	282
2000	642	7128	1237	8.9	266	2139	555	13.2	-	3184	556
2001	642	9117	1519	8.5	254	3111	712	11.7	-	3172	455
2004	642	9421	1195	6.5	307	5747	909	8.1	-	3539	817
2008	407	8285	1599	9.8	299	4954	1025	10.6	-	3716	788
2014	358	3363	561	8.5	358	3363	561	8.5	-	5686	1137

Table 5: Estimates of biomass (*t*) with 95% confidence intervals (CI) where available, and mean density (kg/m^{-2}) for cockles at various sites in Golden and Tasman Bays. Where possible, values are given for the total and recruited (≥ 30 mm) populations. *n* = number of samples in the survey.

Site	Date	Area	*n*	Total biomass			Recruited biomass		
		(ha)		*t*	CI	kg/m^2	*t*	CI	kg/m^2
Tapu Bay-Riwaka	Mar-91	306	321	~3 900	-	1.28	-	-	-
Riwaka	Feb-04	122.7	144	1 423	269	1.16	1 076	235.6	0.88
Riwaka	Mar-08	103	82	1475	257	1.44	939	178	0.9
Riwaka (excl. Tapu Bay)*	Mar-91	-	-	-	-	-	1 880	450	-
Ferry Point	Dec-96	40	552	2 617	190	5.99	2 442	191	5.6
Ferry Point	Feb-04	40	126	646	99.8	1.63	443	79	1.12
Ferry Point	Jan-08	28.2	75	662	112	2.35	470	83	1.7
Collingwood Beach	Mar-93	176	70	334	148	0.19	292	139	0.17
Takaka Beach	Mar-93	338	107	1 850	671	0.55	796	395	0.24
Rangihaeata Beach	Mar-93	197	75	473	345	0.24	438	320	0.22

* Recalculated by Breen (1996) from data in Stark & Asher (1991).

Surveys reporting on cockle abundance have also been produced for Motupipi, Golden Bay, in June 1995 (transect survey, 50 ha, 30 samples, mean density of 87 cockles per m^2, no sizes or weights recorded), and at various sites in the Marlborough Sounds in August 1986 (diver survey below mean low water only, 9 sites, main densities in Kenepuru and inner Pelorus Sounds).

Absolute virgin biomass, B_0, are assumed to be equal to estimated biomass of cockles 30 mm or over shell length from surveys conducted before, or in the early stages of, any commercial fishing. These are listed above in Tables 4 and 5. Absolute current biomass can be estimated similarly from current surveys.

The biomass that will support the maximum sustainable yield (B_{MSY}) is not known for any of the areas fished in COC 7A.

4.3 Yield estimates and projections

Estimates of *MCY* have been made for populations of cockles in various areas, and at various times, using the equation $MCY = 0.25 * F_{ref} * B_0$ (Method 1), where F_{ref} is either $F_{0.1}$ or F_{max}. This method applies to new fisheries, or to those with only very low past levels of exploitation. The value of F_{ref} is dependent on *M*, so owing to the uncertainty of *M* a range of *MCY* estimates have been given for each stock (Table 6). For all estimates in Table 6, B_0 was taken as recruited biomass available for fishing (i.e. not in *Zostera* beds) in the survey area.

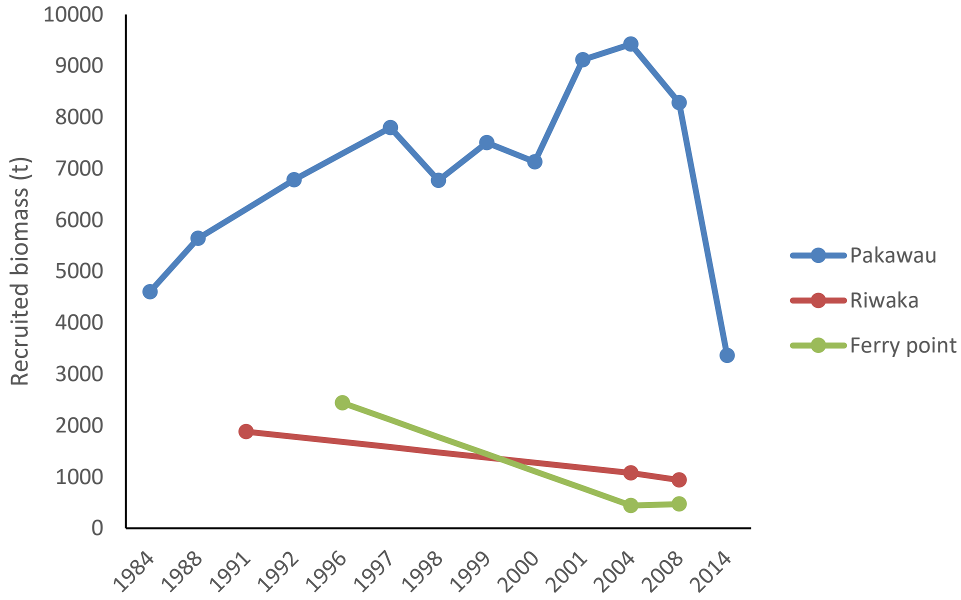


Figure 2: Recruited biomass (≥ 30 mm shell length) over time. Notably, the area surveyed over time has changed (see Tables 4 and 5) and decreased at the last time of survey (compared to previous occasions) at all three sites.

Estimates of *MCY* for Pakawau Beach have also been produced from $MCY = 0.5 * F_{REF} * B_{AV}$ (Method 2), using $F_{0.1}$, and with B_{AV} being the average of the available recruited biomass from the previous comparable surveys. For a range of *M* values, the latest estimates of *MCY* are as follows:

M	0.2	0.3	0.4
MCY	665	996	1 312

Table 6: Estimates of *MCY* (t, using 0.25 * F_{REF} * B_0) for various cockle stocks in Tasman and Golden Bays, assuming a range of values for *M*.

Site	Date	F_{ref}				*M*
			0.2	0.3	0.4	0.5
Pakawau Beach	1992	$F_{0.1}$	230	324	434	554
Pakawau Beach	1997	$F_{0.1}$	397	559	751	957
Pakawau Beach	2001	F_{MAX}	1 182	2 418	4 658	
Pakawau Beach	2004	$F_{0.1}$	482	683	924	
Pakawau Beach	2008	$F_{0.1}$	340	481	651	
Pakawau Beach	2014	$F_{0.1}$	665	996	1 312	
Ferry Point	1996	$F_{0.1}$	127	170	223	284
Ferry Point	1996	F_{MAX}	264	453	789	1 493
Ferry Point	2004	$F_{0.1}$	122	173	234	
Ferry Point	2008	$F_{0.1}$	111	157	212	
Riwaka	1991	$F_{0.1}$	167	224	286	-
Riwaka	2004	$F_{0.1}$	81	115	156	
Riwaka	2008	$F_{0.1}$	118	167	226	
Collingwood Beach	1993	$F_{0.1}$	20	28	37	48
Takaka Beach	1993	$F_{0.1}$	53	74	100	127
Rangihaeata Beach	1993	$F_{0.1}$	23	32	43	55

The level of risk of harvesting the populations at the estimated *MCY* levels cannot be determined for any of the surveyed areas. However, yield estimates are substantially higher when based on F_{MAX} than on $F_{0.1}$, so risk would be greater at *MCY*s based on F_{MAX}.

Estimates of *CAY* have been made in the past for cockle stocks at Pakawau Beach, Ferry Point and Riwaka, using $CAY = F_{REF}/(F_{REF} + M) * (1 - e^{-(FREF + M)}) * B_{BEG}$ (Method 1), where beginning of season biomass (B_{BEG}) is current recruited biomass available to the fishery, and F_{REF} is either $F_{0.1}$ or F_{max}. Estimates of current biomass that allow updated calculations are available in 2008 for Pakawau Beach, Ferry Point and Tapu Bay (Riwaka). The most recent estimates of *CAY* available for all stocks are listed in Table 7.

4.4 Other yield estimates and stock assessment results

$F_{0.1}$ and *CAY* were estimated from a yield per recruit (YPR) analysis using the age and length-weight parameters for Pakawau Beach cockles from Osborne (1992), and assuming size at recruitment to the fishery of either 30 or 35 mm shell length. A range of *M* values was used to produce the latest estimates in Table 8 (Osborne 2014).

Table 7: Estimates of *CAY* (t) for various cockle stocks in Tasman and Golden Bays, assuming a range of values for *M*.

Site	Date	F_{REF}				*M*
			0.2	0.3	0.4	0.5
Pakawau Beach	2001	$F_{0.1}$	778	996	1 210	1 396
Pakawau Beach #	2001	$F_{0.1}$	1 964	2 514	3 053	3 522
Pakawau Beach	2004	$F_{0.1}$	1 202	1 555	1 910	
Pakawau Beach	2008	$F_{0.1}$	1 161	1 501	1 845	
Pakawau Beach	2014	$F_{0.1}$	638	844	1 040	
Ferry Point	1996	$F_{0.1}$	407	501	600	696
Ferry Point	2004	$F_{0.1}$	69	89	109	
Ferry Point	2008	$F_{0.1}$	88	114	140	
Riwaka	1993	$F_{0.1}$	507	615	708	
Riwaka	2004	$F_{0.1}$	138	179	220	
Riwaka	2008	$F_{0.1}$	1 161	1 501	1 845	

Calculations using total recruited biomass, rather than available recruited biomass.

Table 8: Latest estimates of $F_{0.1}$ from a yield per recruit analysis and CAY at different levels of minimum size at harvest (MSH) and natural mortality (M) (Osborne 2014).

					M
	MSH	B_{beg}	0.20	0.30	0.40
$F_{0.1}$	30		0.23	0.34	0.46
CAY		3363	638	844	1040
$F_{0.1}$	35		0.28	0.40	0.54
CAY		2409	541	696	838
$F_{0.1}$	37		0.31	0.43	0.56
CAY		2026	489	617	732

4.5 Other factors

The areas of Golden Bay and Tasman Bay currently commercially fished for cockles are very small with respect to the total resource. Recruitment overfishing is unlikely owing to the extent of the resource protected from the fishery in *Zostera* beds, in sub-tidal areas, and in the protected areas adjacent to Farewell Spit and in other areas of Golden Bay. Cockle larvae are planktonic for about three weeks, so areas like Golden Bay and Tasman Bay probably constitute single larval pools.

Consequently, fisheries in relatively small areas (like Pakawau Beach) are likely to have little effect on recruitment. It is noted, however, that recruitment of juvenile cockles can be reduced by the removal of a large proportion of adult cockles from the area (*i.e.*, successful settlement occurs only in areas containing a population of adult cockles).

It is also likely that growth and mortality of cockles are density-dependent. A reduction in density due to fishing could enhance the growth and survival of remaining cockles.

Because cockles begin to spawn at a shell length of about 18 mm, and the larval pools in Tasman and Golden Bays are probably massive and derive from a wide area (most of which is closed to commercial fishing), there is a low risk of recruitment overfishing at any of the exploited sites.

5. STATUS OF THE STOCKS

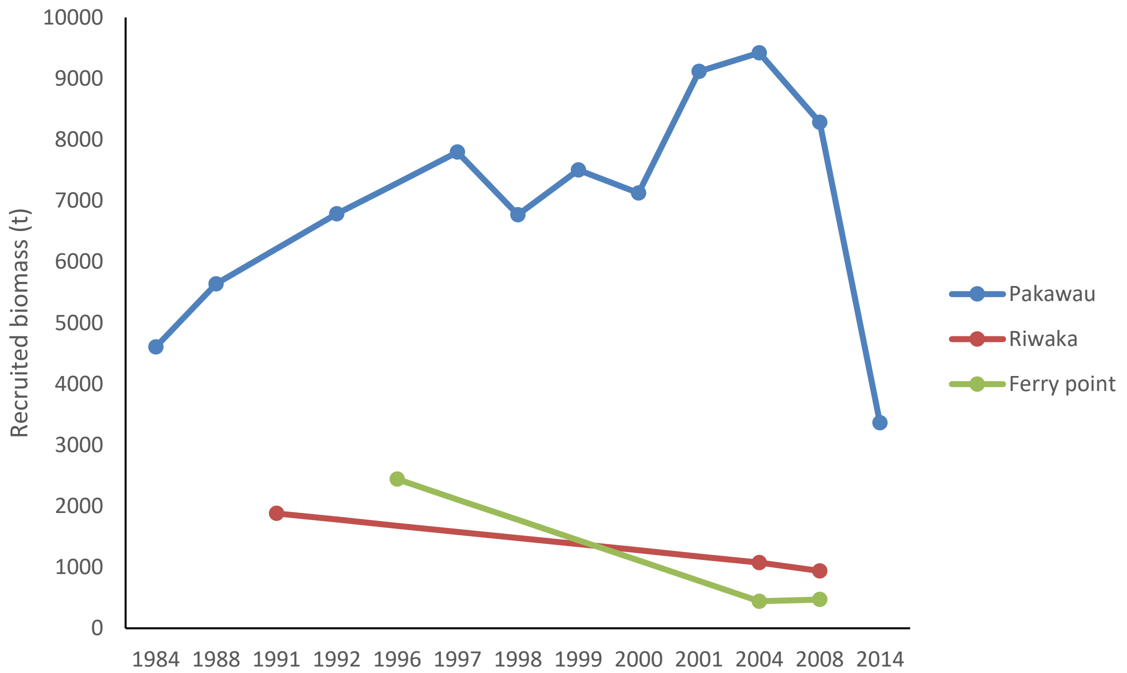
Stock structure assumptions

Little is known of the stock boundaries of cockles. Given differences in growth and mortality within and between different beds and in the absence of more detailed knowledge regarding larval connectivity, this commercial fishery area is managed as a discrete population.

COC 7A

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Survey biomass estimates for ≥ 30 mm shell length
Reference Points	Target(s): Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: - Undefined
Status in relation to Target	About as Likely as Not (40–60%) to be at or above the target (except for local depletion is some bays)
Status in relation to Limits	Unlikely (< 40%) to be below the soft limit and Very Unlikely (< 10%) to be below the hard limit
Status in relation to Overfishing	Overfishing is Very Unlikely (<10%) to be occurring

Historical Stock Status Trajectory and Current Status



Recruited biomass (≥ 30 mm shell length) over time. Notably, the area surveyed over time has changed (see Tables 4 and 5) and decreased at the last time of survey (compared to previous occasions) at all three sites.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The recruited biomass estimates of cockles from Pakawau beach have shown a general trend of increase until 2004, with the lowest value in 1992 (5299 t) and the highest value in 2004 (8803 t); followed by a decline to historically low levels in 2014 (3363 t). The Ferry Point recruited biomass estimates declined from 2442 t in 1996 to 443 t and 470 t in 2004 and 2008, respectively. Riwaka total biomass estimates decreased from 1991 (1880 t) to 2008 (939 t). Notably, the area surveyed has changed over time and decreased at the last survey (compared to previous surveys) at all three sites.
Recent Trend in Fishing Mortality or Proxy	Landings since 2007–08 have fluctuated without trend between 187 and 348 t.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Fishing at present levels is Very Unlikely (< 10%) to cause declines below the soft or hard limits.
Probability of Current Catch or TACC causing Overfishing	Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2: Partial quantitative stock assessment	
Assessment Method	Absolute biomass estimates from quadrant surveys	
Assessment Dates	Latest assessment: 2014	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Abundance - Length frequency	1 – High Quality 1 – High Quality
Data not used (rank)		
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Water quality issues have influenced the amount of time when cockles can be harvested from Ferry Point in recent years.

Fishery Interactions
Interactions with other species are currently being characterised.

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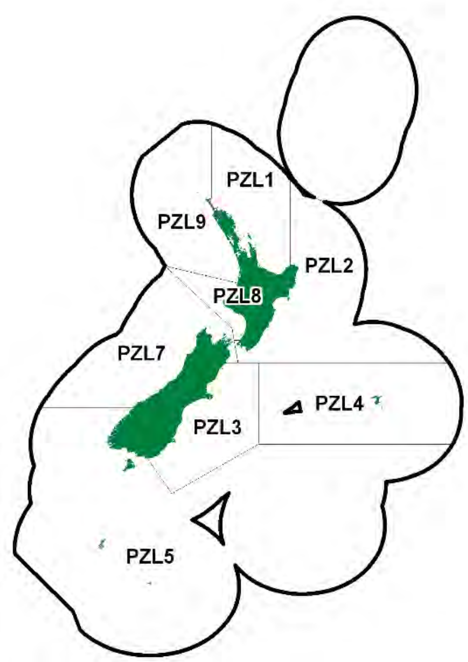
DEEPWATER (KING) CLAM (PZL)

(*Panopea zelandica*)
Hohehohe



1. FISHERY SUMMARY

Deepwater clams (*Panopea zelandica*), commonly referred to as geoducs, geoducks, or New Zealand king clams, were introduced into the Quota Management System on 1 October 2006 with a total TAC of 40.5 t, consisting of 31.5 t TACC and a 9 t allowance for other sources of mortality (Table 1). No changes have occurred to the TAC since. The fishing year is from 1 October to 30 September and commercial catches are measured in greenweight. Deepwater clams are harvested by divers using underwater breathing apparatus and a hydraulic jet.

Table 1: Current TAC, TACC, and allowances for other sources of mortality for *Panopea zelandica.*

Fishstock	TAC (t)	TACC (t)	Other sources of mortality
PZL 1	1.5	1.2	0.3
PZL 2	1.5	1.2	0.3
PZL 3	1.5	1.2	0.3
PZL 4	1.5	1.2	0.3
PZL 5	1.5	1.2	0.3
PZL 7	30.0	23.1	6.9
PZL 8	1.5	1.2	0.3
PZL 9	1.5	1.2	0.3
Total	40.5	31.5	9.0

1.1 Commercial fisheries

The largest landings since 1989 were reported between 1989 and 1992 (Table 2), almost all taken in the Nelson-Marlborough region under a special permit for investigative research. Targeted fishing was also carried out under a special permit in PZL 7 between 2004 and 2005. Rare catches have also been made by trawlers. The largest catch since 1992 occurred in 2011–12 (10.885 t) and was mainly taken from the Nelson-Marlborough region (Table 2). In 2014, a new special permit was granted for further investigative research in Golden Bay.

1.2 Recreational fisheries

There are no estimates of recreational take for this surf clam. Recreational take is likely to be very small or non-existent.

1.3 Customary fisheries

This clam is harvested for customary use when washed ashore after storms but there are no estimates of this use of this clam. Customary take is likely to be very small or non-existent.

Table 2: TACCs and reported landings (t) of deepwater clam by Fishstock from 1989–90 to present, taken from CELR and CLR data. There have never been any reported landings in PZL 2, 4, 5, 8, or 9.

	PZL 1		PZL 3		PZL 7		Total	
Fishing year	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1989–90	0.315	–	0	–	95.232	–	95.547	–
1990–91	0	–	0	–	29.293	–	29.293	–
1991–92	0	–	0.725	–	31.394	–	32.119	–
1992–93	0	–	0.053	–	0	–	0.053	–
1993–94	0	–	0	–	0	–	0	–
1994–95	0	–	0	–	0	–	0	–
1995–96	0	–	0	–	0	–	0	–
1996–97	0	–	0	–	0	–	0	–
1997–98	0	–	0	–	0	–	0	–
1998–99	0	–	0	–	0	–	0	–
1999–00	0	–	0	–	0	–	0	–
2000–01	0	–	0.146	–	0	–	0.146	–
2001–02	0.003	–	0.068	–	0	–	0.071	–
2002–03	0	–	0.001	–	0	–	0.001	–
2003–04	0	–	0	–	1.444	–	1.444	–
2004–05	0	–	0	–	2.944	–	2.944	–
2005–06	0	–	0	–	0	–	0	–
2006–07	0	1.2	0	1.2	0	23.1	0	31.5
2007–08	0	1.2	0.132	1.2	0.320	23.1	0.450	31.5
2008–09	0	1.2	0.016	1.2	5.100	23.1	5.116	31.5
2009–10	0	1.2	0	1.2	4.578	23.1	4.578	31.5
2010–11	0	1.2	0.076	1.2	7.880	23.1	7.956	31.5
2011–12	0	1.2	0.036	1.2	10.849	23.1	10.885	31.5
2012–13	0	1.2	0	1.2	1.746	23.1	1.746	31.5
2013–14	0	1.2	0	1.2	6.072	23.1	6.072	31.5
2014–15	0	1.2	0.003	1.2	3.927	23.1	3.93	31.5
2015–16	0	1.2	0	1.2	4.686	23.1	4.686	31.5
2016–17	0	1.2	0	1.2	3.260	23.1	3.260	31.5
2017–18	0	1.2	0	1.2	6.720	23.1	6.720	31.5
2018–19	0	1.2	0	1.2	6.294	23.1	6.294	31.5

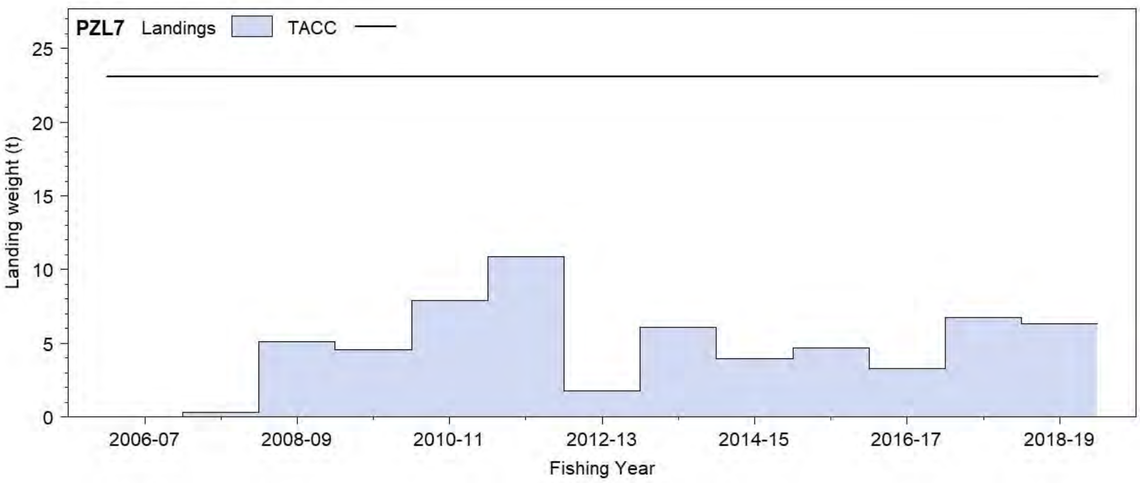


Figure 1: Reported commercial landings and TACCs for the main PZL stock: PZL 7 (Challenger).

1.4 Illegal catch

There is no documented illegal catch of this clam.

1.5 Other sources of mortality

There is little information on other sources of mortality, although the clam has on rare occasions been captured during trawling operations. Adults show poor reburial after being dug out (Gribben & Creese 2005).

2. BIOLOGY

There are two similar *Panopea* species in New Zealand: *P. zelandica*, also referred as geoduc, geoduck, and king clam; and *P. smithae*. Both are endemic and occur around the North, South, and Stewart islands. *P. smithae* has also been reported from the Chatham Islands. *P. smithae* is reported under the Fishstock code PSM and is not included in this Working Group report. Their distributions overlap, but *P. zelandica* occurs mainly in shallow waters (5–25 m) in sand and mud off sandy ocean beaches, whereas *P. smithae* lives mainly at greater depths (110–130 m) on coarse shell bottoms and is also thought to burrow deeper into the substrate. In samples of commercial and exploratory catches, *P. zelandica* is more abundant than *P. smithae*, and it comprises virtually all of the catch.

Deepwater clams are broadcast spawners with separate sexes. Protandric development (where an organism begins life as a male and then becomes a female) is considered likely for a proportion of the population (Gribben & Creese 2003). Fifty percent sexual maturity was calculated at 55 and 57 mm length for populations in Wellington and on the Coromandel Peninsula, respectively. Samples taken from three locations between the Coromandel Peninsula and Nelson showed spawning between spring and late summer (Gribben et al 2004a). Spawning may be controlled by temperature because it occurred at both the Coromandel and Wellington sites when water temperature reached approximately 15 °C (Gribben et al 2004a). The larval life is thought to be about two to three weeks (Gribben & Hay 2003), and there is evidence of significant recruitment variation between years.

The oldest *P. zelandica* based on annual ring counts in Golden Bay, Shelly Bay (Wellington), and Kennedy Bay (Coromandel) were 34, 34, and 85 years respectively (Breen 1991, Gribben & Creese 2005); ring counts were validated from Shelly Bay only. Growth in shell length appeared to be rapid for the first 10–12 years in these populations and total weight increased rapidly until at least 12–13 years of age. Differences in growth rates were seen between the Kennedy Bay and Shelly Bay populations: estimates of K varied between 0.16 and 0.29, t_0 between 1.67 and 3.8, and L_∞ between 103.6 mm and 116.5 mm, respectively (Breen 1991, Gribben & Creese 2005)[1]. The most recent estimate of K in Golden Bay was 0.11 (SE 0.027), L_∞ was 127.5 mm (SE 4.8 mm), and age-at-length-zero was -4.24 years (SE 2.15) (Slater et al 2017).

Estimates of M (instantaneous natural mortality) from catch curve analysis, estimates of maximum age, and the Chapman-Robson estimator from Kennedy Bay and Shelly Bay populations were all between 0.02 and 0.12 (Gribben & Creese 2005). The estimate by Breen (1991) for Golden Bay was 0.15, but in modeling this parameter was varied between 0.1 and 0.2.

3. STOCKS AND AREAS

For management purposes stock boundaries are based on FMAs, however, there is little information on stock structure, recruitment patterns, or other biological characteristics to determine fishstock boundaries.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

Estimates of total mortality (Z) for deepwater clam using Millar's method (2015) in a small part of Golden Bay (PZL 7) were obtained from a biomass survey conducted in 2014 (Slater et al 2017). In this analysis the first 8 age classes were removed because there is age-based selectivity bias. Estimated annual mortality was 0.189 (SE 0.042). The estimated instantaneous mortality Z (inclusive of both natural mortality and fishing mortality) was 0.209 (SE 0.047). This Z was similar to the upper value of instantaneous mortality M (0.20) estimated by Breen (1991) and higher than the M estimated for Kennedy Bay (0.05–0.07) and Shelly Bay (0.02–0.04) (Gribben & Creese 2005); the key difference being that the 2017 Z estimates were determined from both natural causes and fishing. The catch-curve analyses used by Breen (1991) and

[1] No confidence intervals were available for these estimates.

Gribben & Creese (2005) operate under two assumptions: firstly, recruitment rates are approximately constant during the time that aged deepwater clam were recruited; and secondly, mortality is similar for all age classes. Gribben & Creese (2005) concluded that catch-curve analyses may not be appropriate for estimating natural mortality in deepwater clam, and Millar (2015) suggested that general linear mixed modelling (GLMM) is superior in predicting mortality, due to the inclusion of recruitment involving annual variation and the substantial variability known to exist in population dynamics (Myers et al 1995).

The size and age data have been used for comparison with the age-weight growth curve and natural mortality values used in the study of deepwater clam sustainability by Breen (1994). When estimating recruitment, Breen (1994) used animals 8 years or older for recruited biomass, as did Slater et al (2017) because there appeared to be an age-based selectivity bias. The maximum realistic exploitation rate of 0.35 was based on Goodwin's (1977) show-factor and the disturbances created by the fishing method causing nearby individuals to retract their siphons. The upper bound of the 95% confidence interval for show-factor was 31%.

Slater et al (2017) fitted a von Bertalanffy growth curve to the aged individuals and estimated a L_{inf} of 127.5 mm (SE 4.8 mm), a growth rate (K) of 0.11 y^{-1} (SE 0.027), and an age-at-length-zero of -4.24 years (SE 2.15). These results were not dissimilar to earlier studies: a maximum theoretical length of 116.5 mm, $K = 0.16$ y^{-1}, and t_0 of –3.80 years (Breen 1991) and estimated asymptotes of 111.5 mm (Kennedy Bay) and 103.6 mm (Shelly Bay) (Gribben & Creese 2005).

4.2 Biomass estimates

Biomass has not been estimated for any deepwater clam stocks. Slater et al (2017) estimated the biomass for a small area in Golden Bay (PZL 7).

Deepwater clam densities in North America are calculated by the use of established methods that include counting the siphon holes through which deepwater clam filter feed. Problematically, not all deepwater clam "show" their siphon holes at the same time and thus this method could lead to an erroneous population estimate (Hand & Dovey 1999).

This is solved by the use of a "show–factor" which is the number of deepwater clam siphons that are visible, or can be felt, versus the total number of individuals present in a given area. In North America, the number of deepwater clam that "show" their siphon holes is variable depending on different environmental and physiological factors; with more showing during the summer months during periods of feeding and breeding (Campbell et al 1998), and when local water currents are not overly severe with no mechanical disturbances of the bottom due to events such as storm activity (Goodwin 1977).

Gribben et al (2004b) investigated whether the North American methodology used for determining population abundance estimates is transferrable to New Zealand's *P. zelandica*. Experiments were conducted to determine how many deepwater clam were visible at a given point in time (show/no-show factors). Analysis of sediment samples indicated that *P. zelandica* were found in similar habitats to the American species *P. generosa.* There was no significant difference in the show-factor with regard to season or tidal height. A mean show-factor of 0.914 was used to adjust the density estimates from both populations which gave mean densities of 0.058 deepwater clam m^{-2} in Kennedy Bay and 0.489 deepwater clam m^{-2} in Wellington Harbour, with coefficients of variation generally less than 0.2. The density estimates for *P. zelandica* were much lower than those reported for *P. generosa.* But the authors suggested that the North American methodology for estimating deepwater clam populations was transferrable to *Panopea zelandica*.

Gribben & Creese (2005) reported mean maximum drained wet weights of 275.5 g in Kennedy Bay and 223.1 g in Shelly Bay. This would give 0.016 kg m^{-2} average density for Kennedy Bay and 0.109 kg m^{-2} for Shelly Bay. Slater et al (2017) calculated an average density of 0.0619 kg m^{-2} for the area surveyed in Golden Bay. Even accounting for water lost in draining, the Golden Bay area appears to have higher density than Kennedy Bay but not Shelly Bay. However, any difference in density could be explained by different measuring techniques or local environmental and productivity factors. Extrapolating this density to the area delineated in the study yields an estimate of total parent biomass of 1334 t. By employing the very conservative upper confidence interval of 30.8% efficiency of the survey effort as a multiplier to the parent biomass in the surveyed area, a mean density of 0.201 kg m^{-2} and a parent biomass of 4331.17 t would be estimated (Slater et al 2017).

4.3 Yield estimates and projections

MCY has not been estimated for any deepwater clam stocks. However, an age–structured stochastic model suggested that sustainable yields for this species, with realistic management constraints, appear to be on the order of 2% to 4% of virgin biomass (Breen 1994).

CAY has not been estimated for any deepwater clam stocks.

4.4 Research needs

Research should be conducted on:

- diver variability on counts of deepwater clam;
- the role that deepwater clam occurring deeper than 17 m perform; and
- the effects of fertilisation success upon densities.

5. STATUS OF THE STOCKS

PZL 7 – *Panopea zelandica*

Stock Status	
Year of Most Recent Assessment	A small area was surveyed in 2014 in Golden Bay
Assessment Runs Presented	–
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: –
Status in relation to Target	Because of the relatively low levels of exploitation of *P. zelandica*, it is likely that this stocks is still effectively in a virgin state, therefore it is Very Likely (> 60%) to be at or above the target.
Status in relation to Limits	Because of the relatively low levels of exploitation of *P. zelandica*, it is likely that this stocks is still effectively in a virgin state, therefore it is Very Unlikely (< 40%) to be below the soft or hard limit

Historical Stock Status Trajectory and Current Status
Unknown

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	In 1989–92 the landings for PZL 7 averaged 52 t; however, since that time fishing has been light in all QMAs with a maximum of only 10.9 t taken across all QMAs in the 2011–12 fishing year.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Current catches are Unlikely (< 40%) to cause declines below soft or hard limits.

Probability of Current Catch causing Overfishing to continue or to commence	-

Assessment Methodology and Evaluation		
Assessment Type	Level 2: partial quantitative stock assessment	
Assessment Method	Biomass estimate from transects survey	
Assessment Dates	Latest assessment: 2014	Next assessment: unknown
Overall assessment quality rank	-	
Main data inputs (rank)	- Abundance - Length frequency	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Early surveys show that density is generally low compared with North American species but that productivity is higher.

Fishery Interactions
-

6. FOR FURTHER INFORMATION

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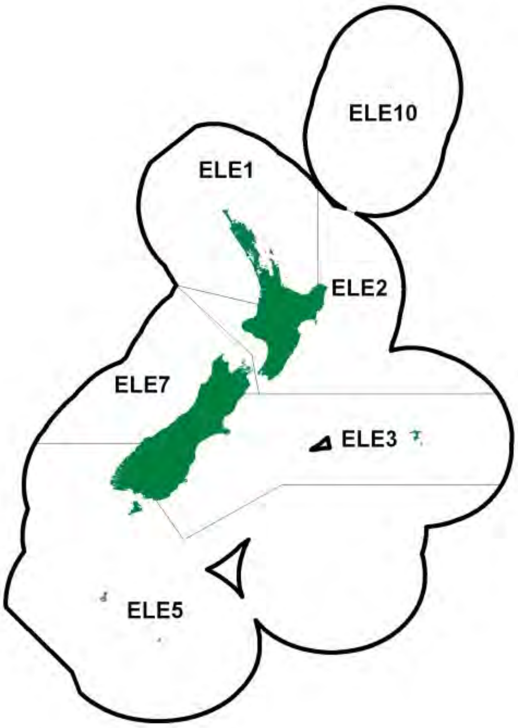
ELEPHANT FISH (ELE)

(*Callorhinchus milii*)
Reperepe



1. FISHERY SUMMARY

1.1 Commercial fisheries

From the mid-1950s to the 1980s, landings of elephant fish of around 1000 t/year were common. Most of these landings were from the area now encompassed by ELE 3, but fisheries for elephant fish also developed on the south and west coasts of the South Island in the late 1950s and early 1960s, with average catches of around 70 t per year in the south (in the 1960s to the early 1980s) and 10–30 t per year on the west coast. Total annual landings of elephant fish dropped considerably in the early 1980s (between 1982–83 and 1994–95 they ranged between 500 and 750 t) but later increased to the point that they have annually exceeded 1 000 t since the 1997–98 fishing season. Reported landings since 1931 are shown in Tables 1 and 2, while an historical record of landings and TACC values for the three main ELE stocks are depicted in Figure 1. ELE 3 has customary, recreational and other mortality allowances of 5 t, 5 t, and 50 t respectively, and ELE 5 has allowances 5 t, 5 t, and 7 t respectively.

Table 1: Reported total landings of elephant fish for calendar years 1936 to 1982. Sources: MAF and FSU data.

Year	Landings (t)	Year	Landings (t)	Year	Landings (t)	Year	Landings (t)	Year	Landings (t)
1936	116	1946	235	1956	980	1966	1 112	1976	705
1937	184	1947	188	1957	1 069	1967	934	1977	704
1938	201	1948	230	1958	1 238	1968	862	1978	596
1939	193	1949	310	1959	1 148	1969	934	1979	719
1940	259	1950	550	1960	1 163	1970	1 128	1980	906
1941	222	1951	602	1961	983	1971	1 401	1981	690
1942	171	1952	459	1962	1 156	1972	1 019	1982	661
1943	220	1953	530	1963	1 095	1973	957		
1944	270	1954	853	1964	1 235	1974	848		
1945	217	1955	802	1965	1 111	1975	602		

The TACC for ELE 3 has, with the exception of 2002–03 and 2018-19, been consistently exceeded since 1986–87. The ELE 3 TACC was increased to 500 t for the 1995–96 fishing year, and then increased twice more under an Adaptive Management Programme (AMP): initially to 825 t in October 2000 and then to 950 t in October 2002. This new TACC combined with the allowances for customary and recreational fisheries (5 t each), increased the new TAC for the 2002–03 fishing year in ELE 3 to 960 t. For the 2009– 10 fishing year, the TACC was increased from 960 t to 1 000 t. This was followed by a further increase to 1 150 t for the fishing year 2018-19. ELE 3 fishing is seasonal, mostly occurring in spring and summer in inshore waters. Most of the increase in catch from the early 2000s in the ELE 3 trawl fishery has been taken as a bycatch of the flatfish target fishery and an emerging target ELE fishery (Starr & Kendrick 2013). During the 1990s, the level of elephant fish bycatch from the RCO 3 trawl fishery increased from around 80 t/year to greater than 400 t in 2000–01 (Starr & Kendrick 2013). There was a steady increase in the level of ELE 3 bycatch from the FLA 3 trawl fishery, with catches increasing from around 70 t in 1994–95 to 300 t in 1999–00. There is also a significant setnet fishery in ELE 3, largely directed at rig and elephant fish.

The fishery in ELE 5 is mainly a trawl fishery targeted at flatfish and to a lesser extent giant stargazer. Very little catch in ELE 5 is taken by target setnet fisheries. Catches increased consistently from 1992–93 (39 t) to 2008-09 (208 t), before decreasing again. The TACCs were exceeded in most years from 1995–96 to 2011-12. The ELE 5 TACC was increased from 71 t to 100 t under an AMP in October 2001. The TACC was further increased under the AMP to 120 t in October 2004 and catches have exceeded this TACC by 70% in 2007–08 and 2008–09. For the 2009–10 fishing season, the TACC was increased by 17% up from 120 t to 140 t. All AMP programmes ended on 30 September 2009. The ELE 5 TACC was further increased to 170 t in 2012–13; landings have repeatedly remained below the TACC since, including in 2018-19 when just 104 t of elephant fish were landed.

From 1 October 2008, a suite of regulations intended to protect Maui’s and Hector’s dolphins was implemented for all of New Zealand by the Minister of Fisheries. For ELE 3, commercial and recreational set netting was banned in most areas to 4 nautical miles offshore of the east coast of the South Island, extending from Cape Jackson in the Marlborough Sounds to Slope Point in the Catlins. Some exceptions were allowed, including an exemption for commercial and recreational set netting to only one nautical mile offshore around the Kaikoura Canyon, and permitting setnetting in most harbours, estuaries, river mouths, lagoons and inlets except for the Avon-Heathcote Estuary, Lyttelton Harbour, Akaroa Harbour and Timaru Harbour. In addition, trawl gear within 2 nautical miles of shore was restricted to flatfish nets with defined low headline heights. For ELE 7, both commercial and recreational setnetting were banned to 2 nautical miles offshore, with the recreational closure effective for the entire year and the commercial closure restricted to the period 1 December to the end of February. The closed area extends from Awarua Point north of Fiordland to the tip of Cape Farewell at the top of the South Island. Some interim relief to these regulations was provided in ELE 5 from 1 October 2008 to 24 December 2009.

Table 2: Reported landings (t) for the main QMAs from 1931 to 1990. [Continued on next page]

Year	ELE 1	ELE 2	ELE 3	ELE 5	ELE 7
1931–32	0	0	0	0	0
1932–33	0	0	0	0	0
1933–34	0	0	0	0	0
1934–35	0	0	0	0	0
1935–36	0	0	0	0	0
1936–37	0	0	79	0	1
1937–38	0	0	183	0	0
1938–39	0	0	194	1	2
1939–40	0	1	190	1	1
1940–41	0	1	243	8	1
1941–42	0	0	220	1	0
1942–43	0	0	163	6	0
1943–44	0	0	219	1	0
1944	0	0	251	10	0
1945	0	2	205	3	3
1946	0	0	228	3	4
1947	0	2	176	0	10
1948	0	2	227	0	9
1949	0	1	296	2	13
1950	0	1	522	14	13
1951	0	2	585	6	10
1952	0	0	440	9	5
1953	0	3	514	13	3
1954	0	2	839	5	7
1955	0	3	771	4	25
1956	0	1	933	16	29
1957	0	2	992	28	46
1958	0	0	1 140	47	51
1959	0	0	1 066	37	44
1960	0	1	1 099	38	27
1961	0	0	913	43	27
1962	0	4	1 066	73	14

Table 2: [Continued]

Year	ELE 1	ELE 2	ELE 3	ELE 5	ELE 7
1963	0	2	976	111	8
1964	0	3	1 109	107	16
1965	0	7	983	88	34
1966	0	1	985	99	27
1967	0	1	812	77	45
1968	0	1	757	54	52
1969	0	1	824	75	33
1970	0	3	987	87	53
1971	0	0	1 243	103	37
1972	0	0	928	70	15
1973	0	0	864	73	21
1974	0	0	766	97	41
1975	0	1	557	55	28
1976	0	0	622	91	52
1977	0	0	601	114	45
1978	0	0	552	49	26
1979	0	0	661	63	18
1980	0	0	794	129	34
1981	0	1	543	114	16
1982	0	0	584	85	34

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data includes both foreign and domestic landings. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

Table 3: Reported landings (t) of elephant fish by Fishstock from 1983–84 to 2018–19 and actual TACCs (t) from 1986–87 to 2018–19. QMR data from 1986 – present. No landings have been reported from ELE 10.

Fishstock	ELE 1		ELE 2		ELE 3		ELE 5		ELE 7			
FMA (s)	1 & 9		2 & 8		3 & 4		5 & 6		7		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84*	< 1	-	5	-	605	-	94	-	60	-	765	-
1984–85*	< 1	-	3	-	517	-	134	-	50	-	704	-
1985–86*	< 1	-	4	-	574	-	57	-	46	-	681	-
1986–87	< 1	10	2	20	506	280	48	60	29	90	584	470
1987–88	< 1	10	3	20	499	280	64	60	44	90	610	470
1988–89	< 1	10	1	22	450	415	49	62	43	100	543	619
1989–90	< 1	10	3	22	422	418	32	62	55	101	510	623
1990–91	< 1	10	5	22	434	422	55	71	59	101	553	636
1991–92	< 1	10	11	22	450	422	58	71	78	101	597	636
1992–93	< 1	10	5	22	501	423	39	71	61	102	606	638
1993–94	< 1	10	6	22	475	424	46	71	41	102	568	639
1994–95	< 1	10	5	22	580	424	60	71	39	102	684	639
1995–96	< 1	10	7	22	688	500	72	71	93	102	862	715
1996–97	< 1	10	9	22	734	500	74	71	94	102	912	715
1997–98	< 1	10	12	22	910	500	95	71	66	102	1 082	715
1998–99	< 1	10	9	22	842	500	129	71	117	102	1 098	715
1999–00	< 1	10	6	22	950	500	105	71	87	102	1 148	715
2000–01	2	10	7	22	956	825	153	71	90	102	1 207	1 040
2001–02	< 1	10	9	22	852	825	105	100	88	102	1 053	1 057
2002–03	1	10	9	22	950	950	106	100	59	102	1 125	1 194
2003–04	< 1	10	10	22	984	950	102	100	42	102	1 139	1 194
2004–05	< 1	10	13	22	972	950	125	120	74	102	1 184	1 214
2005–06	< 1	10	14	22	1 023	950	147	120	76	102	1 260	1 214
2006–07	< 1	10	17	22	960	950	158	120	116	102	1 251	1 214
2007–08	< 1	10	16	22	1 092	950	202	120	125	102	1 435	1 214
2008–09	1	10	21	22	1 063	950	208	120	91	102	1 384	1 214
2009–10	< 1	10	21	22	1 089	1 000	176	140	86	102	1 372	1 274
2010–11	< 1	10	14	22	1 123	1 000	153	140	93	102	1 384	1 283
2011–12	< 1	10	16	22	1 074	1 000	157	140	130	102	1 377	1 283
2012–13	< 1	10	16	22	1 140	1 000	157	170	123	102	1 436	1 304
2013–14	< 1	10	16	22	1 110	1 000	173	170	96	102	1 394	1 304
2014–15	< 1	10	11	22	1 048	1 000	179	170	102	102	1 340	1 304
2015–16	< 1	10	9	22	1 159	1 000	137	170	95	102	1 400	1 304
2016–17	< 1	10	12	22	1 051	1 000	182	170	81	102	1 326	1 304
2017–18	< 1	10	8	22	1 098	1 000	126	170	113	102	1 346	1 304
2018–19	< 1	10	9	22	1 142	1 150	104	170	100	102	1 464	1 304

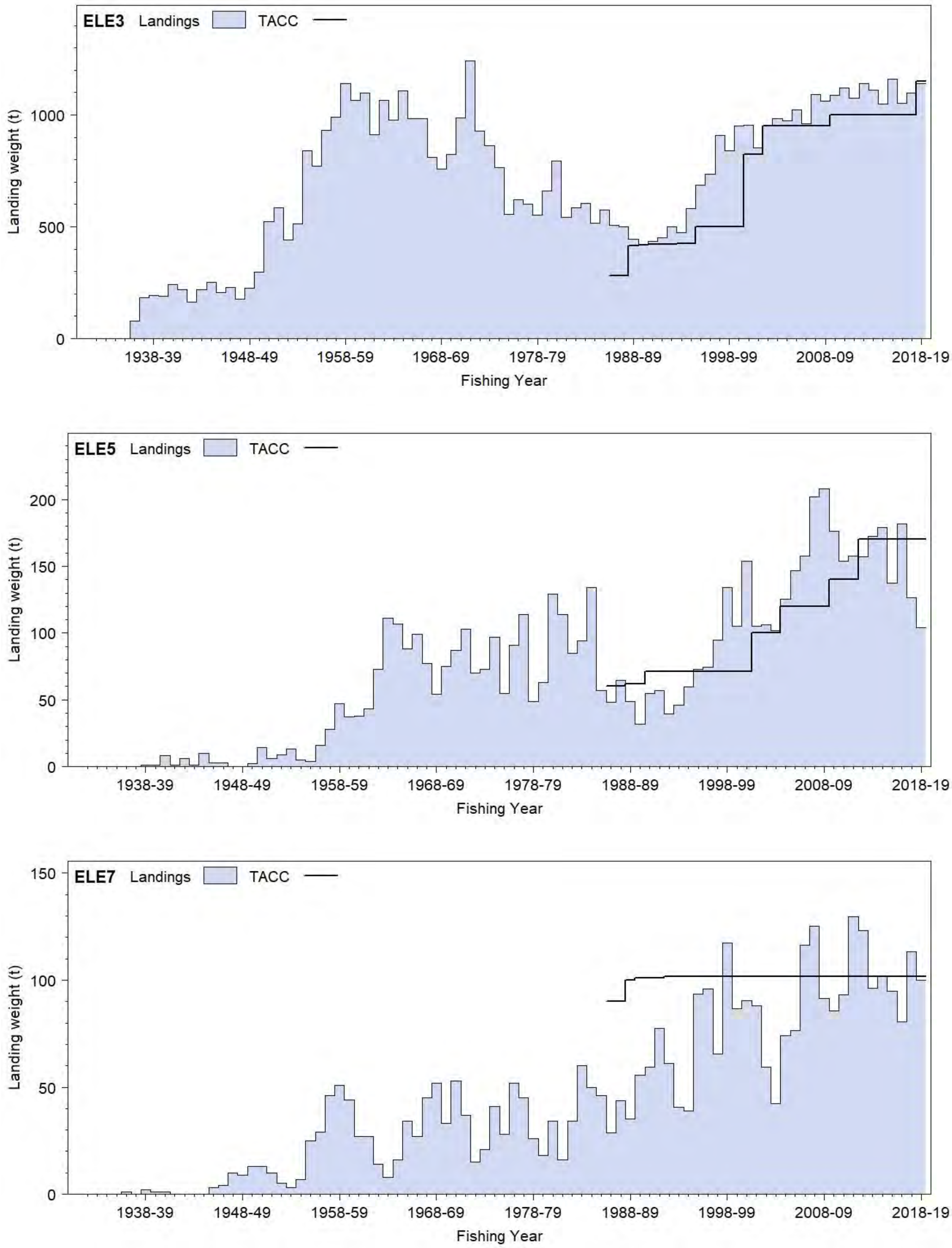


Figure 1: Reported commercial landings and TACC for the three main ELE stocks. From top: ELE 3 (South East Coast and Chatham Rise), ELE 5 (Southland and Sub-Antarctic), and ELE 7 (Challenger).

1.2 Recreational fisheries

Catches of elephant fish by recreational fishers are low compared with those of the commercial sector. Catches estimated using National Panel Surveys (NPS) in 2011–12 and 2017–18 (Wynne-Jones et al 2014, 2019) are shown in Table 4. Recreational catch exceeded 1000 fish only in ELE 3 in the two surveys and all estimates are quite uncertain. Regional surveys in the early 1990s (Teirney et al 1997) and national surveys in 1996, 1999, and 2000 (Bradford 1998, Boyd & Reilly 2002) showed similarly low number of fish harvested and similar geographical patterns. No estimates of mean weight are available to convert these estimates of harvested fish to harvested weights.

Table 4: Recreational harvest estimates for elephantfish stocks (Wynne-Jones et al 2014, 2019). In sufficient data on mean fish weights are available from boat ramp surveys to convert numbers to catch weights.

Stock	Year	Method	Number of fish	Total weight (t)	CV
ELE 2	2011/12	Panel survey	183	-	-
	2017/18	Panel survey	339	-	0.72
ELE 3	2011/12	Panel survey	4 853	-	-
	2017/18	Panel survey	2 458	-	0.36
ELE 5	2011/12	Panel survey	202	-	-
	2017/18	Panel survey	60	-	1.00
ELE 7	2011/12	Panel survey	960	-	-
	2017/18	Panel survey	189	-	0.39

1.3 Customary non-commercial fisheries
Quantitative information on the current level of customary non-commercial catch is not available.

1.4 Illegal catch
There are reports of discards of juvenile elephant fish by trawlers from some areas. However, no quantitative estimates of discards are available.

1.5 Other sources of mortality
The significance of other sources of mortality has not been documented.

2. BIOLOGY

Elephant fish are uncommon off the North Island and occur south of East Cape on the east coast and south of Kaipara on the west coast. They are most plentiful around the east coast of the South Island.

Males mature at a length of 50 cm fork length (FL) at an age of 3 years, females at 70 cm FL at 4 to 5 years of age. The maximum age of elephant fish is unknown. However a tagged, 73 cm total length, Australian male was at liberty for 16 years, suggesting a longevity for males of at least 20 years (Coutin 1992, Francis 1997). Females probably also live to at least 20 years. A longevity of 20 years suggests that M is about 0.23. This results from use of the equation $M = \log_e 100/\text{maximum age}$, where maximum age is the age to which 1% of the population survives in an unexploited stock.

Mature elephant fish migrate to shallow inshore waters in spring and aggregate for mating. Eggs are laid on sand or mud bottoms, often in very shallow areas. They are laid in pairs in large yellow-brown egg cases. The period of incubation is at least 5–8 months, and juveniles hatch at a length of about 10 cm FL. Females are known to spawn multiple times per season. After egg laying the adults are thought to disperse and are difficult to catch; however, juveniles remain in shallow waters for up to 3 years. During this time juveniles are vulnerable to incidental trawl capture, but are of little commercial value.

Von Bertalanffy growth curves based on MULTIFAN analysis of length-frequency data are available for Pegasus Bay and Canterbury Bight in 1966–68 and 1983–88. However, the ages of the larger fish were probably underestimated and the growth curves are only reliable to about 4–5 years (Francis 1997). New empirical growth curves were developed by fitting a Von Bertalanffy growth function to a dataset consisting of (a) the first six length-frequency modes from the study by Francis (1997) and (b) an approximate maximum size and age for male and female elephant fish. The latter points ‘anchor’ the curves at the right hand ends and generate more plausible curve shapes, L_∞ estimates, and therefore length-at-age. The largest measured fish in the ELE 3 samples from 1966–68 and 1983–88 (i.e. 76 cm FL for males and 97 cm FL for females) were considered to be reasonable estimates of the mean maximum lengths of elephant fish in an unfished population. The following data points were therefore used in fitting the growth curves: 76 cm and 20 years for males, and 97 cm and 20 years for females. The best fitting growth model had separate male and female coefficients for K and L_∞ and a common coefficient for t_0 (M. Francis, unpubl. data).

Biological parameters relevant to the stock assessment are shown in Table 5.

Table 5: Estimates of biological parameters for elephant fish.

Fishstock	Estimate						Source
1. Natural mortality (*M*)							
All	0.23						See text
2. Weight = a (length)^b (Weight in g, length in cm fork length)							
	Both sexes						
	a	b					
ELE 3	0.0091	3.02					Gorman (1963)
3. von Bertalanffy Growth Function							
	Females			Males			
	$L\infty$	*k*	*t0*	$L\infty$	*k*	*t0*	
ELE 3	97.88	0.26	-0.55	75.03	0.34	-0.55	See text

3. STOCKS AND AREAS

There are no data that would alter the current stock boundaries. Results from tagging studies conducted during 1966–69 indicate that elephant fish tagged in the Canterbury Bight remained in ELE 3. Separate spawning grounds to maintain each ‘stock’ have not been identified. The boundaries used are related to the historical fishing pattern when this was a target fishery.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

4.1.1 Trawl survey biomass indices

ECSI Trawl Survey

The ECSI winter surveys from 1991 to 1996 in 30–400 m were replaced by summer trawl surveys (1996–97 to 2000–01) which also included the 10–30 m depth range, but these were discontinued after the fifth in the annual time series because of the extreme fluctuations in catchability between surveys (Francis et al 2001). The winter surveys were reinstated in 2007 and this time included additional 10–30 m strata in an attempt to index elephant fish and red gurnard which were officially included in the target species in 2012. Only the 2007, 2012, 2014, 2016, and 2018 surveys provide full coverage of the 10–30 m depth range (Figure 2).

Total biomass in the core strata increased markedly in 1996 and although it has fluctuated since then it has remained high with the post-1994 average (including 2014, but not 2016) about three-fold greater than that of the early 1990s (Figure 2). The 2016 biomass was more than six-fold greater than this average, but the CV around the estimate was 68%, very high compared to previous surveys. The 2018 core strata estimate of 807 t is similar to the post-1994 average. In the core plus shallow strata, biomass followed the same trend as the core strata biomass. The additional elephant fish biomass captured in the 10–30 m depth range accounted for 44%, 64%, 41%, 7% and 28% of the biomass in the core plus shallow strata (10–400 m) for 2007, 2012, 2014, 2016 and 2018 respectively, indicating the importance of shallow strata for elephant fish biomass (Table 6, Figure 2). Further, the addition of the 10–30 m depth range had a significant effect on the shape of the length frequency distributions with the appearance of strong 1+ and 2+ cohorts, otherwise poorly represented in the core strata, particularly in 2007 and 2012. The proportion of pre-recruit biomass in the core plus shallow strata was also generally greater than that of the core strata alone, indicating that younger fish are more common in shallow water (Table 6). For the five core plus shallow strata surveys, the juvenile biomass (based on the length-at-50% maturity) varied from about one third to three quarters of the total biomass in the first three surveys, to 9% in 2016, and back up to 47% in 2018. . The distribution of elephant fish hot spots varies, but overall this species is consistently well represented over the entire survey area from 10 to 100 m, but is most abundant in the shallow 10 to 30 m.

WCSI Trawl Survey

For WCSI Trawl Surveys, elephant fish (ELE 7) total biomass estimates are variable between successive surveys and the biomass estimates are frequently imprecise, particularly for the higher biomass estimates (Table 6). The last three trawl surveys (2009, 2011 and 2013) have estimated relatively high levels of recruited biomass compared to the biomass estimates from the earlier surveys (Figure 3). However, of the three recent surveys, only the 2013 survey provided a biomass estimate with a reasonable level of precision (CV 26%). The survey estimates of pre-recruit biomass are also poorly determined.

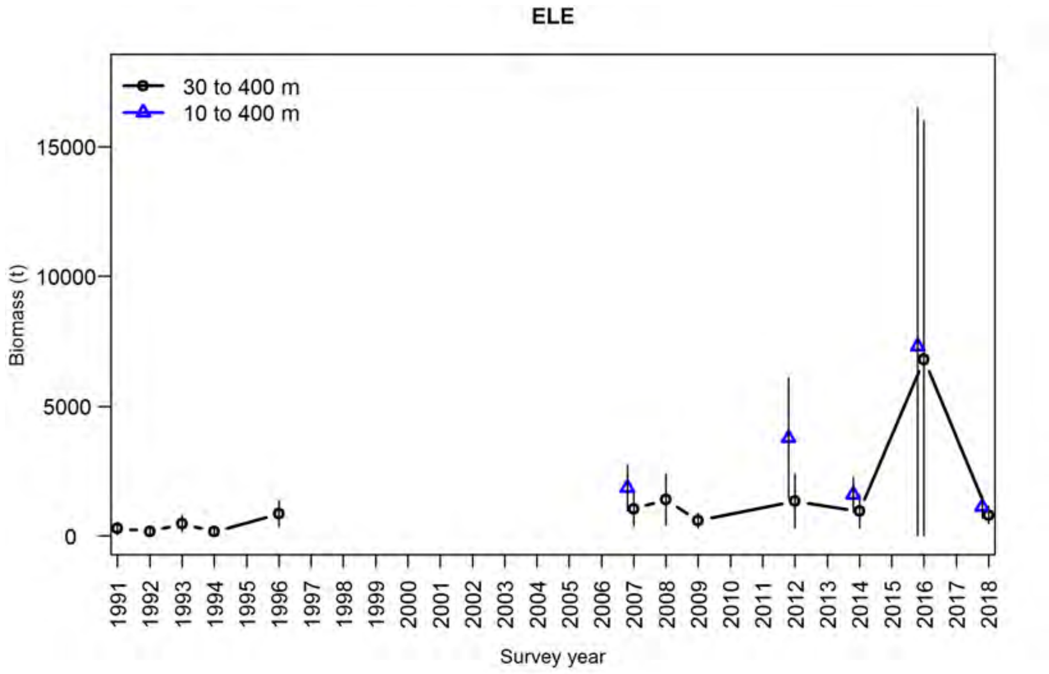


Figure 2: Elephant fish total biomass and 95% confidence intervals for all ECSI winter surveys in core strata (30–400 m), and core plus shallow strata (10–400 m) in 2007, 2012, 2014, 2016 and 2018.

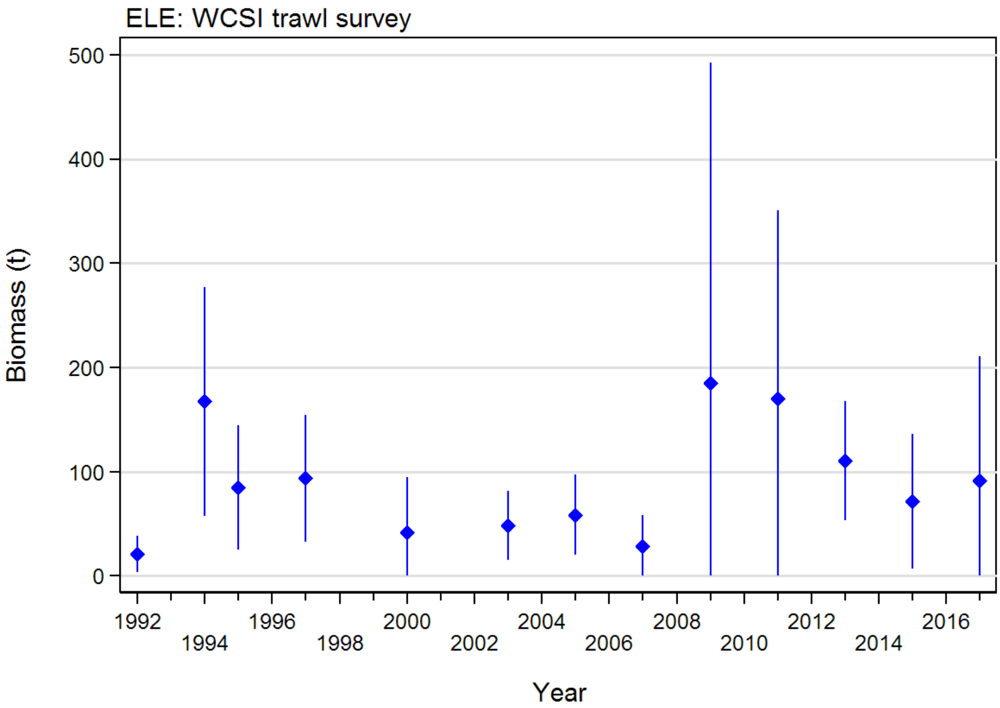


Figure 3: Elephant fish trawl survey total biomass estimates for the west coast South Island survey, with associated 95% confidence intervals.

Table 6: Relative biomass indices (t) and coefficients of variation (CV) for elephant fish for east coast South Island (ECSI) - summer and winter, west coast South Island (WCSI) and the Stewart-Snares Island survey areas*. Biomass estimates for ECSI in 1991 have been adjusted to allow for non-sampled strata (7 and 9 equivalent to current strata 13, 16 and 17). The sum of pre-recruit and recruited biomass values do not always match the total biomass for the earlier surveys because at several stations length frequencies were not measured, affecting the biomass calculations for length intervals. – , not measured; NA, not applicable. Recruited is defined as the size-at-recruitment to the fishery (50 cm).

Region	Fishstock	Year	Trip number	Total Biomass estimate	CV (%)	Total Biomass estimate	CV (%)	Pre-recruit	CV (%)	Pre-recruit	CV (%)	Recruited	CV (%)	Recruited	CV (%)
ECSI(winter)	ELE 3			30–400 m		10–400 m		30–400 m		10–400 m		30–400 m		10–400 m	
		1991	KAH9105	300	40	-	-	NA	NA	-	-	NA	NA	-	-
		1992	KAH9205	176	32	-	-	54	83	-	-	122	28	-	-
		1993	KAH9306	481	33	-	-	60	56	-	-	421	34	-	-
		1994	KAH9406	152	33	-	-	22	51	-	-	142	34	-	-
		1996	KAH9606	858	30	-	-	338	40	-	-	520	26	-	-
		2007	KAH0705	1 034	32	1 859	24	516	59	1 201	36	518	21	658	20
		2008	KAH0806	1404	35	-	-	627	57	-	-	777	27	-	-
		2009	KAH0905	596	23	-	-	210	38	-	-	387	25	-	-
		2012	KAH1207	1 351	39	3 781	31	66	46	581	25	1 285	39	3 199	36
		2014	KAH1402	951	34	1600	21	174	32	429	25	777	40	1 171	28
		2016	KAH1605	6 812	68	7 299	63	62	43	167	30	6 750	68	7 132	64
		2018	KAH1803	807	21	1118	20	266	34	356	28	541	23	761	24
ECSI(summer)	ELE 3	1996–97	KAH9618	21	42	-	-	-	-	-	-	-	-	-	-
		1997–98	KAH9704	167	33	-	-	-	-	-	-	-	-	-	-
		1998–99	KAH9809	85	35	-	-	-	-	-	-	-	-	-	-
		1999–00	KAH9917	94	33	-	-	-	-	-	-	-	-	-	-
		2000–01	KAH0014	42	63	-	-	-	-	-	-	-	-	-	-
				49	34										
WCSI	ELE 7	1992	KAH9204	59	33	-	-	-	-	-	-	-	-	-	-
		1994	KAH9404	28	53	-	-	-	-	-	-	-	-	-	-
		1995	KAH9504	185	83	-	-	-	-	-	-	-	-	-	-
		1997	KAH9701	170	53	-	-	-	-	-	-	-	-	-	-
		2000	KAH0004	110	26	-	-	-	-	-	-	-	-	-	-
		2003	KAH0304	72	45	-	-	-	-	-	-	-	-	-	-
		2005	KAH0503	92	65	-	-	-	-	-	-	-	-	-	-
		2007	KAH0704	21	42	-	-	-	-	-	-	-	-	-	-
		2009	KAH0904	167	33	-	-	-	-	-	-	-	-	-	-
		2011	KAH1104	85	35	-	-	-	-	-	-	-	-	-	-
		2013	KAH1305	94	33										
		2015	KAH1503	42	63										
		2017	KAH1703	49	34										
Stewart-Snares	ELE 5	1993	TAN9301	219	33	-	-	-	-	-	-	-	-	-	-
		1994	TAN9402	177	47	-	-	-	-	-	-	-	-	-	-
		1995	TAN9502	69	49	-	-	-	-	-	-	-	-	-	-
		1996	TAN9604	137	46	-	-	-	-	-	-	-	-	-	-

*Assuming area availability, vertical availability and vulnerability equal 1.0. Biomass is only estimated outside 10 m depth except for COM9901 and CMP0001. Note: because trawl survey biomass estimates are indices, comparisons between different seasons (e.g., summer and winter ECSI) are not strictly valid.

4.1.2 CPUE biomass indices

ELE 3 and ELE 5

Three standardised CPUE series for ELE 3 were prepared for 2012, with each series based on the bycatch of elephant fish in bottom trawl fisheries defined by different target species combinations. Initially, the Working Group accepted a series based solely on the bycatch of elephant fish when targeting red cod. It then requested two further analyses: one [ELE 3(MIX)] where the target species definition was expanded to include STA, BAR, TAR, and ELE, as well as RCO, to investigate the effect of target species switching by explicitly standardising for target species effects. The second analysis [ELE 3(MIX)-trip] was done on all trips that targeted RCO, STA, BAR, TAR, and ELE at least once, then amalgamating all data to the level of a trip. This removed the differences between the TCEPR, TCER and CELR forms, but loses all targeting information.

The three sets of ELE 3 CPUE indices (ELE 3(RCO), ELE 3(MIX) and ELE 3(MIX)-trip) were very similar for the 1989–90 to 2010–11 years. The Working Group agreed in 2009 to drop the ELE 3-SN(SHK) and ELE 5-SN(SHK) (setnet with shark target species) indices because the setnet fisheries in these two QMAs have been substantially affected by management interventions (including measures to reduce the bycatch of Hector's dolphins) and no longer appeared to be an appropriate index of ELE abundance in either QMA.

In 2014, the ELE 3(MIX) CPUE model was updated to include additional data from 2011–12 and 2012–13 (Langley 2014). The resulting CPUE indices were very similar to the previous analysis for the comparable period. The indices were updated again in 2016, extending the time-series to 2014–15. Standardised CPUE has fluctuated without trend since 2009–10 and the 2014–15 data point is near the interim target (see below) (Figure 4).

An analysis of recent CPUE data suggested that bottom trawl fishing operations may be attempting to avoid larger catches of elephant fish. During 2012–13 to 2014–15, there was a lower probability of successive larger catches of elephant fish. This may have negatively biased the CPUE indices from 2012–13 to 2014–15 (Langley 2016 - presentation).

B_{MSY} conceptual proxy: The Working Group proposed using the average of the ELE 3(MIX) series from 1998–99 to 2010–11 to represent a "B_{MSY} conceptual proxy" for the ELE 3 Fishstock. This period was selected because of its relative stability following a period of continuous increase. However, the Working Group has concerns about the reliability of this as a proxy and suggested that it only be used on an interim basis.

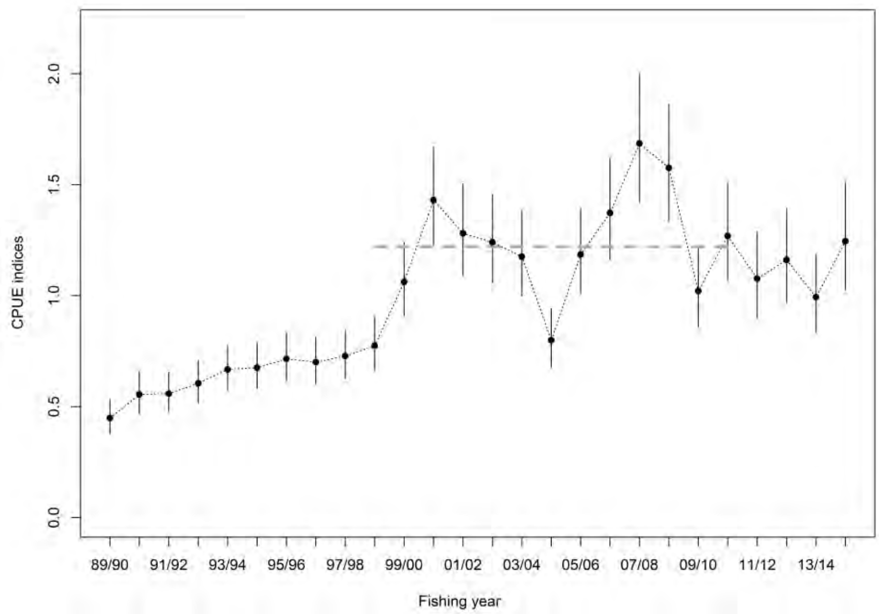


Figure 4: Standardised CPUE indices for the ELE 3 bottom trawl fisheries [ELE 3(MIX)]. The horizontal grey line is the mean of ELE 3(MIX) from 1998–99 to 2010–11 (B_{MSY} conceptual proxy). The CPUE series has been normalised to a geometric mean of 1.0. Error bars show 95% confidence intervals.

ELEPHANT FISH (ELE)

Two standardised CPUE series for ELE 5 were prepared for 2012 with each series based on the bycatch of elephant fish in the bottom trawl fisheries defined by target species combinations (Starr & Kendrick 2013). One of these series [ELE 5 BT(MIX)] is analogous to the MIX series developed for ELE 3, with the series defined by six target species in all valid ELE 5 statistical areas. The second ELE 5 analysis [ELE 5 BT(MIX)-trip] was a trip- based analysis using the same target species selection method as described for ELE 3-BT(MIX)-trip series. The two sets of indices were very similar.

In 2014, the ELE 5-BT(MIX) CPUE model was updated to include data from 2011–12 to 2012–13 (Langley 2014). This model used the "daily effort" method to prepare the data, whereby every record was reduced to a day of fishing, with the predominant statistical area and target species for the day assigned to the record. This method was accepted by the WG as the best procedure to follow when reducing event-based forms to match earlier daily forms. The two most recent indices were lower than the peak CPUE from 2008–09 to 2010–11, although CPUE has been maintained at a relatively high level compared to the 1990s–early 2000s (Figure 5). The ELE 5-BT(MIX) model was again updated in 2017, with data current to the end of 2015–16. Although the fishery definition and data preparation methods were unchanged, a binomial presence/absence series was added because of a declining trend in the proportion of days with zero catch. The Plenary accepted a revised index which combined the binomial and lognormal series using the delta-lognormal method (Starr & Kendrick, in prep). This was done because the Inshore WGs have adopted the standard of combining positive catch and fishing success models when there is a trend in the proportion zero catch. As well, simulation work has indicated that calculating a combined index may reduce bias when reporting small catch amounts (Langley 2015). Recent indices estimated by this updated series are lower than the peak observed at the end of the 2010 decade, but these indices remain above the long-term average CPUE (Figure 5).

***B_{MSY}* conceptual proxy:** The Plenary agreed in 2017 to use the mean combined ELE5-BT(MIX) CPUE for the period 2005–06 to 2015–16 as a "BMSY conceptual proxy" for ELE 5. This period was selected because a plot of CPUE against catch (yield curve) appeared to have levelled out and is assumed to represent a stochastic equilibrium (Figure 6).

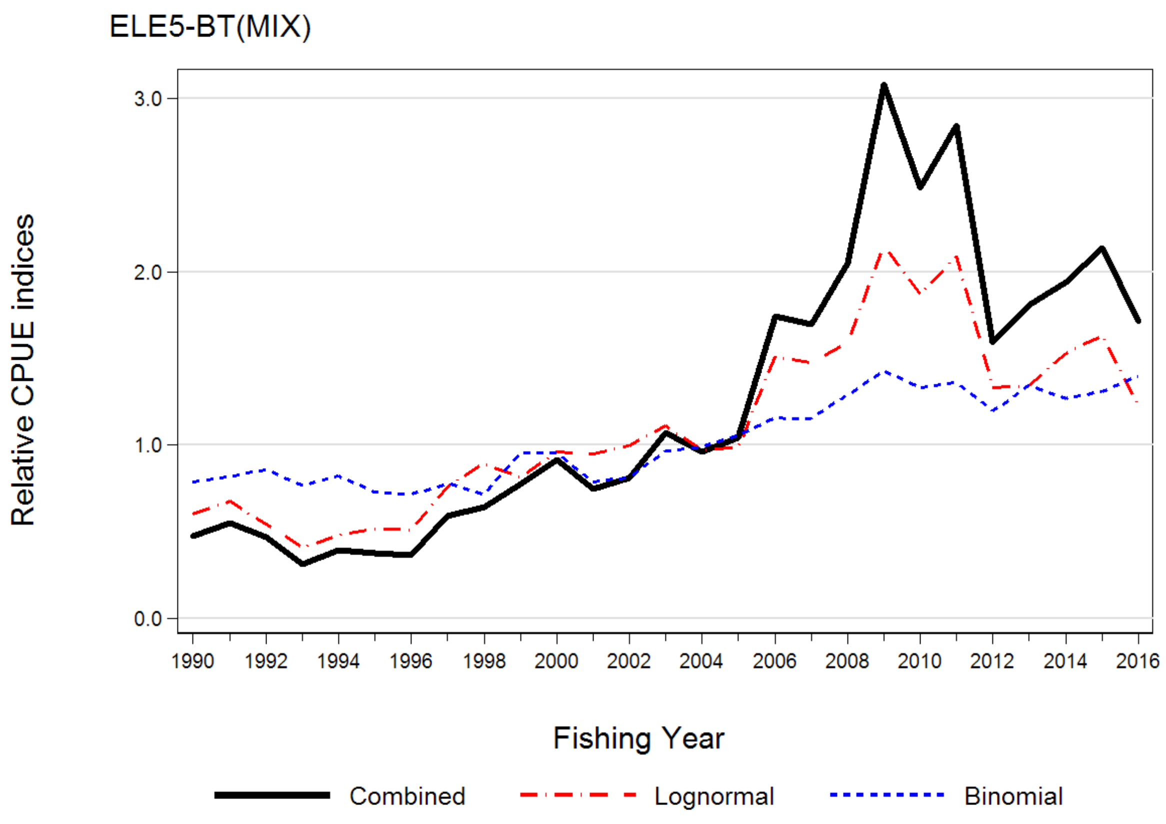


Figure 5: Plots of three ELE5-BT(MIX) CPUE series: a) positive catch (lognormal); b) presence/absence (binomial) and c) combined series using the delta-lognormal method.

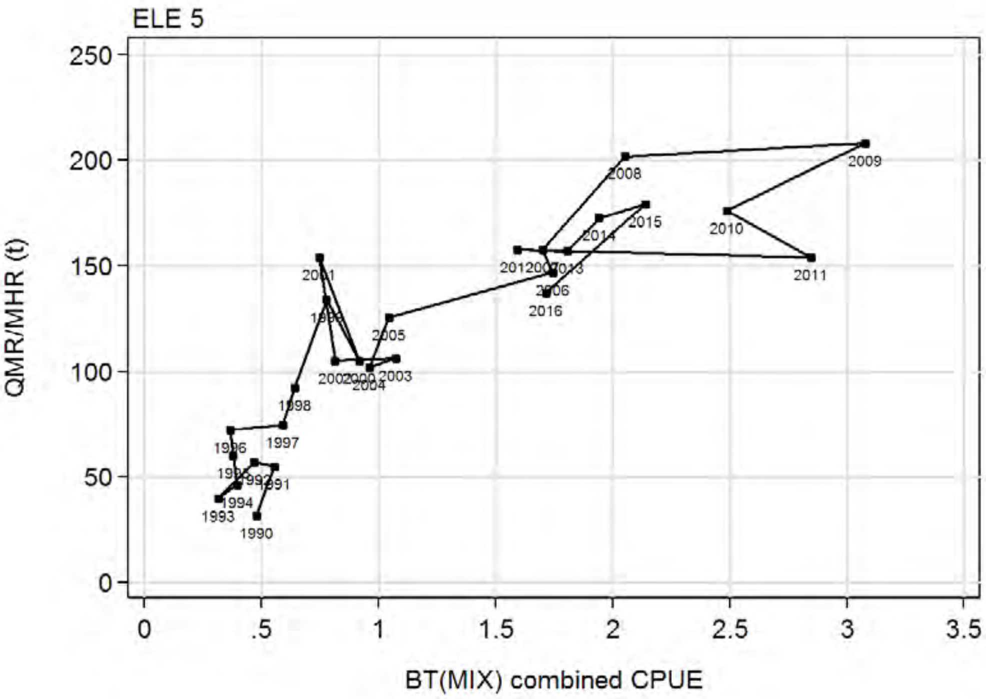


Figure 6: Trace yield plot for ELE 5, showing CPUE and QMR/MHR landings plotted sequentially by fishing year.

ELE 7

A preliminary CPUE analysis of the catch of elephant fish from the WCSI inshore trawl fishery was conducted in 2013 and updated in 2014 (Langley 2014). The analysis included all bottom trawl catch and effort data targeting either flatfish, red gurnard, red cod or elephant fish. These target trawl fisheries encompass almost all the trawl fishing effort within the depth range that encompasses most of the catch of elephant fish off the west coast of the South Island (5–80 m). The primary analysis was conducted based on catch and effort data from 1989–90 to 2012–13 aggregated in a format that was consistent with the CELR reporting format. The landed catch of elephant fish from each trip was apportioned to the effort records either based on the associated level of estimated catch or, where estimated catches were not recorded, in proportion to the number of trawls in each aggregated effort record.

The data set included a significant proportion of trip and effort records with no elephant fish catch, although the proportion of nil catch records decreased steadily over the study period. Thus, the overall CPUE for the fishery was modelled in two components: the binomial model of the proportion of positive catches and the lognormal model of the magnitude of the positive catch. The two components were combined to generate a time series of delta-lognormal CPUE indices. The sensitivity of the catch threshold used to define a positive catch (i.e. 0, 1 kg, 2 kg and 5 kg) was investigated. The resulting binomial and lognormal CPUE indices were sensitive to the applied catch threshold; however, the compensatory changes in the two sets of indices resulted in delta-lognormal indices that were relatively insensitive to the applied catch threshold.

The resulting CPUE indices fluctuated over the study period with a marked peak in CPUE in 1999–2000 and 2000–01 and low CPUE in 1997–98 and 2003–04 (Figure 7). The CPUE indices remained stable during 2007–08 to 2009–10, increased in 2010–11, increased markedly in 2011–12 and remained at the higher level in 2012–13. In 2014, the SINS WG concluded that the CPUE indices were unlikely to be a reliable index of stock abundance, primarily on the basis that the large inter-annual variations in the CPUE indices especially during the late 1990s and early 2000s were not consistent with the dynamics of the stock and may be attributable to changes in the operation of the WCSI trawl fishery at that time.

A separate delta-lognormal CPUE analysis was conducted for the location based TCER catch and effort data from 2007–08 to 2012–13 (Langley 2014). The resulting CPUE models incorporated a number of additional explanatory variables available in the high resolution data format. The TCER delta-lognormal CPUE indices were broadly similar to the CELR format CPUE indices for the comparative period The TCER indices exhibited a comparable increase in CPUE from 2009–10 to 2011–12, although the TCER indices were higher in 2007–08 to 2008–09 than the CELR format indices. In 2015, the TCER CPUE indices were updated to include the 2013–14 fishing year. The SINS WG concluded that the TCER CPUE indices represented the best available information for monitoring trends in ELE 7 stock abundance.

A “rapid update” of the ELE 7 tow-by-tow standardised CPUE analysis was reviewed and accepted by the SINS WG in 2019 (Starr & Kendrick 2019). This analysis duplicated the Langley (2014) analysis reported above, extending the analysis by four years as well as providing additional diagnostics supporting the standardisation procedure (Figure 7). The SINS WG agreed that this series indexed ELE 7 abundance, with the 2017–18 index near the series mean (Figure 7). In addition, the SINS WG agreed that the mean (2007–08 to 2017–18) index of this series could serve as a B_{msy} proxy target for this stock.

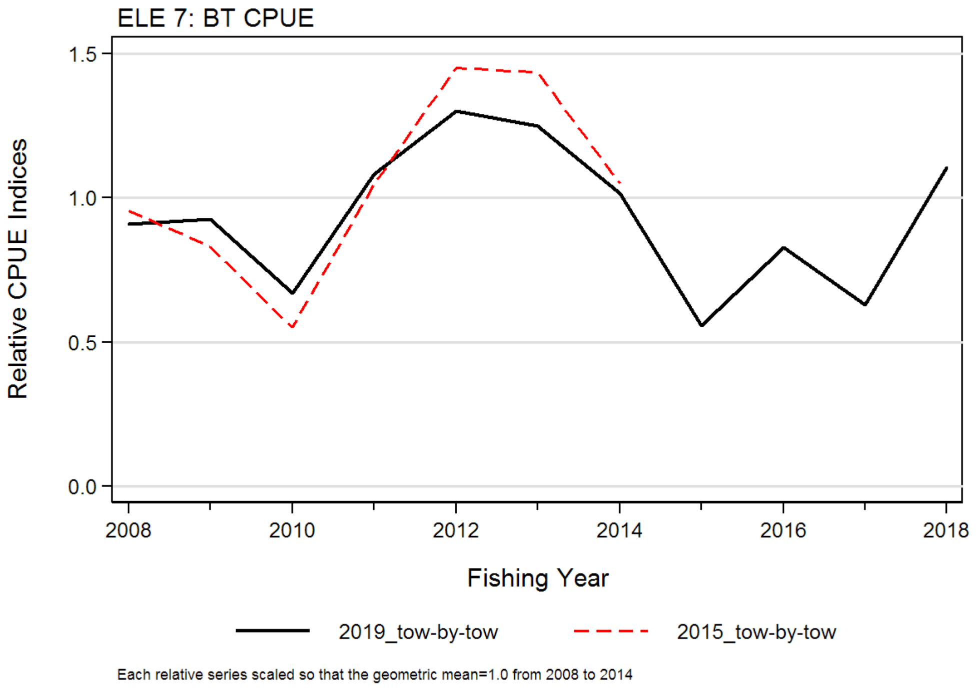


Figure 7. Standardised delta-lognormal CPUE indices for the ELE 7 inshore WCSI trawl fishery based on tow-by-tow TCER data. Two index series are presented: the updated 2019 series and the previously accepted 2015 series. Both sets of indices are normalised to the comparable time period (2007–08 to 2013–14).

4.2 Stock Assessment models

A preliminary stock assessment model was developed for ELE 3. Estimates of current and reference absolute biomass are not available for the other elephant fish stocks.

ELE 3

A stock assessment model was developed for ELE 3 in 2016 using the Stock Synthesis (3.24f) software to implement an age-structured population model. The data sets available for inclusion in the assessment model are, as follows.

- Annual reported catch of elephant fish (1931–2015). The historical catches were derived from Francis & Paul (2013). Additional unreported landed catches were included for the period prior to the introduction of the QMS. The level of unreported landed catch was assumed to represent a third of the reported catch. The magnitude of unreported landed catch was based on discussions with commercial operators in the ELE 3 fishery.
- A time-series of estimates of the magnitude of the discarded catch (unreported but not landed) of elephant fish (1931–2015). Based on the discussions with commercial operators it was assumed that the discarded (and unreported catch) represented 25% of total landed catch (reported and unreported combined). The discarded catch is comprised of smaller elephant fish, usually less than 50 cm FL.
- BT MIX CPUE indices 1989–90 to 2014–15 (26 observations).
- ECSI trawl survey pre-recruit (< 50 cm), recruited (50+ cm) and total biomass estimates from the time series of winter surveys, 30–400 m depth (11 observations).
- ECSI trawl survey length compositions (male and female); winter surveys, 30–400 m depth (11 observations).

- Aggregated length compositions (male and female) of the commercial trawl catch sampled by Scientific Observers during 2009–10.

Additional data are available from the summer ECSI trawl surveys. These data were not included in the analysis as it has previously been concluded that the summer survey series does not represent a reliable index of abundance for elephant fish. In recent years, the winter trawl survey has been extended to include the shallower areas of Canterbury Bight and Pegasus Bay (10–30 m), partly to improve the monitoring of the abundance of elephant fish. However, the time-series of surveys that includes this area is limited (four surveys).

Initial modelling results revealed that the scaled length compositions derived from the winter trawl surveys were highly variable (amongst surveys) and inconsistent with the other key input data sets. Further examination of the length composition data revealed that few elephant fish were caught and sampled during each survey and the scaled length compositions were typically dominated by the sampled catch from a limited number of trawls. The length and sex compositions of these larger catches were highly variable.

On that basis, it was concluded that the survey length compositions were unlikely to be representative of the length composition of the elephant fish population and these data were excluded from the final set of model options. Further, the estimates of trawl survey biomass for pre-recruit (<50 cm) fish are relatively imprecise (CVs 32–83%) and preliminary modelling indicated that these indices were not consistent with the other abundance indices (especially the CPUE indices). Thus, the pre-recruit trawl survey biomass indices were also excluded from the final set of model options.

<u>Model configuration</u>

The final assessment model was configured, as follows.

- Model period 1931–2015, terminal year represents 2014–15 fishing year.
- Age classes 0–19 and 20+ years, two sexes.
- Initial (1931) population age structure assumes equilibrium, unexploited conditions.
- Annual recruitment derived from Beverton and Holt stock-recruitment relationship; R0 parameter estimated (uninformative beta prior) and steepness fixed at 0.6 (base model option), recruitment deviates from SRR estimated for 1989–2013 assuming a SigmaR of 0.6.
- Sexual maturity (female fish) at 70 cm (FL).
- Two commercial fisheries: discard and retained catch. The selectivity of the commercial catch is assumed to be equivalent for the two main fishing methods (BT and SN).
- Commercial length composition data from 2009–10 are partitioned at 50 cm to characterise the length composition of discard (<50 cm) and retained (50+ cm) commercial catches. Both length compositions are assigned a relatively high weighting (ESS 100) to ensure that the model approximates these observations.
- The length-based selectivity of discard commercial fishery is parameterised using a double normal selectivity function (equivalent for both sexes). Selectivity is effectively truncated at about 50 cm (FL).
- Two alternative length-based selectivity options were adopted for the retained commercial fishery with selectivity parameterised using either a logistic or double normal function. Selectivity was allowed to vary by sex.
- The CPUE indices are assumed to represent the relative abundance of the component of the population that is vulnerable to the retained commercial fishery. The CPUE indices were assigned a CV of 20%.
- The ECSI recruited (50+ cm) total biomass estimates were assigned the native CVs from individual surveys. The length-based selectivity of the survey was assumed to be knife edge at 50 cm (FL) with full selectivity for all the larger length intervals.

Model options that assumed a logistic selectivity function for the (retained) commercial fishery resulted in a poor fit to the (retained) commercial length composition for male and female fish (from 2009–10). These models consistently over-estimated the number of larger male (>68 cm FL) and female (>90 cm FL) elephant fish in the commercial catch.

The alternative model option with selectivity parameterised by a double normal function resulted in a substantial improvement in the fit to the commercial length compositions (relative to the logistic selectivity model). The double normal selectivity model estimated selectivity for male and female fish started to rapidly decline above 70 cm and 85 cm FL, respectively. The lower selectivity of larger female fish meant that approximately 40–50% of the mature female population (by weight) is estimated to be invulnerable to the commercial fishery and, consequently, not monitored by the CPUE indices.

Separate model runs were conducted for the two selectivity options, each with three assumed values of SRR steepness: a base level of 0.6 bracketed by values of 0.5 and 0.7. MCMCs were conducted for the six model options. However, the results of the MCMCs were not satisfactory for the model options with the lowest value of steepness and, consequently, only MCMC results for the 0.6 steepness options are reported.

Model results

The overall fit to the CPUE indices was acceptable for all model options. The CPUE indices exhibit a general increase with marked peaks in the early and late 2000s. The models account for these trends by estimating higher recruitments for 1996–1998, 2004, and 2009. As previously noted, the double normal selectivity parameterisation substantially improved the fit to the retained commercial length composition data (compared to logistic selectivity). There was also a marginal improvement in the fit to the CPUE indices with the double normal selectivity.

All model options also estimated an increase in stock abundance that was consistent with the overall increase in the ECSI trawl survey recruited biomass estimates between the 1990s and the more recent period, although the fit to the individual biomass estimates is poor. The quality of the fit is consistent with the relatively low precision of the biomass estimates and the likelihood that the survey vulnerability of elephant fish varies amongst survey years (as indicated by the variability in the length composition of the survey catches).

Two indicators of stock status were derived from the assessment models: current (2014–15) female spawning (=mature) biomass relative to unexploited spawning biomass (SB_{2015}/SB_0), and current spawning biomass relative to the spawning biomass in 1985 (SB_{2015}/SB_{1985}). The latter metric provides an indication of the extent of the stock recovery from the period when the stock was estimated to be at the lowest level.

The MPD results indicate that stock abundance has increased considerably from a low level (approx. 10–20% SB_0) in 1985. The double normal selectivity model runs represent a somewhat more optimistic estimate of the current stock status relative to both SB_0 and SB_{1985}. MPD estimates of stock status tended to be near the lower bound of the MCMC confidence intervals, indicating that the MPD estimates are likely to represent minimum biomass levels consistent with the catch history.

Table 7: Estimates of stock status for the range of commercial selectivity and SRR steepness options (MPD estimates). McMC estimates (median value and 95% confidence interval) are also presented for the two selectivity options with SRR steepness of 0.60.

Selectivity	Steepness		SB_{2015}/SB_0	SB_{2015}/SB_{1985}
Double normal				
	0.6	MPD	0.390	2.99
		MCMC	0.471 (0.266–0.872)	2.86 (2.08–3.97)
	0.7	MPD	0.321	3.77
Logistic				
	0.6	MPD	0.279	2.50
		MCMC	0.386 (0.217–0.651)	2.63 (1.86–3.61)
	0.7	MPD	0.229	3.03

The results are also sensitive to the assumptions regarding SRR steepness. Higher values of steepness correspond to lower estimates of SB_0 and a higher level of depletion by 1985, and while the relative level of recovery from 1985 is higher than for lower steepness options, the current level of stock biomass relative to SB_0 is lower.

The median estimates of SB_{2015}/SB_0 stock status from the MCMCs are more optimistic than the corresponding MPD results for the SRR steepness 0.60 model runs. The MCMC results also reveal that there is considerable uncertainty associated with the estimates of stock status, although the confidence intervals derived from the MCMCs suggest that current biomass is Likely to be above the default soft limit (20% SB_0) and About As Likely as Not to be at or above the default target biomass level (40% SB_0). However, the preliminary nature of the model precludes definitive statements about stock status.

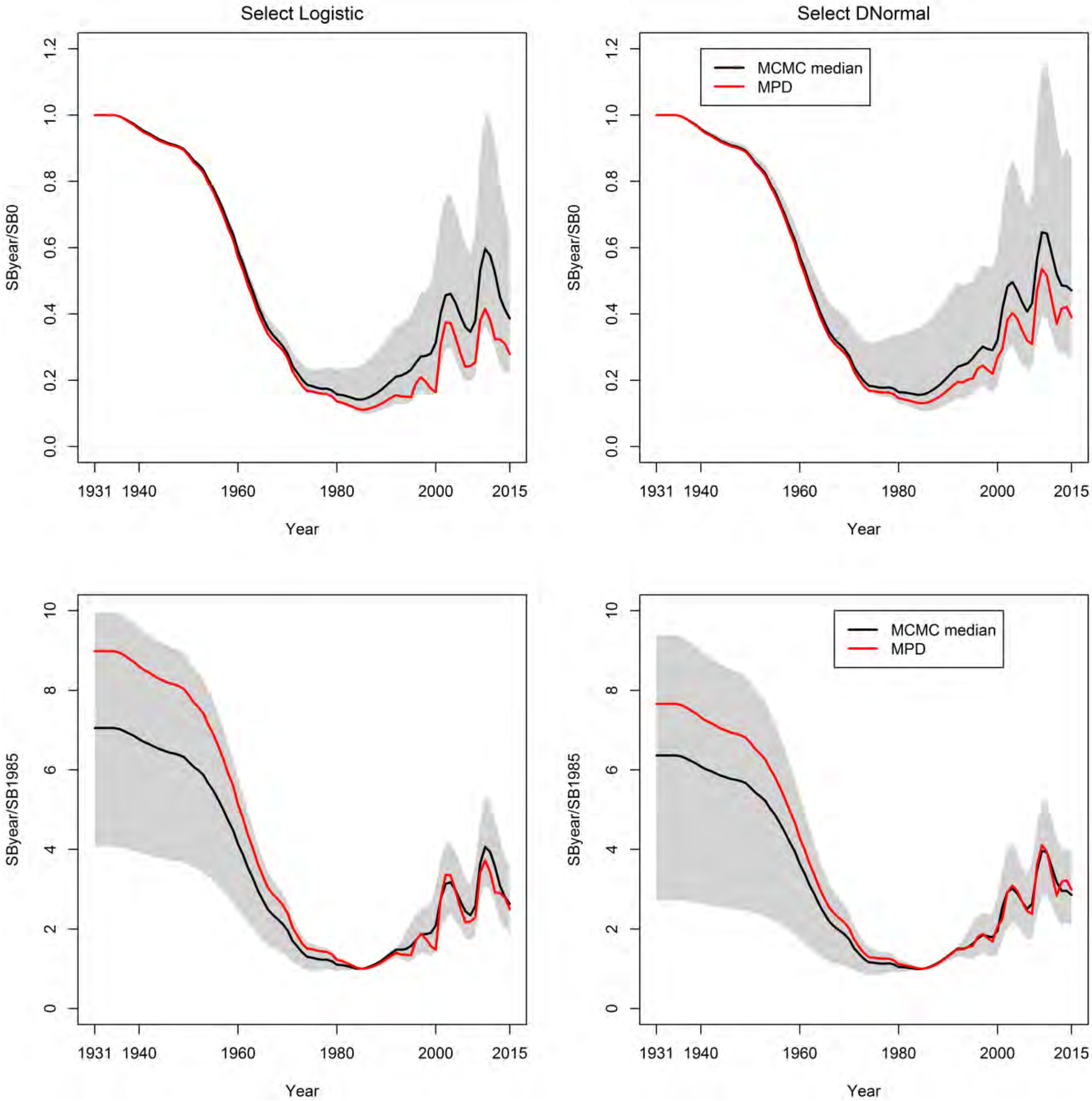


Figure 8: Stock trajectories for the spawning biomass relative to SB_0 (upper panels) and SB_{1985} (lower panels) for logistic (left panels) and double normal (right panels) selectivity options with SRR steepness 0.6. The black line represents the median of the McMCs (with 95% confidence interval) and the red line represents the MPD.

The Southern Inshore Working Group concluded that this preliminary model produced plausible biomass trajectories, but uncertainty about productivity and fits to commercial length data precluded acceptance of the model as a reliable estimator of current stock status.

These conclusions need to be tempered by the possibility that the models may be over-estimating recruitment in the more recent years. This may provide an explanation for the apparent over-estimation of the proportion of larger, older fish in the population in the late 2000s (that were not apparent in the commercial length composition). Conversely, the recent CPUE indices may be biased low (due to apparent avoidance behaviour) and consequently the model may under-estimate the current level of biomass.

Estimates of SB_{2015}/SB_0 stock status are also highly uncertain (and potentially biased) due to the assumptions associated with the estimation of historical, unexploited biomass.

4.3 Yield estimates and projections
No other yield estimates are available.

4.4 Other factors
A data informed qualitative risk assessment was completed on all chondrichthyans (sharks, skates, rays and chimaeras) at the New Zealand scale in 2014 (Ford et al 2015). Elephant fish was ranked fourth highest in terms of risk of the eleven QMS chondrichthyan species. Data were described as existing and sound for the purposes of the assessment and consensus over this risk score was achieved by the expert panel. This risk assessment does not replace a stock assessment for this species but may influence research priorities across species.

5. STATUS OF THE STOCKS

- **ELE 1**

No estimates of current and reference biomass are available.

- **ELE 2**

It is not known if recent catch levels or the current TACC are sustainable. The state of the stock in relation to B_{MSY} is unknown.

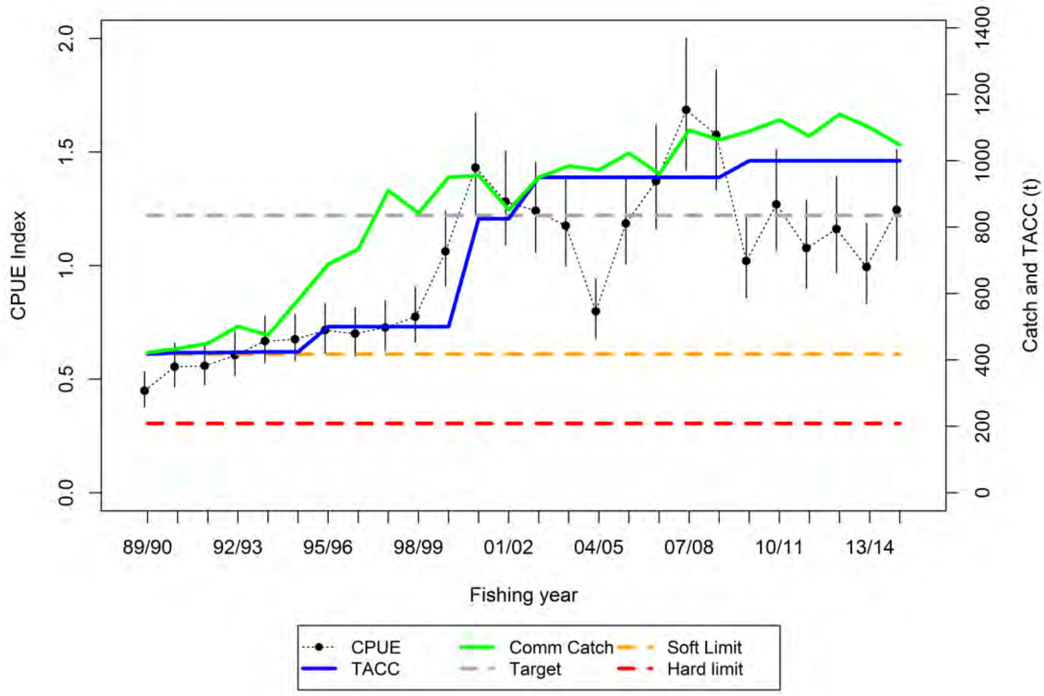
- **ELE 3**

Stock Structure Assumptions
No information is available on the stock separation of elephant fish. The Fishstock ELE 3 is treated in this summary as a unit stock.

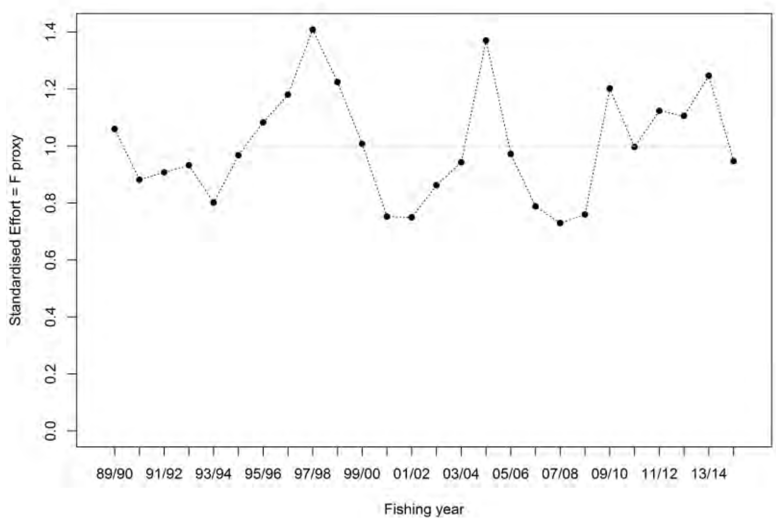
Stock Status	
Year of Most Recent Assessment	2016
Assessment Runs Presented	Update ELE 3 (MIX) CPUE series
Reference Points	Interim target: B_{MSY}-compatible proxy based on CPUE (average from 1998–99 to 2010–11 of the ELE 3(MIX) model as defined in Starr & Kendrick 2013) Soft Limit: 50% of target Hard Limit:25% of target
Status in relation to Target	About as Likely as Not (40–60%) to be at or above the target
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Overfishing is About as Likely as Not (40–60%) to be occurring

Historical Stock Status Trajectory and Current Status

CPUE, Catch and TACC Trajectories



Comparison of the mixed target species bottom trawl CPUE series (ELE 3(MIX)) with the trajectories of catch (ELE 3(QMR/MHR)) and TACCs from 1989–90 to 2014–15. The dashed lines represent the interim target and corresponding soft limit and hard limit.

Fishery and Stock Trends	
Recent trend in Biomass or Proxy	The ELE 3(MIX) CPUE series, which is considered to be an index of stock abundance, showed a generally increasing trend from the beginning to reach a peak in 2007–08. CPUE indices have remained relatively stable below the peak level since 2009–10, remaining near the proposed target.
Recent trend in Fishing Intensity or Proxy	 **Fishing mortality proxy is Standardised Fishing Effort = Total catch/CPUE (normalised). Fishing mortality proxy has fluctuated about the average level and was at about the average in the most recent year.**

Other Abundance Indices	- Although there is high inter-annual variation, the winter ECSI trawl survey index shows a trend that is consistent with the ELE 3(MIX) CPUE index. - Preliminary stock assessment modelling for ELE 3 estimates that the stock abundance has increased substantially from a low level in the 1980s. The assessment models indicate that current biomass levels are probably at or about the default target biomass levels.
Trends in Other Relevant Indicator or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Quantitative stock projections are unavailable.
Probability of Current Catch or TACC causing decline Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Very Unlikely (< 10%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	The TACC and current reported catches are About as Likely as Not (40–60%) to cause overfishing.

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Evaluation of agreed standardised CPUE indices which reflect changes in abundance.	
Assessment Dates	Latest assessment: 2016	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality. The Southern Inshore Working Group agreed that the ELE 3(MIX) CPUE index was a credible measure of abundance.	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	- Compass Rose trawl survey data - Summer ECSI trawl survey data and winter ECSI trawl survey data - Set net CPUE (shark)	3 – Low Quality: insufficient data 2 – Medium or Mixed Quality: variable catchability / selectivity between years 3 – Low Quality: Index compromised by area closures
Changes to Model Structure and Assumptions	None since 2012 assessment	
Major Sources of Uncertainty	- It is possible that fisher avoidance and discarding have biased (low) the CPUE trends reported for this fishery.	

Qualifying Comments

- Elephant fish have shown good recovery since apparently being at low biomass levels in the mid-1980s.
- Preliminary stock assessment modelling results are consistent with assumed level of stock rebuilding, primarily reflecting the increase in the CPUE abundance indices. However, there are considerable uncertainties associated with key biological parameters (natural mortality and growth) and conflict amongst the main input data sets. The modelling results are not considered to be amply reliable to estimate current stock status (relative to MSY levels) and potential yields for the stock. With respect to the conceptual B_{msy} proxy, the Plenary had concerns about the reliability of this as a proxy and advised that it only be used in the interim.
- Historical catches may be poorly estimated. Both current and historical estimates of landings exclude fish discarded at sea and the quantum of discards is unknown. Management interventions since the stock was introduced into the QMS may have influenced the rate of discarding and therefore the reliability of CPUE as a measure of relative abundance.

Fishery Interactions
Elephant fish in ELE 3 are taken as bycatch by bottom trawl fisheries targeting red cod, flatfish and barracouta. Targeting elephant fish in the bottom trawl fishery has increased to around 40% of the landings since 2004–05 when the deemed value regime changed. Around 15% of the ELE 3 landings are taken by setnet in a fishery targeted at a number of shark species, including rig, elephant fish, spiny dogfish and school shark. Both the trawl and setnet fisheries have been subject to management measures designed to reduce interactions with endemic Hector's dolphins. Bottom trawl fishers also have not trawled within one nautical mile of the coast (since 2001) in an effort to preserve ELE egg cases. This may have reduced juvenile and egg mortality in shallow water. Interactions with other species are currently being characterised.

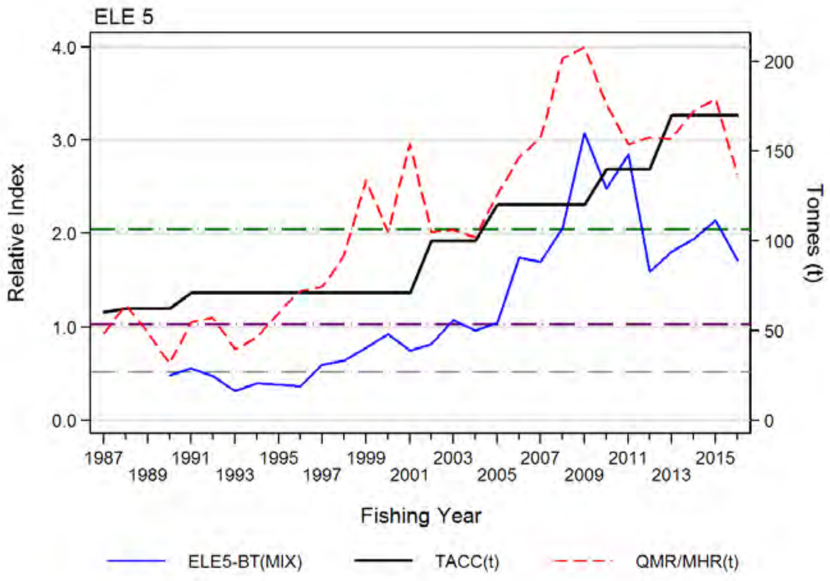
- **ELE 5**

Stock Structure Assumptions

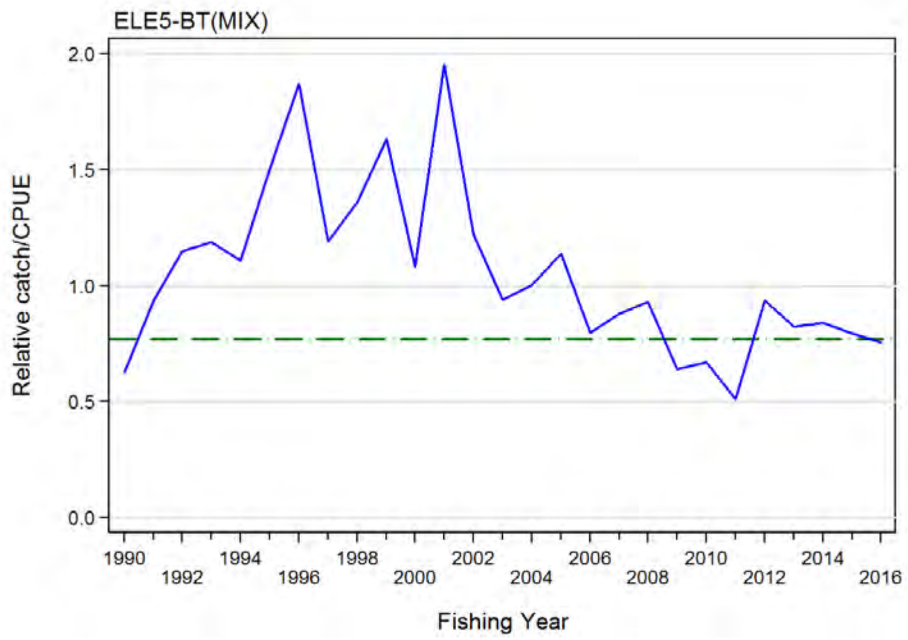
No information is available on the stock separation of elephant fish. The Fishstock ELE 5 is treated in this summary as a unit stock.

Stock Status	
Year of Most Recent Assessment	2017
Assessment Runs Presented	Standardised bottom trawl CPUE series based on mixed target species: combined delta-lognormal series
Reference Points	Target: B_{MSY}-compatible proxy based on mean ELE5-BT(MIX) standardised CPUE: 2005–06 to 2015–16 Soft Limit: 50% of Bmsy proxy Hard Limit: 25% of Bmsy proxy Overfishing threshold: Mean annual relative exploitation rate for the period: 2005–06 to 2015–16
Status in relation to Target	About as Likely as Not (40-60%) to be at or above Bmsy
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Overfishing is About as Likely as Not (40–60%) to be occurring

Historical Abundance and Catch Trajectories



Comparison of the ELE 5-BT(MIX) CPUE series with the TACC and QMR/MHR landings for ELE 5 The agreed B_{MSY} proxy (geometric average: 2006–2016 ELE 5-BT(MIX) CPUE indices=2.051) is shown as a green line; the calculated Soft Limit (=0.5xB_{MSY} proxy) is shown as a purple line; the calculated Hard Limit (=0.25xB_{MSY} proxy) is shown as a grey line.



Relative fishing pressure for ELE 5 based on the ratio of QMR/MHR landings relative to the ELE5-BT(MIX) CPUE series which has been normalised so that its geometric mean=1.0. Horizontal green line is the geometric mean fishing pressure from 2006 to 2016.

Fishery and Stock Trends	
Recent trend in Biomass or Proxy	The ELE 5 (MIX) CPUE series increased up to a peak in 2008–09, dropped sharply in 2011–12 and has fluctuated without trend close to the target since then.
Recent Trend in Fishing Mortality or Proxy	Fishing mortality proxy has remained relatively stable or declining over the last 10 years.
Other Abundance Indices	-
Trends in Other Relevant Indicator or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch and TACC causing biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Very Unlikely (< 10%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Current Catch: About as Likely as Not (40–60%) TACC: About as Likely as Not (40–60%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Evaluation of agreed standardised CPUE indices	
Assessment Dates	Latest assessment: 2017	Next assessment: 2020
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- ELE 5 BT(MIX) CPUE series	1 – High Quality
Data not used (rank)	- Length frequency data summarised from setnet logbooks compiled under the industry Adaptive Management Programme	3 – Low Quality: data sparse and outdated
Changes to Model Structure and Assumptions	Addition of a binomial index to produce a combined CPUE series	

Major Sources of Uncertainty	It is possible that discarding and management changes (including changes in deemed values) in this fishery has affected CPUE estimates.

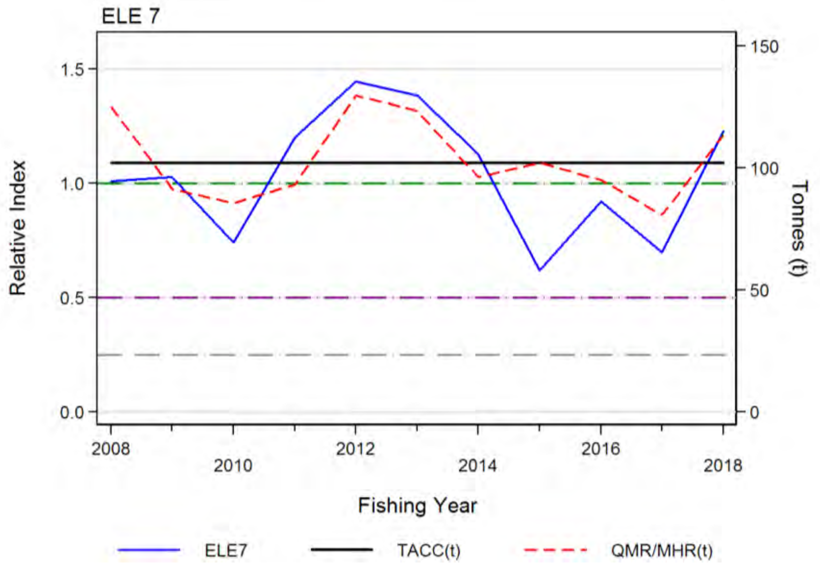
Qualifying Comments
Elephant fish have shown strong recovery since apparently being at low biomass levels in the mid-1980s. The historical catches may be poorly estimated. Both current and historical estimates of landings exclude fish discarded at sea and the quantum of discards is unknown. Confidence intervals for combined CPUE indices are not available.

Fishery Interactions
Elephant fish in ELE 5 are taken by bottom trawl in fisheries targeted at flatfish and stargazer. Targeting elephant fish in the bottom trawl fishery was low (average 14% from 1989–90 to 2015–16) but has increased to 19% of the landings since 2002–03. Around 12% of the ELE 5 landings are taken by setnet in a fishery targeted at rig and school shark. Incidental captures of seabirds and great white sharks occur, and there is a possibility of incidental capture of Hector's dolphins. However, both the trawl and setnet fisheries have been subject to management measures designed to reduce interactions with endemic Hector's dolphins. Interactions with other species are currently being characterised.

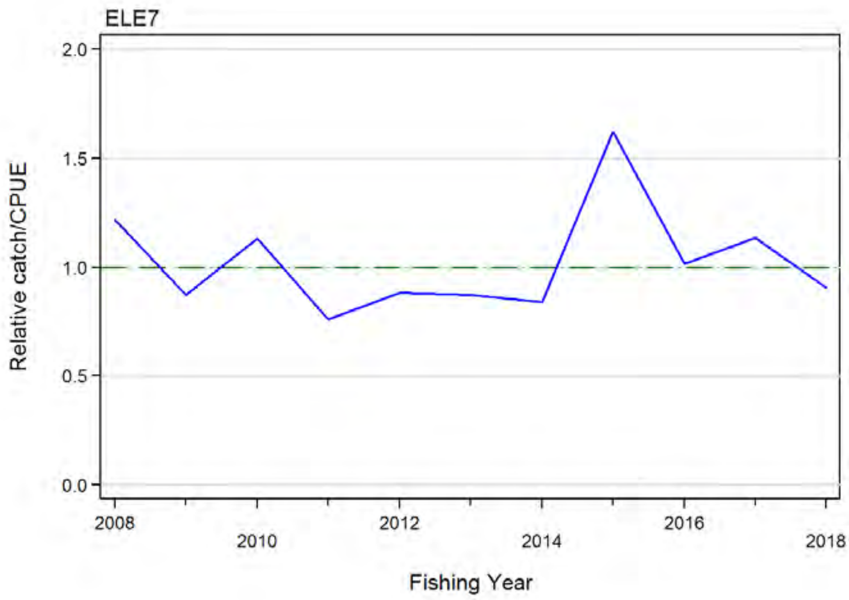
- **ELE 7**

Stock Status	
Year of Most Recent Assessment	2019
Assessment Runs Presented	ELE 7 tow-by-tow bottom trawl mixed target species standardised CPUE
Reference Points	Interim target: B_{MSY} proxy based on the mean of the CPUE series for the period: 2007–08 to 2017–18 Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: : Mean annual relative exploitation rate for the period: 2007–08 to 2017–18
Status in relation to Target	About as Likely as Not (40-60%) to be at or above B_{MSY}
Status in relation to Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Very Unlikely (< 10%)
Status in relation to Overfishing	Overfishing is About as Likely as Not (40–60%) to be occurring

Historical Stock Status Trajectory and Current Status



Comparison of the ELE 7-BT(tow-by-tow) CPUE series with the TACC and QMR/MHR landings for ELE 7. The agreed B_{MSY} proxy (geometric average: 2008–2018 ELE 7-BT(tow-by-tow) CPUE indices=1.0) is shown as a green line; the calculated Soft Limit (=0.5xB_{MSY} proxy) is shown as a purple line; the calculated Hard Limit (=0.25xB_{MSY} proxy) is shown as a grey line.



Relative fishing pressure for ELE 7 based on the ratio of QMR/MHR landings relative to the ELE7-BT(tow-by-tow) CPUE series which has been normalised so that its geometric mean=1.0. Horizontal green line is the geometric mean fishing pressure from 2007–08 to 2017–18.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE was high from 2010–11 to 2012–13 followed by a period of low CPUE from 2014–15 to 2016–17. The 2017–18 CPUE was above the series mean.
Recent Trend in Fishing Intensity or Proxy	Relative exploitation rate has fluctuated about the series mean and in 2017-18 was lower than the overfishing threshold.
Other Abundance Indices	Trawl survey biomass trends for this stock are unreliably estimated by the West Coast South Island survey. However, recent biomass estimates have been relatively high compared to the long term average.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Relative biomass is predicted to continue to fluctuate around the target level at the current catch.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Unlikely (< 40%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Current catches and the current TACC are About as Likely as Not (40–60%) to cause overfishing.

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE index and relative biomass estimates from inshore WCSI trawl survey	
Assessment dates	Latest assessment: 2019	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Standardised CPUE (tow-by-tow) (from 2007–08)	1 – High Quality: The SINSWG had confidence in this part of the CPUE index as a credible measure of abundance 2 – Medium or Mixed

	- Standardised CPUE (MIX) (pre 2007–08)	Quality: less catch (data) and lack of spatial resolution
Data not used (rank)	- Biomass estimates from inshore WCSI trawl survey	2 – Medium or Mixed Quality: low precision and high variability
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- It is possible that discarding and management changes in this fishery have biased the CPUE trends to be low.	

Qualifying Comments
The pre-QMS catches are not well reported. Both current and historical estimates of landings exclude fish discarded at sea and the quantum of discards is unknown.

Fishery Interactions
Trawl target sets for ELE 7 tend to be in shallow water mostly around 25 m. Elephant fish are landed with rig, school shark and spiny dogfish in setnets and in bottom trawls as bycatch in flatfish and red cod target sets. Incidental captures of seabirds occur and there is a possibility of incidental capture of Hector's dolphins. Interactions with other species are currently being characterised.

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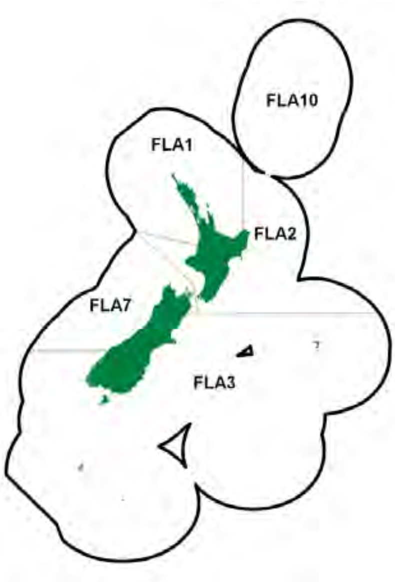
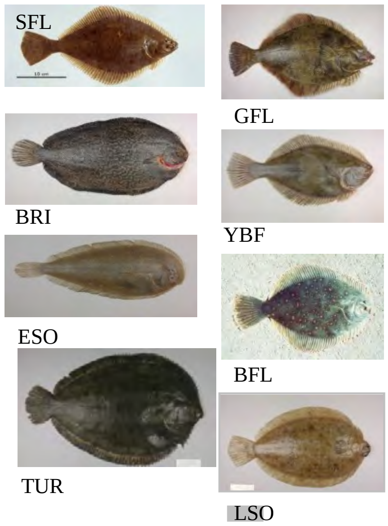
FLATFISH (FLA)

(*Colistium nudipinnis*, *Peltorhamphus novaezelandiae*, *Colistium guntheri*, *Rhombosolea retiaria*, *Rhombosolea plebeia*, *Rhombosolea leporina*, *Rhombosolea tapirina*, *Pelotretis flavilatus*)
Patiki





1. FISHERY SUMMARY

1.1 Commercial fisheries

Flatfish Individual Transferable Quota (ITQ) provides for the landing of eight species of flatfish in the QMS. These are: the yellowbelly flounder, *Rhombosolea leporine* (YBF); sand flounder, *Rhombosolea plebeian* (SFL); black flounder, *Rhombosolea retiaria* (BFL); greenback flounder, *Rhombosolea tapirina* (GFL); lemon sole, *Pelotretis flavilatus* (LSO); New Zealand sole, *Peltorhamphus novaezeelandiae* (ESO); brill, *Colistium guntheri* (BRI); and turbot, *Colistium nudipinnis* (TUR). For management purposes landings of these species are combined.

Flatfish are shallow water species, taken mainly by target inshore trawl and Danish seine fleets around the South Island. Setnet and drag net fishing are important in the northern harbours and the Firth of Thames. Important fishing areas are:

Yellowbelly flounder	Firth of Thames, Kaipara, and Manukau harbours;
Sand flounder	Hauraki Gulf, Tasman Bay/Golden Bay, Bay of Plenty, Canterbury Bight, and Te Wae Wae Bay;
Greenback flounder	Canterbury Bight, Southland;
Black flounder	Canterbury Bight;
Lemon sole	west coast South Island, Otago, and Southland;
New Zealand sole	west coast South Island, Otago, Southland, and Canterbury Bight;
Brill and turbot	west coast South Island.

TACCs were originally set at the level of the sum of the provisional ITQs for each fishery. Between 1983–84 and 1992–93 total flatfish landings fluctuated between 2750 t and 5160 t; from 1992–93 to 1997–98, landings were relatively consistent, between about 4500 t and 5000 t per year. Landings declined to 2963 t in 1999–00, the lowest recorded since 1986–87, before increasing to a peak of 4051 t for the 2006–07 fishing year. Landings thereafter declined to just 1939 t in 2018–19, the lowest landings recorded since 1975. Historical estimated and recent reported flatfish landings and TACCs are shown in Tables 1 and 2, and Figure 1 shows the historical landings and TACC values for the main FLA QMAs.

Flatfish TACCs were first introduced in the fishing year 1986-87. After some minor increases TACCs remained unchanged for all FLA Fishstocks until the 1st October 2007, when a TAC and allowances were set for the first time in FLA 3. The FLA 3 TACC was reduced by 47% to 1430 t and a management procedure (MP) that recommended an in-season increase in the commercial catch allowance if supported by early CPUE data was implemented (see section 4.3 for a description of this procedure – this MP has been suspended, beginning in 2019–20). All FLA fisheries have been listed in Schedule 2 of the Fisheries Act 1996. Schedule 2 allows that, for certain "highly variable" stocks, the Total Annual Catch (TAC) can be increased within a fishing season. Increased commercial catch is provided for through the creation of additional 'in-season' ACE. The base TACC is not changed by this process and the "in-season" TAC reverts to the original level at the end of each season. The FLA 3 management procedure (section 4.3) is an implementation of this form of management. Landings have remained well below the TACC for FLA 1, FLA 2, and FLA 7, and the TACC for FLA 1 was reduced to 890 t for the fishing year 2018–19.

From 1 October 2008, a suite of regulations intended to protect Mauī and Hector's dolphins was implemented for all of New Zealand by the Minister of Fisheries. Commercial and recreational set netting were banned in most areas to 4 nautical miles offshore of the east coast of the South Island, extending from Cape Jackson in the Marlborough Sounds to Slope Point in the Catlins. Some exceptions were allowed, including an exemption for commercial and recreational set netting to only one nautical mile offshore around the Kaikoura Canyon, and permitting set netting in most harbours, estuaries, river mouths, lagoons, and inlets, except for the Avon-Heathcote Estuary, Lyttelton Harbour, Akaroa Harbour, and Timaru Harbour. In addition, trawl gear within 2 nautical miles of shore was restricted to flatfish nets with defined low headline heights. The commercial minimum legal size for sand flounder is 23 cm, and for all other flatfish species is 25 cm.

Table 1: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	FLA 1	FLA 2	FLA 3	FLA 7	Year	FLA 1	FLA 2	FLA 3	FLA 7
1931–32	767	290	219	265	1957	308	64	529	183
1932–33	958	219	61	276	1958	362	59	989	321
1933–34	698	277	181	346	1959	362	48	971	382
1934–35	708	203	83	195	1960	410	58	1257	361
1935–36	686	118	57	209	1961	386	102	665	273
1936–37	438	127	139	139	1962	383	156	584	228
1937–38	570	125	380	123	1963	352	106	627	228
1938–39	717	83	639	94	1964	499	134	879	350
1939–40	721	128	448	83	1965	599	109	917	518
1940–41	1004	180	494	101	1966	547	222	1141	496
1941–42	943	139	622	139	1967	646	231	1273	493
1942–43	591	192	594	154	1968	541	139	973	311
1943–44	669	89	606	172	1969	686	193	936	269
1944	441	104	783	78	1970	557	262	1027	471
1945	435	104	984	83	1971	407	149	1028	276
1946	392	168	1264	146	1972	475	114	548	166
1947	551	99	1685	198	1973	438	149	717	442
1948	433	93	1494	214	1974	503	147	637	748
1949	412	76	1473	202	1975	431	156	598	476
1950	284	31	1446	176	1976	548	132	802	929
1951	308	62	1178	135	1977	764	255	916	1165
1952	349	94	1117	166	1978	706	202	1730	1225
1953	349	149	1510	197	1979	742	287	1962	899
1954	376	112	1184	213	1980	906	219	1562	459
1955	377	125	913	248	1981	1082	760	1369	399
1956	308	106	772	190	1982	934	650	1214	468

1. The 1931–1943 years are April–March but from 1944 onwards are calendar years. .
2. Data up to 1985 are from fishing returns: data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data includes both foreign and domestic landings.

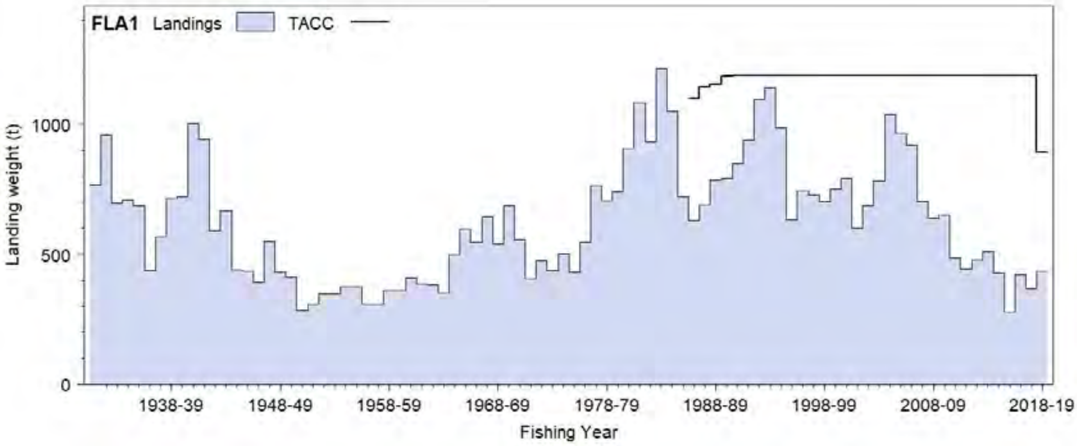
Table 2: Reported landings (t) of flatfish by Fishstock from 1983–84 to present and actual TACCs (t) from 1986–87 to present. QMS data from 1986–present. [Continued on next page]

Fishstock	FLA 1		FLA 2		FLA 3		FLA 7		FLA 10			
FMA (s)	1 & 9		2 & 8		3, 4, 5 & 6		7		10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84*	1 215	–	378	–	1 564	–	1 486	–	0	–	5 160	–
1984–85*	1 050	–	285	–	1 803	–	951	–	0	–	4 467	–
1985–86*	722	–	261	–	1 537	–	385	–	0	–	‡3 215	–
1986–87	629	1 100	323	670	1 235	2 430	563	1 840	0	10	‡2 750	6 050
1987–88	688	1 145	374	677	2 010	2 535	1 000	1 899	0	10	‡4 072	6 266
1988–89	787	1 153	297	717	2 458	2 552	757	2 045	0	10	4 299	6 477
1989–90	791	1 184	308	723	1 637	2 585	745	2 066	0	10	3 482	6 568
1990–91	849	1 187	292	726	1 340	2 681	502	2 066	0	10	2 983	6 670

Table 2 [Continued]

Fishstock	FLA 1		FLA 2		FLA 3		FLA 7		FLA 10			
FMA (s)	1 & 9		2 & 8		3, 4, 5 & 6		7		10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1991–92	940	1 187	288	726	1 229	2 681	745	2 066	0	10	3 202	6 670
1992–93	1 106	1 187	460	726	1 954	2 681	1 566	2 066	0	10	5 086	6 670
1993–94	1 136	1 187	435	726	1 926	2 681	1 108	2 066	0	10	4 605	6 670
1994–95	964	1 187	543	726	1 966	2 681	1 107	2 066	0	10	4 580	6 670
1995–96	628	1 187	481	726	2 298	2 681	1 163	2 066	1	10	4 571	6 670
1996–97	741	1 187	363	726	2 573	2 681	1 117	2 066	0	10	4 794	6 670
1997–98	728	1 187	559	726	2 351	2 681	1 020	2 066	0	10	4 657	6 670
1998–99	690	1 187	274	726	1 882	2 681	868	2 066	0	10	3 714	6 670
1999–00	751	1 187	212	726	1 583	2 681	417	2 066	0	10	2 963	6 670
2000–01	792	1 187	186	726	1 702	2 681	447	2 066	0	10	3 127	6 670
2001–02	596	1 187	177	726	1 693	2 681	614	2 066	0	10	3 080	6 670
2002–03	686	1 187	144	726	1 650	2 681	819	2 066	0	10	3 299	6 670
2003–04	784	1 187	218	726	1 286	2 681	918	2 066	0	10	3 206	6 670
2004–05	1 038	1 187	254	726	1 353	2 681	1 231	2 066	0	10	3 876	6 670
2005–06	964	1 187	296	726	1 177	2 681	1 283	2 066	0	10	3 720	6 670
2006–07	922	1 187	296	726	1 429	2 681	1 419	2 066	0	10	4 066	6 670
2007–08	703	1 187	243	726	1 365	1 430	1 313	2 066	0	10	3 624	5 419
2008–09	639	1 187	214	726	1 544	**1 780	1 020	2 066	0	10	3 417	5 419
2009–10	652	1 187	212	726	1 525	**1 763	884	2 066	0	10	3 273	5 835
2010–11	486	1 187	296	726	1 027	1 430	659	2 066	0	10	2 467	5 509
2011–12	445	1 187	262	726	1 507	1 430	646	2 066	0	10	2 861	5 419
2012–13	480	1 187	274	726	1 512	**1 727	526	2 066	0	10	2 792	5 716
2013–14	511	1 187	216	726	1 377	1 430	568	2 066	0	10	2 672	5 419
2014–15	426	1 187	166	726	1 231	1 430	640	2 066	0	10	2 464	5 419
2015–16	277	1 187	238	726	1 622	**1 650	656	2 066	0	10	2 792	5 639
2016–17	421	1 187	136	726	1 421	*#2 065	873	2 066	0	10	2 851	6 054
2017–18	367	1 187	108	726	886	1 430	651	2 066	0	10	2 014	5 419
2018–19	436	890	82	726	968	1 430	454	2 066	0	10	1 939	5 122

* FSU data.
‡ Includes 11 t Turbot, area unknown but allocated to QMA 7.
§ Includes landings from unknown areas before 1986–87.
** Commercial catch allowance increased with additional 'in-season' ACE provided under S68 of Fisheries Act 1996
*# The increase in commercial catch under S68 of Fisheries Act 1996 was not approved until late August 2017



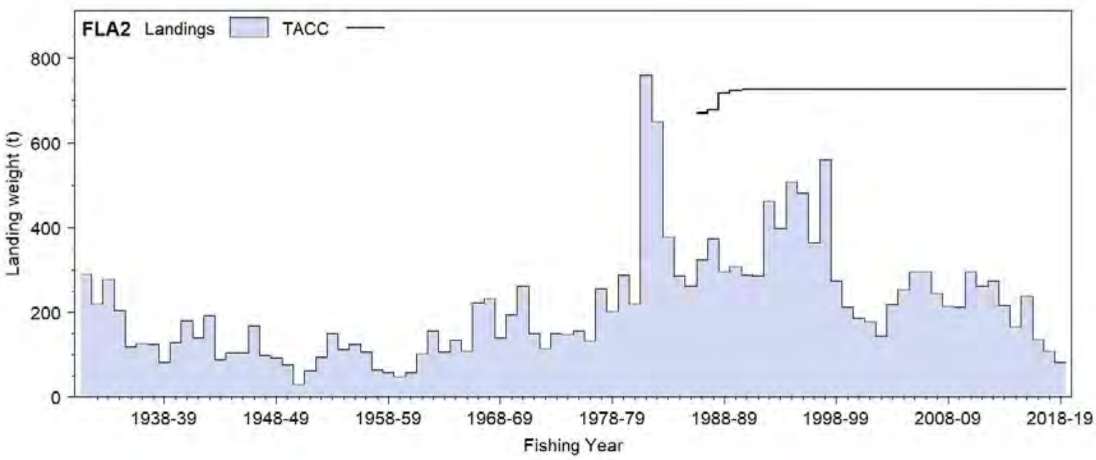
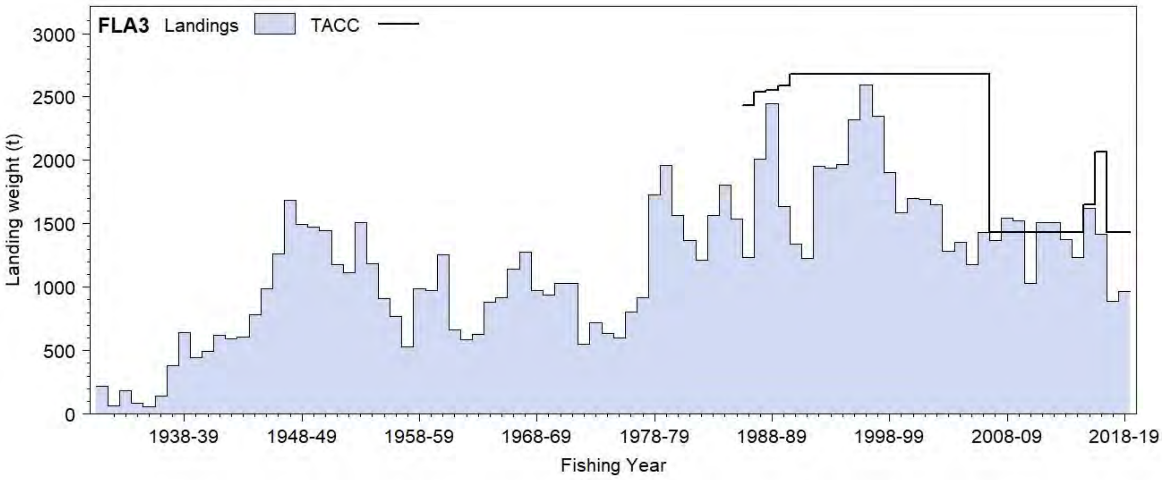


Figure 1: Historical landings and TACC for the four main FLA stocks. FLA 1 (Auckland) and FLA 2 (Central). [Continued on next page]



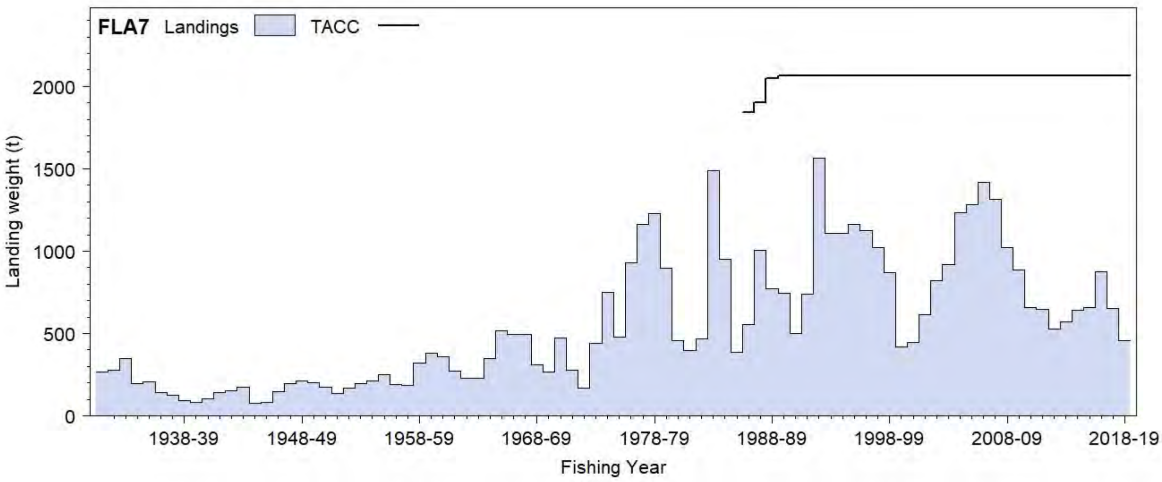


Figure 1 [Continued]: Historical landings and TACC for the four main FLA stocks. FLA 3 (South East Coast, South East Chatham Rise, Sub-Antarctic, Southland FLA 7 (West Coast South Island).

Fishers and processors are required to use a generic flatfish (FLA) code in the monthly harvest returns to report landed catches of flatfish species as well as in the landings section of the catch and effort forms. Fishers have been expected to use the specific flatfish species code when reporting estimated catches of flatfish since the 1990–91 fishing year. However, there is no penalty if fishers use the generic "FLA" code, so reporting by species has been inconsistent across years and FLA QMAs. Starr & Kendrick (2019b) found that very few FLA 1 fishers reported species-specific catch. Bentley (2009, 2010), when initially developing the FLA 3 MP, introduced the concept of "splitters", where derived species composition estimates were based on vessels which consistently reported estimated catches using species-specific species codes and avoided using the generic FLA code. Starr & Kendrick (2018) investigated four different definitions of "splitters", demonstrating all were roughly equivalent, but settled on the "trip splitter" definition, where every trip which did not use the FLA code for estimated catches but which landed FLA, was used. They showed that this definition maximised the proportion of the total landings included in the splitter category, which varied between 42 and 77% for FLA 3 and 24 to 80% for FLA 7 (Figure 2). The percentage distribution of species-specific catch for FLA 3 and FLA 7, based on "trip splitter" trips, is presented in Table 3.

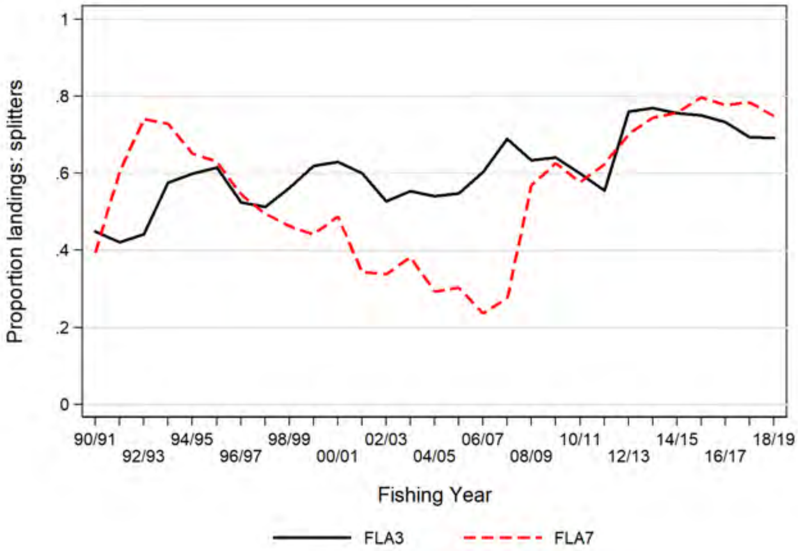


Figure 2: Proportion of annual landings represented by "splitter" trips in FLA 3 and FLA 7, where splitter trips are defined as those which reported FLA landings but did not use the generic FLA code to report estimated catches. FLA 3 annual percentages reported by Starr & Kendrick (2020a) and for FLA 7 by Starr & Kendrick (2020b).

Table 3: Percent flatfish catch by species in FLA 3 and FLA 7 for "splitter" trips, which are trips which landed FLA but which did not use the generic FLA code in the estimated catch section of the catch/effort form. Trip estimated catches by species were scaled to the total FLA landings for the trip and summed for the period 1990–91 to 2018–19 (see Figure 2 for annual time series of splitter trips in FLA 3 and FLA 7).

Species code	Common name	FLA 3 (%)[1]	FLA 7 (%)[2]
BFL	Black Flounder	3.6	0.3
BOT	Lefteyed Flounders	<0.01	0
BRI	Brill	3.0	5.7
ESO	N.Z. Sole	27.6	35.8
GFL	Greenback Flounder	1.3	3.6
LSO	Lemon Sole	43.3	5.4
MAN	Finless Flounder	<0.01	<0.01
SDF	Spotted Flounder	<0.01	0
SFL	Sand Flounder	14.7	33.7
SLS	Slender Sole	<0.01	<0.01
TUR	Turbot	1.3	11.2
WIT	Witch	0.8	0.3
YBF	Yellowbelly Flounder	4.3	3.9

[1]Starr & Kendrick (2020a); [2]Starr & Kendrick (2020b)

1.2 Recreational fisheries

There are important recreational fisheries, mainly for the four flounder species, in most harbours, estuaries, coastal lakes. and coastal inlets throughout New Zealand. The main methods are set netting, drag netting (62.8% combined), and spearing (36.1%) (Wynne-Jones et al 2014). In the northern region, important areas include the west coast harbours, the lower Waikato, the Hauraki Gulf, and the Firth of Thames. In the Bay of Plenty, Ohiwa and Tauranga harbours are important. In the Challenger FMA, there is a moderate fishery in Tasman Bay and Golden Bays and in areas of the Mahau-Kenepuru Sound and in Cloudy Bay. In the South-East and Southland FMAs, flatfish are taken in areas such as Lake Ellesmere, inlets around Banks Peninsula and the Otago Peninsula, the Oreti and Riverton estuaries, Bluff Harbour, and the inlets and lagoons of the Chatham Islands (for further details see the 1995 Plenary Report).

1.2.1 Management controls

The main method used to manage recreational harvests of flatfish are minimum legal sizes (MLS) and daily bag limits. General spatial and method restrictions also apply, particularly to the use of set nets. The flatfish MLS for recreational fishers is 25 cm for all species except sand flounder for which the MLS is 23 cm. Fishers can take up to 20 flatfish as part of their combined daily bag limit in the

Auckland, Central, and Challenger Fishery Management Areas. Fishers can take up to 30 flatfish as part of their combined daily bag limit in the South-East, Kaikoura, Fiordland, and Southland Fishery Management Areas.

1.2.2 Estimates of recreational harvest

There are two broad approaches to estimating recreational fisheries harvest: the use of onsite or access point methods where fishers are surveyed or counted at the point of fishing or access to their fishing activity; and, offsite methods where some form of post-event interview and/or diary are used to collect data from fishers.

The first estimates of recreational harvest for flatfish were calculated using an offsite regional telephone/diary survey approach. Estimates for 1996 came from a national telephone-diary survey (Bradford 1998). Another national telephone-diary survey was carried out in 2000 (Boyd & Reilly 2005). The harvest estimates provided by telephone/diary surveys between 1993 and 2001 are no longer considered reliable for various reasons. A Recreational Technical Working Group concluded that these harvest estimates should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries. In response to these problems and the cost and scale challenges associated with onsite methods, a National Panel Survey was conducted for the first time throughout the 2011–12 fishing year. The panel survey used face-to-face interviews of a random sample of 30 390 New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and harvest information collected in standardised phone interviews. The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly comparable results (Wynne-Jones et al 2019). Recreational catch estimates from the two national panel surveys are given in Table 4. Note that national panel survey estimates do not include recreational harvest taken under s111 general approvals.

Table 4: Estimated number and weight of flatfish, by Fishstock and survey, harvested by recreational fishers. Surveys were carried out in different years in the Fisheries regions: South in 1991–92, Central 1992–93, North 1993–94 (Teirney et al 1997) and nationally in 1996 (Bradford 1998) and 1999–00 (Boyd & Reilly 2005). (– Data not available). National panel surveys (Wynne-Jones et al 2014, 2019) were conducted 1 October to 30 September and used mean weights for flatfish from boat ramp surveys (Hartill & Davey 2015, Davey et al 2019).

Fishstock	Survey	Number	CV	Harvest range (t)	Point estimate (t)
1991–92					
FLA 1	South	3 000	–	–	
FLA 3	South	15 200	0.31	50–90	
FLA 7	South	3 000	–	–	
1992–93					
FLA 1	Central	6 100	–	–	
FLA 2	Central	73 000	0.26	20–40	
FLA 7	Central	37 100	0.59	10–30	
1993–94					
FLA 1	North	520 000	0.19	225–275	
FLA 2	North	3 000	–	0–5	
1996					
FLA 1	National	308 000	0.11	95–125	110
FLA 2	National	67 000	0.19	13–35	24
FLA 3	National	113 000	0.14	30–50	40
FLA 7	National	44 000	0.18	10–20	16
1999–00					
FLA 1	National	702 000	0.25	203–336	–
FLA 2	National	380 000	0.49	82–238	–
FLA 3	National	395 000	0.33	128–252	–
FLA 7	National	114 000	0.53	23–73	–
2011–12					
FLA 1	Panel	64 999	0.37	–	27.2
FLA 2	Panel	12 885	0.31	–	5.4
FLA 3	Panel	53 475	0.31	–	21.7
FLA 7	Panel	12 259	0.37	–	4.7
2017–18					
FLA 1	Panel	37 289	0.28	–	15.2
FLA 2	Panel	22 324	0.41	–	9.1
FLA 3	Panel	23 316	0.38	–	9.5
FLA 7	Panel	12 930	0.43	–	5.3

1.3 Customary non-commercial fisheries
Quantitative information on the current level of customary non-commercial catch is not available.

1.4 Illegal catch
There is no quantitative information on the current level of illegal catch available.

1.5 Other sources of mortality
The extent of unrecorded fishing mortality is unknown.

2. BIOLOGY

Some New Zealand flatfish species are fast-growing and short-lived, generally only surviving to 3–4 years of age, with very few reaching 5–6 years. Others, such as brill and turbot, are longer lived, reaching a maximum age of 21 years and 16 years, respectively (Stevens et al 2001). However, these estimates have yet to be fully validated. Size limits (set at 25 cm for most species) are generally at or above the size at which the fish reach maturity and confer adequate protection to the juveniles.

Available biological parameters relevant to stock assessment are shown in Table 5. The estimated parameters in sections 1 and 3 of the table apply only to sand flounder in Canterbury and brill and turbot in west coast South Island — growth patterns are likely to be different for these species in other areas and for other species of flatfish.

Table 5: Estimates of biological parameters for flatfish.

Fishstock	Estimate	Source
1. Natural mortality (M)		
Brill - West coast South Island (FLA 7)	0.20	Stevens et al (2001)
Turbot - West coast South island (FLA 7)	0.26	Stevens et al (2001)
Sand flounder - Canterbury (FLA 3)	1.1–1.3	Colman (1978)
Lemon sole - West coast South island (FLA 7)	0.62–0.96	Gowing et al (unpub.)

2. Weight = a(length)^b (Weight in g, length in cm total length).

	Females		Males		
	a	b	a	b	
Brill (FLA 7)	0.01443	2.9749	0.02470	2.8080	Hickman & Tait (unpub.)
Turbot (FLA 7)	0.00436	3.3188	0.00571	3.1389	Hickman & Tait (unpub.)
Sand flounder (FLA 1)	0.03846	2.6584	-	-	McGregor et al (unpub.)
Yellowbelly flounder (FLA 1)	0.07189	2.5117	0.00354	3.3268	McGregor et al (unpub.)
New Zealand sole (FLA 3)	0.03578	2.6753	0.007608	3.0728	McGregor et al (unpub.)

3. von Bertalanffy growth parameters

	Females			Males			
	L_∞	k	t_0	L_∞	k	t_0	
Brill							
West coast South Island (FLA 7)	43.8	0.10	–15.87	38.4	0.37	38.4	Stevens et al (2001)
Turbot							
West coast South island (FLA 7)	57.1	0.39	0.30	49.2	0.34	49.2	Stevens et al (2001)
Sand flounder							
Canterbury (FLA 3)	59.9	0.23	–0.083	37.4	0.781	37.4	Mundy (1968), Colman (1978)
Lemon sole							
West coast South island (FLA 7)	26.1	1.29	–0.088	25.6	1.85	25.6	Gowing et al (unpub.)
Greenback flounder (FLA 5)	55.82	0.26	–1.06	52.21	0.25	–1.32	Sutton et al (2010)

Sutton et al (2010) undertook an age and growth analysis of greenback flounder. That analysis showed that growth is rapid throughout the lifespan of greenback flounder. Females reached a slightly greater maximum length than males, but the difference was not significant at the 95% level of confidence. Over 90% of sampled fish were 2 or 3 years of age, with maximum ages of 5 and 10 years being obtained for male and female fish respectively. This difference in maximum age resulted in estimated natural mortalities using Hoenig's (1983) regression method, of 0.85 for males and 0.42 for females. It is suggested that 0.85 is the most appropriate estimate at this stage because only 1% of all fish exceeded 5 years. However, it was also noted that a complete sample of the larger fish was not obtained and as a result these estimates should be considered preliminary. Growth rings were not validated.

Flatfish are shallow-water species, generally found in waters less than 50 m depth. Juveniles congregate in sheltered inshore waters, e.g., estuarine areas, shallow mudflats, and sandflats, where they remain for up to two years. Juvenile survival is highly variable. Flatfish move offshore for first spawning at 2–3 years of age during winter and spring. Adult mortality is high, with many flatfish spawning only once and few spawning more than two or three times. However, fecundity is high, e.g., from 0.2 million eggs to over 1 million eggs in sand flounders.

3. STOCKS AND AREAS

There is evidence of many localised stocks of flatfish. However, the inter-relationships of adjacent populations have not been well studied. The best information is available from studies of the variation in morphological characteristics of sand flounders and from the results of tagging studies, conducted mainly on sand and yellowbelly flounders. Variation in morphological characteristics indicate that sand flounder stocks off the east and south coasts of the South Island are clearly different from stocks in central New Zealand waters and from those off the west coast of the South Island. There also appear to be differences between west coast sand flounders and those in Tasman Bay, and between sand flounders on either side of the Auckland-Northland peninsula. Tagging experiments show that sand flounders, and other species of flounder, can move substantial distances off the east and south coasts of the South Island. However, fish tagged in Tasman Bay or the Hauraki Gulf have never been recaptured very far from their point of release.

Thus, although the sand flounders off the east and south of the South Island appear to be a single, continuous population, fish in enclosed waters may be effectively isolated from neighbouring populations and should be considered as separate stocks. Examples of such stocks are those in Tasman Bay and the Hauraki Gulf and possibly areas such as Hawke Bay and the Bay of Plenty.

There are no new data which would alter the stock boundaries used in previous assessment documents.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

FLA 1

Four standardised CPUE series have been used to track FLA 1 abundance (Kendrick & Bentley 2011; Kendrick & Bentley 2012), which were updated again in 2015 (Kendrick & Bentley in prep.), using estimated catches as the dependent variable:

1. FLA+YBF in Manukau Harbour (Statistical Area 043);
2. FLA+YBF in Kaipara Harbour (Statistical Area 044);
3. YBF in Hauraki Gulf (Statistical Areas 005, 006, and 007);
4. SFL in Hauraki Gulf (Statistical Areas 005, 006, and 007).

These series were again updated in 2018 with an additional three years of data (Starr & Kendrick 2019b), based on estimated catches as well as using a procedure (termed “F2”) which scales estimated catches to landings using a “vessel correction factor”. This procedure multiplies estimated catches with the ratio of landings to estimated catches for a vessel in a fishing year. A comparison of the two series showed no material difference in output between the two procedures, even though the F2 procedure truncates the data set to avoid excessively large and small ratios. Starr & Kendrick (2019b) also summed all flatfish estimated catches for the Manukau Harbour and Kaipara Harbour analyses to create a TOT category. This was done because estimated catches of other flatfish species are negligible in these harbours (Table 6) and a comparison with 2015 series showed no difference in the overlapping years. The Northern Inshore Working Group accepted series 1, 2, and 3 (above) as reflecting abundance. However, the SFL series in the Hauraki Gulf was rejected by the NINSWG because it was noted that the reporting of SFL in the estimated catches fell away in the early to mid-2000s which was also a period when the SFL CPUE dropped while, at the same time, there was little change in the species-specific reporting of YBF. This trend in the reporting pattern for SFL makes the associated CPUE series unreliable, resulting in a recommendation that the SFL series be replaced with a TOT series (which sums all flatfish species catch).

Less than half of the estimated FLA 1 flatfish catch in each year was identified by species (Table 6), but most of the flatfish caught in FLA 1 West were likely to be yellowbelly flounder under the assumption that the flatfish reported using the generic "FLA" code are YBF. This assumption is supported by the fact that the preferred muddy bottom habitat of yellowbelly flounder dominates the west coast harbours. Over 80% of the west coast catch is taken from Kaipara Harbour and Manukau Harbour (Table 6). Standardised CPUE trends were derived for these two areas using TOT (sum of all flatfish estimated catches) or the F2 procedure applied to the TOT estimated catches (upper panels, Figure 3). In spite of fluctuations, both the Manukau and Kaipara series show a long-term declining trend and are currently 68% and 65% below the respective peaks in the early to mid-1990s (upper panels, Figure 3). Work by NIWA (McKenzie et al 2013) in the Manukau Harbour has linked the decrease in local CPUE with an increase in eutrophication, suggesting that there may be factors other than fishing contributing to the decline.

Table 6: Total FLA 1 estimated catches by declared flatfish species, summed over the period 1989–90 to 2016–17.

	Manukau	Kaipara	Lower Waikato	Northwest	FLA 1 West	East Northland	Hauraki Gulf	Bay of Plenty	FLA 1 East	Total FLA 1
FLA	1 876.2	2 682.4	543.9	523.1	5 625.6	565.3	3 097.1	264.3	3 926.7	9 552.3
YBF	127.4	1 661.8	96.6	163.5	2 049.3	401.9	2 510.9	133.4	3 046.2	5 095.5
SFL	3.9	44.0	18.5	8.7	75.1	58.2	1 198.5	308.0	1 564.7	1 639.8
ESO	0.0	0.0	10.8	16.1	26.9	1.1	5.4	204.7	211.2	238.1
GFL	0.0	0.1	7.5	0.2	7.8	0.0	202.6	12.7	215.3	223.1
LSO	0.0	0.0	1.2	2.4	3.6	0.5	1.0	76.8	78.3	81.9
BRI	0.0	0.0	7.4	2.6	10.0	0.1	0.1	19.5	19.7	29.7
BFL	0.0	0.0	0.1	0.2	0.3	0.3	26.3	2.3	28.9	29.2
TUR	0.0	0.0	4.3	4.4	8.7	0.1	0.3	1.2	1.6	10.3
Total	2 007.5	4 388.2	690.4	721.3	7 807.4	1 027.6	7 042.2	1 022.7	9 092.5	16 899.9

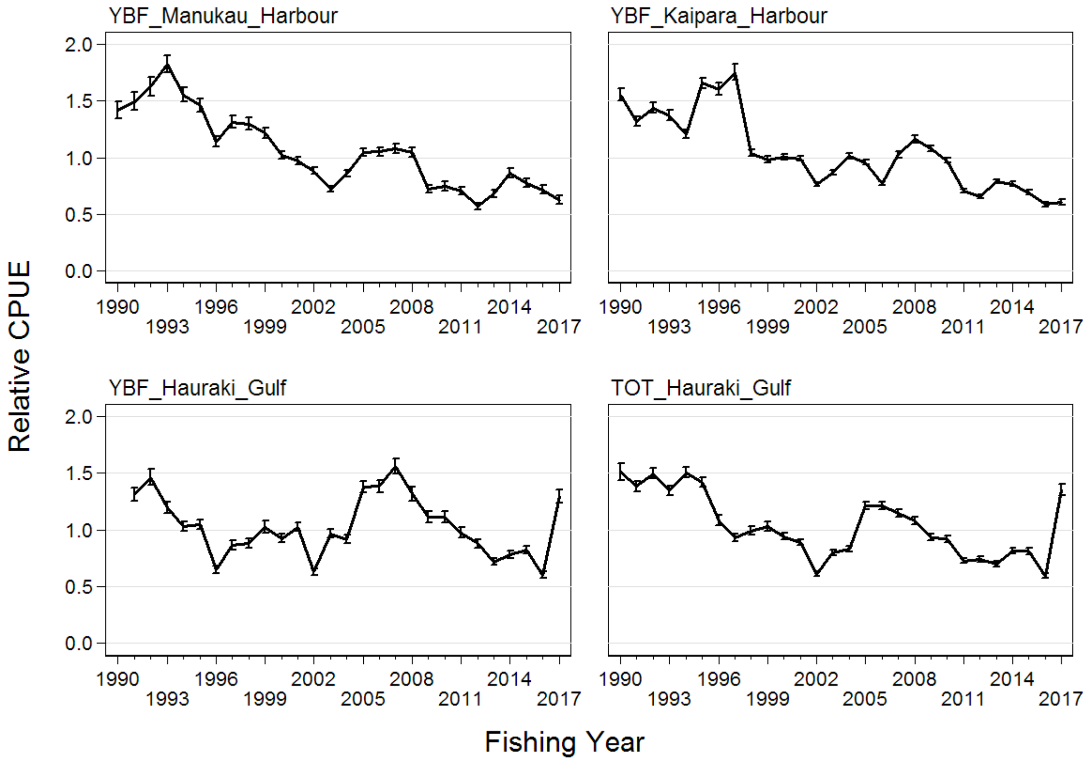


Figure 3: Standardised CPUE indices for yellowbelly flounder from models of catch rate in successful set net trips in Manukau Harbour, Kaipara Harbour (YBF assumed), and in the Hauraki Gulf (YBF reported). Also shown is the series for total FLA in Hauraki Gulf. All models based on estimated catches scaled by a "vessel correction factor" (F2 procedure).

Seventy-seven percent of the flatfish catch from FLA 1 East, including a substantial and variable proportion of sand flounder, is taken in the Hauraki Gulf, particularly from the Firth of Thames (Area 007). Separate indices were calculated for sand and yellowbelly flounder in Statistical Areas 005 to 007, and the portion of FLA catch not identified by species was excluded. However, the SFL series was not accepted by the NINSWG in 2018 (see above for rationale) and a FLA(TOT) series was prepared instead. The Hauraki Gulf yellowbelly CPUE index peaked in 2006–07 and then declined steadily to 2015–16. However, there was a sharp upturn in the YBF series in 2016–17, with the final index returning to above the series mean (lower left panel, Figure 3). A total FLA series for the Hauraki Gulf was created to replace the rejected sand flounder index in the same region (lower right panel, Figure 3). This series shows an overall declining trend except for a three-year increase from 2002 to 2005 and a single strong increase in the final 2017 fishing year, which brings the series above the long-term average.

FLA 2

In 2017, Schofield et al (2018a) provided standardised CPUE for FLA 2 (Figure 4) based on the flatfish target fishery in Statistical Areas 013 and 014. Estimated catches were allocated to daily aggregated effort using methodology described by Langley (2014) to improve the comparability between the data collected from two different statutory reporting forms (CELR and TCER). A core fleet of 15 vessels that had completed at least five trips per year in at least seven years was identified. The model, using a gamma error distribution, adjusted for changes in duration, month, and vessel, accounted for 33% of the variance in catch. Area was not included in the model because the change in reporting forms appears to have influenced the catch split between areas 013 and 014.

The NINS WG noted that most of the records in the aggregated data had catches of flatfish and that a binomial index was flat. As a result the positive catch index was retained as the key monitoring series. The CPUE series exhibits moderate fluctuations around the long-term mean, with no overall trend up or down and appears currently to be in an increasing phase.

Characterisation using the estimated catch data suggests that the FLA 2 catch comprises mainly sand flounder (SFL) and New Zealand sole (ESO). CPUE indices for ESO and SFL were provided by Schofield et al (2018a) for 2008 to 2016 using the tow by tow data from vessels consistently estimating catches by flatfish species. Trends were apparent in the probability of catch, so combined (binomial and positive catch modelled with a gamma distribution) indices were produced. There is reasonable consistency between the species-specific indices and the overall FLA 2 index (Figure 4), noting that — because the FLA 2 fishery is small — the datasets for the individual species are small and the indices variable.

These indices were updated in 2018 (Schofield et al 2018b) to include data to 30 September 2017.

Establishing B_{MSY} compatible reference points

In 2014, the Working Group adopted mean CPUE from the bottom trawl flatfish target series for the period 1989–90 to 2012–13 as a B_{MSY}-compatible proxy for FLA 2. The Working Group accepted the default Harvest Strategy Standard definitions that the Soft and Hard Limits would be one half and one quarter the target, respectively.

FLA 3

CPUE trends

CPUE trends for the three principal FLA 3 species (New Zealand sole [ESO], sand flounder [SFL] and lemon sole [LSO]) and an aggregated catch landed to FLA [TOT], based on bottom trawl catch and effort data, were updated in 2020 (Starr & Kendrick 2020a). The species-specific catch data were based on "splitter" trips, defined as trips which landed FLA 3 but which did not use the FLA code in the estimated catch section of the catch/effort form. Alternative definitions of "splitters" based on vessel performance were investigated in 2015 (Starr & Kendrick 2018), but CPUE trends were found to be similar to those derived from the “trip splitter” algorithm. The latter was selected because it retained the greatest amount of catch, particular in the early years of the series.

The CPUE data were prepared by matching the FLA landing data for a trip with the effort data from the same trip that had been amalgamated to represent a day of fishing. The procedure assigns the modal statistical area and modal target species (defined as the observation with the greatest effort) to the trip/date record. All estimated catches for the day were summed and the five top species with the greatest catch were assigned to the date. This “daily-effort stratum” preparation method was followed so that the event-based data forms that are presently being used in these fisheries can be matched as well as possible with the earlier daily forms to create a continuous CPUE series. For this procedure to function correctly, given that there are multiple flatfish species in the estimated catches, the matching procedure with landings is done twice: first by summing all flatfish estimated catches into a single generic “flatfish” category. The ratio of the total FLA landings relative to the sum of the estimated flatfish catches can then be used to scale each of the species-specific estimated catches on the same trip as the second step.

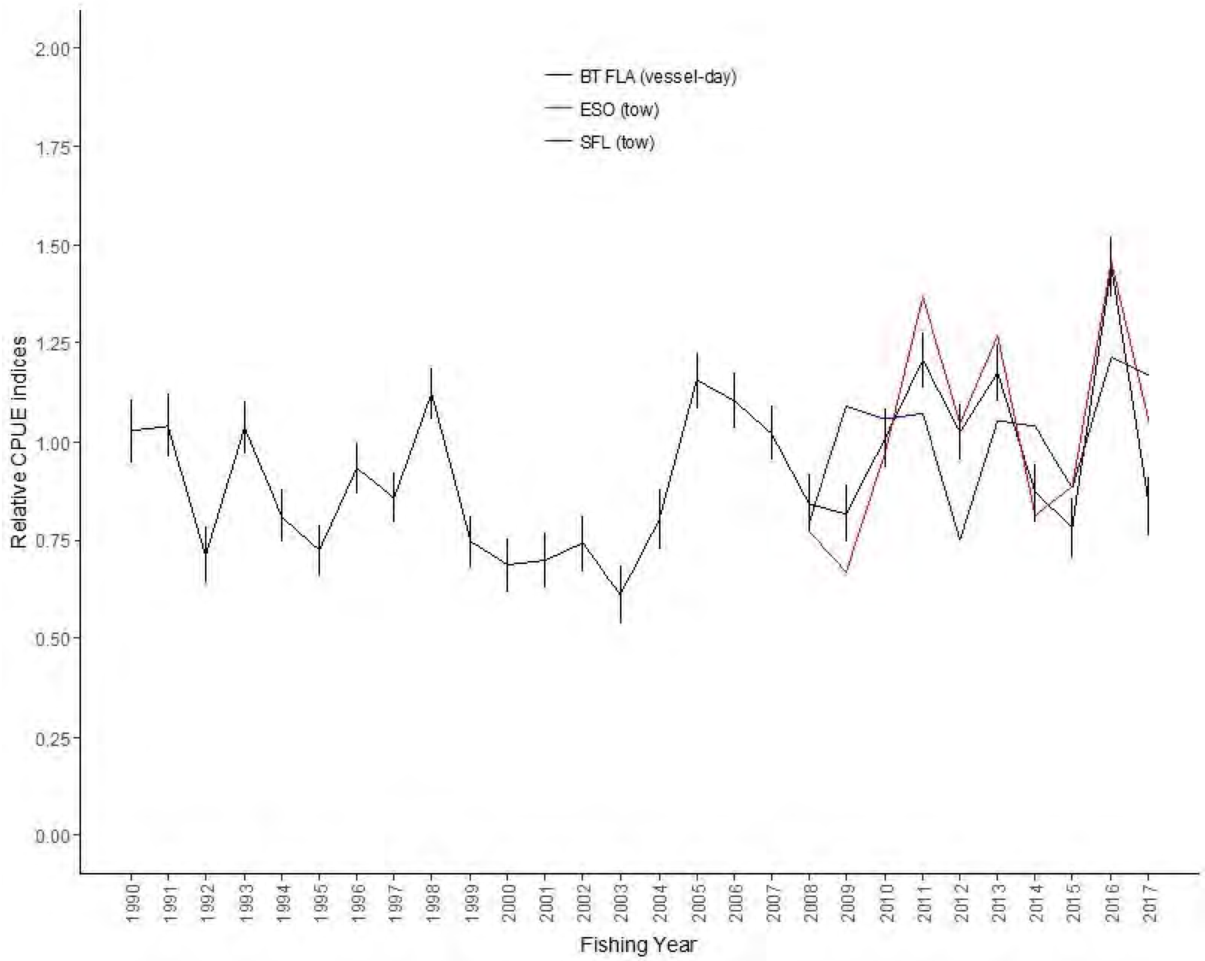


Figure 4: Standardised CPUE indices in FLA 2 for BT targeting all species of flatfish, (aggreeedgated to combine data across form types, BT_flats(day)), and shorter combined series for sand flounder (BT_sfl(tow)) and New Zealand sole (BT_eso(tow)) based on tow by tow resolution data (Schofield et al 2018b).

Each analysis was confined to a set of core vessels which had participated consistently in the fishery for a reasonably long period (5 trips for at least 5 years). The explanatory variables offered to each model included fishing year (forced), month, vessel, statistical area, number tows, and duration of fishing, with the scaled estimated species catch used as the dependent variable. The WG agreed to report only the lognormal series for these analyses because zero records only meant that the species had not been reported, rather than being a true zero. The WG also agreed to restrict all analyses to target FLA records and to the following six statistical areas: 020, 022, 024, 026, 025, and 030.

The estimated CPUE trends by species were used to evaluate the relative status of the three main species in the FLA 3 fishery. The generic FLA series was used to drive an MP by estimating the CPUE for the terminal year based on early harvest returns for the fishery (see description below). There were similarities among the three species-specific standardised CPUE indices (Figure 4), with all indices increasing in the early 1990s and peaking at some point in the early to mid-1990s. All indices then have a trough in the early- to mid-2000s, followed by an increase for LSO and SFL and a decrease for ESO, with the ESO and SFL indices showing similarity in their fluctuations. The LSO index had its peak in the 1990s; i.e., later than the other indices, and increased sooner than the other species in the mid-2000s (Figure 4). The SFL index has increased and then levelled out, whereas the other two indices have dropped from peaks reached in 2009–10.

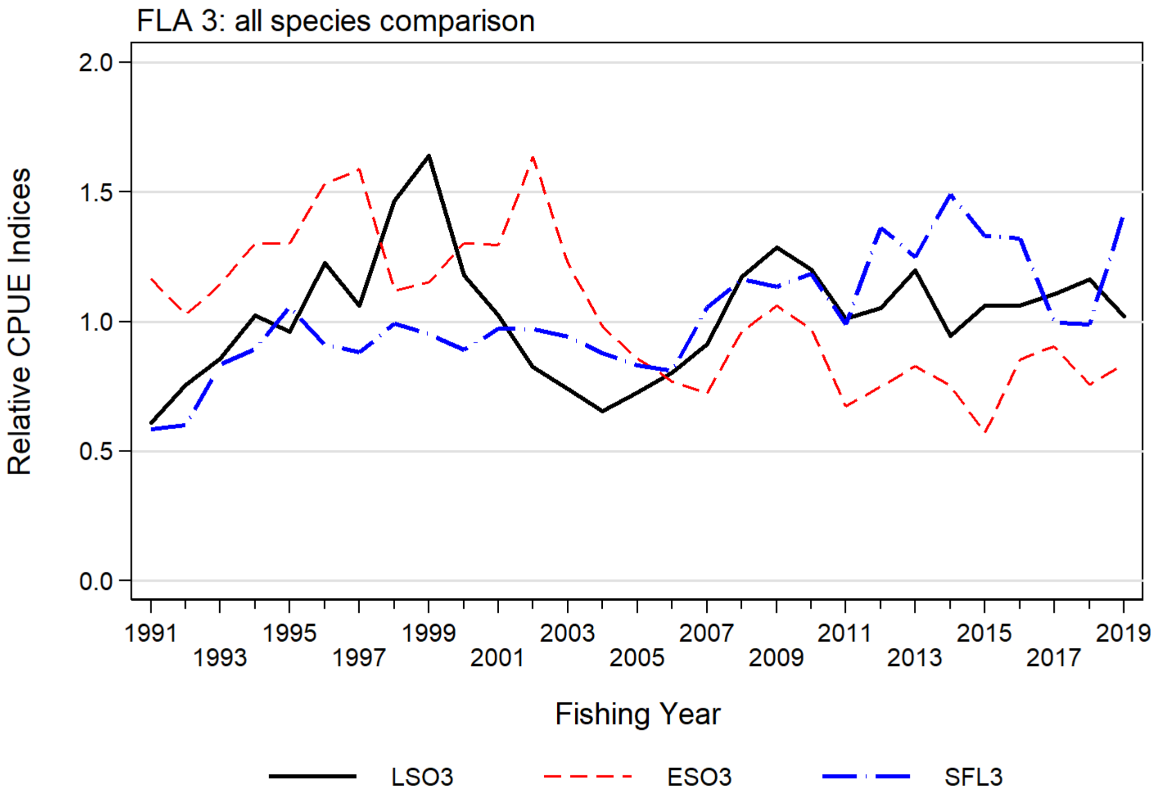


Figure 5: Comparison of standardised bottom trawl lognormal CPUE indices in FLA 3 for LSO (lemon sole), ESO (New Zealand sole), and SFL (sand flounder) (from Starr & Kendrick 2020a).

ECSI trawl survey biomass estimates for LSO, ESO, and SFL

Lemon sole biomass indices in the core strata (30–400 m) from the east coast South Island trawl survey (Table 7) show no trend (Figure 6). Coefficients of variation are moderate to low, ranging from 15 to 33% (mean 23%). The additional biomass captured in the 10–30 m depth range region accounted for 1% to 5% of the biomass in the core plus shallow strata (10–400 m) for the five years with usable biomass estimates in the 10–30 m region, indicating that the existing core strata time series in 30–400 m are more important for this species. A comparison of the LSO CPUE series with the LSO ECSI biomass indices shows that both series fluctuate without trend and show considerable variation (Figure 6). The correspondence between the two sets of indices is weak (rho=-0.342; R^2=12%).

The shallow 10–30 m region holds a substantial fraction of the biomass of the other two important FLA 3 species, ESO and SFL. This fraction ranges from 54–90% of the total annual ESO biomass whereas the equivalent range for SFL is 41–96% (Table 7). There is reasonable correspondence between the summed survey biomass estimates and the equivalent commercial CPUE series over the five overlapping years (Figure 7), although the CVs for these estimates are large for both species (Table 7).

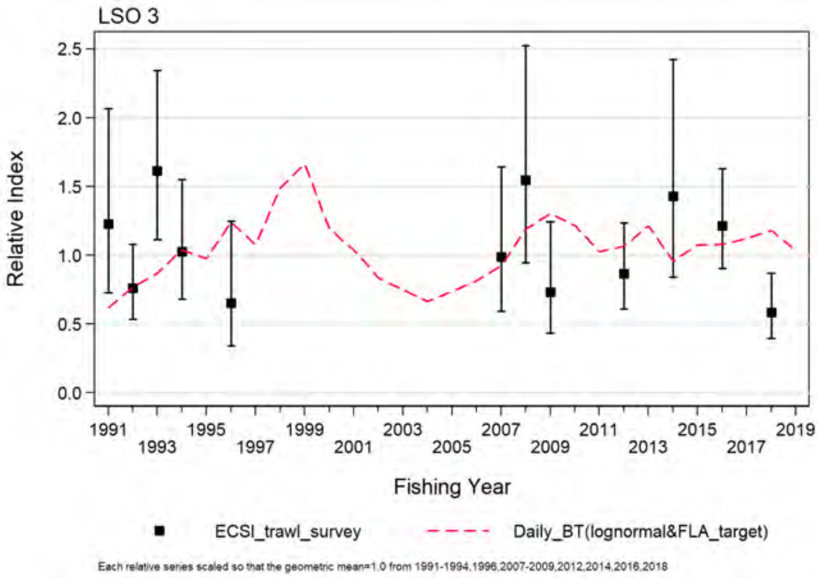


Figure 6: Lemon sole total biomass and 95% confidence intervals for the ECSI winter survey in core strata (30–400 m) plotted against the LSO bottom trawl CPUE series.

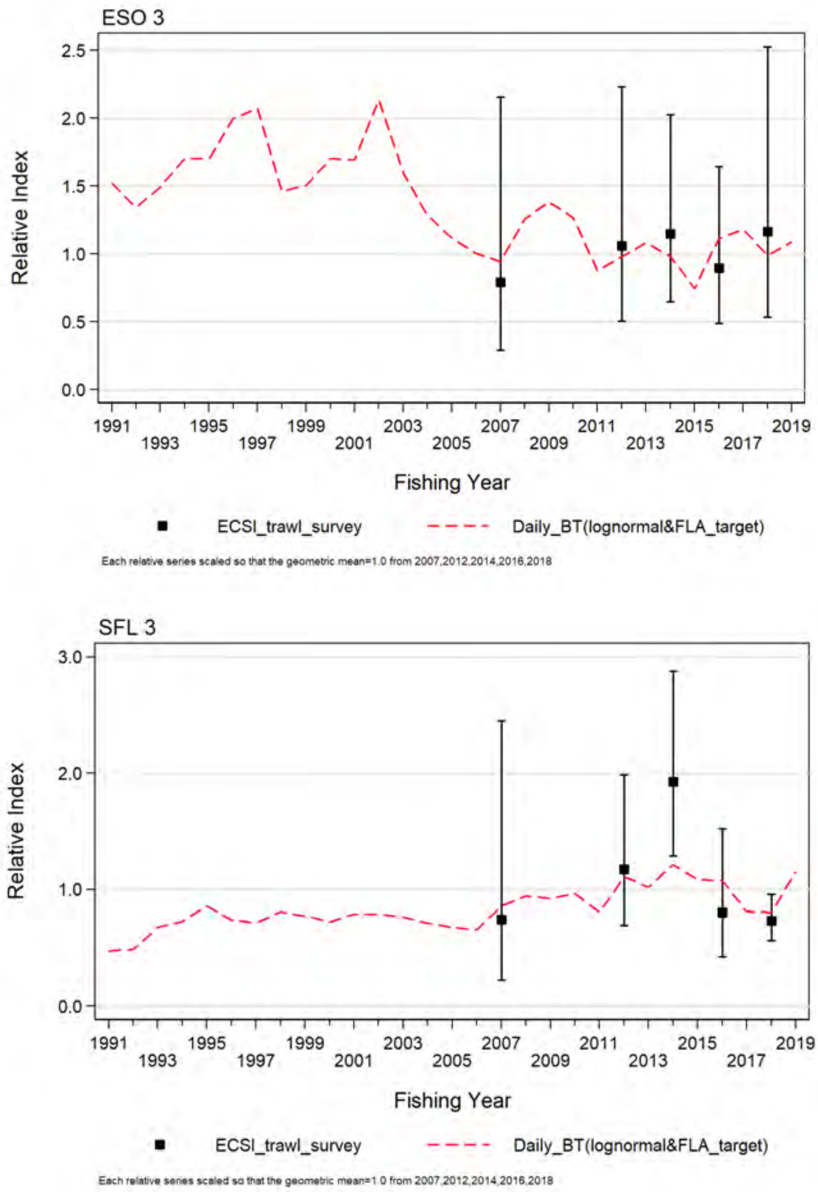


Figure 7: New Zealand sole (ESO: top panel) and sand flounder (SFL: bottom panel) total biomass and 95% confidence intervals for the summed ECSI winter survey core + shallow strata plotted against the respective ESO and SFL bottom trawl CPUE series.

Table 7: Relative biomass indices (t) and coefficients of variation (CV) for lemon sole (LSO). New Zealand sole (ESO) and sand flounder (SFL) from the east coast South Island (ECSI) - winter survey area. Biomass estimates are provided for the core (30–400 m) region and for the shallow (10–30 m) region introduced in 2007. NA: insufficient tows for shallow region.

Species	Year	Trip number	Total Biomass estimate (t)	CV (%)	Total Biomass estimate (t)	CV (%)
			30–400 m (core)		10–30 m	
LSO	1991	KAH9105	92	27	–	–
	1992	KAH9205	57	18	–	–
	1993	KAH9306	121	19	–	–
	1994	KAH9406	77	21	–	–
	1996	KAH9606	49	33	–	–
	2007	KAH0705	74	26	3	38
	2008	KAH0806	116	25	NA	NA
	2009	KAH0905	55	27	NA	NA
	2012	KAH1207	65	18	1	55
	2014	KAH1402	107	27	2	50
	2016	KAH1605	91	15	3	52
	2018	KAH1803	44	20	2	33
ESO	2007	KAH0705	5	51	19	72
	2008	KAH0806	6	38	NA	NA
	2009	KAH0905	2	48	NA	NA
	2012	KAH1207	15	82	17	38
	2014	KAH1402	13	41	22	29
	2016	KAH1605	4	64	23	31
	2018	KAH1803	3	60	32	40
SFL	2007	KAH0705	16	61	31	64
	2008	KAH0806	9	52	NA	NA
	2009	KAH0905	2	74	NA	NA
	2012	KAH1207	43	71	30	27
	2014	KAH1402	55	42	65	21
	2016	KAH1605	2	63	48	33
	2018	KAH1803	5	99	40	14

In-season Management Procedure

In 2007 concerns were expressed about the sustainability of FLA 3 catches and the TACC was reduced from 2681 t to 1430 t from 1 October 2007. In the 2008–09 fishing year anecdotal information indicated an increase in abundance of lemon and New Zealand sole in the FLA 3 QMA above a level that fishers were able to utilise within the available TACC. It was considered that there was opportunity for increased utilisation that would not adversely impact on the long-term sustainability of the FLA 3 stock complex and for 2008–09 'in-season' commercial allowances were set at 1780 t based on the 15 year average of commercial FLA3 catches.

In 2010, an 'in-season' Management Procedure (MP) was developed which has been used to inform in-season adjustments to the FLA 3 TACC since 2010–11 (Bentley 2009, 2010). This MP was updated and revised in 2015 (Starr et al 2018). It used the relationship between annual standardised CPUE for all FLA 3 species (shown as FLA in Figure 5) and the total annual FLA 3 landings to estimate an average exploitation rate which is then used to recommend a level of full-season catch based on an early estimate of standardised CPUE. Only the period 1989–90 to 2006–07 was used to estimate the average exploitation rate because this was the period before the TACC was reduced which allowed the fishery to operate at an unconstrained level. A partial year in-season estimate of standardised CPUE is used as a proxy for the final annual index, with the recommended catch defined by the slope of the regression line (Figure 8) multiplied by the CPUE proxy estimate (Figure 8 shows the outcome of this procedure for 2019).

The 2010 FLA 3 MP approximated the standardisation procedure by applying fixed coefficients to a data set specified by a static core vessel definition. This approach deteriorated over time as vessels dropped out of the core vessel fleet, thus reducing the available data set. The 2015 MP was based on a re-estimated standardisation procedure using a data set specified annually by a dynamic core vessel definition, allowing new vessels to enter the data set as they meet the minimum eligibility criteria. The 2015 MP was validated through a retrospective analysis which used the data available up to end of the previous year and the partial data in the final year to determine how the model performed across years (Figure 9). In most years, the MP performance was satisfactory after only two months of data were accumulated. The poor performance of the model in some years (e.g., 2012) persisted across all four early months, indicating that collecting additional data in those years would not have improved the recommendation (relative to the end of year recommendation).

Starr & Kendrick (2020a) repeated the 2015 evaluation of the capacity of the FLA 3 MP to estimate the final annual CPUE, given the accumulation of two to five months of data in the final (predictive) year. This evaluation was made retrospectively over 12 years of observations from 2007–08 to 2018–19, using partial year data to estimate the annual CPUE in the final year. They showed that the first two months of data (October, November) had an average absolute prediction error of 11% (range: 4.7% to 23.1%). This statistic dropped by less than 1% with the addition of data from the month of December and by less than another 2% after the addition of the January data. This relative insensitivity to adding additional months of data to the analysis indicates that the MP should be able to provide benefit to the fishery once the implementation difficulties are solved.

Table 8 shows the results of the operation of the FLA 3 in-season MP since the inception of the Schedule 2 programme. Five TACC in-season increases have been recommended since 2010 based on the operation of the MP (2009–10, 2010–11, 2012–13, 2015–16, and 2016–17; Table 8). However, MPI approval of the 2016–17 increase was delayed until late August, resulting in limited opportunity to take advantage of the increase in commercial catch allowance. The FLA 3 MP was suspended by Fisheries New Zealand from 2019–20 due to the long delays which are consequent to the consultation requirements attendant to catch limit changes, even if they are temporary. These delays resulted in reduced (or even eliminated) opportunities to catch the additional flatfish.

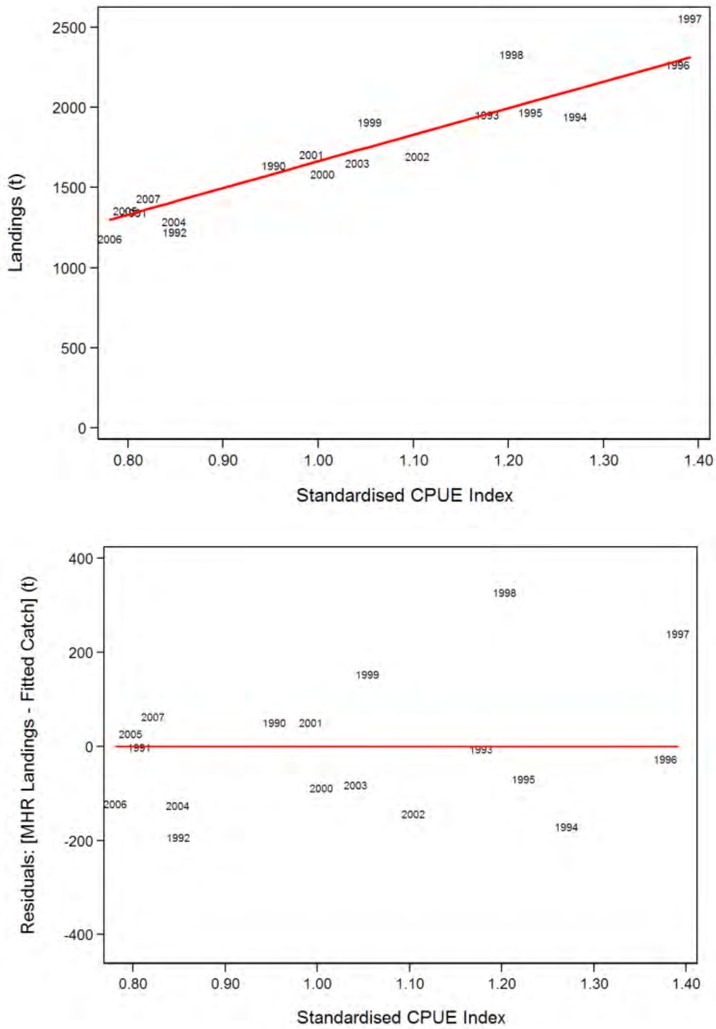


Figure 8: [top panel] Relationship between annual FLA 3 CPUE and total annual FLA 3 QMR/MHR landings from 1989–90 to 2006–07 (calculated for the 2019 in-season MP, the most recent year of the operation of this MP); [bottom panel] residuals from the left panel regression.

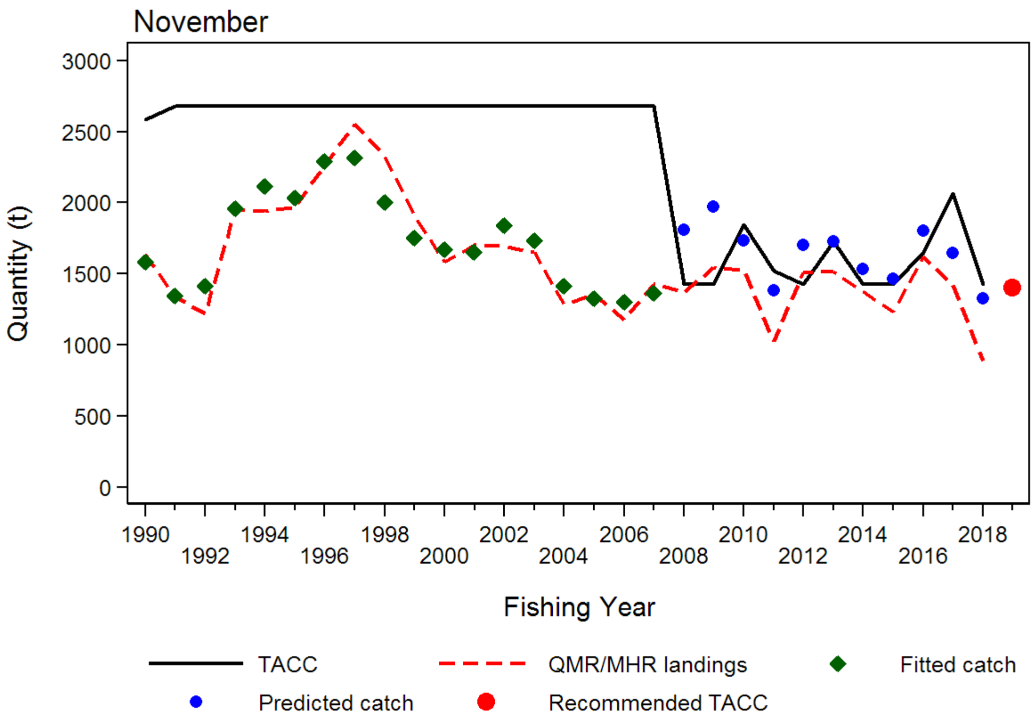


Figure 9: Operation of the 2015 FLA 3 MP in 2019 (the most recent year of operation), showing the relationship of the fitted catch estimates to the observed MHR/QMR landings and the annual recommended catches from 2008 onward based on the estimated standardised CPUE up to the end of November.

Table 8: Results of the operation of the FLA 3 MP by prediction year. NA: not available.

Prediction Year	Fishing Year	CPUE Prediction	CPUE Total year[1]	Recom-mended commercial allowance	Approved commercial allowance (t)[2]	Annual catch (t)	Date of Approval[2]	Reference
2010*	2009–10	64.98 (kg/tow)	75.82	1 846	1 763	1 525	18 June 2010	Bentley (2010)
2011*	2010–11	59.83 (kg/tow)	58.76	1 520	1 430	1 027	–	Bentley (2011)
2012	2011–12	58.45 (kg/tow)	57.56	1 495	–	1 507	–	Bentley (2012)
2013*	2012–13	67.97 (kg/tow)	69.70	1 727	1 727	1 512	17 May 2013	Brouwer (2013)
2014	2013–14	NA	54.80	NA	–	1 377	–	NA
2015	2014–15	53.20 (kg/tow)	NA	1 362	1 352	1 231	–	Bentley (2015)
2016*	2015–16	0.984	1.048	1 650	1 650	1 622	15 July 2016	Starr et al (2016)
2017*	2016–17	1.215	0.978	2 065	2 065	1 421	23 Aug 2017	Starr & Kendrick (2017)
2018	2017–18	0.870	0.796	1 461	–	886	–	Starr & Kendrick (2018)
2019	2018–19	0.843	0.803	1 402	1 430	968	–	Starr & Kendrick (2019a)

[1] calculated in the year following
[2] information provided by MPI
* MP operation that resulted in a commercial catch allowance increase recommendation

Establishing B_{MSY} compatible reference points

Given the large recruitment driven fluctuations in biomass observed for FLA, a target biomass is not meaningful. In-season adjustments are therefore based on relative fishing mortality for all FLA species combined, with increases made when this drops below the target value. F_{msy} proxies accepted for FLA 3 are the relative fishing mortality values calculated by dividing the baseline TACCs by the corresponding CPUE values on the landings:CPUE regressions shown in Figure 8.

FLA 7

CPUE trends

CPUE trends for four principal FLA 7 species (New Zealand sole [ESO], sand flounder [SFL], brill [BRI], and turbot [TUR]), based on bottom trawl catch and effort data, were estimated in 2020 (Starr & Kendrick 2020b). The data preparation description given for FLA 3 [above] also applies to FLA 7, including the use of “splitter” trips to estimate the time sequences of catch by species, the “daily effort” amalgamation procedure, and scaling all a species-specific catches to the total FLA landings in a trip. The same criteria were used to select core vessels (5 trips for at least 5 years) to screen data used in the analysis which consisted of offering six explanatory variables to each model, including fishing year (forced), month, vessel, statistical area, number of tows, and duration of fishing, using the scaled estimated species catch for the dependent variable. The WG agreed to report only the lognormal series for these species-specific analyses because zero records only meant that the species had not been reported, rather than being a true zero. The WG also agreed to restrict the analyses to target FLA records and to the following spatial restrictions: [SFL]: Tasman Bay/Golden Bay (Area 038); [ESO, BRI, TUR]: west coast South Island (Areas 032, 033, 034 and 035).

The estimated CPUE trends by species were used to evaluate the relative status of the four main species in the FLA 7 fishery. There are similarities in the fluctuations in the standardised CPUE series for ESO and SFL (Figure 10 [left panel]), with each species showing approximate decadal periodicity. They peak three times in the early- to mid-1990s, in the mid-2000s and finally at the end of the 2010s. The final "peak" is low relative to the two previous peaks, indicating that both these species are likely to be at below average levels at the end of the 2010–2019 decade (Figure 10 [left panel]). The more long-lived brill and turbot (Figure 10 [right panel]) show a nadir in the late-1990s to early 2000s, followed by an increasing trend and subsequent levelling of the series. Brill appear to be more ascendant at the end of the series when brill have the highest indices in the series, whereas turbot appears to be declining at the end of the 2010–2019 decade (Figure 10 [right panel]).

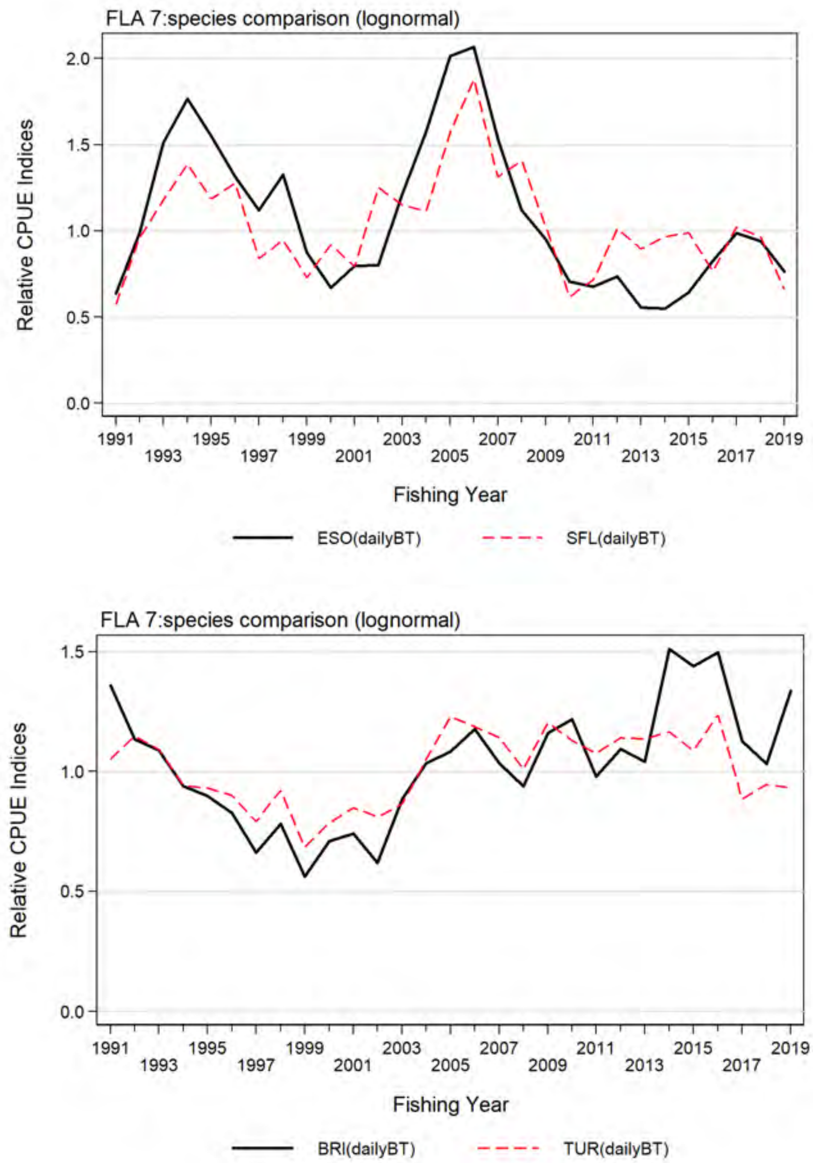


Figure 10: Comparison of FLA 7 standardised bottom trawl lognormal CPUE indices in FLA 7 for [top panel] SFL (sand flounder), ESO (New Zealand sole) [bottom panel] BRI (brill), TUR (turbot) (from Starr & Kendrick 2020b)

Establishing B_{MSY} compatible reference points
The WG discussed establishing B_{MSY} proxy reference points for the four FLA 7 species with CPUE index series. Given that there appeared to be about three decadal cycles in the ESO/SFL series (see Figure 10 [left panel]), the WG agreed to use the average over the entire series as the target. The same conclusion was made for turbot (Figure 10 [right panel]), given that this series appeared to be relatively stable across the 30 years of the time series, making the average of the series the B_{MSY} reference level. The B_{MSY} proxy for brill was based on mean standardised CPUE from 1990–91 to 2018–19(Figure 10 [right panel]), which corresponded with a stable period of high abundance and catch.

4.2 Other Factors

The flatfish complex is comprised of QMS eight species although typically only a few are dominant in any one QMA and some are not found in all areas. For management purposes all species are combined to form a unit fishery. The proportion that each species contributes to the catch is expected to vary annually. It is not possible to estimate *MCY* for each species and stock individually.

Because the adult populations of most species generally consist of only one or two year classes at any time, the size of the populations depends heavily on the strength of the recruiting year class and is therefore thought to be highly variable. Brill and turbot are notable exceptions with the adult population consisting of a number of year classes. Early work revealed that although yellowbelly flounder are short-lived, inter-annual abundance in FLA 1 was not highly variable, suggesting that some factor, e.g. size of estuarine nursery area, could be smoothing the impact of random environmental effects on egg and larval survival. Work by NIWA (McKenzie et al 2013) in the Manukau harbour has linked the decrease in local CPUE with an increase in eutrophication, suggesting that there may be factors other than fishing contributing to the decline.

Flatfish TACCs were originally set at high levels so as to provide fishers with the flexibility to take advantage of the perceived variability associated with annual flatfish abundance. This approach has been modified with an in-season increase procedure for FLA 3.

5. STATUS OF THE STOCKS

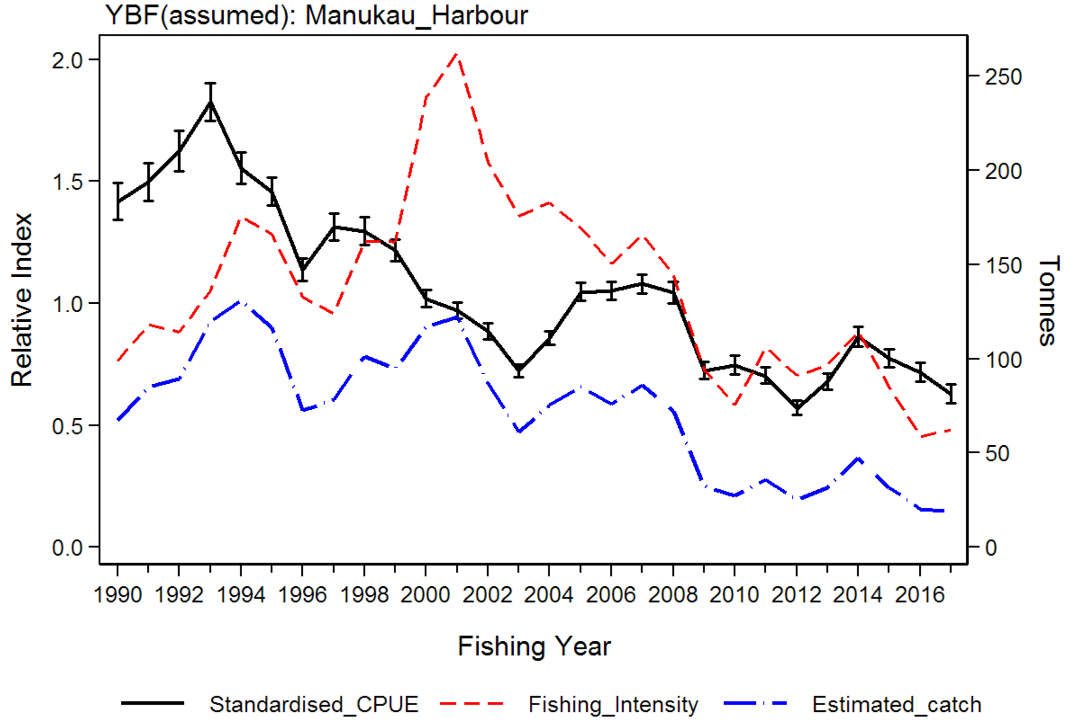
Estimates of current and reference biomass are not available.

- **Yellowbelly flounder in FLA 1**

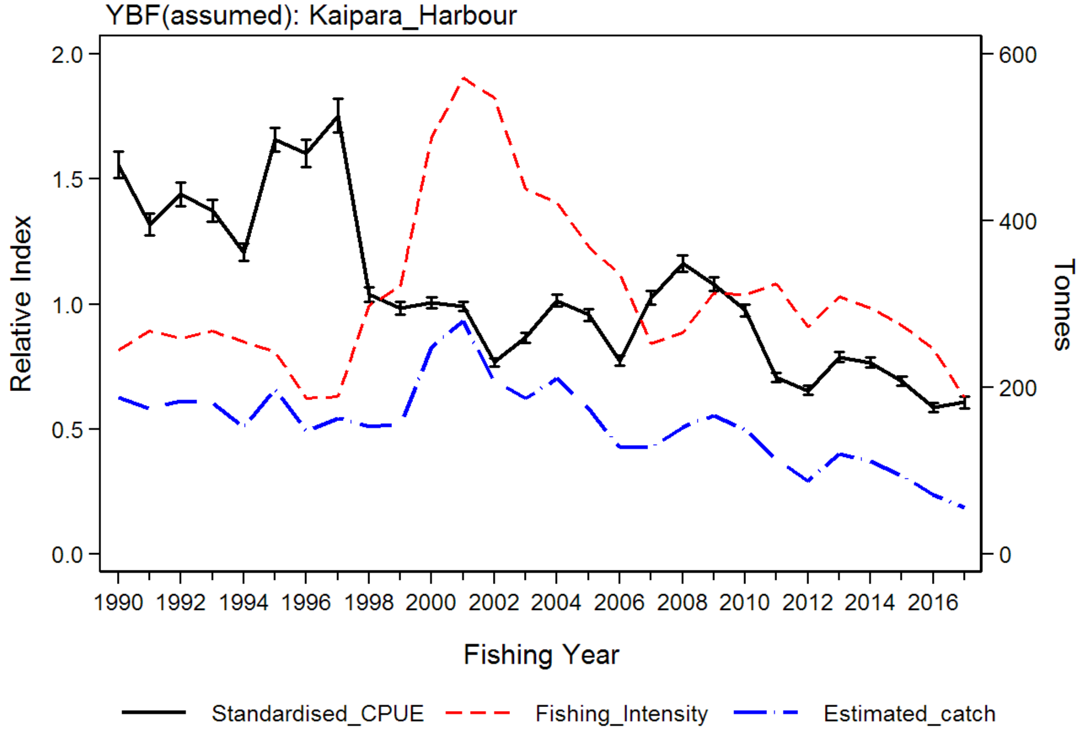
Stock Structure Assumptions
Based on tagging studies, yellowbelly flounder appear to comprise localised populations, especially in enclosed areas such as harbours and bays.

Stock Status	
Year of Most Recent Assessment	2018
Assessment Runs Presented	CPUE in Manukau and Kaipara harbours, and the Hauraki Gulf
Reference Points	Target: Not established but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing Threshold: F_{MSY}
Status in relation to Target	Manukau: Unknown Kaipara: Unknown Hauraki Gulf: Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

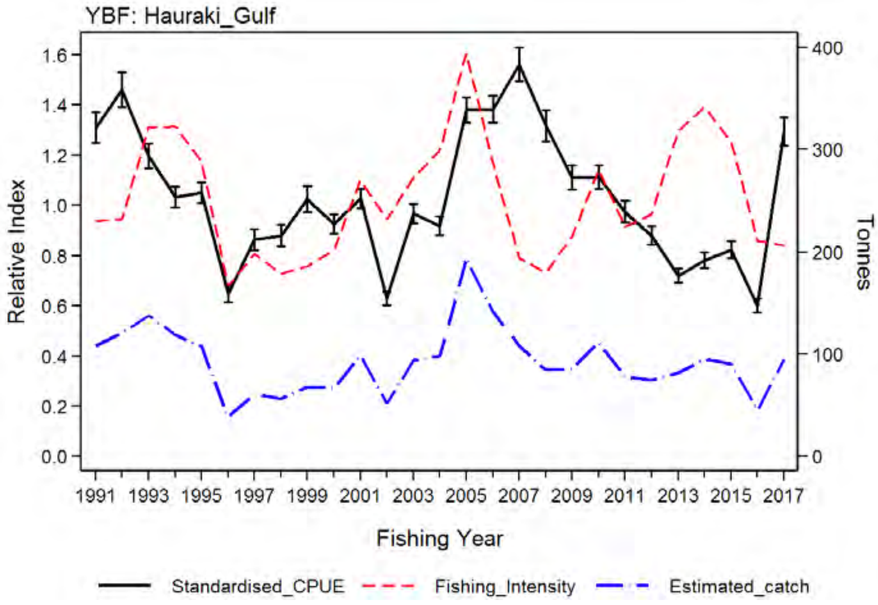
Historical Stock Status Trajectory and Current Status



CPUE and total annual estimated catches for YBF in Manukau Harbour. Also shown is the fishing intensity (catch/CPUE), standardised relative to the geometric mean. Fishing year designated by second year of the pair.



CPUE and total annual estimated catches for YBF in Kaipara Harbour. Also shown is the fishing intensity (catch/CPUE), standardised relative to the geometric mean. Fishing year designated by second year of the pair.



CPUE and total annual estimated catches for YBF in the Hauraki Gulf. Also shown is the fishing intensity (catch/CPUE), standardised relative to the geometric mean. Fishing year designated by second year of the pair.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	In spite of fluctuations, both the Manukau and Kaipara series show a long-term declining trend. The Hauraki Gulf yellowbelly CPUE index has fluctuated, peaking in 2006–07 at the highest point in the series and then declining steadily to 2015–16. However, there was a strong upturn in the final year of the series, with the 2016–17 index returning to above the series mean.
Recent Trend in Fishing Intensity or Proxy	Recent fishing intensity is relatively low in both of the west coast harbours while it sits near the series mean in the Hauraki Gulf series.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches	
Assessment Dates	Latest assessment: 2018	Next assessment: 2021
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Uncertainty in the stock structure and relationship between CPUE and biomass	

Qualifying Comments
Work by NIWA (McKenzie et al 2013) in the Manukau harbour has linked the decrease in local CPUE with an increase in eutrophication, suggesting that there may be factors other than fishing contributing to the decline. The lack of species specific reporting for FLA stocks is limiting the ability to assess these stocks, as is the possible reduction in carrying capacity for Manukau and Kaipara Harbours.

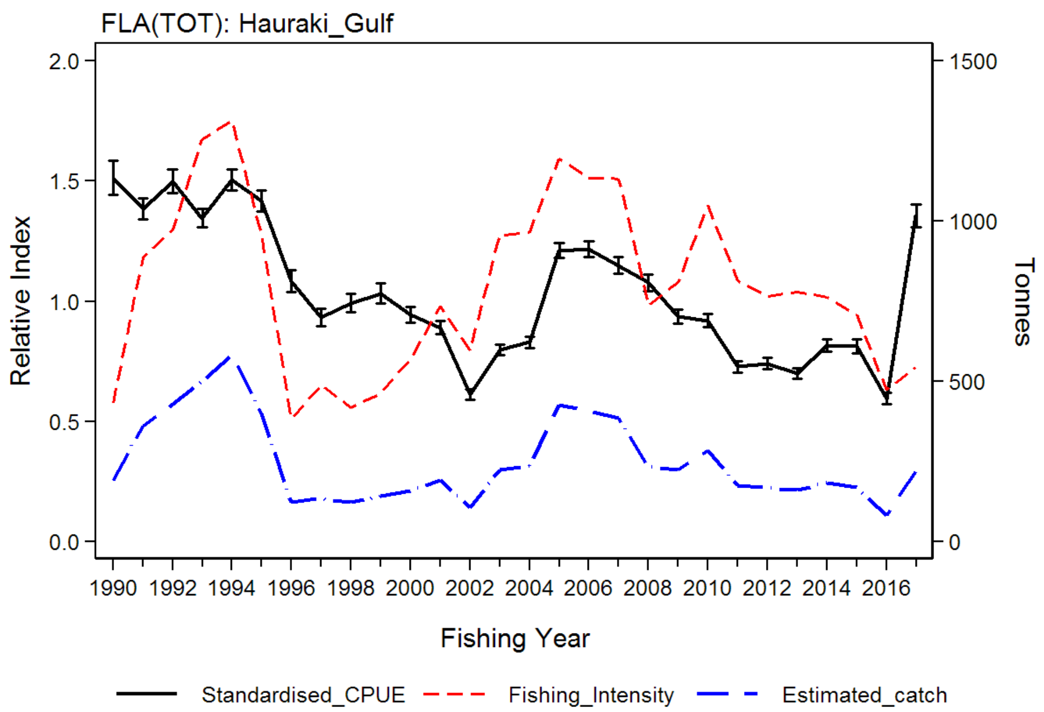
Fishery Interactions
Main bycatch is sand flounder, especially on the east coast. FLA 1 species are mostly targeted with setnets in harbours. Interactions with other species are currently being characterised.

- **Total FLA in Hauraki Gulf**

Because the Hauraki Gulf sand flounder CPUE series was rejected by the Northern Inshore Working Group, a total FLA CPUE analysis is substituted, which will be predominantly comprised of mixed sand flounder and yellowbelly flounder.

Stock Status	
Year of Most Recent Assessment	2018
Assessment Runs Presented	Standardised CPUE for Hauraki Gulf
Reference Points	Target(s): Not established but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: Not established
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



CPUE and total annual estimated catches for FLA(TOT) in the Hauraki Gulf. Also shown is the fishing intensity (catch/CPUE), standardised relative to the geometric mean. Fishing year designated by second year of the pair.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The FLA(TOT) series shows an overall declining trend except for a three-year increase from 2002 to 2005 and a single strong increase in the final 2017 fishing year, which brings the series above the long-term average.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity appears to be dropping after peaking in 2005
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches	
Assessment Dates	Latest assessment: 2018	Next assessment: 2021
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	Catch and effort data	1 – High Quality
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Uncertainty in the catch of sand flounder	

Qualifying Comments
The lack of species specific reporting for FLA stocks limits the ability to assess these stocks.

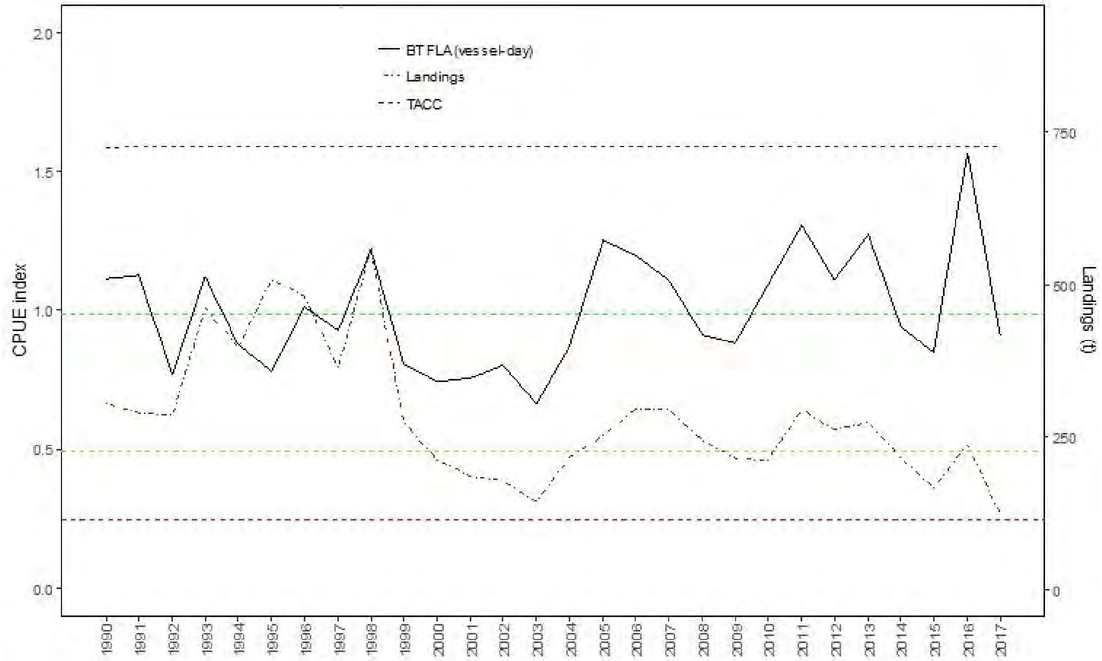
Fishery Interactions
Main QMS bycatch species is yellowbelly flounder, especially on the east coast. FLA 1 species are mostly targeted with setnets in harbours. Interactions with other species are under characterisation.

- **FLA 2**

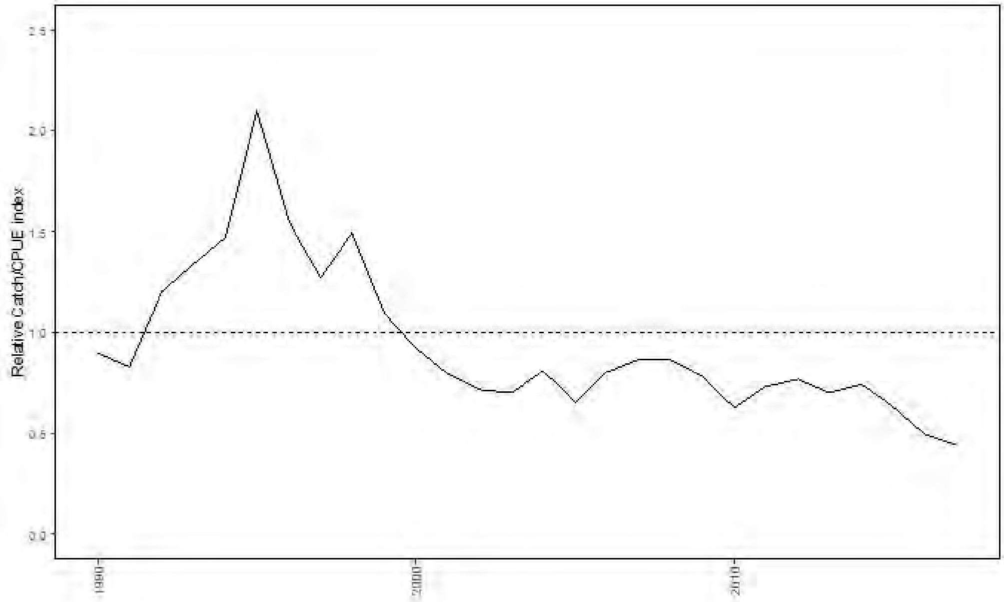
Stock Structure Assumptions
Sand flounder off the East Coast (FMA2) of North Island appear to be a single continuous population. The stock structure of New Zealand sole (ESO) is unknown.

Stock Status	
Year of Most Recent Assessment	2018
Assessment Runs Presented	Standardised CPUE for all flatfish combined in FLA 2
Reference Points	Target: B_{MSY}-compatible proxy based on the mean CPUE 1989–90 to 2012–13 for the bottom trawl flatfish target series Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: F_{MSY}
Status in relation to Target	About as Likely as Not (40–60%) to be at or above the target
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status



Annual landings and standardised CPUE index based on positive catches for BT_FLA, (all flatfish species combined) at day resolution (Schofield et al 2018b). Fishing years are labelled according to the second calendar year e.g. 1990 = 1989–90. Horizontal lines are the target and the soft and hard limits.



Annual relative exploitation rate for flatfish in FLA 2.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Relative abundance has fluctuated without trend since 1989–90 and is currently just below the target.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has trended down since the mid-1990s and is currently below the reference period (1990–2013) average
Other Abundance Indices	Tow based CPUE analysis for SFL and ESO from 2007–08 to 2016–17 data are reasonably consistent with the aggregated data index for combined species, although the decrease in abundance from 2016 to 2017 is more evident in ESO than SFL
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Stock is likely to continue to fluctuate around current levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown for TACC; Unlikely (< 40%) for current catch Hard Limit: Unknown for TACC; Unlikely (< 40%) for current catch
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown for TACC; Unlikely (< 40%) for current catch

Assessment Methodology		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches	
Assessment Dates	Latest assessment: 2018	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
-

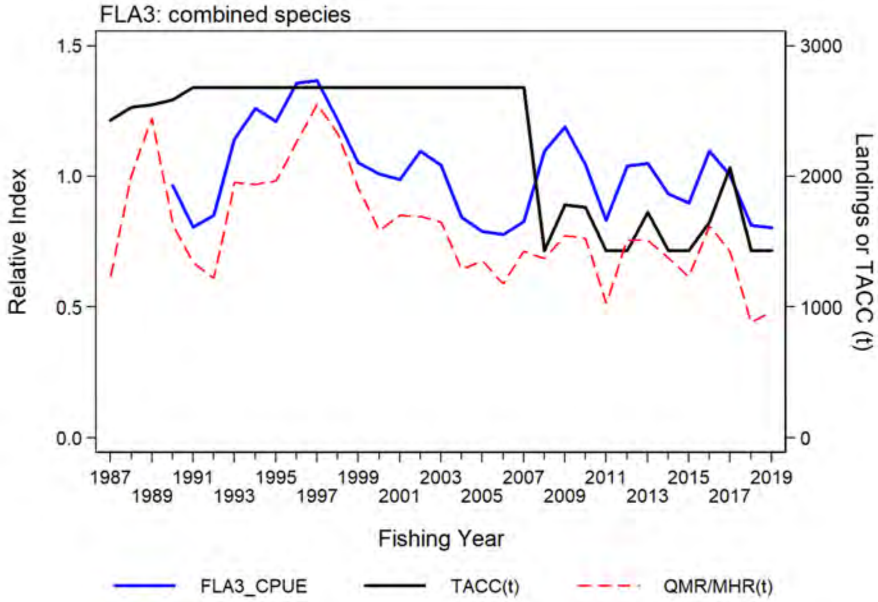
Fishery Interactions
The fishery is mainly confined to the inshore domestic trawl fleet except for a small incidental bycatch of soles, brill and turbot by offshore trawlers. The main fisheries landing flatfish as bycatch in FLA 2 target gurnard, snapper and trevally. Interactions with other species are currently being characterised.

- **FLA 3 (all species combined)**

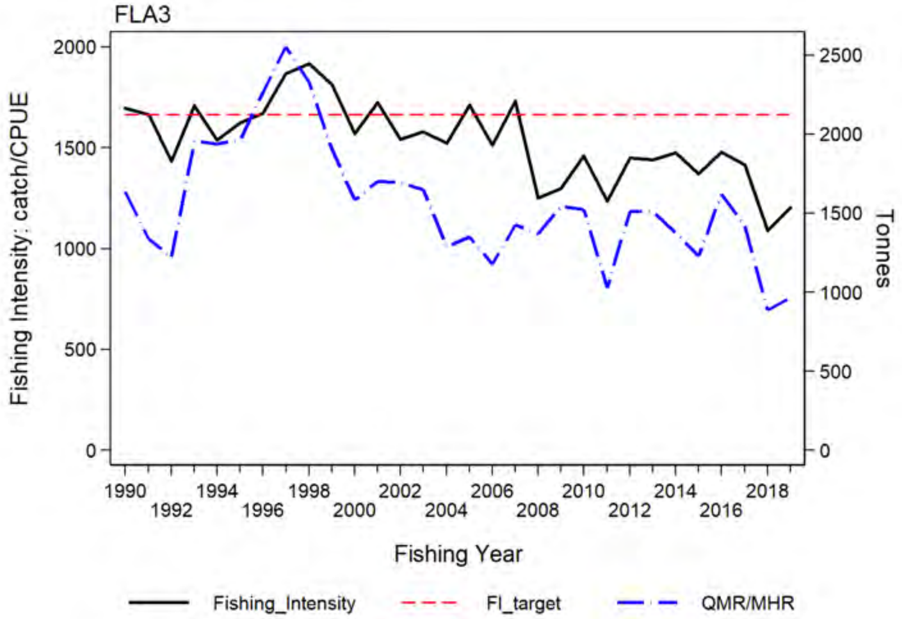
Stock Structure Assumptions
New Zealand sole and lemon sole appear to be a continuous population extending from Canterbury Bight to Foveaux Strait. Sand flounder off the East and South Coasts of South Island show localised concentrations that roughly correspond to the existing statistical areas. The stock relationships among these localised concentrations are unknown.

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised lognormal bottom trawl CPUE for all flatfish combined in FLA 3
Reference Points	Target: F_{MSY} proxy Soft Limit: to be determined Hard Limit: to be determined Overfishing threshold: F_{MSY} proxy
Status in relation to Target	Fishing mortality is Likely (> 60%) to be at or below the target
Status in relation to Limits	Soft limit: Not determined Hard Limit: Not determined
Status in relation to Overfishing	Unlikely (< 40%) that overfishing is occurring

Historical Stock Status Trajectory and Current Status



Standardised CPUE indices based on positive catches for all flatfish species combined (Starr & Kendrick 2020a). Also shown are the QMR/MHR declared FLA 3 landings and the annual FLA 3 commercial catch allowance. Fishing year designated by second year of the pair.



Fishing intensity (catch/CPUE) and a target fishing intensity calculated by dividing the base FLA 3 TACC by the CPUE associated with the base FLA 3 TACC from the catch/CPUE regression (left panel, Figure 8). Also plotted are the annual FLA 3 QMR/MHR landings. Fishing year designated by second year of the pair.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE has fluctuated over the long-term near the 30-year mean.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has dropped since the reduction of the TACC in 2007–08 and the introduction of in-season variation to commercial catch allowance and remains below the F_{MSY} proxy.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Stockexpected to vary in abundance around the long-term mean
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unlikely (<40%) to cause overfishing

Assessment Methodology		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches	
Assessment Dates	Latest assessment: 2020	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Mixed species complex managed without explicitly considering each species - Uncertainty in stock structure assumptions	

Qualifying Comments
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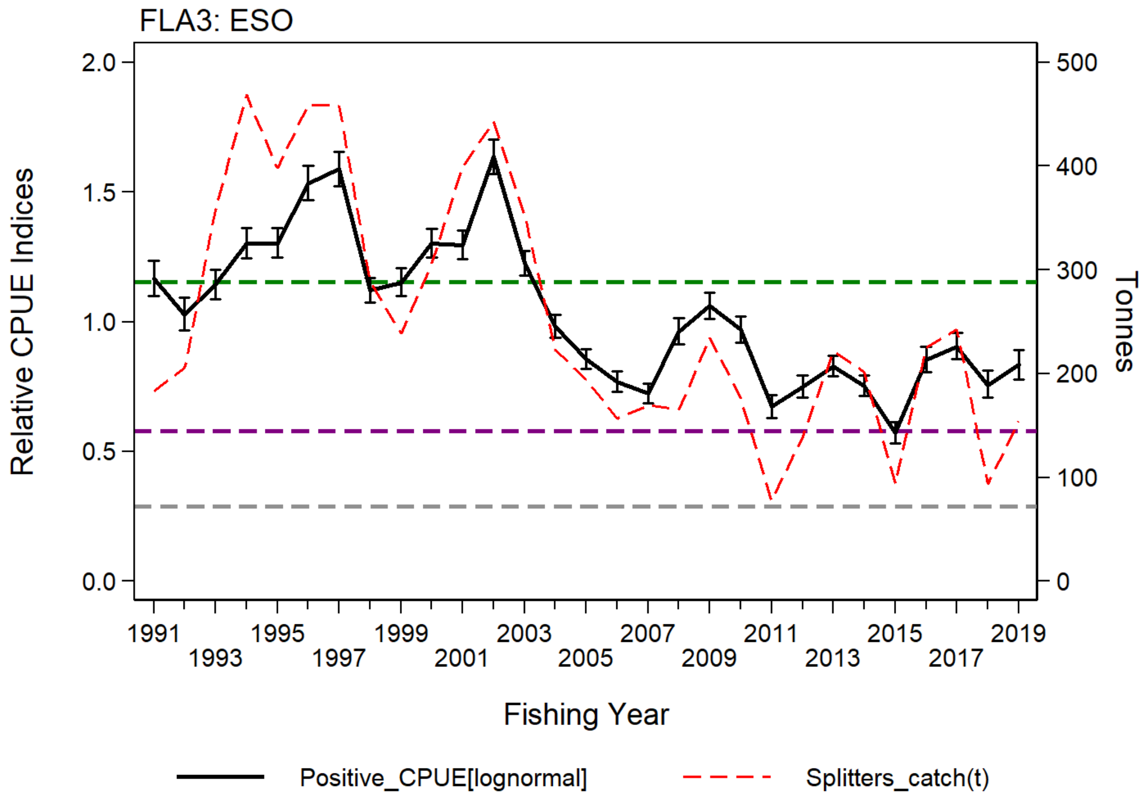
Fishery Interactions
The fishery is mainly confined to the inshore domestic trawl fleet except for a small incidental bycatch of soles, brill and turbot by offshore trawlers. The main target species landing flatfish as bycatch in FLA 3 are red cod, barracouta, stargazer, gurnard, tarakihi and elephant fish. Interactions with other species are currently being characterised.

- **FLA 3: New Zealand (ESO) sole**

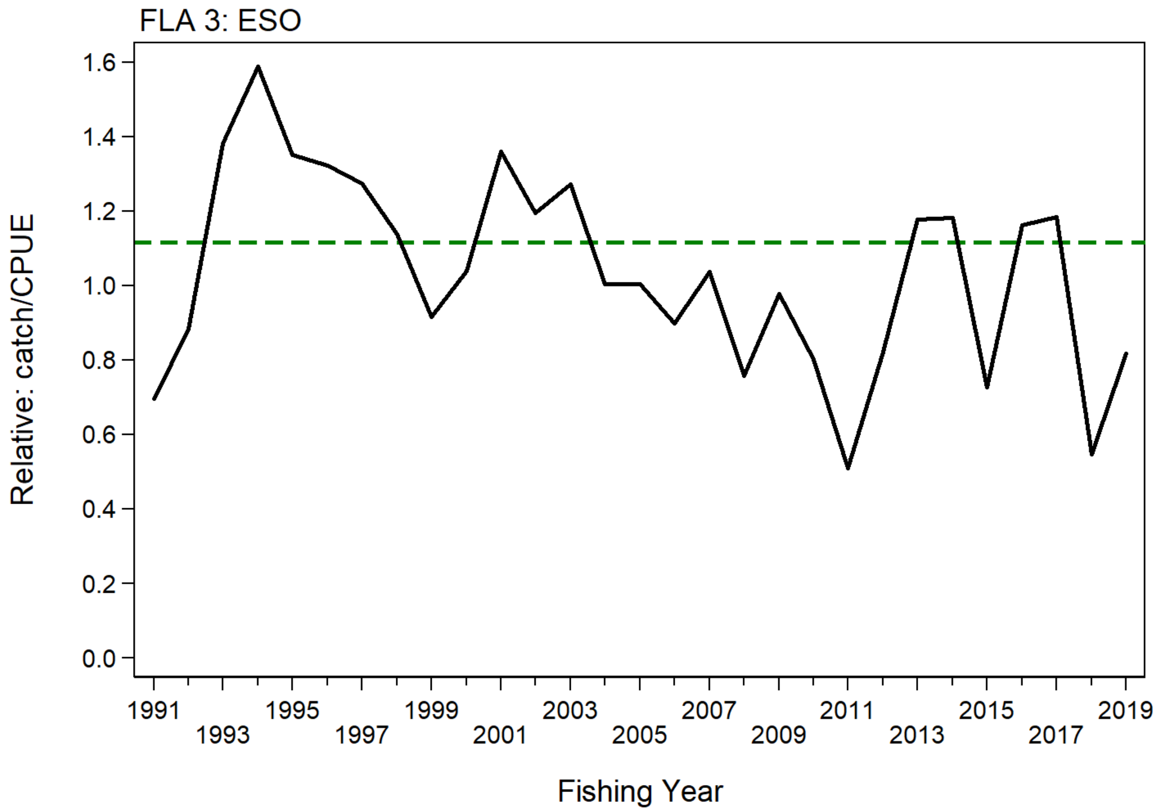
Stock Structure Assumptions
New Zealand sole appear to be a continuous population extending from Canterbury Bight to Foveaux Strait.

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised lognormal bottom trawl CPUE for ESO in FLA 3, based on trips which landed FLA 3 but which did not use the FLA species code
Reference Points	Interim Target: B_{MSY} proxy based on mean standardised CPUE from 1990–91 to 2006–07 (the final year of unconstrained catches) Soft Limit: 50% B_{MSY} proxy Hard Limit: 25% B_{MSY} proxy Overfishing threshold: F_{MSY} proxy based on mean relative exploitation rate for the period 1990–91 to 2006–07
Status in relation to Target	Unlikely (< 40%) to be at or above target
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Unlikely (< 40%) that overfishing is occurring

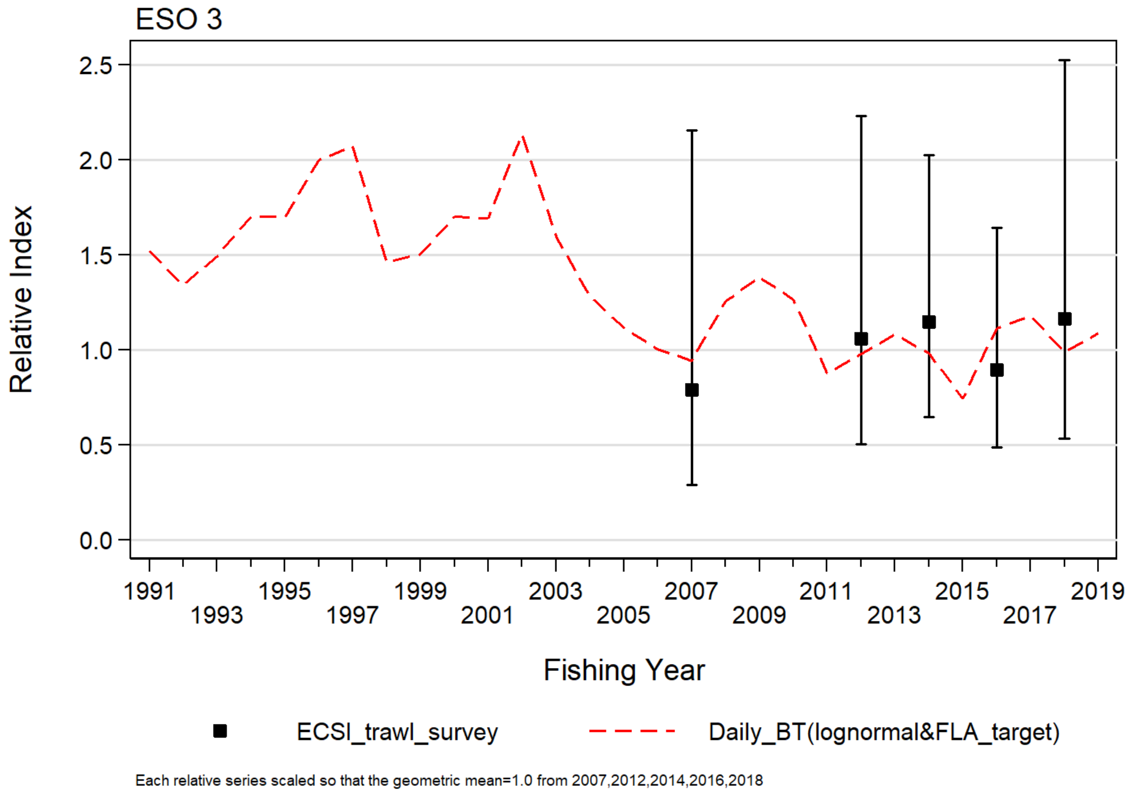
Historical Stock Status Trajectory and Current Status



Standardised CPUE indices based on lognormal CPUE series for New Zealand sole (ESO), showing the agreed B_{MSY} proxy (green dashed line: average 1990–91 to 2006–07 CPUE index) and the associated Soft (purple dashed line) and Hard (grey dashed line) Limits (Starr & Kendrick 2020a). Also shown is the ESO estimated catch by trips that landed FLA 3 but which did not use the FLA code. Fishing year designated by second year of the pair.



Relative fishing intensity for ESO in FLA 3, based on the ESO 'splitter' catch and the standardised lognormal ESO CPUE series. The horizontal dashed green line corresponds to the mean fishing intensity for the period 1991–2007.



Standardised indices based on the lognormal CPUE series for New Zealand sole (ESO), shown with the 5 total (core+shallow strata) trawl survey ESO biomass indices from the *Kaharoa* ECSI winter trawl survey.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE has declined from a peak reached in 2001–02 but has remained above the Soft Limit since 2007–08.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has declined to below the target in the most recent two years
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Unlikely (< 40%) to be at or above target
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (<40%) for current catch Hard Limit: Very Unlikely (< 10%) for current catch
Probability of Current Catch or TACC causing Overfishing to continue or to commence	As Likely as Not (40-60%) for current catch

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches	
Assessment Dates	Latest assessment: 2020	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- uncertainty in stock structure assumptions	

Qualifying Comments
The lack of historic species specific reporting for FLA stocks limits the ability to assess the long-term trends in these stocks; there is an expectation that the adoption of Eletronic Reporting of catch will improve the reporting of species-specific estimated flatfish catch.

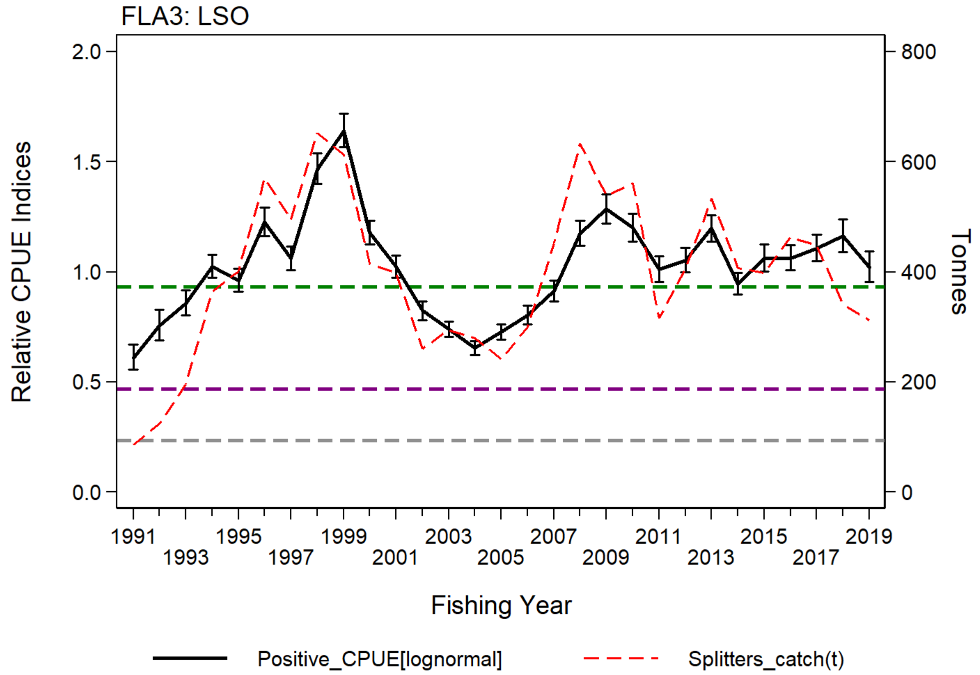
Fishery Interactions
The fishery is mainly confined to the inshore domestic trawl fleet except for a small incidental bycatch of soles, brill and turbot by offshore trawlers. The main target species landing flatfish as bycatch in FLA 3 are red cod, barracouta, stargazer, gurnard, tarakihi and elephant fish.

- **FLA 3: Lemon (LSO) sole**

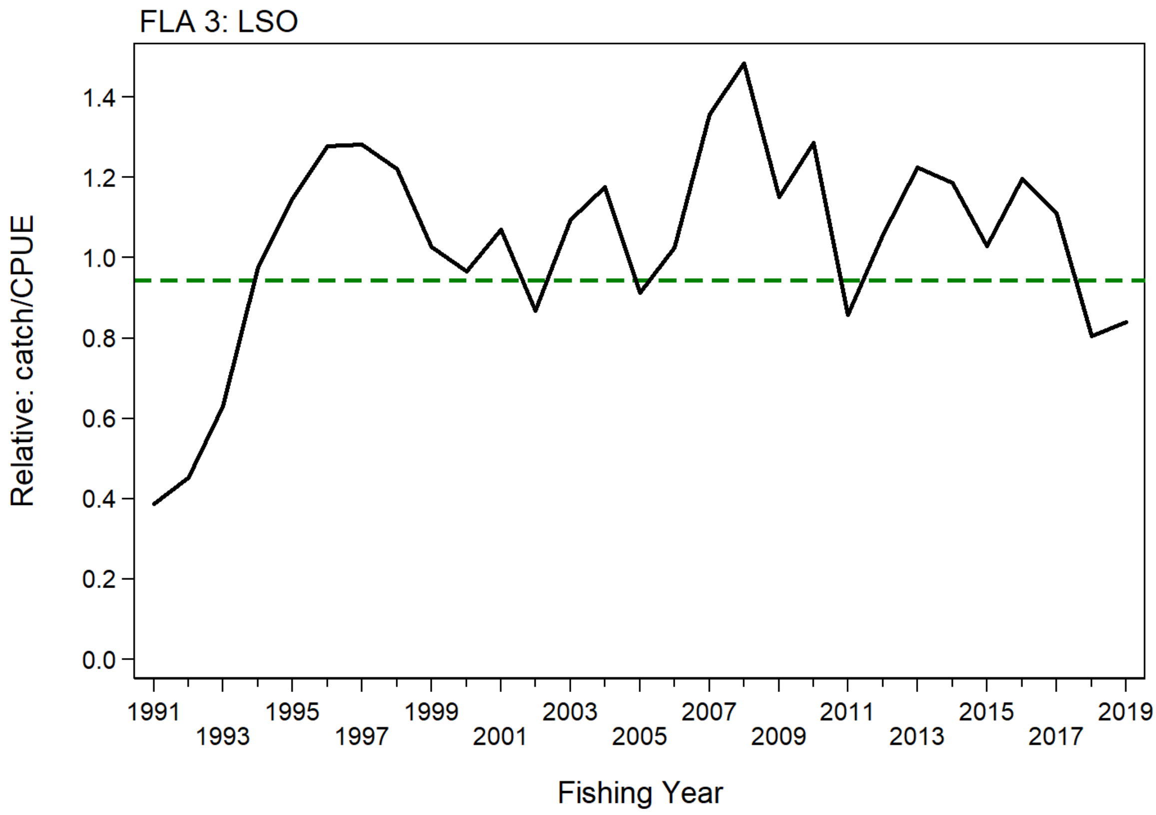
Stock Structure Assumptions
Lemon sole appear to be a continuous population extending from Canterbury Bight to Foveaux Strait.

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised lognormal bottom trawl CPUE for LSO in FLA 3, based on trips which landed FLA 3 but which did not use the FLA species code
Reference Points	Interim Target: B_{MSY} proxy based on mean standardised CPUE from 1990–91 to 2006–07 (the final year of unconstrained catches) Soft Limit: 50% B_{MSY} proxy Hard Limit: 25% B_{MSY} proxy Overfishing threshold: F_{MSY} proxy based on mean relative exploitation rate for the period 1990–91 to 2006–07
Status in relation to Target	About as Likely as Not (40–60%) to be at or above target
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	About as Likely as Not (40–60%) that overfishing is occurring

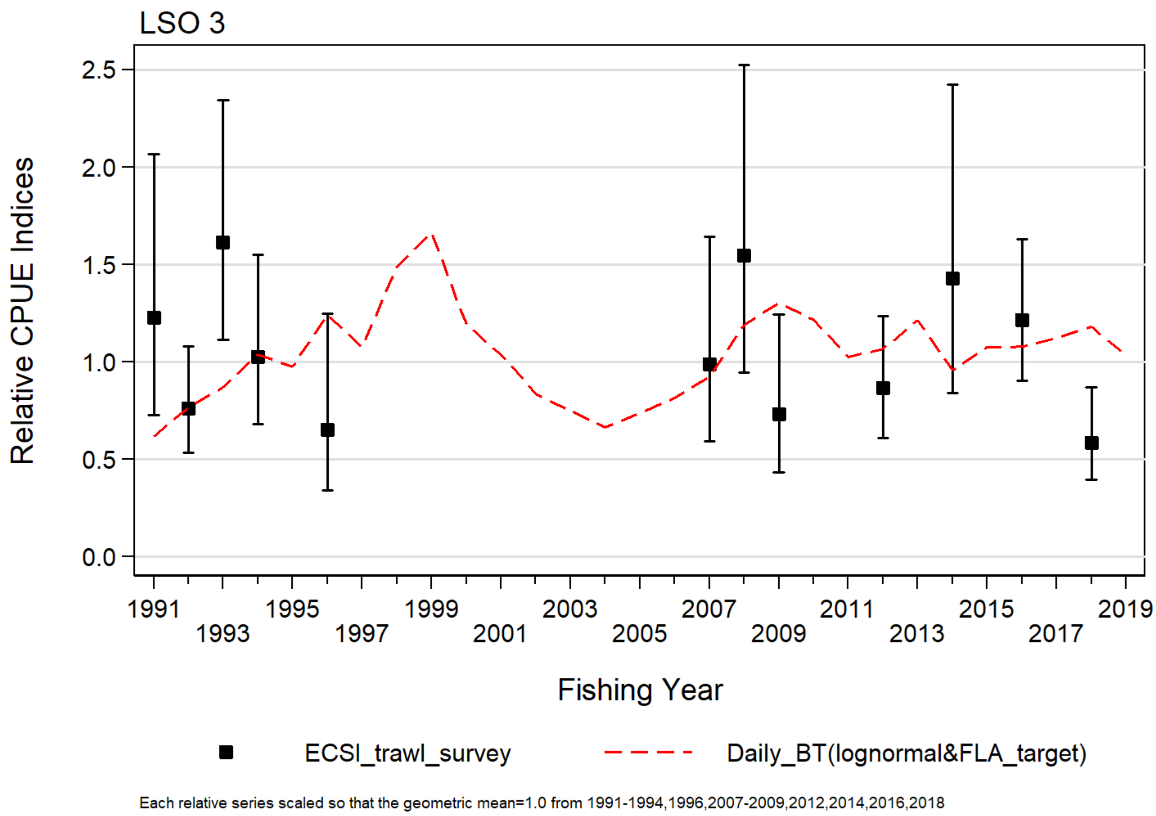
Historical Stock Status Trajectory and Current Status



Standardised indices based on lognormal CPUE series for Lemon sole (LSO), showing the agreed B_{MSY} proxy (green dashed line: average 1990–91 to 2006–07 CPUE index) and the associated Soft (purple dashed line) and Hard (grey dashed line) Limits (Starr & Kendrick 2020a). Also shown is the LSO estimated catch by trips that landed FLA 3 but which did not use the FLA code. Fishing year designated by second year of the pair.



Relative fishing intensity for LSO in FLA 3, based on the LSO 'splitter' catch and the standardised lognormal LSO CPUE series. The horizontal dashed green line corresponds to the mean fishing intensity for the period 1991–2007.



Standardised indices based on the lognormal CPUE series for Lemon sole (LSO) shown with the 12 trawl survey LSO core strata biomass indices from the *Kaharoa* ECSI winter trawl survey. Fishing year designated by second year of the pair.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE reached a nadir in 2003–04, but then climbed to a new level near the long-term mean in 2007–08 and has since remained at that level.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has fluctuated, mostly above the F_{MSY} proxy since 1994–95 but has dropped to just below target in 2017-18 and 2018–19
Other Abundance Indices	Relative abundance from the ECSI winter trawl survey has fluctuated without trend since 1991.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	About as Likely or Not (40-60%) to remain at or above the target
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Very Unlikely (< 10%) Hard Limit: Very Unlikely (< 10%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	For current catch, About as Likely as Not (40–60%) to occur

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches	
Assessment Dates	Latest assessment: 2020	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- uncertainty in stock structure assumptions	
Qualifying Comments		
The lack of historic species specific reporting for FLA stocks limits the ability to assess the long-term trends in these stocks; there is an expectation that the adoption of Eletronic Reporting of catch will improve the reporting of species-specific estimated flatfish catch.		

Fishery Interactions
The fishery is mainly confined to the inshore domestic trawl fleet except for a small incidental bycatch of soles, brill and turbot by offshore trawlers. The main target species landing flatfish as bycatch in FLA 3 are red cod, barracouta, stargazer, gurnard, tarakihi and elephant fish. Interactions with protected species are believed to be low. Incidental captures of seabirds occur.

- **FLA 3: Sand Flounder (SFL)**

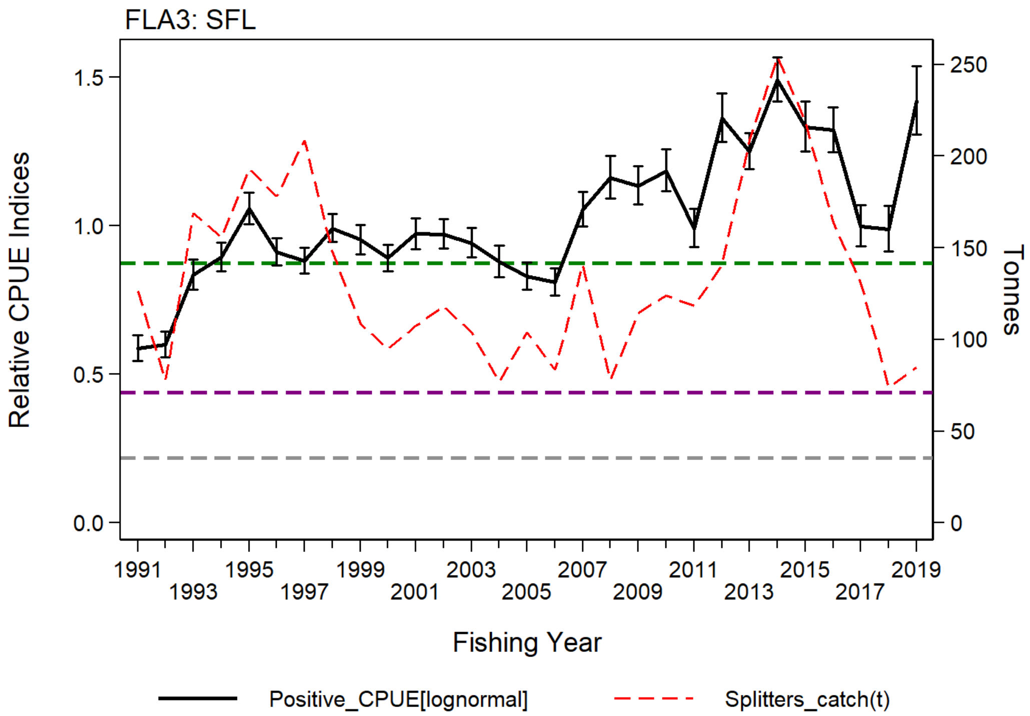
Stock Structure Assumptions

Sand flounder off the East and South Coasts of South Island show localised concentrations that roughly correspond to the existing statistical areas. The stock relationships among these localised concentrations are unknown.

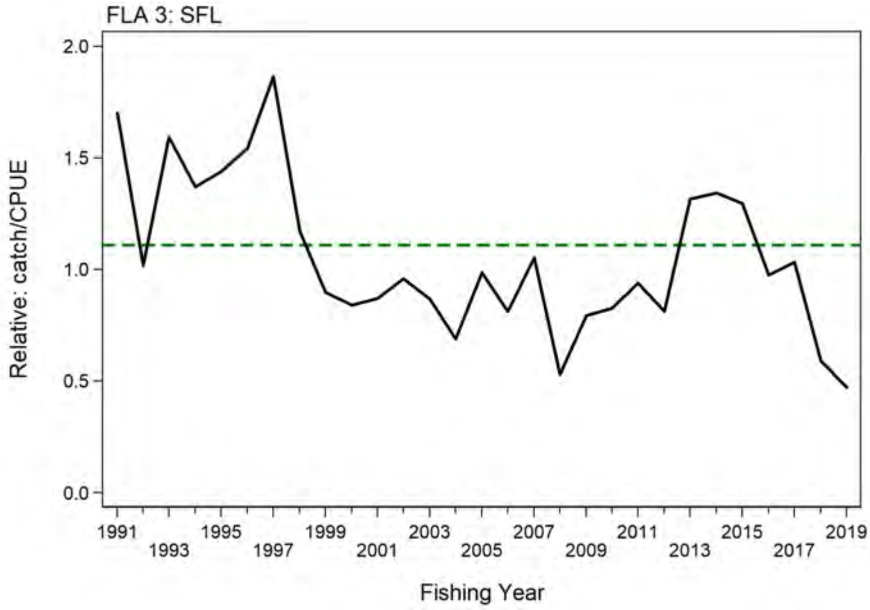
Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised lognormal bottom trawl CPUE for SFL in FLA 3, based on trips which landed FLA 3 but which did not use the FLA species code
Reference Points	Interim Target: B_{MSY} proxy based on mean standardised CPUE

	from 1990–91 to 2006–07 (the final year of unconstrained catches) Soft Limit: 50% B_{MSY} proxy Hard Limit: 25% B_{MSY} proxy Overfishing threshold: F_{MSY} proxy based on mean relative exploitation rate for the period 1990–91 to 2006–07
Status in relation to Target	Very Likely (> 90%) to be at or above target
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Unlikely (< 40%) that overfishing is occurring

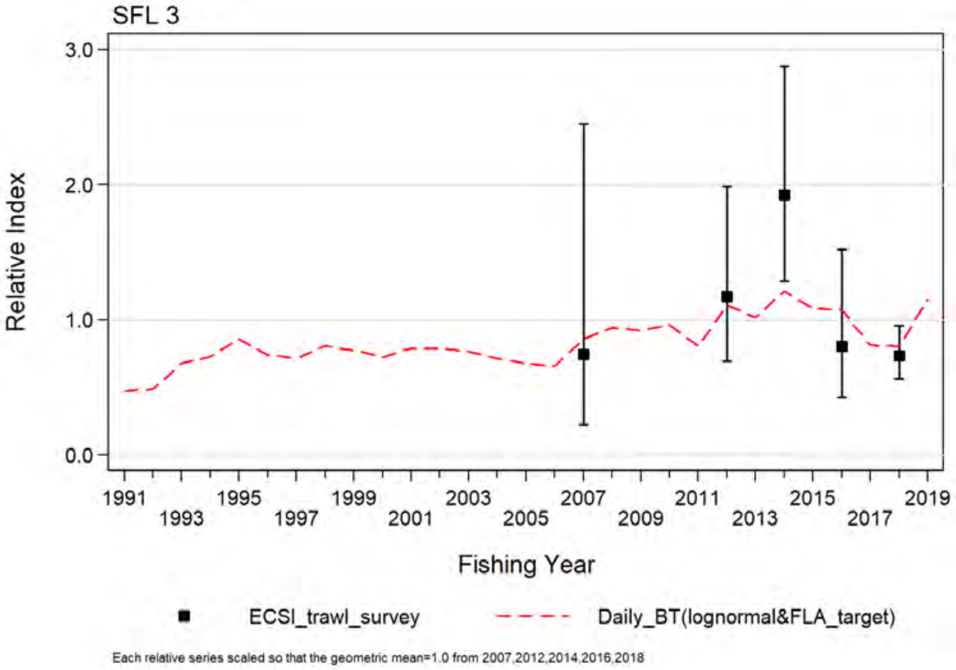
Historical Stock Status Trajectory and Current Status



Standardised indices based on lognormal CPUE series for Sand flounder (SFL), showing the agreed B_{MSY} proxy (green dashed line: average 1990–91 to 2006–07 CPUE index) and the associated Soft (purple dashed line) and Hard (grey dashed line) Limits (Starr & Kendrick 2018). Also shown is the SFL estimated catch by trips that landed FLA 3 but which did not use the FLA code. Fishing year designated by second year of the pair.



Relative fishing intensity for SFL in FLA 3, based on the SFL 'splitter' catch and the standardised lognormal SFL CPUE series. The horizontal dashed green line corresponds to the mean fishing intensity for the period 1991–2007.



Standardised indices based on the lognormal CPUE series for sand flounder (SFL), shown with the 5 total (core+shallow strata) trawl survey SFL biomass indices from the *Kaharoa* ECSI winter trawl survey.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE rose from a nadir in 2003–04 to above the long-term mean by 2007–08 and has fluctuated above this level since then.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has dropped steeply since 2014–15 and was well below the target in 2018–19
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	- Likely (> 60%) to remain at or above the target
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Very Unlikely (< 10%) for current catch Hard Limit: Very Unlikely (< 10%) for current catch
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unlikely (< 40%) for current catch

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches	
Assessment Dates	Latest assessment: 2020	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- uncertainty in stock structure assumptions	

Qualifying Comments
The lack of historic species specific reporting for FLA stocks limits the ability to assess the long-term trends in these stocks; there is an expectation that the adoption of Eletronic Reporting of catch will improve the reporting of species-specific estimated flatfish catch.

Fishery Interactions
The fishery is mainly confined to the inshore domestic trawl fleet except for a small incidental bycatch of soles, brill and turbot by offshore trawlers. The main target species landing flatfish as bycatch in FLA 3 are red cod, barracouta, stargazer, gurnard, tarakihi and elephant fish. Interactions with other species are currently being characterised.

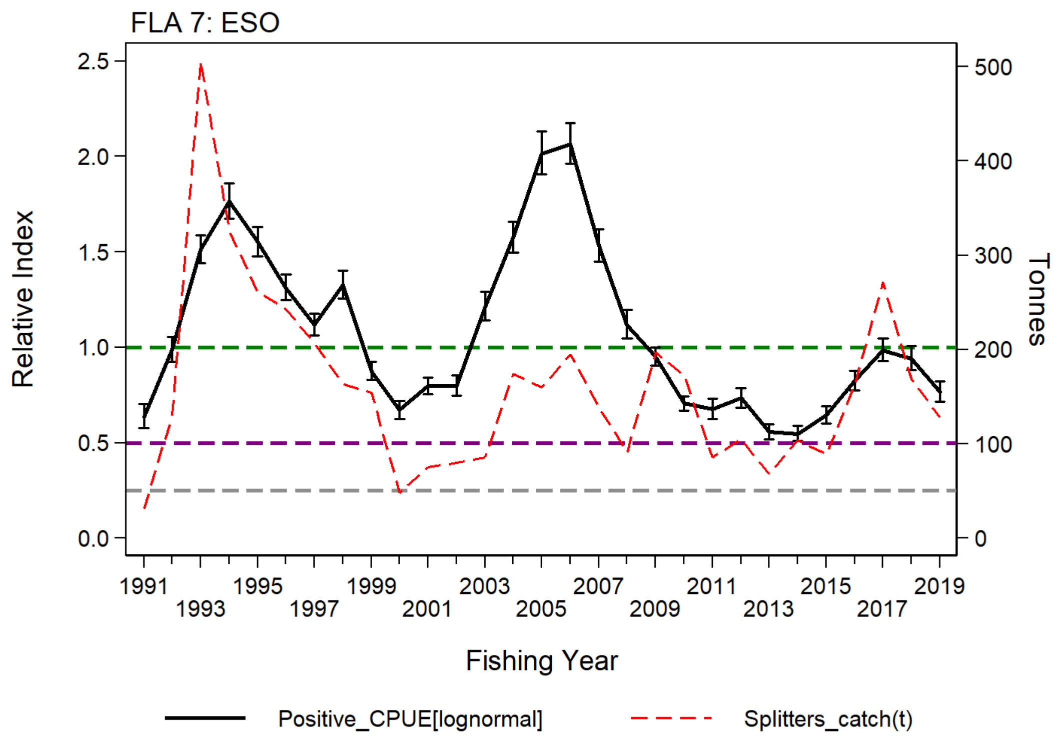
- **FLA 7: New Zealand (ESO) sole**

Stock Structure Assumptions

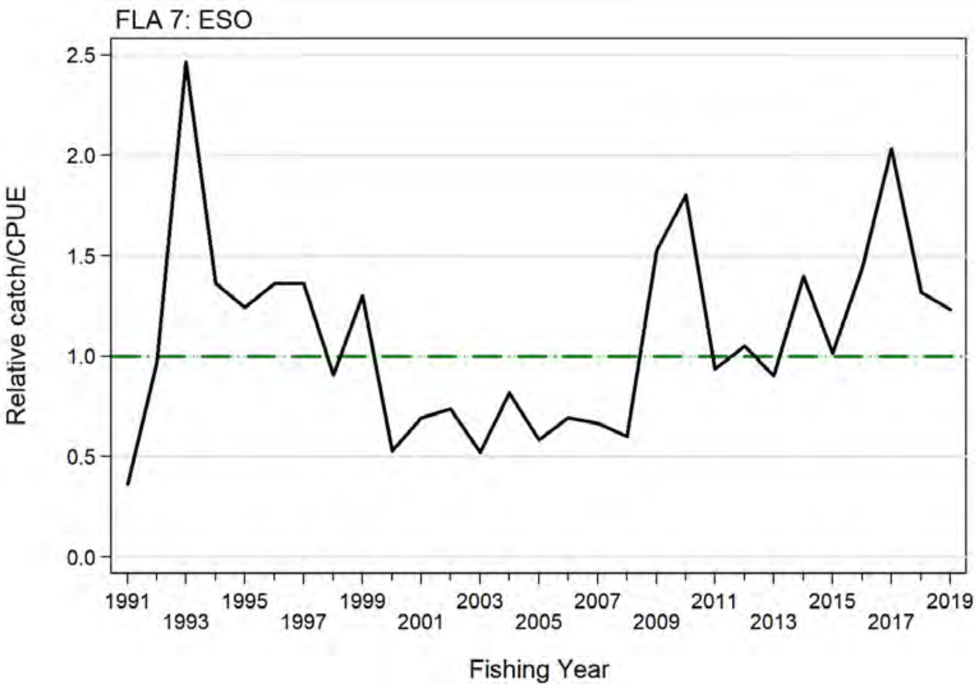
New Zealand sole are mostly taken off the west coast South Island portion of FLA 7, and there is very little catch taken in Tasman/Golden Bay. The CPUE analysis presented in the table below is based on catch and effort data from the west coast (Areas 032, 033, 034 and 035).

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised lognormal bottom trawl CPUE for ESO in FLA 7, based on trips which landed FLA 7 but which did not use the FLA species code
Reference Points	Interim Target: B_{MSY} proxy based on mean standardised CPUE from 1990–91 to 2018–19 Soft Limit: 50% B_{MSY} proxy Hard Limit: 25% B_{MSY} proxy Overfishing threshold: F_{MSY} proxy based on mean relative exploitation rate for the period 1990–91 to 2018–19
Status in relation to Target	Unlikely (< 40%) to be at or above target
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Very Likely (< 10%) to be below
Status in relation to Overfishing	Likely (> 60%) that overfishing is occurring

Historical Stock Status Trajectory and Current Status



Standardised indices based on lognormal CPUE series for New Zealand sole (ESO), showing the agreed B_{MSY} proxy (green dashed line: average 1990–91 to 2018–19 CPUE index) and the associated Soft (purple dashed line) and Hard (grey dashed line) Limits (Starr & Kendrick 2020b). Also shown is the ESO estimated catch by trips that landed FLA 7 but which did not use the FLA code. Fishing year designated by second year of the pair.



Relative fishing intensity for ESO in FLA 7, based on the ESO 'splitter' catch and the standardised lognormal ESO CPUE series. The horizontal dashed green line corresponds to the mean fishing intensity for the period 1991–2019.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE declined from a 2005–06 peak to a low in 2013–14, increased to 2016–17 and declined again to 0.77 in 2018–19
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has increased since 2010–11 to above the mean level.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Likely (> 60%) to remain below target for current catch
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) for current catch Hard Limit: Very Unlikely (< 10%) for current catch
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Likely (> 60%) for current catch

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches	
Assessment Dates	Latest assessment: 2020	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- uncertainty in stock structure assumptions	

Qualifying Comments
The lack of historic species specific reporting for FLA stocks limits the ability to assess the long-term trends in these stocks; there is an expectation that the adoption of Eletronic Reporting of catch will improve the reporting of species-specific estimated flatfish catch.

Fishery Interactions
The fishery is mainly confined to the inshore domestic trawl fleet except for a small incidental bycatch of soles, brill and turbot by offshore trawlers. The main non-FLA target species landing flatfish as bycatch in FLA 7 are red cod, barracouta, gurnard and tarakihi. The bycatch of FLA 7 in other QMS species has averaged 18% of the total 1989–90 to 2018–19 FLA 7 catch.

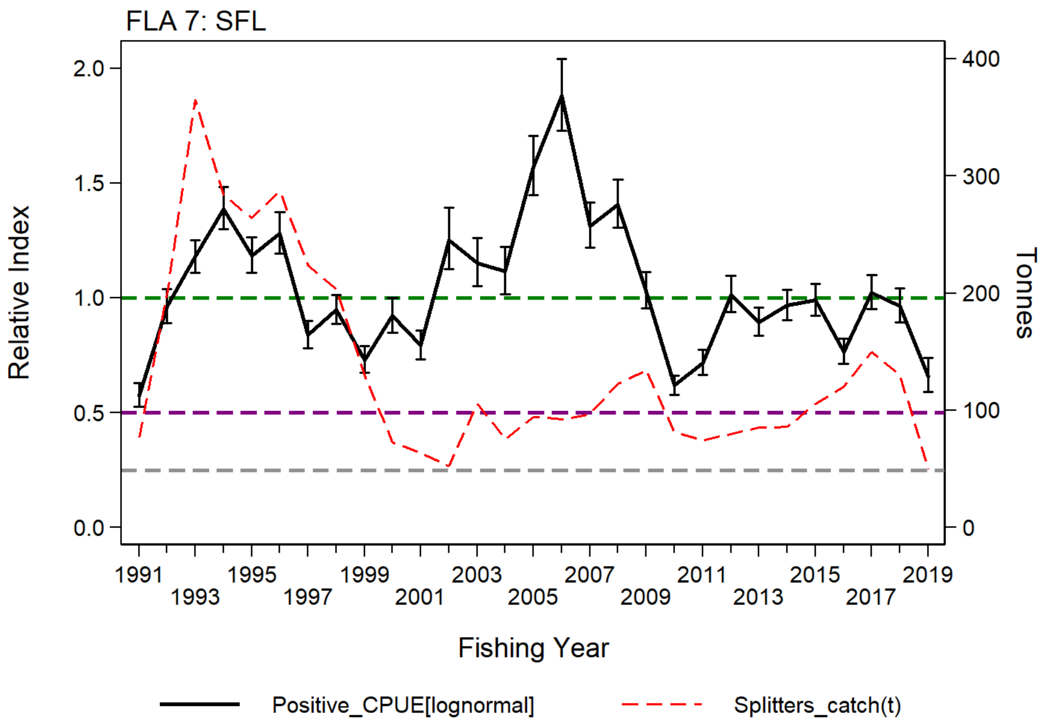
- **FLA 7: Sand Flounder (SFL)**

Stock Structure Assumptions

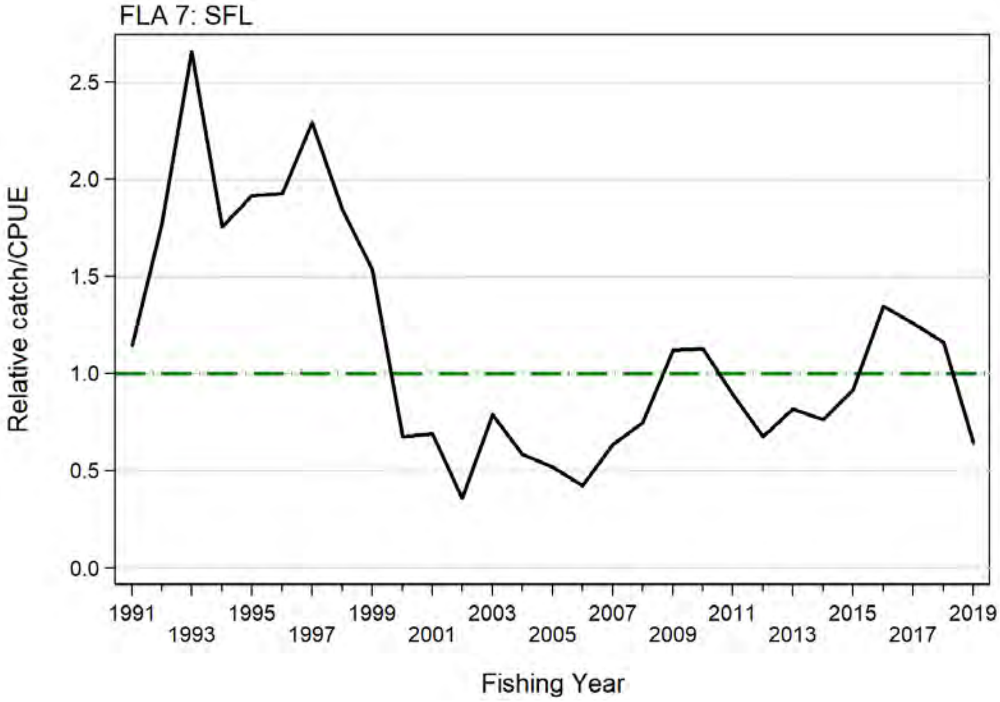
Sand flounder in FLA 7 is mostly taken in Tasman/Golden Bay, with a small component of the catch coming from eastern Cook Strait. There is very little SFL catch from the west coast of the South Island. The analysis presented in the table below is based on catch and effort data from Tasman/Golden Bays (Area 038).

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised lognormal bottom trawl CPUE for SFL in FLA 7, based on trips which landed FLA 7 but which did not use the FLA species code
Reference Points	Interim Target: B_{MSY} proxy based on mean standardised CPUE from 1990–91 to 2018–19 Soft Limit: 50% B_{MSY} proxy Hard Limit: 25% B_{MSY} proxy Overfishing threshold: F_{MSY} proxy based on mean relative exploitation rate for the period 1990–91 to 2018–19
Status in relation to Target	About as Likely as Not (40–60%) to be at or above target
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	About as Likely as Not (40–60%) that overfishing is occurring

Historical Stock Status Trajectory and Current Status



Standardised indices based on lognormal CPUE series for Sand flounder (SFL), showing the agreed B_{MSY} proxy (green dashed line: average 1990–91 to 2018–19 CPUE index) and the associated Soft (purple dashed line) and Hard (grey dashed line) Limits (Starr & Kendrick 2020b). Also shown is the SFL estimated catch by trips that landed FLA 7 but which did not use the FLA code. Fishing year designated by second year of the pair.



Relative fishing intensity for SFL in FLA 7, based on the SFL'splitter' catch and the standardised lognormal SFL CPUE series. The horizontal dashed green line corresponds to the mean fishing intensity for the period 1991–2019.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE has fluctuated without trend near the long-term average from 2010–11;
Recent Trend in Fishing Intensity or Proxy	Fishing intensity dropped to relatively low levels in the late 2000s, and has since climbed back to the level of the F_{MSY} proxy
Other Abundance Indices	Relative abundance from the WCSI trawl survey has fluctuated without trend since 1992.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	About as Likely as Not (40–60%) to remain near target for current catch
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) for current catch Hard Limit: Very Unlikely (< 10%) for current catch
Probability of Current Catch or TACC causing Overfishing to continue or to commence	About as Likely as Not (40–60%) to remain near overfishing threshold for current catch

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches	
Assessment Dates	Latest assessment: 2020	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- uncertainty in stock structure assumptions	

Qualifying Comments
The lack of historic species specific reporting for FLA stocks limits the ability to assess the long-term trends in these stocks; there is an expectation that the adoption of Eletronic Reporting of catch will improve the reporting of species-specific estimated flatfish catch.

Fishery Interactions
The fishery is mainly confined to the inshore domestic trawl fleet fishing in Tasman/Golden Bays, which primarily targets gurnard and snapper, in addition to flatfish. Other species are incidental.

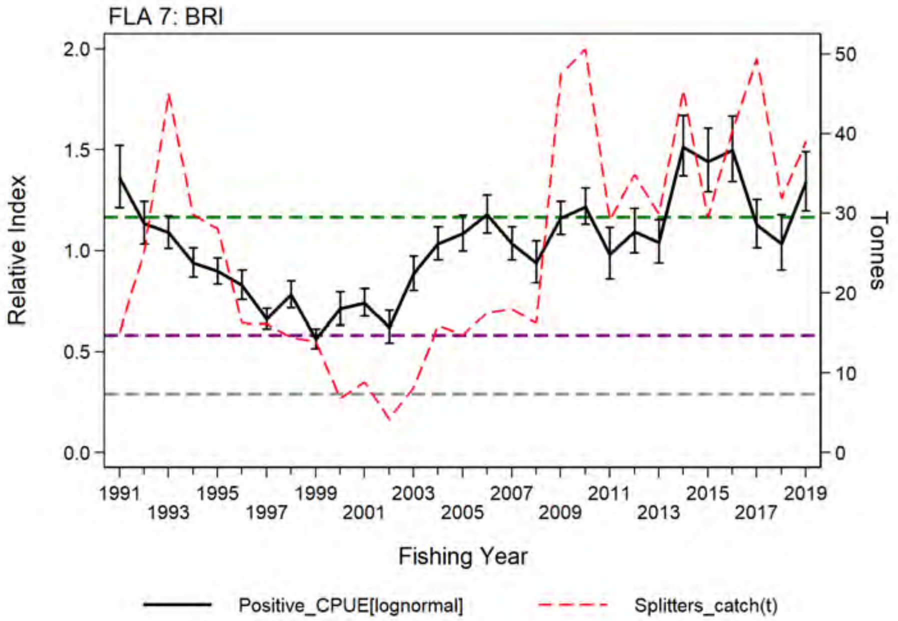
- **FLA 7: Brill (BRI)**

Stock Structure Assumptions

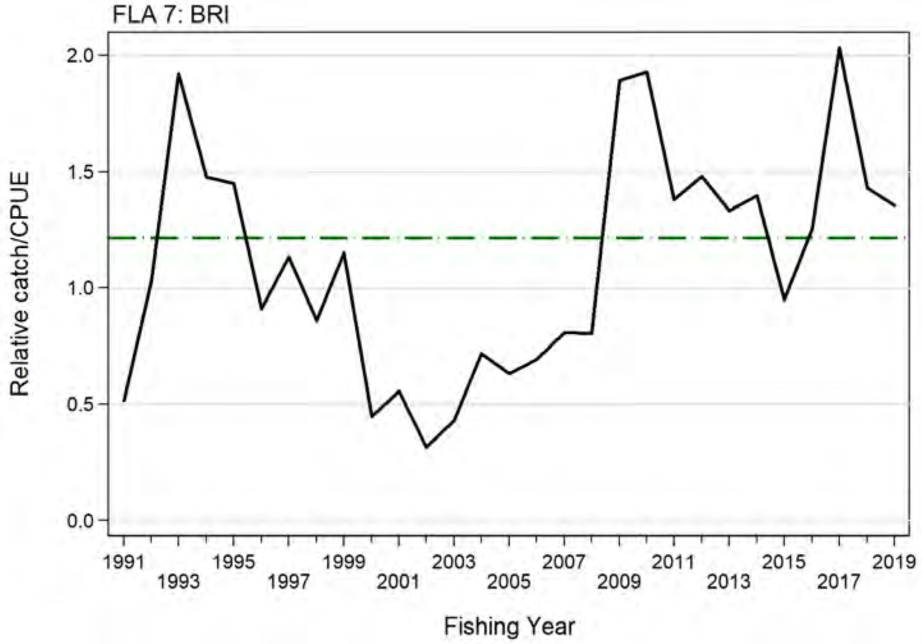
Brill are mostly taken off the west coast South Island portion of FLA 7, where they appear to comprise a continuous population, and there is very little catch taken in Tasman/Golden Bay. The CPUE analysis presented in the table below is based on catch and effort off the west coast (Areas 032, 033, 034 and 035).

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised lognormal bottom trawl CPUE for BRI in FLA 7, based on trips which landed FLA 7 but which did not use the FLA species code
Reference Points	Interim Target: B_{MSY} proxy based on mean standardised CPUE from 2004–05 to 2018–19 Soft Limit: 50% B_{MSY} proxy Hard Limit: 25% B_{MSY} proxy Overfishing threshold: F_{MSY} proxy based on mean relative exploitation rate for the period 1990–91 to 2018–19
Status in relation to Target	About as Likely as Not (40–60%) to be at or above target
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	About as Likely as Not (40–60%) that overfishing is occurring

Historical Stock Status Trajectory and Current Status



Standardised indices based on lognormal CPUE series for Brill (BRI), showing the agreed B_{MSY} proxy (green dashed line: average 2004–05 to 2018–19 CPUE index) and the associated Soft (purple dashed line) and Hard (grey dashed line) Limits (Starr & Kendrick 2020b). Also shown is the BRI estimated catch by trips that landed FLA 7 but which did not use the FLA code. Fishing year designated by second year of the pair.



Relative fishing intensity for BRI in FLA 7, based on the BRI 'splitter' catch and the standardised lognormal BRI CPUE series. The horizontal dashed green line corresponds to the mean fishing intensity for the period 2005–2019.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE has been relatively constant at a high level since 2004–05 with a three-year excursion to 1.5X the long-term average from 2014–15 to 2016–17
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has fluctuated, mostly above the F_{MSY} proxy since 2004–05, and was near the Fmsy proxy in 2018–19
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	About as Likely as Not (40–60%) to remain near target for current catch
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Very Unlikely (< 10%) for current catch Hard Limit: Very Unlikely (< 10%) for current catch
Probability of Current Catch or TACC causing Overfishing to continue or to commence	About as Likely as Not (40–60%) to remain near overfishing threshold for current catch

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches	
Assessment Dates	Latest assessment: 2020	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- uncertainty in stock structure assumptions	
Qualifying Comments		
The lack of historic species specific reporting for FLA stocks limits the ability to assess the long-term trends in these stocks; there is an expectation that the adoption of Eletronic Reporting of catch will improve the reporting of species-specific estimated flatfish catch.		

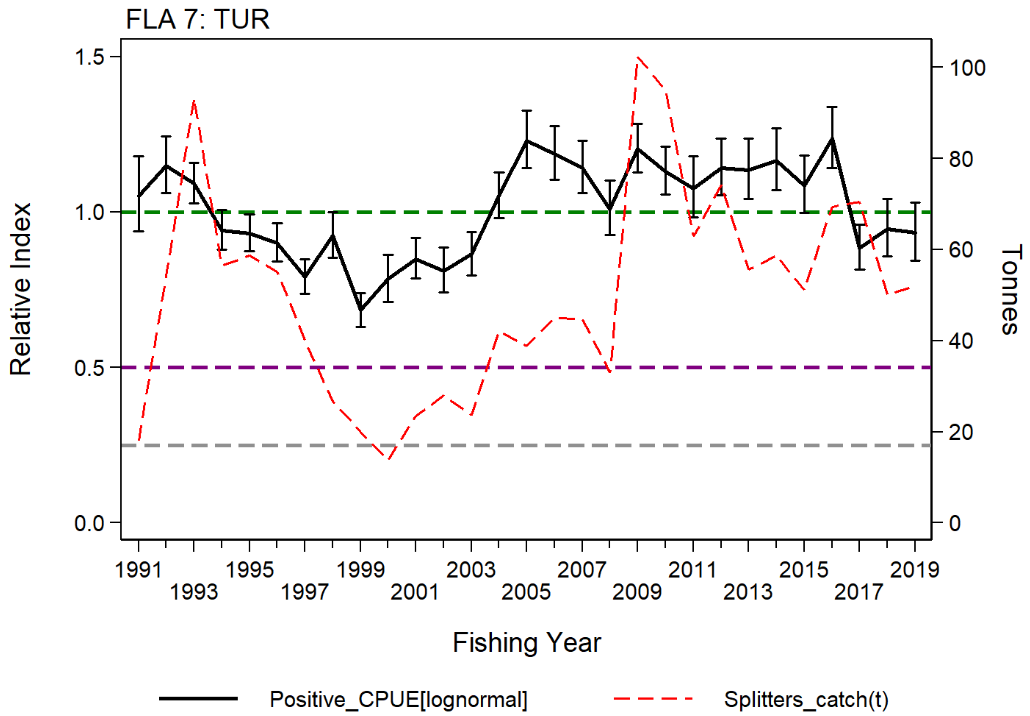
Fishery Interactions
The fishery is mainly confined to the inshore domestic trawl fleet except for a small incidental bycatch of soles, brill and turbot by offshore trawlers. The main non-FLA target species landing flatfish as bycatch in FLA 7 are red cod, barracouta, gurnard and tarakihi. The bycatch of FLA 7 in other QMS species has averaged 18% of the total 1989–90 to 2018–19 FLA 7 catch.

- **FLA 7: Turbot (TUR)**

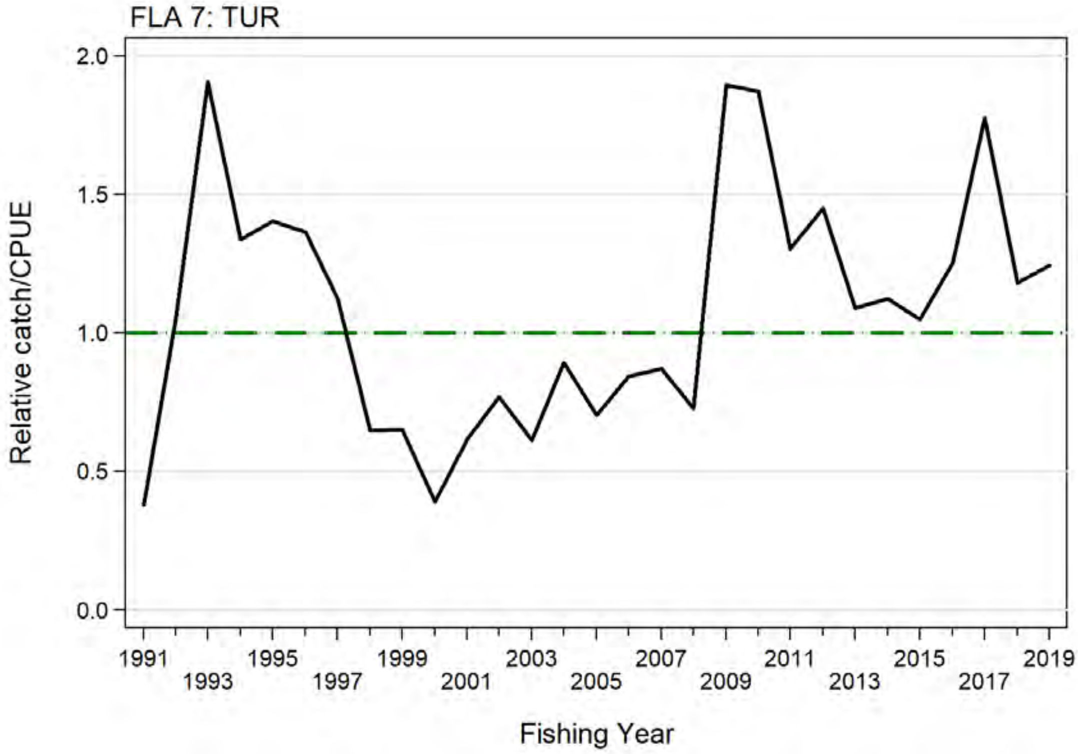
Stock Structure Assumptions
Turbot are mostly taken off the west coast South Island portion of FLA 7, where they appear to comprise a continuous population, and there is very little catch taken in Tasman/Golden Bay. The CPUE analysis presented in the table below is based on catch and effort off the west coast (Areas 032, 033, 034 and 035).

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised lognormal bottom trawl CPUE for TUR in FLA 7, based on trips which landed FLA 7 but which did not use the FLA species code
Reference Points	Interim Target: B_{MSY} proxy based on mean standardised CPUE from 1990–91 to 2018–19 Soft Limit: 50% B_{MSY} proxy Hard Limit: 25% B_{MSY} proxy Overfishing threshold: F_{MSY} proxy based on mean relative exploitation rate for the period 1990–91 to 2018–19
Status in relation to Target	About as Likely as Not (40–60%) to be at or above target
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	About as Likely as Not (40–60%) that overfishing is occurring

Historical Stock Status Trajectory and Current Status



Standardised indices based on lognormal CPUE series for Turbot (TUR), showing the agreed B_{MSY} proxy (green dashed line: average 1990–91 to 2018–19 CPUE index) and the associated Soft (purple dashed line) and Hard (grey dashed line) Limits (Starr & Kendrick 2020b). Also shown is the TUR estimated catch by trips that landed FLA 7 but which did not use the FLA code. Fishing year designated by second year of the pair.



Relative fishing intensity for TUR in FLA 7, based on the TUR 'splitter' catch and the standardised lognormal TUR CPUE series. The horizontal dashed green line corresponds to the mean fishing intensity of-r the period 1991–2019.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE has been relatively stable in this fishery, with a long period above the long-term average from 2004–05 to 2015–16; CPUE has dropped to below the long-term average after 2016–17
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has fluctuated, above the F_{MSY} proxy since 2007–08 and was just above the Fmsy proxy in 2018–19
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	About as Likely as Not (40–60%) to remain near target for current catch
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Very Unlikely (< 10%) for current catch Hard Limit: Very Unlikely (< 10%) for current catch
Probability of Current Catch or TACC causing Overfishing to continue or to commence	About as Likely as Not (40–60%) to remain near overfishing threshold for current catch

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches	
Assessment Dates	Latest assessment: 2020	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- uncertainty in stock structure assumptions	

Qualifying Comments
The lack of historic species specific reporting for FLA stocks limits the ability to assess the long-term trends in these stocks; there is an expectation that the adoption of Eletronic Reporting of catch will improve the reporting of species-specific estimated flatfish catch.

Fishery Interactions
The fishery is mainly confined to the inshore domestic trawl fleet except for a small incidental bycatch of soles, brill and turbot by offshore trawlers. The main non-FLA target species landing flatfish as bycatch in FLA 7 are red cod, barracouta, gurnard and tarakihi. The bycatch of FLA 7 in other QMS species has averaged 18% of the total 1989–90 to 2018–19 FLA 7 catch.

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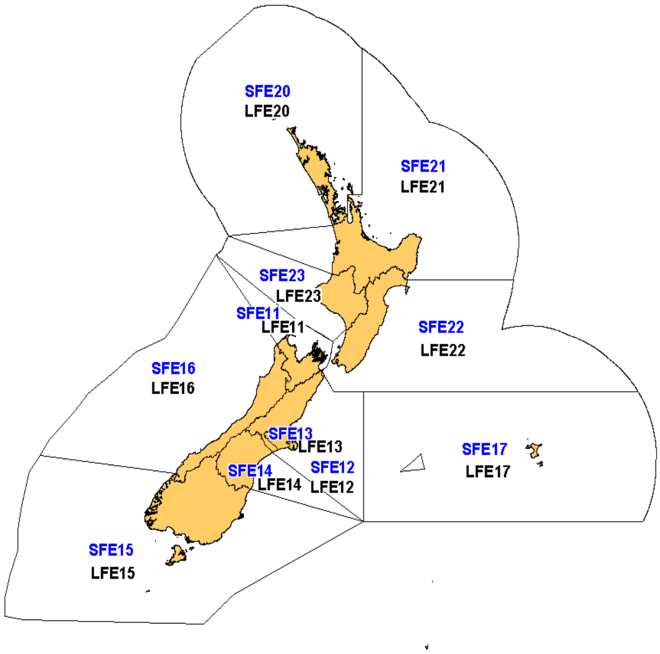
FRESHWATER EELS (SFE, LFE, ANG)

(Anguilla australis, Anguilla dieffenbachii, Anguilla reinhardtii)



1. FISHERY SUMMARY

1.1 Commercial fisheries

The freshwater eel fishery is distributed throughout accessible freshwaters (lakes, rivers, streams, farm ponds, tarns) and some estuarine and coastal waters of New Zealand, including the Chatham Islands. The contemporary commercial fishery dates from the mid-1960s when markets were established in Europe and Asia.

The New Zealand eel fishery is based on the two temperate species of freshwater eels occurring in New Zealand, the shortfin eel *Anguilla australis* and the longfin eel *A. dieffenbachii*. A third species of freshwater eel, the Australasian longfin (*A. reinhardtii*), identified in 1996, has been confirmed from North Island landings. The proportion of this species in landings is unknown but is thought to be small. Virtually all eels (98%) are caught with fyke nets. Eel catches are greatly influenced by water temperature, flood events (increased catches), and drought conditions (reduced catches). Catches decline in winter months (May to September), particularly in the South Island where fishing ceases.

The South Island eel fishery was introduced into the Quota Management System (QMS) on 1 October 2000 with shortfin and longfin species combined into six fish stocks (codes ANG 11 to ANG 16). The Chatham Island fishery was introduced into the QMS on 1 October 2003 with two fish stocks (shortfins and longfins separated into SFE 17 and LFE 17, respectively). The North Island eel fishery was introduced into the QMS on 1 October 2004 with eight fish stocks (four longfin stocks LFE 20–23 and four shortfin stocks SFE 20–23). On 1 October 2017 the former South Island ANG QMAs were split into corresponding longfin (LFE 11–16) and shortfin (SFE 11–16) QMAs, each with its own TACC. The Australasian longfin eel is combined as part of the shortfin eel stocks in the Chatham Islands and North Island, because this species has productivity characteristics closer to shortfins than longfins, and because the catch is not sufficient to justify its own separate stocks. The occasional catch of Australasian longfins is mainly confined to the upper North Island.

The fishing year for all stocks extends from 1 October to 30 September except for ANG 13 (Te Waihora/Lake Ellesmere) which has a fishing year from 1 February to 31 January (since 2002). Currently, there exist minimum and maximum commercial size limits for both longfins and shortfins

(220 g and 4 kg, respectively) throughout New Zealand. North Island quota owners agreed in August 2012 to use 31 mm escapement tubes (equivalent to South Island regulation). The minimum legal diameter for escape tubes on the North Island was increased to 31 mm in October 2013. Quota owners from both islands formally agreed in 1995–96 not to land migratory female longfin eels. In the South Island the eel industry agreed to voluntary incremental increases in the diameter of escape tubes in fyke nets which increased from 25 mm to 26 mm in 1990–91, to 27 mm in 1993–94, to 28.5 mm in 1994–95, and finally to 31 mm in 1997–98, which effectively increases the minimum size limit of both main species to about 300 g. Since about 2006 there has been a voluntary code of practice to return all longfin eels caught in Te Waihora; catches of these longfins are recorded on Eel Catch Effort Returns (ECERs), but not on the Eel Catch Landing Returns (ECLRs).

In early 2005 the Mohaka, Motu, and much of the Whanganui River catchments were closed to commercial fishing and there are a number of smaller areas elsewhere that have been reserved as customary fisheries (see section 1.3). In addition, all Public Conservation lands managed by the Department of Conservation require at a minimum a concession to be commercially fished and in most cases are closed to commercial fishing. In the Waikato-Tainui rohe (region), fisheries bylaws were introduced in March 2014 to limit the minimum harvest size to 300 g for SFE and 400 g for LFE. Amongst other things, these bylaws also introduced an upper limit of 2 kg for both species (to prevent the taking of longfin females that are in a migratory state) and added seasonal closures in some reaches.

Commercial catch data are available from 1965 and originate from different sources. Catch data prior to 1988 are for calendar years, whereas those from 1988 onwards are for fishing years (Table 1, Figure 1). Licensed Fish Receiver Returns (LFRRs), Quota Management Reports (QMRs), and Monthly Harvest Returns (MHRs) provide the most accurate data on landings over the period 1988–89 to 2018–19 for the whole of New Zealand.

Table 1: Eel catch data (t) from for calendar years 1965 to 1988 and fishing years 1988–89 to 2018–19 based on MAF Fisheries Statistics Unit (FSU) and Licensed Fish Receiver Returns (LFRR), Quota Management Reports (QMR), and Monthly Harvest Returns (MHR)*.

Year	Landings	Year	Landings	Year	Landings	Year	Landings
1965	30	1980	1 395	1994–95	1 438	2009–10	560
1966	50	1981	1 043	1995–96	1 429	2010–11	626
1967	140	1982	872	1996–97	1 342	2011–12	755
1968	320	1983	1 206	1997–98	1 210	2012–13	717
1969	450	1984	1 401	1998–99	1 219	2013–14	678
1970	880	1985	1 505	1999–00	1 133	2014–15	547
1971	1 450	1986	1 166	2000–01	1 071	2015–16	455
1972	2 077	1987	1 114	2001–02	978	2016–17	511
1973	1 310	1988	1 281	2002–03	808	2017–18	505
1974	860	1988–89	1 315	2003–04	729	2018–19	422
1975	1 185	1989–90	1 356	2004–05	708		
1976	1 501	1990–91	1 590	2005–06	771		
1977	906	1991–92	1 585	2006–07	718		
1978	1 583	1992–93	1 466	2007–08	660		
1979	1 640	1993–94	1 255	2008–09	518		

* MAF data, 1965–1982; FSU, 1983 to 1989–90; CELR, 1990–91 to 1999–2000; ECLR 2000–01 to 2003–04; MHR 2004–05–present.

There was a rapid increase in commercial catches during the late 1960s, with catches rising to a peak of 2077 t in 1972. Landings were relatively stable from 1983 to 2000, a period when access to the fishery was restricted, although overall catch limits were not in place. In 2000–01 landings dropped to 1070 t, and these reduced further during 2001–02 to 2004–05 as eel stocks were progressively introduced into the Quota Management System (QMS). Landings on the North Island were further constrained by the reduction in TACCs for both species introduced on 1 October 2007. Eel landings have remained below the TACCs as a result of reduced international market demand and ACE shelving by some iwi, and from 2007–08 to 2018–19 have ranged between 422 t and 678 t. For the period 1991–92 to 2015–16, the North Island provided on average 61% of the total New Zealand eel catch (Table 2).

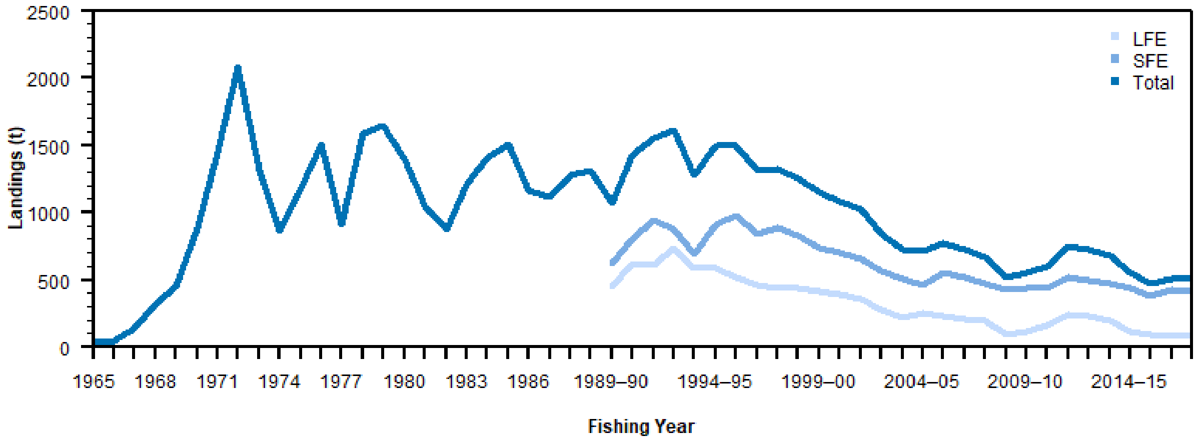


Figure 1: Total eel landings from 1965 to 2017–18, as well as separate shortfin and longfin landings from 1989–90 to 2017–18. Prior to 1988–89, the data points represent estimates for the period prior to the introduction of Eel Catch Landing Return (ECLR) forms and were generated by prorating the unidentified eel catch by the LFE:SFE ratio (see below).

In 2016, South Island eel stocks (ANG 11–16) were separated into individual shortfin (SFE 11–16) and longfin (LFE 11–16) stocks. The new stocks utilise the same geographical areas as the pre-existing stocks (ANG 11–16), but were separated to allow species specific management of the individual eel species. After the stocks were separated new catch limits and allowances were set. For the SFE stocks the new TACs were based on the highest historical catch, apart from SFE 13, which received a 10% increase as the CPUE index was well above the target. For LFE stocks, the TAC was reduced to a point that effectively eliminated commercial targeting (a TAC close to zero) for four of the six stocks (LFE 11, 12, 13, and 14). For the remaining two LFE stocks (LFE 15 and 16), TACs allow continued commercial utilisation, but at significantly reduced levels. The separated stocks and their associated catch limits and allowances came into force on 1 October 2016 for SFE/LFE 11, 12, 14, 15, and 16, and 1 Feb 2017 for SFE/LFE 2013.

Prior to the 2000–01 fishing year, three species codes were used to record species landed, SFE (shortfin), LFE (longfin), and EEU (eels unidentified). A high proportion of eels (46% in 1990–91) were identified as EEU between the fishing years 1989–90 and 1998–99. Prorating the EEU catch by the ratio of LFE : SFE by fishing year provides a history of landings by species (Table 3), although it should be noted that prorated catches prior to 1999–00 are influenced by the high proportion of EEU from some eel statistical areas (e.g., Waikato) and therefore may not provide an accurate species breakdown. The introduction of the new Eel Catch Landing Return (ECLR) form in 2001–02 improved the species composition information, because the EEU code was not included. There was a gradual decline in the proportion of longfin eels in landings, from over 40% in 1989–90 to about 30% in 2007–08, followed by a marked drop to 18% in 2008–09 (Table 3). The proportion of longfins in the catch then gradually increased and was about 30% of the total in 2013–14, before once again declining to 19% in 2015–16. Several factors have contributed to the pattern in the proportion of longfin eels, including: declining abundance in the early part of the series; reduced quotas; the closure of some catchments to commercial fishing; and declining/fluctuating market demand.

Table 2: North Island and South Island eel catch (t) compiled from data from individual processors 1991–92 to 1999–00 and LFRR/QMR/MHR 2000–01 to 2015–16. Numbers in parentheses represent the percentage contribution from the North Island fishery. [Continued on next page]

Fishing year	North Island	South Island	Total individual processors	LFRR/QMR/MHR Total NZ (excluding Chatham Islands)
1991–92	989	631	1 621 (61%)	–
1992–93	865	597	1 462 (59%)	–
1993–94	744	589	1 334 (56%)	–
1994–95	1 004	510	1 515 (66%)	–
1995–96	962	459	1 481 (65%)	–
1996–97	830	418	1 249 (66%)	–

Table 2: [Continued]

Fishing year	North Island	South Island	Total individual processors	LFRR/QMR/MHR Total NZ (excluding Chatham Islands)
1997–98	795	358	1 153 (69%)	_
1998–99	804	381	1 185 (68%)	_
1999–00	723	396	1 119 (65%)	_
2000–01	768	303	_	1 071 (72%)
2001–02	644	319	_	962 (67%)
2002–03	507	296	_	803 (63%)
2003–04	454	282	_	737 (62%)
2004–05	426	285	_	712 (60%)
2005–06	497	285	_	781 (64%)
2006–07	440	278	_	718 (61%)
2007–08	372	288	_	660 (56%)
2008–09	303	215	_	517 (59%)
2009–10	318	242	_	560 (57%)
2010–11	330	296	_	626 (53%)
2011–12	418	337	_	755 (55%)
2012–13	364	353	–	717 (51%)
2013–14	367	311	–	678 (54%)
2014–15	306	241	–	547 (56%)
2015–16	254	201	–	455 (56%)

Table 3: Total NZ eel landings (t) by species and fishing year. Numbers in parentheses represent the longfin proportion of total landings.

Fishing year	Shortfin (SFE)	Longfin (LFE)	Total landings
1989–90	617	453	1 069 (42%)
1990–91	808	616	1 424 (43%)
1991–92	941	612	1 553 (39%)
1992–93	872	741	1 613 (46%)
1993–94	692	588	1 279 (46%)
1994–95	909	588	1 497 (39%)
1995–96	977	518	1 495 (35%)
1996–97	841	465	1 307 (36%)
1997–98	881	442	1 323 (33%)
1998–99	824	434	1 258 (34%)
1999–00	741	413	1 154 (36%)
2000–01	698	388	1 086 (36%)
2001–02	660	360	1 020 (35%)
2002–03	560	279	839 (33%)
2003–04	510	216	726 (30%)
2004–05	460	254	713 (36%)
2005–06	553	226	774 (29%)
2006–07	520	210	730 (29%)
2007–08	470	196	666 (29%)
2008–09	424	95	519 (18%)
2009–10	441	114	555 (20%)
2010–11	440	159	599 (26%)
2011–12	515	237	752 (32%)
2012–13	491	230	721 (32%)
2013–14	475	201	676 (30%)
2014–15	434	116	550 (21%)
2015–16	378	89	467 (19%)

The species proportion of the landings varies by geographical area. From analyses of landings to eel processing factories and estimated catch from ECLRs, longfins are the dominant species in most areas of the South Island, except for a few discrete locations such as lakes Te Waihora (Ellesmere) and Brunner, and the Waipori Lakes, where shortfins dominate landings. Shortfins are dominant in North Island landings. The shortfin eel catches mostly comprise pre-migratory female feeding eels, with the exception of Te Waihora (Lake Ellesmere), where significant quantities of seaward migrating male shortfin eels (under 220 g) are taken during February to March.

Table 4: TACCs and commercial landings (t) for South Island eel stocks (based on ECLR data).

Fishing	ANG11		ANG12		ANG13		ANG14		ANG15		ANG16		Total
year	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	landings
Shortfin Eel (SFE)													
2000–01	40	4.5	43	4.4	122	102.2	35	6.1	118	19.4	63	9.8	146.6
2001–02	40	18.9	43	5.7	122	63.6*	35	10.1	118	20.2	63	20.2	83.8
2002–03	40	19.2	43	5.9	122	95.4	35	9.9	118	11.7	63	4.5	146.7
2003–04	40	8.7	43	4.8	122	118.2	35	7.5	118	13.0	63	9.4	161.8
2004–05	40	2.7	43	1.4	122	121.3	35	5.7	118	1.5	63	9.6	156.0
2005–06	40	9.0	43	4.3	122	119.9	35	7.4	118	12.0	63	11.2	164.0
2006–07	40	10.9	43	6.3	122	121.5	35	4.4	118	15.4	63	16.5	175.2
2007–08	40	8.5	43	1.2	122	119.7	35	5.8	118	21.2	63	11.5	167.9
2008–09	40	4.7	43	<1	122	123.0	35	1.8	118	16.6	63	19.7	166.0
2009–10	40	3.8	43	5.8	122	97.3	35	3.9	118	29.1	63	30.3	170.2
2010–11	40	10.0	43	6.9	122	89.3	35	3.7	118	19.4	63	19.9	149.2
2011–12	40	8.8	43	10.8	122	113.3	35	7.3	118	21.4	63	13.1	174.8
2012–13	40	7.6	43	19.9	122	125.0	35	2.6	118	16.7	63	22.8	194.6
2013–14	40	3.4	43	16.5	122	119.3	35	2.5	118	11.7	63	16.8	170.2
2014–15	40	2.8	43	13.6	122	112.1	35	1.3	118	14.4	63	11.8	156.0
2015–16	40	< 1	43	0	122	109.9	35	< 1	118	22.7	63	10.2	144.4
New FMA	**SFE11**		**SFE 12**		**SFE 13**		**SFE 14**		**SFE 15**		**SFE 16**		**Total**
2016–17	19	0	20	0.2	134.1	132.8	10	0	29	20.7	30	12.97	166.7
2017–18	19	6.2	20	2.7	134.1	130.3	10	1.0	29	15.1	30	5.9	161.2
2018–19	19	4.1	20	4.2	134.1	81.6	10	0.2	29	12.3	30	8.5	110.9
Longfin Eel (LFE)													
2000–01	40	10.6	43	22.6	122	2.1	35	12.6	118	63.6	63	28.4	140.1
2001–02	40	16.4	43	15.6	122	1.0*	35	6.0	118	80.5	63	30.2	150.1
2002–03	40	10.6	43	10.1	122	1.4	35	10.0	118	73.0	63	27.2	132.6
2003–04	40	2.8	43	2.7	122	< 1	35	10.2	118	64.7	63	21.2	102.9
2004–05	40	2.8	43	3.4	122	< 1	35	2.3	118	79.6	63	34.4	123.7
2005–06	40	6.0	43	9.8	122	< 1	35	6.4	118	61.1	63	21.1	105.5
2006–07	40	4.4	43	1.7	122	<1	35	7.0	118	65.0	63	32.8	112.1
2007–08	40	11.9	43	6.5	122	< 1	35	7.4	118	73.0	63	23.1	122.9
2008–09	40	1.4	43	< 1	122	0	35	2.3	118	33.7	63	13.2	51.0
2009–10	40	8.0	43	< 1	122	< 1	35	3.2	118	40.0	63	15.3	68.0
2010–11	40	13.1	43	6.1	122	< 1	35	6.7	118	73.9	63	14.1	114.9
2011–12	40	11.2	43	11.0	122	2.0	35	18.4	118	85.4	63	27.6	155.7
2012–13	40	15.6	43	7.6	122	< 1	35	22.3	118	88.6	63	30.4	164.5
2013–14	40	14.0	43	6.1	122	< 1	35	10.7	118	77.9	63	29.3	138.5
2014–15	40	2.5	43	3.7	122	0	35	2.1	118	56.3	63	15.3	79.9
2015–16	40	< 1	43	0	122	0	35	4.5	118	43.0	63	10.5	59.0
New FMA	**LFE11**		**LFE 12**		**LFE 13**		**LFE 14**		**LFE 15**		**LFE 16**		**Total**
2016–17	1	0	1	<1	1	0	1	0	52	33.4	25	14.1	47.5
2017–18	1	0	1	0.3	1	0.5	1	0.5	52	36.2	25	10.1	47.6
2018–19	1	0	1	0.2	1	0	1	0	52	34.2	25	9.5	43.9

*For the transition from a 1 October to 1 February fishing year, an interim TACC of 78 t was set for the period 1 October 2001 to 31 January 2002. From January 2002 the Te Waihora (Lake Ellesmere) fishing year was 1 February to 31 January. Fishing year for all other areas is 1 October to 30 September.

The Total Allowable Commercial Catch (TACC) and reported commercial landings by species for the South Island eel stocks are shown in Table 4 from 2000–01 (when eels were first introduced into the QMS) to 2018–19. The annual landings are based on data recorded on ECLR forms, because the MHR forms report QMA catches for the two species combined.

The TACCs and commercial landings for the Chatham Island and North Island shortfin and longfin eel stocks are shown in Tables 5 and 6. The Chatham Island and North Island fisheries were first introduced into the QMS in 2003–04 and 2004–05, respectively. Note that from 1 October 2007 the TACCs were markedly reduced for all North Island shortfin and longfin stocks.

Table 5: TACCs and commercial landings (t) for Chatham Island (SFE 17) and North Island shortfin stocks from 2003–04 to 2018–19 (based on ECLR data).

Fishing	SFE 17		SFE 20		SFE 21		SFE 22		SFE 23		Total
year	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	landings
2003–04	10	0.7	–	–	–	–	–	–	–	–	0.7
2004–05	10	1.3	149	78.4	163	123.0	108	80.5	37	15.0	298.1
2005–06	10	2.7	149	93.3	163	144.3	108	106.9	37	31.5	378.6
2006–07	10	0.0	149	107.8	163	113.5	108	91.3	37	30.2	342.8
2007–08	10	0.0	86	76.0	134	125.3	94	82.5	23	15.8	299.5
2008–09	10	0.0	86	66.8	134	110.0	94	70.9	23	10.3	258.0
2009–10	10	0.0	86	60.2	134	124.1	94	68.5	23	17.5	270.3
2010–11	10	0.0	86	85.5	134	133.9	94	58.8	23	16.1	294.3
2011–12	10	0.0	86	85.6	134	140.9	94	95.7	23	18.8	341.0
2012–13	10	0.0	86	78.8	134	124.3	94	82.0	23	14.7	299.8
2013–14	10	0.0	86	71.6	134	139.2	94	82.1	23	14.5	307.4
2014–15	10	0.0	86	63.8	134	122.8	94	73.3	23	13.7	273.6
2015–16	10	0.0	86	53.8	134	119.1	94	49.2	23	10.4	232.5
2016–17	10	0.0	86	46.2	134	123.4	94	81.3	23	13.0	263.9
2017–18	10	0.0	86	59.6	134	120.3	94	67.1	23	10.0	257.1
2018–19	10	0.0	86	61.3	134	108.5	94	66.8	23	8.3	245.0

Table 6: TACCs and commercial landings (t) for Chatham Island (LFE 17) and North Island longfin stocks from 2003–04 to 2018–19 (based on ECLR data).

Fishing	LFE 17		LFE 20		LFE 21		LFE 22		LFE 23		Total
Year	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	landings
2003–04	1	< 1	–	–	–	–	–	–	–	–	0.2
2004–05	1	< 1	47	27.4	64	53.5	41	23.9	41	24.5	129.3
2005–06	1	< 1	47	23.7	64	41.2	41	31.6	41	24.2	120.8
2006–07	1	0	47	27.2	64	29.8	41	25.9	41	14.5	97.4
2007–08	1	0	19	17.5	32	31.0	21	17.7	9	6.5	72.8
2008–09	1	0	19	11.5	32	22.7	21	7.7	9	2.5	44.4
2009–10	1	< 1	19	9.6	32	21.6	21	10.6	9	5.8	47.6
2010–11	1	< 1	19	10.2	32	13.7	21	5.7	9	6.2	35.8
2011–12	1	< 1	19	19.9	32	32.0	21	18.6	9	6.7	77.3
2012–13	1	< 1	19	18.3	32	25.1	21	15.1	9	5.6	64.1
2013–14	1	0	19	14.7	32	25.9	21	14.7	9	4.4	59.7
2014–15	1	0	19	10.1	32	9.9	21	12.0	9	3.3	35.3
2015–16	1	< 1	19	6.5	32	9.4	21	4.1	9	1.5	21.5
2016–17	1	0	19	8.0	32	13.9	21	7.4	9	3.9	33.2
2017–18	1	0	19	13.1	32	12.2	21	9.5	9	4.5	39.3
2018–19	1	0	14	5.8	23	11.8	21	4.8	9	0.3	22.3

1.2 Recreational fisheries

In October 1994, a recreational individual daily bag limit of six eels was introduced throughout New Zealand. There is no quantitative information on the recreational harvest of freshwater eels. The recreational fishery for eels includes any eels taken by people fishing under the amateur fishing regulations and includes any harvest by Māori not taken under customary provisions. The extent of the recreational fishery is not known although the harvest by Māori might be significant.

1.3 Customary non-commercial fisheries

Eels are an important food source for use in customary Māori practices. Māori developed effective methods of harvesting and hold a good understanding of the habits and life history of eels. Fishing methods included ahuriri (eel weirs), hinaki (eel pots), and other methods of capture. Māori exercised conservation and management methods, which included seeding areas with juvenile eels and imposing restrictions on harvest times and methods. The customary fishery declined after the 1900s but in many areas Māori retain strong traditional ties to eels and their harvest.
In the South Island, Lake Forsyth (Waiwera) and its tributaries have been set aside exclusively for Ngai Tahu. Other areas, such as the lower Pelorus River, Taumutu (Te Waihora), Wainono Lagoon and its catchment, the Waihao catchment, the Rangitata Lagoon, and the Ahuriri Arm of Lake Benmore, have been set aside as non-commercial areas for customary fisheries. Mātaitai reserves covering freshwater have been established in the South Island on the Mataura River, Okarito Lagoon, Waihao River (including Wainono Lagoon and parts of Waituna Stream and Hook River), Lake Forsyth, and the Waikawa River. Commercial fishing is generally prohibited in mātaitai reserves. In the North Island, commercial fishing has been prohibited from the Taharoa lakes, Whakaki Lagoon, Lake Poukawa, and the Pencarrow lakes (Kohangapiripiri and Kohangatera) and associated catchments.

Customary non-commercial fishers desire eels of a greater size, i.e., over 750 mm and 1 kg. Currently, there appears to be a substantially lower number of larger eels in the main stems of some major river catchments throughout New Zealand, which may limit customary fishing. Consequently the access to eels for customary non-commercial purposes has declined over recent decades in many areas. There is no overall assessment of the extent of the current or past customary non-commercial take. For the introduction of the South Island eel fishery into the QMS, an allowance was made for customary non-commercial harvest. It was set at 20% of the TAC for each QMA, equating to 107 t (Table 7). For the introduction of the North Island fishery into the QMS, the customary non-commercial allowance was set at 74 t for shortfins and 46 t for longfins (Tables 8 and 9). For the Chatham Islands, the customary non-commercial allowance was 3 t for shortfin and 1 t for longfin eels (Tables 8 and 9).

Eels may be harvested for customary non-commercial purposes under an authorisation issued under fisheries regulations. Such authorisations are used where harvesting is undertaken beyond the recreational rules. The majority of the South Island customary harvest comes from QMAs ANG 12 (North Canterbury) and ANG 13 (Te Waihora/Lake Ellesmere). Customary regulations were only extended to freshwaters of the Chatham Islands and North Island in November 2008.

Table 7: TACs, TACCs, and customary non-commercial and recreational allowances (t) for South Island eel stocks. Note that an allowance for other sources of fishing-related mortality has not been set.

	LFE 11 Nelson/ Marlborough	LFE 12 North Canterbury	LFE 13 Te Waihora Lake Ellesmere	LFE 14 South Canterbury	LFE 15 Otago/ Southland	LFE 16 West Coast
2016 TAC	3	3	3	3	66.54	32.41
TACC	1	1	1	1	52	25
Customary Non-Commercial Allowance	1	1	1	1	13.27	6.41
Recreational Allowance	1	1	1	1	1.27	1
	SFE 11	**SFE 12**	**SFE 13**	**SFE 14**	**SFE 15**	**SFE 16**
2016 TAC	24.87	26.1	171.94	13.57	37.42	38.69
TACC	19	20	134.12	10	29	30
Customary Non-Commercial Allowance	4.87	5.1	34.38	2.57	7.42	7.69
Recreational Allowance	1	1	3.44	1	1	1

Table 8: TACs and customary non-commercial, recreational, and other fishing-related mortality allowances (t) for the Chatham Island and North Island shortfin stocks.

	SFE 17	SFE 20	SFE 21	SFE 22	SFE 23
TAC	15	148	181	121	36
Customary Non-Commercial Allowance	3	30	24	14	6
Recreational Allowance	1	28	19	11	5
Other fishing-related mortality	1	4	4	2	2

Table 9: TACs and customary non-commercial, recreational, and other mortality allowances (t) for the Chatham Island and North Island longfin eel fisheries.

	LFE 17	LFE 20	LFE 21	LFE 22	LFE 23
TAC	3	39	60	34	34
Customary Non-Commercial Allowance	1	10	16	6	14
Recreational Allowance	1	8	10	5	9
Other fishing-related mortality	0	2	2	2	2

1.4 Illegal catch
No reliable estimates of illegal catch are available. There is some evidence of fishers exceeding the amateur bag limit, and some historical incidences of commercial fishers operating outside of the reporting regime, but overall the extent of any current illegal take is not considered to be significant.

1.5 Other sources of mortality
Although there is no information on the level of fishing-related mortality associated with the eel fishery (i.e., how many eels die while in the nets), it is not considered to be significant given that the fishing methods used are passive and catch eels in a live state.

Eels are subject to significant sources of mortality from non-fishing activities, although this has not been quantified. Direct mortality occurs through the mechanical clearance of drainage channels, and damage by hydro-electric turbines and flood control pumping (Beentjes et al 2005). Survival of eels through hydroelectric turbines is affected by eel length, turbine type, and turbine rotation speed. The mortality of larger eels (specifically longfin females) is estimated to be 100%. Given the large number of eels in hydro lakes, this source of mortality could be significant and reduce spawner escapement from New Zealand. Mitigation activities such as trap and transfer of downstream migrants, installation of downstream bypasses, and spillway opening during runs, are expected to have reduced this impact at those sites where such measures have been implemented. In addition to these direct sources of mortality, eel populations are likely to have been significantly reduced since European settlement from the 1840s by wetland drainage (wetland areas have been reduced by up to 90% in some areas), and ongoing habitat modification brought about by irrigation, channelisation of rivers and streams, and the reduction in littoral habitat. Ongoing drain maintenance activities by mechanical means to remove weeds may cause direct mortality to eels through physical damage or by stranding and subsequent desiccation.

2. BIOLOGY

Species and general life history
There are 16 species of freshwater eel worldwide, with the majority of species occurring in the Indo-Pacific region. New Zealand freshwater eels are regarded as temperate species, similar to the Northern Hemisphere temperate species, the European eel *A. anguilla*, the North American eel *A. rostrata,* and the Japanese eel *A. japonica*. Freshwater eels have a life history unique among fishes that inhabit New Zealand waters. All *Anguilla* species are facultative catadromous, living predominantly in freshwater, and undertaking a spawning migration to an oceanic spawning ground. They spawn once and then die (i.e., are semelparous). The major part of the life cycle is spent in freshwater or estuarine/coastal habitat. Spawning of New Zealand species is presumed to take place in the southwest Pacific. Progeny undertake a long oceanic migration to freshwater where they grow to maturity before migrating to the oceanic spawning grounds. The average larval life is 6 months for shortfins and 8 months for longfins.

The longfin eel is endemic to New Zealand and is thought to spawn east of Tonga. The shortfin eel is also found in South Australia, Tasmania, and New Caledonia; spawning is thought to occur northeast of Samoa. Larvae (leptocephali) are transported to New Zealand largely passively on oceanic surface currents, and the metamorphosed juveniles (glass eels) enter freshwater from August to November. The subsequent upstream migration of elvers (pigmented juvenile eels) in summer distributes eels throughout the freshwater habitat. The two species occur in abundance throughout New Zealand and have overlapping habitat preferences with shortfins predominating in lowland lakes and slow moving, soft bottom rivers and streams, whereas longfins prefer fast flowing stony rivers and are dominant in high country lakes.

Growth

Age and growth of New Zealand freshwater eels was reviewed by Horn (1996). Growth in freshwater is highly variable and dependent on food availability, water temperature, and eel density. Eels, particularly longfins, are generally long lived. Maximum recorded age is 60 years for shortfins and 106 years for longfins. Ageing has been validated (e.g., Chisnall & Kalish 1993). Growth rates determined from the commercial catch sampling programme (1995–97) indicate that in both the North Island and South Island, growth rates are highly variable within and between catchments. Shortfins often grow considerably faster than longfins from the same location, although in the North Island longfins grow faster than shortfins in some areas (e.g., parts of the Waikato catchment). South Island shortfins take, on average, 12.8 years (range 8.1–24.4 years) to reach 220 grams (minimum legal size) compared with 17.5 years (range 12.2–28.7 years) for longfins, whereas in the North Island the equivalent times are 5.8 years (3–14.1 years) and 8.7 years (range 4.6–14.9 years) respectively. Australasian longfin growth is generally greater than that of New Zealand longfins, and closer to that of shortfins.

Growth rates (in length) are usually linear. Sexing immature eels is difficult, but from length at age data for migratory eels, there appears to be little difference in growth rate between the sexes. Sex determination in eels appears to be influenced by environmental factors and by eel density, with female eels being more dominant at lower densities. Age at migration may vary considerably between areas depending on growth rate. Males of both species mature and migrate at a smaller size than females. Migration appears to be dependent on attaining a certain length/weight combination and condition. The range in recorded age and length at migration for shortfin males is 5–22 years and 40–48 cm, and for females 9–41 years and 64–80 cm. For longfin eels the range in recorded age and length at migration is 11–34 years and 48–74 cm for males, and 27–61 years and 75–158 cm for females. However, because of the variable growth rates, eels of both sexes and species may migrate at younger or older ages.

Recruitment

The most sensitive measure of recruitment is monitoring of glass eels, the stage of arrival from the sea. In the Northern Hemisphere where glass eel fisheries exist, catch records provide a long-term time series that is used to monitor eel recruitment. In the absence of such fisheries in New Zealand, MPI took the unique opportunity that exists to monitor the relative abundance of elvers arriving at large in-stream barriers, where established elver trap and transfer programmes operate. Provided that the data are collected in a consistent manner every year, these data can be used to provide an index of eel recruitment into New Zealand’s freshwaters.

Although New Zealand has a small dataset of elver catch data compared to Asian, European, and North American recruitment records, including the 2014–15 season, there are now up to 20 years of reliable and accurate elver catch information for some sites (Martin et al 2016). These records show that the magnitude of the elver catch varies markedly between sites and that there are large variations in catches between seasons at all the sites (Table 10a). Whilst the majority of this variability is likely to be caused by natural oceanic and climatic influences, some is due to changes in fishing effort, technological advances, and recording procedures. Consequently, a number of existing records need to be excluded from recruitment trend analyses.

Because of the variability between sites and years, elver catch records were normalised following the method of Durif et al (2008), and a “normal” catch index was calculated for each species, season, and location. The normalised catch index (Xij) is calculated as follows:

$$X_{i,j} = (x_{i,j} - \mu_j)/\sigma_j$$

Where:

$x_{i,j}$ = elver catch for a season
μ_j = mean elver catch at a site for all seasons
σ_j = standard deviation of elver catch at a site for all seasons.

Although several of the sites show that catches peaked during the 2007–08 and 2008–09 migration seasons this is not consistent across all sites and also varies slightly between shortfins and longfins. A trend of increasing catches at Piripaua, however, stand out at present (Figure 2a).

Variation in the distance of dam sites from the sea and possibly differences in migration rates and growth rate between rivers has resulted in some variability in the size (age) structure of elvers captured at the monitored sites. Consequently the median ages of elvers at key sites were determined from examination of otoliths extracted from elvers captured during the 2013–14 season (Table 10b). The median ages were then used to standardise the normalised catch index so that it reflected the relative recruitment of glass eels (0 yrs old) into each catchment.

The standardised recruitment indices indicate that there was a recruitment peak for both shortfins and longfins in the Waikato, Mokau, Patea, and Grey rivers around 2006–2007 (Figure 2b). A recruitment peak also occurred at the same time on the Rangitaiki River which, unlike the other four rivers, is on the East Coast.

The Waikato and Northern Wairoa rivers and possibly the Patea River on the west coast and the Rangitaiki and Wairoa rivers on the east coast of the North Island all show an increased recruitment of shortfins around 2011 and 2012. In the South Island the Grey River on the west coast and the Waitaki River on the east coast also showed increased recruitment of shortfins in 2012 (Figure 2b). Because of the time it takes for longfins to reach these two South Island dams it is still too early to know if longfin recruitment also increased in 2011 and 2012.

The Wairoa and Waiau rivers do not follow the general patterns shown by other sites. Issues with inconsistent fishing effort in the past most likely have disguised the actual recruitment trend for the Waiau River (Figure 2b).

Since the early 1990s there have been four peaks of the average recruitment index for shortfins (1996, 2001, 2006, and 2013) and longfins (1996, 2000, 2006, and 2012) (Figure 2b). The length of time between these peaks varies from four to seven years, indicating a short-term cycle that appears to be influencing recruitment of both species.

Eel larvae are thought to not only actively swim but also use sea currents to reach the New Zealand continental shelf. Examination of regional differences in glass eel mean size and condition indicated an arrival pattern from the north in an anti-clockwise dispersal pattern around New Zealand (Chisnall et al 2002).

There is evidence from duration of runs and catch-effort data that glass eel runs may now be smaller in the Waikato River than in the 1970s (Jellyman et al 2009). However, studies on the variability and temporal abundance of glass eels over a seven year period from 1995 to 2002 at five sites showed no decline in recruitment for either species (Jellyman & Sykes 2004). At these same sites the density of shortfin glass eels exceeded that of longfins for any one year, but the annual trends for both species were generally similar (Jellyman et al 2002).

There is some evidence of annual variation influenced by the El Niño Southern Oscillation (ENSO), with the arrival route of glass eels from the northwest being stronger during the La Niña phase and stronger from the northeast during the El Niño phase (Chisnall et al 2002). This may also explain the recruitment pattern seen in the elver trap and transfer programmes (Martin et al 2014). A greater understanding of sea currents, notably along the coastline, and their effects on recruitment patterns, together with longer catch records, particularly from the east coast (e.g., Waitaki and Roxburgh dams), may further elucidate recruitment trends and drivers.

Spawning

Because eels are harvested before spawning, the escapement of sufficient numbers of eels to maintain a spawning population is essential to maintain recruitment. For shortfin eels the wider geographic distribution for this species (Australia, New Zealand, southwest Pacific) means that spawning escapement occurs from a range of locations throughout its range. In contrast, the more limited distribution of longfin eels (New Zealand and offshore islands) means that the spawning escapement must occur from New Zealand freshwaters and offshore islands.

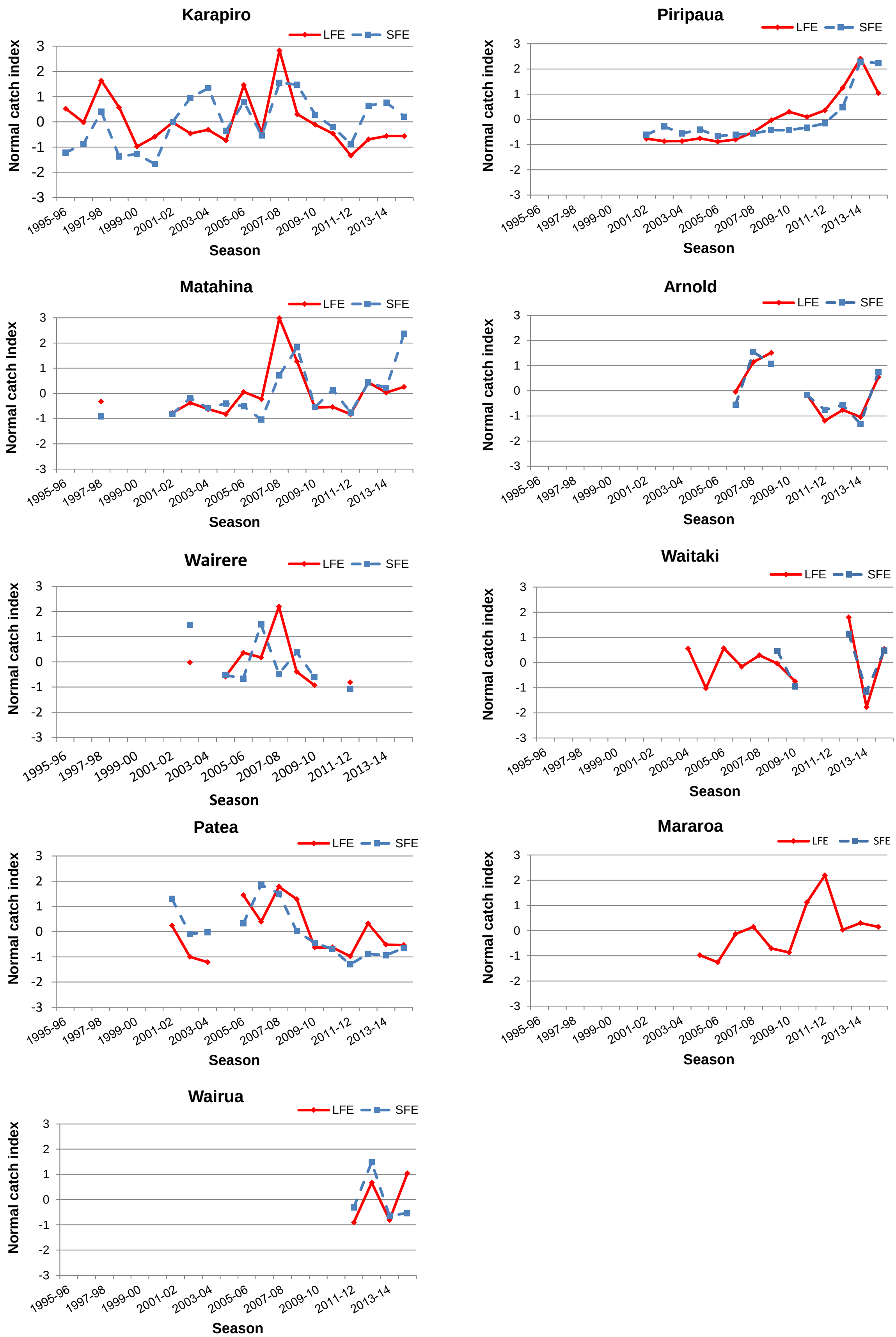


Figure 2a: Normal catch index for longfin (LFE) and shortfin (SFE) elvers at monitored sites from 1995–96 to 2014–15. (Notes: incomplete records for season have been omitted; 0 = mean index for entire monitoring period for each site; few shortfins recorded at Mararoa Weir). Mararoa has inconsistent fishing effort so the trend shown may reflect increased trapping efficiency rather than increased recruitment.

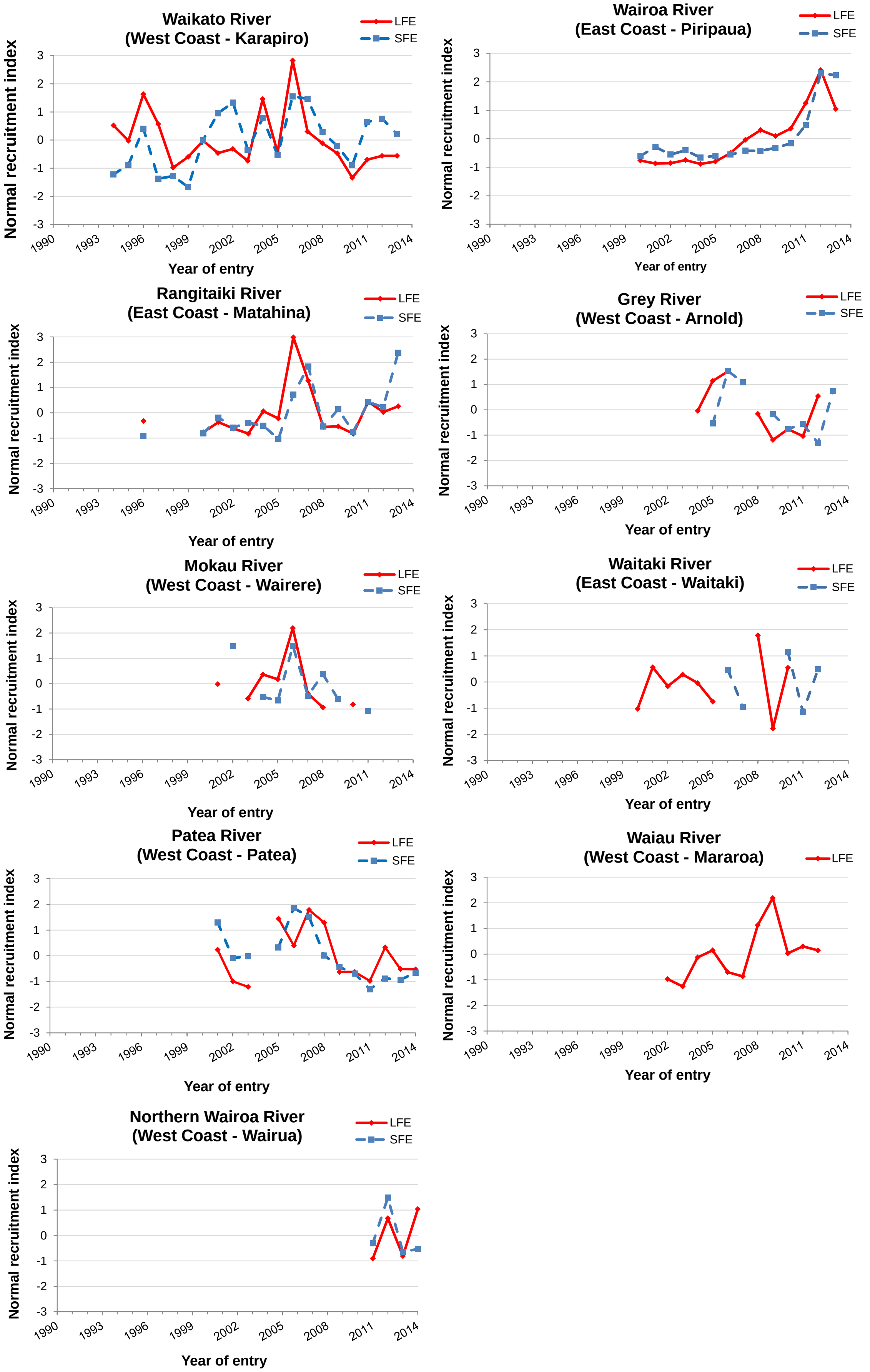


Figure 2b: Normal recruitment indices for longfin (LFE) and shortfin (SFE) elvers at the main monitored sites from 1995–96 to 2014–15 (0 = mean catch for entire monitoring period for each site). Mararoa has inconsistent fishing effort so the trend shown may reflect increased trapping efficiency rather than increased recruitment.

Table 10a: Estimated numbers (1000s) of all elvers and, in parentheses, longfins only; trapped at key elver trap and transfer monitoring sites by season (Dec–Apr) 1992–93 to 2013–14. Shaded cells indicate seasons when the records are considered unsuitable for trend analysis (monitoring disruption, flood damage, etc.). N/A = no species composition (from Martin et al 2016 and NIWA unpublished records.)

Year	Wairua	Karapiro	Matahina	Wairere	Patea	Piripaua	Arnold	Waitaki	Roxburgh	Mararoa
1992–93		92	> 32							
		(31)	(>2)							
1993–94		518	> 215							
		(176)	(NA)							
1994–95		282	> 39							
		(96)	(NA)							
1995–96		1 155	> 144							
		(333)	(NA)							
1996–97		1 220	14			2.1			0.3	
		(246)	(4)			(1)				
1997–98		2 040	615			7.3			11	
		(510)	(136)			(NA)				
1998–99		1 097	1 002			3.1			7.4	43
		(341)	(NA)			(0.4)				(43)
1999–00		892	2 001	166	461	2.6				90
		(94)	(NA)	(NA)	(NA)	(<0.1)				(90)
2000–01		782	2 054	191	495	6				28
		(155)	(NA)	(NA)	(NA)	(0.2)				(28)
2001–02		1 596	619	130	754	4.1			1	NA
		(246)	(27)	(NA)	(48)	(0.4)				
2002–03		1 942	1 484	289	380	10.2		<0.1	0.1	36
		(176)	(124)	(22)	(8)	(0.2)		(<0.1)		(36)
2003–04		2 131	945	330	391	4.9		4.6	1.4	98
		(200)	(64)	(NA)	(1)	(0.2)		(4.6)		(98)
2004–05		1 333	1 117	155	450	8.1	27	1.5		64
		(132)	(15)	(13)	(NA)	(0.5)	(7)	(1.5)		(64)
2005–06		2 178	1 193	163	562	2.8	14	4.7		46
		(483)	(228)	(28)	(87)	(0.1)	(8)	(4.7)		(46)
2006–07		1 296	485	294	896	4.2	107	3.3		118
		(179)	(159)	(25)	(53)	(0.3)	(52)	(3.3)		(118)
2007–08		2 728	3 378	204	857	5.7	186	4.1		133
		(701)	(928)	(57)	(98)	(1.1	(78)	(4.1)		(133)
2008–09		2 288	4 307	216	480	9.5	183	4.7		81
		(298)	(517)	(16)	(82)	(2.2)	(87)	(3.5)		(81)
2009–10		1 708	1 002	146	309	10.3	20	2.4		71
		(232)	(78)	(7)	(20)	(2.9)	(5)	(2.1)		(71)
2010–11		1 434	1 841	227	247	11.8	114	2.9		198
		(175)	(84)	(NA)	(20)	(2.5)	(49)	(2.4)		(198)
2011–12	3 178	1 003	641	119	72	15.6	76	7	NA	266
	(11)	(36)	(15)	(0.5)	(6.8)	(3.1)	(26)	(5.8)	(NA)	(266)
2012–13	5 488	1 771	2 421	182	74	33	90	8.9	14	128
	(98)	(139)	(317)	(NA)	(16)	(5.2)	(36)	(7.1)	(14)	(128)
2013–14	2 780	1 843	2 068	193.1	193.2	68.7	65.3	0.2	0.8	150.4
	(16.2)	(160)	(220)	(NA)	(23.5)	(7.9)	(29.4)	(0.1)	(0.8)	(150.4)
2014–15	3 010	1 604	4 736	241.9	260.6	61.2	152.5	6.0	1.3	135.6
	(118)	(160)	(275)	(NA)	(23.1)	(4.7)	(65)	(4.6)	(1.3)	(135.5)

Table 10b: Summary of elver weights, lengths, and estimated ages at sites where individual weights and lengths of 100 SFE and 100 LFE (if available) were measured monthly during 2013–14 (from Martin et al 2016). [Continued on next page]

Location	Species	n	Length (mm)			Weight (g)			Estimated age[a]
			Mean	Median	Range	Mean	Median	Range	
Wairua Falls	LFE	7	60	59	66–55	0.24	0.22	0.35–0.17	–[b]
	SFE	1 318	63	61	130–48	0.26	0.22	1.67–0.07	0
Karapiro	LFE	140	106	104	157–75	1.60	1.3	5.2–0.5	1
	SFE	295	93	91	153–74	0.9	0.8	3.9–0.4	1
Matahina	LFE	272	111	110	152–86	1.53	1.4	4.0–0.6	1
	SFE	750	97	96	133–75	0.96	0.9	2.9–0.4	1

Table 10b [Continued]

Location	Species		Length (mm)			Weight (g)			Estimated age
			Mean	Median	Range	Mean	Median	Range	
Piripaua	LFE	166	115	112	188–90	1.7	1.5	8.7–0.8	1
	SFE	497	101	100	142–85	1.1	1.1	3.4–0.5	1
Patea	LFE	124	80	79	124–59	0.62	0.56	2.57–0.18	0
	SFE	1 247	74	73	121–57	0.46	0.43	1.95–0.16	0
Arnold	LFE	400	130	126	202–101	2.1	1.8	8.9–0.7	2
	SFE	418	111	108	175–90	1.1	1.0	4.3–0.5	1
Waitaki	LFE	53	196	200	260–118	10.0	8.65	22.1–1.7	4
	SFE	103	132	130	203–102	2.25	1.98	11.3–0.9	2
Roxburgh	LFE	16	159	163	210–120	4.38	4.34	7.5–2.3	–[b]
Mararoa Weir	LFE	1 591	152	137	240–92	4.9	3.0	18.92–0.7	2
	SFE	15	108	104	150–92	1.34	0.99	3.8–0.6	–[b]

[a] Freshwater age based on median lengths of elver at each site and nation-wide age vs length regression.
[b] Insufficient number of elvers measured to accurately determine age distribution.

3. STOCKS AND AREAS

The lifecycle of each species has not been completely resolved but evidence supports the proposition of a single (panmictic) stock for each species. Biochemical evidence suggests that shortfins found in both New Zealand and Australia form a single biological stock. Longfins are endemic to New Zealand and are assumed to be a single biological stock.

Within a catchment, post-elver eels generally undergo limited movement until their seaward spawning migration. Therefore once glass eels have entered a catchment, each catchment effectively contains a separate population of each eel species. The quota management areas mostly reflect a combination of these catchment areas.

Shortfin and longfin eels have different biological characteristics in terms of diet, growth, maximum size, age of maturity, reproductive capacity, and behavioural ecology. These differences affect the productivity of each species, and the level of yield that may be sustainable on a longer term basis, as well as their interactions with other species. In order that catch levels for each species are sustainable in the longer term, and the level of removals does not adversely affect the productivity of each species, it is appropriate that the level of removals of each species is effectively managed.

4. STOCK ASSESSMENT

There is no formal stock assessment available for freshwater eels. Fu et al (2012) developed a length-structured longfin population model that generated New Zealand-wide estimates of the pre-exploitation female spawning stock biomass (approximately 1 700 t) as well as the pre-exploitation biomass of legal-sized eels (16 000 t in all fished areas and 6 000 t in protected areas). By contrast, the model estimated current female spawning stock biomass to be approximately 55% of pre-exploitation levels, whereas the current biomass of legal-sized eels ranged from 20% to 90% of the pre-exploitation level for the fished areas. However, the Working Group did not accept the assessment and noted that further analyses were necessary to investigate the models underlying assumptions; given that the results were strongly driven by estimates of longfin commercial catches from individual eel statistical areas as well as GIS-based estimates of recruitment.

4.1 Size/age composition of commercial catch

Catch sampling programmes sampled commercial eel landings throughout New Zealand over three consecutive years between 1995–96 and 1997–98, and then in 1999–2000 and 2003–04 (Beentjes 2005, Speed et al 2001). Sampling provided information on the length and age structure, and sex composition of the commercially caught eel populations throughout the country, and indicated a high degree of variability within and among catchments.

Monitoring commercial eel fisheries programme

The commercial eel monitoring programme collects processor recorded catch data for each species by size-grade (market determined; two to three grades) and catch location (eel statistical sub-area; catchment based), from virtually all commercial landings throughout New Zealand. This programme began in 2003–04 in the North Island and 2010–11 in the South Island (Beentjes 2013, 2016, 2019) with fifteen years of North Island data and eight years of South Island data collected by the end of 2017–18. This programme is ongoing with collection of data from 2018–19 to 2020–21 in progress.

North Island (2003–04 to 2017–18). The North Island commercial eel catch is highly aggregated with nearly one-third of the shortfin catch caught from just 3 of the 65 subareas (AA4, Dargaville; AD12, Lake Waikare and Port Waikato; and AC1, Hauraki Plains west). Similarly, one third of North Island longfin was caught from just four subareas (AA4, Dargaville; AD10, Waipa River; AD12, Lake Waikare, Port Waikato; and AL1, Lake Wairarapa). North Island shortfin annual catch over 15 years (2003–04 to 2017–18) showed no consistent trend in annual catch weight or in the distribution of these catches in the three size grades. The longfin fishery is more prone to market demand fluctuations than shortfin because it is a less desirable species of eel. Longfin landed catches over the same period fluctuated more than shortfin and are characterised by particularly low catches in 2008–09 to 2010–11 and since 2014–15, with an overall trend of declining catch. Factors that may have influenced annual longfin catches, overall and within size ranges, include the 58% TACC reductions for North Island longfin stocks for the 2007–08 fishing year, fluctuating market demands, annual rainfall, and, more recently and most importantly, a progressive decline in the availability of ACE to fishers. The number of subareas for which shortfin and longfin catch was landed has been declining, indicating a contraction in the spatial distribution of fishing effort over time. Despite this the catch of both species in the key subareas over the 15 years shows no apparent trends.

South Island (2010–11 to 2017–18). South Island commercial eel catch is highly aggregated especially shortfin where nearly three-quarters of the catch originates from just two of the 58 subareas (Te Waihora, AS1 and AS2; and Lake Brunner, AX4). Longfin in the South Island is less aggregated than shortfin, but half of the catch originated from just seven subareas (AW11, Mataura River coast; AW9, Oreti River coast; AW3, Oreti River inland down to Bog Burn; AV10, Clutha River coast; AP2,Wairau River; AU5,Waitaki River; and AX3, Grey River Arnold River). There is no consistent trend in annual shortfin landed catch over the eight-year time series (2010–11 to 2017–18), although the proportions of large eels has declined. There is a trend of declining longfin landed catch over the same period, and in the largest weight grade. The lower longfin landed catch in recent years can be attributed to lower port price for large longfin, and primarily the split into separate shortfin and longfin stocks in 2016–17. The longfin landed catch is also well below the current TACC introduced in 2016–17, as a result of fisher retirements, shelved quota, and ACE imbalances resulting from the nominal 1 t TACCs set in LFE 11 to LFE 14 essentially closing these areas to target longfin fishing. Catch of longfin has been stable in the key subareas, but more variable for the subareas with smaller catches. The pattern of South Island shortfin landed catch by subarea is generally similar over the eight years, except that AS1 and AS2 catches tend to display opposite trends because fishers can catch their quota from either.

4.2 Catch-per-unit-effort analyses

Each species of eel is considered to be a New Zealand wide stock, with common species-specific spawning grounds within the Fiji Basin. However, once recruited to a river system, eels do not move between catchments, so eels within each catchment may be regarded as separate sub-populations for management purposes. Maintaining sub-populations within each QMA at or above (sub-area proxies for) B_{MSY}, will ensure that the entire (national) stock of each species is maintained at that level. To develop subarea proxies, standardised catch-per-unit-effort (CPUE) analyses have been conducted for the commercial shortfin and longfin eel fisheries by Eel Statistical Area (ESA; Table 11 and Figure 3) from 1990–91 to 2017–18 for all North Island ESAs and from 1990–91 to 2012–13 for all South Island ESAs (Tables 12ab–13ab and Figures 4–7). These CPUE series monitor the relative abundance of each eel species within the area fished commercially within each ESA.

North Island CPUE

The North Island CPUE analyses undertaken using data up to 2014–15 included, for the first time, a binomial analyses on the valid zero catches, as well as the routine GLM analyses of positive catch. In addition, reconstructed target species was included as an explanatory variable, as were water quality variables. The variable ‘catcher_ID’ was not included because it has only been recorded since 2001–02 on the new ECER forms (Beentjes & McKenzie 2017); however, the data were linked by permit holder and client name (see below). Target species was recorded on CELR forms, but not on ECER forms. Target species was reconstructed for all records from recorded CELR target species and species proportions using a simple optimisation to evaluate the best proportion to use (Cohen’s kappa coefficient). Target species was reconstructed for all records, including those from CELR data. In some cases, target species was defined on the basis of a minimum catch composition of 80%. Higher values tended to assign too many records to the category ‘either’, when kappa was above 80%. Target species often explained the most variance in the positive catch GLM, especially for longfin for which the trends in CPUE changed more than shortfin compared with previous analyses when target was not offered to the model. Target species could not be offered to the binomial model because, by definition, a target of longfin or shortfin cannot result in zero catch in the models and consequently the May 2017 plenary rejected the binomial model.

Prior to the introduction of North Island eel stocks into the QMS in 2004–05, some fishers had fished for existing permit holders during the permit moratorium and following introduction of eels into the QMS began fishing under their own permit numbers (Beentjes & Dunn 2010). If these fishers had fished for someone else pre-QMS and if they were the only fisher that had landed catch under a pre-QMS *Client_name*, and that client did not land catch pre- and post-QMS, they were linked in the analyses. There were 16 linkages made.

The transition between CELR and ECER in 2001–02 is unlikely to have biased trends in relative abundance (CPUE) because there was no change in the estimation of catches or recording of effort data, with both forms providing estimated catch of shortfin and longfin eels, the number of nets set per night, and the statistical area where eels were caught.

The most recent CPUE analyses using data up to 2017–18 used the same methods described above but no binomial analyses were carried out (Beentjes 2020). In general, CPUE for North Island shortfin, with the exception of Northland (ESA AA) where CPUE steadily increased throughout the time series, either initially declined or there were no trends, followed by strong increases, beginning from around 2002 (Table 12a, Figure 4) (Beentjes 2020). For longfin there were generally fewer data than for shortfin for most areas and indices were often more variable, associated with wider confidence intervals, or could not be estimated for all years (Table 12b, Figure 5). In general, longfin CPUE indices declined over the first 10 years of the time series, and then either remained stable or slightly increased (Table 12b, Figure 5).

Several factors may have resulted in conservative estimates of North Island longfin eel CPUE, especially after 2005–06:

1. The unrecorded return of small and medium sized longfin eels to the water. This became more prevalent after the substantial reduction in NI longfin quotas in 2007–08, because many fishers did not have ACE to cover all of their catch (larger longfins are more valuable than small and medium specimens). Industry were previously unaware that eels of legal size (220 g to 4 kg) that are released are supposed to be recorded on ECLRs under the Destination ‘X ‘ code which was only available as a legitimate code on ECLRs from 2007–08. Further, at the Eel Working Group Meeting in April 2017 it was established that some fishers were incorrectly recording only their retained legal sized eels on the ECERs and thus the estimated catch used in CPUE analyses was possibly biased downward as was the CPUE. North Island Destination ‘X’ catch was only 3% of the landed eel catch in 2014–15. Destination ‘X’ was first used in 2008 for shortfin and in 2009 for longfin and its use has generally increased each year peaking in 2017 when 12.7 t of longfin and 4.3 t of shortfin were released and recorded under Destination ‘X’ accounting for 13% and 2% of the species estimated catch, respectively (Beentjes 2020). Investigations into catch recorded on ECERs and ECLRs in 2019 indicate that, Destination ‘X’ is now being used by most fishers as intended (Beentjes 2020). In 2007–08, a maximum size of 4 kg was introduced for longfins. Longfins over 4 kg could be legally landed before this date. There was no legal requirement to record the catch of eels over 4 kg on ECLRs. The introduction

of electronic catch and position reporting for the eel fishery in 2019 requires fishers to record the numbers and weight of all longfin eels over 4 kg released, as well as other information such as finer-scale catch location details. This will provide estimates of the quantities of longfins (over 4 kg) that are caught and released, but not included in the estimated catch used for CPUE analyses.

2. Avoidance of longfin habitat post 2006–07 in some statistical areas because there is currently insufficient available ACE to allow targeting of longfin eels. The QMA most affected is LFE 23 (current TACC is 9 t) where, since 2007–08, up to half the ACE has not been made available for lease. Of the available longfin ACE, almost all is leased to a fisher operating in the Taranaki statistical area (AJ) of this QMA, leaving very little for the Wanganui-Rangitikei statistical area. The fisher in the latter statistical area consequently targets shortfin eels in farm dams, dune lakes, and the lower reaches of some rivers; thereby avoiding high longfin eel catch rates in the Rangitikei River. Shelving of ACE has continued through to 2017–18 for all QMAs, but is most marked in SFE 23 and LFE 23 (Beentjes 2019).

3. Voluntary uptake of larger escape tubes (31 mm) from 2010–11 (regulated in 2012–13) may have resulted in a stepped drop in CPUE. This is expected to result in a stepped increase in CPUE in future analyses, when excluded eels begin recruiting to the fishery.

Figure 3: New Zealand Eel Statistical Areas (ESAs).

Table 11: New Zealand Eel Statistical Areas (ESAs). Areas were given a numeric designation prior to Oct. 2001, at which point letter codes were assigned.

ESA	Letter code	Numeric code
Northland	AA	1
Auckland	AB	2
Hauraki	AC	3
Waikato	AD	4
Bay of Plenty	AE	5
Poverty Bay	AF	6
Hawke Bay	AG	7
Rangitikei-Wanganui	AH	8
Taranaki	AJ	9
Manawatu	AK	10
Wairarapa	AL	11
Wellington	AM	12
Nelson	AN	13
Marlborough	AP	14
South Marlborough	AQ	14
Westland	AX	15
North Canterbury	AR	16
South Canterbury	AT	17
Waitaki	AU	18
Otago	AV	19
Southland	AW	20
Te Waihora (outside-migration area)	AS1	21
Te Waihora migration area	AS2	21
Chatham Islands	AZ	22
Stewart Island	AY	23

Table 12a: North Island CPUE indices for shortfin eels by Eel Statistical Area (ESA). Fishing years are referred to by the second year (e.g., 1990–91 is referred to as 1991). – insufficient data. See Table 11 for ESA area names; data from Beentjes (2020).

	Shortfin (North Island ESAs)										
Year	**AA**	**AB**	**AC**	**AD**	**AE**	**AF**	**AG**	**AH**	**AJ**	**AK**	**AL**
1991	0.71	1.20	1.09	0.83	1.01	–	1.12	1.1	1.66	1.86	–
1992	0.65	0.82	0.95	0.85	0.73	–	1.15	0.99	2.70	3.79	–
1993	0.67	0.76	1.06	0.97	0.65	0.92	1.1	0.92	1.00	2.11	0.67
1994	0.61	0.93	0.96	1.07	0.71	0.63	1.16	1.04	0.69	0.71	1.03
1995	0.81	0.98	1.07	1.09	0.86	0.93	1.25	0.97	1.35	0.63	1.12
1996	0.86	1.04	1.03	1.16	0.92	1.17	0.92	1.24	1.23	0.53	1.06
1997	0.83	0.77	0.80	1.03	0.73	0.71	0.72	0.90	1.09	0.86	0.77
1998	0.91	0.97	0.73	1.02	0.48	–	0.64	0.82	0.96	0.70	0.85
1999	1.06	1.16	0.68	0.90	0.72	–	0.84	0.84	1.02	0.90	0.75
2000	1.03	0.86	0.82	0.78	0.45	0.95	0.75	0.77	0.93	0.47	0.74
2001	1.05	0.84	0.79	0.78	0.60	1.29	0.83	0.83	0.77	0.57	0.77
2002	0.97	0.72	1.07	0.81	0.42	0.82	0.49	0.65	0.8	0.74	0.58
2003	0.96	0.72	0.92	0.74	0.60	0.46	0.52	0.78	0.72	0.47	0.49
2004	1.01	0.84	1.07	0.90	0.69	1.37	0.73	0.21	0.87	1.25	–
2005	0.97	0.88	0.93	0.93	1.04	0.73	0.78	0.67	0.74	1.02	1.10
2006	1.02	0.92	1.00	1.01	1.08	1.54	0.94	1.06	0.97	1.06	1.08
2007	1.12	0.99	0.85	1.00	1.13	1.19	0.74	1.07	0.71	1.23	1.20
2008	1.12	1.21	0.89	1.04	1.37	–	0.90	1.16	0.91	1.36	1.30
2009	1.05	0.99	0.91	1.11	1.53	2.64	1.03	1.42	–	0.95	0.99
2010	1.18	1.05	0.93	1.16	1.47	–	1.08	1.13	1.33	1.11	1.48
2011	1.15	1.10	1.23	1.18	1.60	–	0.99	1.40	0.91	0.94	1.38
2012	1.15	1.06	1.33	1.00	2.12	–	1.09	1.64	0.88	0.87	1.45
2013	1.19	1.10	1.28	0.98	1.78	–	1.44	1.39	1.43	0.98	0.94
2014	1.12	1.12	1.32	0.98	1.28	–	1.73	1.12	0.74	1.03	1.23
2015	1.24	1.16	1.10	1.01	1.55	–	1.39	1.10	0.96	1.27	1.15
2016	1.18	1.38	1.08	1.16	–	–	1.74	1.88	–	1.24	0.96
2017	1.45	1.50	1.29	1.41	2.58	–	1.95	1.30	–	1.56	1.78
2018	1.62	1.45	1.28	1.41	2.61	–	1.74	1.37	–	1.17	1.24

Table 12b: North Island CPUE indices for longfin eels by Eel Statistical Area (ESA). Fishing years are referred to by the second year (e.g., 1990–91 is referred to as 1991). – insufficient data. See Table 11 for ESA area names; data from Beentjes (2020).

	Longfin (North Island ESAs)										
Year	**AA**	**AB**	**AC**	**AD**	**AE**	**AF**	**AG**	**AH**	**AJ**	**AK**	**AL**
1991	1.15	0.68	1.73	1.09	1.78	–	1.23	1.73	1.50	–	0.87
1992	1.00	1.21	1.80	1.19	1.24	–	1.34	1.88	1.75	–	–
1993	1.07	1.07	1.55	0.96	1.03	0.74	1.30	1.38	1.23	2.49	1.34
1994	1.02	1.04	1.13	1.15	1.05	1.10	1.23	1.66	1.07	1.84	0.85
1995	0.98	1.19	1.33	1.24	0.99	0.74	0.99	1.37	1.30	1.14	1.08
1996	1.07	0.90	1.47	1.06	0.74	0.69	1.03	1.36	1.24	1.26	0.92
1997	0.86	0.91	1.19	0.97	0.67	–	0.62	1.43	1.10	–	0.73
1998	1.06	1.23	0.94	0.87	0.76	–	0.79	0.90	1.06	0.52	0.83
1999	1.16	1.26	1.02	0.82	1.31	–	1.02	0.86	0.97	–	0.73
2000	1.09	1.07	1.02	0.85	0.59	0.92	1.11	1.03	0.94	0.86	0.69
2001	1.19	1.22	0.80	0.92	1.32	1.16	0.86	0.73	0.82	1.01	0.72
2002	1.05	0.89	0.82	0.83	0.81	1.10	0.64	0.68	0.82	0.45	0.66
2003	0.97	0.89	0.87	0.86	0.86	–	0.82	0.61	0.70	0.44	0.66
2004	1.02	0.95	0.84	0.95	1.06	–	0.70	0.47	0.77	1.18	1.08
2005	0.96	1.26	1.18	0.94	0.82	1.11	0.95	0.72	0.85	1.03	0.86
2006	0.99	0.82	0.91	0.91	1.10	–	0.88	0.82	0.83	0.86	1.15
2007	0.99	1.02	0.83	0.97	0.94	1.83	0.86	0.75	0.90	1.22	1.16
2008	0.97	1.02	0.84	0.95	1.02	–	0.78	–	0.97	0.99	1.06
2009	0.72	0.82	0.81	0.99	1.35	–	–	–	–	0.97	0.81
2010	0.82	0.89	0.77	1.06	0.84	–	–	–	0.89	1.14	1.13
2011	0.84	0.81	0.84	1.04	1.33	–	–	–	1.05	1.23	1.54
2012	0.83	1.02	1.01	1.10	1.23	–	1.02	–	1.11	1.09	1.38
2013	0.97	1.00	0.94	1.06	1.36	–	1.20	–	1.02	1.01	1.07
2014	0.80	0.97	0.93	0.95	0.69	–	1.52	–	0.88	0.89	1.14
2015	0.92	0.93	0.54	1.00	–	–	1.23	–	0.79	0.93	1.00
2016	0.92	0.82	0.92	0.98	–	–	1.58	–	–	1.18	1.08
2017	1.51	1.17	0.87	1.27	–	–	1.18	–	0.88	0.87	1.71
2018	1.39	1.33	1.10	1.27	–	–	0.88	–	1.17	1.08	1.87

South Island CPUE

The Eel Working Group in 2012 (EELWG-2012-05) made the decision to split South Island CPUE analyses into pre- and post-QMS time series with post-QMS CPUE analyses only required for areas with sufficient data and fishers (ESAs: Westland AX, Otago AV, Southland AW). This was done because many fishers fishing under existing permits pre-QMS obtained their own quota and entered the fishery as "new" entrants when the QMS was introduced. Fishing coefficients for existing permit holders were therefore likely to have changed considerably after the QMS was introduced. It is not possible to separate catches in the pre-QMS data into individual fisher catch and effort, as was done in the North Island analysis, because the CELR forms used up to 2001–02 included only a field for permit holder, with no way of identifying individual operators. This problem was solved in 2001–02 with the introduction of the new ECER form by adding a field which identified the fisher (i.e.,"catcher") filling out the form.

This problem was less severe in the North Island because NI eels were introduced to the QMS after the new ECER forms had been developed, making it possible to link catcher and permit holders before and after the introduction to the QMS. The most recent South Island CPUE analyses, up to 2012–13, included new predictor variables including: target species, water quality data (e.g., nitrogen, phosphates, clarity, temperature), and catcher (Beentjes & Dunn 2015). Catcher was only available for the post-QMS analyses. The first year in the post-QMS standardised CPUE time series is 2001–02 when catcher was first recorded on the new ECERs.

Table 13a: South Island CPUE indices for shortfin eels by Eel Statistical Area (ESA). Separate indices are presented for pre-QMS (1991–2000) and post-QMS (2001–2013). Fishing years are referred to by the second year (e.g., 1990–91 is referred to as 1991). – insufficient data. See Table 11 for ESA area names; data from Beentjes & Dunn (2015).

QMS		Shortfin (South Island ESAs)								
status	Year	AN	AP_AQ	AR	AT	AU	AV	AW	AX	AS1
Pre-QMS	1991	–	2.36	1.13	2.09	1.70	1.51	1.30	0.96	–
	1992	–	1.94	1.09	1.07	1.46	1.20	1.03	0.61	–
	1993	1.24	1.59	0.94	0.84	0.69	1.05	0.99	1.07	–
	1994	–	1.34	1.01	1.01	1.06	1.03	1.33	0.95	–
	1995	1.16	1.14	0.81	0.79	0.84	0.92	1.01	0.90	–
	1996	0.89	0.65	0.98	0.97	1.31	0.87	0.88	0.85	–
	1997	0.41	0.55	0.97	0.85	0.85	0.90	0.79	0.75	–
	1998	0.97	0.38	1.00	1.07	1.10	0.84	0.89	1.31	–
	1999	1.37	0.73	1.13	0.67	0.61	0.83	0.90	1.52	–
	2000	1.43	0.91	0.99	1.13	0.88	1.02	1.01	1.48	–
Post-QMS	2001	–	–	–	–	–	–	–	–	–
	2002	–	–	–	–	–	0.86	0.68	0.81	0.37
	2003	–	–	–	–	–	0.86	0.61	0.73	0.42
	2004	–	–	–	–	–	0.76	0.91	0.87	0.51
	2005	–	–	–	–	–	1.05	1.03	0.99	0.58
	2006	–	–	–	–	–	0.89	0.83	0.87	0.79
	2007	–	–	–	–	–	1.21	1.07	0.99	1.17
	2008	–	–	–	–	–	0.80	1.29	0.89	1.28
	2009	–	–	–	–	–	1.26	0.80	1.49	1.31
	2010	–	–	–	–	–	1.27	1.23	1.16	1.17
	2011	–	–	–	–	–	1.34	1.35	1.16	2.34
	2012	–	–	–	–	–	1.12	1.26	1.11	2.29
	2013	–	–	–	–	–	0.81	1.34	1.16	2.23

Table 13b: South Island CPUE indices for longfin eels by Eel Statistical Area (ESA). Separate indices are presented for pre–QMS (1991–2000) and post QMS (2001–2013). Fishing years are referred to by the second year (e.g., 1990–91 is referred to as 1991). - insufficient data; –, no analysis. See Table 11 for ESA area names; data from Beentjes & Dunn (2015).

		Longfin (South Island ESAs)							
QMS status	Year	AN	AP_AQ	AR	AT	AU	AV	AW	AX
Pre-QMS	1991	2.29	1.72	1.29	1.89	1.19	1.35	1.46	1.09
	1992	1.15	1.18	0.87	0.74	0.95	1.20	1.13	0.95
	1993	0.80	1.21	1.00	0.78	0.82	1.14	1.13	0.76
	1994	1.06	1.43	1.06	1.05	0.78	1.27	1.22	0.89
	1995	0.85	1.17	0.75	0.88	0.69	0.93	0.99	1.10
	1996	0.81	1.19	1.21	0.78	1.22	0.80	1.00	0.99
	1997	0.66	0.68	1.09	0.96	1.11	0.86	0.92	0.94
	1998	0.72	0.77	0.75	0.99	0.97	0.87	0.79	0.97
	1999	1.10	0.83	1.02	0.85	1.34	0.85	0.68	1.11
	2000	1.23	0.47	1.10	1.59	1.14	0.91	0.91	1.29
	2001	–	–	–	–	–	–	–	–
Post-QMS	2002	–	–	–	–	–	0.91	1.00	0.80
	2003	–	–	–	–	–	0.84	1.09	0.79
	2004	–	–	–	–	–	0.92	0.85	0.93
	2005	–	–	–	–	–	1.11	1.10	0.94
	2006	–	–	–	–	–	0.95	1.05	0.96
	2007	–	–	–	–	–	1.05	0.82	1.01
	2008	–	–	–	–	–	0.98	0.92	0.95
	2009	–	–	–	–	–	1.12	0.92	1.06
	2010	–	–	–	–	–	0.94	0.86	1.28
	2011	–	–	–	–	–	1.32	1.23	1.23
	2012	–	–	–	–	–	0.96	1.15	1.01
	2013	–	–	–	–	–	0.99	1.12	1.16

Westland (AX). Shortfin pre-QMS CPUE fluctuated without trend from 1990–91 to 1996–97 and then increased sharply to 1999–2000. Post-QMS shortfin CPUE increased steadily from 2001–02 to 2012–13. Longfin pre-QMS CPUE declined from 1990–91 to 1992–93, and then increased steadily to 1999–2000. Post-QMS longfin CPUE increased steadily from 2001–02 to 2012–13 (Tables 13a, b, Figure 6).

Otago (AV). Shortfin pre-QMS CPUE declined steadily to 1998–99, then increased sharply to 1999–2000. Post-QMS shortfin CPUE increased steadily from 2001–02 to 2010–11, and then declined. Longfin pre-QMS CPUE declined steadily from 1990–91 to 1995–96 and was stable from then to 1999–2000. Post-QMS longfin CPUE was variable but overall increased slightly from 2001–02 to 2012–13 (Tables 13a, b, Figure 6).

Southland (AW). Shortfin pre-QMS CPUE declined slowly from 1990–91 to 1996–97 and then gradually increased to 1999–2000. Post-QMS shortfin CPUE was variable but generally increased steadily from 2001–02 to 2012–13. Longfin pre-QMS CPUE declined steadily from 1990–91 to 1999–2000. Post-QMS longfin CPUE was variable and showed a gradual decline from 2001–02 to 2009–10, and then a substantial increase to 2012–13 (Tables13a, b, Figure 6).

Te Waihora

CPUE analyses for Te Waihora were only carried out for AS1 feeder shortfin (the lake, outside the migration area) from 2000–01, coinciding with the introduction of the reporting codes (AS1 and AS2), to 2012–13. The most recent analyses included new predictor variables: lake level, status of lake opening (i.e., open or closed), catcher (Beentjes & Dunn 2015). The standardised CPUE time series begins in 2001–02, when the new ECER form was introduced and catcher was first recorded. CPUE of feeder shortfin eels in Te Waihora increased six fold from 2001–02 to 2010–11 and was reasonably stable from 2010–11 to 2012–13 (Figure 7).

It is very likely that the fishery has experienced a progressive improvement in yield per recruit as the minimum legal size was incrementally increased from 140 g in 1993–94 to 220 g in 2001–02. Analyses of eel size composition in the lake in the 1990s compared with that in recent years demonstrates that the size of commercially caught eels has substantially increased over time, supporting the concept of an improved yield per recruit (Figure 8; Beentjes & Dunn 2014).

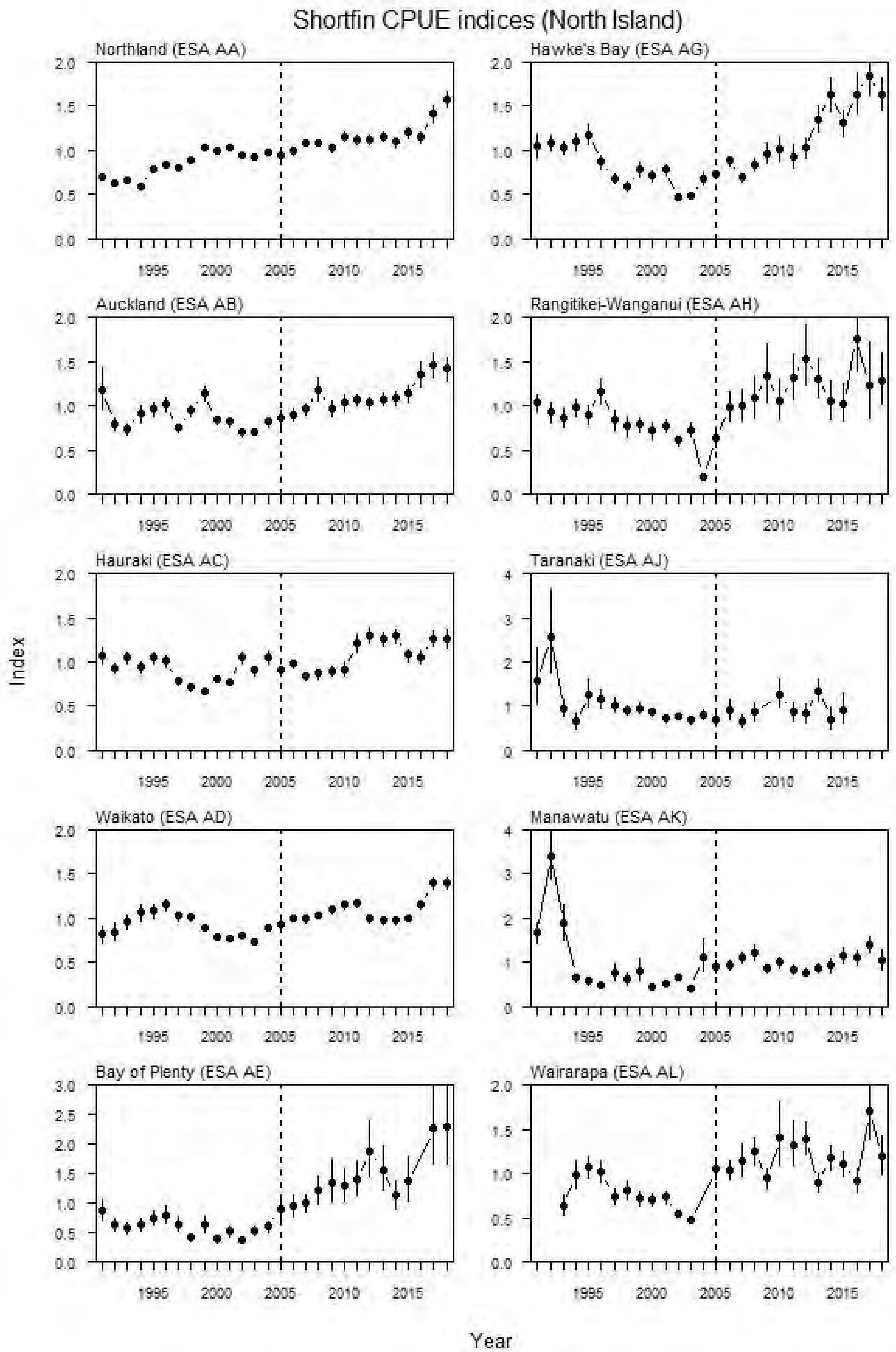


Figure 4: Trends in North Island shortfin CPUE indices for all North Island ESAs from 1990–91 to 2017–18, except Poverty Bay (AF) and Wellington (AM) where there were insufficient data. Vertical dotted line indicates the introduction to the QMS in 2004–05 (from Beentjes 2020).

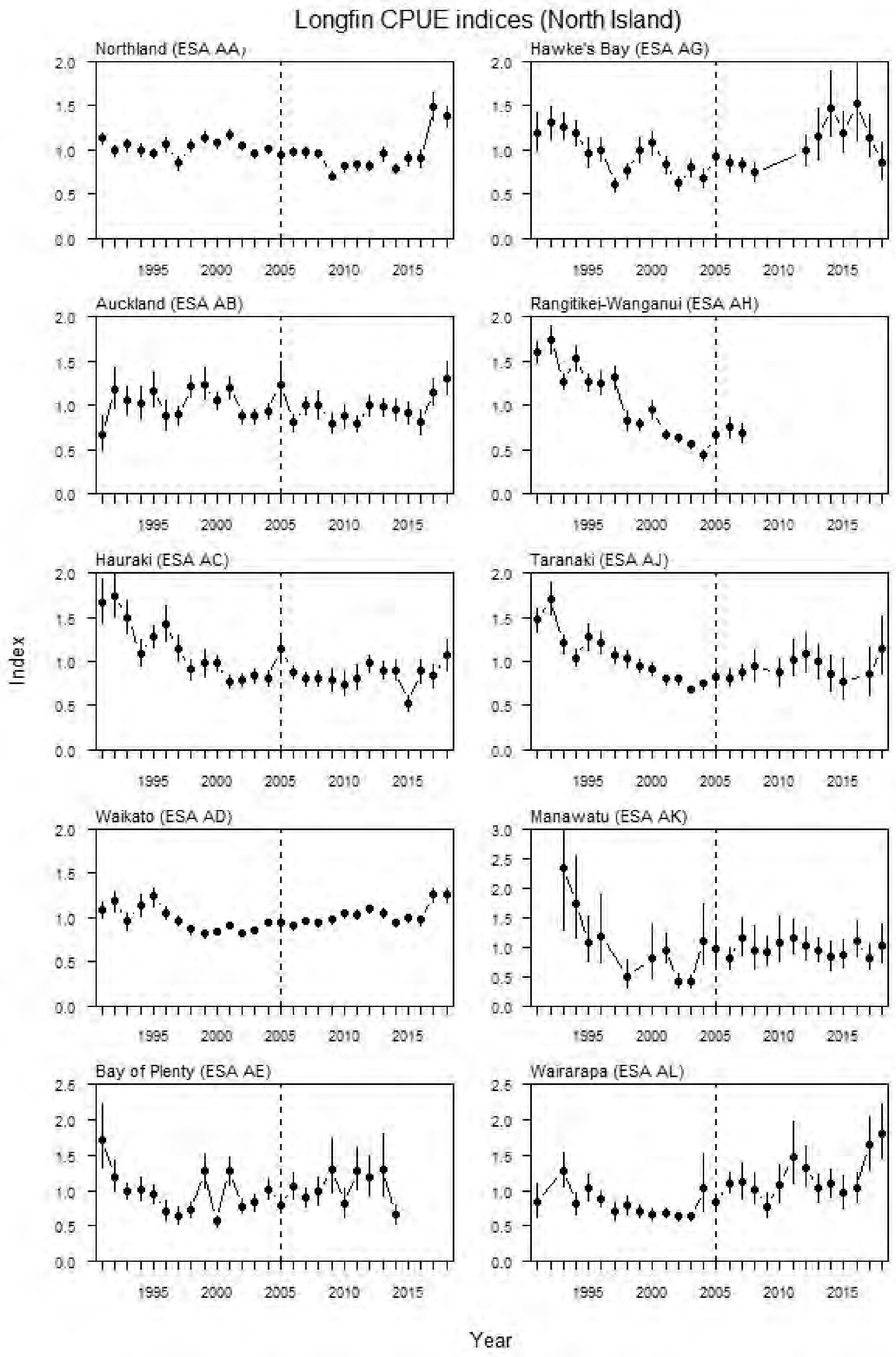


Figure 5: Trends in North Island longfin CPUE indices for all North Island ESAs from 1990–91 to 2018–19, except Poverty Bay (AF) and Wellington (AM) where there were insufficient data. Vertical dotted line indicates the introduction to the QMS in 2004–05 (from Beentjes 2020).

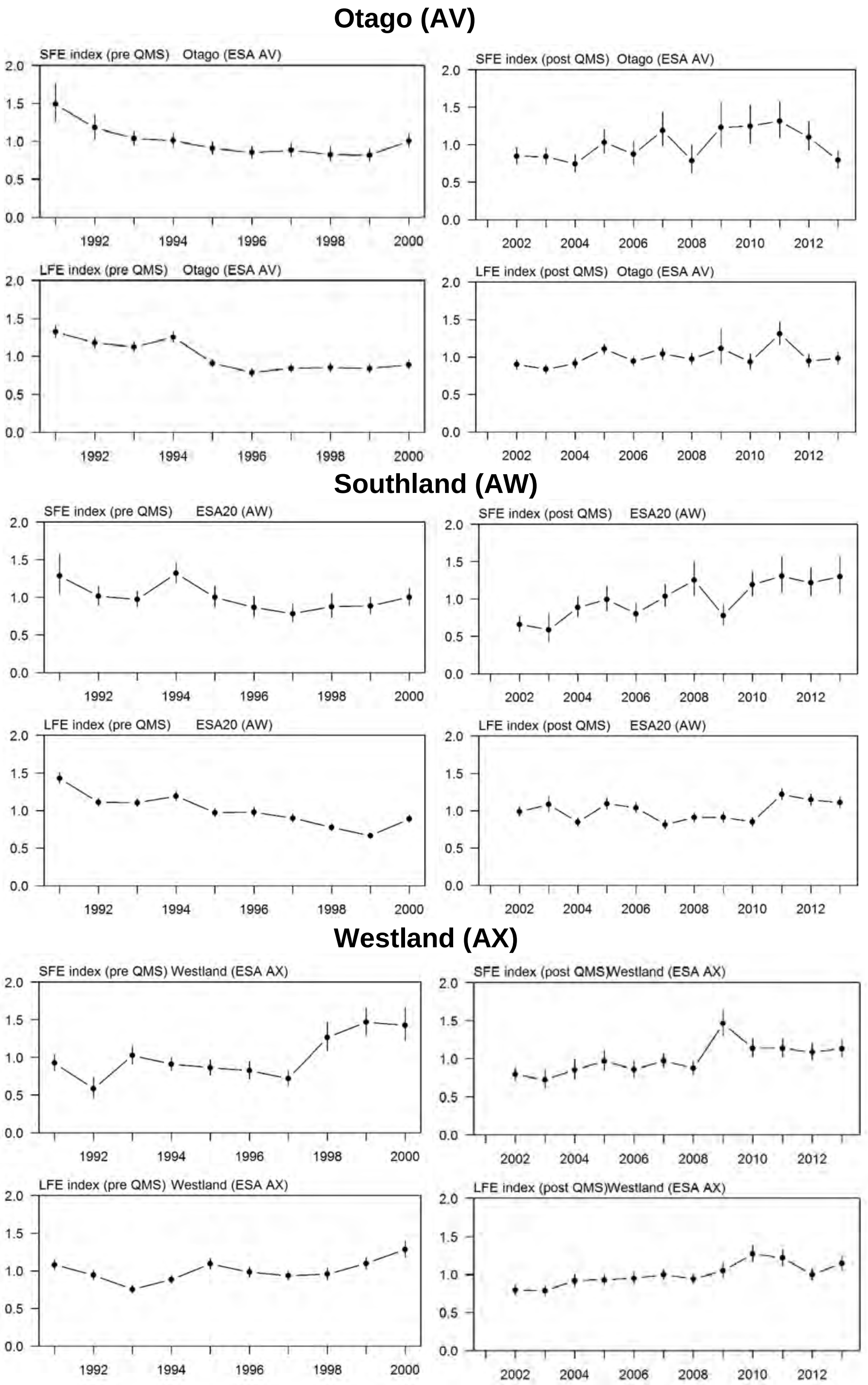


Figure 6: Trends in South Island shortfin and longfin CPUE indices for key ESAs: Otago (AV), Southland (AW), and Westland (AX). Separate indices are presented for pre-QMS (1991–2000) and post-QMS (2002–2013) (from Beentjes & Dunn 2015).

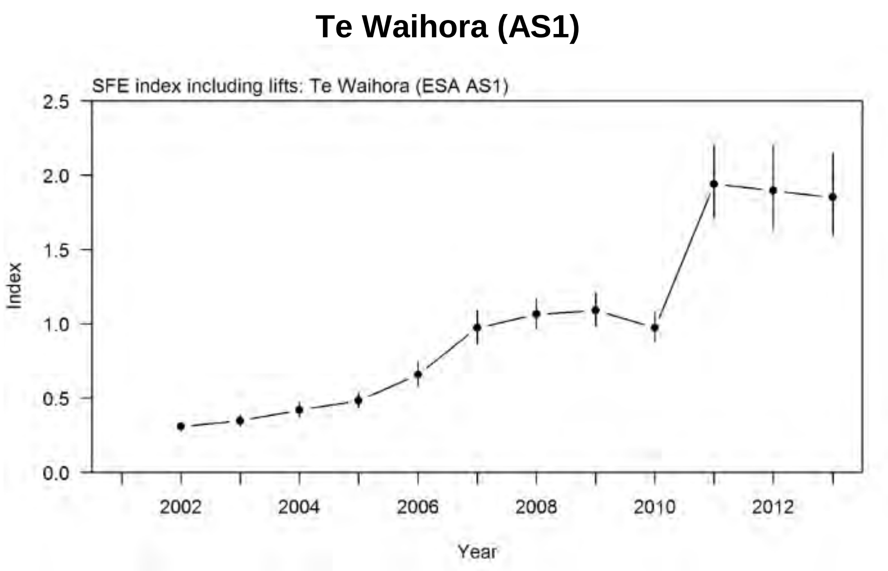


Figure 7: Te Waihora shortfin CPUE indices for AS1 (outside migration area) from 2001–02 to 2012–13 (from Beentjes & Dunn 2015).

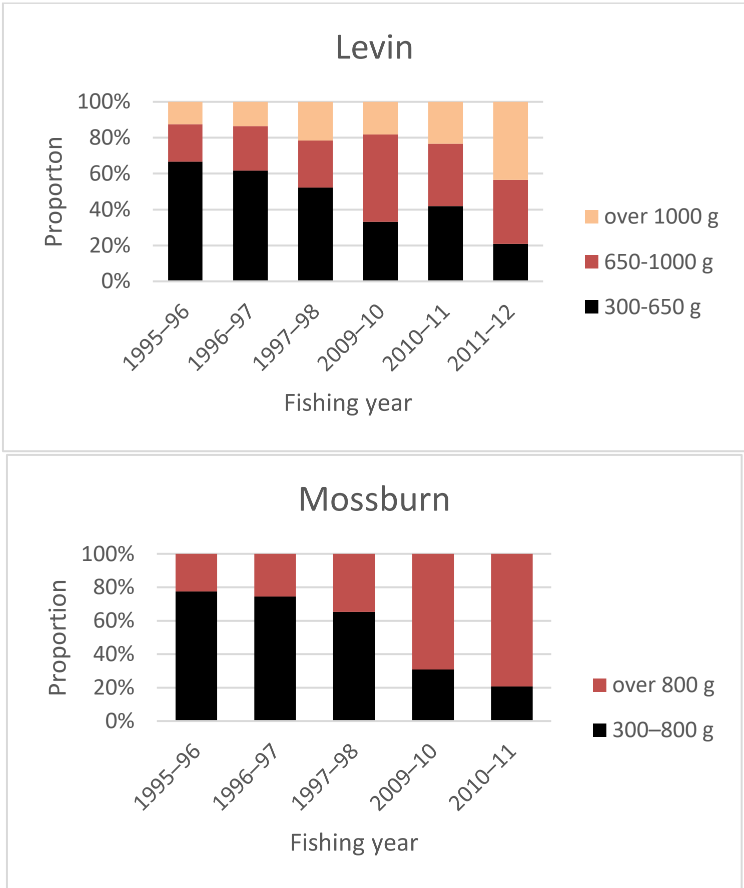


Figure 8: Size grade proportions of shortfin eels harvested from Te Waihora AS1 (lake) from eel processors Levin Eel Trading Ltd in 2009–10 to 2011–12, and Mossburn Enterprises Ltd in 2010–11 and 2011–12. The equivalent size grades have been estimated from the length of eels taken during commercial catch sampling of the commercial catch in 1995–96 to 1997–98 (from Beentjes & Dunn 2014).

4.3 Biomass estimates

Estimates of current and reference biomass for any eel fish stock are not available. Recent estimates of approximately 12 000 t have been made for longfin eels (Graynoth et al 2008, Graynoth & Booker 2009), but these are based on limited data on density, growth, and sex composition of longfin eel populations in various habitat types, including lakes and medium to large rivers.

4.4 Yield estimates and projections

In the absence of accurate current biomass estimates, this could not be estimated. Biological parameters relevant to the stock assessment are given in Table 14.

Table 14: Estimates of biological parameters.

Fishstock	Estimate	Source
1. Natural mortality (*M*)		
Unexploited shortfins (Lake Pounui)	$M = 0.038$	Jellyman (unpub. Data)
Unexploited longfins (Lake Pounui)	$M = 0.036$	Jellyman (unpub. Data)
Unexploited longfins (Lake Rotoiti)	$M = 0.02$	Jellyman (1995)
2. Weight (g) of shortfin and longfin eels at 500 mm total length		
	Mean weight	Range
Shortfins Lake Pounui	263	210–305
Shortfins Waihora	250	210–303
Longfins Lake Pounui	307	250–380

4.5 Other factors

Yield-per-recruit

Yield-per-recruit (YPR) models have been run on Te Waihora (Lake Ellesmere) and Lake Pounui data to test the impact of increases in size limit. Results indicated that an increase in minimum size should result in a small gain in YPR for shortfins in Te Waihora and longfins in Lake Pounui, but a decrease for shortfins in Lake Pounui.

A practical demonstration of the benefits of an increase in size limit has been reported from the Waikato area, where a voluntary increase in minimum size from 150 to 220 g in 1987 resulted in decreased CPUE for up to 18 months, but an increase thereafter.

Spawning escapement

A key component to ensuring the sustainability of eels is to maintain spawner escapement. As a sustainability measure, the Mohaka, Motu, and much of the Whanganui River catchments were closed to commercial fishing in early 2005 to aid spawning escapement. The importance of adequate spawner escapement for eels is evident from the three northern hemisphere (*A. anguilla, A. rostrata*, and *A. japonica*) species, which are all extensively fished at all stages of their estuarine/freshwater life and are subject to a variety of anthropogenic impacts similar to the situation in New Zealand. There has been a substantial decline in recruitment for all three northern hemisphere species since the mid-1970s with less than 1% of juvenile resources estimated to be remaining for major populations in 2003 (Quebec Declaration of Concern 2003). More recently, Dekker & Casselman (2014) concluded that “the recent recruitment increase of some [northern hemisphere] stocks, and the relative stability of others, indicate that after many decades of continued decline depleted eel stocks around the world have the potential to recover”.

Longfin habitat

It was estimated, based on GIS modelling in the early 2000s (Graynoth et al 2008), that 5% of longfin eel habitat throughout New Zealand is in water closed to fishing where there is protected egress to the sea to ensure spawning escapement. A further 10% of longfin habitat was estimated to be in areas closed to fishing in upstream areas but where the spawning migration could be subject to exploitation in downstream areas (migratory eels are not normally taken by commercial fishers). An additional 17% of longfin habitat was in small streams that are rarely or not commercially fished. Therefore, about 30% of longfin habitat in the North Island and 34% in the South Island was either in a reserve or in rarely/non-fished areas (Graynoth et al 2008). However, the estimate of the proportion of longfin habitat in streams rarely or not commercially fished was based on poor assumptions and was consequently vastly underestimated.

In 2015, commercial longfin eel fishing effort throughout New Zealand was mapped using GIS methods, providing the first detailed and high resolution representation of where and how often fishers set their nets in New Zealand rivers, lakes, and harbours (Beentjes et al 2016). The data used in the study came from face to face interviews with 53 commercial longfin fishers from throughout New Zealand and covered the five year period from 2009–10 to 2013–14. From these data, estimates were made of the proportion of longfin habitat that is currently fished (Beentjes et al 2016). The total current longfin habitat in rivers was derived from 'probability of longfin capture' models. About one quarter (27.2%) of the New Zealand longfin river and lake habitat, currently accessible to longfin eels, was commercially fished (32.5% in the South Island and 22.5% in the North Island) (Table 15). The proportion of virgin/original longfin habitat affected by anthropogenic activity (impeded access by dams and other structures, habitat degradation, and commercial fishing) is estimated at 42% (= Max. impacted abundance) (Table 15). Forty percent of the current habitat available to longfin eels in New Zealand is estimated to be within DOC Public Conservation Land, and just over half of this is in natural lakes (Beentjes et al 2016). Generally DOC will not issue concessions for commercial eel fishing in Public Conservation Land, except for short fin eels in Lake Brunner.

Table 15: Estimates of total current longfin habitat fished, virgin habitat fished, and maximum impacted abundance from all rivers and lakes by QMA, eel statistical area, and overall for South Island, North Island, and New Zealand. Current lake habitat includes that from natural lakes over 0.9 km^2, and rivers where longfin eels have unimpeded access to, and egress to the sea. Maximum impacted abundance is the proportion of virgin habitat affected by anthropogenic activities including loss to dams, impeded access, commercial fishing, and habitat loss. Max, maximum. QMA, Quota Management Area (from Beentjes et al 2016).

					Percent (%)
Island	**QMA**	**Eel Statistical Area**	**Current habitat fished**	**Virgin habitat fished**	**Max. impacted abundance**
North Island	LFE 20	AA	36.1	34.7	40.2
North Island	LFE 20	AB	34.9	33.8	38.2
North Island	LFE 21	AC	50.0	47.6	55.0
North Island	LFE 21	AD	43.2	34.4	55.7
North Island	LFE 21	AE	17.4	16.2	23.9
North Island	LFE 21	AF	8.6	8.2	13.6
North Island	LFE 22	AG	17.3	16.0	24.7
North Island	LFE 23	AH	24.8	23.6	29.9
North Island	LFE 23	AJ	17.0	15.9	23.6
North Island	LFE 22	AK	36.0	34.5	40.6
North Island	LFE 22	AL	4.2	4.1	5.0
North Island	LFE 22	AM	2.4	2.2	7.4
South Island	ANG 11	AN	11.5	11.1	15.5
South Island	ANG 11	AP	42.1	40.1	47.1
South Island	ANG 12	AQ	7.9	7.6	12.4
South Island	ANG 12	AR	58.1	55.9	61.7
South Island	ANG 13	AS	0.0	0.0	0.4
South Island	ANG 14	AT	38.6	37.3	42.1
South Island	ANG 14	AU	52.2	12.4	85.9
South Island	ANG 15	AV	46.2	12.5	82.8
South Island	ANG 15	AW	32.2	24.2	40.7
South Island	ANG 16	AX	30.2	29.0	34.0
North Island	All	All	22.5	20.9	29.0
South Island	All	All	32.5	21.8	52.6
New Zealand	All	All	27.2	21.4	42.1

Sex ratio

The shortfin fishery is based on the exploitation of immature female eels, because most shortfin male eels migrate before reaching the minimum size of 220 g. The exception to this is Te Waihora where migratory male shortfin eels are also harvested. The longfin fishery is based on immature male and female eels.

A study on the Aparima River in Southland in 2001–02 found that female longfins were rare in the catchment. Only five of 738 eels sexed were females (McCleave & Jellyman 2004). This is in contrast to a predominance of larger female longfins in southern rivers established by earlier research in the 1940s and 1950s, prior to commercial fishing. The sex ratio in other southern catchments, determined from analysis of commercial landings, also show a predominance of males. In contrast, some other catchments (Waitaki River, some northern South Island rivers) showed approximately equal sex ratios. The predominance of males in the size range below the minimum legal size of 220 g cannot be attributed directly to the effects of fishing. Because the sexual differentiation of eels can be influenced by environmental factors, it is possible that changing environmental factors are responsible for the greater proportion of male eels in these southern rivers (Davey & Jellyman 2005).

Enhancement

The transfer of elvers and juvenile eels has been established as a viable method of enhancing eel populations and increasing productivity in areas where recruitment has been limited. Elver transfer operations are conducted in summer months when elvers reach river obstacles (e.g., the Karapiro Dam on the Waikato River; see Table 10a) on their upriver migration. Nationally some 10 million elvers are now regularly caught and transferred upstream of dams each year.

To mitigate the impact of hydro turbines on migrating eels, a catch and release programme for large longfin females has been conducted from Lake Aniwhenua with release below the Matahina Dam since 1995. An extensive capture and release programme has also been conducted from Lake Manapouri to below the Mararoa Weir on the Waiau River, Southland by Meridian Energy since 1998. Limited numbers of longfin migrants are also transferred to below the Waitaki Dam by local Runanga. Adult eel bypasses have been installed at the Wairere Falls and Mokauiti power stations in the Mokau River catchment since 2002 and controlled spillway openings have been undertaken at Patea Dam during rain events in autumn (when eels are predicted to migrate downstream) since the late 1990s. Additional eel protection infrastructure is currently being installed at Patea Dam and ongoing studies, including downstream bypass trials are in progress at Karapiro Dam (Waikato), Lake Whakamarino (Waikaremoana Power Scheme) and Wairua (Titoki) Power Station. So far, the effectiveness of none of these varied mitigation activities has been fully assessed.

Several projects have been undertaken to evaluate the enhancement of depleted customary fisheries through the transfer of juvenile eels. In 1997, over 2000 juvenile shortfin eels (100–200 g) were caught from Te Waihora (Lake Ellesmere), tagged and transferred to Cooper’s Lagoon a few kilometres away (Jellyman & Beentjes 1998, Beentjes & Jellyman 2002). Only ten tagged eels, all females, were recovered in 2001. It is likely that a large number of eels migrated to sea as males following the transfer. Another project in 1998 transferred 7600 (21% tagged) mostly shortfin eels weighing less than 220 g from Lake Waahi in the Waikato catchment to the Taharoa Lakes near Kawhia (Chisnall 2000). No tagged eels were recovered when the lakes were surveyed in 2001. It is considered that a large number of shortfin eels migrated from the lake as males following the transfer. The conclusion from these two transfers is that transplanted shortfin eels need to be females, requiring that eels larger than 220 g and above the maximum size of migration for shortfin males need to be selected for transfer.

In 1998 approximately 10 000 juvenile longfin eels were caught in the lower Clutha River and transferred to Lake Hawea, of which 2010 (about 20%) were tagged (Beentjes 1998). In 2001, of 216 recaptured eels, 42 (19.4%) had tags (i.e. very little tag loss) (Beentjes & Jellyman 2003). The transferred eels showed accelerated growth and the mean annual growth in length was almost double that of eels from the original transfer site and all recaptures were females. A further sample of Lake Hawea in 2008 showed that of 399 longfin eel recaptures, 79 had tags (19.2%), indicating continued good tag retention (Beentjes & Jellyman 2011). Growth rate from the 2008 tag-recaptures was significantly greater than at release, but less than in 2001, and all recaptures were females.

Trends in the commercial catches from areas upstream of hydro dams on the Waikato, Rangitaiki, and Patea rivers indicate that elver trap and transfer operations has improved or at least maintained the eel populations upstream of barriers (Beentjes & Dunn 2010). Comparison of historical eel survey results have confirmed these observations (e.g., Beentjes et al 1997, Boubée et al 2000, Boubée & Hudson 2009, Crow & Jellyman 2010)

5. FUTURE RESEARCH CONSIDERATIONS

- The “target species” reconstruction based on CELR data needs to be examined further by, for example, running sensitivities to determine the effect of different assumptions.
- For the Te Waihora shortfin CPUE, explore the possibility of developing an index of the ratio between the AS1 and AS2 catch as a potential explanatory variable.
- Investigate the utility of using more stringent criteria for choosing core permits.
- Examine trends over time for individual fishers; i.e., consider deriving fisher-based indices as an alternative way of standardising.
- Determine whether ancillary data exist to refine or verify the derived targets.
- Determine the proportion of fishers using destination code X to report the catches of legal-sized fish that are released.
- Identify the fishers who haven’t been using destination X correctly and fix this to the extent possible. Identify whether the issue is specific to certain areas. For some fishers it may be necessary to add the destination code X estimates from the ECLR forms to the catch estimates from the ECER forms to obtain a more accurate estimate of catch per day for the CPUE analyses.
- Investigate ways of compensating for the lack of recording of eels over 4 kg since 2007–08 (especially since this should be rectified once new forms are developed).
- For areas with few fishers or records, the Eel Working group should consider merging statistical areas and analysing at the QMA level. Alternatively the Working Group needs to consider ways of developing statements about stock status for areas with few fisheries or low effort.
- Investigate the possibility of augmenting the current data with information from customary fisheries.
- Calculate a weighted CPUE by QMA, with the weighting based on the amount of suitable habitat in each area.

6. STATUS OF THE STOCKS

There are no Level 1 Full Quantitative Stock Assessments on which to base specific recommendations on eel catch levels. Nevertheless, recruitment data, commercial CPUE indices, information on spawner escapement, and information on the proportion of longfin habitat fished allow for Level 2 Partial Quantitative Stock Assessments of longfin and shortfin eels.

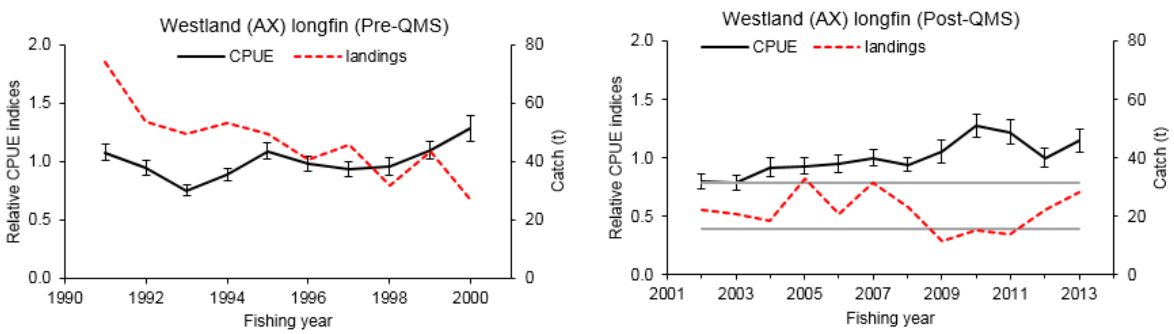
Stock Structure Assumptions
Longfin and shortfin eels are considered to be New Zealand wide stocks, with common species-specific spawning grounds within the Fiji Basin. However, once recruited to a river system, eels do not move between catchments, so eels within each catchment may be regarded as separate sub-populations for management purposes. Maintaining sub-populations within each QMA at or above (sub-area proxies for) B_{MSY}, will ensure that the entire (national) stock of each species is maintained at that level. North Island QMAs have from two to four ESAs, and South Island QMAs all have two, except Westland (LFE 16 and SFE 16) which has one. ESAs also contain multiple catchments or subpopulations from which eels are harvested.

Status of South Island Eels
Level 2 Partial Quantitative Stock Assessments are conducted by statistical area and species, and are only possible where accepted indices of abundance are available; i.e. Westland, Otago, Southland and Te Waihora). Standardised CPUE provides information on the abundance of commercially harvested eels (300 g–4000 g) in areas that are fished commercially. Aproximately 67% of currently available longfin habitat on the South Island is either in reserves or in areas rarely or never fished by commercial fishers.

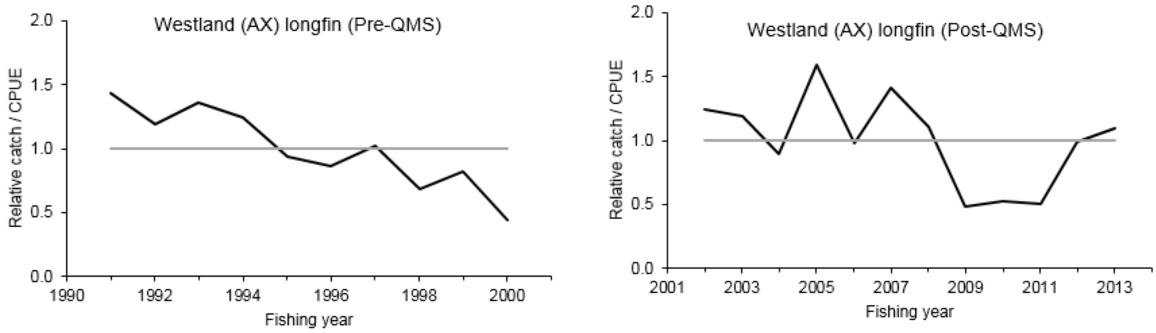
- **Westland (AX) longfin**

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Standardised CPUE
Reference Points	Target: B_{MSY} assumed, but not estimated Interim Soft Limit: Mean CPUE from 2001–02 to 2002–03 Hard Limit: 50% of Soft Limit Overfishing threshold: F_{MSY} assumed, but not estimated
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Comparison of standardised CPUE for longfin eels in Westland (AX) from 1990–91 to 1999–2000 (pre-QMS) and 2001–02 to 2012–13 (post-QMS) (from Beentjes & Dunn 2015). Also shown is the total estimated longfin catch in AX from ECERs. The two CPUE series have been scaled to the mean for each time series. Horizontal lines represent the soft and hard limits. 2000 = 1999–2000 fishing year. Error bars are 95% confidence intervals.



Annual relative exploitation rate for longfin eels in the Westland (AX) pre- and post-QMS. 2000 = 1999–2000 fishing year.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Pre-QMS CPUE declined from 1990–91 to 1992–93, and then increased steadily to 1999–2000. Post-QMS CPUE increased steadily from 2001–02 to 2012–13.
Recent Trend in Fishing intensity or Proxy	Relative exploitation rate declined steeply throughout the pre-QMS time series and generally declined from 2001–02 to 2008–09 before increasing to 2012–13 post-QMS.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of longfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment.

Projections and Prognosis	
Stock Projections or Prognosis	Unlikely (< 40%) to decline in the medium term under current catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) if catch remains at current levels Hard Limit: Unlikely (< 40%) if catch remains at current levels South Island TACCs include both longfin and shortfin eels. As the TACC is substantially higher than the current longfin eel catch, it is not meaningful to evaluate potential impacts if catches of longfins increased to the level of the TACC.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown if catch remains at current levels Likely (> 60%) if catch were to increase to the level of the TACC

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2014	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers • Uncertainty in target species after 2000 • Exclusion of zero catches • Changes in MLS and retention in early parts of the series (pre-QMS)	

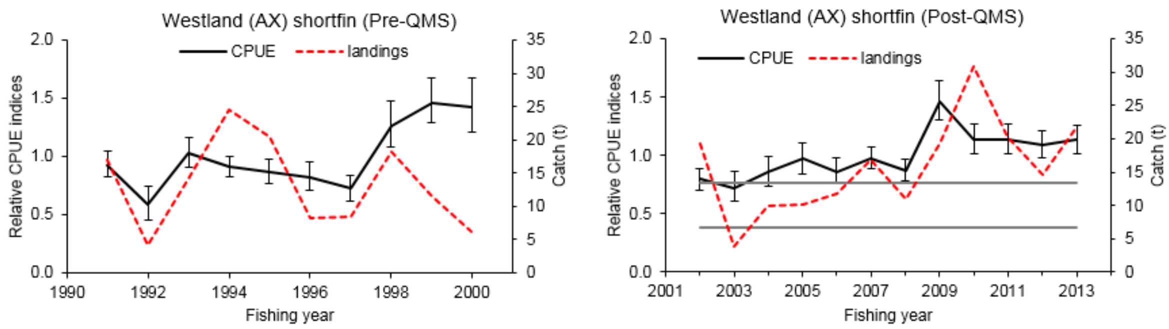
Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as culling (primarily 1930s to 1950s) and habitat alteration (historical and current) have also reduced abundance prior to the CPUE series. The basis for the biological reference points is tenuous, and should be revised whenever new relevant information becomes available. The proportion of current longfin habitat in Westland (Statistical Area AX, ANG 11) fished commercially during the period 2009–10 and 2013–14 is estimated at 30% (Table 15). The proportion of virgin habitat impacted by hydro dams, commercial fishing and other anthropogenic activity was estimated to be 34%.

Fishery Interactions
Bycatch of other species in the commercial eel fishery is low, and may include brown trout, galaxiids, yellow-eyed mullet, and koura in order of amount caught. Bycatch species are usually returned alive.

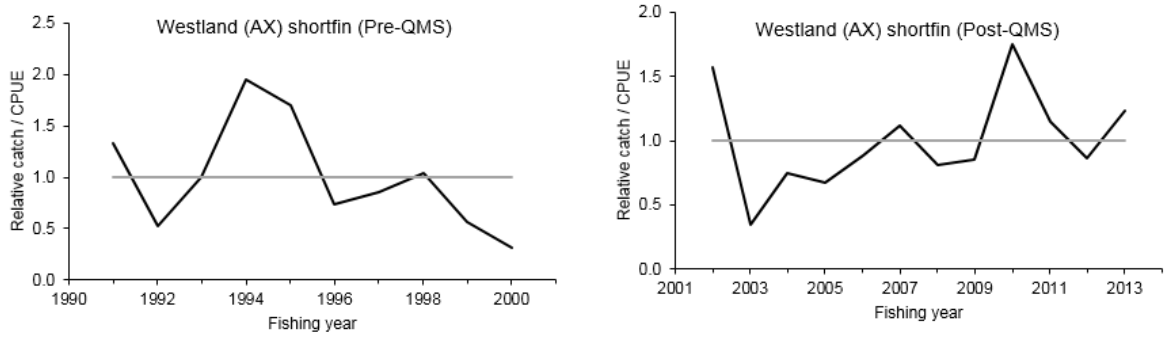
- **Westland (AX) shortfin**

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Standardised CPUE
Reference Points	Target: B_{MSY} assumed, but not estimated Interim Soft Limit: Mean CPUE from 2001–02 to 2002–03 Hard Limit: 50% of Soft Limit Overfishing threshold: F_{MSY} assumed, but not estimated
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Comparison of standardised CPUE for shortfin eels in Westland (AX) from 1990–91 to 1999–2000 (pre-QMS) and 2001–02 to 2012–13 (post-QMS) (from Beentjes & Dunn 2015). Also shown is the total estimated shortfin catch in AX from ECERs. The two CPUE series have been scaled to the mean of each time series. Horizontal lines represent the soft and hard limits. 2000 = 1999–2000 fishing year. Error bars are 95% confidence intervals.



Annual relative exploitation rate for shortfin eels in the Westland (AX) pre- and post-QMS. 2000 = 1999–2000 fishing year.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Pre-QMS CPUE fluctuated without trend from 1990–91 to 1996–97 and then increased sharply to 1999–2000. Post-QMS CPUE increased steadily from 2001–02 to 2012–13.
Recent Trend in Fishing intensity or Proxy	Relative exploitation rate has shown large inter-annual fluctuations, with an increasing trend since 2003.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of shortfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment.

Projections and Prognosis	
Stock Projections or Prognosis	Unlikely (< 40%) to decline in the medium term under current catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) if catch remains at current levels Hard Limit: Very Unlikely (< 10%) if catch remains at current levels South Island TACCs include both longfin and shortfin eels. As the TACC is approximately 2–3 times higher than the current shortfin eel catch, it is not meaningful to evaluate potential impacts if catches of shortfins were to increase to the level of the TACC.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown if catch remains at current levels Likely (> 60%) if catch were to increase to the level of the TACC

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2014	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers • Uncertainty in target species after 2000 • Exclusion of zero catches • Changes in MLS and retention in early parts of the series (pre-QMS)	

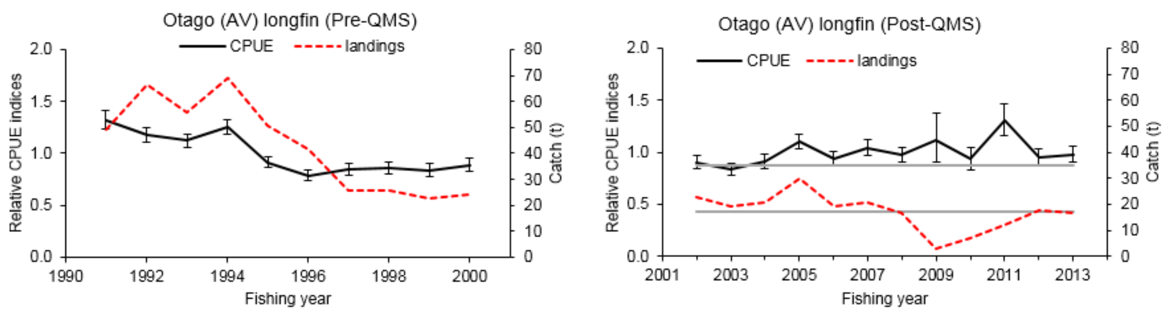
Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as culling (primarily 1930s to 1950s) and habitat alteration (historical and current) have also reduced abundance prior to the CPUE series. The basis for the biological reference points is tenuous, and should be revised whenever new relevant information becomes available.

Fishery Interactions
Bycatch of other species in the commercial eel fishery is low, and may include brown trout, galaxiids, yellow-eyed mullet, and koura in order of amount caught. Bycatch species are usually returned alive.

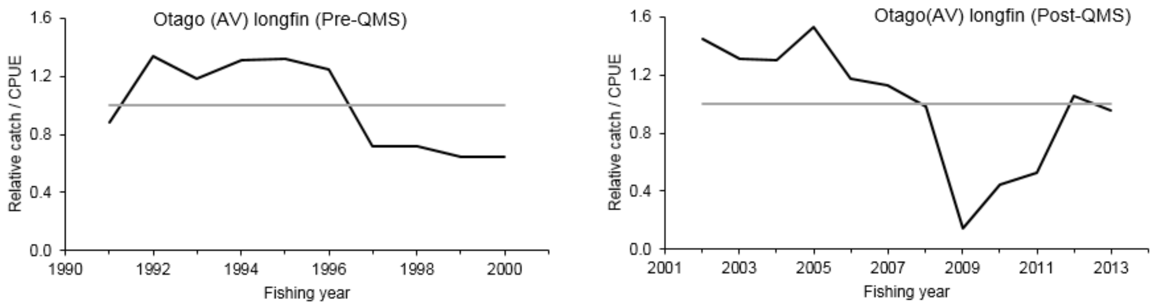
- **Otago (AV) longfin**

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Standardised CPUE
Reference Points	Target: B_{MSY} assumed, but not estimated Interim Soft Limit: Mean CPUE from 2001–02 to 2002–03 Hard Limit: 50% of Soft Limit Overfishing threshold: F_{MSY} assumed, but not estimated
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Comparison of standardised CPUE for longfin eels in Otago (AV) from 1990–91 to 1999–2000 (pre-QMS) and 2001–02 to 2012–13 (post-QMS) (from Beentjes & Dunn 2015). Also shown is the total estimated longfin catch in AV from ECERs. The two CPUE series have been scaled to the mean of each time series. Horizontal lines represent the soft and hard limits. 2000 = 1999–2000 fishing year. Error bars are 95% confidence intervals.



Annual relative exploitation rate for longfin eels in the Otago (AV) pre- and post-QMS. 2000 = 1999–2000 fishing year.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Pre-QMS CPUE declined steadily from 1990–91 to 1995–96 and was stable to 1999–2000. Post-QMS CPUE is variable, but overall increased marginally from 2001–02 to 2012–13.
Recent Trend in Fishing intensity or Proxy	Relative exploitation rate declined markedly from 2002 to 2009 and then increased to the average for the post-QMS series.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of longfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment.

Projections and Prognosis	
Stock Projections or Prognosis	Unlikely (< 40%) to decline in the medium term if catch remains at current levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: About as Likely as Not (40–60%) if catch remains at current levels Hard Limit: Unlikely (< 40%) if catch remains at current levels South Island TACCs include both longfin and shortfin eels. ANG 15 comprises statistical areas AV (Otago) and AW (Southland). As the TACC is substantially higher than the current longfin eel catch, it is not meaningful to evaluate potential impacts if catches were to increase to the level of the TACC.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown if catch remains at current levels Unknown if catch were to increase to the level of the TACC

Assessment Methodology		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2014	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers • Uncertainty in target species after 2000 • Exclusion of zero catches • Changes in MLS and retention in early parts of the series (pre-QMS)	

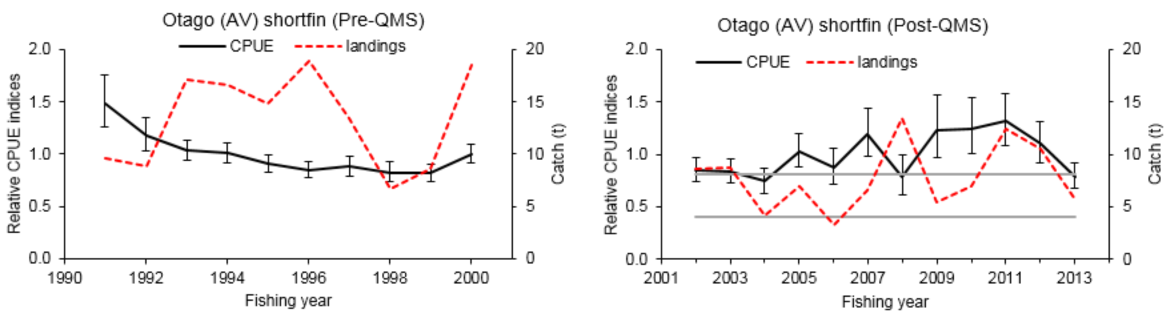
Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as culling (primarily 1930s to 1950s) and habitat alteration (historical and current) have also reduced abundance prior to the CPUE series. The basis for the biological reference points is tenuous, and should be revised whenever new relevant information becomes available. The proportion of current longfin habitat in Otago (Statistical Area AV) fished commercially during the period 2009–10 and 2013–14 is estimated at 46% (Table 15). The proportion of virgin habitat impacted by hydro dams, commercial fishing and other anthropogenic activity was estimated to be 82.8%.

Fishery Interactions
Bycatch of other species in the commercial eel fishery is low, and may include brown trout, galaxiids, yellow-eyed mullet, and koura in order of amount caught. Bycatch species are usually returned alive.

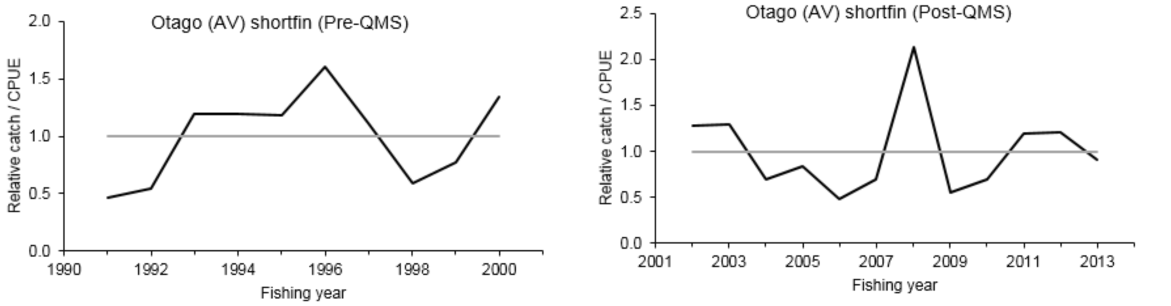
- **Otago (AV) shortfin**

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Standardised CPUE
Reference Points	Target: B_{MSY} assumed, but not estimated Interim Soft Limit: Mean CPUE from 2001–02 to 2003–04 Hard Limit: 50% of Soft Limit Overfishing threshold: F_{MSY} assumed, but not estimated
Status in relation to Target	Unlikely (< 40%) to be at or above
Status in relation to Limits	Soft Limit: About as Likely as Not (40–60%) to be below Hard Limit: Unlikely (< 40%) to be below
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Comparison of standardised CPUE for shortfin eels in Otago (AV) from 1990–91 to 1999–2000 (pre-QMS) and 2001–02 to 2012–13 (post-QMS) (from Beentjes & Dunn 2015). Also shown is the total estimated shortfin catch in AV from ECERs. The two CPUE series have been scaled to the mean of each time series. Horizontal lines represent the soft and hard limits. 2000 = 1999–2000 fishing year. Error bars are 95% confidence intervals.



Annual relative exploitation rate for shortfin eels in the Otago (AV) pre- and post-QMS. 2000 = 1999–2000 fishing year.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Pre-QMS CPUE declined steadily from 1990–91 to 1998–99 and then increased slightly to 1999–2000. Post-QMS CPUE increased steadily from 2001–02 to 2010–11, and then declined markedly to just below the long-term average.
Recent Trend in Fishing intensity or Proxy	Relative exploitation rate has fluctuated without trend since 2002.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of shortfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment.

Projections and Prognosis	
Stock Projections or Prognosis	As both catch and exploitation rate show large inter-annual variation, it is not clear whether the population will continue to decline.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: About as Likely as Not (40–60%) if catch remains at current levels Hard Limit: Unlikely (< 40%) if catch remains at current levels South Island TACCs include both longfin and shortfin eels. ANG 15 comprises statistical areas AV (Otago) and AW (Southland). The TACC is 6–7 fold higher than the current shortfin eel catch in ANG 15. Catch at the level of the TACC is Likely (> 60%) to cause decline below both the soft and hard Limits
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown if catch remains at current levels Likely (> 40%) if catch were to increase to the level of the TACC

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2014	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers • Uncertainty in target species after 2000 • Exclusion of zero catches • Changes in MLS and retention in early parts of the series (pre-QMS)	

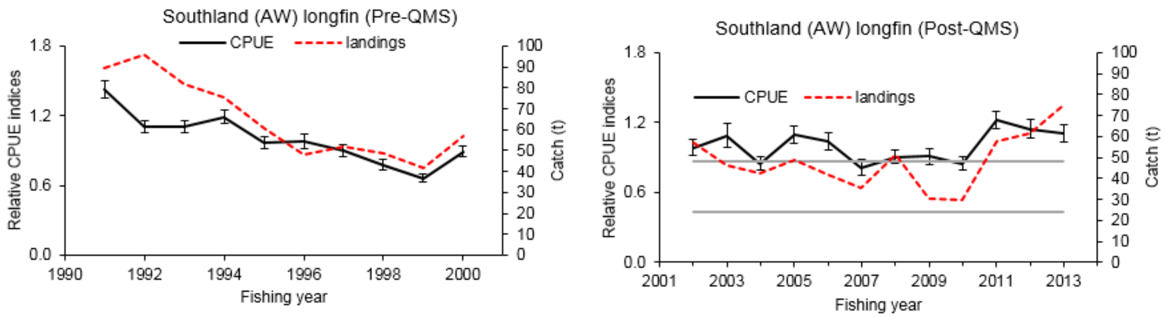
Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as culling (primarily 1930s to 1950s) and habitat alteration (historical and current) have also reduced abundance prior to the CPUE series.

Fishery Interactions
Bycatch of other species in the commercial eel fishery is low, and may include: brown trout, black flounder, koura, yellow-eyed mullet, galaxiids, yellowbelly flounder, and bullies in order of amount caught. Bycatch species are usually returned alive.

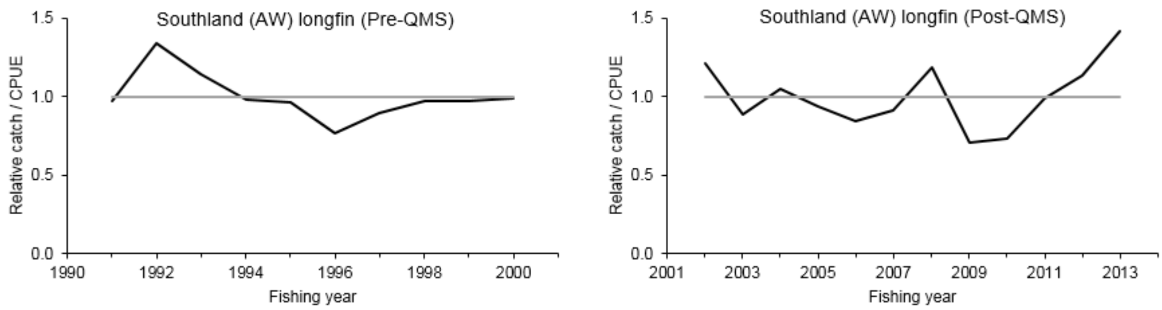
- **Southland (AW) longfin**

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Standardised CPUE
Reference Points	Target: B_{MSY} assumed, but not estimated Interim Soft Limit: Mean CPUE from 2006–07 to 2009–10 Hard Limit: 50% of Soft Limit Overfishing threshold: F_{MSY} assumed, but not estimated
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Comparison of standardised CPUE for longfin eels in Southland (AW) from 1990–91 to 1999–2000 (pre-QMS) and 2001–02 to 2012–13 (post-QMS) (from Beentjes & Dunn 2015). Also shown is the total estimated longfin catch in AW from ECERs. The two CPUE series have been scaled to the mean of each time series. Horizontal lines represent the soft and hard limits. 2000 = 1999–2000 fishing year. Error bars are 95% confidence intervals.



Annual relative exploitation rate for longfin eels in the Southland (AW) pre- and post-QMS. 2000 = 1999–2000 fishing year.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Pre-QMS CPUE declined steadily from 1990–91 to 1998–98 and increased to 1999–2000. Post-QMS CPUE is variable and showed a gradual decline from 2001–02 to 2009–10, then an increase since.
Recent Trend in Fishing intensity or Proxy	Relative exploitation rate declined from 2002 to 2010 and then increased steeply to well above the long-term average to 2013.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of longfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment.

Projections and Prognosis	
Stock Projections or Prognosis	Likely (> 60%) to decline under recent levels of catch and exploitation rate
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) if catch remains at current levels Hard Limit: Unlikely (< 40%) if catch remains at current levels South Island TACCs include both longfin and shortfin eels. ANG 15 comprises statistical areas AV (Otago) and AW (Southland). As the TACC is substantially higher than the current longfin eel catch, it is not meaningful to evaluate potential impacts if catches increased to the level of the TACC.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown if catch remains at current levels Very Likely (> 90%) if catch were to increase to the level of the TACC

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2014	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers • Uncertainty in target species after 2000 • Exclusion of zero catches • Changes in MLS and retention in early parts of the series (pre-QMS)	

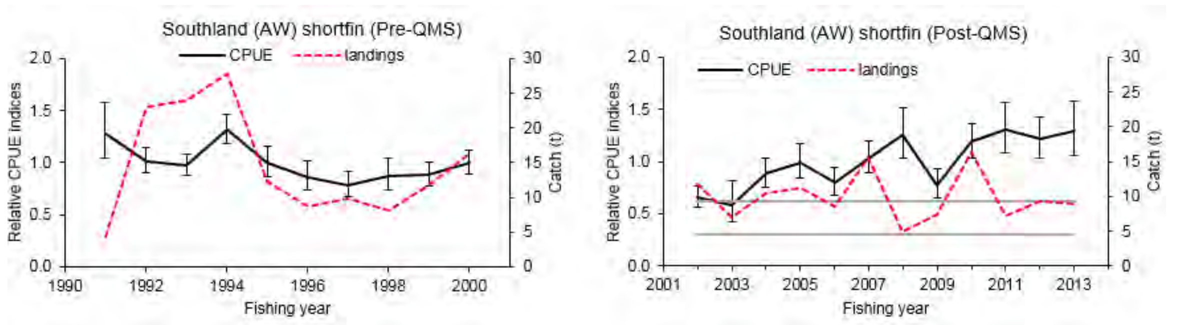
Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as culling (primarily 1930s to 1950s) and habitat alteration (historical and current) have also reduced abundance prior to the CPUE series. The basis for the biological reference points is tenuous, and should be revised whenever new relevant information becomes available. The proportion of current longfin habitat in Southland (Statistical Area AW) fished commercially during the period 2009–10 and 2013–14 is estimated at 32% (Table 15). The proportion of virgin habitat impacted by hydro dams, commercial fishing and other anthropogenic activity was estimated to be 41%.

Fishery Interactions
Bycatch of other species in the commercial eel fishery is low, and may include brown trout, giant bullies, koura, galaxiids, and common bullies in order of amount caught. Bycatch species are usually returned alive.

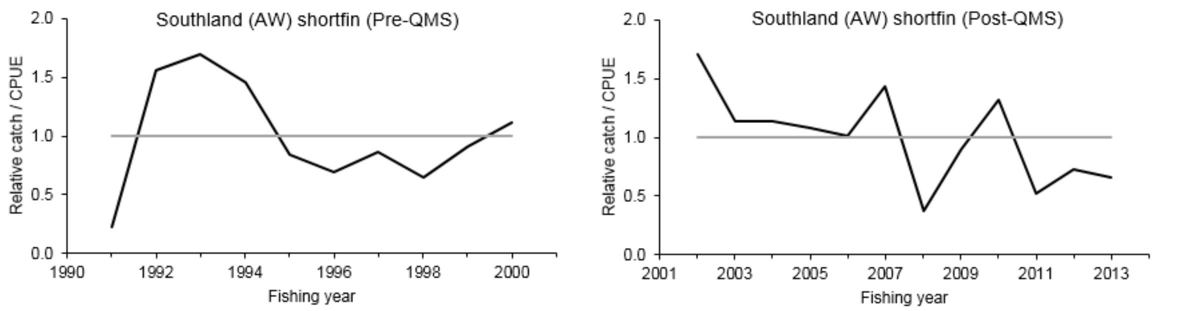
- **Southland (AW) shortfin**

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Standardised CPUE
Reference Points	Target: B_{MSY} assumed, but not estimated Interim Soft Limit: Mean CPUE from 2001–02 to 2002–03 Hard Limit: 50% of Soft Limit Overfishing threshold: F_{MSY} assumed, but not estimated
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Comparison of standardised CPUE for shortfin eels in Southland (AW) from 1990–91 to 1999–2000 (pre-QMS) and 2001–02 to 2012–13 (post-QMS) (from Beentjes & Dunn 2015). Also shown is the total estimated shortfin catch in AW from ECERs. The two CPUE series have been scaled to the mean of each time series. Horizontal lines represent the soft and hard limits. 2000 = 1999–2000 fishing year. Error bars are 95% confidence intervals.



Annual relative exploitation rate for shortfin eels in the Southland (AW) pre- and post-QMS. 2000 = 1999–2000 fishing year.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Pre-QMS CPUE declined slowly from 1990–91 to 1996–97 and then gradually increased to 1999–2000. Post-QMS CPUE fluctuated but increased substantially from 2001–02 to 2012–13.
Recent Trend in Fishing intensity or Proxy	Relative exploitation rate shows high inter-annual variation, but a consistently declining trend since 2002.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of shortfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment.

Projections and Prognosis	
Stock Projections or Prognosis	Likely (> 60%) to continue to increase in the medium term under current catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) if the catch remains at current levels Hard Limit: Very Unlikely (< 10%) if the catch remains at current levels South Island TACCs include both longfin and shortfin eels. ANG 15 comprises statistical areas AV (Otago) and AW (Southland). As the TACC is substantially higher than the current longfin eel catch, it is not meaningful to evaluate potential impacts if catches increased to the level of the TACC.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown if catch remains at current levels Likely (> 60%) if catch were to increase to the level of the TACC

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2014	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers • Uncertainty in target species after 2000 • Exclusion of zero catches • Changes in MLS and retention in early parts of the series (pre-QMS)	

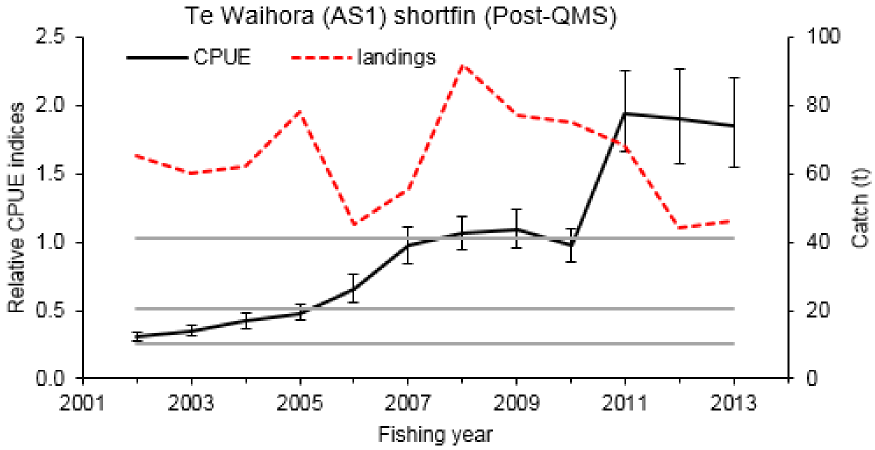
Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as culling (primarily 1930s to 1950s) and habitat alteration (historical and current) have also reduced abundance prior to the CPUE series. The basis for the biological reference points is tenuous, and should be revised whenever new relevant information becomes available.

Fishery Interactions
Bycatch of other species in the commercial eel fishery is low, and may include brown trout, giant bullies, koura, galaxiids, and common bullies in order of amount caught. Bycatch species are usually returned alive.

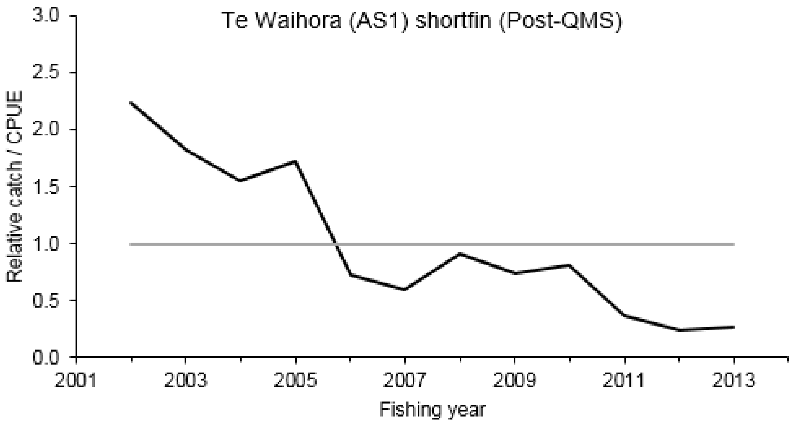
- **Te Waihora (AS1) shortfin**

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Standardised CPUE of feeder eels in AS1
Reference Points	Interim Target: B_{MSY}-compatible proxy based on mean CPUE for the period: 2006–07 to 2009–10. Soft Limit: 50% of target Hard Limit: 50% of soft limit Overfishing threshold: F_{MSY}
Status in relation to Target	Very Likely (> 60%) to be at or above B_{MSY}
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status



Comparison of standardised CPUE for shortfin eels in Te Waihora (AS1) from 2001–02 to 2012–13 (post-QMS) (from Beentjes & Dunn 2015). Also shown is the total estimated shortfin catch in AS1 from ECERs. The CPUE series have been scaled to the mean of each time series. Horizontal lines represent the target, and soft and hard limits. 2002 = 2001–2002 fishing year. Error bars are 95% confidence intervals.



Annual relative exploitation rate for shortfin eels in the Te Waihora (AS1) post-QMS. 2002 = 2001–02 fishing year.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE of feeder shortfin eels in Te Waihora (AS1) increased 6-fold from 2001–02 to 2010–11, but showed no trend to 2012–13.
Recent Trend in Fishing intensity or Proxy	Relative exploitation rate has declined substantially (9-fold) since 2002, and is now well below the series average.

Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of shortfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment. Increasing mean size since the mid-1990s suggests reduced exploitation rates.

Projections and Prognosis	
Stock Projections or Prognosis	Likely (> 60%) to remain well above the target in the medium term under current catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Very Unlikely (< 10%) if catch remains at current levels Hard Limit: Very Unlikely (< 10%) if catch remains at current levels Unlikely (< 40%) if catch were to increase to the level of the TACC, provided not all of the catch is taken from AS1
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unlikely (< 40%) if catch remains at current levels Unlikely (< 40%) if catch were to increase to the level of the TACC, provided not all of the catch is taken from AS1

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2014	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers • Exclusion of zero catches • Changes in MLS and retention in early parts of the series (pre-QMS)	

Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as habitat alteration (historical and current) have also reduced abundance prior to the CPUE series. The shortfin eel catch from Te Waihora comprises small migrant males from AS2 and feeder females from AS1. The index of abundance is based on the catch rates of feeder eels. The basis for the biological reference points is tenuous, and should be revised whenever new relevant information becomes available. Shortfin eels in Te Waihora have a markedly different (mostly strongly increasing) pattern in CPUE compared to other eel sub-populations. This could be due to a number of factors, both positive and negative, including eutrophication, and changes in productivity, lake opening regimes, and management measures.

Fishery Interactions
Bycatch of other species in the commercial eel fishery may include: bullies, black flounder, yellowbelly flounder, sand flounder, and goldfish in order of the amount caught. The flatfish species are usually released alive or retained if caught under quota. Longfin eels are not abundant and are usually voluntarily released alive. All other bycatch is released alive.

Status of North Island Eels

Level 2 Partial Quantitative Stock Assessments are conducted by statistical area and species where accepted indices of abundance are available. Standardised CPUE provides information on the abundance of commercially harvested eels (300 g–4000 g) in areas that are fished commercially.

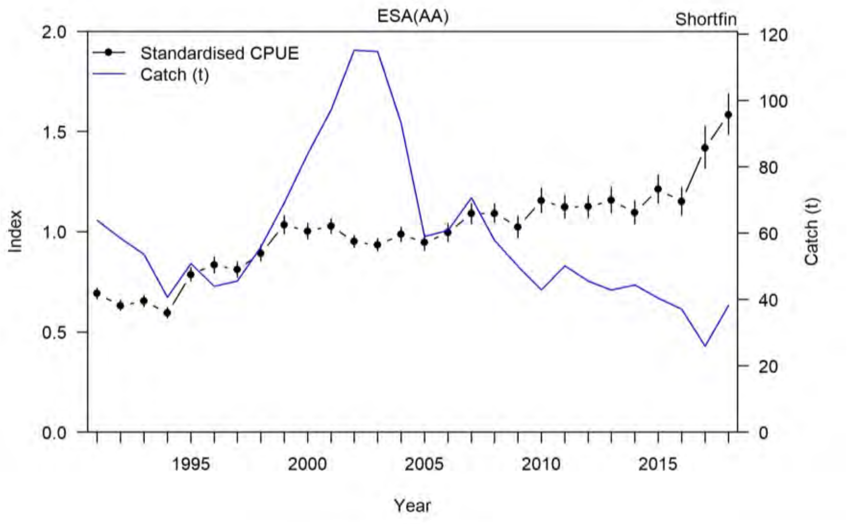
Aproximately 73% of current longfin habitat in the North Island is either in reserves or in areas rarely or never fished by commercial fishers. Statements regarding the status of longfin eels in relation to reference points are made separately for the entire ESA and for the area commercially fished within it. There is no information available on the proportion of shortfin habitat in each ESA that is fished commercially.

QMA SFE 20 and LFE 20 (includes ESAs AA and AB)

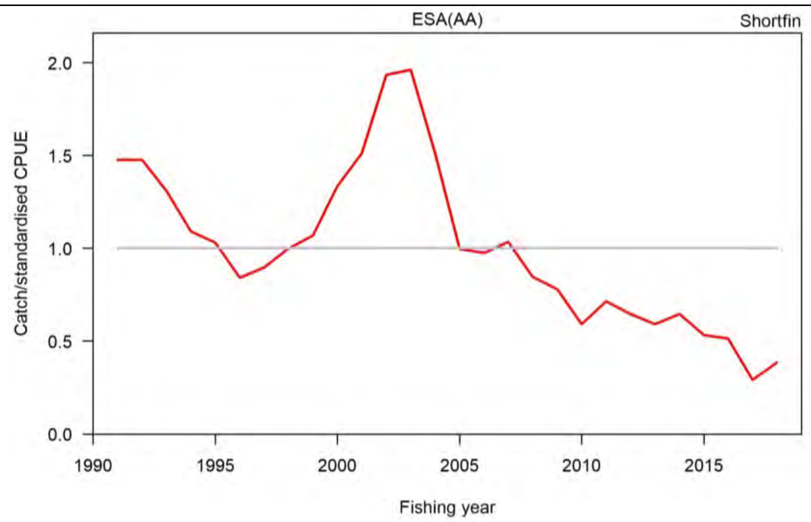
- **Northland (AA) shortfin**

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised CPUE on positive catch
Reference Points	Target: B_{MSY} proxy based on CPUE; not determined Default Soft Limit: 20% B_0 Default Hard Limit: 10% B_0 Overfishing threshold: F_{MSY} proxy based on relative exploitation rate; not determined
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Standardised CPUE for shortfin eels in Northland (AA) from 1990–91 to 2017–18 (from Beentjes 2020). Also shown is the total estimated core fisher shortfin catch in AA from ECERs. Error bars are 95% confidence intervals. Before 2001, 37% of the catch was recorded as EEU (unidentified) and these catches are omitted. 2000 = 1999–2000 fishing year.



Annual relative exploitation rate for shortfin eels in the Northland (AA). Because some catch of shortfin was reported as EEU (unidentified) and has not been allocated to species, the exploitation rate is likely to have been higher than shown before 2001.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Increasing trend in CPUE since early 1990s, with steep increase in the last two years
Recent Trend in Fishing intensity or Proxy	The relative exploitation rate has declined steeply since 2003 and in 2018 was well below the series mean
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of shortfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment.

Projections and Prognosis	
Stock Projections or Prognosis	Unlikely (< 40%) to decline in the medium term under current catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2017	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers • Uncertainty in target species after 2000 • Exclusion of zero catches	

	• Changes in MLS and retention in early parts of the series and increased escape tube size from 25 mm to 31 mm in 2012–13 • Failure of some fishers to record on ECE returns all legal sized eels caught, not just those retained

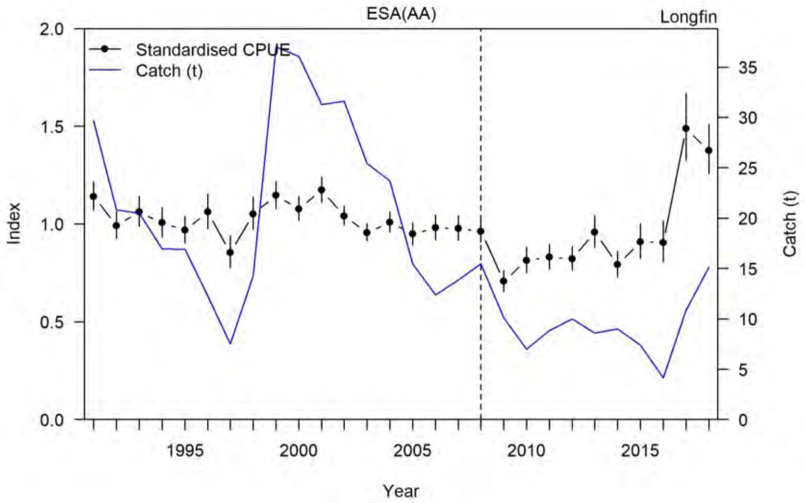
Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as habitat alteration (historical and current) have also reduced abundance prior to the CPUE series.

Fishery Interactions
Bycatch of other species in the commercial Northland eel fishery includes mainly catfish, with lesser quantities of koura, goldfish and perch. Most bycatch species are usually returned alive.

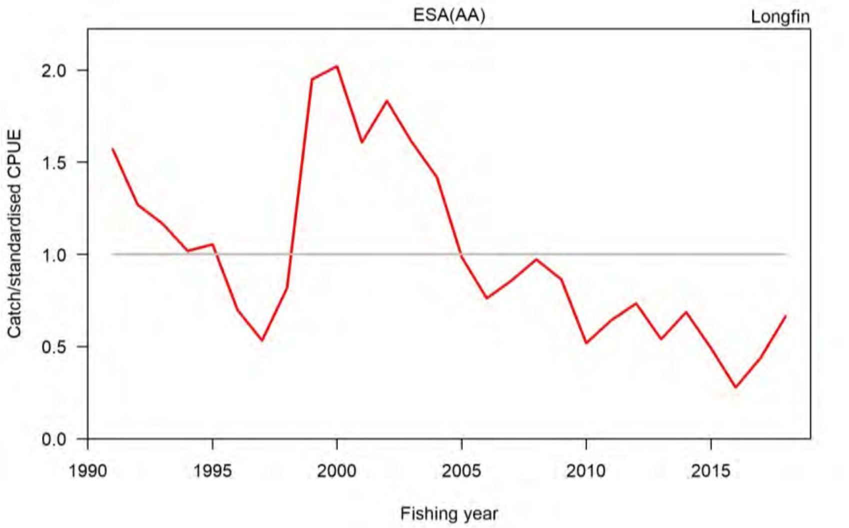
- **Northland (AA) longfin**

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised CPUE on positive catch
Reference Points	For ESA, Interim Target is 40% B_0 For commercially fished area, Target is B_{MSY} proxy based on CPUE; not determined Default Soft Limit: 20% B_0 Default Hard Limit: 10% B_0 For ESA, Overfishing threshold is F_{MSY} For commercially fished area, Overfishing threshold is F_{MSY} proxy based on relative exploitation rate; not determined
Status in relation to Target	For total ESA: Likely (> 60%) to be at or above For fished area: Unknown
Status in relation to Limits	For ESA, Soft Limit: Very Unlikely (< 10%) to be below For ESA, Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	For ESA: Unlikely (< 40%) to be overfishing For fished area: Unknown

Historical Stock Status Trajectory and Current Status



Standardised CPUE for longfin eels in Northland (AA) from 1990–91 to 2017–18 (fromBeentjes 2020). Also shown is the total estimated core fisher longfin catch in AA from ECERs. Error bars are 95% confidence intervals. Vertical dashed line indicates when the 4 kg maximum size was introduced in 2007–08 after which longfin eels 4 kg and over are not recorded on ECERs. Before 2001, 37% of the catch was recorded as EEU (unidentified) and these catches are omitted.



Annual relative exploitation rate for longfin eels in the Northland (AA). Because some catch of longfin was reported as EEU (unidentified) and has not been allocated to species, the exploitation rate is likely to have been higher than shown before 2001.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Very slight downward trend in CPUE over the time series, with large increase in last two years.
Recent Trend in Fishing intensity or Proxy	The relative exploitation rate has declined steeply since 2002 and in 2018 was well below the series mean.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of longfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment.

Projections and Prognosis	
Stock Projections or Prognosis	Unlikely (< 40%) to decline in the medium term under current catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	For ESA, Soft Limit: Very Unlikely (< 10%) if catch remains at current levels For ESA, Hard Limit: Very Unlikely (< 10%) if catch remains at current levels
Probability of Current Catch or TACC causing Overfishing to continue or to commence	For ESA, Unlikely (< 40%) if catch remains at current levels

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2017	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers (for some ESAs)	

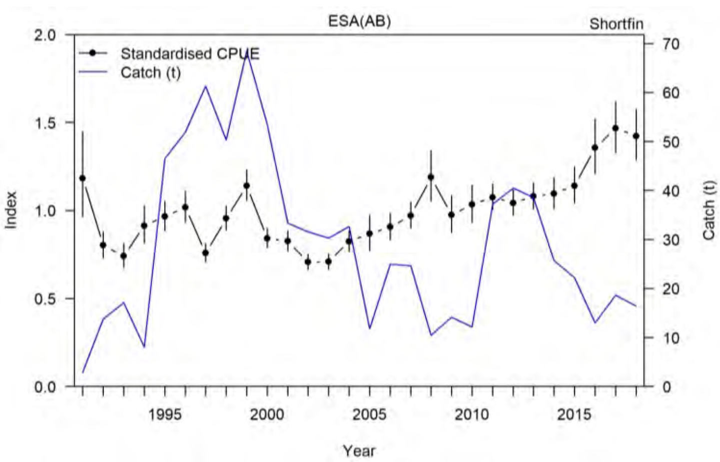
	• Uncertainty in the method used to derive target species • Changes in MLS and retention in early parts of the series and increased escape tube size from 25 mm to 31 mm in 2012–13 • Failure of some fishers to record on ECE returns all legal sized eels caught, not just those retained • Unrecorded release of > 4kg eels since 2007–08

Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as habitat alteration (historical and current) have also reduced abundance prior to the CPUE series. The proportion of current longfin habitat in Northland (Statistical Area AA) fished commercially during the period 2009–10 and 2013–14 is estimated at 36% (Table 15) The proportion of virgin habitat impacted by hydro dams, commercial fishing and other anthropogenic activity was estimated to be 40%.
Fishery Interactions
Bycatch of other species in the commercial Northland eel fishery includes mainly catfish, with lesser quantities of koura, goldfish and perch. Most bycatch species are usually returned alive.

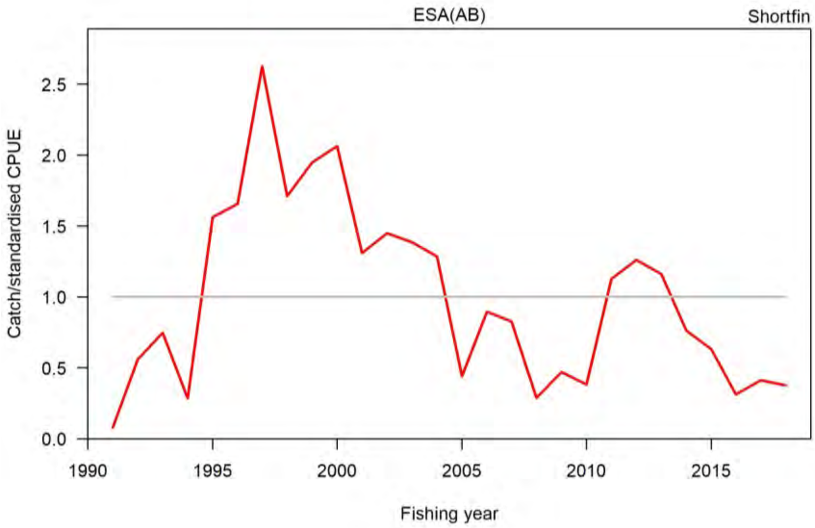
- **Auckland (AB) shortfin**

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised CPUE on positive catch
Reference Points	Target: B_{MSY} proxy based on CPUE; not determined Default Soft Limit: 20% B_0 Default Hard Limit: 10% B_0 Overfishing threshold: F_{MSY} proxy based on relative exploitation rate; not determined
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Standardised CPUE for shortfin eels in Auckland (AB) from 1990–91 to 2017–18 (from Beentjes 2020). Also shown is the total estimated core fisher shortfin catch in AB from ECERs. Error bars are 95% confidence intervals. Before 2000, 26% of the catch was recorded as EEU (unidentified) and these catches are omitted.



Annual relative exploitation rate for shortfin eels in the Auckland (AB). Because some catch of shortfin was reported as EEU (unidentified) and has not been allocated to species, the exploitation rate is likely to have been higher than shown before 2000.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	No trend in CPUE until 2003, after which it increases consistently and steeply in the last three years.
Recent Trend in Fishing intensity or Proxy	The relative exploitation rate declined from 2012 and in 2018 was below the series mean.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of shortfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment.

Projections and Prognosis	
Stock Projections or Prognosis	Unlikely (< 40%) to decline in the medium term under current catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2017	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers • Uncertainty in target species after 2000	

	• Exclusion of zero catches • Changes in MLS and retention in early parts of the series and increased escape tube size from 25 mm to 31 mm in 2012–13 • Failure of some fishers to record on ECE returns all legal sized eels caught, not just those retained

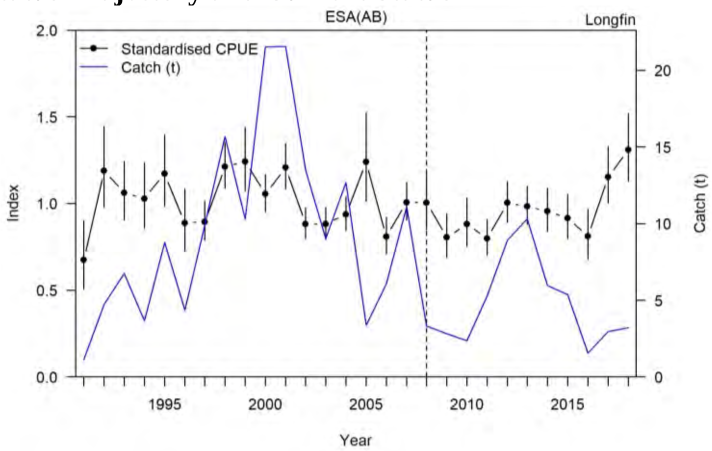
Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as habitat alteration (historical and current) have also reduced abundance prior to the CPUE series.

Fishery Interactions
Bycatch of other species in the commercial Auckland eel fishery includes mainly catfish, with lesser quantities of Koi carp, goldfish, koura, grey mullet and yellowbelly flounder. Most bycatch species are usually returned alive.

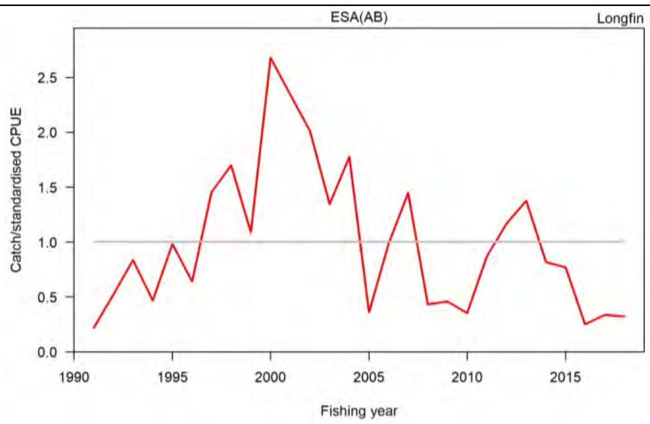
- **Auckland (AB) longfin**

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised CPUE on positive catch
Reference Points	For ESA, Interim Target is 40% B_0 For commercially fished area, Target is B_{MSY} proxy based on CPUE; not determined Default Soft Limit: 20% B_0 Default Hard Limit: 10% B_0 For ESA, Overfishing threshold is F_{MSY} For commercially fished area, Overfishing threshold is F_{MSY} proxy based on relative exploitation rate; not determined
Status in relation to Target	For total ESA: Likely (> 60%) to be at or above For fished area: Unknown
Status in relation to Limits	For ESA, Soft Limit: Very Unlikely (< 10%) to be below For ESA, Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	For ESA: Unlikely (< 40%) to be overfishing For fished area: Unknown

Historical Stock Status Trajectory and Current Status



Comparison of standardised CPUE for longfin eels in Northland (AB) from 1990–91 to 2017–18 (from Beentjes 2020). Also shown is the total estimated core fisher longfin catch in AB from ECERs. Vertical dashed line indicates when the 4 kg maximum size was introduced in 2007–08 after which longfin eels 4 kg and over are not recorded on ECERs. Error bars are 95% confidence intervals. Before 2000, 26% of the catch was recorded as EEU (unidentified) and these catches are omitted.



Annual relative exploitation rate for longfin eels in the Auckland (AB). Because some catch of longfin was reported as EEU (unidentified) and has not been allocated to species, the exploitation rate is likely to have beenhigher than shown before 2000.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	A slight decline in CPUE to 2016, with a steep increase in the last two years.
Recent Trend in Fishing intensity or Proxy	The relative exploitation rate has declined since 2013 and in 2018 was below the series mean.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of longfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment.

Projections and Prognosis	
Stock Projections or Prognosis	Unlikely (< 40%) to decline in the medium term under current catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	For ESA, Soft Limit: Very Unlikely (< 10%) if catch remains at current levels For ESA, Hard Limit: Very Unlikely (< 10%) if catch remains at current levels
Probability of Current Catch or TACC causing Overfishing to continue or to commence	For ESA, Unlikely (< 40%) if catch remains at current levels

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2017	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers • Uncertainty in target species after 2000 • Exclusion of zero catches • Changes in MLS and retention in early parts of the series and increased escape tube size from 25 mm to 31 mm in 2012–13	

	• Failure of some fishers to record on ECE returns all legal sized eels caught, not just those retained • Unrecorded release of > 4kg eels since 2007–08

Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as habitat alteration (historical and current) have also reduced abundance prior to the CPUE series. The proportion of current longfin habitat in Auckland (Statistical Area AB) fished commercially during the period 2009–10 and 2013–14 is estimated at 35% (Table 15). The proportion of virgin habitat impacted by hydro dams, commercial fishing and other anthropogenic activity was estimated to be 38%.

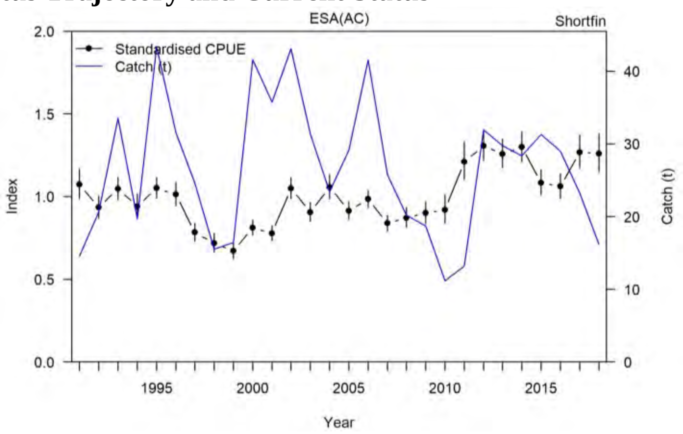
Fishery Interactions
Bycatch of other species in the commercial Auckland eel fishery includes mainly catfish, with lesser quantities of Koi carp, goldfish, koura, grey mullet and yellowbelly flounder. Most bycatch species are usually returned alive.

QMA SFE 21 and LFE 21 (includes ESAs AC, AD, AE and AF)

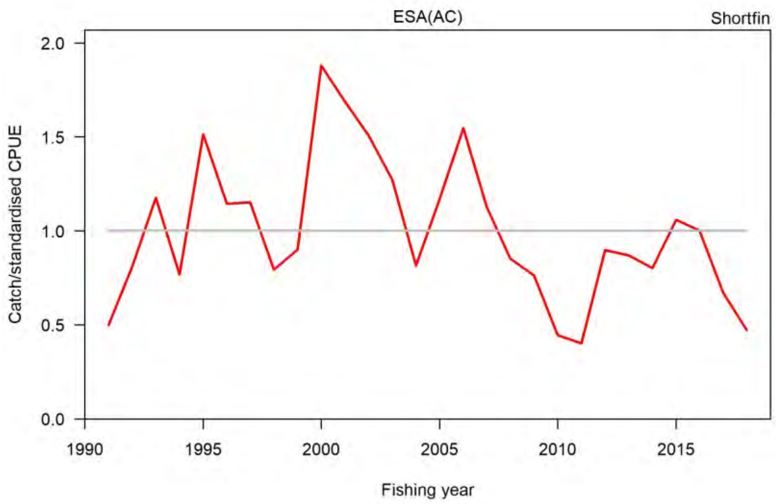
- **Hauraki (AC) shortfin**

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised CPUE on positive catch
Reference Points	Target: B_{MSY} proxy based on CPUE; not determined Default Soft Limit: 20% B_0 Default Hard Limit: 10% B_0 Overfishing threshold: F_{MSY} proxy based on relative exploitation rate; not determined
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Standardised CPUE for shortfin eels in Hauraki (AC) from 1990–91 to 2017–18 (from Beentjes 2020). Also shown is the total estimated core fisher shortfin catch in AC from ECERs. Error bars are 95% confidence intervals. Before 2002, 16% of the catch was recorded as EEU (unidentified) and these catches are omitted.



Annual relative exploitation rate for shortfin eels in the Hauraki (AC). Because some catch of shortfin was reported as EEU (unidentified) and has not been allocated to species, the exploitation rate is likely to have been higher than shown before 2002.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	No trend in CPUE until 2010, after which it has increased
Recent Trend in Fishing intensity or Proxy	The relative exploitation rate has declined since 2006, and in 2018 was below the series mean.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of shortfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment.

Projections and Prognosis	
Stock Projections or Prognosis	Unlikely (< 40%) to decline in the medium term under current catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2017	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers • Uncertainty in target species after 2000 • Exclusion of zero catches	

	• Changes in MLS and retention in early parts of the series and increased escape tube size from 25 mm to 31 mm in 2012–13 • Failure of some fishers to record on ECE returns all legal sized eels caught, not just those retained

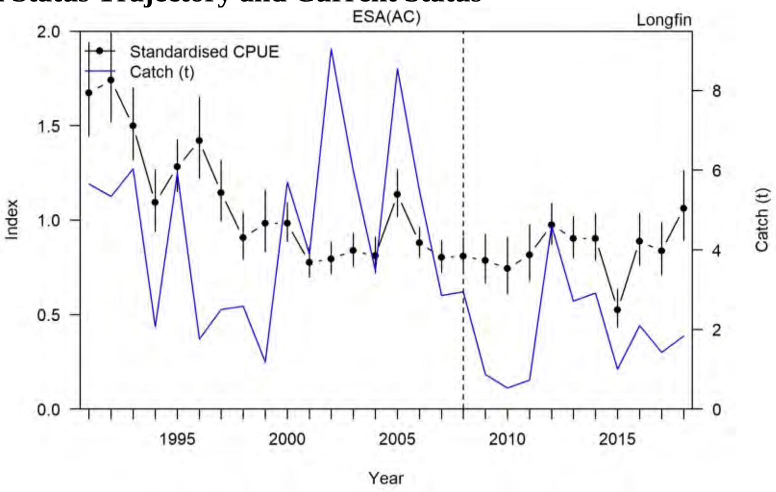
Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as habitat alteration (historical and current) have also reduced abundance prior to the CPUE series.

Fishery Interactions
Bycatch of other species in the commercial Hauraki eel fishery includes mainly catfish, with lesser quantities of brown trout, goldfish, koi carp, and kokopu. Most bycatch species are usually returned alive.

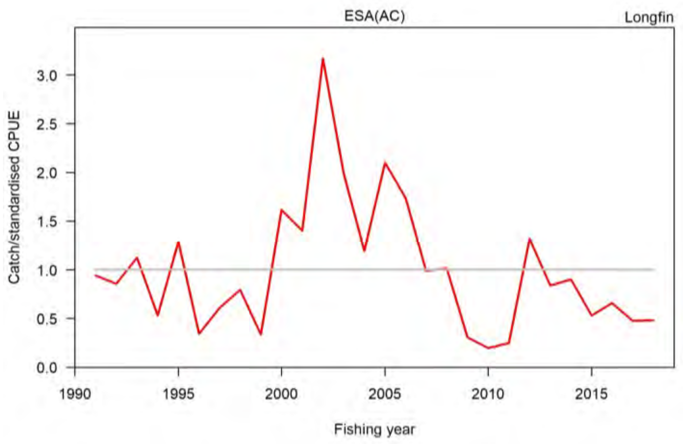
- **Hauraki (AC) longfin**

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised CPUE on positive catch
Reference Points	For ESA, Interim Target is 40% B_0 For commercially fished area, Target is B_{MSY} proxy based on CPUE; not determined Default Soft Limit: 20% B_0 Default Hard Limit: 10% B_0 For ESA, Overfishing threshold is F_{MSY} For commercially fished area, Overfishing threshold is F_{MSY} proxy based on relative exploitation rate; not determined
Status in relation to Target	For total ESA: Likely (> 60%) to be at or above For fished area: Unknown
Status in relation to Limits	For ESA, Soft Limit: Very Unlikely (< 10%) to be below For ESA, Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	For ESA: Unlikely (< 40%) to be overfishing For fished area: Unknown

Historical Stock Status Trajectory and Current Status



Standardised CPUE for longfin eels in Hauraki (AC) from 1990–91 to 2017–18 (from Beentjes 2020). Also shown is the total estimated core fisher longfin catch in AC from ECERs. Vertical dashed line indicates when the 4 kg maximum size was introduced in 2007–08 after which longfin eels 4 kg and over are not recorded on ECERs. Error bars are 95% confidence intervals. Before 2002, 16% of the catch was recorded as EEU (unidentified) and these catches are omitted.



Annual relative exploitation rate for longfin eels in the Hauraki (AC). Because some catch of longfin was reported as EEU (unidentified) and has not been allocated to species, the exploitation rate is likely to have been higher than shown before 2002.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Steep decline in CPUE to 2000–01, and then without trend/stable to 2017–18
Recent Trend in Fishing intensity or Proxy	The relative exploitation rate has declined steeply since 2012 and in 2018 was well below the average for the series.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of longfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment.
Projections and Prognosis	
Stock Projections or Prognosis	Unlikely (< 40%) to decline in the medium term under current catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	For ESA, Soft Limit: Very Unlikely (< 10%) if catch remains at current levels For ESA, Hard Limit: Very Unlikely (< 10%) if catch remains at current levels
Probability of Current Catch or TACC causing Overfishing to continue or to commence	For ESA, Unlikely (< 40%) if catch remains at current levels

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2017	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers • Uncertainty in target species after 2000 • Exclusion of zero catches • Changes in MLS and retention in early parts of the series and increased escape tube size from 25 mm to 31 mm in 2012–13	

	• Failure of some fishers to record on ECE returns all legal sized eels caught, not just those retained • Unrecorded release of > 4kg eels since 2007–08

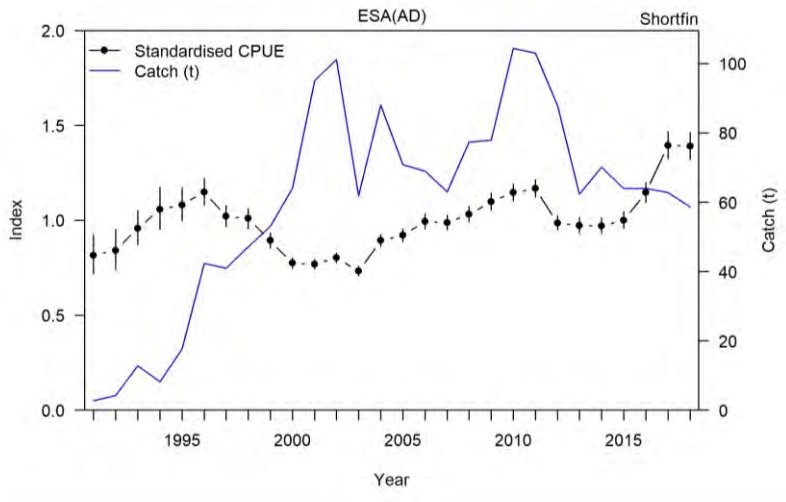
Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as habitat alteration (historical and current) have also reduced abundance prior to the CPUE series. The proportion of current longfin habitat in Hauraki (Statistical Area AC) fished commercially during the period 2009–10 and 2013–14 is estimated at 50% (Table 15). The proportion of virgin habitat impacted by hydro dams, commercial fishing and other anthropogenic activity was estimated to be 55%.

Fishery Interactions
Bycatch of other species in the commercial Hauraki eel fishery includes mainly catfish, with lesser quantities of Koi carp, goldfish, koura, grey mullet and yellowbelly flounder. Most bycatch species are usually returned alive.

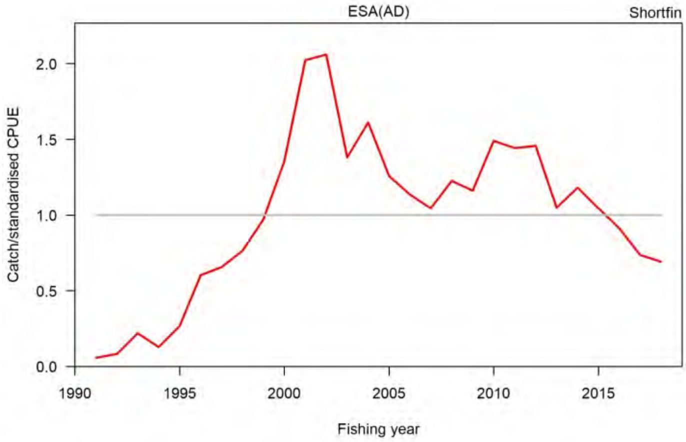
- **Waikato (AD) shortfin**

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised CPUE on positive catch
Reference Points	Target: B_{MSY} proxy based on CPUE; not determined Default Soft Limit: 20% B_0 Default Hard Limit: 10% B_0 Overfishing threshold: F_{MSY} proxy based on relative exploitation rate; not determined
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Standardised CPUE for shortfin eels in Waikato (AD) from 1990–91 to 2017–18 (from Beentjes 2020). Also shown is the total estimated core fisher shortfin catch in AD from ECERs. Error bars are 95% confidence intervals. Before 2002, 71% of the catch was recorded as EEU (unidentified) and these catches are omitted.



Annual relative exploitation rate for shortfin eels in the Waikato (AD). Because considerable catch of shortfin was reported as EEU (unidentified) and has not been allocated to species, the exploitation rate is likely to have been much higher than shown before 2002.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	No long-term trend in CPUE until 2003, after which it increased, most steeply in the last three years.
Recent Trend in Fishing intensity or Proxy	The relative exploitation rate has declined since 2009 and in 2018 was below the series mean.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of shortfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment.

Projections and Prognosis	
Stock Projections or Prognosis	Unlikely (< 40%) to decline in the medium term under current catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2017	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers • Uncertainty in target species after 2000 • Exclusion of zero catches • Changes in MLS and retention in early parts of the series and increased escape tube size from 25 mm to 31 mm in 2012–13	

	• Failure of some fishers to record on ECE returns all legal sized eels caught, not just those retained

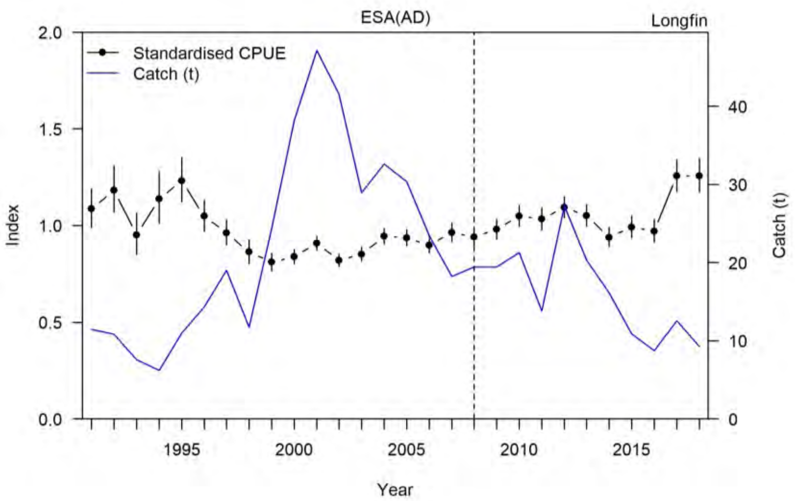
Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as habitat alteration (historical and current) have also reduced abundance prior to the CPUE series.

Fishery Interactions
Bycatch of other species in the commercial Waikato eel fishery includes large quantities of catfish and koi carp, as well as goldfish, rudd, koura, brown trout, perch, and kokopu. Most bycatch species are usually returned alive.

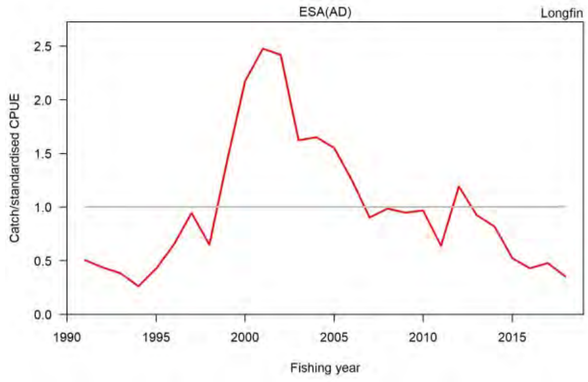
- **Waikato (AD) longfin**

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised CPUE on positive catch
Reference Points	For ESA, Interim Target is 40% B_0 For commercially fished area, Target is B_{MSY} proxy based on CPUE; not determined Default Soft Limit: 20% B_0 Default Hard Limit: 10% B_0 For ESA, Overfishing threshold is F_{MSY} For commercially fished area, Overfishing threshold is F_{MSY} proxy based on relative exploitation rate; not determined
Status in relation to Target	For total ESA: Likely (> 60%) to be at or above For fished area: Unknown
Status in relation to Limits	For ESA, Soft Limit: Very Unlikely (< 10%) to be below For ESA, Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	For ESA: Unlikely (< 40%) to be overfishing For fished area: Unknown

Historical Stock Status Trajectory and Current Status



Standardised CPUE for longfin eels in Waikato (AD) from 1990–91 to 2017–18 (from Beentjes 2020). Also shown is the total estimated core fisher longfin catch in AD from ECERs. Vertical dashed line indicates when the 4 kg maximum size was introduced in 2007–08 after which longfin eels 4 kg and over are not recorded on ECERs. Error bars are 95% confidence intervals. Before 2002, 71% of the catch was recorded as EEU (unidentified) and these catches are omitted.



Annual relative exploitation rate for longfin eels in the Waikato (AD). Because considerable catch of longfin was reported as EEU (unidentified) and has not been allocated to species, the exploitation rate is likely to have been much higher than shown before 2002.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	A moderate decline in CPUE to 1998, and then a gradual increase, steepest in the last two yearsto around the level of the former peak.–18
Recent Trend in Fishing intensity or Proxy	The relative exploitation rate has declined steeply since 2002 and in 2018 was well below the series mean.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of longfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment.

Projections and Prognosis	
Stock Projections or Prognosis	Unlikely (< 40%) to decline in the medium term under current catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	For ESA, Soft Limit: Very Unlikely (< 10%) if catch remains at current levels For ESA, Hard Limit: Very Unlikely (< 10%) if catch remains at current levels
Probability of Current Catch or TACC causing Overfishing to continue or to commence	For ESA, Unlikely (< 40%) if catch remains at current levels

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2017	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers • Uncertainty in target species after 2000 • Exclusion of zero catches • Changes in MLS and retention in early parts of the series and increased escape tube size from 25 mm to 31 mm in 2012–13	

	• Failure of some fishers to record on ECE returns all legal sized eels caught, not just those retained • Unrecorded release of > 4kg eels since 2007–08

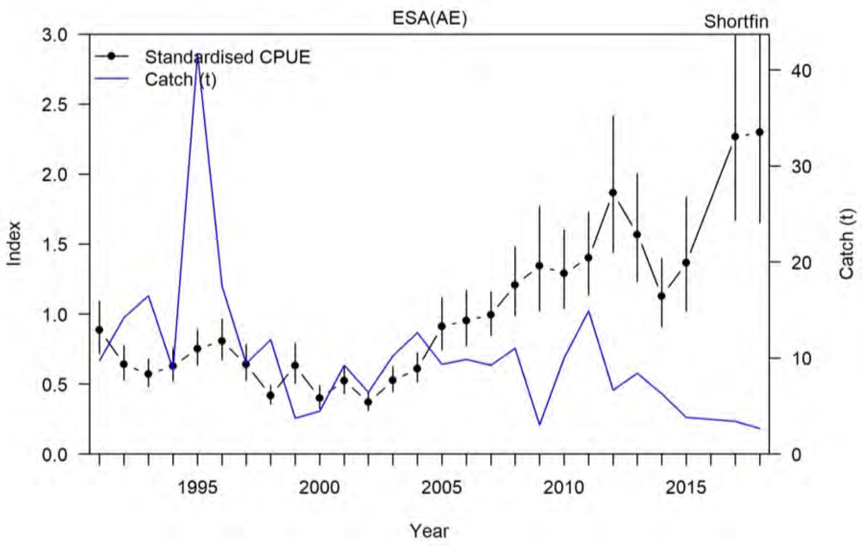
Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as habitat alteration (historical and current) have also reduced abundance prior to the CPUE series. The proportion of current longfin habitat in Waikato (Statistical Area AD) fished commercially during the period 2009–10 and 2013–14 is estimated at 43% (Table 15). The proportion of virgin habitat impacted by hydro dams, commercial fishing and other anthropogenic activity was estimated to be 56%.

Fishery Interactions
Bycatch of other species in the commercial Waikato eel fishery includes large quantities of catfish and koi carp, as well as goldfish, rudd, koura, brown trout, perch, and kokopu. Most bycatch species are usually returned alive.

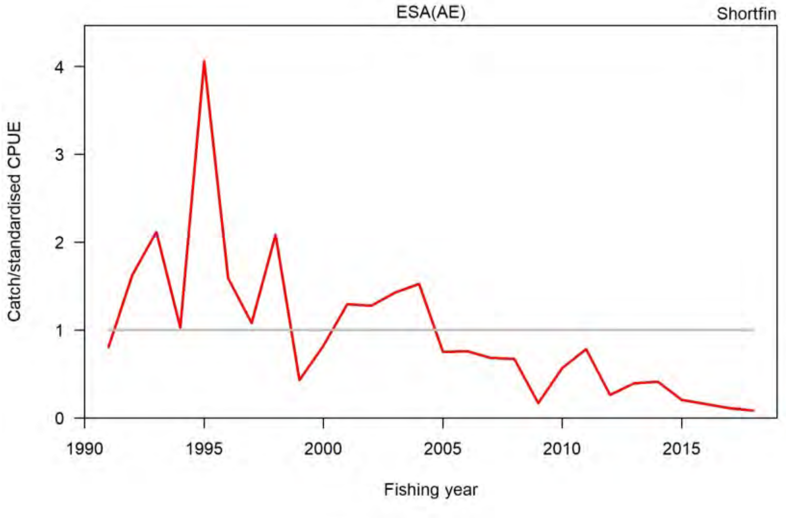
- **Bay of Plenty (AE) shortfin**

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised CPUE on positive catch
Reference Points	Target: B_{MSY} proxy based on CPUE; not determined Default Soft Limit: 20% B_0 Default Hard Limit: 10% B_0 Overfishing threshold: F_{MSY} proxy based on relative exploitation rate; not determined
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Standardised CPUE for shortfin eels in Bay of Plenty (AE) from 1990–91 to 2017–18 (from Beentjes 2020). Also shown is the total estimated core fisher shortfin catch in AE from ECERs. Error bars are 95% confidence intervals. Before 2000, 13% of the catch was recorded as EEU (unidentified) and these catches are omitted.



Annual relative exploitation rate for shortfin eels in the Bay of Plenty (AE). Because some catch of shortfin was reported as EEU (unidentified) and has not been allocated to species, the exploitation rate is likely to have been higher than shown before 2000.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	No trend in CPUE until 2002, after which it increases steeply to a peak in 2018
Recent Trend in Fishing intensity or Proxy	Relative exploitation rate has declined since 2002, and in 2018 was well below the series mean.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of shortfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment.

Projections and Prognosis	
Stock Projections or Prognosis	Unlikely (< 40%) to decline in the medium term under current catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2017	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers • Uncertainty in target species after 2000 • Exclusion of zero catches	

	• Changes in MLS and retention in early parts of the series and increased escape tube size from 25 mm to 31 mm in 2012–13 • Failure of some fishers to record on ECE returns all legal sized eels caught, not just those retained

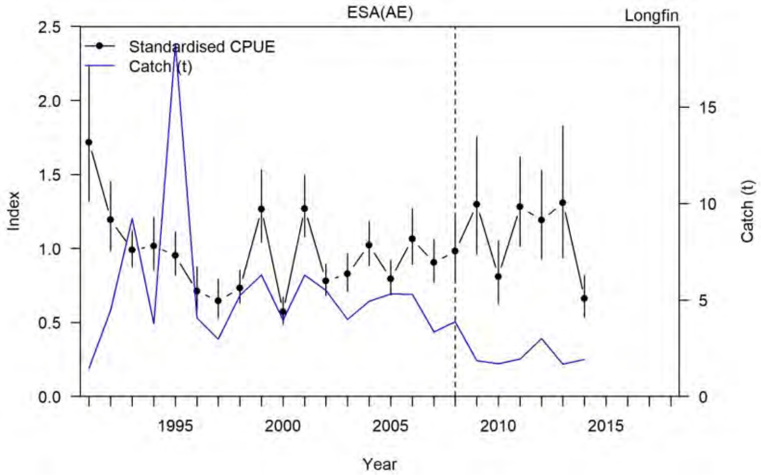
Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as habitat alteration (historical and current) have also reduced abundance prior to the CPUE series.

Fishery Interactions
Bycatch of other species in the commercial Bay of Plenty eel fishery includes very small quantities of goldfish and bullies. Most bycatch species are usually returned alive.

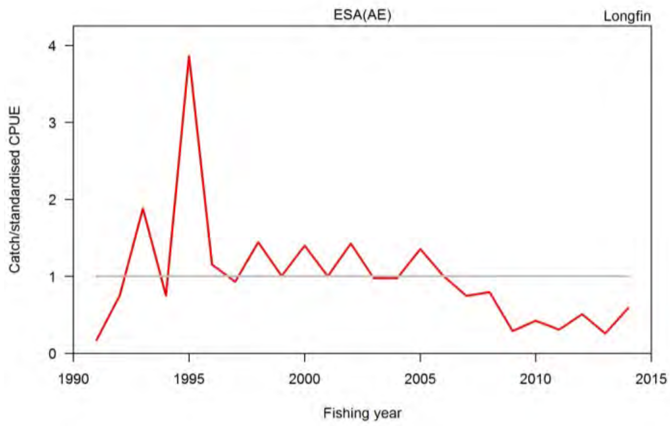
- **Bay of Plenty (AE) longfin**

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised CPUE on positive catch
Reference Points	For ESA, Interim Target is 40% B_0 For commercially fished area, Target is B_{MSY} proxy based on CPUE; not determined Default Soft Limit: 20% B_0 Default Hard Limit: 10% B_0 For ESA, Overfishing threshold is F_{MSY} For commercially fished area, Overfishing threshold is F_{MSY} proxy based on relative exploitation rate; not determined
Status in relation to Target	For total ESA: Likely (> 60%) to be at or above For fished area: Unknown
Status in relation to Limits	For ESA, Soft Limit: Very Unlikely (< 10%) to be below For ESA, Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	For ESA: Unlikely (< 40%) to be overfishing For fished area: Unknown

Historical Stock Status Trajectory and Current Status



Standardised CPUE for longfin eels in Bay of Plenty (AE) from 1990–91 to 2017–18 (from Beentjes 2020). Also shown is the total estimated core fisher longfin catch in AE from ECERs. Vertical dashed line indicates when the 4 kg maximum size was introduced in 2007–08 after which longfin eels 4 kg and over are not recorded on ECERs. Error bars are 95% confidence intervals. Before 2000, 13% of the catch was recorded as EEU (unidentified) and these catches are omitted.



Annual relative exploitation rate for longfin eels in the Bay of Plenty (AE). Because some catch of longfin was reported as EEU (unidentified) and has not been allocated to species, the exploitation rate is likely to have been higher than shown before 2000.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	A steep decline in CPUE to 2000, and then variable with no clear trend. Insufficient data to produce indices after 2013–14.
Recent Trend in Fishing intensity or Proxy	The relative exploitation rate has declined since 2005, and since 2007 has been below the series mean. Insufficient data to produce exploitation rate after 2013–14.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of longfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment.

Projections and Prognosis	
Stock Projections or Prognosis	Unlikely (< 40%) to decline in the medium term under current catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	For ESA, Soft Limit: Very Unlikely (< 10%) if catch remains at current levels For ESA, Hard Limit: Very Unlikely (< 10%) if catch remains at current levels
Probability of Current Catch or TACC causing Overfishing to continue or to commence	For ESA, Unlikely (< 40%) if catch remains at current levels

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2017	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers • Uncertainty in target species after 2000 • Exclusion of zero catches	

	• Changes in MLS and retention in early parts of the series and increased escape tube size from 25 mm to 31 mm in 2012–13 • Failure of some fishers to record on ECE returns all legal sized eels caught, not just those retained • Unrecorded release of > 4kg eels since 2007–08

Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as habitat alteration (historical and current) have also reduced abundance prior to the CPUE series. The proportion of current longfin habitat in Bay of Plenty (Statistical Area AE) fished commercially during the period 2009–10 and 2013–14 is estimated at 17% (Table 15). The proportion of virgin habitat impacted by hydro dams, commercial fishing and other anthropogenic activity was estimated to be 24%.

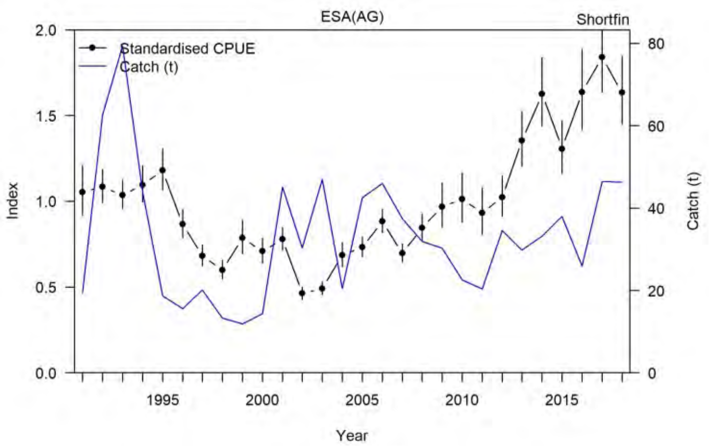
Fishery Interactions
Bycatch of other species in the commercial Bay of Plenty eel fishery includes very small quantities of goldfish and bullies. Most bycatch species are usually returned alive.

QMA SFE 22 and LFE 22 (includes ESAs AG, AK, AL and AM)

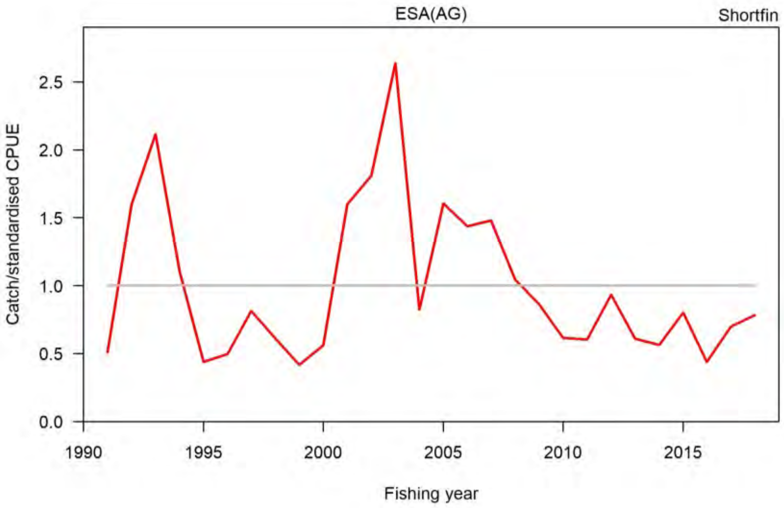
- **Hawkes Bay (AG) shortfin**

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised CPUE on positive catch
Reference Points	Target: B_{MSY} proxy based on CPUE; not determined Default Soft Limit: 20% B_0 Default Hard Limit: 10% B_0 Overfishing threshold: F_{MSY} proxy based on relative exploitation rate; not determined
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Standardised CPUE for shortfin eels in Hawkes Bay (AG) from 1990–91 to 2017–18 (from Beentjes 2020). Also shown is the total estimated core fisher shortfin catch in AG from ECERs. Error bars are 95% confidence intervals. Before 2001, 5% of the catch was recorded as EEU (unidentified) and these catches are omitted.



Annual relative exploitation rate for shortfin eels in the Hawkes Bay (AG). Because some catch of shortfin was reported as EEU (unidentified) and has not been allocated to species, the exploitation rate is likely to have been higher than shown before 2001.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE declined until 2002, followed by a steep increase to well above the previous peak in 1995.
Recent Trend in Fishing intensity or Proxy	The relative exploitation rate has declined since 2007, and from 2009 has been below the series mean.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of shortfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment.

Projections and Prognosis	
Stock Projections or Prognosis	Unlikely (< 40%) to decline in the medium term under current catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2017	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers • Uncertainty in target species after 2000 • Exclusion of zero catches	

	• Changes in MLS and retention in early parts of the series and increased escape tube size from 25 mm to 31 mm in 2012–13 • Failure of some fishers to record on ECE returns all legal sized eels caught, not just those retained

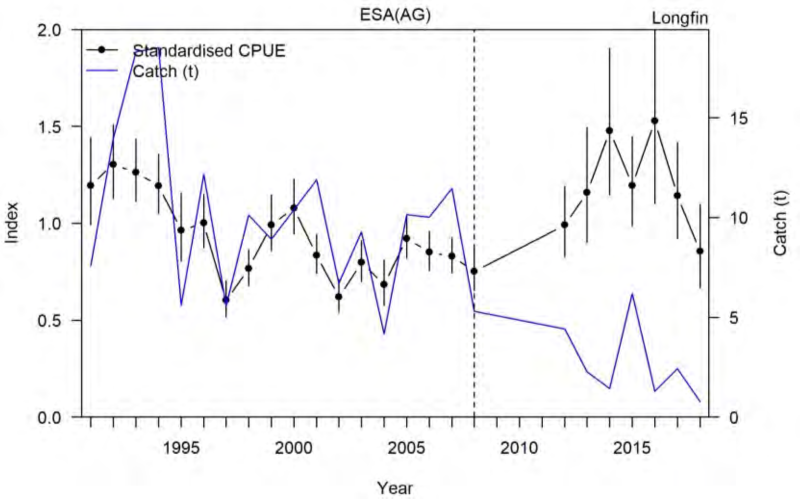
Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as habitat alteration (historical and current) have also reduced abundance prior to the CPUE series.

Fishery Interactions
Bycatch of other species in the commercial Hawkes Bay eel fishery includes mostly goldfish and small quantities of brown trout. Most bycatch species are usually returned alive.

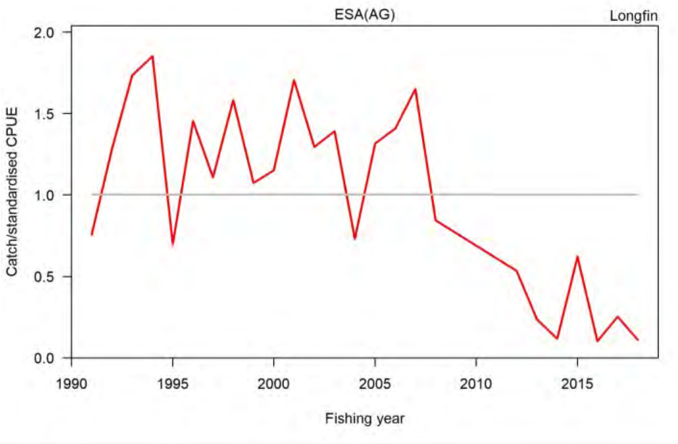
- **Hawkes Bay (AG) longfin**

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised CPUE on positive catch
Reference Points	For ESA, Interim Target is 40% B_0 For commercially fished area, Target is B_{MSY} proxy based on CPUE; not determined Default Soft Limit: 20% B_0 Default Hard Limit: 10% B_0 For ESA, Overfishing threshold is F_{MSY} For commercially fished area, Overfishing threshold is F_{MSY} proxy based on relative exploitation rate; not determined
Status in relation to Target	For total ESA: Likely (> 60%) to be at or above For fished area: Unknown
Status in relation to Limits	For ESA, Soft Limit: Very Unlikely (< 10%) to be below For ESA, Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	For ESA: Unlikely (< 40%) to be overfishing For fished area: Unknown

Historical Stock Status Trajectory and Current Status



Standardised CPUE for longfin eels in Hawkes Bay (AG) from 1990–91 to 2017–18 (from Beentjes 2020). Also shown is the total estimated core fisher longfin catch in AG from ECERs. Vertical dashed line indicates when the 4 kg maximum size was introduced in 2007–08 after which longfin eels 4 kg and over are not recorded on ECERs. Error bars are 95% confidence intervals. Before 2001, 5% of the catch was recorded as EEU (unidentified) and these catches are omitted.



Annual relative exploitation rate for longfin eels in the Hawke's Bay (AG). Because some catch of longfin was reported as EEU (unidentified) and has not been allocated to species, the exploitation rate is likely to have been higher than shown before 2001.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE declined until 1997, was stable until 2008 and then increased until 2015–16, declining steeply in the last two years.
Recent Trend in Fishing intensity or Proxy	The relative exploitation rate has declined steeply since 2007, and in 2018 was well below the series mean.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of longfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment.

Projections and Prognosis	
Stock Projections or Prognosis	Unlikely (< 40%) to decline in the medium term under current catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	For ESA, Soft Limit: Very Unlikely (< 10%) if catch remains at current levels For ESA, Hard Limit: Very Unlikely (< 10%) if catch remains at current levels
Probability of Current Catch or TACC causing Overfishing to continue or to commence	For ESA, Unlikely (< 40%) if catch remains at current levels

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2017	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers • Uncertainty in target species after 2000 • Exclusion of zero catches	

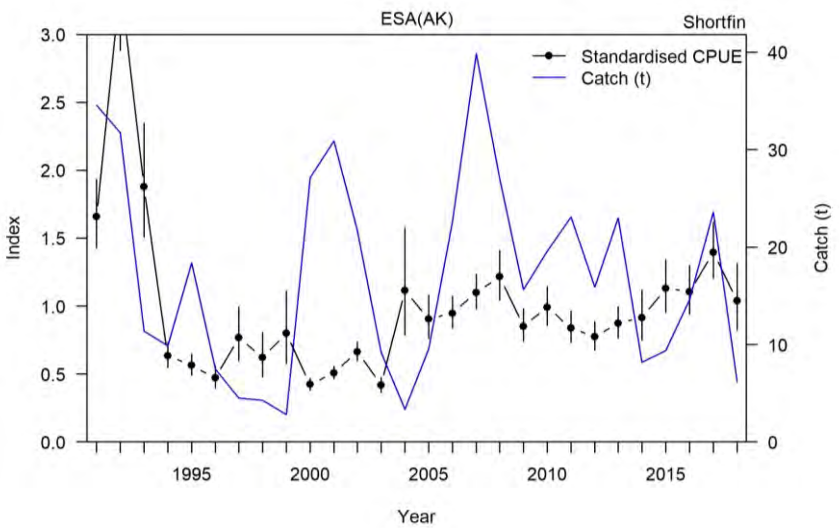
	• Changes in MLS and retention in early parts of the series and increased escape tube size from 25 mm to 31 mm in 2012–13 • Failure of some fishers to record on ECE returns all legal sized eels caught, not just those retained • Unrecorded release of > 4kg eels since 2007–08

Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as habitat alteration (historical and current) have also reduced abundance prior to the CPUE series. The proportion of current longfin habitat in Hawkes Bay (Statistical Area AG) fished commercially during the period 2009–10 and 2013–14 is estimated at 17% (Table 15). The proportion of virgin habitat impacted by hydro dams, commercial fishing and other anthropogenic activity was estimated to be 25%.
Fishery Interactions
Bycatch of other species in the commercial Hawkes Bay eel fishery includes mostly goldfish and small quantities of brown trout. Most bycatch species are usually returned alive.

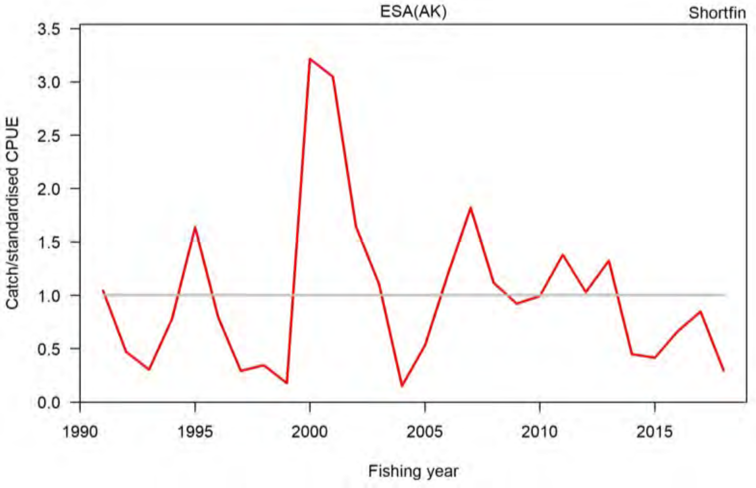
- **Manawatu (AK) shortfin**

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised CPUE on positive catch
Reference Points	Target: B_{MSY} proxy based on CPUE; not determined Default Soft Limit: 20% B_0 Default Hard Limit: 10% B_0 Overfishing threshold: F_{MSY} proxy based on relative exploitation rate; not determined
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Standardised CPUE for shortfin eels in Manawatu (AK) from 1990–91 to 2017–18 (from Beentjes 2020). Also shown is the total estimated core fisher shortfin catch in AK from ECERs. Error bars are 95% confidence intervals. Before 2001, 56% of the catch was recorded as EEU (unidentified) and these catches are omitted.



Annual relative exploitation rate for shortfin eels in the Manawatu (AK). Because some catch of shortfin was reported as EEU (unidentified) and has not been allocated to species, the exploitation rate is likely to have been higher than shown before 2001.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE dropped markedly from 1992 to 1994, was stable until an increase in 2004, and has since fluctuated without a longterm trend.
Recent Trend in Fishing intensity or Proxy	The relative exploitation rate has declined since 2013, and in 2018 was below the series mean.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of shortfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment.

Projections and Prognosis	
Stock Projections or Prognosis	Unlikely (< 40%) to decline in the medium term under current catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2017	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers • Uncertainty in target species after 2000 • Exclusion of zero catches	

	• Changes in MLS and retention in early parts of the series and increased escape tube size from 25 mm to 31 mm in 2012–13 • Failure of some fishers to record on ECE returns all legal sized eels caught, not just those retained

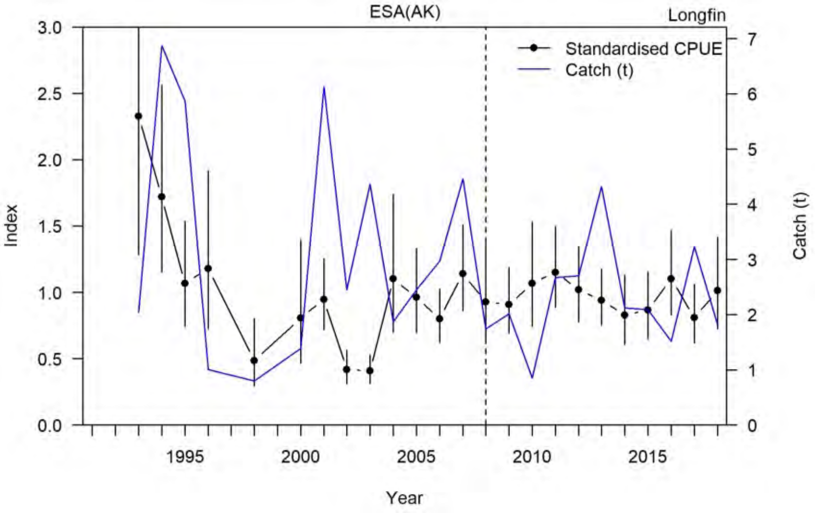
Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as habitat alteration (historical and current) have also reduced abundance prior to the CPUE series.

Fishery Interactions
Bycatch in the commercial Manawatu eel fishery include small quantities of koi carp, black flounder, yellowbelly flounder, and perch. Most bycatch species are usually returned alive.

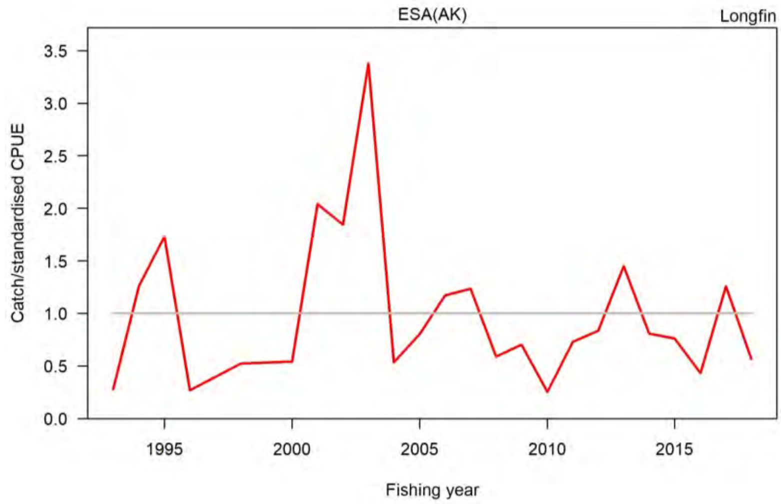
- **Manawatu (AK) longfin**

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised CPUE on positive catch
Reference Points	For ESA, Interim Target is 40% B_0 For commercially fished area, Target is B_{MSY} proxy based on CPUE; not determined Default Soft Limit: 20% B_0 Default Hard Limit: 10% B_0 For ESA, Overfishing threshold is F_{MSY} For commercially fished area, Overfishing threshold is F_{MSY} proxy based on relative exploitation rate; not determined
Status in relation to Target	For total ESA: Likely (> 60%) to be at or above For fished area: Unknown
Status in relation to Limits	For ESA, Soft Limit: Very Unlikely (< 10%) to be below For ESA, Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	For ESA: Unlikely (< 40%) to be overfishing For fished area: Unknown

Historical Stock Status Trajectory and Current Status



Standardised CPUE for longfin eels in Manawatu (AK) from 1990–91 to 2017–18 (from Beentjes 2020). Also shown is the total estimated core fisher longfin catch in AK from ECERs. Vertical dashed line indicates when the 4 kg maximum size was introduced in 2007–08 after which longfin eels 4 kg and over are not recorded on ECERs. Error bars are 95% confidence intervals. Before 2001, 56% of the catch was recorded as EEU (unidentified) and these catches are omitted.



Annual relative exploitation rate for longfin eels in the Manawatu (AK). Because some catch of longfin was reported as EEU (unidentified) and has not been allocated to species, the exploitation rate is likely to have been higher than shown before 2001.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE declined steeply until 2003, increased in 2004 and has fluctuated without trend since then.
Recent Trend in Fishing intensity or Proxy	The relative exploitation rate has fluctuated around the series mean since 2003 and in 2018 was below the series mean.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of longfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment.

Projections and Prognosis	
Stock Projections or Prognosis	Unlikely (< 40%) to decline in the medium term under current catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	For ESA, Soft Limit: Very Unlikely (< 10%) if catch remains at current levels For ESA, Hard Limit: Very Unlikely (< 10%) if catch remains at current levels
Probability of Current Catch or TACC causing Overfishing to continue or to commence	For ESA, Unlikely (< 40%) if catch remains at current levels

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2017	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers • Uncertainty in target species after 2000 • Exclusion of zero catches	

	• Changes in MLS and retention in early parts of the series and increased escape tube size from 25 mm to 31 mm in 2012–13 • Failure of some fishers to record on ECE returns all legal sized eels caught, not just those retained • Unrecorded release of > 4kg eels since 2007–08

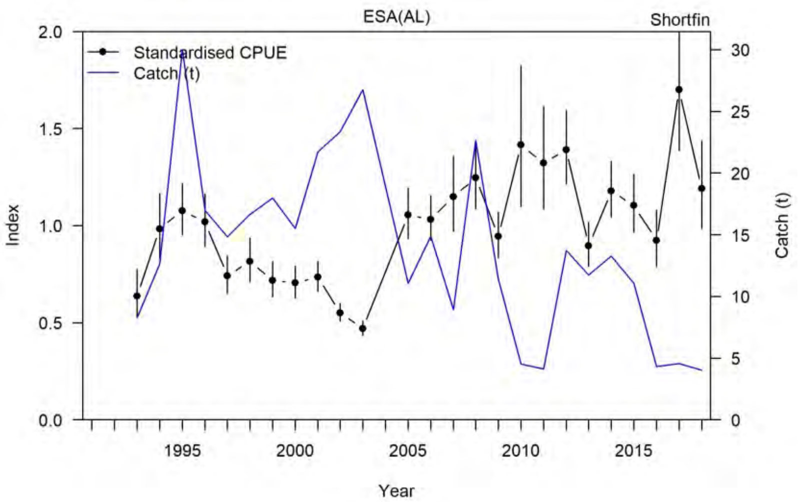
Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as habitat alteration (historical and current) have also reduced abundance prior to the CPUE series. The proportion of current longfin habitat in Manawatu (Statistical Area AK) fished commercially during the period 2009–10 and 2013–14 is estimated at 36% (Table 15). The proportion of virgin habitat impacted by hydro dams, commercial fishing and other anthropogenic activity was estimated to be 41%.

Fishery Interactions
Bycatch in the commercial Manawatu eel fishery include small quantities of koi carp, black flounder, yellowbelly flounder, and perch. Most bycatch species are usually returned alive.

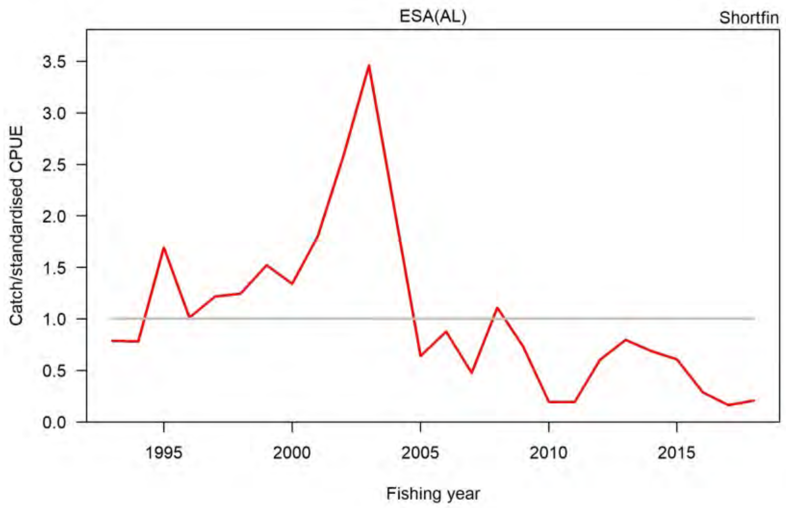
- **Wairarapa (AL) shortfin**

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised CPUE on positive catch
Reference Points	Target: B_{MSY} proxy based on CPUE; not determined Default Soft Limit: 20% B_0 Default Hard Limit: 10% B_0 Overfishing threshold: F_{MSY} proxy based on relative exploitation rate; not determined
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Standardised CPUE for shortfin eels in Wairarapa (AL) from 1990–91 to 2017–18 (from Beentjes 2020). Also shown is the total estimated core fisher shortfin catch in AL from ECERs. Error bars are 95% confidence intervals. Before 1999, 33% of the catch was recorded as EEU (unidentified) and these catches are omitted.



Annual relative exploitation rate for shortfin eels in the Wairarapa (AL). Because some catch of shortfin was reported as EEU (unidentified) and has not been allocated to species, the exploitation rate is likely to have been higher than shown before 1999.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE declined from 1995 to 2003, increased in 2005 and has fluctuated without trend since then.
Recent Trend in Fishing intensity or Proxy	The relative exploitation rate declined steeply after 2003, and has been below the series mean since 2005.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of shortfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment.

Projections and Prognosis	
Stock Projections or Prognosis	Unlikely (< 40%) to decline in the medium term under current catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2017	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers • Uncertainty in target species after 2000 • Exclusion of zero catches	

	• Changes in MLS and retention in early parts of the series and increased escape tube size from 25 mm to 31 mm in 2012–13 • Failure of some fishers to record on ECE returns all legal sized eels caught, not just those retained

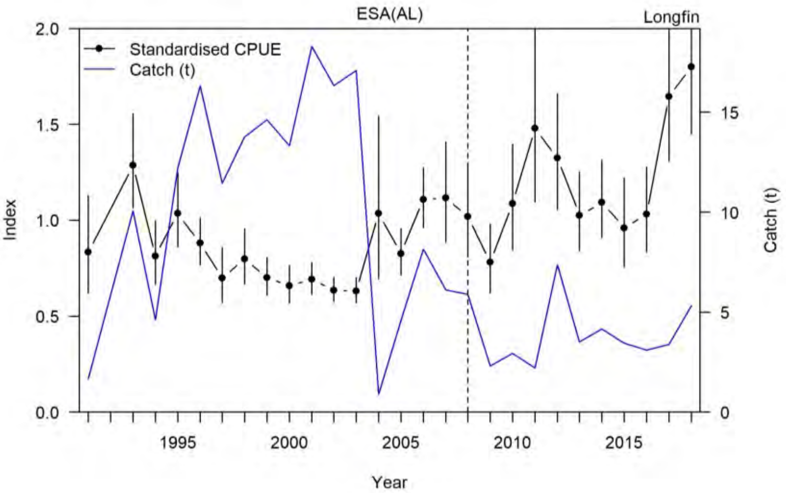
Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as habitat alteration (historical and current) have also reduced abundance prior to the CPUE series.

Fishery Interactions
Bycatch in the commercial Wairarapa eel fishery include mostly rudd and perch, with smaller quantities of flatfish and goldfish. Most bycatch species are usually returned alive.

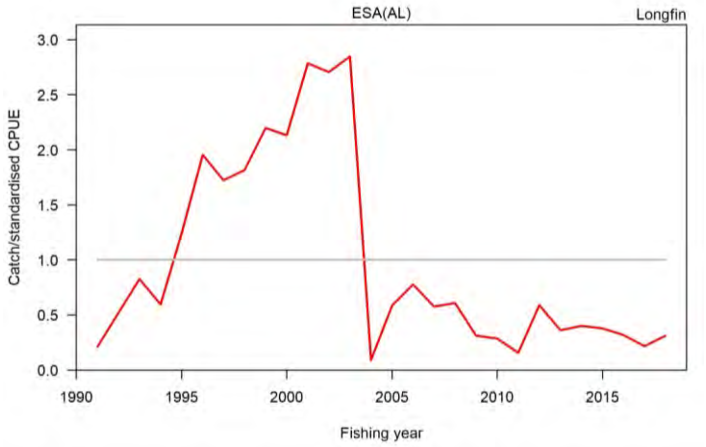
- **Wairarapa (AL) longfin**

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised CPUE on positive catch
Reference Points	For ESA, Interim Target is 40% B_0 For commercially fished area, Target is B_{MSY} proxy based on CPUE; not determined Default Soft Limit: 20% B_0 Default Hard Limit: 10% B_0 For ESA, Overfishing threshold is F_{MSY} For commercially fished area, Overfishing threshold is F_{MSY} proxy based on relative exploitation rate; not determined
Status in relation to Target	For total ESA: Likely (> 60%) to be at or above For fished area: Unknown
Status in relation to Limits	For ESA, Soft Limit: Very Unlikely (< 10%) to be below For ESA, Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	For ESA: Unlikely (< 40%) to be overfishing For fished area: Unknown

Historical Stock Status Trajectory and Current Status



Standardised CPUE for longfin eels in Wairarapa (AL) from 1990–91 to 2017–18 (from Beentjes 2020). Also shown is the total estimated core fisher longfin catch in AL from ECERs. Vertical dashed line indicates when the 4 kg maximum size was introduced in 2007–08 after which longfin eels 4 kg and over are not recorded on ECERs. Error bars are 95% confidence intervals. Before 1999, 33% of the catch was recorded as EEU (unidentified) and these catches are omitted.



Annual relative exploitation rate for longfin eels in the Wairarapa (AL). Because some catch of longfin was reported as EEU (unidentified) and has not been allocated to species, the exploitation rate is likely to have been higher than shown before 1999.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE declined until 2003, increased in 2004 and fluctuated without trend until the last two years when CPUE increased steeply
Recent Trend in Fishing intensity or Proxy	The relative exploitation rate declined steeply after 2003, and has been below the series mean since 2005.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of longfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment.

Projections and Prognosis	
Stock Projections or Prognosis	Unlikely (< 40%) to decline in the medium term under current catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	For ESA, Soft Limit: Very Unlikely (< 10%) if catch remains at current levels For ESA, Hard Limit: Very Unlikely (< 10%) if catch remains at current levels
Probability of Current Catch or TACC causing Overfishing to continue or to commence	For ESA, Unlikely (< 40%) if catch remains at current levels

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2017	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers • Uncertainty in target species after 2000 • Exclusion of zero catches	

	• Changes in MLS and retention in early parts of the series and increased escape tube size from 25 mm to 31 mm in 2012–13 • Failure of some fishers to record on ECE returns all legal sized eels caught, not just those retained • Unrecorded release of > 4kg eels since 2007–08

Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as habitat alteration (historical and current) have also reduced abundance prior to the CPUE series. The proportion of current longfin habitat in Wairarapa (Statistical Area AL) fished commercially during the period 2009–10 and 2013–14 is estimated at 4% (Table 15) (Beentjes et al 2016). The proportion of virgin habitat impacted by hydro dams, commercial fishing and other anthropogenic activity was estimated to be 5%.

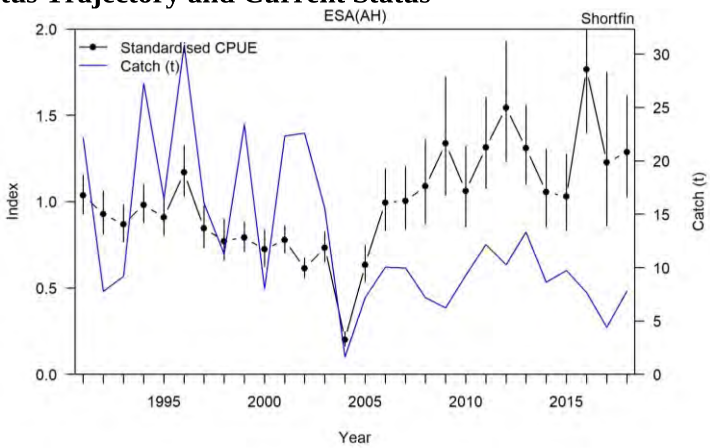
Fishery Interactions
There has been no recorded bycatch in the commercial Wairarapa eel fishery since 2000–01. Most bycatch species are usually returned alive.

QMA SFE 23 and LFE 23 (includes ESAs AH, AJ)

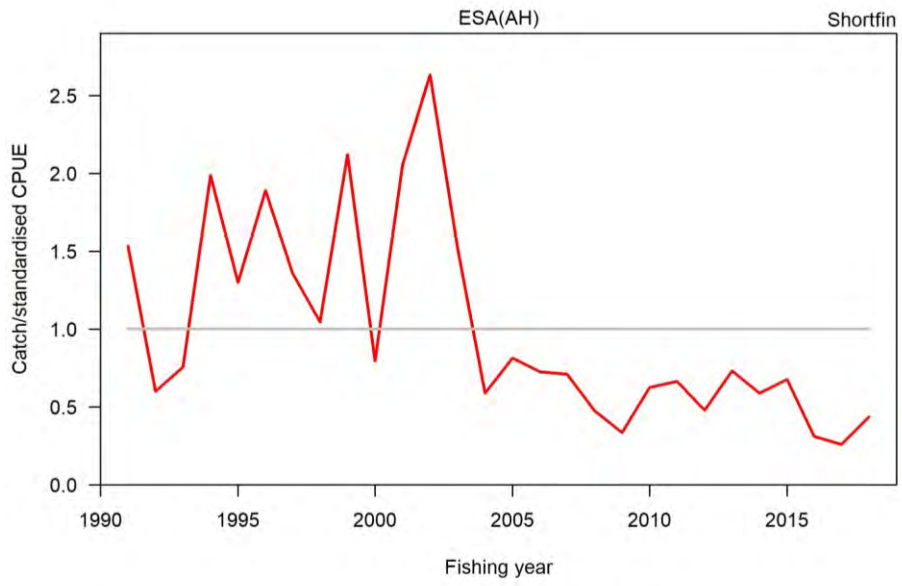
- **Rangitikei-Wanganui (AH) shortfin**

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised CPUE on positive catch
Reference Points	Target: B_{MSY} proxy based on CPUE; not determined Default Soft Limit: 20% B_0 Default Hard Limit: 10% B_0 Overfishing threshold: F_{MSY} proxy based on relative exploitation rate; not determined
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Standardised CPUE for shortfin eels in Rangitikei-Wanganui (AH) from 1990–91 to 2017–18 (from Beentjes 2020). Also shown is the total estimated core fisher shortfin catch in AH from ECERs. Error bars are 95% confidence intervals. Before 2001, 7% of the catch was recorded as EEU (unidentified) and these catches are omitted.



Annual relative exploitation rate for shortfin eels in the Rangitikei-Wanganui (AH). Because some catch of shortfin was reported as EEU (unidentified) and has not been allocated to species, the exploitation rate is likely to have been higher than shown before 2001.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE declined gradually until 2005, and then increased to well above the former peak.
Recent Trend in Fishing intensity or Proxy	The relative exploitation rate declined steeply after 2003, and has been below the series mean since 2004.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of shortfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment.

Projections and Prognosis	
Stock Projections or Prognosis	Unlikely (< 40%) to decline in the medium term under current catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2017	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers	

	• Uncertainty in target species after 2000 • Exclusion of zero catches • Changes in MLS and retention in early parts of the series and increased escape tube size from 25 mm to 31 mm in 2012–13 • Failure of some fishers to record on ECE returns all legal sized eels caught, not just those retained

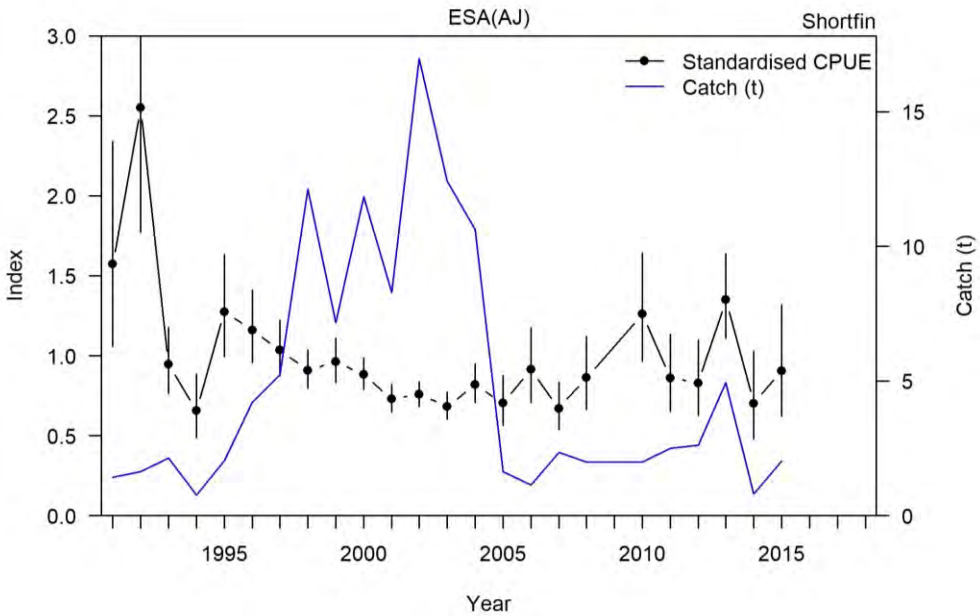
Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as habitat alteration (historical and current) have also reduced abundance prior to the CPUE series.

Fishery Interactions
The only recorded bycatch in the commercial Rangitikei-Wanganui eel fishery since 2000–01 has been brown trout. Most bycatch species are usually returned alive.

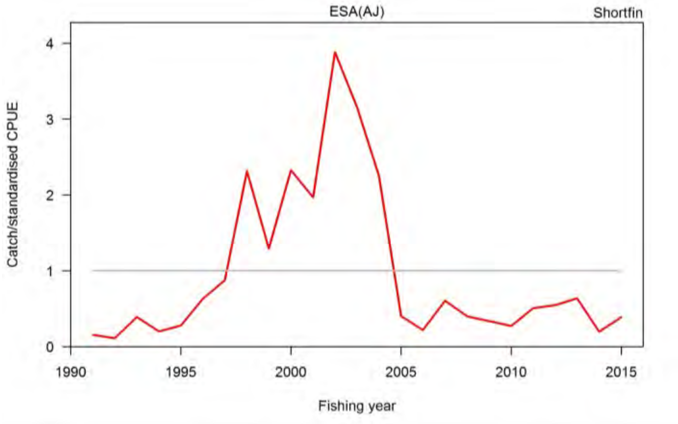
- **Taranaki (AJ) shortfin**

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised CPUE on positive catch
Reference Points	Target: B_{MSY} proxy based on CPUE; not determined Default Soft Limit: 20% B_0 Default Hard Limit: 10% B_0 Overfishing threshold: F_{MSY} proxy based on relative exploitation rate; not determined
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Standardised CPUE for shortfin eels in Taranaki (AJ) from 1990–91 to 2017–18 (from Beentjes 2020). Also shown is the total estimated core fisher shortfin catch in AJ from ECERs. Error bars are 95% confidence intervals. Before 2001, 16% of the catch was recorded as EEU (unidentified) and these catches are omitted.



Annual relative exploitation rate for shortfin eels in the Taranaki (AJ). Because some catch of shortfin was reported as EEU (unidentified) and has not been allocated to species, the exploitation rate is likely to have been higher than shown before 2001.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE declined to 2003, and then fluctuated without trend.. There were insufficient data to generate indices after 2014–15.
Recent Trend in Fishing intensity or Proxy	Relative exploitation rate declined steeply after 2002, and has been below the series mean since 2005. There were insufficient data to generate relative exploitation rates after 2014–15.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of shortfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment.

Projections and Prognosis	
Stock Projections or Prognosis	Unlikely (< 40%) to decline in the medium term under current catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2017	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers • Uncertainty in target species after 2000 • Exclusion of zero catches	

	• Changes in MLS and retention in early parts of the series and increased escape tube size from 25 mm to 31 mm in 2012–13 • Failure of some fishers to record on ECE returns all legal sized eels caught, not just those retained

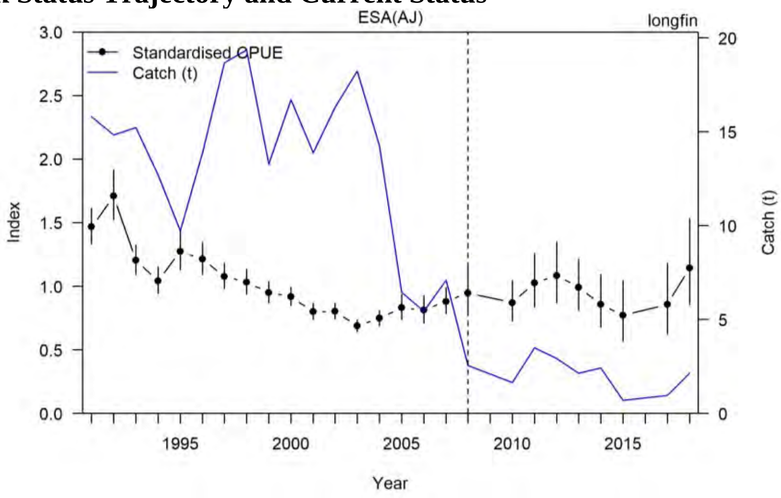
Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as habitat alteration (historical and current) have also reduced abundance prior to the CPUE series.

Fishery Interactions
There has been no recorded bycatch in the commercial Taranaki eel fishery since 2000–01. Most bycatch species are usually returned alive.

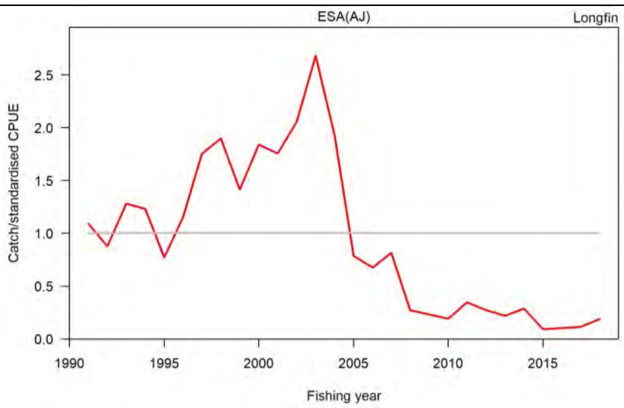
- **Taranaki (AJ) longfin**

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised CPUE on positive catch
Reference Points	For ESA, Interim Target is 40% B_0 For commercially fished area, Target is B_{MSY} proxy based on CPUE; not determined Default Soft Limit: 20% B_0 Default Hard Limit: 10% B_0 For ESA, Overfishing threshold is F_{MSY} For commercially fished area, Overfishing threshold is F_{MSY} proxy based on relative exploitation rate; not determined
Status in relation to Target	For total ESA: Likely (> 60%) to be at or above For fished area: Unknown
Status in relation to Limits	For ESA, Soft Limit: Very Unlikely (< 10%) to be below For ESA, Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	For ESA: Unlikely (< 40%) to be overfishing For fished area: Unknown

Historical Stock Status Trajectory and Current Status



Standardised CPUE for longfin eels in Taranaki (AJ) from 1990–91 to 2017–18 (from Beentjes 2020). Also shown is the total estimated core fisher longfin catch in AJ from ECERs. Vertical dashed line indicates when the 4 kg maximum size was introduced in 2007–08 after which longfin eels 4 kg and over are not recorded on ECERs. Error bars are 95% confidence intervals. Before 2001, 16% of the catch was recorded as EEU (unidentified) and these catches are omitted.



Annual relative exploitation rate for longfin eels in the Taranaki (AJ). Because some catch of longfin was reported as EEU (unidentified) and has not been allocated to species, the exploitation rate is likely to have been higher than shown before 2001.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Moderate decline in CPUE until 2003, then fluctuating without trend.
Recent Trend in Fishing intensity or Proxy	The relative exploitation rate declined steeply after 2003, and in 2018 was well below the series mean.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches of longfin elvers at primary monitoring sites have fluctuated without trend since the series of reliable data begins in 1995–96, suggesting no overall trend in recruitment.

Projections and Prognosis	
Stock Projections or Prognosis	Unlikely (< 40%) to decline in the medium term under current catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	For ESA, Soft Limit: Very Unlikely (< 10%) if catch remains at current levels For ESA, Hard Limit: Very Unlikely (< 10%) if catch remains at current levels
Probability of Current Catch or TACC causing Overfishing to continue or to commence	For ESA, Unlikely (< 40%) if catch remains at current levels

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2017	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Standardised CPUE only provides an index of abundance for eels in areas fished by commercial fishers. Other potential issues with the CPUE indices include: • Low numbers of fishers • Uncertainty in target species after 2000 • Exclusion of zero catches • Changes in MLS and retention in early parts of the series and increased escape tube size from 25 mm to 31 mm in 2012–13	

	• Failure of some fishers to record on ECE returns all legal sized eels caught, not just those retained • Unrecorded release of > 4kg eels since 2007–08

Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other sources of mortality, such as habitat alteration (historical and current) have also reduced abundance prior to the CPUE series. The proportion of current longfin habitat in Taranaki (Statistical Area AJ) fished commercially during the period 2009–10 and 2013–14 is estimated at 17% (Table 15). The proportion of virgin habitat impacted by hydro dams, commercial fishing and other anthropogenic activity was estimated to be 24%.

Fishery Interactions
There has been no recorded bycatch in the commercial Taranaki eel fishery since 2000–01. Most bycatch species are usually returned alive.

6. FOR FURTHER INFORMATION

Beentjes, M P (1998) Enhancement of Lake Hawea eel stocks by transfer of juveniles. *NIWA Technical Report 41*. 15 p.

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Beentjes, M P (2005) Monitoring commercial eel fisheries in 2003–04. *New Zealand Fisheries Assessment Report 2005/39*. 57 p.

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Beentjes, M P (2020) Catch per unit effort (CPUE) analyses and characterisation of the North Island commercial freshwater eel fishery, 1990–91 to 2017–18. Draft New Zealand Fisheries Assessment Report held by Fisheries New Zealand.

Beentjes, M P; Boubée, J A T; Jellyman, D J; Graynoth, E (2005) Non-fishing mortality of freshwater eels (*Anguilla* spp.). *New Zealand Fisheries Assessment Report 2005/34*. 38 p.

Beentjes, M P; Bull, B (2002) CPUE analyses of the commercial freshwater eel fishery. *New Zealand Fisheries Assessment Report 2002/18*. 55 p.

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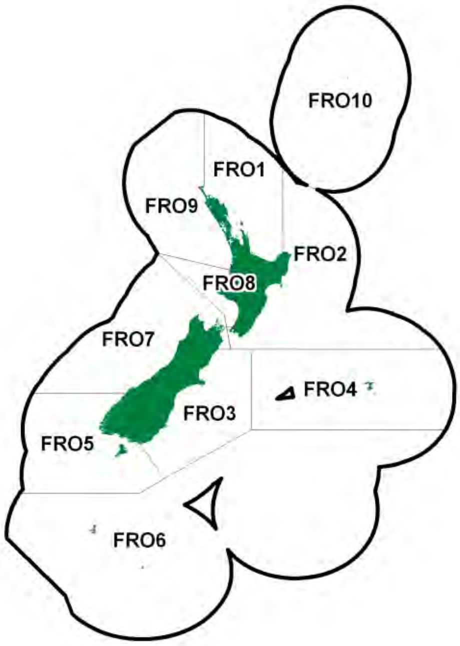
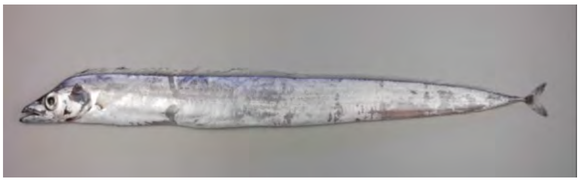
FROSTFISH (FRO)

(*Lepidopus caudatus)*
Para, Taharangi, Hikau





1. FISHERY SUMMARY

1.1 Commercial fisheries

Frostfish are predominantly taken as bycatch from target trawl fisheries on jack mackerel and hoki and to a lesser extent, arrow squid, barracouta and gemfish. These fisheries are predominantly targeted by larger vessels owned or chartered by New Zealand fishing companies. Target fishing for frostfish is reported from the west coast of both the South Island and North Island and at Puysegur Bank, with the best catches taken from the west coast of the South Island.

The main areas reporting frostfish catches are to the west of New Zealand primarily in QMA 7 on the west coast of the South Island and to a lesser extent QMA 8 and 9 in the north and south Taranaki Bight. The highest annual catches are associated with hoki fishing during winter (since 1986–87) and jack mackerel fishing during late spring and early summer. The proportion of catch coming from these two main fisheries has varied over time. Sources of error in the catch figures include unreported catch and discarded catch. Compliance investigations have shown that damaged and small hoki were recorded as frostfish by some vessels.

Since the mid-2000s, most frostfish landings have come from the trawl fishery targeting jack mackerel (JMA) in the North and South Taranaki Bights and off the west coast of the South Island (Statistical Areas 035 to 041; FRO 7, 8, 9). In 2009–10, over 80% of the national frostfish landings came from this fishery. Since 1999–2000, the fishery has been dominated by seven vessels which use midwater trawling exclusively. Catches of frostfish have become more concentrated on two distinct periods, October to January and June to July, and in the north and south Taranaki Bight (Statistical Areas 037, 040, 041) rather than the west coast of the South Island (Statistical Areas 034, 035, 036).

No catch data from deepwater vessels for frostfish are available prior to the introduction of the EEZ in 1978 (Table 1). Frostfish were introduced into the QMS from 1 October 1998.The total reported landings and TACCs for each QMA are given in Table 2 and 3, while Figure 1 shows the historical landings and TACC values for the main FRO stocks. An allowance of 2 t was made for non-commercial catch in each of FRO 1, 2, 7 and 9 and therefore TACs for these stocks are 2 t higher than the TACCs. TACCs were increased from 1 October 2006 in FRO 2 to 110 t, in FRO 3 to 176 t and in FRO 4 to 28 t. In these stocks landings were above the TACC for a number of years and the

TACCs were increased to the average of the previous seven years plus an additional 10% (Table 3). Landings have since been well below the TACCs for FRO 2, FRO 3, and FRO 4, with the exception of FRO 4 in 2014–15, when the 28 t TACC was exceeded by just under 150% and in 2018–19, when the landings were over 250%. Landings frequently exceeded the TACCs for FRO 8 until 2016–17, but has declined slightly since. In FRO 9, landings follow a similar pattern to FRO 8 until 2018–19 when the TACC was exceeded by 23%.

Table 1: Reported landings (t) of frostfish by fishing year and area, by foreign licensed and joint venture vessels, 1978–79 to 1983–83. The EEZ areas (see figure 2 of Baird & McKoy 1988) correspond approximately to the QMAs as indicated. Fishing years are from 1 April to 31 March. The 1983–83 is a 6 month transitional period from 1 April to 30 September. No data are available for the 1980–81 fishing year.

EEZ area	**B**	**C(M)**	**C(-)**	**D**	**E**	**F**	**G**	**H**	**Total**
QMA	1 & 2	3	3	4	6	5	7	8 & 9	
1978–79	5	1	6	0	1	0	1 283	226	1 522
1979–80	13	0	1	23	1	1	26	151	216
1980–81	-	-	-	-	-	-	-	-	-
1981–82	0	5	2	19	1	4	55	464	550
1982–83	0	1	0	9	3	1	56	1 545	1 615
1983–83	0	1	1	1	1	1	22	123	150

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982 [Continued on next page].

Year	**FRO 1**	**FRO 2**	**FRO 3**	**FRO 4**	**FRO 5**
1931–32	0	0	0	0	0
1932–33	0	0	0	0	0
1933–34	0	0	0	0	0
1934–35	0	0	0	0	0
1935–36	0	0	0	0	0
1936–37	0	0	0	0	0
1937–38	0	0	0	0	0
1938–39	0	0	0	0	0
1939–40	0	0	0	0	0
1940–41	0	0	0	0	0
1941–42	0	1	0	0	0
1942–43	0	0	0	0	0
1943–44	0	0	0	0	0
1944	0	0	0	0	0
1945	0	0	0	0	0
1946	0	0	0	0	0
1947	3	0	0	0	0
1948	0	0	0	0	0
1949	0	0	0	0	0
1950	0	0	0	0	0
1951	0	0	0	0	0
1952	0	0	0	0	0
1953	0	0	0	0	0
1954	0	0	0	0	0
1955	0	0	0	0	0
1956	0	0	0	0	0

Year	**FRO 1**	**FRO 2**	**FRO 3**	**FRO 4**	**FRO5**
1957	0	0	0	0	0
1958	0	0	0	0	0
1959	0	0	0	0	0
1960	0	0	0	0	0
1961	0	0	0	0	0
1962	0	0	0	0	0
1963	0	0	0	0	0
1964	0	0	0	0	0
1965	0	0	0	0	0
1966	0	5	0	0	0
1967	0	0	0	0	0
1968	0	0	0	0	0
1969	0	0	0	0	0
1970	0	0	0	0	0
1971	0	0	0	0	0
1972	0	0	0	0	0
1973	0	0	0	0	0
1974	0	0	0	0	0
1975	0	0	0	0	0
1976	0	0	0	0	0
1977	0	0	0	0	0
1978	1	4	2	0	0
1979	1	14	4	19	1
1980	0	0	2	20	7
1981	0	0	6	25	3
1982	4	0	0	8	13

Year	**FRO 6**	**FRO 7**	**FRO 8**	**FRO 9**
1931–32	0	0	0	0
1932–33	0	0	0	0
1933–34	0	0	0	0
1934–35	0	0	0	0
1935–36	0	0	0	0
1936–37	0	0	0	0
1937–38	0	0	0	0
1938–39	0	0	0	0
1939–40	0	0	0	0
1940–41	0	0	0	0
1941–42	0	0	0	0
1942–43	0	0	0	0
1943–44	0	0	0	0
1944	0	0	0	0
1945	0	0	0	0
1946	0	0	0	0
1947	0	0	0	1
1948	0	0	0	0
1949	0	0	0	0
1950	0	0	0	0

Year	**FRO 6**	**FRO 7**	**FRO 8**	**FRO 9**
1957	0	0	0	0
1958	0	0	0	0
1959	0	0	0	0
1960	0	0	0	0
1961	0	0	0	0
1962	0	0	0	0
1963	0	0	0	0
1964	0	0	0	0
1965	0	0	0	0
1966	0	0	0	0
1967	0	0	0	0
1968	0	0	0	0
1969	0	0	1	0
1970	0	0	1	0
1971	0	0	0	0
1972	0	0	0	0
1973	0	0	0	0
1974	0	0	0	0
1975	0	0	0	0
1976	0	0	0	0

Table 2 [Continued]

Year	FRO 6	FRO 7	FRO 8	FRO 9	Year	FRO 6	FRO 7	FRO 8	FRO 9
1951	0	0	0	0	1977	0	0	0	0
1952	0	0	0	0	1978	0	782	30	16
1953	0	0	0	0	1979	1	614	93	88
1954	0	0	0	0	1980	1	41	54	10
1955	0	0	0	0	1981	0	327	226	209
1956	0	0	0	0	1982	0	132	385	546

Notes:
The 1931–1943 years are April–March but from 1944 onwards are calendar years, Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports, Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data includes both foreign and domestic landings.

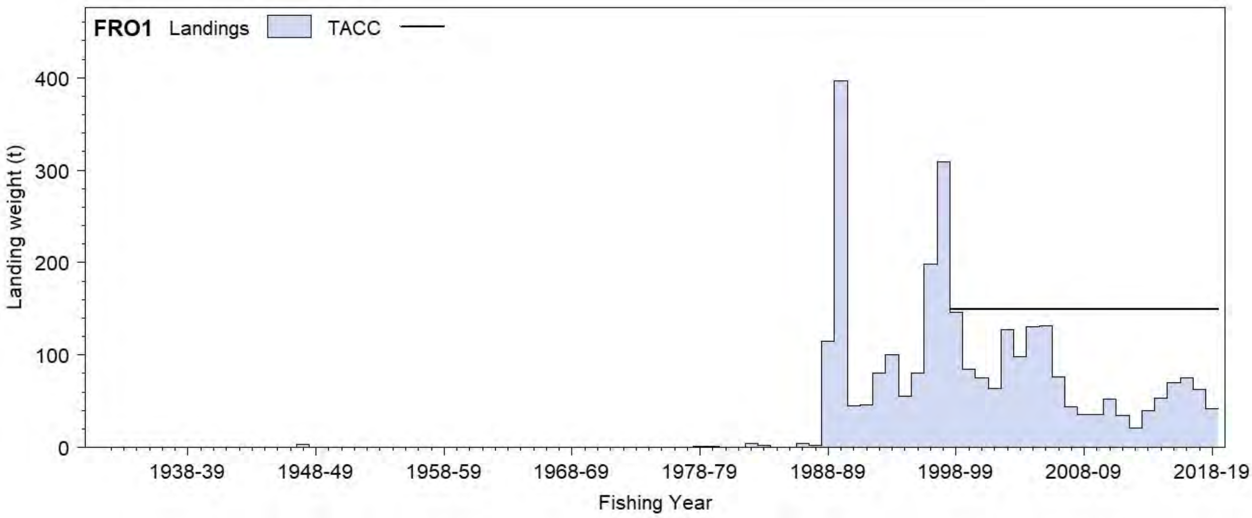
Table 3: Reported landings (t) of frostfish by QMA and fishing year, 1983–84 to 2018–19. The data in this table has been updated from that published in the 1998 Plenary Report by using the data up to 1996–97 in table 26 on p. 244 of the "Review of Sustainability Measures and Other Management Controls for the 1998–99 Fishing Year - Final Advice Paper" dated 6 August 1998. Data since 1997–98 based on catch and effort returns (where area was not reported catch was pro-rated across all QMAs). There are no landings reported from QMA 10. [Continued on next page].

Fishstock		FRO 1		FRO 2		FRO 3		FRO 4		FRO 5
FMA		1		2		3		4		5
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84	2	-	0	-	0	-	10	-	28	-
1984–85	0	-	0	-	2	-	1	-	100	-
1985–86	0	-	0	-	9	-	2	-	258	-
1986–87	4	-	4	-	5	-	6	-	71	-
1987–88	2	-	0	-	3	-	1	-	20	-
1988–89	115	-	0	-	1	-	0	-	15	-
1989–90	397	-	0	-	58	-	0	-	146	-
1990–91	45	-	24	-	224	-	0	-	496	-
1991–92	46	-	3	-	143	-	0	-	337	-
1992–93	80	-	9	-	51	-	0	-	0	-
1993–94	100	-	19	-	168	-	0	-	0	-
1994–95	55	-	14	-	120	-	0	-	87	-
1665–96	80	-	40	-	72	-	29	-	0	-
1996–97	198	-	6	-	12	-	4	-	8	-
1997–98	309	-	273	-	35	-	< 1	-	9	-
1998–99	146	149	134	20	39	128	< 1	5	19	135
1999–00	84	149	161	20	97	128	< 1	5	57	135
2000–01	76	149	194	20	107	128	48	5	33	135
2001–02	64	149	67	20	176	128	81	5	59	135
2002–03	127	149	66	20	268	128	15	5	63	135
2003–04	98	149	52	20	19	128	7	5	14	135
2004–05	130	149	38	20	427	128	15	5	20	135
2005–06	132	149	40	20	45	128	31	5	17	135
2006–07	76	149	31	110	21	176	13	28	16	135
2007–08	44	149	30	110	31	176	7	28	5	135
2008–09	36	149	24	110	6	176	10	28	2	135
2009–10	36	149	24	110	15	176	3	28	4	135
2010–11	52	149	41	110	< 1	176	4	28	14	135
2011–12	34	149	15	110	8	176	14	28	3	135
2012–13	21	149	18	110	32	176	2	28	4	135
2013–14	40	149	34	110	63	176	15	28	11	135
2014–15	54	149	41	110	13	176	69	28	14	135
2015–16	70	149	46	110	10	176	13	28	8	135
2016–17	75	149	52	110	9	176	9	28	27	135
2017–18	62	149	51	110	12	176	16	28	44	135
2018–19	42	149	34	110	12	176	100	28	4	135

Fishstock		FRO 6		FRO 7		FRO 8		FRO 9		
FMA		6		7		8		9		Total
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84	7	-	432	-	539	-	457	-	1 475	-
1984–85	0	-	214	-	455	-	129	-	901	-
1985–86	0	-	344	-	574	-	226	-	1 415	-
1986–87	4	-	1 089	-	898	-	190	-	2 272	-
1987–88	0	-	3 466	-	875	-	22	-	4 391	-
1988–89	3	-	1 950	-	413	-	455	-	2 952	-
1989–90	29	-	1 370	-	132	-	0	-	2 132	-
1990–91	67	-	3 029	-	539	-	0	-	4 424	-
1991–92	7	-	2 295	-	750	-	1	-	3 582	-
1992–93	0	-	1 360	-	1 165	-	0	-	2 665	-
1993–94	0	-	1 998	-	696	-	12	-	2 993	-
1994–95	0	-	3 069	-	388	-	7	-	3 740	-
1995–96	0	-	1 536	-	22	-	9	-	1 788	-
1996–97	0	-	2 881	-	126	-	93	-	3 328	-
1997–98	0	-	2 590	-	143	-	205	-	3 564	-
1998–99	0	11	2 461	2 623	156	649	33	138	2 969	3 858

Table 3 [Continued]

Fishstock	FRO 6		FRO 7		FRO 8		FRO 9			
FMA	6		7		8		9		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1999–00	< 1	11	917	2 623	28	649	48	138	1 392	3 858
2000–01	< 1	11	1 620	2 623	303	649	43	138	2 424	3 858
2001–02	< 1	11	2 303	2 623	138	649	25	138	2 913	3 858
2002–03	< 1	11	1 025	2 623	621	649	67	138	2 252	3 858
2003–04	< 1	11	959	2 623	293	649	367	138	1 809	3 858
2004–05	< 1	11	934	2 623	770	649	327	138	2 661	3 858
2005–06	< 1	11	888	2 623	787	649	181	138	2 119	3 858
2006–07	< 1	11	951	2 623	722	649	142	138	1 972	4 019
2007–08	< 1	11	906	2 623	678	649	136	138	1 837	4 019
2008–09	< 1	11	576	2 623	605	649	110	138	1 369	4 019
2009–10	< 1	11	382	2 623	686	649	238	138	1 389	4 019
2010–11	< 1	11	248	2 623	578	649	167	138	1 106	4 019
2011–12	< 1	11	500	2 623	893	649	198	138	1 665	4 019
2012–13	< 1	11	570	2 623	890	649	278	138	1 814	4 019
2013–14	<1	11	880	2 623	814	649	261	138	2 120	4 019
2014–15	<1	11	1 027	2 623	732	649	373	138	2 322	4 019
2015–16	<1	11	1 063	2 623	692	649	310	138	2 212	4 019
2016–17	<1	11	1 164	2 623	553	649	96	138	1 986	4 019
2017–18	<1	11	2 062	2 623	380	649	65	138	2 693	4 019
2018–19	<1	11	1 999	2 623	507	649	171	138	2 869	4 019



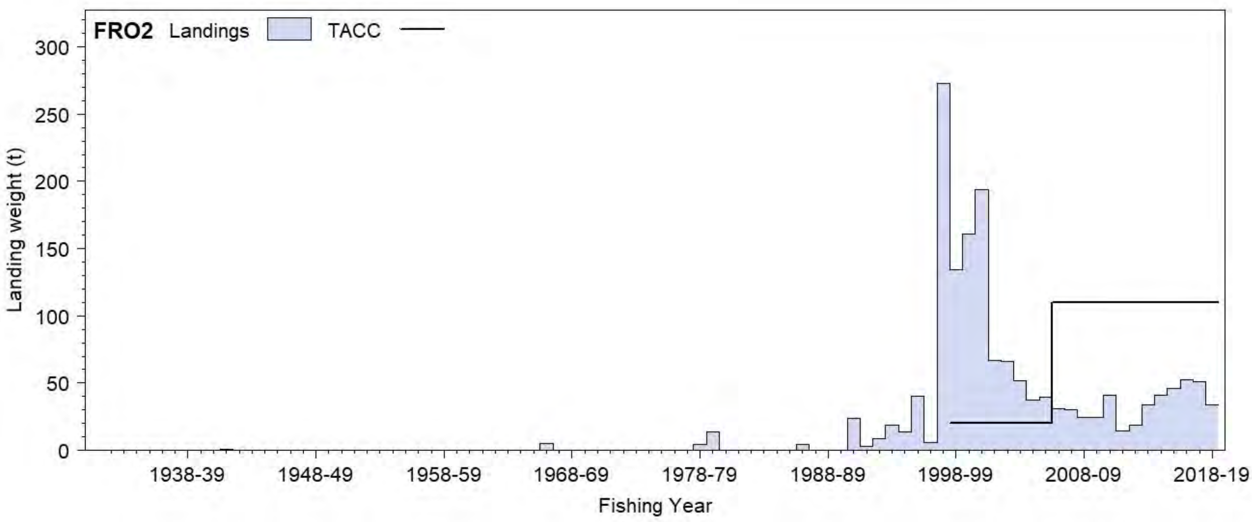


Figure 1: Reported commercial landings and TACC for the eight main FRO stocks. From top: FRO 1 (Auckland East) and FRO 2 (Central East). [Continued on next page]

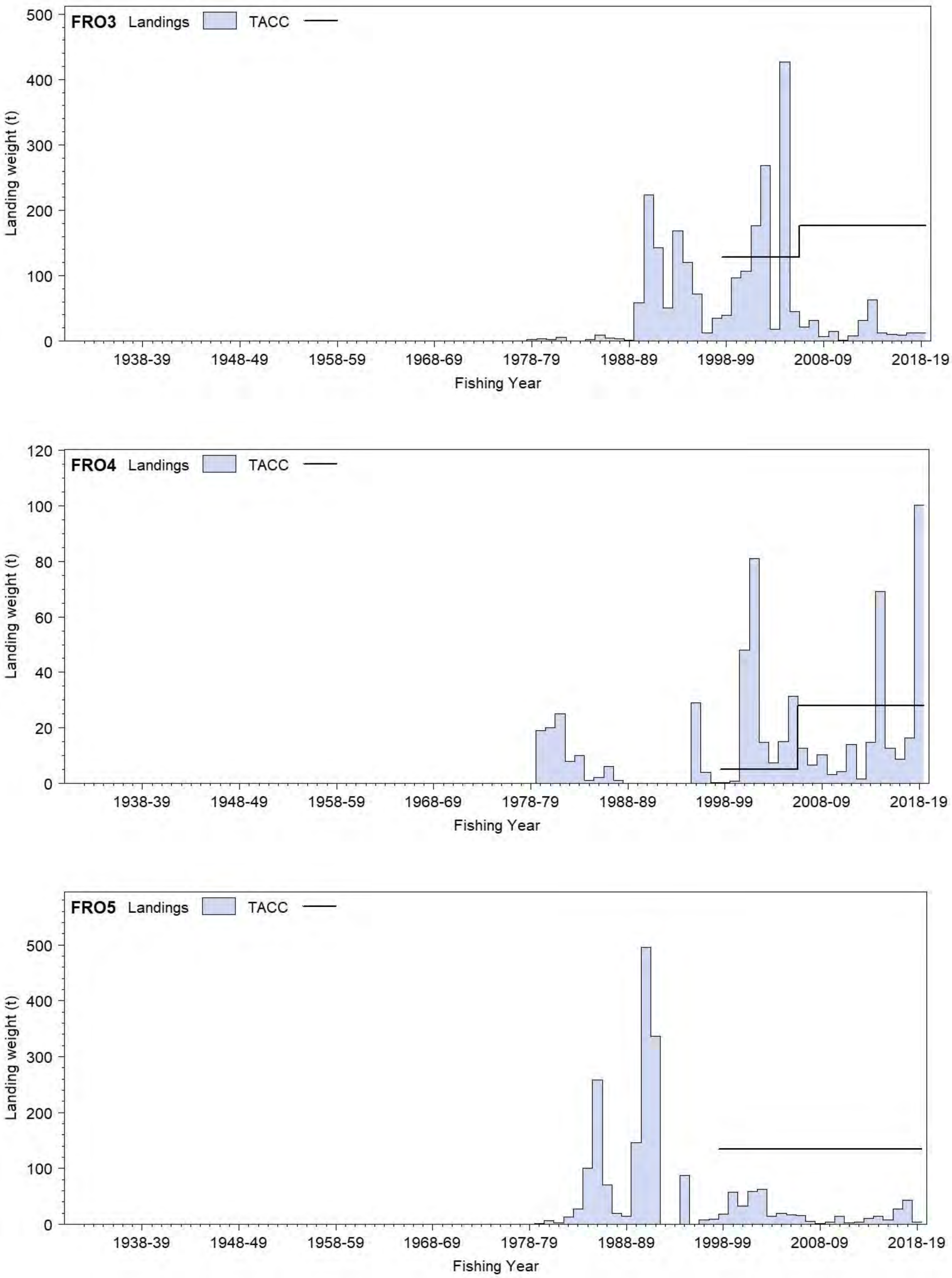


Figure 1 [Continued]: Reported commercial landings and TACC for the eight main FRO stocks. From top: FRO 3 (South East Coast), FRO 4 (South East Chatham Rise) and FRO 5 (Southland). [Continued on next page]

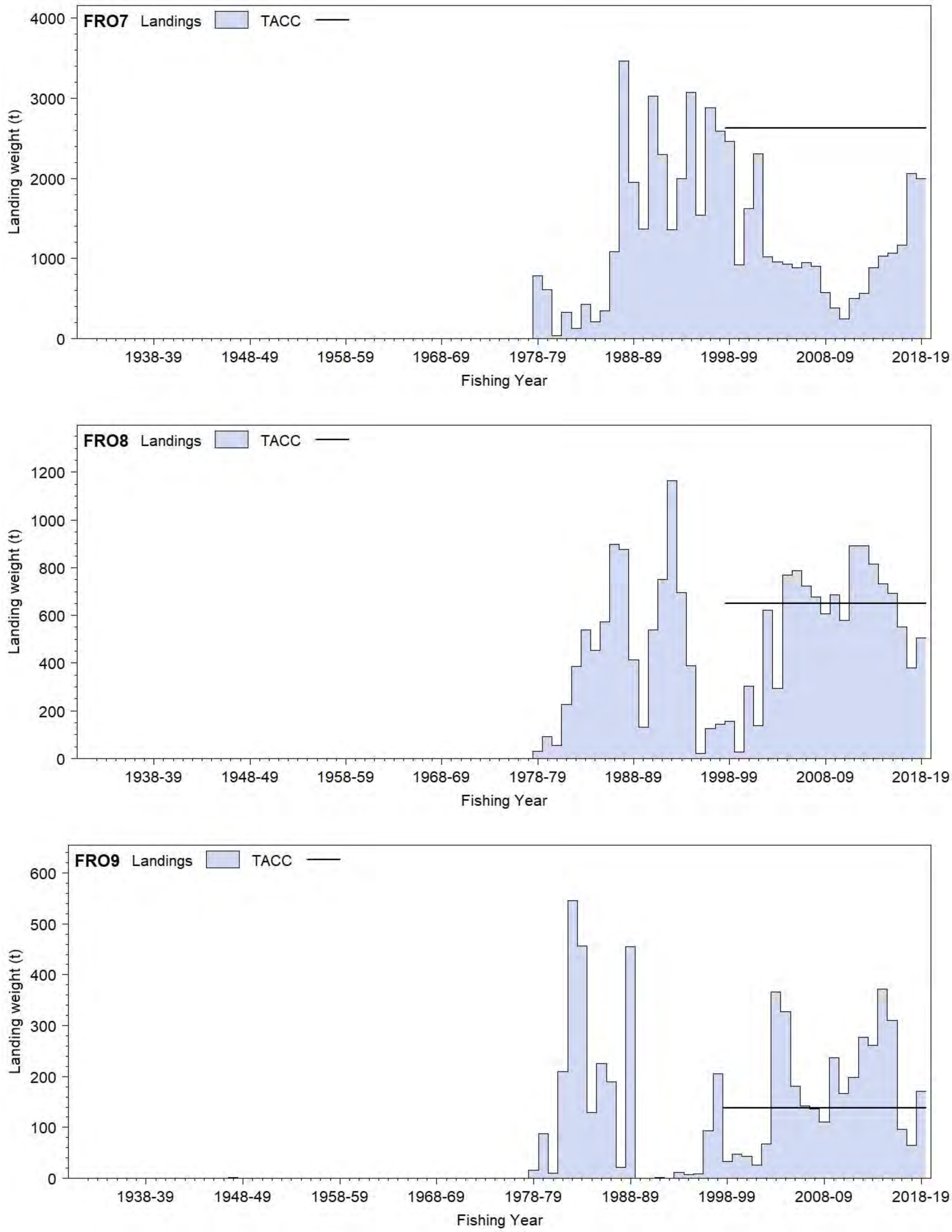


Figure 1 [Continued]: Reported commercial landings and TACC for the eight main FRO stocks. From top: FRO 7 (Challenger), FRO 8 (Central West) and FRO 9 (Auckland West). Note that these figures do not show data prior to entry into the QMS.

1.2 Recreational fisheries

Frostfish are occasionally taken by recreational fishers. Small numbers have been reported from recreational diary surveys, mainly in QMA 1, and rarely in QMA 2 and 9.

1.3 Customary non-commercial fisheries
No quantitative information is available on the current level of customary non-commercial take. Maori have collected beach cast frostfish in the past (Graham 1956).

1.4 Illegal catch
No information is available.

1.5 Other sources of mortality
No information is available on other sources of mortality.

2. BIOLOGY

Frostfish are widely distributed throughout the continental shelf and upper slopes of all oceans, except the North Pacific, and have a benthopelagic lifestyle. In New Zealand, frostfish are found from about 34ºS to 49ºS, but are most common between 36ºS and 44ºS. They occur mainly in depths of 50–600 m with the largest catches made at around 200 m bottom depth. Preferred bottom temperatures range between 10 and 16ºC. There is one species of *Lepidopus* recorded from New Zealand waters. However, scabbardfishes (*Benthodesmus* species) and the false frostfish (*Paradiplospinosus gracilis*) may be confused with small *Lepidopus caudatus*.

Frostfish reach a maximum length of 165 cm (fork length) around New Zealand, although the same species may reach 205 cm and 8 kg weight in the eastern North Atlantic (Nakamura & Parin 1993). In the northwestern Mediterranean males reach sexual maturity at 97 cm and a maximum length of 176 cm, whilst females reach sexual maturity at 111 cm and a maximum length of 196 cm (Demestre et al 1993).

The adults probably congregate in the late spring months, and spawn during the summer and autumn over the mid to outer shelf. Fertilisation has been calculated to take place between noon and sunset at depths greater than 50 m where the surface waters have a temperature of 17.5 to 22.0ºC (Robertson 1980).

A 2013 study developed ageing methods and estimated growth rates for frostfish from the west coast of New Zealand (Horn 2013). This study confirmed that frostfish are fast growing and relatively short lived. Most fish reach 100 cm FL (fork length) by the end of their third year and the maximum estimated age for both sexes was 10.6 years. The von Bertalanffy parameters estimated for both sexes combined were: L_∞=137 cm, k=0.505 yr^{-1}, t_0=0.07 yr. The estimated growth curves were similar, for the first four years, to those estimated for northern hemisphere frostfish, although the asymptotic length is lower. Horn (2013) estimated the instantaneous rate of natural mortality to be 0.6 yr^{-1} based on 1% of the population reaching 7–8 years of age.

A length-weight relationship for New Zealand frostfish is available from the *Kaharoa* trawl surveys (Horn 2013).

Frostfish migrate into mid-water at night and feed on crustaceans, small fish and squid (Nakamura & Parin 1993). Euphausids and *Pasiphaea* spp. (both crustaceans) are the most common prey of frostfish in the northwest Mediterranean (Demestre et al 1993). In Tasmanian waters, the diet of frostfish consists mainly of myctophids and euphausids (Blaber & Bulman 1987).

Frostfish are distributed widely in temperate seas but are most commonly reported in the north-eastern Atlantic (including the Mediterranean), in the southern Atlantic off Namibia and South Africa, and in the south-west Pacific around Australia and New Zealand (Nakamura & Parin 1993, Froese & Pauly 2012). Morphometric studies have shown differences in dorsal-fin pigmentation and meristic characteristics between north-eastern Atlantic and southern Atlantic populations (Mikhailin 1977). Genome sequencing of frostfish showed strong genetic differentiation between the northern and southern hemisphere populations and suggests that there are two distinct biological species (Ward et al 2008).

Robertson (1980) examined the seasonality and location of frostfish spawning based on the occurrence of planktonic eggs. He concluded that spawning probably occurs around all of New Zealand except for the south-east coast and adults probably congregate in the late spring months, and spawn during the summer and autumn over the mid to outer shelf. Fertilisation was calculated to take place between noon and sunset at depths greater than 50 m where the surface waters have a temperature of 17.5 to 22.0ºC. Analysis of data on female gonad stages from the scientific observer programme (see Section 6.1) suggests that for the west coast of both the North and South Islands frostfish have a protracted spawning period starting in mid-winter with a peak from summer to early autumn.

Biological parameters relevant to the stock assessment are shown in Table 4.

Table 4: Estimates of biological parameters for frostfish.

Fishstock							**Estimate**	**Source**
1. Natural mortality (M)								
All stocks	$M = 0.6\ y^{-1}$ considered best estimate for all areas for both sexes							Horn (2013)
2. Weight = a (length)^b (Weight in g, length in cm fork length)								
			a	b				
WCSI trawl surveys			0.000407	3.155				Horn (2013)
3. von Bertalanffy growth parameters								
			Male				Female	
	L_∞	k	t_0		L_∞	k	t_0	
WCSI	129.2	0.56	0.08		143.5	0.457	-0.04	Horn (2013

3. STOCKS AND AREAS

Spawning areas identified from eggs taken in plankton tows include the outer shelf from the Bay of Islands to south of East Cape, and an area off Fiordland (Robertson 1980). No eggs were recorded from the south-east coast of the South Island and no spawning has been recorded on the Chatham Rise. Spawning is also known to take place on the west coast of the South Island in March.

Juvenile frostfish (less than 30 cm) have been reported from trawl surveys in the Bay of Plenty, the Hauraki Gulf, off Northland, the west coast of the North Island and the west coast of the South Island.

The occurrence of spawning in three areas at similar times of year and the distribution of frostfish from catches suggest that there may be at least three separate stocks. A fourth stock is also possible based on known distribution of juveniles and adults and analogies with other species which often have a separate Chatham Rise stock. Bagley et al (1998) proposed the following Fishstock areas for management of frostfish: FRO 1: (FMA 1 and 2); FRO 3: (FMA 3 and 4); FRO 5: (FMA 5 and 6) and FRO 7: (FMA 7, 8, and 9). There have been no reported landings from QMA 10. TACs were set for each QMA (1–9) in 1998 and each FMA is managed separately.

4. STOCK ASSESSMENT

There are no stock assessments available for any stocks of frostfish and therefore estimates of biomass and yields are not available.

4.1 Estimates of fishery parameters and abundance

No estimates of fishery parameters are available for frostfish.

Biomass indices on frostfish are available from trawl surveys carried out by different vessels (Table 5). Few surveys cover the central west coast of New Zealand where the commercial catch records highest landings. The catchability of frostfish is not known but, because they are known to occur frequently well off the bottom, catchability is expected to be low and variable between surveys.

Table 5: Doorspread biomass indices (t) and CVs (%) of frostfish from random stratified trawl surveys 1981–2013.

Vessel	Trip Code	Depth Range (m)	Biomass index (t)	CV (%)	Date
QMA 1					
Bay of Plenty					
Kaharoa	KAH9004	10–150	246	87	February/March 1990
Kaharoa	KAH9202	10–150	92	48	February 1992
Kaharoa	KAH9601	10–250	328	49	February 1996
Kaharoa	KAH9902		193	34	February 1999
QMA 2					
Kaharoa	KAH9304	20–400	573	38	March/April 1993
Kaharoa	KAH9402	20–400	1 079	40	February/March 1994
Kaharoa	KAH9502	20–400	493	22	February/March 1995
Kaharoa	KAH9602	20–400	693	17	February/March 1996
QMA 7 & 8					
Tomi Maru		30–300	2 173	22	December 1980 - January 1981
Shinkai Maru	SHI8102	20–300	6 638	12	October/November 1981
Cordella	COR9001	25–300	2 189	20	February/March 1990
QMA 7 (WCSI)					
Kaharoa	KAH9006	20–400	121	27	March/April 1990
Kaharoa	KAH9204	20–400	24	29	March/April 1992
Kaharoa	KAH9404	20–400	53	37	March/April 1994
Kaharoa	KAH9504	20–400	89	31	March/April 1995
Kaharoa	KAH9701	20–400	259	32	March/April 1997
Kaharoa	KAH0004	20–400	316	16	March/April 2000
Kaharoa	KAH0304	20–400	494	22	March/April 2003
Kaharoa	KAH0504	20–400	423	45	March/April 2005
Kaharoa	KAH0704	20–400	529	38	March/April 2007
Kaharoa	KAH0904	20–400	835	34	March/April 2009
Kaharoa	KAH1104	20–400	251	28	March/April 2011
Kaharoa	KAH1305	20–400	424	24	March/April 2013
WCSI south of 41° 30’					
James Cook	JCO8311	25–450	183	34	September/October 1983
James Cook	JCO8415	25–450	181	25	August/September 1985

4.2 Biomass estimates
No biomass estimates are available for frostfish.

4.3 Yield estimates and projections
MCY cannot be determined as only a small percentage (less than 2%) of the reported catch in recent years is from target fishing. Annual catches are likely to vary according to effort targeting other species in areas of frostfish abundance. It is therefore not possible to choose a catch history which represents a period of stable and unrestricted effort in order to estimate yields. Other problems include under-reporting of frostfish catches and restrictions on targeting frostfish in QMAs 3, 4, 5, and 6.

There are no reliable data on current biomass; *CAY* was therefore not estimated.

4.4 Other factors
None available.

5. STATUS OF THE STOCKS

Estimates of current and reference biomass are not available. The stock structure is uncertain; the fishery is variable and almost entirely a bycatch of other target fisheries. No age data or estimates of abundance are available.

It is therefore not possible to estimate yields. It is not known if recent catches are sustainable or whether they are at levels that will allow the stock to move towards a size that will support the maximum sustainable yield.

TACCs and reported landings for the 2018–19 fishing year are summarised in Table 6.

Table 6: Summary of TACCs (t), and reported landings (t) of frostfish for the most recent fishing year.

Fishstock		FMA	2018–19 Actual TACC	2018–19 Reported landings
FRO 1	Auckland (East)	1	149	42
FRO 2	Central (East)	2	110	34
FRO 3	South-east (Coast)	3	176	12
FRO 4	South-east (Chatham)	4	28	100
FRO 5	Southland	5	135	4
FRO 6	Sub-Antarctic	6	11	< 1
FRO 7	Challenger	7	2 623	1 999
FRO 8	Central (West)	8	649	507
FRO 9	Auckland (West)	9	138	171
FRO 10	Kermadec	10	0	0
Total			4 019	2 869

6. FOR FURTHER INFORMATION

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GARFISH (GAR)

(*Hyporhamphus ihi*)
Takeke

1. FISHERY SUMMARY

Garfish was introduced into the QMS from 1 October 2002 with allowances, TACCs and TACs as shown in Table 1. These have not changed.

Table 1: Recreational and Customary non-commercial allowances, TACCs and TACs (t) of garfish by Fishstock.

Fishstock	Recreational Allowance	Customary Non-Commercial Allowance	TACC	TAC
GAR 1	20	10	25	55
GAR 2	8	4	5	17
GAR 3	2	1	5	8
GAR 4	1	1	2	4
GAR 7	10	5	8	23
GAR 8	8	4	5	17
GAR 10	0	0	0	0

1.1 Commercial fisheries

Garfish landings were first recorded in 1933, and a minor fishery must have existed before this (Table 2). Moderate quantities of garfish can be readily caught by experienced fishers, it is a desirable food fish, and informal sales at beaches or from wharves are likely to have been made from the late 1800s onwards. Reported landings to 1990 almost certainly understate the actual "commercial" catch.

Table 2: Reported total New Zealand landings (t) of garfish from 1931 to 1990.

Year	Landings	Year	Landings	Year	Landings	Year	Landings	Year	Landing	Year	Landing
1931	–	1941	1	1951	4	1961	3	1971	11	1981	7
1932	–	1942	1	1952	7	1962	4	1972	4	1982	11
1933	1	1943	1	1953	6	1963	4	1973	10	1983	12
1934	–	1944	2	1954	8	1964	2	1974	6	1984	13
1935	–	1945	9	1955	9	1965	2	1975	2	1975	8
1936	–	1946	3	1956	7	1966	3	1976	5	1986	14
1937	–	1947	2	1957	2	1967	4	1977	5	1987	36
1938	–	1948	1	1958	2	1968	3	1978	15	1988	20
1939	4	1949	6	1959	4	1969	5	1979	12	1989	15
1940	6	1950	2	1960	6	1970	13	1980	12	1990	24

Source: Annual Reports on Fisheries (Marine Department/Ministry of Agriculture & Fisheries) to 1974, and subsequent MAF data.

By 1990 reported landings were in the range 20–40 t, and the total catches may have reached 50 t. Reported catches and landings through the 1990s were of a similar order of magnitude, before catches declined to lower levels during the 2000–01 to 2011-12 fishing seasons. Since 2012 landings have increased to levels last seen in the 1990s (Table 3).

Largest catches and landings (8–31 t) were made in FMA 1, mostly in Statistical Area 003 (southern east Northland) and 009 (central Bay of Plenty). Small (2–6 t) quantities were taken in FMA 7, almost entirely in area 017 (Marlborough Sounds). Only minor and intermittent catches and landings were made elsewhere. The most consistent catches were taken by beach seine, with some catches by lampara net. Most of the catch is reported as targeted.

In the early 1990s about 50 vessels reported a catch or landing in a year; by the late 1990s this had declined to 20–30. Most vessels reported garfish in only a few years. Annual reported landings have fluctuated between 9 and 26 tonnes since 2010–11.

Table 3: Reported catches or landings (t) of garfish by Fishstock from 1990–91 to 2018–19*. Prior to 2001–02 the catches or landings (t) of garfish were reported by FMA.

Fishstock	GAR 1		GAR 2		GAR 3		GAR 4	
FMA (s)	1		2		3,5&6		4	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1990–91†	31	-	< 1	-	2	-	-	-
1991–92†	22	-	< 1	-	1	-	-	-
1992–93†	14	-	< 1	-	1	-	-	-
1993–94†	23	-	0	-	2	-	-	-
1994–95†	17	-	< 1	-	< 1	-	-	-
1995–96†	15	-	< 1	-	1	-	-	-
1996–97†	15	-	< 1	-	1	-	-	-
1997–98†	21	-	< 1	-	< 1	-	-	-
1998–99†	19	-	< 1	-	< 1	-	-	-
1999–00†	17	-	< 1	-	< 1	-	-	-
2000–01†	11	-	0	-	< 1	-	-	-
2001–02†	8	25	0	5	< 1	5	0	2
2002–03†	6	25	0	5	< 1	5	0	2
2003–04†	11	25	0	5	0	5	0	2
2004–05†	13	25	< 1	5	0	5	0	2
2005–06†	7	25	< 1	5	1	5	0	2
2006–07†	10	25	0	5	0	5	0	2
2007–08†	8	25	0	5	0	5	< 1	2
2008–09†	10	25	0	5	0	5	0	2
2009–10†	9	25	0	5	0	5	0	2
2010–11†	11	25	0	5	< 1	5	0	2
2011–12†	8	25	0	5	0	5	0	2
2012–13	12	25	< 1	5	< 1	5	0	2
2013–14	15	25	0	5	0	5	0	2
2014–15	16	25	0	5	0	5	0	2
2015–16	25	25	0	5	0	5	0	2
2016–17	26	25	0	5	0	5	0	2
2017–18	22	25	0	5	0	5	0	2
2018–19	16	25	0	5	< 1	5	0	2

Fishstock	GAR 7		GAR 8		GAR 10			
FMA (s)	7		8&9		10			Total
	Landings	TACC	Landings	TACC	Landings	TACC	Landings#	TACC
1990–91†	4	-	1	-	0	-	38	
1991–92†	6	-	0	-	0	-	29	-
1992–93†	2	-	2	-	0	-	18	-
1993–94†	2	-	0	-	0	-	26	-
1994–95†	2	-	0	-	0	-	19	-
1995–96†	3	-	< 1	-	0	-	19	-
1996–97†	5	-	< 1	-	0	-	20	-
1997–98†	4	-	1	-	0	-	27	-
1998–99†	6	-	1	-	0	-	26	-
1999–00†	4	-	< 1	-	0	-	21	-
2000–01†	2	-	0	-	0	-	13	-
2001–02†	3	8	0	5	0	0	11	50
2002–03†	< 1	8	0	5	0	0	6	50
2003–04†	1	8	< 1	5	0	0	12	50
2004–05†	0	8	< 1	5	0	0	13	50
2005–06†	0	8	0	5	0	0	9	50
2006–07†	< 1	8	< 1	5	0	0	10	50

Table 3 [Continued]

Fishstock	GAR 7		GAR 8		GAR 10			
FMA (s)		7		8&9		10		Total
	Landings	TACC	Landings	TACC	Landings	TACC	Landings[#]	TACC
2007–08†	< 1	8	0	5	0	0	8	50
2008–09†	1	8	0	5	0	0	11	50
2009–10†	3	8	0	5	0	0	12	50
2010–11†	1	8	0	5	0	0	13	50
2011–12†	< 1	8	< 1	5	0	0	9	50
2012–13	0	8	0	5	0	0	12	50
2013–14	0	8	0	5	0	0	15	50
2014–15	<1	8	0	5	0	0	16	50
2015–16	<1	8	0	5	0	0	25	50
2016–17	0	8	0	5	0	0	26	50
2017–18	0	8	0	5	0	0	22	50
2018–19	0	8	0	5	0	0	16	50

* Listed as landings, but are the higher of catch or landing values. There were relatively small differences between the two series.
† CELR data.
# Note totals may not match figures in the tables due to rounding errors.

1.2 Recreational fisheries

Some garfish is taken, probably incidentally, using rod and line but most is taken in a small and specific fishery using beach seines from the shore in northern FMAs. The total annual harvest is estimated to be 20–30 000 fish (Wynne-Jones et al 2019).

1.3 Customary non-commercial fisheries

Quantitative information on the current level of customary non-commercial catch is not available.

1.4 Illegal catch

Estimates of illegal catch are not available, but this is probably insignificant or nil.

1.5 Other sources of mortality

There may be some accidental catches of garfish in small-mesh nets (purse seines, lampara nets, and beach seines) used in the fisheries for pilchard and yellow-eyed mullet.

2. BIOLOGY

Only one species of garfish or piper is common in New Zealand waters, *Hyporhamphus ihi*. It is endemic, but very similar species occur in Australia. A larger garfish, *Euleptorhamphus viridis*, is occasionally recorded in northern New Zealand. The common garfish is not closely related to the ocean piper or saury, *Scomberexox saurus*. Garfish occur around most of New Zealand, and are present at the Chatham Islands. They are most abundant in sheltered gulfs, bays, and large estuaries, particularly near seagrass beds in shallow water, and over shallow reefs. The pale green, almost transparent colouring, and localised schooling behaviour of garfish makes them difficult to see and their abundance difficult to estimate.

Spawning occurs during spring and summer probably in suitable shallow bays; the eggs sink to the seafloor and adhere to vegetation. Larvae are seldom taken in coastal plankton surveys. Patterns of age and growth are not known in New Zealand, but likely to be similar to Australia, where the larger of two closely related species (southern garfish, *H. melanochir*) matures at 25 cm (2–3 years) and reaches 52 cm (10 years). The New Zealand garfish matures at 22 cm, and with a maximum size of 40 cm may have a lower maximum age. Average size is 20–30 cm.

Garfish feed on zooplankton. They form single-species schools, but occur in close proximity with other small pelagic fishes in shallow coastal waters, particularly yellow-eyed mullet.

There have been no biological studies that are directly relevant to the recognition of separate stocks, or to yield estimates. Consequently no estimates of biological parameters are available.

3. STOCKS AND AREAS

There is no information on whether separate biological stocks occur in New Zealand. Given their preferred habitat of shallow sheltered waters, and the mode of reproduction in which the eggs are attached to the seafloor rather than free-floating, it is probable that localised populations occur, and possible that these may differ in some biological parameters (e.g., growth and recruitment). Consequently these populations may be susceptible to local depletion.

Garfish are sometimes taken as a non-target catch in the pilchard fishery, but this catch is likely to be very small. Although the target fisheries for these two species are quite separate, it is convenient for their Fishstocks to have the same boundaries.

4. STOCK ASSESSMENT

There have been no previous stock assessments of garfish.

4.1 Estimates of fishery parameters and abundance

No fishery parameters are available.

4.2 Biomass estimates

No estimates of biomass (B_0, B_{MSY}, or $B_{current}$) are available.

4.3 Yield estimates and projections

MCY cannot be determined.

Current biomass cannot be estimated, so *CAY* cannot be determined.

4.4 Other yield estimates and stock assessment results

No information is available.

4.5 Other factors

The extent of natural variability in the size of garfish populations is not known, but from their very shallow inshore distribution, and demersal rather than pelagic eggs, it is suspected that they are less variable than other small pelagic species. However, these features also suggest localised populations, susceptible to local depletion.

There is anecdotal information that garfish are very abundant in some localities. It is not known whether this represents similar abundance over a larger region, or a tendency for a few schools to become concentrated in these localities. Apparent abundance, and initial catches, may be misleading in terms of sustainable yields.

The maximum age of 10 years proposed for a similar Australian garfish implies that productivity might not be as high as would be expected from a small pelagic species.

There is no reliable information on catches from the recreational fishery for garfish, or even their size relative to that of the commercial fishery.

5. STATUS OF THE STOCKS

No estimates of current biomass are available. A fishery has existed for several decades, but it is not known how heavily this has exploited the stock. It is not possible to determine if recent catch levels will allow the stock(s) to move towards a size that would support the *MSY*.

TACCs and reported landings by Fishstock are summarised in Table 4.

Table 4: Summary of yield estimates (t), TACCs (t), and reported landings (t) for garfish for the most recent fishing year.

Fishstock	QMA	FMAs	*MCY* estimates	2018–19 Actual TACC	2018–19 Reported Landings
GAR 1	Auckland (East)	1	–	25	16
GAR 2	Central (East)	2	–	5	0
GAR 3	South East (Coast), Southland, Sub-Antarctic	3, 5, 6	–	5	<0.1
GAR 4	South East (Chatham)	4	–	2	0
GAR 7	Challenger	7	–	8	0
GAR 8	Auckland (West), Central (West)	8, 9	–	5	0
GAR 10	Kermadec	10	–	0	0
Total			–	50	16

6. FOR FURTHER INFORMATION

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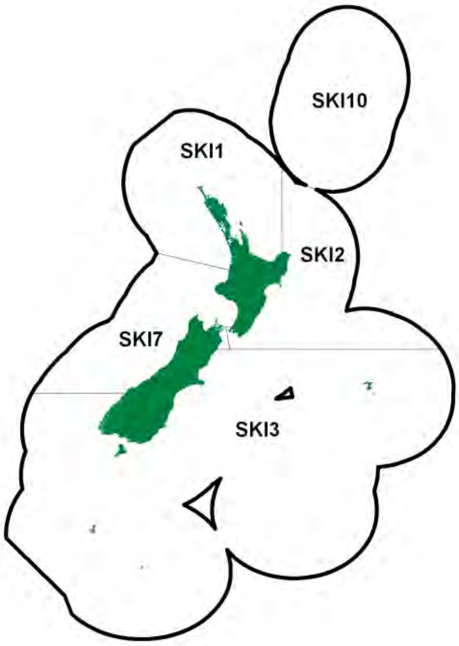
GEMFISH (SKI)

(*Rexea solandri*)
Maka-tikati



1. FISHERY SUMMARY

Gemfish were introduced into the QMS on 1 October 1986. Current allowances, TACCs, and TACs are given in Table 1.

Table 1: Recreational and customary non-commercial allowances (t), TACCs (t), and TACs (t) by Fishstock, as at 1 October 2019.

Fishstock	Recreational Allowance	Customary non–commercial Allowance	Other sources of fishing related mortality	TACC	TAC
SKI 1	5	3	0	210	218
SKI 2	5	3	0	240	248
SKI 3	0	1	6	599	606
SKI 7	0	1	6	599	606
SKI 10	–	–	–	10	–

1.1 Commercial fisheries

Gemfish are caught in coastal waters around mainland New Zealand down to about 550 m. Historical estimated and recent reported gemfish landings and TACCs are shown in Tables 2–4, and Figure 1 shows the historical and recent landings and TACC values for the main gemfish stocks. Annual catches increased significantly in the early 1980s and peaked at about 8250 t in 1985–86 (Table 2). In the late 1980s, annual catches generally ranged from about 4200 t to 4800 t per annum (Table 4). Annual catches declined substantially in the late 1980s and early 1990s and total landings were less than 1200 t in the subsequent years (to 2015–16) (Table 4). TACCs were reduced in SKI 3 and SKI 7 for the 1996–97 fishing year and were progressively reduced in SKI 1 and SKI 2 from 1997–98. Annual catches in all areas remained below the TACCs until 2016–17. Catches were substantially in excess of the TACCs for SKI 3 and SKI 7 in 2017–18 and 2018–19, and the TACC was increased in both these areas from 1 October 2019. However, the 2018–19 catch in SKI 7 was already in excess of the new TACC. In SKI 1 and SKI 2, the 2018–19 catches exceeded the TACC by 67% and 37% respectively.

Table 2: Reported gemfish catch (t) from 1978–79 to 1987–88. Source - MAF and FSU data.

Fishing year	New Zealand		Foreign Licensed			
	Domestic	Chartered	Japan	Korea	USSR	Total
1978–79*	352	53	1 509	1 079	0	2 993
1979–80*	423	1 174	1 036	78	60	2 771
1980–81*	1 050	N/A	N/A	N/A	N/A	> 1 050
1981–82*	1 223	1 845	391	16	0	3 475
1982–83*	822	1 368	274	567	0	3 031
1983–83†	1 617	1 799	57	37	0	3 510
1983–84‡	1 982	3 532	819	305	0	6 638
1984–85‡	1 360	2 993	470	223	0	5 046
1985–86‡	1 696	4 056	2 059	442	0	8 253
1986–87‡	1 603	2 277	269	76	0	4 225 §
1987–88‡	1 016	2 331	90	35	0	3 472 §

* 1 April–31 March.
‡ 1 October–30 September.
† 1 April–30 September.
§ These totals do not match those in Table 3 due to under-reporting to the FSU.
N/A Unknown.

Table 3: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	SKI 1	SKI 2	SKI 3	SKI 7	Year	SKI 1	SKI 2	SKI 3	SKI 7
1931–32	0	0	0	0	1957	2	12	21	10
1932–33	0	0	0	0	1958	5	34	19	28
1933–34	0	42	0	66	1959	2	40	58	38
1934–35	0	70	0	105	1960	3	61	65	39
1935–36	0	39	0	59	1961	6	42	14	19
1936–37	0	37	13	57	1962	5	58	49	27
1937–38	0	86	19	130	1963	19	72	19	38
1938–39	0	50	47	66	1964	17	48	20	29
1939–40	0	48	47	72	1965	19	96	11	28
1940–41	0	58	72	87	1966	12	102	15	26
1941–42	1	63	50	96	1967	32	173	14	46
1942–43	0	47	22	71	1968	18	183	15	33
1943–44	0	15	15	23	1969	60	308	11	22
1944	0	14	15	23	1970	50	281	22	28
1945	6	19	13	30	1971	52	315	24	59
1946	5	20	30	33	1972	85	261	15	37
1947	0	23	74	32	1973	56	237	46	102
1948	1	28	51	44	1974	21	150	14	89
1949	4	19	48	28	1975	2	96	172	37
1950	15	32	59	30	1976	11	108	8	36
1951	5	29	35	27	1977	22	118	4	74
1952	1	21	45	22	1978	36	235	411	1069
1953	1	13	42	10	1979	82	235	2104	628
1954	2	31	12	38	1980	278	287	1899	924
1955	0	25	22	23	1981	236	350	1369	1669
1956	0	31	27	35	1982	546	219	971	676

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data includes both foreign and domestic landings.

Table 4: Reported landings (t) of gemfish by Fishstock from 1983–84 to present and actual TACs from 1986–87. [Continued on next page]

Fishstock	SKI 1		SKI 2		SKI 3		SKI 7		SKI 10		
FMA (s)	1 & 9		2		3, 4, 5, & 6		7 & 8		10	Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	TACC	Landings	TACC
1983–84*	588	–	632	–	3 481	–	1 741	–	† –	6 442 §	–
1984–85*	388	–	381	–	2 533	–	1 491	–	† –	4 793 §	–
1985–86*	716	–	381	–	5 446	–	1 468	–	† –	8 011 §	–
1986–87	773	550	896	860	2 045	2 840	1 069	1 490	†10	4 783	5 750
1987–88	696	632	1 095	954	1 664	2 852	1 073	1 543	†10	4 528	5 991
1988–89	1 023	1 139	1 011	1 179	1 126	2 922	1 083	1 577	†10	4 243	6 827
1989–90	1 230	1 152	1 043	1 188	1 164	3 259	932	1 609	†10	4 369	7 218
1990–91	1 058	1 152	949	1 188	616	3 339	325	1 653	†10	2 948	7 342
1991–92	1 017	1 152	1 208	1 197	287	3 339	584	1 653	†10	3 096	7 350
1992–93	1 292	1 152	1 020	1 230	371	3 345	469	1 663	†10	3 152	7 401
1993–94	1 156	1 152	1 058	1 300	75	3 345	321	1 663	†10	2 616	7 470
1994–95	1 032	1 152	905	1 300	160	3 355	103	1 663	†10	2 169	7 480
1995–96	801	1 152	789	1 300	49	3 355	81	1 663	†10	1 720	7 480

Table 4 [Continued]

Fishstock	SKI 1		SKI 2		SKI 3		SKI 7		SKI 10		Total
FMA (s)	1 & 9		2		3, 4, 5, & 6		7 & 8		10		
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	TACC	Landings	TACC
1996–97	965	1 152	978	1 300	58	1 500	238	900	†10	2 240	4 862
1997–98	627	752	671	849	27	300	44	300	†10	1 369	2 211
1998–99	413	460	336	520	17	300	59	300	†10	825	1 590
1999–00	409	460	506	520	62	300	107	300	†10	1 083	1 590
2000–01	335	460	330	520	47	300	87	300	†10	799	1 590
2001–02	201	210	268	240	72	300	123	300	†10	664	1 060
2002–03	206	210	313	240	115	300	268	300	†10	902	1 060
2003–04	221	210	301	240	78	300	542	300	†10	1 142	1 060
2004–05	234	210	259	240	72	300	635	300	†10	1 199	1 060
2005–06	230	210	182	240	27	300	248	300	†10	687	1 060
2006–07	215	210	317	240	26	300	209	300	†10	767	1 060
2007–08	216	210	249	240	18	300	179	300	†10	662	1 060
2008–09	191	210	191	240	11	300	213	300	†10	606	1 060
2009–10	247	210	176	240	20	300	144	300	†10	587	1 060
2010–11	226	210	300	240	33	300	301	300	†10	860	1 060
2012–13	182	210	140	240	23	300	234	300	†10	580	1 060
2013–14	198	210	268	240	39	300	268	300	†10	764	1 060
2014–15	83	210	168	240	21	300	231	300	†10	503	1 060
2015–16	188	210	224	240	80	300	186	300	†10	677	1 060
2016–17	244	210	236	240	248	300	431	300	†10	1 159	1 060
2017–18	277	210	286	240	466	300	583	300	†10	1 612	1 060
2018–19	354	210	328	240	577	300	937	300	†10	2 196	1 060

* FSU data.
§ The totals do not match those in Table 2 because some fish were not reported by area (FSU data prior to 1986–87).
† No recorded landings.

Most of the recorded catch is taken by trawlers. Target fisheries developed off the eastern and northern coasts of the North Island. From 1993 to 2000 there was a major shift in effort from east of North Cape to the west, and over 50% of the SKI 1 catch was taken from QMA 9 in some years. However, the distribution of fishing changed substantially after 2001 when the quota was reduced. The west coast fishery virtually disappeared, as did the fishery off East Northland. Although landings were historically concentrated in the months of May and June, they are now spread fairly evenly through the year. Most SKI 1 and SKI 2 landings are now bycatch in a range of trawl fisheries, including tarakihi, barracouta, scampi, and hoki, although targeting of gemfish does occur. Catches off the west and southern coasts of the South Island are primarily bycatch of hoki and squid target fisheries and the mixed inshore trawl fishery off the west coast of the South Island.

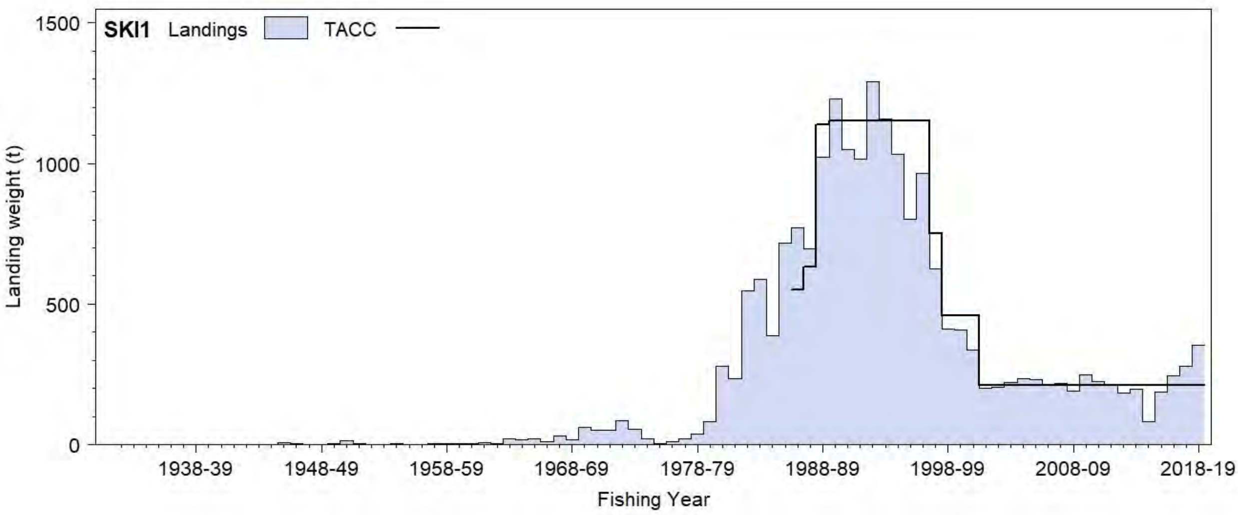


Figure 1: Reported commercial landings and TACC for the four main SKI stocks. , SKI 1 (Auckland East). [Continued on next page]

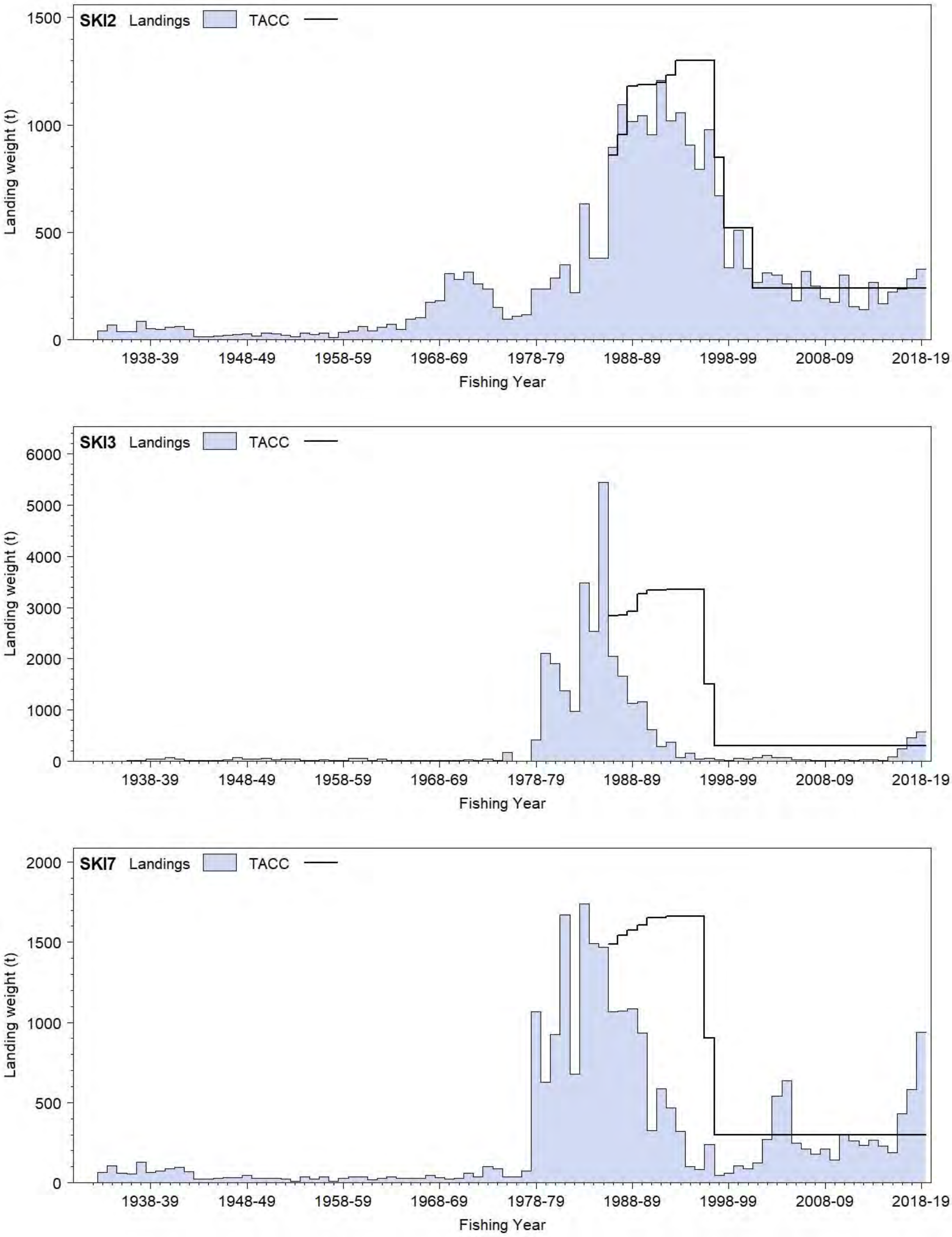


Figure 1 [Continued]: Reported commercial landings and TACC for the four main SKI stocks. From top to bottom SKI 2 (Central East), SKI 3 (South East Coast), and SKI 7 (Challenger).

1.2 Recreational fisheries

Little or no recreational catch was reported in marine recreational fishing telephone/diary surveys between 1992 and 2001, but the harvest estimates provided by these surveys are no longer considered reliable. A Recreational Technical Working Group concluded that these harvest estimates should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries. In response to these problems and the cost and scale challenges associated with onsite methods, a National Panel Survey was conducted for the first time throughout the 2011–12 fishing year (Wynne-Jones et al 2014). The panel survey used face-to-face interviews of a random sample of 30 390 New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and harvest information was collected in standardised phone interviews. The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly comparable results (Wynne-Jones et al 2019). Recreational catch estimates from the two national panel surveys are given in Table 5. Note that National Panel survey estimates do not include recreational harvest taken under s111 general approvals.

Table 5: Recreational harvest estimates for gemfish stocks (Wynne-Jones et al 2014, 2019). Mean fish weights were not available from boat ramp surveys so catches cannot be converted to weight.

Stock	Year	Method	Number of fish	Total weight (t)	CV
SKI 1	2011/12	Panel survey	2 752	–	0.39
	2017/18	Panel survey	7 140	–	0.33
SKI 2	2011/12	Panel survey	0	–	-
	2017/18	Panel survey	1 299	–	0.53
SKI 7	2011/12	Panel survey	137	–	1.03
	2017/18	Panel survey	27	–	1.01

1.3 Customary non-commercial fisheries

Quantitative information on the current level of customary non-commercial take is not available and is assumed to be negligible.

1.4 Illegal catch

The amount of gemfish misreported is not available and is assumed to be negligible.

1.5 Other sources of mortality

There may have been some gemfish discarded prior to the introduction of the EEZ, but this is likely to have been minimal since the early 1980s as gemfish is a medium value species.

2. BIOLOGY

Gemfish occur on the continental shelf and slope, from about 50–550 m depth. They are known to undertake spawning migrations and the pre-spawning runs have formed the basis of winter target fisheries, but exact times and locations of spawning are not well known. Spawning probably takes place about July near North Cape and late August/September off the west coast of the South Island.

Ageing of southern gemfish indicates that fish attain about 30 cm at the end of the first year, 45 cm at the end of the second year, 53 cm at the end of the third year, and 63 cm at the end of the fourth year. Both sexes display similar growth rates until age 5, but subsequently females grow larger. The maximum ages recorded for gemfish (from 1989 to 1994) are 17 years for both sexes. In the northern fishery (SKI 1, SKI 2), males and females appear to recruit into the fishery from age 3, but are probably not fully recruited until about age 5 (SKI 2) or age 7 or 8 (spawning fishery in SKI 1). In the southern fishery, gemfish start to recruit at age 2 into spawning and non-spawning fisheries, but age at full recruitment is difficult to determine because of large variation in year class strength.

Recruitment variability in SKI 3 and SKI 7 (during the 1980s and early 1990s) has been correlated with wind and sea surface temperature patterns during the spawning season (Renwick et al 1998). Patterns of recruitment from 2000–2015 in SKI 3 and SKI 7 do not appear to be consistent with the previous correlation with SST (Langley 2020). No significant correlations were found between SKI 1 and SKI 2 recruitment indices and a range of climate variables (Hurst et al 1999).

Biological parameters relevant to stock assessment are given in Table 6.

Table 6: Estimates of biological parameters for gemfish.

Fishstock							**Source**
1. Natural mortality (M)							
All stocks	M = 0.25 y^{-1} considered best estimate for all areas for both sexes						Horn & Hurst (1999)
2. Weight = a (length)^b (Weight in g, length in cm fork length)							
		Male			Female		
		a	b		a	b	
SKI 1		0.0034	3.22		0.0008	3.55	Langley et al (1993)
SKI 3		0.0012	3.41		0.0095	3.47	Hurst & Bagley (1998)

3. von Bertalanffy growth parameters

	Male			Female			
	L_∞	k	t_0	L_∞	k	t_0	
East Northland	90.7	0.204	-0.49	122.7	0.114	-1.1	Langley et al (1993)
East Northland	88.4	0.235	-0.54	108.5	0.167	-0.71	Horn & Hurst (1999)
Wairarapa	90.8	0.287	0.00	103.4	0.231	-0.1	Horn & Hurst (1999)
West Northland	86.3	0.295	-0.11	103.4	0.209	-0.37	Horn & Hurst (1999)
North combined	87.4	0.266	-0.35	105	0.194	-0.55	Horn & Hurst (1999)
Southland	88.5	0.242	-0.66	104.2	0.178	-0.88	Horn & Hurst (1999)

3. STOCKS AND AREAS

In previous assessments, analysis of seasonal trends in gemfish fisheries indicated that there may be at least two stocks:

1. A southern/west coast stock (SKI 3 & 7), caught in the southern area in spring, summer, and autumn, which presumably migrates to the west coast of the South Island to spawn and is caught there mainly in August–September. Spawning is thought to occur in late August/early September.
2. A northern/east coast stock (SKI 1E & SKI 2), caught mainly on the east coast in spring and summer, which migrates in May–June to spawn north of the North Island. Seasonal trends in commercial catch data from SKI 1E (FMA 1) are consistent with pre- and post-spawning migrations through the area; similar data from SKI 2 are inconclusive but indicate lower catches during the peak spawning months, although this could be partly due to target fishing on other species, particularly orange roughy, at this time.

The relationship of the pre-spawning fishery in SKI 1W (FMA 9) to the pre-spawning fishery in SKI 1E was investigated by Horn & Hurst (1999). They presented age frequency distributions from commercial catches for SKI 1E, SKI 1W, and SKI 2 and from research sampling for SKI 3. Age distributions for the two SKI 1 spawning fisheries appear similar, with year classes in 1980, 1982, 1984, 1986, and 1991 appearing to be strong relative to other year classes. The SKI 2 distribution also exhibits the same pattern, although the relative dominance of the 1991 year class was greater, as might be expected from an area in which pre-recruit fish occur. The age distribution from SKI 3 gemfish showed that the 1982, 1984, 1985, and 1989 year classes were the stronger ones. There were no significant differences in the von Bertalanffy growth parameters calculated for northern and southern gemfish (Horn & Hurst 1999).

Recent biochemical analyses of Australasian gemfish suggested that there may be a very low level of mixing between eastern Australian and New Zealand gemfish, but not high enough to treat them as a single stock. There was also a suggestion of a difference between north-eastern and southern New Zealand gemfish.

Two alternative hypotheses have been proposed: that both SKI 1 and SKI 2 are one stock, or that SKI 1W is separate from SKI 1E and SKI 2. The Middle Depths Working Group concluded that based on the close similarity in declines in CPUE indices and in age distributions from commercial catches that the northern gemfish should be assessed using SKI 1 and 2 combined.

4. STOCK ASSESSMENT

The most recent fully quantitative stock assessment for SKI 1 and SKI 2 was conducted in 2008 (Fu et al 2008). Subsequent trends in stock abundance are assessed using standardised CPUE indices, updated in 2020.

In 2008, the northern gemfish stock was assessed using the hypothesis of one stock (SKI 1 and SKI 2). The alternative hypothesis, that SKI 1W is separate from SKI 1E and SKI 2 was not modelled, because results from previous assessments were similar to those from SKI 1 and SKI 2 combined. Estimates of virgin biomass (B_0) and mature biomass in 2006 and 2007 are presented below.

A stock assessment of the southern stock (SKI 3 & 7) was conducted in 1997. Since then, additional information are available from CPUE indices derived from the west coast South Island hoki fishery, length composition data from the main commercial fisheries (from Observers), and trawl surveys of the west coast of the South Island by *Kaharoa* and *Tangaroa*. These data were incorporated in a preliminary stock assessment model for the southern stock in 2019. The Deepwater Working Group concluded that the preliminary stock assessment model was not sufficiently reliable to be able to estimate current stock status.

4.1 Auckland (SKI 1) and Central East (SKI 2)

4.1.1 Combined landings and TACCs for SKI 1 and SKI 2

Figure 2 shows the landings and TACCs for SKI 1 and SKI 2 combined.

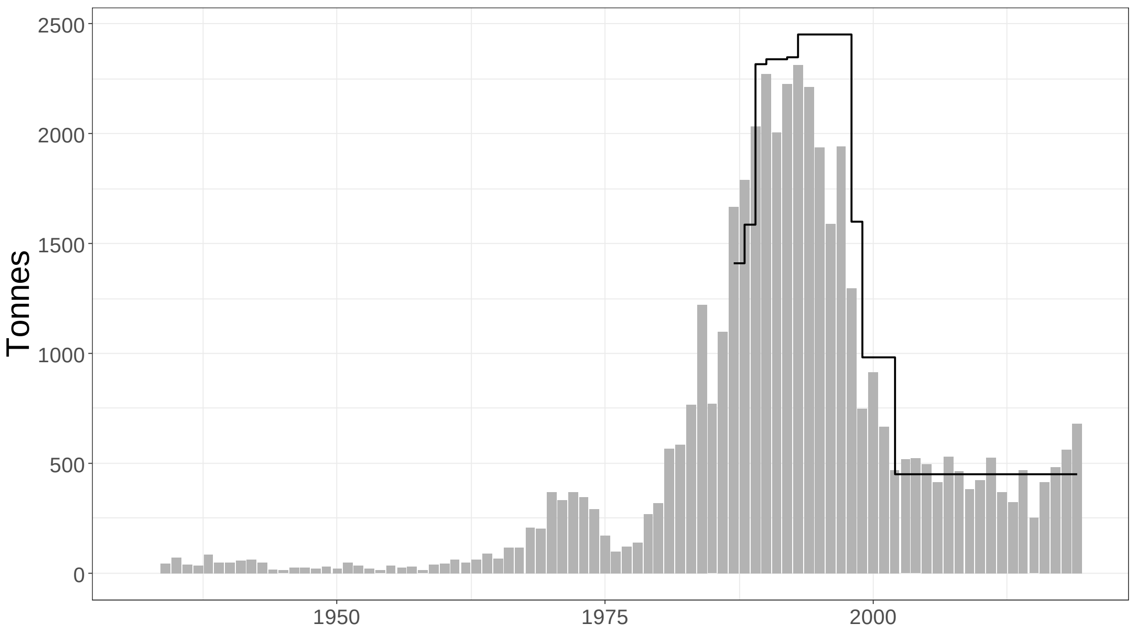


Figure 2: Combined landings (bars) and TACC (line) for SKI 1 and SKI 2.

4.1.2 Age composition of commercial catches

Commercial catch-at-age data included in the models were: SKI 1E for 1989–94, 1997–99, 2002, and 2006; SKI 1W for 1996–99, and 2002; and SKI 2 for 1996–2005, and 2007. Age data for SKI 1E and SKI 1W were combined for the stock assessment model. Catch-at-age was subsequently reported for the 2010 SKI 1 target trawl fishery (Langley et al 2012).

4.1.3 Estimates of abundance used in the 2008 assessment

Standardised CPUE indices for SKI 1 and SKI 2 were calculated for three fishery sub-groups in 2007: (1) target catch only, (2) all gemfish catch, and (3) all gemfish catch on TCEPR forms. The indices for TCEPR all gemfish catch (SKI 1 for 1990–2006, SKI 2 for 1994–2006) were used in the assessment. The indices for SKI 1 from SKI 1E and SKI 1W combined and for SKI 2 included both midwater and bottom trawl methods. Both time series showed steep declines to the early 2000s, followed by marked increases.

4.1.4 Assessment model

The 2008 stock assessment model for SKI 1 and SKI 2 (Fu et al 2008) included two fishery types, based on spawning activity. The first was the home ground fishery, SKI 2, where all age classes occur and where fishing is mainly in the non-spawning season. The second was on the spawning migration fishery, SKI 1, where only mature age classes occur and where fishing was in the winter months. The stock assessment was implemented as a Bayesian single stock model using the general-purpose stock assessment program CASAL v2.20 (Bull et al 2008).

The assessment model partitioned the stock into two areas (spawning (SKI 1E and 1W) and home ground (SKI 2)), two sexes and age groups 1–20, with no plus group. There were four time steps in the model (Table 7). In the first time step, the 1 year-olds recruit to the population, which is then subjected to fishing mortality in SKI 2. In the second time step, fish migrate into SKI 1, and again are subjected to fishing mortality. In time step 3, fish ages are incremented, and spawning occurs. Fish migrate back to SKI 2 in the final time step.

Table 7: Annual cycle of the stock model for gemfish, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur within a time step occur after all other processes, with half of the natural mortality for that time step occurring before and half after the fishing mortality.

				Observations	
Step	**Period**	**Processes**	***M*[1]**	**Description**	**%*M*[2]**
1	Oct–Apr	Fishing (SKI 2)	0.58	CPUE (SKI 2)	50
		Recruitment		Proportions at age (SKI 2)	50
2	May–Jun	Migration to SKI 1	0.17	CPUE (SKI 1)	50
		Fishing (SKI 1)		Proportions at age (SKI 1)	50
3	Jul	Spawning	0.08		
		Increment age			
4	Aug–Sep	Migration to SKI 2	0.17		

1. *M* is the proportion of natural mortality that was assumed to have occurred in that time step.
2. %*M* is the percentage of the natural mortality within each time step that was assumed to have taken place at the time each observation was made.

4.1.5 Results

Estimates of biomass were obtained using the biological parameters and model input described by Fu et al (2008). Three model runs were considered, because there were concerns that the most recent SKI 2 catch-at-age samples could be biased due to changes in the fishery. Model run "$2006_{YCS2000}$" used data up to 2006 and estimated year class strengths from 1978 to 2000; run "$2006_{YCS2001}$" used the same data but estimated the year class strengths from 1978 to 2001; run "$2007_{YCS2003}$" incorporated data up to 2007, with year class strengths estimated from 1978 to 2003. Table 8 describes the three model runs.

Table 8: Model run labels and descriptions for the base case and sensitivity model runs.

Model run	Description
$2006_{YCS2000}$	Fitting to catch-at-age up to 2006, and CPUE indices based on TCEPR to 2001, and estimating YCSs 1978–00, using an average natural mortality of 0.25 y^{-1} and separate age-based logistic fishing selectivities for SKI 2 fisheries before and after 2001.
$2006_{YCS2001}$	$2006_{YCS2000}$, but estimated YCS from 1978–2001.
$2007_{YCS2003}$	$2006_{YCS2000}$, but included 2007 SKI 1 and 2 catch and 2007 SKI 2 catch-at-age, and estimated YCSs 1978–2003.

For each model run, MPD fits were obtained and qualitatively evaluated. MPD estimates of biomass trajectories are shown in Figure 3. MCMC estimates of the posterior median and 95% percentile credible intervals for current and virgin biomass are reported in Table 9, and for year class strengths are shown in Figure 4.

Year class strengths were poorly estimated before 1990 when the only data available to determine year class strength were from older fish (see Figure 4). The estimates suggest a period of generally higher than average recruitment during the 1980s, followed by a period of generally lower than average recruitment (1992–2000). For run *2006YCS2001*, the 2001 year class strength was estimated to be weak. For run *2007YCS2003*, recruitment appeared to have improved in 2002 and 2003, but was still below average, and the estimate of 2003 year class strength was very uncertain.

The stock declined markedly during the early 1980s, followed by a small period of recovery due to recruitment of strong year classes in the late 1980s. After 1992, the stock declined to its lowest level due to increasing exploitation rates combined with a long period of low recruitment beginning in the early 1990s (see Figure 3). For model runs including data up to 2006, the estimated posterior median of B_{2006} was at about 32% of B_0 when the 2001 year class strength was fixed at 1, or 26% of B_0 when this year class was being estimated. More pessimistic estimates of biomass were obtained when 2007 catch-at-data were included, which suggest that the posterior median of B_{2007} was at about 22% of B_0 (see Table 9).

Table 9: Bayesian median and 95% credible intervals of B_0, $B_{current}$, and $B_{current}$ as a percentage of B_0 for the northern stock (SKI 1 & 2) from three model runs. $B_{current}$ refers to B_{2006} for run *2006YCS2000* and *2006YCS2001*, and B_{2007} for run *2007YCS2003*;

Model run	B_0	$B_{current}$	$B_{current}$ (%B_0)
2006YCS2000	12 672 (11 398–14 709)	4 007(2 759–5 766)	32(24–40)
2006YCS2001	11 691 (10 636–13 283)	3 008(2 024–4 593)	26(19–35)
2007YCS2003	10 900 (9 853–12 403)	2 443(1 448–3 924)	22(15–32)

The effect of using a lower and higher value of natural mortality was investigated for run 2*007YCS2003*: with the average *M* set at 0.20, the current biomass is about 16% B_0; with an average *M* set at 0.30, the current biomass is about 28% B_0. Estimates of other model parameters were relatively insensitive to the assumed value of natural mortality.

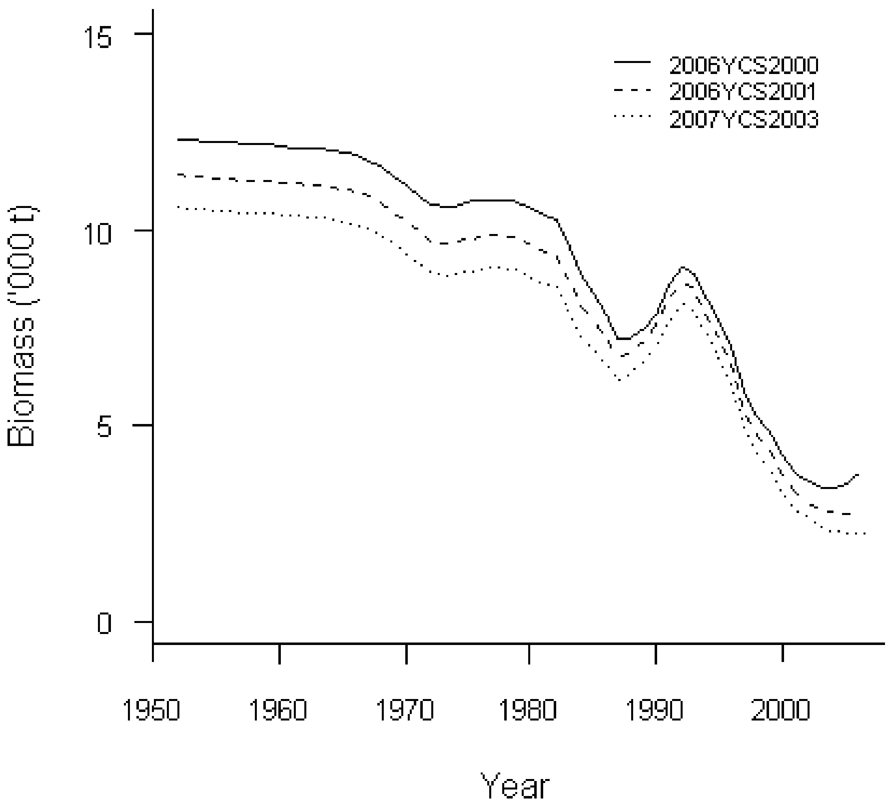


Figure 3: MPD biomass trajectories for the northern stock (SKI 1 & 2) from northern stock (SKI 1 & 2) from three model runs: *2006YCS2000*, *2006YCS2001*, and *2007YCS2003*.

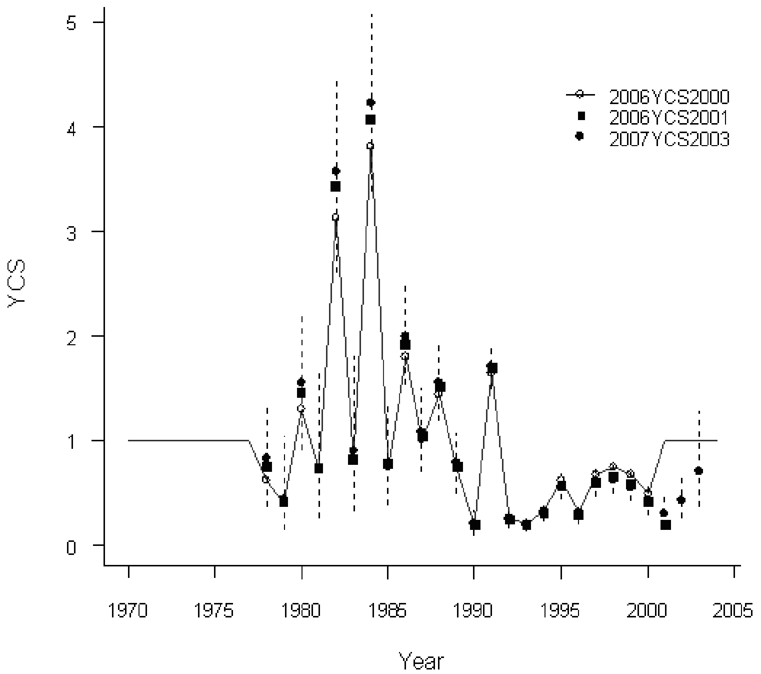


Figure 4: Bayesian median of year class strength for the three model runs *2006*$_{YCS2000}$, *2006*$_{YCS2001}$, and *2007*$_{YCS2003}$. Dotted lines are the 95% credible intervals for run *2007*$_{YCS2003}$.

4.1.6 Yield estimates

MCY and *CAY* were determined using stochastic sample-based simulations. One simulation run was done for each sample from the posterior, ultimately producing an estimate of yield that has been averaged over all samples (Bull et al 2008). Each run extended over 150 years with recruitment randomly sampled, but with the first 100 of those years discarded to allow the population to stabilise. Yield calculation was based on the procedures of Francis (1992), where yields were maximised subject to the constraint that spawning stock biomass should not fall below 20% of B_0 more than 10% of the time (Table 10).

Table 10: Yield estimates (*MCY* and *CAY*) and associated parameters for the for the northern stock (SKI 1 & 2) from three model runs where simulations were based on recruits resampled from the entire period in which year class strengths were estimated.

Model run	B_{MCY} (t)	B_{MCY} (%B_0)	*MCY* (t)	B_{MAY} (t)	B_{MAY} (%B_0)	*MAY* (t)	*CAY* (t)
2006$_{YCS2000}$	6 698	53	995	4 117	32	1 404	1 305
2006$_{YCS2001}$	6 304	54	865	3 934	34	1 270	925
2007$_{YCS2003}$	5 928	48	816	3 676	34	1 194	755

4.1.7 2020 SKI 1 and SKI 2 CPUE update

The SKI 2 CPUE series was previously updated in 2014 with data up to the end of 2012–13 (Starr & Kendrick 2016). The 2014 SKI 2 CPUE series differed from the series used in the 2008 assessment in a number of ways: a) only bottom trawl was used; b) data from all form types were amalgamated into a day of fishing by a vessel, selecting the modal target species and modal statistical area when there were multiple values within a day; c) target species (including SKI) was included in the analysis as an explanatory variable. These analyses appeared to be robust, with only small differences in the models that excluded or included SKI as a target category. The Working Group concluded that future CPUE analyses should include data from the Bay of Plenty.

In 2020, the 2014 CPUE indices were initially updated using the same approaches and with the addition of data from the Bay of Plenty. The updated series showed large increases in 2017-18 and 2018–19 that were primarily driven by data from the tarakihi target fishery. The tarakihi target fishery generally operates in shallower depths than the gemfish target fishery. Examination of sparse length-frequency data collected by observers from the tarakihi target bottom-trawl fishery in SKI 2, and comparisons with historical landings data from the gemfish target fishery, suggested that the tarakihi fishery took a mix of sub-adult and adult gemfish, and that adult gemfish were taken when targeting gemfish.

As a result, separate CPUE indices were developed for the TAR and SKI target fisheries, with both including data from SKI 2 and the east and west coast fisheries in SKI 1 on the basis that SKI 1 and SKI 2 are assessed as a single biological stock. This was supported by implied residual plots from the 2020 CPUE analyses that showed consistent trends across all statistical areas for each series.

For the SKI target fisheries, event-based data were available from the mid-1990s in SKI 1. However, the Fisheries Assessment Plenary concluded that the BT-SKI indices could not be accepted as indexing abundance of SKI 1 and SKI 2 due to sparse data, large changes in distribution of fishing effort and considerably reduced targeting.

For the TAR target fisheries a trip-resolution index was developed, which addressed the fact that gemfish may not be well estimated in event level data from the tarakihi fishery. Gemfish were landed in all trips included in the analysis dataset, so only a positive catch index was required. This series showed a steep decline from 1990 to 1999, a stable period to 2016, and then a rapid increase (Figure 5). The plenary accepted the BT-TAR trip-based index as an index of abundance for mixed sub-adult and adult gemfish in SKI 1 and SKI 2. Because the BT-TAR index did not index the whole adult stock, CPUE based reference points were not developed.

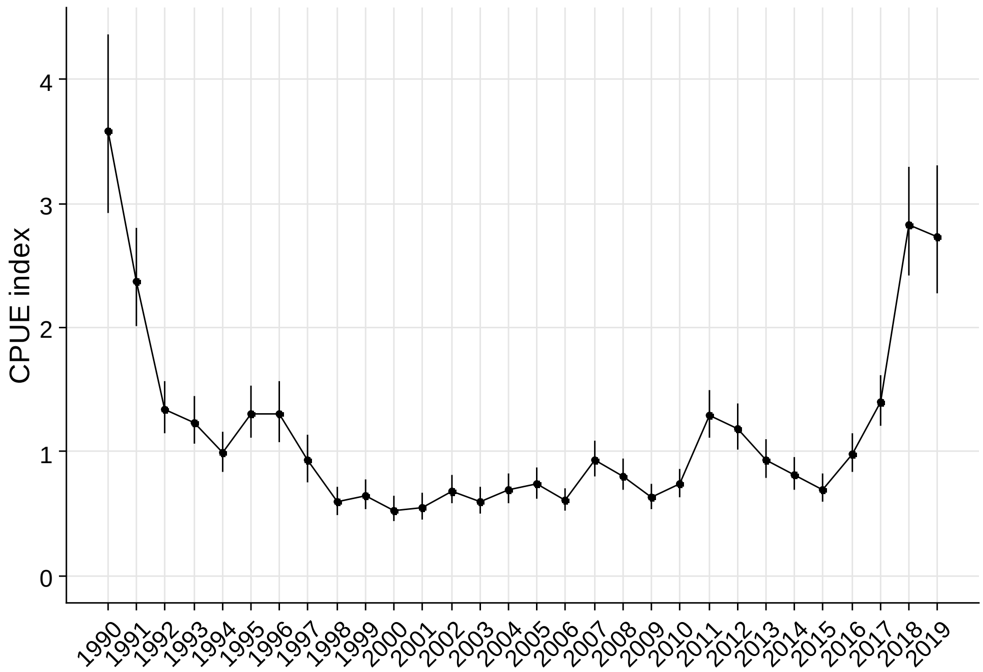


Figure 5: The SKI 1 and SKI 2 CPUE series using trip-resolution data from the tarakihi-target bottom trawl fishery, scaled to a geometric mean of one.

4.2 South-East/Southland (SKI 3) and Challenger/Central (West) (SKI 7)

4.2.1 Trawl survey biomass indices

The relative abundance of gemfish in the Southland area (SKI 3) was monitored by trawl surveys conducted by *Shinkai Maru* (early 1980s) and *Tangaroa* (early 1990s) (Table 11). Since the early 1990s, a regular series of inshore trawl survey of the west coast South Island (SKI 7) has been conducted by *Kaharoa* during April-May. Although gemfish is not considered to be a target species for the survey, the survey appears to monitor the relative abundance of juvenile gemfish in the survey area. The more recent series of trawl surveys of the west coast South Island by *Tangaroa* overlaps the main distribution of gemfish and may occur during the early part of the spawning period. The survey appears to monitor the adult and juvenile components of the gemfish stock in the WCSI.

Table 11: Biomass indices (t) and coefficients of variation (CV) from trawl surveys (assuming area availability, vertical availability and vulnerability = 1).

Fishhstock	Area	Vessel	Trip code	Date	Biomass	% CV
SKI 3	Southland	*Shinkai Maru*	SHI8102	Feb 1981	3 900	17
			SHI8201	Mar–Apr 1982	3 100	31
			SHI8303	Apr 1983	5 500	33
SKI 3	Southland	*Tangaroa*	TAN9301	Feb–Mar 1993	1 066	17
			TAN9402	Feb–Mar 1994	406	18
			TAN9502	Feb–Mar 1995	539	25
			TAN9604	Feb–Mar 1996	529	23
SKI 7	WCSI	*Kaharoa*	KAH9204	Mar–Apr 1992	130	19
			KAH9404	Mar–Apr 1994	68	29
			KAH9504	Mar–Apr 1995	21	55
			KAH9701	Mar–Apr 1997	704	83
			KAH0004	Mar–Apr 2000	120	30
			KAH0304	Mar–Apr 2003	137	23
			KAH0503	Mar–Apr 2005	474	49
			KAH0704	Mar–Apr 2007	101	19
			KAH0904	Mar–Apr 2009	143	29
			KAH1104	Mar–Apr 2011	101	34
			KAH1305	Mar–Apr 2013	113	28
			KAH1503	Mar–Apr 2015	186	17
			KAH1703	Mar–Apr 2017	545	28
			KAH1902	Mar–Apr 2019	559	22
SKI 7	WCSI	*Tangaroa*	TAN1210	Jul–Aug 2012	14	32
			TAN1308	Aug 2013	11	43
			TAN1609	Aug 2016	127	23
			TAN1807	Jul–Aug 2018	702	33

Footnote: The *Tangaroa* WCSI survey in 2000 was not used as the survey in that year did not extend inshore of 300 m depth.

4.2.2 SKI 7 standardised CPUE analysis

A significant proportion of the catch from SKI 7 is taken as a bycatch from the WSCI hoki fishery. In 2019, two sets of CPUE indices were derived for SKI 7 from the gemfish catch and effort data from this fishery. The sets of CPUE indices were derived from two sets of catch and effort data:

i) a complete set of catch and effort data from the target HOK trawls conducted by the WCSI trawl (BT and MW) fishery during July-September from 1989–90 to 2017–18. The CPUE data set was restricted to include a core set of vessels (present in the fishery for at least six years) which accounted for approximately 80% of the total gemfish catch *all data CPUE*.

ii) a subset of the catch and effort data limited to the component of the WCSI hoki fishery that accounts for a substantial proportion of the gemfish catch; i.e., trawls in a restricted depth range (250–600 m) within the northern area of the fishery during late August-September. The dataset was further restricted to New Zealand domestic vessels on the basis that these vessels were likely to have more accurately reported the gemfish catch throughout the time period. The latter criterion also restricted the time period of the analysis to commence in 1996–97. Overall, the *partial data* set represented 19% of the gemfish catch and 2% of the trawl records included in the total data set (*partial data CPUE*).

For the *all data CPUE* set, the standardised CPUE indices were derived from a negative binomial model of the catch of gemfish (including zero catches). The main explanatory variables included in the model were fishing year, month, vessel, bottom depth, and gear headline height.

For the *partial data CPUE* set, the standardised CPUE indices were derived using a delta-lognormal model. The binomial model of the presence/absence of gemfish in the catch was largely informed by the fishing year, day of the fishing season, and fishing depth. The lognormal model of the positive catches included fishing year, fishing gear (BT or MW), vessel, and day of the fishing season.

For both CPUE analyses, the indices were low during the late 1990s and early 2000s and then increased in 2003–04, although the extent of the increase differed considerably between the two sets of CPUE indices (Figure 6). The *all data CPUE* indices increased substantially in 2003–04 and remained at the higher level in 2004–05. The indices returned to the initial, lower level in 2006–07 and remained at about that level until 2015–16. The short period of high CPUE indices in 2003–04 and 2004–05 corresponded to a period of higher gemfish catches by vessels operating in the northern area of the fishery late in the hoki fishing season. It is likely that there was a degree of targeting of gemfish by some sectors of the fleet during that period.

In contrast, the *partial data CPUE* indices increased to a lesser extent in 2003–04 and then fluctuated about that level until 2015–16. Both sets of CPUE indices increased substantially from 2014–15 to 2017–18.

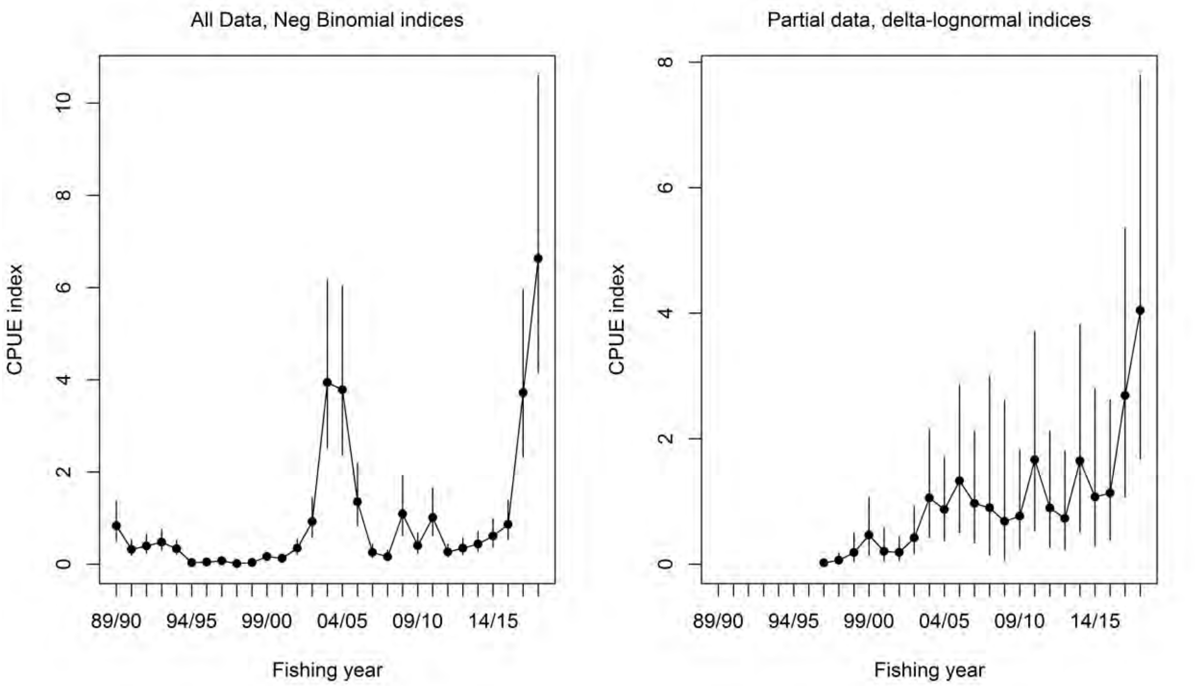


Figure 6: Gemfish (SKI 7) CPUE indices derived from the entire WCSI hoki fleet (*all data CPUE*, left) and a subset of the fleet (*partial data CPUE*, right). (Approximate 95% confidence intervals).

Overall, the CPUE indices for the *partial data CPUE* model have lower precision than the *all data CPUE* indices reflecting the high variability in both the binomial and lognormal components of the delta-lognormal CPUE indices and the use of a reduced data set. There are also different, and somewhat contradictory trends, in the annual indices from the two model components. These differences may indicate changes in the accuracy of the reporting of gemfish catches across years.

The Working Group considered that the CPUE indices qualitatively reflected an increase in biomass in recent years, but are unlikely to be directly proportional to abundance.

A range of other data are available from SKI 7, including length composition data from the observer sampling of the gemfish bycatch of the WCSI hoki fishery (25 years) and relative biomass estimates and length compositions from the time series of *Kaharoa* WCSI inshore trawl surveys (13 surveys 1992–2017) and the *Tangaroa* WCSI trawl surveys (4 surveys 2012–2018). From 2015–16, the biomass estimates for gemfish from the two sets of trawl surveys increased considerably (see Table 11), corresponding to the presence of strong length modes of small gemfish in the 2017 *Kaharoa* trawl survey and 2016 and 2018 *Tangaroa* trawl surveys. Corresponding length modes are also evident in the length compositions from the commercial fisheries in SKI 3 and SKI 7. The observed length modes represented age cohorts (Figure 7). These strong length modes were consistent with the increase in the CPUE indices and increase in catch in recent years.

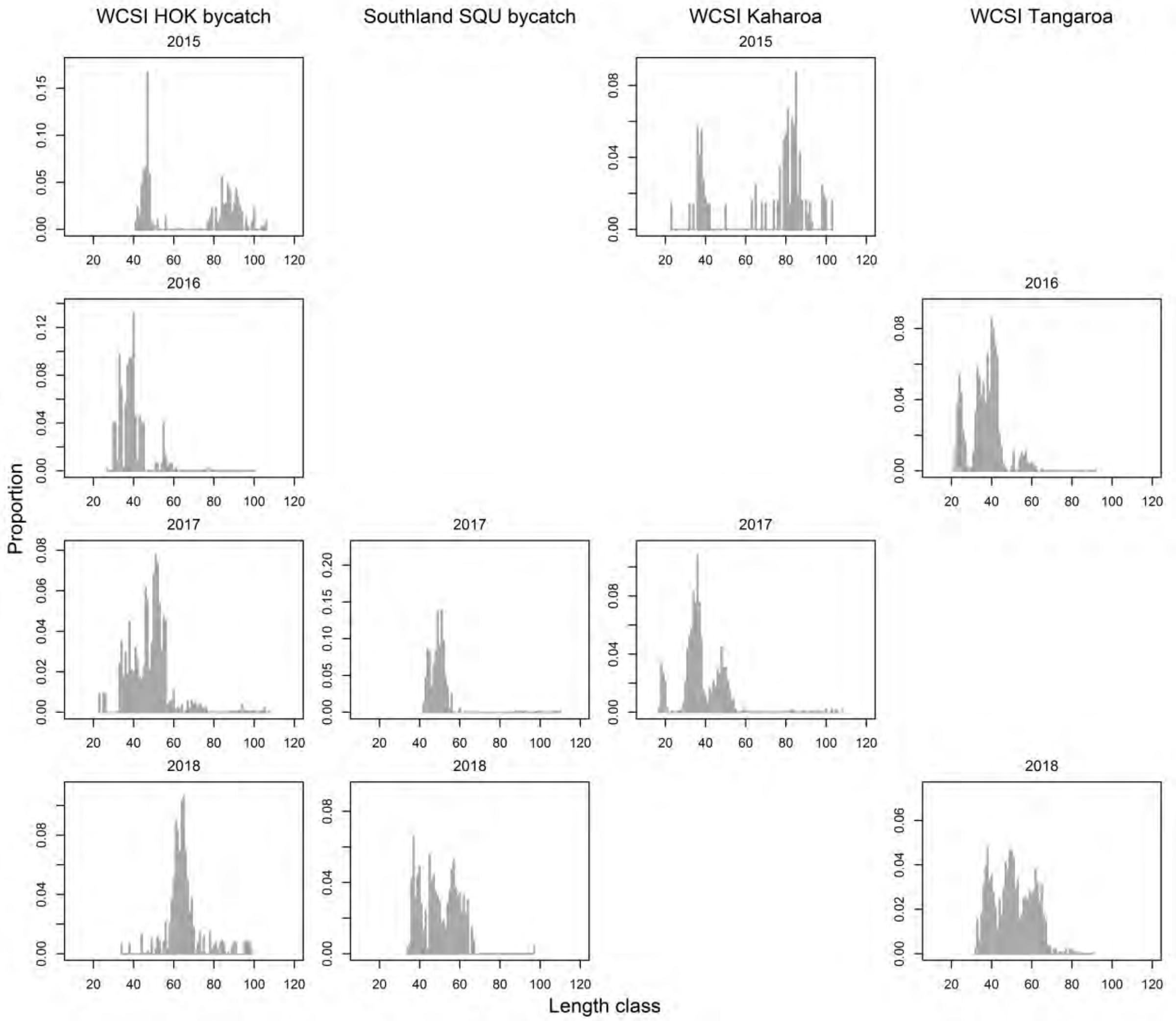


Figure 7: Length compositions (cm) of gemfish from the main commercial fisheries within SKI 3 and SKI 7 and the two WCSI trawl surveys from 2015 to 2018 (the years correspond to the end of the fishing year, 2015 represents the 2014–15 fishing year). The length modes at about 20 cm, 35 cm, 47 cm, 56 cm, and 64 cm represent the 0+, 1+, 2+, 3+ and 4+ age classes.

4.2.3 Exploratory population modelling

A preliminary age structured population model was configured to integrate the various data sets available from SKI 7 and extended to include the entire southern gemfish stock (SKI 3 and SKI 7). The data sets also included trawl survey biomass estimates and age composition data available from the *Tangaroa* Southland surveys (4 surveys 1993–1996) and biomass estimates from three earlier *Shinkai Maru* trawl surveys (3 surveys 1981–1983). Total annual catches were available from SKI 3 and SKI 7 for 1975 to 2017–18. Additional observer sampled length composition data were also available from the gemfish sampled from the Southland squid fishery (SKI 3) (14 years of observations).

The model was implemented in Stock Synthesis and configured as follows.

- Model period 1975–2018 (2018 = 2017–18 fishing year).
- Initial conditions equilibrium, unexploited in 1975 with the first year of catch in 1975.
- Population structure: two sexes, 15 age classes (1–15+), 1 cm length bins (10–110 cm).
- Biological parameters (natural mortality, growth, maturity, length-weight) as documented in Table 6.
- Single model region, i.e., spatial structure of fisheries not explicitly modelled.
- Beverton-Holt spawner-recruitment relationship (steepness h 0.85). Recruitment deviates 1975–2016, with models using sigmaR from 1.0 to 2.0.

- Abundance indices: four sets of trawl survey indices and SKI 7 CPUE indices *(all data or partial data* indices, with CV 0.30).
- Annual catches from two fisheries (SKI 3 and SKI 7) with allowance for under reporting pre- and post-QMS.
- Length-based selectivity functions. Logistic selectivities estimated for two commercial fisheries. Southland trawl surveys were assumed to have the equivalent selectivity to the SKI 3 fishery selectivity. Double normal selectivities estimated for *Kaharoa* and *Tangaroa* WCSI trawl surveys.

In general, the model provided a reasonable fit to most of the data sets. However, the fit to the *all data CPUE* indices was poor because the short period of high CPUE indices in 2003–04 and 2004–05 appears to be inconsistent with the annual catches and fishery length composition data from the following years (given the biological parameters of the species). The model yielded a much better fit to the *partial data CPUE* indices throughout the time series (1997–2018).

The model estimated a period of relatively high recruitment in the late 1970s-early 1980s, minimal recruitment during the late 1980s-1990s and intermittent recruitment during the 2000s. The model estimated exceptionally high recruitment estimates in 2014 and 2015 to fit the recent large increases in the CPUE indices and WCSI trawl survey biomass indices and the higher recent catches. The magnitude of these recent recruitment estimates is not consistent with the recruitment estimates for the entire preceding period. Further, the magnitudes of the recent recruitment estimates were inconsistent with the individual year classes evident in the length compositions from the 2018 WCSI fishery and *Tangaroa* trawl survey. It was only possible to appreciably improve the fit to the recent length compositions by excluding the last few years of CPUE indices and trawl survey biomass estimates and by reducing the catches in the terminal year.

The Working Group considered that the model was not sufficiently reliable to provide estimates of current biomass and stock status. Nonetheless, the Working Group considered that there was sufficient information available from the trawl surveys and commercial fisheries data to conclude that there has been a considerable increase in stock abundance in recent years due to strong cohorts from the 2014, 2015, and 2016 year classes.

4.3 Future research considerations

SKI 1 and SKI 2:

- Improved information on the size composition of gemfish taken in the tarakihi target fishery will enable better understanding of the component of the population being monitored by the TAR CPUE series. Available information on the size composition of gemfish taken in the TAR fishery is sparse, and is also limited to a single year in SKI 2.
- Investigate whether the trip-based aggregation masks subtle changes in fishing behaviour; e.g., a change of depth in the TAR target fishery to avoid gemfish. This should include an event-based index beginning in 2007–08.
- Evaluate the utility of conducting a fully quantitative stock assessment, including sampling to provide series of the length and age composition of catches made by the SKI 1 and SKI 2 gemfish target fisheries. This should ideally include reading otoliths previously collected in SKI 1E.
- Better sampling is needed to estimate the size at maturity of gemfish in SKI 1 and 2.
- Evaluate potential environmental influences on SKI distribution and recruitment. It is recognised that there is considerably more information available from the SKI 3 and 7 stocks and that these data provide the best opportunity to progress such an analysis and provide inferences about the dynamics of the SKI 1 and 2 stock.

5. STATUS OF THE STOCKS

Stock Structure Assumptions

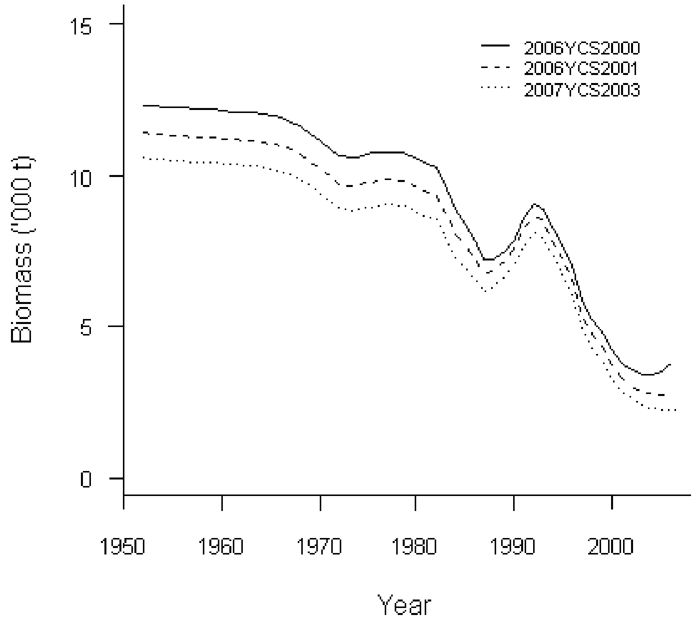
Gemfish are assessed as two biological stocks, based on spawning migration and timing and the location of spawning grounds. These stocks are managed and assessed separately and are assumed to be non-mixing. The SKI 1&2 stock is found off the east and west coasts of the North Island, with adults migrating north to spawn north of the North Island during May–June. The SKI 3&7 stock occurs in the south of New Zealand and migrates to the west coast South Island to spawn in August–September.

- **SKI 1&2**

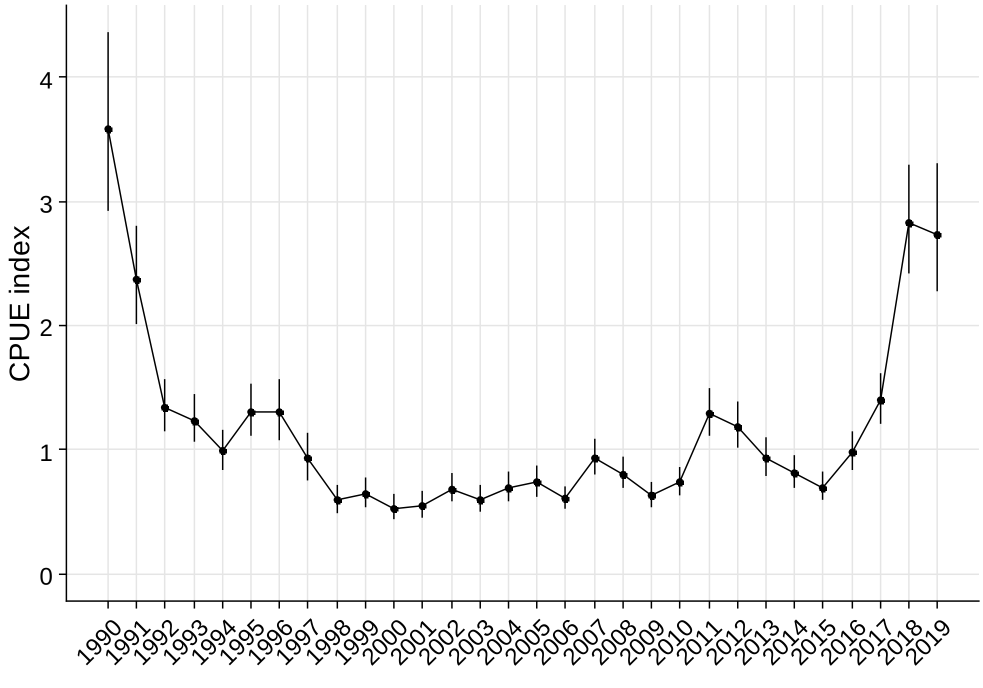
Stock Status	
Year of Most Recent Assessment	2008: Stock Assessment 2020: CPUE
Assessment Runs Presented	Stock Assessment Three cases are presented. There was no single preferred model. CPUE Update Trip based index from tarakihi target bottom trawl in SKI 1 and SKI 2
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	B_{2006} was estimated at 32% B_0 ($2006_{YCS2000}$) and 26% B_0 ($2006_{YCS2001}$), and B_{2007} at 22% B_0 ($2007_{YCS2003}$) in the three models. Unlikely (< 40%) to be at or above the target in 2006. The 2020 CPUE analysis indicates that the relative abundance of mixed sub-adult/adult fish taken by the tarakihi target fishery has increased at least threefold since 2007. Although biomass is increasing, it is not known whether the stock has reached or exceeded the target.
Status in relation to Limits	As B_{2006} was estimated to be Unlikely (< 40%) to be below both the Soft Limit and the Hard Limit and the relative abundance of SKI 1&2 has subsequently increased substantially: Spawning stock biomass in 2020 is Unlikely (< 40%) to be below the soft limit and Very Unlikely (< 10%) to be below the hard limit
Status in relation to Overfishing	Unknown

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The relative abundance of mixed sub-adult/adult fish taken by the tarakihi fishery has increased at least threefold since 2007
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Historical Stock Status Trajectory and Current Status



MPD biomass trajectories for the three model runs: *2006*$_{YCS2000}$, *2006*$_{YCS2001}$, and *2007*$_{YCS2003}$.



Biomass trajectory from the 2008 stock assessment (top); and standardised catch per unit effort (CPUE) index for mixed sub-adult/adult SKI 1 and SKI 2 from bottom trawling targeting tarakihi (BT-TAR trip index) (bottom).

Projections and Prognosis	
Stock Projections or Prognosis	The recent large increase in the subadult/adult tarakihi target CPUE index indicates that the spawning stock will increase in the short term (next 2–3 years).
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	For current (1 October 2019) TACC:Soft Limit: Very Unlikely (< 10%) Hard Limit: Very Unlikely (< 10%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	-

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Quantitative Stock Assessment (to 2006) Level 2 - Partial Quantitative Stock Assessment (2020)	
Assessment Method	2008: Age-structured CASAL model with Bayesian estimation of posterior distributions 2020: CPUE analysis	
Assessment Dates	Latest assessment: 2008; CPUE update: 2020	Next assessment: 2023
Overall assessment quality rank	2 – Medium or Mixed quality: stock assessment dates to 2008; CPUE update provides an index for mixed sub-adult/adult fish only	
Main data inputs (rank)	Stock Assessment - CPUE abundance indices separately for SKI 1 and SKI 2 up to 2001 - Proportions-at-age data CPUE Analysis - MPI catch and effort data for tarakihi bottom trawl	 1 – High quality 1 – High quality 1 – High quality
Data not used (rank)	- Target gemfish CPUE index	3 – Low Quality: sparse data, large changes in distribution of fishing effort and considerably reduced targeting
Changes to Model Structure and Assumptions	2008 assessment: incorporation of: - Age based selectivities - Differential natural mortality - Additional year of age data The 2020 CPUE update only retained an index for the tarakihi target fishery which takes mixed sub-adult and adult fish. The 2020 analysis used data from SKI 1 and SKI 2, whereas the 2014 analysis used SKI 2 data only.	
Major Sources of Uncertainty	2008 Stock Assessment Uncertainty in recent recruitment necessitated the development of multiple models; however, without more reliable abundance indices to estimate recent recruitment it is unwise to prefer a single model. 2020 CPUE The tarakihi target fishery does not sample the full depth distribution of gemfish and, based on limited data, appears to catch mostly sub-adult fish. The target gemfish fishery is now small and CPUE from this fishery does not currently provide an index of adult biomass after 2005.	

Qualifying Comments
Avoidance of gemfish in the tarakihi target trawl fishery may bias the BT-TAR CPUE index downwards

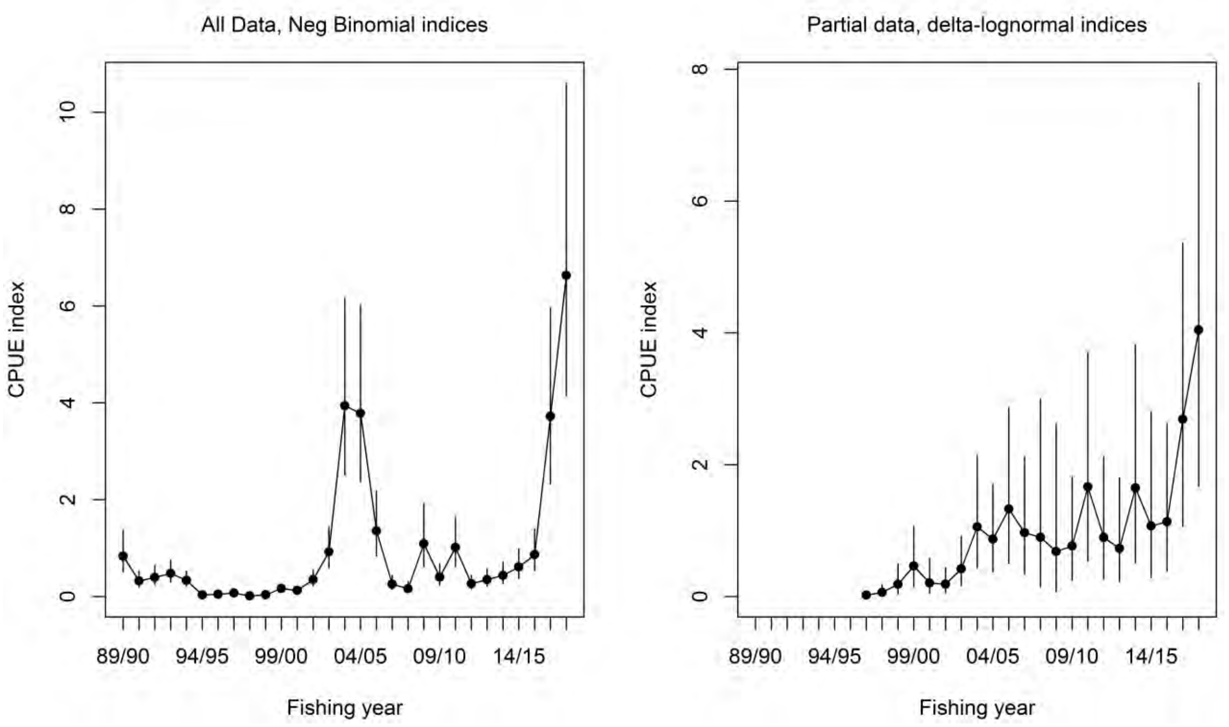
Fishery Interactions
Gemfish are common bycatch in the hoki, tarakihi, rubyfish and scampi target fisheries, and are also taken in gemfish target fishing. Bycatch of gemfish target fishing is variable but includes hoki and tarakihi.

- **SKI 3 & 7**

Updated CPUE analyses and preliminary stock assessments were conducted for SKI 3 & 7 in 2019. The preliminary stock assessment model was not considered sufficiently reliable to estimate current stock status.

Stock Status	
Year of Most Recent Assessment	2019
Assessment Runs Presented	Standardised CPUE indices (SKI 7 *all data CPUE* and *partial data CPUE* set), and trawl survey biomass indices: *Kaharoa* WCSI trawl surveys (1992–2017) and *Tangaroa* WCSI trawl surveys (2012–2018).
Reference Points	Target: 40% SB_0 Soft Limit: 20% SB_0 Hard Limit: 10% SB_0 Overfishing threshold: *FSB40%*
Status in relation to Target	$SB_{2017–18}$ is Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unlikely (< 40%) to be below
Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring

Historical Stock Status Trajectory and Current Status



All data **and** ***partial data CPUE*** **indices derived from the bycatch of gemfish from the WCSI hoki fishery.**

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass has increased considerably from 2015 following improved recruitment during the last five years.
Recent Trend in Fishing Intensity or Proxy	Catches have increased in line with increased biomass over the last few years. Fishing intensity has likely decreased in recent years.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	The length compositions from the recent trawl surveys revealed three consecutive year classes that have started to recruit to the commercial fishery.

Projections and Prognosis	
Stock Projections or Prognosis	Given recent recruitments, stock size is likely to increase over the short term (1–3 years).
Probability of Current Catch or TACC causing biomass to remain below or to decline below Limits	Current Catch or TACC Soft Limit: Unknown Hard Limit: Unlikely (< 40%) to decline below over 1–3 years
Probability of Current Catch or TACC causing overfishing to continue or to commence	TACC Unlikely (< 40%) Current catch: Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE indices, trawl survey biomass indices	
Assessment Dates	Latest assessment: 2019	Next assessment: Unknown
Overall assessment of quality rank	1 – High Quality	
Main data inputs (rank)	- Commercial catch history - CPUE indices - *Kaharoa* trawl survey abundance estimates and length frequencies - *Tangaroa* trawl survey abundance estimates and length frequencies - Recent commercial length frequency	1 – High Quality 2 – Medium or Mixed Quality: large confidence intervals in recent years 1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	The previous stock assessment model (1997) is no longer applicable. This assessment is based on CPUE and trawl survey indices.	
Major Sources of Uncertainty	While the CPUE indices and trawl survey biomass indices reveal stock abundance has increased considerably in recent years, the indices do not provide an indication of the level of current stock biomass relative to historical (unfished) levels (SB_0). The increase in biomass according to the most recent CPUE indices are poorly determined. The magnitude of the recent increase in stock biomass is dependent on the strength of the recent year classes which are poorly determined.	

Qualifying Comments
- The *Kaharoa* WCSI trawl survey monitors the juvenile component of the stock. The survey does not fully monitor the adult component of the stock due to the timing and extent of the survey. - The time series of WCSI *Tangaroa* trawl surveys is relatively limited. - Standardised CPUE indices from the WCSI hoki fishery are likely to be influenced by changes in the operation of the hoki fishery. - Although there are uncertainties for this assessment, catches at the level of 2017–18 are unlikely to result in a reduction of biomass over the next 1–3 years.

Fishery Interactions
Gemfish is predominantly caught as a bycatch of the WCSI hoki fishery (SKI 7) and the Southland squid trawl fishery (SKI 3). There is also a significant catch of gemfish taken by the WCSI inshore trawl fishery (SKI 7). The associated species in these fisheries are the same as for the relevant target fisheries (e.g., squid and hoki).

Table 12: Summary of yields (t) from base case assessments, TACCs (t) and reported landings (t) for gemfish for the most recent fishing year.

Fishstock	QMA	FMAs	*MCY*	*CAY*	2018–19 Actual TACC	2018–19 Reported landings
SKI 1	Auckland (East) (West)	1 & 9 }			210	354
SKI 2	Central (East)	2 }	816	-	240	328
SKI 3	South-East (Coast) (Chatham), Southland, Sub-Antarctic	3, 4, 5, & 6 }			300	577
SKI 7	Challenger, Central (West)	7 & 8 }	990–2 770	-	300	937
SKI 10	Kermadec	10	-	-	10	0
Total					1 060	2 196

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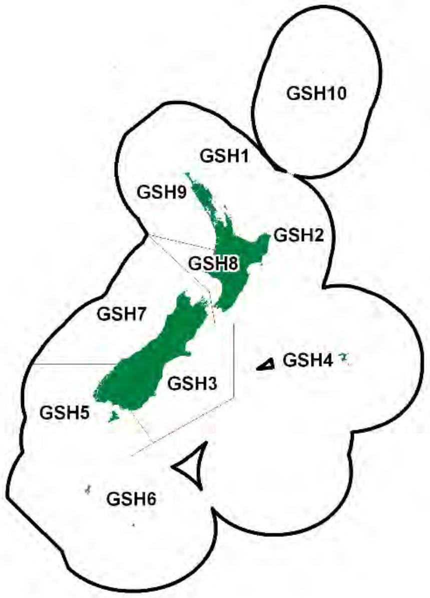
DARK GHOST SHARK (GSH)

(*Hydrolagus novaezealandiae*)



1. FISHERY SUMMARY

1.1 Commercial fisheries

Two species (dark and pale ghost sharks) make up effectively all commercial ghost shark landings. Dark ghost shark (*Hydrolagus novaezealandiae*) was introduced into the QMS from the beginning of the 1998–99 fishing year for the 10 FMAs shown above.

Both ghost shark species are taken almost exclusively as a bycatch of other target trawl fisheries. In the 1990s, about 43% of ghost sharks were landed as a bycatch of the hoki fishery, with fisheries for silver warehou, arrow squid and barracouta combining to land a further 36%. The two ghost shark species were seldom differentiated on catch landing returns prior to the start of the 1998–99 fishing year. Estimated landings of both species by foreign licensed and joint venture vessels over the period 1 April 1978 to 30 September 1983 are presented in Table 1. Landings by domestic (inshore) vessels would have been negligible during this time period. The unknown quantities of ghost sharks that were discarded and not recorded will have resulted in an under-reported total, particularly before both species were included in the QMS.

In the early to mid-1980s about half of the reported ghost shark landings were from FMA 3. Virtually all the additional catch was spread over FMAs 4–7. In 1988–89, landings from west coast South Island (FMA 7) began to increase, almost certainly associated with the development of the hoki fishery. In 1990–91, significant landing increases were apparent on the Chatham Rise, off southeast South Island and on the Campbell Plateau. The development of fisheries for non-spawning hoki were probably responsible for these increases.

Estimated landings of dark ghost shark by QMA are shown in Tables 2 and 3, while the historical landings and TACC for the main GSH stocks are depicted in Figure 1. Landings from 1983–84 to 1994–95 were derived by splitting all reported ghost shark landings into depth and area bins, and allocating to species based on distribution data derived from trawl surveys (*see* section 2). Landings from 1995–96 to 1998–99 were estimated assuming dark ghost shark made up 70% of the total ghost shark catch in FMAs 5 and 6, and 75% in all other FMAs. However this approach assumes that the proportion that each species contributes to the whole is consistent from year to year and does not change in response to various sources of mortality, fishing-induced or otherwise. As such, the data covered by this period of time should be treated with caution. Catches from the 1999–00 fishing year are more reliable, when pale ghost shark had also been included in the QMS, bringing both under the system.

Table 1: Reported landings (t) of both ghost shark species by fishing year and EEZ area, taken by foreign licensed and joint venture vessels. An approximation of these areas with respect to current QMA boundaries is used to assign catches to QMAs. No data are available for the 1980–81 fishing year.

Year												EEZ Area	
	B	**C(M)**	**C(1)**	**D**	**E(B)**	**E(P)**	**E(C)**	**E(A)**	**F(E)**	**F(W)**	**G**	**H**	**Total**
QMA	1&2	3	4	6	5	7	8						
78–79*	1	37	99	26	3	16	11	88	90	8	68	17	465
79–80*	1	55	54	426	10	4	28	138	183	7	1	5	912
80–81*													-
81–82*	0	84	28	117	0	2	6	29	71	9	4	0	350
82–83*	0	108	35	84	0	2	17	98	99	29	1	1	474
83–83#	0	84	41	73	0	0	17	5	16	17	0	0	253

* 1 April to 31 March # 1 April to 30 Sept.

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	GSH 1	GSH 2	GSH 3	GSH 4	Year	GSH 1	GSH 2	GSH 3	GSH 4
1931–32	0	0	0	0	1957	0	0	0	0
1932–33	0	0	0	0	1958	0	0	0	0
1933–34	0	0	0	0	1959	0	0	0	0
1934–35	0	0	0	0	1960	0	0	0	0
1935–36	0	0	0	0	1961	0	0	0	0
1936–37	0	0	0	0	1962	0	0	0	0
1937–38	0	0	0	0	1963	0	0	0	0
1938–39	0	0	0	0	1964	0	0	0	0
1939–40	0	0	0	0	1965	0	0	0	0
1940–41	0	0	0	0	1966	0	0	0	0
1941–42	0	0	0	0	1967	0	0	0	0
1942–43	0	0	0	0	1968	0	0	0	0
1943–44	0	0	0	0	1969	0	0	0	0
1944	0	0	0	0	1970	0	0	0	0
1945	0	0	0	0	1971	0	0	0	0
1946	0	0	0	0	1972	0	0	103	0
1947	0	0	0	0	1973	0	0	0	0
1948	0	0	0	0	1974	0	0	7	0
1949	0	0	0	0	1975	0	0	8	0
1950	0	0	0	0	1976	0	0	19	0
1951	0	0	0	0	1977	0	0	2	0
1952	0	0	0	0	1978	0	0	54	0
1953	0	0	0	0	1979	0	2	486	383
1954	0	0	0	0	1980	0	0	150	230
1955	0	0	0	0	1981	0	0	233	243
1956	0	0	0	0	1982	0	0	320	97

Year	GSH 5	GSH 6	GSH 7	GSH 8	Year	GSH 5	GSH 6	GSH 7	GSH 8
1931–32	0	0	0	0	1957	0	0	0	0
1932–33	0	0	0	0	1958	0	0	0	0
1933–34	0	0	0	0	1959	0	0	0	0
1934–35	0	0	0	0	1960	0	0	0	0
1935–36	0	0	0	0	1961	0	0	0	0
1936–37	0	0	0	0	1962	0	0	0	0
1937–38	0	0	0	0	1963	0	0	0	0
1938–39	0	0	0	0	1964	0	0	0	0
1939–40	0	0	0	0	1965	0	0	0	0
1940–41	0	0	0	0	1966	0	0	0	0
1941–42	0	0	0	0	1967	0	0	0	0
1942–43	0	0	0	0	1968	0	0	0	0
1943–44	0	0	0	0	1969	0	0	0	0
1944	0	0	0	0	1970	0	0	0	0
1945	0	0	0	0	1971	0	0	0	0
1946	0	0	0	0	1972	11	0	0	0
1947	0	0	0	0	1973	0	0	0	0
1948	0	0	0	0	1974	1	0	0	0
1949	0	0	0	0	1975	1	0	0	0
1950	0	0	0	0	1976	2	0	0	1
1951	0	0	0	0	1977	0	0	0	0
1952	0	0	0	0	1978	100	30	15	2
1953	0	0	0	0	1979	178	131	268	2
1954	0	0	0	0	1980	92	144	144	28
1955	0	0	0	0	1981	111	35	17	17
1956	0	0	0	0	1982	223	29	11	7

Notes:

The 1931–1943 years are April–March but from 1944 onwards are calendar years. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data includes both foreign and domestic landings. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

Table 3: Estimated landings (t) of dark ghost shark by Fishstock from 1982–83 to 2018–19, based on reported landings of both ghost shark species combined, and actual TACCs set from 1998–99..

Fishstock	GSH 1		GSH 2		GSH 3		GSH 4		GSH 5	
FMA (s)	1		2		3		4		5	
	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC
1982–83*	1	-	< 1	-	151	-	65	-	35	-
1983–84*	0	-	< 1	-	185	-	65	-	42	-
1984–85*	< 1	-	4	-	136	-	95	-	50	-
1985–86*	< 1	-	1	-	276	-	60	-	30	-
1986–87	3	-	13	-	472	-	97	-	34	-
1987–88	4	-	< 1	-	539	-	53	-	49	-
1988–89	9	-	27	-	460	-	21	-	67	-
1989–90	1	-	14	-	383	-	29	-	78	-
1990–91	1	-	40	-	665	-	271	-	70	-
1991–92	4	-	7	-	444	-	179	-	81	-
1992–93	8	-	5	-	399	-	151	-	76	-
1993–94	7	-	7	-	569	-	144	-	51	-
1994–95	3	-	2	-	737	-	187	-	63	-
1995–96	13	-	37	-	678	-	253	-	71	-
1996–97	17	-	66	-	817	-	402	-	94	-
1997–98	17	-	17	-	767	-	262	-	70	-
1998–99	18	15	60	37	950	1 187	318	373	64	109
1999–00	15	15	51	37	938	1 187	173	373	71	109
2000–01	15	10	50	33	1 111	1 185	179	370	85	109
2001–02	22	10	52	33	1 068	1 185	241	370	76	109
2002–03	17	10	58	33	1 371	1 185	265	370	93	109
2003–04	21	10	84	33	894	1 185	157	370	45	109
2004–05	14	10	74	33	880	1 185	282	370	80	109
2005–06	20	10	57	33	583	1 185	318	370	61	109
2006–07	20	22	60	66	654	1 185	396	370	115	109
2007–08	19	22	100	66	484	1 185	562	370	67	109
2008–09	14	22	71	66	490	1 185	251	370	61	109
2009–10	13	22	64	66	520	1 185	233	370	108	109
2010–11	17	22	95	66	640	1 185	311	370	73	109
2011–12	11	22	57	66	497	1 185	482	370	72	109
2012–13	12	22	51	66	420	1 185	210	370	111	109
2013–14	15	22	83	89	667	1 185	201	370	53	109
2014–15	16	22	44	89	406	1 185	217	370	42	109
2015–16	21	22	38	89	547	1 185	217	370	56	109
2016–17	21	22	47	89	493	1 185	223	370	83	109
2017–18	21	22	53	89	584	1 185	198	370	63	109
2018–19	28	22	40	89	528	1 185	166	370	51	109

Fishstock	GSH 6		GSH 7		GSH 8		GSH 9			
FMA (s)	6		7		8		9		Total	
	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC
1982–83*	19	-	10	-	< 1	-	0	-	282	-
1983–84*	56	-	38	-	< 1	-	0	-	387	-
1984–85*	61	-	63	-	< 1	-	0	-	409	-
1985–86*	41	-	31	-	3	-	0	-	442	-
1986–87	36	-	71	-	4	-	0	-	729	-
1987–88	6	-	68	-	1	-	0	-	720	-
1988–89	6	-	133	-	2	-	0	-	725	-
1989–90	9	-	180	-	27	-	0	-	722	-
1990–91	94	-	217	-	3	-	0	-	1 361	-
1991–92	80	-	124	-	3	-	1	-	923	-
1992–93	68	-	221	-	11	-	0	-	938	-
1993–94	53	-	513	-	14	-	0	-	1 357	-
1994–95	61	-	703	-	3	-	0	-	1 778	-
1995–96	68	-	548	-	8	-	3	-	1 679	-
1996–97	135	-	926	-	9	-	11	-	2 477	-
1997–98	136	-	170	-	3	-	12	-	1 454	-
1998–99	110	95	409	1 121	7	12	22	14	1 958	2 963
1999–00	117	95	466	1 121	19	12	25	14	1 875	2 963
2000–01	76	95	475	1 121	22	12	31	8	2 043	2 943
2001–02	94	95	463	1 121	22	12	25	8	2 063	2 943
2002–03	99	95	593	1 121	15	12	20	8	2 531	2 943
2003–04	72	95	652	1 121	27	12	12	8	1 964	2 943
2004–05	53	95	694	1 121	31	12	10	8	2 118	2 943
2005–06	31	95	625	1 121	22	12	8	8	1 725	2 943
2006–07	43	95	696	1 121	16	22	6	22	2 006	3 012
2007–08	36	95	601	1 121	29	22	13	22	1 911	3 012
2008–09	49	95	991	1 121	24	22	16	22	1 967	3 012
2009–10	19	95	1 037	1 121	29	22	6	22	2 028	3 012
2010–11	38	95	1 129	1 121	33	22	6	22	2 341	3 012
2011–12	37	95	1 041	1 121	37	22	6	22	2 240	3 012
2012–13	70	95	767	1 121	32	22	10	22	1 683	3 012
2013–14	72	95	691	1 121	27	34	9	22	1 817	3 047
2014–15	72	95	458	1 121	20	34	7	22	1 283	3 047
2015–16	64	95	400	1 121	19	34	6	22	1 368	3 047
2016–17	59	95	423	1 121	19	34	14	22	1 382	3 047
2017–18	71	95	329	1 121	18	34	25	22	1 363	3 047
2018–19	68	95	485	1 121	21	34	19	22	1 406	3 047

* FSU data.

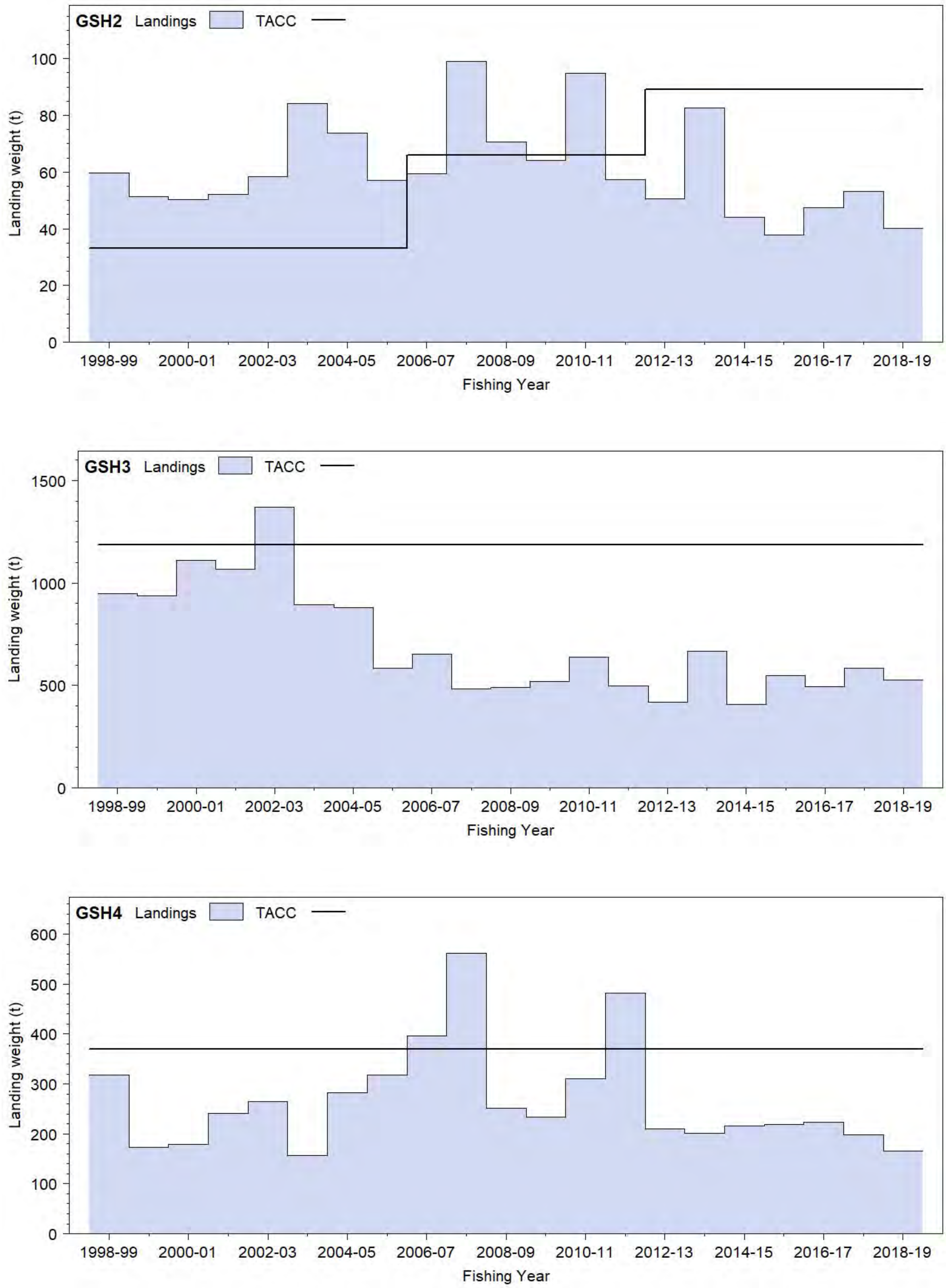


Figure 1: Reported commercial landings and TACC for GSH stocks. From top GSH 2 (Central East), GSH 3 (South East Coast), GSH 4 (South East Chatham Rise). [Continued on next page]

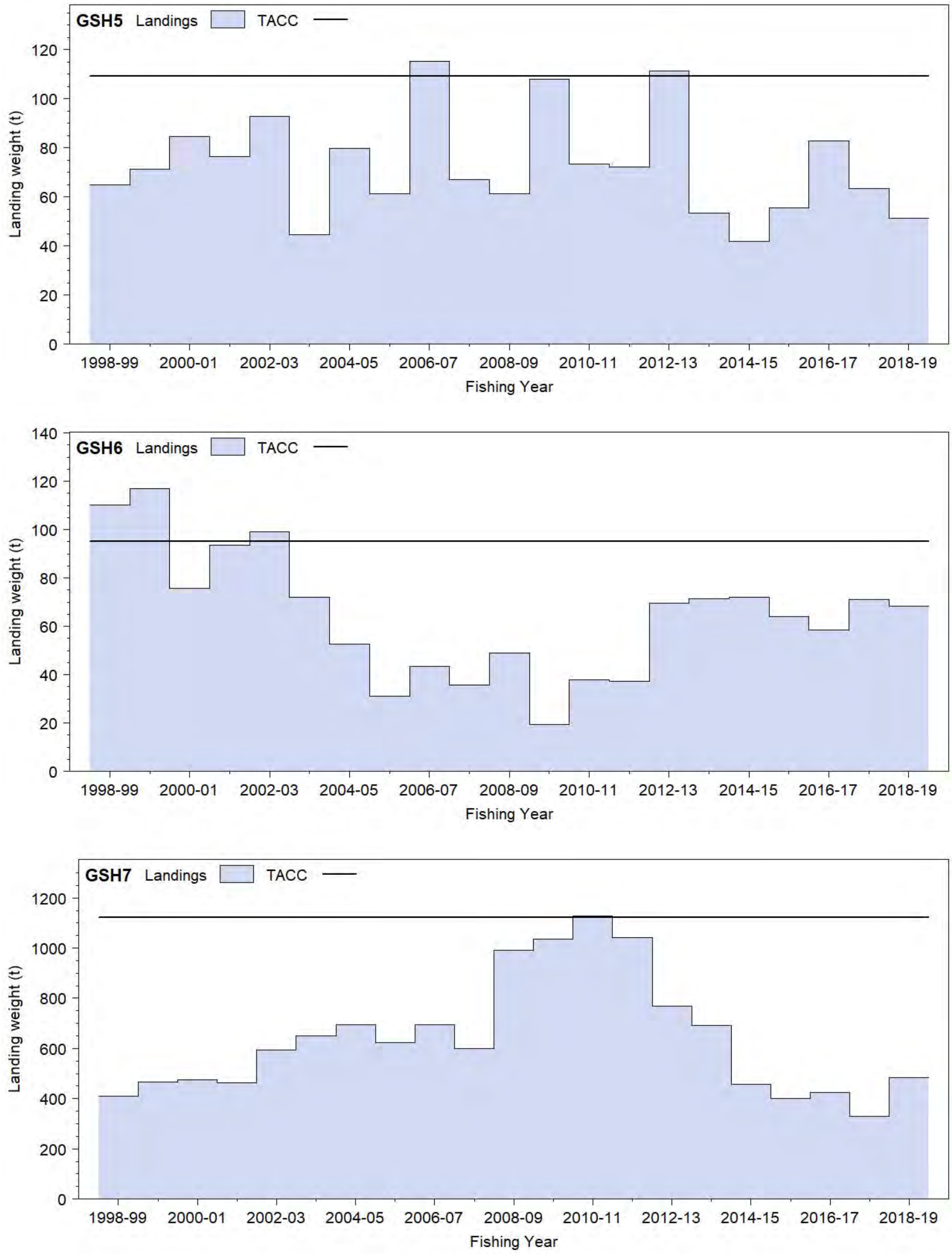


Figure 1 [Continued]: Reported commercial landings and TACC for GSH stocks. From top GSH 5 (Southland), GSH 6 (Sub-Antarctic), and GSH 7 (West Coast South Island).

The TACs currently applied to dark ghost shark were initially intended to apply to a combined fishery for both species, and were based on the average catch of both species over various periods (see the "Review of Sustainability Measures and Other Management Controls for the 1998–99 Fishing Year - Final Advice Paper" dated 6 August 1998). No allowance for non-commercial interests was included in the final allocation because recreational and customary non-commercial catches are likely to be very small due to the depth distribution of this species.

TACCs were increased from 1 October 2006 in GSH 1 to 22 t, in GSH 2 to 66 t, in GSH 8 to 22 t and in GSH 9 to 22 t. In these stocks landings had been above the TACC for a number of years and the TACCs were increased to the average of the previous 7 years plus an additional 10%. In GSH 2 and 8 landings continued to consistently exceed the TACCs after 2006. Consequently the TACCs were further increased to 89 t in GSH 2 and 34 t in GSH 8 in 2013. Landings have remained below the TACCs for all GSH stocks since 2013.

1.2 Recreational fisheries

Current catches of dark ghost sharks by recreational fishers are believed to be negligible in all areas.

1.3 Customary non-commercial fisheries

Quantitative information on the current level of customary non-commercial catch is not available but is likely to be negligible

1.4 Illegal catch

Quantitative information on the level of illegal catch is not available. In 1998–99 (when dark ghost shark were in the QMS, but pale ghost shark were not), a quantity of dark ghost shark were reported as pale ghost shark.

1.5 Other sources of mortality

Ghost sharks have been dumped and not reported in the past by commercial fishers in QMAs 1 and 2. Similar behaviour is believed to occur in all other QMAs. The extent of the unreported dumping is unknown in all areas.

2. BIOLOGY

Dark ghost shark (*Hydrolagus novaezelandiae*) occur through much of the New Zealand EEZ in depths from 30 to 850 m, but they are sparse north of 40° S and have not been recorded from the Bounty Platform. They are most abundant in waters 150–500 m deep on the west coast of the South Island and the Chatham Rise, and in depths of 150–700 m on the Stewart-Snares shelf and Southland/sub-Antarctic. Smaller sharks (under 40 cm chimaera length) are more abundant in waters shallower than 200 m, particularly in the Canterbury Bight.

Trawl surveys show that dark and pale ghost shark exhibit niche differentiation, with water depth being the most influential factor, although there is some overlap of habitat. On the Chatham Rise, the main overlap range appears quite compact (from about 340 to 540 m). In the Southland/sub-Antarctic region, the overlap range is wider (about 350 to 770 m). Stomach contents indicate that both species are predominantly benthic feeders.

No published information is available on the age or growth rate of any *Hydrolagus* species, or even any species in the family Chimaeridae. A research report by Francis & Ó Maolagáin (2001) found that eye lens diameter showed potential as an ageing technique but further work was needed. They calculated Von Bertalanffy parameters (Table 4) from trawl survey caught fish and found that growth rates were similar and moderately rapid for males and females with both sexes reaching 50 cm in 5–9 years. They caution the use of these parameters, however, as ageing of dark ghost sharks has not been validated. Length-frequency histograms indicate that females grow to a larger size than males. Without population age structures or confident estimates of longevity, it is not possible to estimate natural or total mortalities.

On the Chatham Rise, the estimated size at 50% sexual maturity for dark ghost sharks is 52–53 cm for males and 62–63 cm for females. As for most other elasmobranchs, ghost shark fecundity is likely to be low.

Length-weight parameters are shown in Table 5.

Table 4: Von Bertalanffy growth parameters for dark ghost shark. Source: Francis & Ó Maolagáin (2001).

		Von Bertalanffy growth parameters		
Region	**Sex**	L_∞	**K**	t_0
East coast South Island	Female	135.3	0.052	–0.94
	Male	89.0	0.091	–0.61
West coast South Island	Female	123.0	0.065	–1.15
	Male	123.4	0.044	–1.43
Stewart–Snares Shelf	Female	122.1	0.087	–1.01
	Male	108.0	0.073	–1.34
Chatham Rise	Female	97.0	0.090	–1.17
	Male	-	-	-

Table 5: Length-weight parameters for dark ghost shark.

1. Weight = a (length)^b (Weight in g, length in cm chimaera length)

FMA	Estimate		
	a	**b**	**Source**
Chatham Rise	0.002986	3.170546	O'Driscoll et al (2011)
Sub-Antarctic	0.001653	3.3256	Bagley et al (2013)

3. STOCKS AND AREAS

The only information which may indicate a stock boundary is an apparent difference in maximum size of dark ghost sharks, with both males and females from the Chatham Rise attaining a maximum size 3–4 cm greater than those in Southland/sub-Antarctic waters.

Horn (1997) proposed that ghost sharks be managed as three Fishstocks, i.e., east coast New Zealand (FMAs 1–4), Stewart-Snares shelf and Campbell Plateau (FMAs 5 and 6), and west coast New Zealand (FMAs 7, 8, and 9). Areas of narrow continental shelf separate these FMA groupings, so they could well provide barriers to stock mixing for pale ghost shark which have a preference for deeper water. This would be less influential for dark ghost shark, however, which are found much shallower. Pale ghost shark were given the QMAs recommended by Horn when introduced into the QMS, but dark ghost shark were already based on the generic FMAs.

4. STOCK ASSESSMENT

No assessment of any stocks of dark ghost shark has been completed. Therefore, no estimates of yield are available.

4.1 Estimates of fishery parameters and abundance

Estimates of fishery parameters are not available for dark ghost sharks. Several time series of relative biomass estimates are available from fishery independent trawl surveys (Table 6), but wide fluctuations between years suggest the need for caution in using these as indicators of relative abundance. The Chatham Rise time series may provide a reasonable index of abundance for GSH 4, but not GSH 3 as the survey does not fish shallower than 200 m where dark ghost shark are abundant. Much of GSH 3 is covered by the winter east coast South Island trawl survey however, which is optimised for dark ghost shark among other species.

4.2 Biomass estimates

Biomass estimates from various trawl surveys are given in Table 6. Of those, ongoing estimates are available from random stratified bottom trawl surveys from the east coast South Island, Chatham Rise, sub-Antarctic, and west coast South Island trawl surveys.

Table 6: Biomass indices (t) and coefficients of variation (CV). Estimates for the Chatham Rise and sub-Antarctic summer surveys on *Tangaroa* are for core strata only (200–800 and 300–800 m respectively). **[Continued on next page]**

FMA	Area	Vessel	Trip code	Date	Biomass	% CV
3 & 4	Chatham Rise	*Tangaroa*	TAN9106	Jan-Feb 1992	6 700	11.1
			TAN9212	Jan-Feb 1993	5 950	9.2
			TAN9401	Jan-94	10 360	15.3
			TAN9501	Jan-95	3 490	11.2
			TAN9601	Jan-96	6 170	12.4
			TAN9701	Jan-97	6 240	11.7
			TAN9801	Jan-98	6 720	14.1
			TAN9901	Jan-99	12 125	23.4
			TAN0001	Jan-00	9 154	25.2
			TAN0101	Jan-01	10 356	12
			TAN0201	Jan-02	9 997	11.1
			TAN0301	Jan-03	10 341	9.1
			TAN0401	Jan-04	10 471	15
			TAN0501	Jan-05	11 885	16.3
			TAN0601	Jan-06	11 502	12
			TAN0701	Jan-07	7 852	11
			TAN0801	Jan-08	9 391	10.9
			TAN0901	Jan-09	8 445	13.7
			TAN1001	Jan-10	11 596	16.8
			TAN1101	Jan-11	6 588	17
			TAN1201	Jan-12	13 162	20.6
			TAN1301	Jan-13	11 723	11.6
			TAN1401	Jan-14	9 050	18
			TAN1601	Jan-16	11 925	12
5 & 6	Southland	*Tangaroa*	TAN9105	Nov-Dec 1991	1 030	25.4
	Sub-Antarctic	(summer)	TAN9211	Nov-Dec 1992	710	43.2
			TAN9310	Nov-Dec 1993	1 060	33.6
			TAN0012	Nov-Dec 2000	1 459	89.6
			TAN0118	Nov-Dec 2001	1 391	35.7
			TAN0219	Nov-Dec 2002	175	37.7
			TAN0317	Nov-Dec 2003	382	48.9
			TAN0414	Nov-Dec 2004	843	41.7
			TAN0515	Nov-Dec 2005	517	40
			TAN0617	Nov-Dec 2006	354	32
			TAN0714	Nov-Dec 2007	659	37
			TAN0813	Nov-Dec 2008	1128	32
			TAN0911	Nov-Dec 2009	433	43
			TAN1117	Nov-Dec 2011	3 709	75
			TAN1215	Nov-Dec 2012	1 794	68.3
		Tangaroa	TAN9204	Mar-Apr 1992	3 740	48.6
		(autumn)	TAN9304	Apr-May 1993	750	44.7
			TAN9605	Mar-Apr 1996	3 080	47.6
			TAN9805	Apr-May 1998	2 490	44
5	Stewart-Snares#	*Tangaroa*	TAN9301	Feb-Mar 1993	120	44
			TAN9402	Feb-Mar 1994	490	43
			TAN9502	Feb-Mar 1995	790	71
			TAN9604	Feb-Mar 1996	1 870	63
2	East coast	*Kaharoa*	KAH9304	Mar-Apr 1993	450	61.5
	North Island		KAH9402	Feb-Mar 1994	40	41.3
			KAH9502	Feb-Mar 1995	10	48.6
			KAH9602	Feb-Mar 1996	80	33.5
3	ECSI	*Kaharoa*	KAH9105	May-91	962	42
	winter surveys		KAH9205	May-92	934	44
			KAH9306	May-93	2 911	42
			KAH9406	May-94	2 702	25
			KAH9606	May-96	3 176	23
			KAH0705	May-07	4 483	25
			KAH0806	May-June-08	3 763	20
			KAH0905	May-Jun-09	4 330	24
			KAH1207	Apr-Jun-13	10 704	29
			KAH1402	Apr-Jun-14	13 137	26
			KAH1605	Apr-Jun-16	15 271	26
			KAH1803	Apr-Jun-18	6 485	23

Table 6 [continued]

FMA	Area	Vessel	Trip code	Date	Biomass	% CV
3	ECSI	*Kaharoa*	KAH9618	Dec ’96 - Jan ’97	3 066	18
	summer surveys		KAH9704	Dec ’97 - Jan ’98	5 870	33
			KAH9809	Dec ’98 - Jan ’99	7 416	27
			KAH9917	Dec ’99 - Jan ’00	2 512	19
			KAH0014	Dec ’00 - Jan ’01	2 950	18
7	West coast	*Kaharoa*	KAH9204	Mar-Apr 1992	380	20
	South Island		KAH9404	Mar-Apr 1994	720	14.3
			KAH9504	Mar-Apr 1995	770	23.7
			KAH9701	Mar-Apr 1997	1 590	21.2
			KAH0004	Mar-Apr 2000	2 260	9
			KAH0304	Mar-Apr 2003	540	15
			KAH0503	Mar-Apr 2005	830	22
			KAH0704	Mar-Apr 2007	2 215	21
			KAH0904	Mar-Apr 2009	900	17
			KAH1104	Mar-Apr 2011	2 363	23
			KAH1305	Mar-Apr 2013	981	23

East coast South Island winter trawl surveys

Total biomass in the east coast South Island winter surveys core strata (30–400 m) increased 16-fold between 1992 and 2016, but declined substantially in 2018 to 6485 t (Table 6, Figure 2) (MacGibbon et al. 2019). All surveys had a large component of pre-recruit biomass ranging from 30–61%. In 2018 the pre-recruit biomass was 42% of total biomass. The juvenile and adult biomass (based on length-at-50% maturity) of both sexes have generally increased proportionately over the time series and juvenile biomass comprised about half of the total biomass. In 2018 the juvenile biomass was 40% of total biomass.

Distribution over the ECSI winter trawl survey time series was similar and was confined to the continental slope and edge mainly in the Canterbury Bight, although the larger biomass from 2007 to 2016 is commensurate with a slightly expanded distribution throughout the survey area in this depth range and into Pegasus Bay. The size distributions in each of the last eleven surveys (1993–2016) were similar and generally bimodal (Beentjes et al 2016). The 2012, 2014 and 2016 length frequency distributions were distinct from previous years with relatively large numbers of adults or mature fish. These larger fish still account for a large proportion of the total in 2018 although overall numbers are lower than in 2016. The distributions differ from those of the Chatham Rise and Southland/Sub-Antarctic surveys (O'Driscoll & Bagley 2001, Livingston et al. 2002, Stevens et al. 2015, Bagley et al. 2017) in that ECSI has a large component of juvenile fish, suggesting that this area may be an important nursery ground for dark ghost shark.

Chatham Rise winter trawl surveys

The Chatham Rise trawl survey time series is not optimised for dark ghost shark and there has been some year-to-year variation between surveys, particularly for the first ten years (Figure 3). This time series may provide a reasonable index of abundance for that part of the eastern fishery (see Section 5) covered by GSH 4. However the survey extends into GSH 3 where commercial catches of dark ghost shark are significant but shallower than the survey’s starting depth of 200 m.

Sub-Antarctic winter trawl surveys

Biomass indices from the sub-Antarctic trawl survey time series are significantly lower than those for the east coast South Island and Chatham Rise surveys. Indices have fluctuated somewhat (Figure 4). The large spike seen in 2011 is due to randomly allocated stations within stratum 6 (300–600 m) being located at the shallower, northern end of the stratum where dark ghost shark are more likely to be encountered. The starting depth of 300 m may mean that this survey is unlikely to be a reliable index of abundance.

West coast South Island winter trawl surveys

Biomass estimates from the west coast South Island inshore trawl survey are lower than those from the east coast South Island and Chatham Rise surveys. Estimates fluctuate considerably and are unlikely to reflect real changes in abundance (Figure 5).

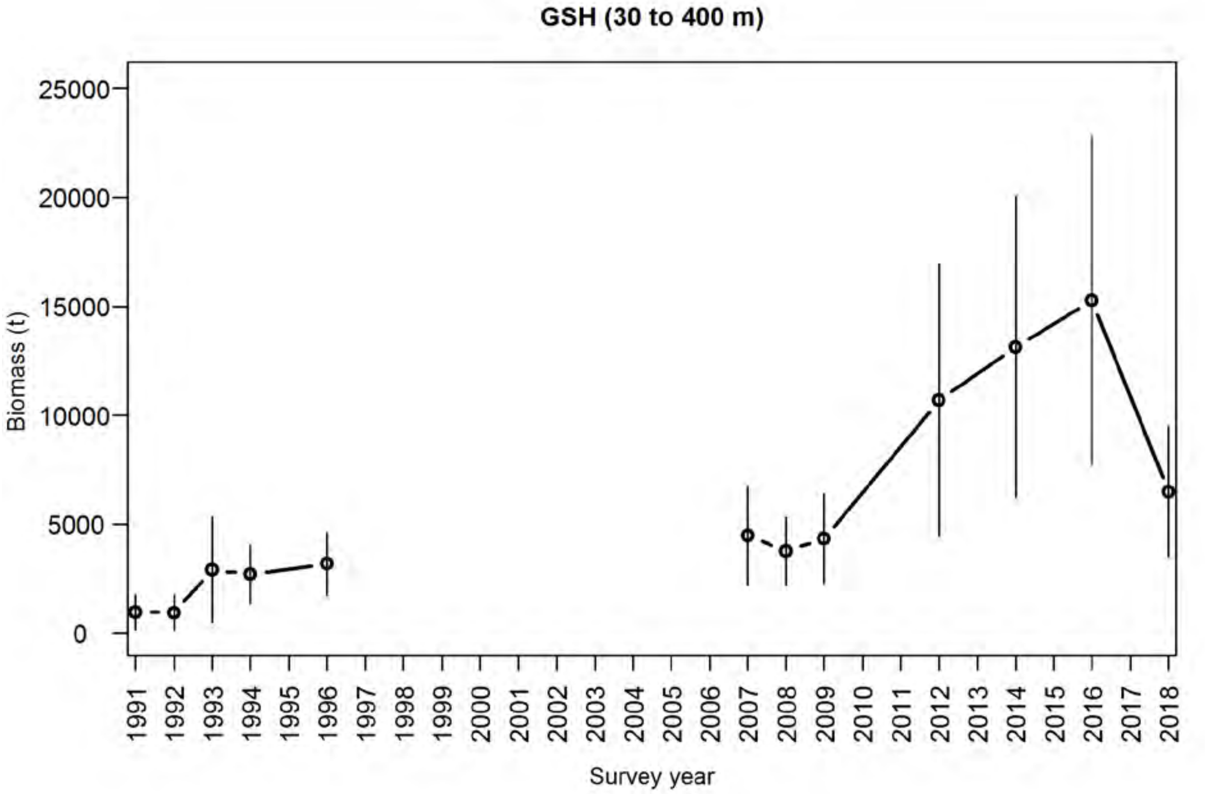


Figure 2: Biomass for dark ghost shark from the east coast South Island winter trawl surveys in core strata (30–400 m). Error bars are ±2 standard errors.

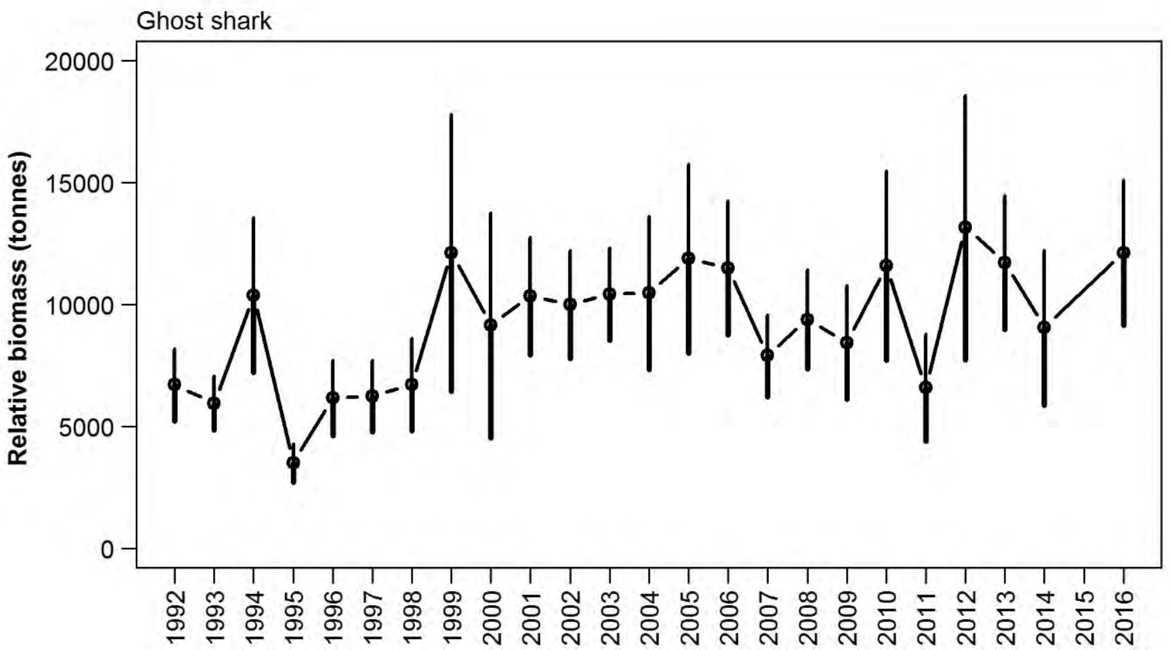


Figure 3: Biomass for dark ghost shark from the Chatham Rise trawl survey. Error bars are ± 2 standard errors.

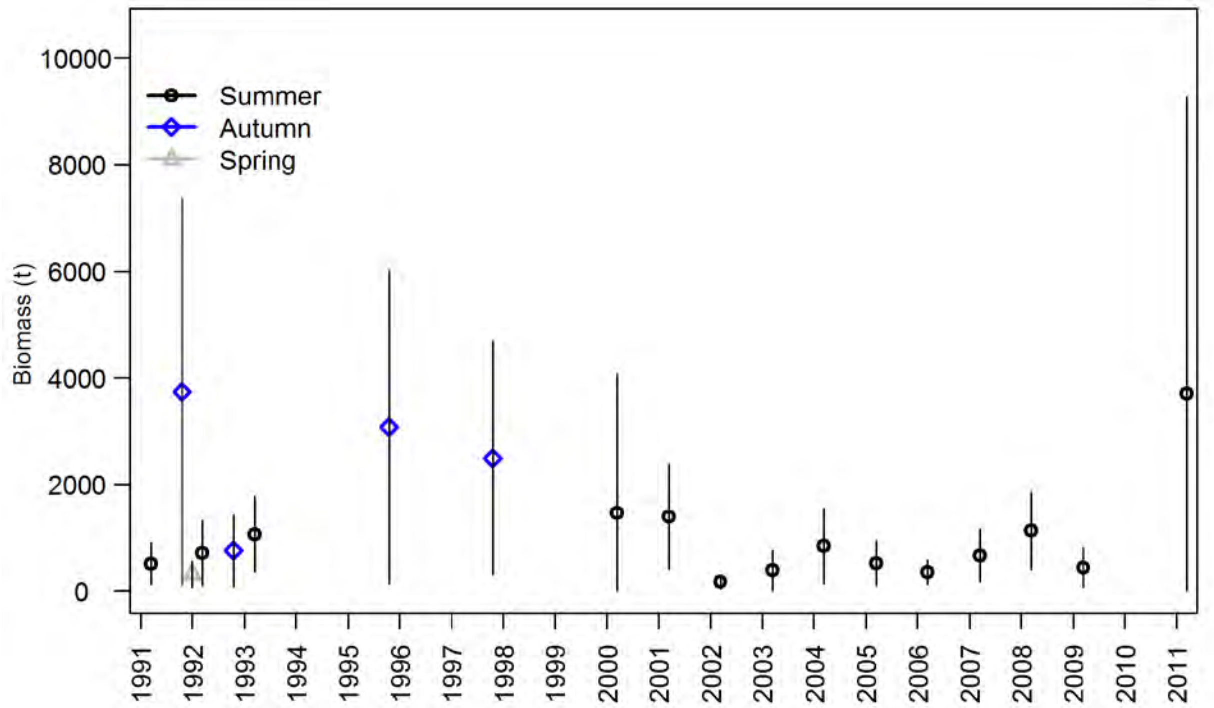


Figure 4: Biomass trends ±95% CI (estimated from survey CVs assuming a lognormal distribution) from the Sub-Antarctic trawl survey.

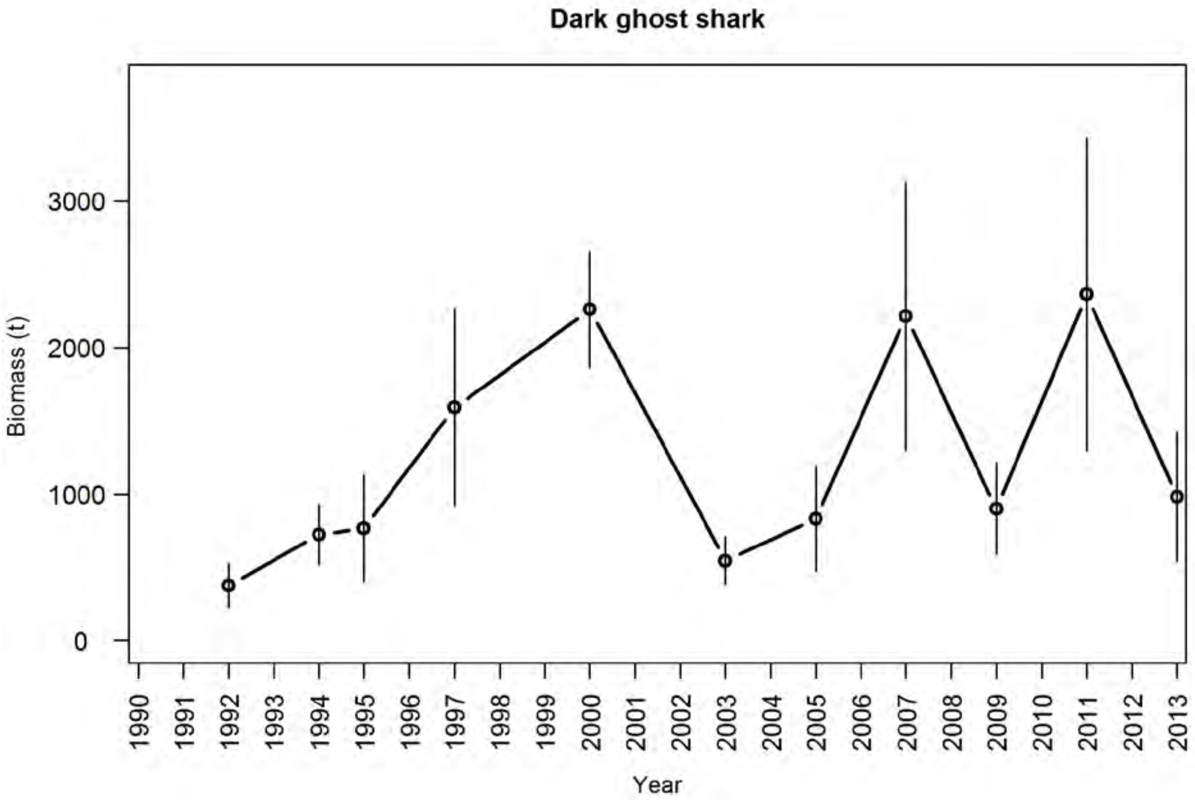


Figure 5: Biomass trends ±95% CI (estimated from survey CVs assuming a lognormal distribution) from the West Coast South Island trawl survey.

4.3 Estimation of Maximum Constant Yield (*MCY*)

As there are no available estimates of biomass or harvest rates, the only possible method of calculating maximum constant yield is $MCY = cY_{AV}$ (Method 4). However, it was decided that no estimates of *MCY* would be presented because:

i. *M* (and hence, the natural variability factor *c*) is unknown;

ii. the level of discarding is unknown and may have been considerable; and

iii. no sufficiently long period of catches was available where there were no systematic changes in catch or effort (noting that the period of catches from which Y_{AV} is derived should be at least half the exploited life span of the fish).

4.4 Estimation of Current Annual Yield (*CAY*)
In the absence of estimates of current biomass, *CAY* has not been estimated.

4.5 Other yield estimates and stock assessment results
No other yield estimates are available.

4.6 Other factors
Elasmobranchs are believed to have a strong stock-recruit relationship; the number of young born is related directly to the number of adult females. Ghost shark fecundity is unknown, but is probably low. Assuming a strong stock-recruit relationship, Francis & Francis (1992) showed that the estimates of *MCY* obtained using the equations in current use in New Zealand stock assessments were overly optimistic for rig, and it is likely that they are also unsuitable for ghost sharks.

A data informed qualitative risk assessment was completed on all chondrichthyans (sharks, skates, rays and chimaeras) at the New Zealand scale in 2014 (Ford et al 2015). Dark ghost shark was ranked seventh highest in terms of risk of the eleven QMS chondrichthyan species. Data were described as existing but poor for the purposes of the assessment and consensus over this risk score was achieved by the expert panel. This risk assessment does not replace a stock assessment for this species but may influence research priorities across species.

5. STATUS OF THE STOCKS

Stock Structure Assumptions

Based on differences in length frequency distributions between the sub-Antarctic and Chatham Rise trawl surveys, and the location of commercial catches, there are most likely two main stocks of dark ghost shark.

1. The eastern fishery; extending from the upper east coast of the South Island and out east across the Chatham Rise.
2. The southern fishery; extending from the lower east coast of the South Island, south around the Stewart/Snares Shelf, Campbell Plateau, and Puysegur trench.

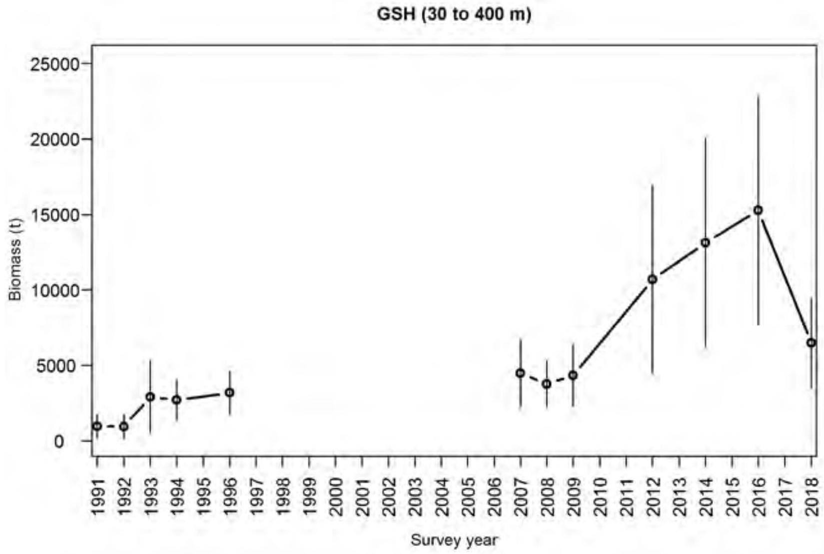
Further work needs to be done to investigate what if any relationship there is between dark ghost shark caught on the west coast of the South Island, around both coasts of the North Island, and the eastern and southern stocks.

- **Chatham Rise and ECSI**

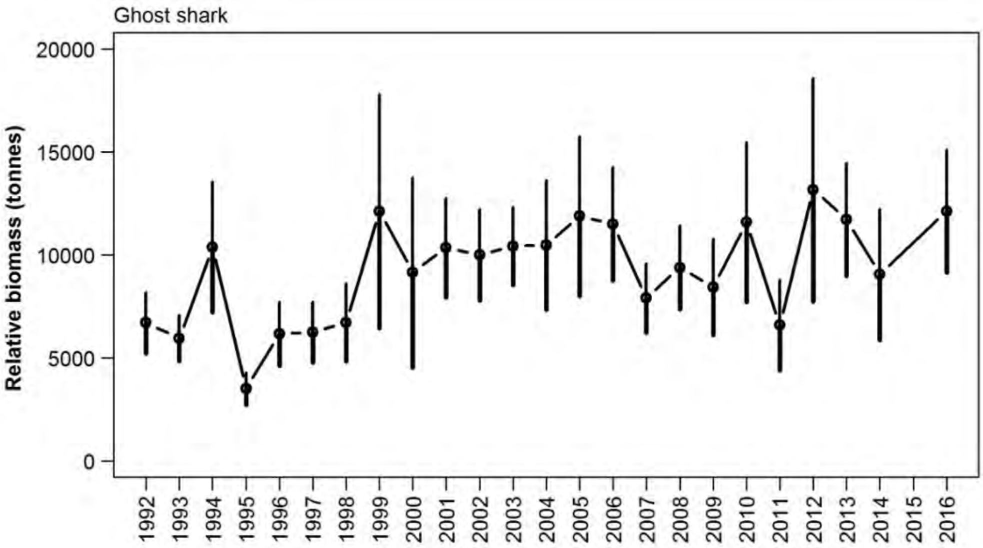
Stock Status	
Year of Most Recent Assessment	2016
Assessment Runs Presented	-
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: Not defined
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status

ECSI core strata



Biomass trajectory for dark ghost shark from the ECSI trawl survey. Error bars are ± 2 standard errors.



Biomass for dark ghost shark from the Chatham Rise trawl survey. Error bars are ± 2 standard errors.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass indices from the east coast South Island inshore trawl survey time series have been steadily increasing since 2009 but decline substantially in 2018. Biomass indices from the Chatham Rise have fluctuated somewhat over the time series. Estimates from the last ten years have been more stable.
Recent Trend in Fishing Intensity or Proxy	Landings have been stable for the last five years from GSH 3, and relatively stable from GSH 4, apart from a small spike in the 2007–08 fishing year.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown, but there is no evidence of a systematic decline in biomass indices from either the east coast of the South Island or the Chatham Rise.

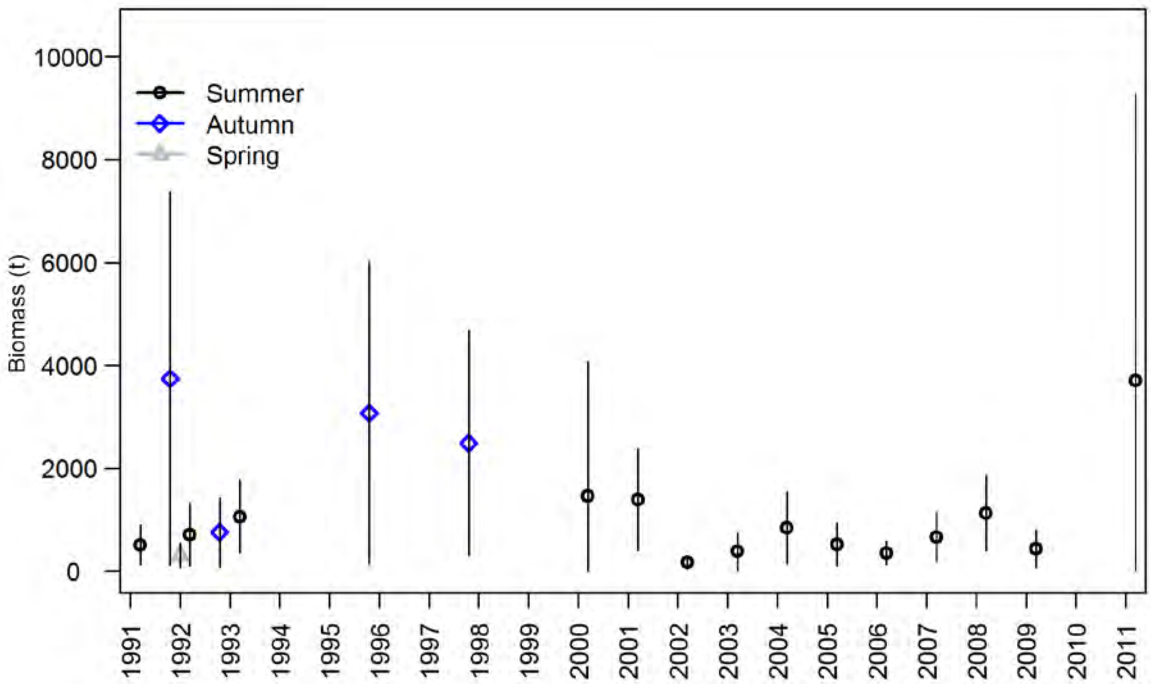
Qualifying Comments
-

Fishery Interactions
Dark ghost shark in the eastern fishery is caught exclusively as bycatch in other target fisheries with the two most important ones being hoki followed by arrow squid. For both target fisheries, incidental interactions and associated mortalities are noted for New Zealand fur seals and seabirds, and low productivity species taken in the fisheries include basking sharks and deepsea skates.

- **Southern stock**

Stock Status	
Year of Most Recent Assessment	2011
Assessment Runs Presented	-
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: Not defined
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Biomass trends ±95% CI (estimated from survey CVs assuming a lognormal distribution) from the Sub-Antarctic trawl survey.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass indices from the summer sub-Antarctic trawl survey time series have been relatively flat for the last few years apart from a large spike in 2011 due to a number of randomly allocated stations occurring at the shallower end of the depth range for dark ghost shark.
Recent Trend in Fishing Intensity or Proxy	Unknown. Landings have fluctuated somewhat from GSH 5 in recent years, and have been relatively stable from GSH 6.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown, but there is no evidence of a systematic decline in biomass indices from the sub-Antarctic survey.

Qualifying Comments
-

Fishery Interactions
Dark ghost shark in the southern fishery is caught exclusively as bycatch in other target fisheries with the two most important ones being arrow squid followed by hoki. For both target fisheries, incidental interactions and associated mortalities have been recorded for New Zealand fur seals and seabirds, and low productivity species taken in the fisheries include basking sharks and deepsea skates. Interactions with other species are currently being characterised.

Table 7: Summary of TACCs (t) and reported landings (t) for dark ghost shark for the most recent fishing year.

Fishstock		**QMA**	**2018–19 Actual TACC**	**2018–19 Estimated Landings**
GSH 1	Auckland (East)	1	22	28
GSH 2	Central (East)	2	89	40
GSH 3	South-east (Coast)	3	1 185	528
GSH 4	South-east (Chatham)	4	370	166
GSH 5	Southland	5	109	51
GSH 6	Sub-Antarctic	6	95	68
GSH 7	Challenger	7	1 121	485
GSH 8	Central (West)	8	34	21
GSH 9	Auckland (West)	9	22	19
GSH 10	Kermadec	10	0	0
Total			3 047	1 406

6. FOR FURTHER INFORMATION

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PALE GHOST SHARK (GSP)

(*Hydrolagus bemisi*)

1. FISHERY SUMMARY

1.1 Commercial fisheries

Two species (dark and pale ghost sharks) make up virtually all the commercial ghost shark landings. Pale ghost shark (*Hydrolagus bemisi*) was introduced into the QMS from the beginning of the 1999–00 fishing year as three Fishstocks: GSP 1 (FMAs 1 to 4, and 10), GSP 5 (FMAs 5 and 6) and GSP 7 (FMAs 7, 8 and 9).

Both ghost shark species are taken almost exclusively as a bycatch of other target trawl fisheries. In the 1990s, about 43% of ghost sharks were landed as a bycatch of the hoki fishery, with fisheries for silver warehou, arrow squid and barracouta combining to land a further 36%. The two ghost shark species were seldom differentiated on catch landing returns prior to the start of the 1998–99 fishing year. Estimated landings of both species by foreign licensed and joint venture vessels over the period 1 April 1978 to 30 September 1983 are presented in Table 1. Landings by domestic (inshore) vessels would have been negligible during this time period. The unknown quantities of ghost sharks that were discarded and not recorded are likely to have resulted in under-reported total catches over the full period for which data are available.

Table 1: Reported landings (t) of both ghost shark species by fishing year and EEZ area, taken by foreign licensed and joint venture vessels. An approximation of these areas with respect to current FMA boundaries is used to assign catches to QMAs. No data are available for the 1980–81 fishing year.

Year		EEZ Area												Total
		B	C(M)	C(1)	D	E(B)	E(P)	E(C)	E(A)	F(E)	F(W)	G	H	
	FMA	1&2		3	4				6		5	7	8	
1978–79*		1	37	99	26	3	16	11	88	90	8	68	17	465
1979–80*		1	55	54	426	10	4	28	138	183	7	1	5	912
1980–81*														-
1981–82*		0	84	28	117	0	2	6	29	71	9	4	0	350
1982–83*		0	108	35	84	0	2	17	98	99	29	1	1	474
1983–83#		0	84	41	73	0	0	17	5	16	17	0	0	253

* 1 April to 31 March. # 1 April to 30 Sept

In the early to mid 1980s, about half of the reported ghost shark landings were from FMA 3. Virtually all the additional catch was spread over FMAs 4–7. In 1988–89, landings from west coast South Island (FMA 7) began to increase, almost certainly associated with the development of the hoki fishery. In 1990–91, significant increases in landings were apparent on the Chatham Rise, off southeast South Island, and on the Campbell Plateau. The development of fisheries for non-spawning hoki was probably responsible for these increases.

Estimated landings of pale ghost shark by QMA are shown in Table 2. Landings from 1983–84 to 1994–95 were derived by splitting all reported ghost shark landings into depth and area bins, and allocating to species based on distribution data derived from trawl surveys (Section 2). Landings from 1995–96 to 1998–99 were estimated assuming that pale ghost shark made up 30% of the total ghost shark catch in FMAs 5 and 6, and 25% in all other FMAs.

Table 2: Estimated landings (t) of pale ghost shark by Fisheries Management Area for fishing years 1982–83 to 1998–99 based on the reported landings of both species combined. The estimated landings up to 1994–95 are based on data in the 1997 Plenary Report. Landings from 1995–96 to 1998–99 were estimated assuming pale ghost shark made up 30% of the total ghost shark catch in FMAs 5 and 6, and 25% in all other FMAs.

	FMA										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
1982–83	1	1	74	35	21	13	2	1	0	0	148
1983–84	0	1	63	24	11	15	7	1	0	0	122
1984–85	1	1	60	49	16	19	12	0	0	0	158
1985–86	1	1	96	23	10	14	7	1	0	0	153
1986–87	1	2	110	27	11	12	13	1	0	0	177
1987–88	1	1	138	21	13	2	15	1	0	0	192
1988–89	2	7	124	9	19	2	34	1	0	0	198
1989–90	1	3	86	8	41	5	33	5	0	0	182
1990–91	1	7	148	63	61	82	39	1	0	0	402
1991–92	1	2	218	95	64	54	35	2	1	0	472
1992–93	2	1	227	99	77	55	53	7	0	0	521
1993–94	1	2	173	42	36	32	99	4	0	0	389
1994–95	1	1	246	62	27	26	234	1	0	0	598
1995–96	4	12	226	84	30	29	183	3	1	0	572
1996–97	6	22	272	134	40	58	309	3	3	0	847
1997–98	6	6	256	87	30	58	57	1	4	0	505
1998–99	6	20	315	107	27	47	136	2	7	0	667

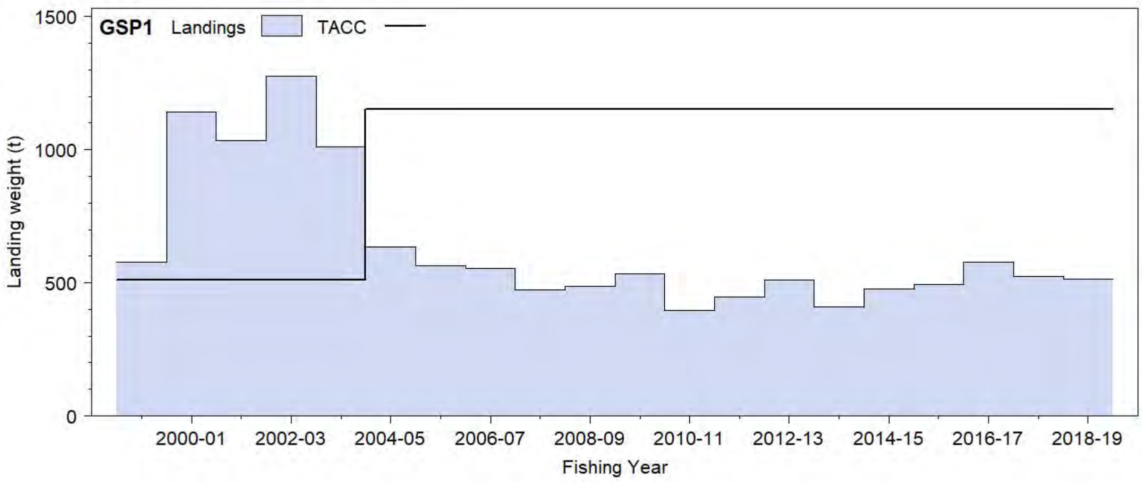
From 1 Oct 1999 TACCs were set for pale ghost shark fishstocks as follows: GSP 1 509 t, GSP 5 118 t and GSP 7 176 t. The TAC in each case was set equal to the TACC. Estimated and reported landings for this period are shown in Table 3, while Figure 1 shows the historical landings and TACC values for the main GSP stocks. The fisheries in GSP 1 and GSP 5 exceeded the TACC by large amounts, possibly as a result of better reporting of catches. From 1 October 2004 the TACCs for GSP 1 and GSP 5 were increased to 1150 t and 454 t respectively, the level of catch being reported from the fisheries. Catches have since declined to well below the TACC levels in GSP 1 and GSP 7. Landings of pale ghost sharks in GSP 5 exceeded the TACC for the first time since the 2004 introduction of the higher TACC in 2017-18.

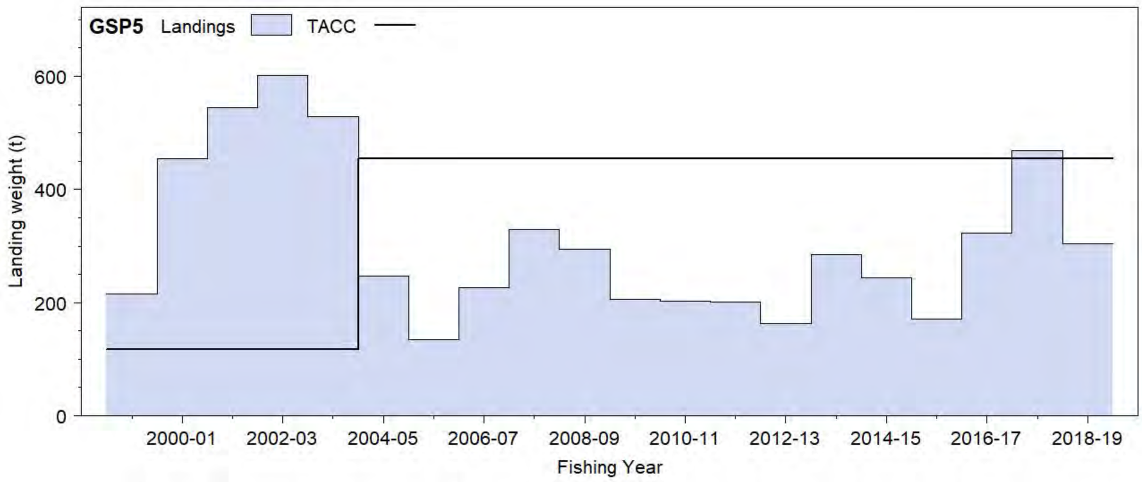
Table 3: Estimated landings (t) of pale ghost shark by Fishstock for 1999–2000 to 2018–19 and actual TACCs set from 1999–2000 (QMR data).

Fishstock		**GSP 1**		**GSP 5**		**GSP 7**		
FMA (s)		**1,2,3,4,10**		**5,6**		**7,8,9**		**Total**
	Landings	**TACC**	**Landings**	**TACC**	**Landings**	**TACC**	**Landings**	**TACC**
1999–00	577	509	216	118	35	176	828	803
2000–01	1 142	509	454	118	16	176	1 613	803
2001–02	1 033	509	545	118	71	176	1 649	803
2002–03	1 277	509	602	118	16	176	1 895	803
2003–04	1 009	509	529	118	15	176	1 553	803
2004–05	635	1 150	247	454	5	176	887	1 780
2005–06	565	1 150	134	454	9	176	708	1 780
2006–07	553	1 150	226	454	15	176	794	1 780
2007–08	473	1 150	329	454	16	176	818	1 780
2008–09	486	1 150	294	454	15	176	795	1 780
2009–10	534	1 150	206	454	11	176	751	1 780
2010–11	395	1 150	203	454	13	176	611	1 780
2011–12	447	1 150	201	454	10	176	659	1 780
2012–13	510	1 150	163	454	25	176	697	1 780
2013–14	409	1 150	286	454	33	176	727	1 780

Table 3 [Continued]

Fishstock	GSP 1		GSP 5		GSP 7			
FMA (s)	1,2,3,4,10		5,6		7,8,9		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2014–15	476	1 150	243	454	38	176	759	1 780
2015–16	493	1 150	171	454	26	176	690	1 780
2016–17	577	1 150	324	454	25	176	926	1 780
2017–18	525	1 150	469	454	35	176	1 029	1 780
2018–19	515	1 150	305	454	21	176	841	1 780





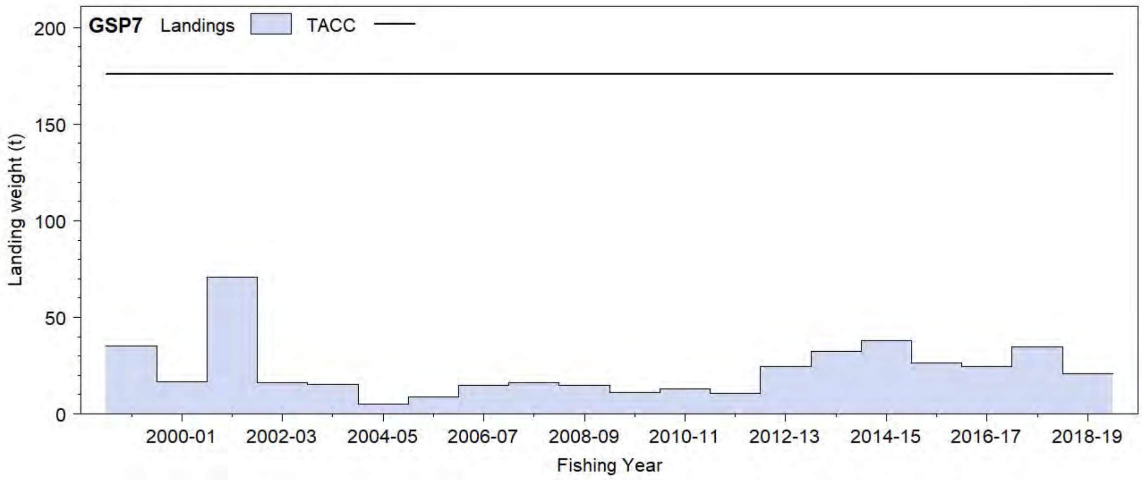


Figure 1: Reported commercial landings and TACC for the three main GSP stocks. From top: GSP 1 (Auckland East), GSP 5 (Southland) and GSP 7 (Challenger). Note that these figures do not show data prior to entry into the QMS.

In GSP 1, catches are mainly taken on the Chatham Rise while in GSP 5 catches are mainly taken in the Sub-Antarctic area; both as bycatch of the hoki trawl fisheries. Estimated catches appear to have been under-reported both before and after the introduction to the QMS. The original TACCs were based on estimated catches, but these are likely to have been much lower than the actual catches. Estimated catches on TCEPR forms since 1999–2000 have been only 25–30% of the QMR totals.

1.2 Recreational fisheries
Current catches of ghost sharks by recreational fishers are believed to be negligible in all areas.

1.3 Customary non-commercial fisheries
Quantitative information on the current level of customary non-commercial take is not available.

1.4 Illegal catch
Quantitative information on the level of illegal catch is not available. In 1998–99 (when dark ghost shark were in the QMS, but pale ghost shark were not), a quantity of dark ghost shark were reported as pale ghost shark.

1.5 Other sources of mortality
Ghost sharks have been dumped and not reported in the past by commercial fishers in FMAs 1 and 2. Similar behaviour is believed to occur in all other FMAs. The extent of the unreported dumping is unknown in all areas.

2. BIOLOGY

Pale ghost shark occur throughout the EEZ and have been recorded in depths ranging from 270 to 1200 m. They are most abundant in depths of 400–1000 m on the Chatham Rise and Southland/Sub-Antarctic, but are uncommon north of 40° S and appear to inhabit a narrower depth range in that region (600–950 m).

Trawl surveys show that dark and pale ghost shark exhibit niche differentiation, with water depth being the most influential factor, although there is some overlap of habitat. On the Chatham Rise, the main overlap range appears quite compact (from about 340 to 540 m). In the Southland/Sub-Antarctic region, the overlap range is wider (about 350 to 770 m). Stomach contents indicate that both species are predominantly benthic feeders.

No published information is available on the age or growth rate of any *Hydrolagus* species, or even any species in the family Chimaeridae. Length-frequency histograms indicate that females grow to a larger size (and presumably have a faster growth rate) than males. Hard parts of pale ghost shark have not yet been examined to check the existence of any banding pattern that may represent annual growth zones. Without population age structures or confident estimates of longevity it is not possible to estimate natural or total mortalities. A recent study has shown that eye lens measurements and spine band counts are potentially useful ageing techniques for dark ghost sharks (Francis & Ó Maolagáin 2001). However, these techniques have yet to be validated.

On the Chatham Rise, the estimated size at 50% sexual maturity for pale ghost sharks is 59–60 cm for males and 69–70 cm for females. As for most other elasmobranchs, their fecundity is likely to be low.

Biological parameters relevant to the stock assessment are shown in Table 4.

Table 4: Estimates of biological parameters for pale ghost shark, from Horn (1997).

FMA	Estimate	
1. Weight = a (length)^b (Weight in g, length in cm chimaera length)		
Pale ghost shark	a	b
3 & 4	0.00512	3.037
5 & 6	0.00946	2.883

3. STOCKS AND AREAS

Horn (1997) proposed that ghost sharks be managed as three Fishstocks, i.e., east coast New Zealand (FMAs 1–4), Stewart-Snares shelf and Campbell Plateau (FMAs 5 and 6), and west coast New Zealand (FMAs 7, 8, and 9). Areas of narrow continental shelf separate these FMA groupings, so they could well provide barriers to stock mixing, particularly for the pale ghost shark. The deep water separating the Bounty Platform from the Campbell Plateau may also provide a barrier to mixing, and these areas may hold separate stocks.

4. STOCK ASSESSMENT

No assessment of any stocks of ghost shark has been completed. Therefore, no estimates of yield are available.

4.1 Estimates of fishery parameters and abundance

Table 5: Biomass indices (t) and coefficients of variation (CV)

					Pale ghost shark	
GSP	**Area**	**Vessel**	**Trip code**	**Date**	**Biomass**	**% CV**
1	Chatham Rise	*Tangaroa*	TAN9106	Jan–Feb 1992	6 060	5.7
			TAN9212	Jan–Feb 1993	3 570	7
			TAN9401	Jan-94	5 900	8.6
			TAN9501	Jan-95	2 750	8.4
			TAN9601	Jan-96	7 900	10
			TAN9701	Jan-97	2 870	12.2
			TAN9801	Jan-98	4 052	9.3
			TAN9901	Jan-99	5 272	9.7
			TAN0001	Jan-00	4 892	7.6
			TAN0101	Jan-01	7 094	9
			TAN0201	Jan-02	4 896	10
			TAN0301	Jan-03	4 653	12.1
			TAN0401	Jan-04	3 627	8.6
			TAN0501	Jan-05	4 061	9.2
			TAN0601	Jan-06	3 237	11
			TAN0701	Jan-07	4 766	9.0
			TAN0801	Jan-08	3 235	6.1
			TAN0901	Jan-09	3 995	7.6
			TAN1001	Jan-10	3 216	11.7
			TAN1101	Jan-11	2 550	14.2
			TAN1201	Jan-12	4 327	8.5
			TAN1301	Jan-13	4 270	18.0
5	Southland	*Tangaroa*	TAN9105	Nov–Dec 1991	11 210	6.1
	Sub-Antarctic		TAN9211	Nov–Dec 1992	4 750	7.2
			TAN9310	Nov–Dec 1993	11 670	9.4
			TAN0012	Nov–Dec 2000	17 823	12.4
			TAN0118	Nov–Dec 2001	11 219	8.8
			TAN0219	Nov–Dec 2002	9 297	9.3
			TAN0317	Nov–Dec 2003	10 360	8.7
			TAN0414	Nov–Dec 2004	8 549	10.3
			TAN0515	Nov–Dec 2005	9 416	10
			TAN0617	Nov–Dec 2006	12 619	10
			TAN0714	Nov–Dec 2007	13 107	11
			TAN0813	Nov–Dec 2008	10 098	13
			TAN0911	Nov–Dec 2009	13 553	9
			TAN1117	Nov–Dec 2011	11 677	9.6
			TAN1215	Nov–Dec 2012	16 181	12.6
5	Southland	*Tangaroa*	TAN9204	Mar–Apr 1992	10 530	6.1
	Sub-Antarctic		TAN9304	Apr–May 1993	14 640	9.5
			TAN9605	Mar–Apr 1996	16 380	9.9
			TAN9805	Apr–May 1998	15 758	10

Estimates of fishery parameters are not available for ghost sharks. Several time series of relative biomass estimates are available from trawl surveys (Table 5). In 2004, the Plenary agreed that the trawl survey series for both GSP 1 and GSP 5 indicated that previous catch levels had made little impact on the biomass of pale ghost shark, however, the actual level of catch is not known. The recorded catch history for this species is likely to underestimate actual catches. The trawl series fluctuates over time and decreases in 2010 and 2011 on the Chatham Rise. In the Sub-Antarctic the trawl biomass indices have increased since 2005.

4.2 Biomass estimates

No biomass estimates are available for ghost shark.

4.3 Yield estimates and projections

As no estimate of biomass or harvest rate are available, the only possible method of calculating maximum constant yield is $MCY = cY_{AV}$ (Method 4).

However, it was decided that no estimates of *MCY* would be presented because:

i. *M* (and hence, the natural variability factor *c*) is unknown;

ii. the level of discarding is unknown and may have been considerable; and

iii. no sufficiently long period of catches was available where there were no systematic changes in catch or effort (noting that the period of catches from which Y_{AV} is derived should be at least half the exploited life span of the fish).

In the absence of estimates of current biomass, *CAY* has not been estimated.

4.4 Other factors

Elasmobranchs are believed to have a strong stock-recruit relationship; the number of young born is related directly to the number of adult females. Ghost shark fecundity is unknown, but is probably low. Assuming a strong stock-recruit relationship, Francis & Francis (1992) showed that the estimates of *MCY* obtained using the equations in current use in New Zealand stock assessments were overly optimistic for rig, and it is likely that they are also unsuitable for ghost sharks.

A data informed qualitative risk assessment was completed on all chondrichthyans (sharks, skates, rays and chimaeras) at the New Zealand scale in 2014 (Ford et al 2015). Pale ghost shark was ranked ninth highest in terms of risk of the eleven QMS chondrichthyan species. Data were described as existing but poor for the purposes of the assessment and no consensus over this risk score was achieved by the expert panel. This risk assessment does not replace a stock assessment for this species but may influence research priorities across species.

5. STATUS OF THE STOCKS

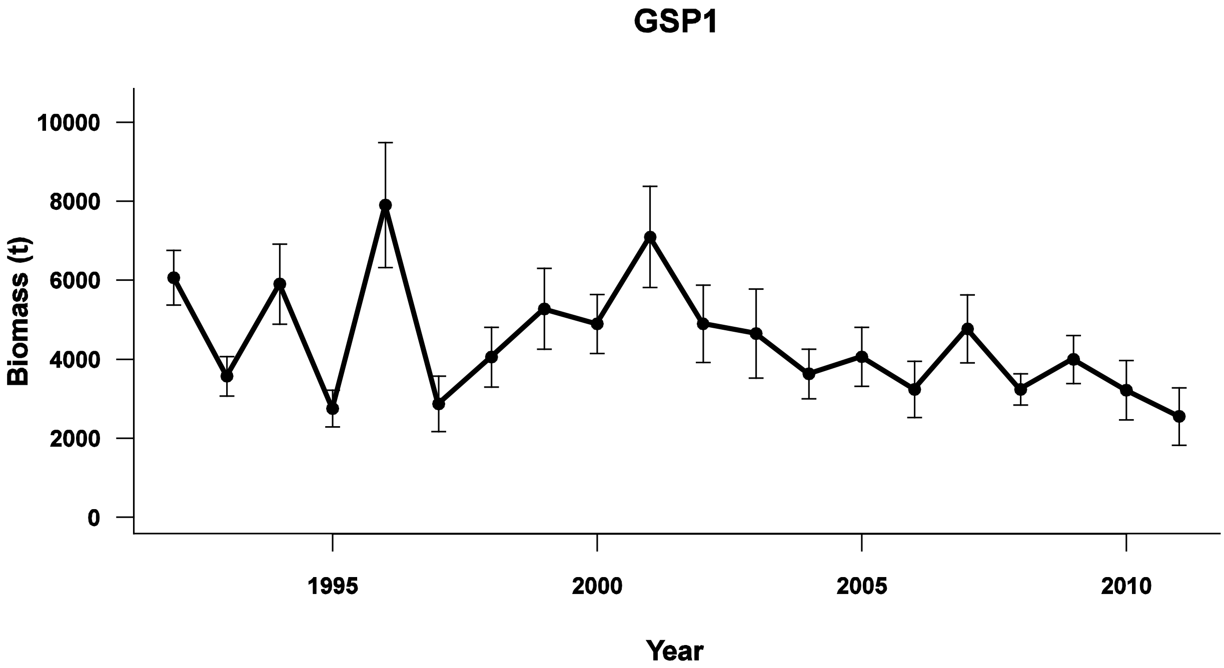
No estimates of current and reference biomass are available for pale ghost shark.

- **GSP 1**

Stock Status	
Year of Most Recent Assessment	2011
Assessment Runs Presented	
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold:-

Status in relation to Target	Unknown
Status in relation to Limits	Unlikely (< 40%) to be below soft limit Very Unlikely (< 10%) to be below hard limit
Status in relation to Overfishing	-

Historical Stock Status Trajectory and Current Status



Doorspread biomass estimates of pale ghost shark (error bars are ± two standard deviations) from the Chatham Rise, from *Tangaroa* surveys from 1992 to 2011.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass estimates from trawl surveys on the Chatham Rise have fluctuated over the time series showing a decreasing trend since 2001. Precision is generally good in this time series (< 10%). The Working Group considered this index to be suitable to monitor major trends in this stock.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches have been well below the TACC since 2004–05.

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) at recent catch levels; unknown at the TACC Hard Limit: Very Unlikely (< 10%) at recent catch levels; unknown at the TACC
Probability of Current Catch or TACC causing Overfishing to continue or to commence	-

Assessment Methodology and Evaluation	
Assessment Type	Level 2 – Partial Quantitative Stock Assessment
Assessment Method	Evaluation of trawl survey indices on the Chatham Rise

Assessment Dates	Latest assessment: 2011	Next assessment: Unknown
Overall assessment quality rank		
Main data inputs (rank)	- Research time series of abundance indices (trawl surveys)	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	The core strata in the trawl survey do not cover the full depth distribution of pale ghost shark.	

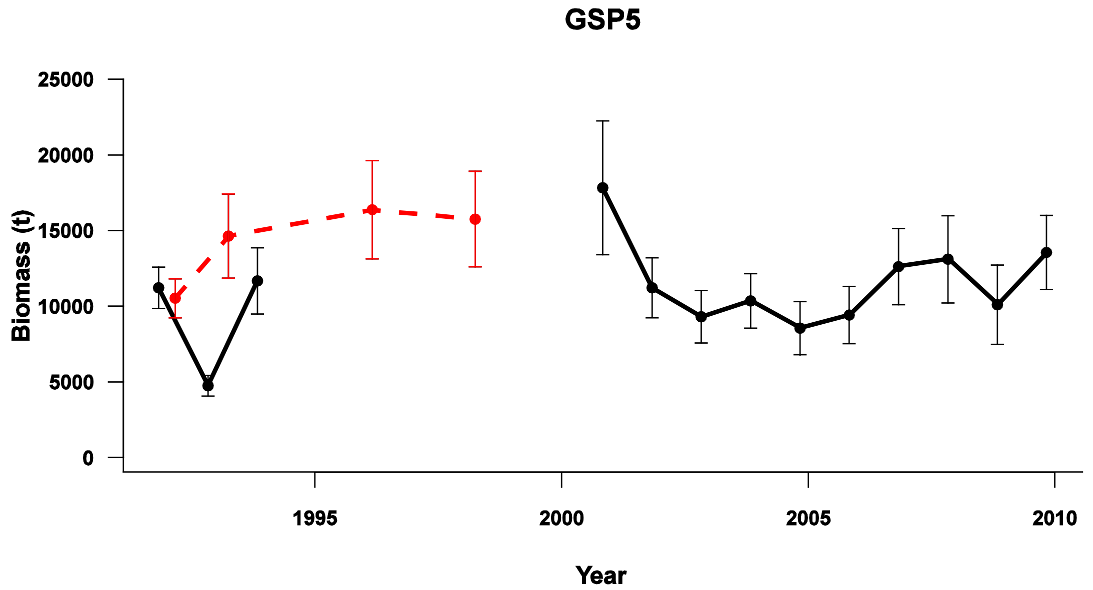
Qualifying Comments
The catch history for this species is likely to underestimate actual catches.

Fishery Interactions
The pale ghost shark in GSP 1 is mainly taken as bycatch of the hoki fishery. Interactions with other species are currently being characterised.

- **GSP 5**

Stock Status	
Year of Most Recent Assessment	2011
Assessment Runs Presented	-
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold:-
Status in relation to Target	Unknown
Status in relation to Limits	Unlikely (< 40%) to be below soft limit Very Unlikely (< 10%) to be below hard limit
Status in relation to Overfishing	-

Historical Stock Status Trajectory and Current Status



Doorspread biomass estimates of pale ghost shark (error bars are ± two standard deviations) from the Sub-Antarctic, from *Tangaroa* summer surveys from 1991 to 1993, and 2000 to 2009 (solid line) and autumn surveys from 1992 to 1998 (dashed line).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass estimates from trawl surveys on the Sub-Antarctic have increased in recent years. Precision is generally good in this time series (about 10%). The Working Group considered this index to be suitable to monitor major trends in this stock.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Catches have been well below the TACC since 2004–05.
Projections and Prognosis	
Stock Projections or Prognosis	Stock size is Unlikely (< 40%) to change much at current catch levels in FMA 5&6.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) at recent catch levels; unknown at the TACC Hard Limit: Very Unlikely (< 10%) at recent catch levels; unknown at the TACC
Probability of Current Catch or TACC causing overfishing to continue or to commence	-

Assessment Methodology		
Assessment Type	Level 2 - Quantitative stock assessment	
Assessment Method	Evaluation of trawl survey indices on the Chatham Rise	
Assessment Dates	Latest assessment: 2011	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs	- Research time series of abundance indices (trawl surveys)	
Data not used (rank)		
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
The early catch history for this species is likely to underestimate actual catches.

Fishery Interactions
The pale ghost shark in GSP 5 is mainly taken as bycatch of the hoki fishery. Interactions with other species are currently being characterised.

- **GSP 7**

There are no accepted stock monitoring indices available for GSP 7.

TACCs and reported landings for the 2017–18 fishing year are summarised in Table 6.

Table 6: Summary of TACCs (t) and reported landings (t) of pale ghost shark for the most recent fishing year.

Fishstock		FMAs	2018–19 Actual TACC	2018–19 Estimated Landings
GSP 1	Auckland (East), Central (East) South-East (Coast) (Chatham), Kermadec	1, 2, 3, 4, 10	1 150	515
GSP 5	Southland, Sub-Antarctic	5, 6	454	305
GSP 7	Challenger, Central (West), Auckland (West)	7, 8, 9	176	21
Total			1 780	841

6. FOR FURTHER INFORMATION

Ford, R B; Galland, A; Clark, M R; Crozier, P; Duffy, C A J; Dunn, M R; Francis, M P; Wells, R (2015) Qualitative (Level 1) Risk Assessment of the impact of commercial fishing on New Zealand Chondrichthyans. *New Zealand Aquatic Environment and Biodiversity Report No. 157*. 111p.

Francis, M P; Francis, R I C C (1992) Growth, mortality, and yield estimates for rig (*Mustelus lenticulatus).* New Zealand Fisheries Assessment Research Document 1992/5. 32 p. (Unpublished document held by NIWA library, Wellington.)

Francis, M P; McMillan, P; Lasenby, R; Didier, D (1998) How to tell dark and pale ghost sharks apart. *Seafood New Zealand* 6 (11): 29–30. (December 1998.)

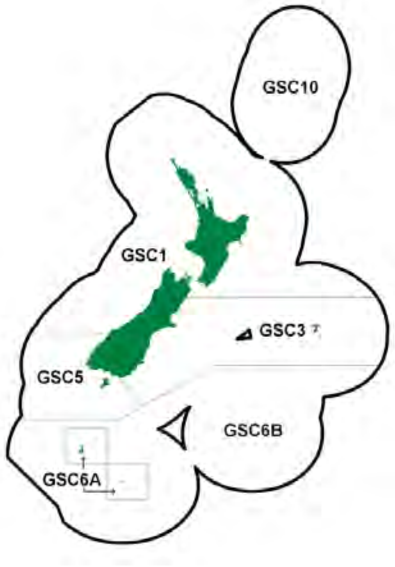
Francis, M P; Ó Maolagáin, C (2001) Development of ageing techniques for dark ghost shark (*Hydrolagus novaezelandiae*). Final Research Report for Ministry of Fisheries Research Project MOF2000/03C. 10 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

Horn, P L (1997) A summary of biology and commercial landings, and a stock assessment of ghost sharks (*Hydrolagus* spp.) in New Zealand waters. New Zealand Fisheries Assessment Research Document 1997/3. 36 p. (Unpublished document held by NIWA library, Wellington.)

Stevens, D; Livingston, M; Bagley, N (2001) Trawl survey of hoki and middle depth species on the Chatham Rise, January 2001 (TAN0101). Final Research Report for Ministry of Fisheries Research Project HOK2000/02, Objectives 1 and 2. 13 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

GIANT SPIDER CRAB (GSC)

(*Jacquinotia edwardsii*)



1. FISHERY SUMMARY

1.1 Commercial fisheries

The giant spider crab (*Jacquinotia edwardsii*) was introduced into the Quota Management System on 1 April 2004 with a combined TAC of 451 t and TACC of 419 t. There are no allowances for customary or recreational take, and there is an allowance for other sources of mortality of 32 t. The fishing year is from 1 April to 31 March and commercial catches are measured in greenweight.

There is no target fishery for this species and all catch is taken as bycatch, predominantly in trawl fisheries. Further, over 90% of GSC reported as estimated catch in the period post-QMS introduction was taken as bycatch in the squid trawl fishery. Up until 2001–02, reported commercial catches of this crab were generally low (Table 1). Since then, total reported landings have risen from about 8 t to more than 243 t (Table 1).

There was exploratory fishing for this crab in the late 1960s and early 1970s in the Auckland Islands and Pukaki Rise areas. Following that, catches remained low (maximum 1 tonne) until the 1999–2000 fishing year when catches started to increase. Figure 1 shows the historical landings and TACC for the two main GSC stocks.

Table 1: TACCs and reported landings (t) of giant spider crab by Fishstock from 1990–91 to 2018–19. The fishing year is from 1 April to 31 March [Continued on next page].

	GSC 1		GSC 3		GSC 5		GSC 6A		GSC 6B	
Fishstock	**Landings**	**TACC**	**Landings**	**TACC**	**Landings**	**TACC**	**Landings**	**TACC**	**Landings**	**TACC**
1990–91	< 1	-	0	-	0	-	0	-	0	-
1991–92	0	-	0	-	0	-	0	-	0	-
1992–93	0	-	0	-	0	-	0	-	0	-
1993–94	< 1	-	0	-	0	-	0	-	0	-
1994–95	0	-	0	-	0	-	0	-	0	-
1995–96	0	-	0	-	0	-	0	-	0	-
1996–97	< 1	-	0	-	< 1	-	0	-	0	-
1997–98	0	-	0	-	< 1	-	0	-	0	-
1998–99	< 1	-	0	-	0	-	0	-	0	-
1999–00	0	-	< 1	-	0	-	0	-	0	-
2000–01	0	-	< 1	-	0	-	0	-	0	-
2001–02	0	-	< 1	-	1	-	0	-	0	-
2002–03	0	-	< 1	-	< 1	-	0	-	0	-
2003–04	0	-	< 1	-	2	-	0	-	0	-
2004–05	0	1	< 1	14	5	19	24	148	2	237
2005–06	0	1	< 1	14	8	19	63	148	1	237
2006–07	0	1	< 1	14	5	19	23	148	< 1	237
2007–08	0	1	< 1	14	11	19	16	148	2	237
2008–09	< 1	1	13	14	10	19	13	148	< 1	237

Table 1 [Continued]

	GSC 1		GSC 3		GSC 5		GSC 6A		GSC 6B	
Fishstock	**Landings**	**TACC**	**Landings**	**TACC**	**Landings**	**TACC**	**Landings**	**TACC**	**Landings**	**TACC**
2009–10	< 1	1	12	14	25	19	44	148	3	237
2010–11	0	1	1	14	19	19	23	148	< 1	237
2011–12	0	1	2	14	14	19	83	148	< 1	237
2012–13	<1	1	<1	14	54	19	80	148	5	237
2013–14	0	1	2	14	72	19	52	148	<1	237
2014–15	0	1	14	14	80	19	128	148	2	237
2015–16	0	1	2	14	39	19	37	148	2	237
2016–17	0	1	6	14	48	19	132	148	<1	237
2017–18	0	1	8	14	91	19	140	148	4.2	237
2018–19	<1	1	6	14	66	19	89	148	<1	237

	GSC 10		TOTAL	
Fishstock	**Landings**	**TACC**	**Landings**	**TACC**
1990–91	0	-	< 1	-
1991–92	0	-	0	-
1992–93	0	-	0	-
1993–94	0	-	1	-
1994–95	0	-	0	-
1995–96	0	-	< 1	-
1996–97	0	-	< 1	-
1997–98	0	-	< 1	-
1998–99	0	-	0	-
1999–00	0	-	2	-
2000–01	0	-	< 1	-
2001–02	0	-	8	-
2002–03	0	-	4	-
2003–04	0	0	27	419
2004–05	0	0	35	419
2005–06	0	0	72	419
2006–07	0	0	30	419
2007–08	0	0	29	419
2008–09	0	0	36	419
2009–10	0	0	84	419
2010–11	0	0	43	419
2011–12	0	0	99	419
2012–13	0	0	140	419
2013–14	0	0	127	419
2014–15	0	0	224	419
2015–16	0	0	80	419
2016–17	0	0	186	419
2017–18	0	0	243	419
2018–19	0	0	162	419

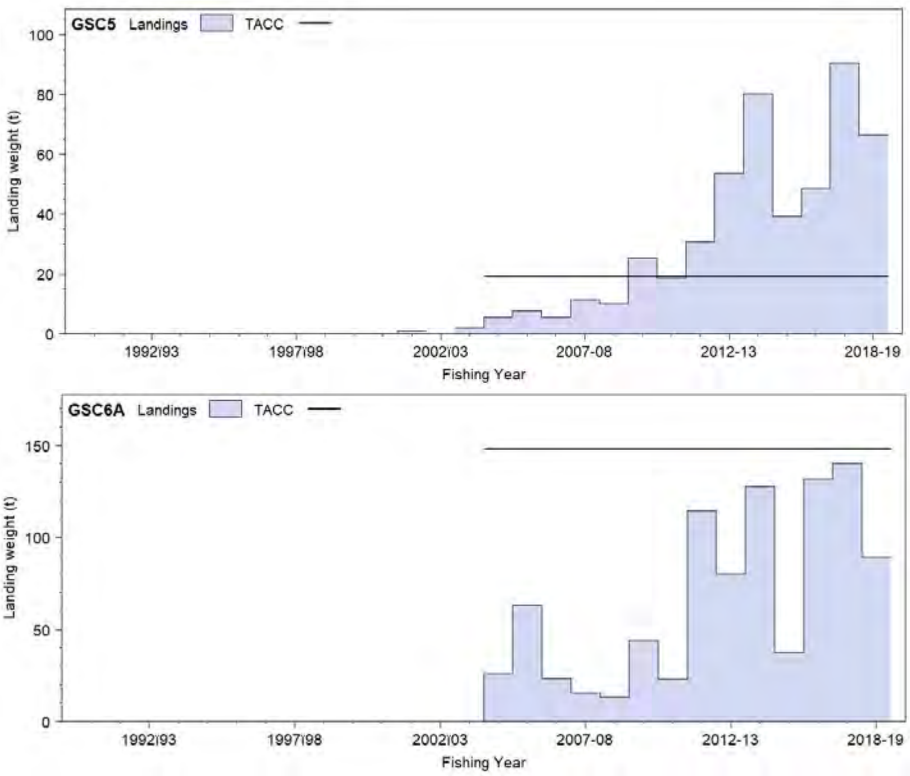


Figure 1: Reported commercial landing and TACC for GSC 5 (Southland) and GSC 6A (Southern Islands). The fishing year is from 1 April to 31 March.

1.2 Recreational fisheries
There are no known records of recreational use of this crab.

1.3 Customary non-commercial fisheries
There are no known records of customary use of this crab.

1.4 Illegal catch
There is no known illegal catch of this crab.

1.5 Other sources of mortality
There is no quantitative information on other sources of mortality.

2. BIOLOGY

Jacquinotia is found from the intertidal to over 500 m in the southeast and south of New Zealand from near Mernoo Gap to Campbell Island. It appears to attain highest densities southeast of the Snares, on the Pukaki Rise, and around the Auckland Islands. Ryff & Voller (1976) recorded *Jacquinotia* in highest quantities on the Pukaki Rise and at the Auckland Islands, with decreasing quantities at the Campbell Islands, Bounty Islands, Stewart Island, Stewart-Snares shelf, Puysegur Bank, and off Otago Heads, an observation consistent with earlier resource surveys (Ritchie 1970, 1973; Webb 1972). At the Auckland Islands they appear to be most abundant between 20 m and 40 m, but on the Pukaki Rise between 140 m and 160 m.

This spider crab, also sometimes known as the southern spider crab or the Auckland Islands crab, is a large, conspicuous brachyuran with a brick red carapace and bright red to yellowish-white chelae. The male grows much larger than the female, to at least 20 cm across the back and, together with its up to 40 cm long clawed legs, can give a total spread approaching 1 m. The males at least seem to be migratory. There have been reports of 'mounding' behaviour associated with moulting and mating (Bennett 1964, Ritchie 1970) in which large numbers of crabs form clumps, particularly in spring and autumn. This is consistent with trawl vessels occasionally reporting catches of several tonnes of crabs in a single tow.

Large males have been observed feeding on ribbed mussels (*Aulacomya maoriana*) and they probably also feed on other shellfish, both bivalves (*Mytilus*, *Mactra*) and gastropods (*Haliotis*, *Maurea*, *Struthiolaria*). In contrast, females are detritus feeders on sandy substrates, and juveniles seem to feed on drift algae. These differences mean that, although both males and females may enter pots, only males have been observed feeding on fish bait.

Sexes are separate and in both there appears to be a terminal moult. Males reach maturity at 110 mm carapace length (CL) and females at 100 mm CL. It appears that, at least near land masses, large males migrate between shallow and deep water seasonally. Pairs form in shallow water (less than 10 m) or just out of the water in September–November, when females are in late berry. Egg extrusion probably takes place in September to February and larval release in September to November. A female of 101 mm CL carries about 37 500 eggs; a female of 126 mm CL about 71 200 eggs. Only one batch of eggs is produced each year and the interval between hatching of one lot of eggs and extrusion of the next batch is very short. In summer, females and pre-puberty males occur mainly in shallow water whereas large males are found deeper.

Larval duration, survival, behaviour, and settlement are poorly known. There are two zoeal stages but the megalopa is unknown. Zoea probably occur in the plankton during September to November. Juveniles have been found in large numbers close inshore at the Auckland Islands, where shoreline rock meets the deeper mud and sand flats. Seaweed present here was apparently both food and shelter for the young crabs.

There is little or no information available on age, growth, and natural mortality. Moulting appears to take place between November and March. Males reach 220 mm CL; females 144 mm. According to Ritchie (1970), M for mature females is 13–25% and may be slightly higher for mature males.

3. STOCKS AND AREAS

For management purposes stock boundaries are based on FMAs, however, there is currently no biological or fishery information which could be used to identify stock boundaries. The GSC6A and 6B fishstocks were intentionally aligned with those for the sub-Antarctic scampi stocks.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

There are no estimates of fishery parameters or abundance for any giant spider crab fishstock.

4.2 Biomass estimates

There are no biomass estimates for any giant spider crab fishstock.

4.3 Yield estimates and projections

There are no estimates of *MCY* for any giant spider crab fishstock.

There are no estimates of *CAY* for any giant spider crab fishstock.

5. STATUS OF THE STOCKS

There are no estimates of reference or current biomass for any giant spider crab fishstock.

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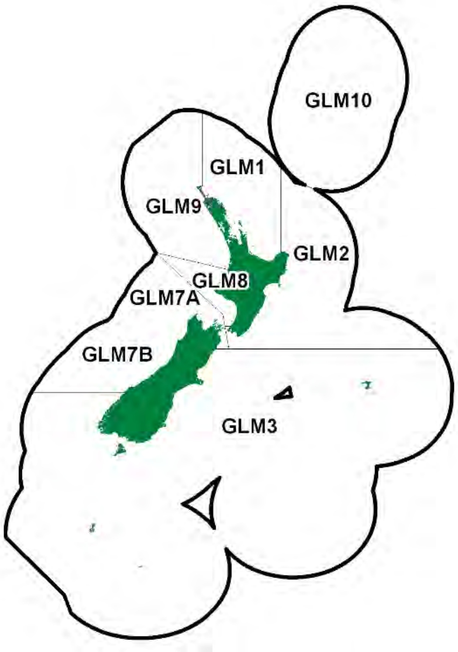
GREEN-LIPPED MUSSEL (GLM)

(Perna canaliculus)
Kuku, Kutai



1. FISHERY SUMMARY

1.1 Commercial fisheries

Commercial harvesting of green-lipped mussels began with handpicking of inter-tidal beds in the late nineteenth century, and expanded in 1927 with the development of a dredge fishery for sub-tidal mussels in the Hauraki Gulf. Following a brief decline in catch rates from 1935–45, landings increased steadily to peak in 1961 at more than 2 000 t. Overexploitation of the Hauraki Gulf beds caused the fishery to close in 1966. A second dredge fishery developed in Tasman Bay and Kenepuru Sound in 1962; however, under an open access regime this fishery also declined within five years.

Between 2004 and 2007 reported landings were dominated by GLM 7A; since 2007 GLM 9 landings have been dominant. Total landings have been low and declining compared to the total TACC in GLM 1 and GLM 7A, but landings exceeded the GLM 9 TACC in 2009-10, 2014-15, 2015-16, and 2016-17. Recent estimated landings of green-lipped mussels are shown in Table 1, while Figure 1 shows the historical landings and TACC for the three main GLM stocks.

Table 1: Reported landings (t) of Green-lipped mussel and actual TACCs (t) from 2004–05 to the present.

Fishstock	GLM 1		GLM 2		GLM 3		GLM7A		GLM 9		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2004–05	6.2	10	0	10	0.2	10	410.9	1 500	121.3	180	539	1 720
2005–06	12.5	10	0.2	10	0.2	10	229.0	1 500	93.0	180	335	1 720
2006–07	7.8	10	0	10	0	10	84.3	1 500	136.9	180	229	1 720
2007–08	3.5	10	0	10	<0.1	10	7.4	1 500	141.7	180	153	1 720
2008–09	6.7	10	0	10	<0.1	10	0.1	1 500	67.9	180	75	1 720
2009–10	4.4	10	0	10	<0.1	10	<1	1 500	183.3	180	187	1 720
2010–11	1.0	10	0	10	0	10	1.4	1 500	78.1	180	80	1 720
2011–12	0.5	10	0	10	0	10	0.1	1 500	162.0	180	163	1 720
2012–13	0.6	10	0	10	0	10	0	1 500	129.0	180	130	1 720
2013–14	0.1	10	0	10	0	10	8.3	1 500	159.9	180	167	1 720
2014–15	<0.1	10	0	10	0	10	8.3	1 500	207.0	180	215	1 720
2015–16	0.1	10	0	10	0	10	0	1 500	203.4	180	203	1 720
2016–17	0.2	10	0	10	0	10	0	1 500	208.9	180	209	1 720
2017–18	<0.1	10	0	10	0	10	0	1 500	151.9	180	152	1 720
2018–19	0	10	0	10	0.7	10	0	1 500	148.1	180	148.8	1 720

Spat collecting is the other commercial venture with green-lipped mussels. Until green-lipped mussels were introduced into the QMS a permit was required to harvest spat attached to beach cast seaweed. Green-lipped mussels were introduced into the Quota Management System on 1 October 2004 with TAC and TACC listed in Table 2.

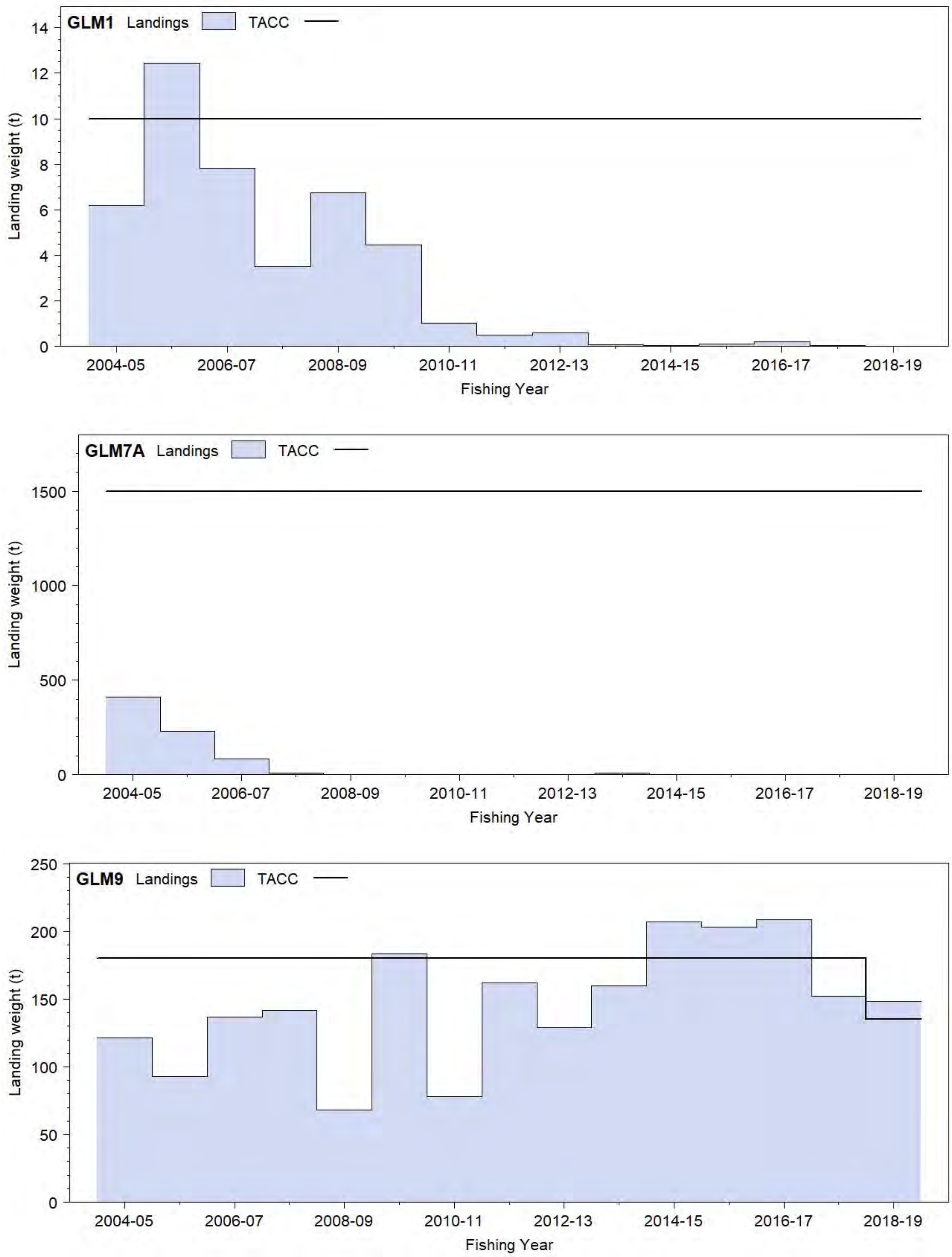


Figure 1: Reported commercial landings and TACC for the three main GLM stocks. From top: GLM 1 (Auckland East), GLM 7A (Nelson Marlborough), and GLM 9 (Auckland West). Note that these figures do not show data prior to entry into the QMS.

Table 2: Recreational and Customary non-commercial allowances, TACC and TAC for green-lipped mussel.

Fishstock	Recreational allowance	Customary non-commercial allowance	TACC	TAC
GLM 1	162	243	10	415
GLM 2	10	15	10	35
GLM 3	58	87	10	155
GLM 7A	19	29	1 500	1 548
GLM 7B	5	8	100	23
GLM 8	17	26	0	43
GLM 9	39	59	180	278
GLM 10	0	0	0	0
Total	310	467	1 720	2 497

1.2 Recreational fisheries

Recreational harvest estimates for green-lipped mussels have been obtained from the 1996, 2000 and 2001 national telephone diary surveys of recreational fishers (Table 3). Estimates of green-lipped mussels from the 1996 survey are only available for FMA 1. No weights were available from the surveys to estimate recreational harvest by tonnage. The Recreational Technical Working Group has reviewed the harvest estimates from the national telephone diary surveys and considered that the estimates from the 1996 survey are unreliable because the survey contained a methodological error. The estimated number of green-lipped mussels from the 2000 and 2001 surveys is also considered to be unreliable. In response to these problems and the cost and scale challenges associated with onsite methods, a National Panel Survey was conducted for the first time throughout the 2011–12 fishing year (Wynne-Jones et al. 2014). The panel survey used face-to-face interviews of a random sample of 30 390 New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and harvest information collected in standardised phone interviews. The panel survey was repeated in 2017–18 (Wynne-Jones et al. 2019).

Table 3: Harvest estimates of mussels (000s of individuals of *P. canaliculus* combined) from the 1996, 2000 and 2001 national recreational surveys, by FMA (Bradford 1998, Boyd et al. 2004) and the national panel surveys in 2011–12 and 2017–18 (Wynne-Jones et al. 2014, Wynne-Jones et al. 2019).

Area	Number (thousands)	CV
1996 (telephone-diary)		
GLM 1	818	
GLM 2		
GLM 3		
GLM 5		
GLM 7		
GLM 8		
GLM 9		
2000 (telephone diary)		
GLM 1	1 308	
GLM 2	8	
GLM 3	402	
GLM 5	1	
GLM 7	3	
GLM 8	242	
GLM 9	25	
2002 (telephone diary)		
GLM 1	949	
GLM 2	22	
GLM 3	187	
GLM 5	36	
GLM 7	363	
GLM 8	-	
GLM 9	148	
2011–12 (national panel survey)		
GLM 1	576	
GLM 2	56	
GLM 3	73	
GLM 5	8	
GLM 7	78	
GLM 8	39	
GLM 9	154	
GLM total	983	
2017–18 (national panel survey)		
GLM 1	147	0.29
GLM 2	54	0.44
GLM 3	44	0.41
GLM 5	23	0.49
GLM 7	55	0.42
GLM 8	3	0.72
GLM 9	17	0.46
GLM total	342	

1.3 Customary non-commercial fisheries

Green-lipped mussels are very important to customary fishing. This species was used extensively by Māori, appearing in middens throughout the country. The species continues to be important to Māori and, anecdotally, a number of customary fishers have noted its importance as a resource in a number of areas. While little information is available, the green-lipped mussel remains an important element of customary fishing throughout many parts of New Zealand and efforts are being made collaboratively with iwi to manage populations in localised areas, e.g., Ōhiwa Harbour Implementation Forum.

Limited quantitative information on the level of customary take is available from Fisheries New Zealand (Table 4). These numbers are likely to be an underestimate of customary harvest as only the catch in numbers and kilograms are reported in the table below.

Table 4: Fisheries New Zealand records of customary harvest of green-lipped mussels (reported as weight (kg) and numbers), 2013–14 to 2017–18. – no data.

		Weight (kg)		Numbers	
Stock	Fishing year	Approved	Harvested	Approved	Harvested
GLM 1	2009–10	280	25	1 000	700
	2010–11	470	120	725	545
	2011–12	80	30	75	50
	2014–15	530	500	350	300
	2015–16	445	440	–	–
	2016–17	340	80	160	45
	2017–18	–	–	300	200
GLM 2	2013–14	–	–	350	350
GLM 3	2005–06	–	–	225	75
	2006–07	–	–	1 410	694
	2007–08	–	–	4 569	4 284
	2008–09	–	–	9 820	7 920
	2009–10	–	–	2 890	2 175
	2010–11	–	–	1 900	1 900
	2011–12	–	–	1 905	1 725
	2012–13	–	–	4 115	3 300
	2013–14	–	–	300	100
	2014–15	–	–	–	–
	2015–16	–	–	9 430	7 934
	2016–17	–	–	3 150	1 224
	2017–18	–	–	600	308
	2018–19	–	–	400	203
GLM 7B	2006–07	200	200	–	–
	2007–08	–	–	200	200
	2016–17	–	–	650	650

1.4 Illegal catch

Current levels of illegal harvest are not known.

1.5 Other sources of mortality

There is no quantitative information.

2. BIOLOGY

The green-lipped mussel is a filter-feeding mollusc. While distributed throughout New Zealand, it is most common in central and northern parts where it frequently forms dense beds of up to 100 m^2. This species is absent from the Chatham Islands and other offshore islands. It is typically a bivalve of the lower shore and open coast and is found from the mid-littoral to depths of over 50 m. The species can grow to over 240 mm in shell length (anterior-posterior axis).

The green-lipped mussel is a dioecious (uni-sexual) broadcast spawner. Gonadal development takes place at temperatures above 11ºC and is also related to food availability, environmental conditions, and stock origin. Most spawning occurs in late spring to early autumn, but larvae can be present all year. Sexual maturity has been observed in some populations to begin from 27 mm shell length, with most individuals sexually mature by 40 mm shell length. Sexual maturity is reached in the first year, and females can produce up to 100 million eggs per season. Fertilisation is largely dependent on the proximity of adults.

Settlement processes associated with marine farms have been well studied, but less is known about natural settlement. The planktonic stage (pediveligers) of the green-lipped mussel is ready to settle at 220–350 μm in length, after a three to five week larval phase. The larvae swim only vertically but they can be transported large distances by currents and tides. Settlement is most intense from late winter to early summer, but is highly variable spatially and temporally. In the wild, larvae settle over a wide range of depths, preferring fine filamentous substrata including hydroids, bryozoans, and filamentous and turfing algae. Settlement is completed with the attachment of byssus threads and subsequent metamorphosis.

Primary settlement onto beds of adult mussels is uncommon, but can take place on surrounding algae and on the byssi of adults. Secondary settlement, after a form of byssopelagic migration or mucous drifting, is thought to be the means by which most juveniles recruit into mussel beds. The spat detaches from the substrate by severing the byssus threads and the secreted mucous strand, this enables it to swim or drift to new areas for attachment. Juvenile mussels may move numerous times like this before settling on adult mussel beds. This drifting ability is lost once spat reach about 6 mm in shell length.

There is little information on age, growth and natural mortality, particularly for wild populations, however recent evidence suggests that stock origin can have a significant effect on their growth indicating a large genetic component. Green-lipped mussels in suspended culture typically grow from 10 to 75 mm shell length in six months, to 111–115 mm in one year, and to 195 mm in three and a half years. Growth is typically faster in cultured situations compared with natural beds, which are often overcrowded, are on exposed coasts, and are not constantly submerged so feeding is discontinuous. At Piha and West Tamaki Head, green-lipped mussel growth is variable, with individuals reaching 20–70 mm shell length in their first year.

3. STOCKS AND AREAS

Green-lipped mussels are distributed in seven of the ten FMAs (1–3, 5 and 7–9) but are most common in the central and northern parts of New Zealand.

There is little information on stock structure, recruitment patterns, or other biological characteristics. There appears to be strong genetic structuring of the New Zealand green-lipped mussel population, with a northern and southern group being differentiated by frequency shifts in common haplotypes, and the occurrence of a unique haplotype in the south island west coast population. The southern-northern population split occurs south of Cook Strait.

4. STOCK ASSESSMENT

There are no stock assessments or biomass estimates for green-lipped mussels.

5. STATUS OF THE STOCKS

It is not known whether green-lipped mussel stocks are at, above, or below a level that can produce *MSY* as no estimates of reference or current biomass are available for any green-lipped mussel fishstock at a management area level. However, some localised information is available. Green-lipped mussel populations have been intermittently surveyed in Ōhiwa Harbour since 2006. What this monitoring has shown is a reduction in the historical distribution of green-lipped mussels within the harbour along with a >99% reduction in abundance in the decade since 2006 across all size-classes due to sediment deposition.

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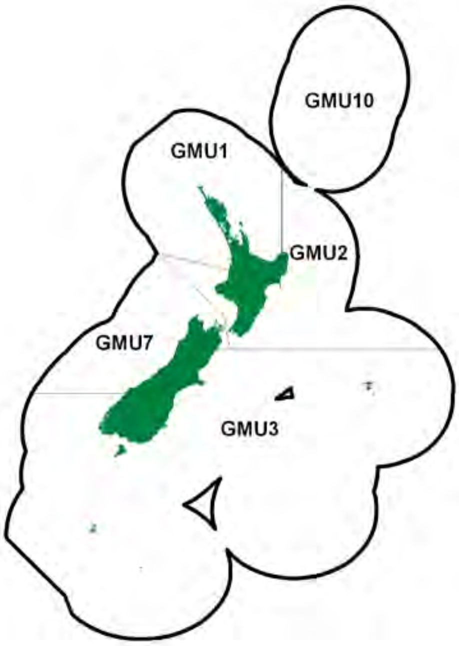
GREY MULLET (GMU)

(*Mugil cephalus*)
Kanae, Hopuhopu



1. FISHERY SUMMARY

1.1 Commercial fisheries

Commercial fishing for grey mullet occurs predominantly in GMU 1, where annual landings increased from approximately 128 t in 1931 to a maximum of 1 142 t in 1983–84 (Table 1; 2). Marked changes in fishing effort occurred during this period through the development of more efficient fishing techniques and an increase in the market demand for this species. Before the introduction of the QMS, total domestic catches declined from the maximum (1 160 t) in 1983–84 to 901 t in 1985–86. The TACC was consistently under caught after GMU 1 was introduced into the QMS (Figure 1). The Minister of Fisheries therefore reduced the TACC for GMU 1 to 925 t, beginning in 1998–99. The reduction in TACC had little effect on the annual catches, and it has only ever been reached in GMU 1 in 2004–05 and 2013–14 (Table 2).

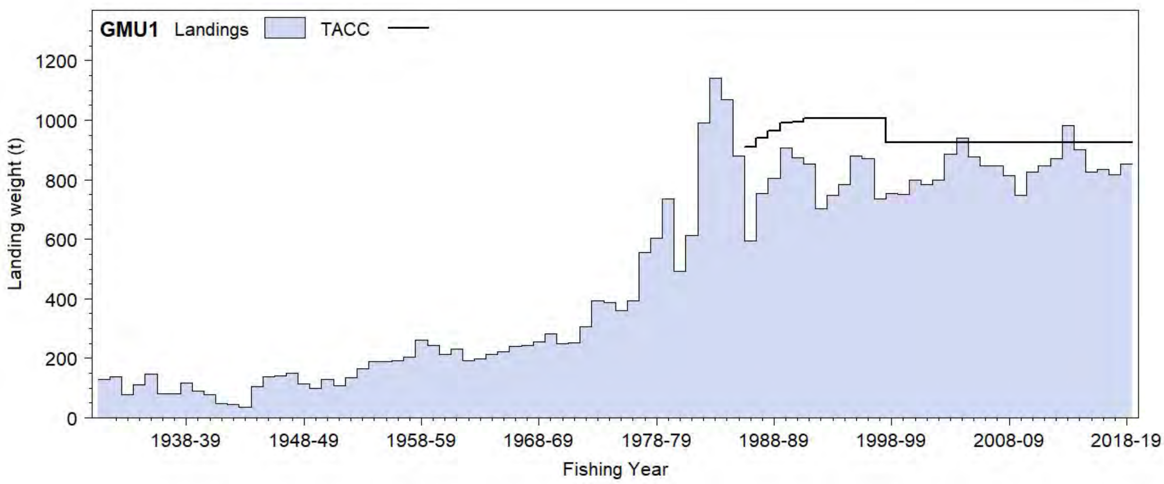


Figure 1: Reported commercial landings and TACC for the main GMU stock; GMU 1 (Auckland).

Table 1: Reported landings (t) for the main QMAs from 1931 to 1990.

Year	GMU 1	GMU 2	GMU 3	GMU 7	Year	GMU 1	GMU 2	GMU 3	GMU7
1931–32	128	0	0	0	1957	204	1	0	0
1932–33	138	0	0	0	1958	262	0	0	0
1933–34	78	0	0	0	1959	244	0	0	0
1934–35	111	0	0	0	1960	213	0	0	0
1935–36	147	0	0	0	1961	230	0	0	0
1936–37	80	0	0	0	1962	191	0	0	0
1937–38	82	0	0	0	1963	199	0	0	0
1938–39	117	1	0	1	1964	214	0	0	0
1939–40	91	0	0	0	1965	222	2	3	0
1940–41	77	0	0	0	1966	240	0	0	0
1941–42	48	2	0	0	1967	243	0	0	0
1942–43	44	2	0	0	1968	256	0	0	0
1943–44	35	0	0	0	1969	283	1	1	0
1944	104	0	0	0	1970	248	1	0	0
1945	138	0	0	0	1971	253	1	0	0
1946	141	0	0	0	1972	305	0	1	0
1947	151	0	0	0	1973	393	1	4	2
1948	114	0	0	0	1974	386	0	0	0
1949	100	0	0	0	1975	360	0	0	0
1950	129	0	0	0	1976	394	0	0	0
1951	108	0	0	0	1977	557	0	0	0
1952	136	0	0	0	1978	604	0	0	0
1953	166	0	0	0	1979	735	0	0	0
1954	190	0	0	0	1980	494	0	0	0
1955	188	0	0	0	1981	612	0	0	0
1956	193	0	0	0	1982	990	0	8	2

Notes:

1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data includes both foreign and domestic landings.

Table 2: Reported landings (t) of grey mullet by Fishstock from 1983–84 to 2018–19 and actual TACCs (t) for 1986–87 to 2018–19. QMS data from 1986-present. There have been no report landings for GMU 10.

Fishstock		GMU 1		GMU 2		GMU 3		GMU 7	GMU 10		
QMA (s)		1 & 9		2 & 8		3, 4, 5 & 6		7	10		Total
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	TACC	Landings	TACC
1983–84*	1 142	-	6	-	5	-	7	-	-	1 160	-
1984–85*	1 069	-	5	-	0	-	15	-	-	1 089	-
1985–86*	881	-	10	-	0	-	10	-	-	901	-
1986–87	595	910	3	20	<1	30	0	20	10	598	990
1987–88	751	941	3	20	0	30	0	20	10	754	1 021
1988–89	792	963	3	20	0	30	0	20	10	795	1 043
1989–90	907	990	2	20	0	30	4	20	10	913	1 070
1990–91	875	994	2	20	1	30	<1	20	10	879	1 073
1991–92	848	1 006	1	20	2	30	1	20	10	852	1 086
1992–93	711	1 006	<1	20	<1	30	0	20	10	712	1 086
1993–94	743	1 006	<1	20	<1	30	0	20	10	706	1 086
1994–95	776	1 006	0	20	<1	30	10	20	10	787	1 086
1995–96	866	1 006	0	20	<1	30	<1	20	10	866	1 086
1996–97	870	1 006	<1	20	1	30	<1	20	10	872	1 086
1997–98	730	1 006	<1	20	<1	30	<1	20	10	730	1 086
1998–99	750	925	<1	20	<1	30	<1	20	10	750	1 005
1999–00	749	925	<1	20	0	30	<1	20	10	750	1 005
2000–01	797	925	1	20	0	30	<1	20	10	798	1 005
2001–02	782	926	2	20	<1	30	<1	20	10	784	1 005
2002–03	797	926	1	20	<1	30	0	20	10	798	1 005
2003–04	886	926	<1	20	0	30	<1	20	10	796	1 005
2004–05	941	926	<1	20	0	30	0	20	10	941	1 005
2005–06	878	926	<1	20	<1	30	0	20	10	878	1 005
2006–07	847	926	1	20	0	30	<1	20	10	845	1 005
2007–08	848	926	1	20	<1	30	<1	20	10	849	1 005
2008–09	814	926	1	20	0	30	0	20	10	815	1 005
2009–10	746	926	<1	20	0	30	0	20	10	746	1 005
2010–11	825	926	<1	20	<1	30	<1	20	10	826	1 006
2011–12	848	926	<1	20	<1	30	<1	20	10	848	1 006
2012–13	871	926	<1	20	<1	30	<1	20	10	871	1 006
2013–14	981	926	<1	20	0	30	0	20	10	981	1 006
2014–15	900	926	<1	20	0	30	<1	20	10	901	1 006
2015–16	827	926	<1	20	0	30	0	20	10	827	1 006
2016–17	835	926	<1	20	0	30	0	20	10	836	1 006
2017–18	817	926	0	20	0	30	3	20	10	820	1 006
2018–19	852	926	<1	20	<1	30	0	20	10	852	1 006

*FSU data.

1.2 Recreational fisheries

Grey mullet are a popular recreational species particularly in the Auckland FMA. Information is available on the relative levels of commercial and amateur catch of this species in the Manukau Harbour and the lower Waikato River based on limited tagging work undertaken in 1987. Of the number of tags returned 38% were from amateur fishers, suggesting that recreational use of the resource was relatively high.

Telephone-diary surveys is 1993–94 (Teirney et al 1997), 1996 (Bradford 1998), and 2000 (Boyd et al 2004) were used to estimate the annual recreational catch from GMU 1 as 150, 106, and 100 t, respectively (Table 3). The Minister of Fisheries provided an allowance for customary harvest of 100 t beginning in 1998–99.

The harvest estimates provided by telephone-diary surveys between 1993 and 2001 are no longer considered reliable for various reasons. A Recreational Technical Working Group concluded that these harvest estimates should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries. In response to these problems and the cost and scale challenges associated with onsite methods, a National Panel Survey was conducted for the first time throughout the 2011–12 fishing year. The panel survey used face-to-face interviews of a random sample of 30 390 New Zealand households to recruit a panel of fishers and non-fishers for a full year (Wynne-Jones et al 2014). The panel members were contacted regularly about their fishing activities and harvest information collected in standardised phone interviews. The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly comparable results (Wynne-Jones et al 2019). Recreational catch estimates from the two national panel surveys are given in Table 3. Note that national panel survey estimates do not include recreational harvest taken under s111 general approvals.

Table 3: Estimated number of grey mullet harvested by recreational fishers by Fishstock and survey year (Wynne-Jones et al 2014, 2019 for panel surveys), and the estimated Fishstock harvest (using mean weights from Hartill & Davey 2015 and Davey et al 2019).

Survey	Fishstock	Number	CV	Harvest range (t)	Harvest estimate (t)
1994 telephone-diary	GMU 1	170 000	0.19	90–210	150
1996 telephone-diary	GMU 1	110 000	0.25	80–130	106
2000 telephone-diary	GMU 1	110 000	0.33	68–136	102
2011/12 panel survey	GMU 1	29 622	0.41	-	27.3
2011/12 panel survey	GMU 2	1 531	0.53	-	2.8
2011/12 panel survey	GMU 3	5 252	0.93	-	4.8
2011/12 panel survey	GMU 7	191	0.73	-	0.2
2017/18 panel survey	GMU 1	38 088	0.62	-	29.9
2017/18 panel survey	GMU 2	2 400	0.63	-	1.9
2017/18 panel survey	GMU 3	25	1.00	-	<0.1
2017/18 panel survey	GMU 7	25 453	0.35	-	20.0

1.3 Customary non-commercial fisheries

No quantitative information is available on the current level of customary non-commercial take. The Minister of Fisheries provided an allowance for customary harvest of 100 t per annum beginning in 1998–99.

1.4 Illegal catch

Estimates of illegal catch are unknown but anecdotal evidence suggests 10–20% under-reporting is plausible. In the latest stock assessment, an annual under-reporting of 20% was assumed for the period before 1986 and 10% thereafter.

1.5 Other sources of mortality

No quantitative estimates are available regarding the impact of other sources of mortality on grey mullet stocks. Grey mullet principally occur in sheltered harbours and estuarine ecosystems. Some of these habitats are known to have suffered environmental degradation.

2. BIOLOGY

Grey mullet has a worldwide distribution, occurring commonly along coasts, in estuaries, and in lower river systems between latitudes of 42º N and 42º S. Overseas and New Zealand tagging studies indicate that movement patterns of adult grey mullet are complex. Some schools remain in one locality, while others appear to be on the move almost continuously. Recorded movements of tagged grey mullet of 160 km within a few weeks of release are not uncommon.

Females grow faster than males and attain a larger size. Both sexes mature at 3 years of age at an average size of 33 cm fork length (FL) for males and 35 cm FL for females. Maximum ages appear to be 12 to 14 years, with ages 4–8 making up the bulk of the commercial fishery.

Natural mortality was estimated from the equation $M = \log_e 100/\text{maximum age}$, where maximum age is the age to which 1% of the population survives in an unexploited stock. Using 15 years for the maximum age results in an estimate of $M = 0.33$. (Note: the maximum age of 15 years was obtained from an exploited population, so M is likely to be less than 0.33).

Grey mullet commonly occur in schools, which generally become larger and more prevalent in the spawning season. Spawning in northern New Zealand occurs during November to February. Females are highly fecund and may release up to 1 million eggs in a spawning event. It is likely that grey mullet spawn at sea, because running-ripe females have only been caught off coastal beaches or in offshore waters, and eggs and larvae are a component of the offshore coastal plankton at certain times of the year. Small post-larval grey mullet occur seasonally in estuaries, which serve as nursery grounds for juveniles.

Adult grey mullet typically feed on diatom algae and small invertebrates which are gulped along with surface scum or with detrital ooze and sifted by fine teeth and gill-rakers.

Biological parameters relevant to stock assessment are shown in Table 4.

Table 4: Estimates of biological parameters of grey mullet.

Fishstock							**Estimate**	**Source**
1. Natural mortality (M)								
GMU 1							0.33	NIWA (unpubl. data)
2. Weight = a(length)^b (Weight in g, length in cm fork length).								
	Both Sexes							
	a	b						
GMU 1	0.04236	2.826						Breen & McKenzie (unpublished)
3. Von Bertalanffy growth parameters								
	Females			Males				
	L_∞	k	t_0	L_∞	k	t_0		
GMU 1	40.1	0.587	1.3469	37.0	0.619	1.3257		Breen & McKenzie (unpublished)

3. STOCKS AND AREAS

There is little biological data to determine the level of sub stock separation within GMU 1. Results from a small scale tagging program in the Manukau Harbour and the Lower Waikato River indicated that there is fish movement between these two localities and also north along the west coast but the net level of movement cannot be ascertained. There is evidence in the CPUE data that GMU 1 may be comprised of six populations with low to moderate mixing between them (McKenzie 1997).

GMU 1 has been divided into two sub-stocks (east coast and west coast) for the purposes of fisheries stock assessment. The boundary between the two sub-stocks is assumed to be due north from North Cape.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

Standardised CPUE analyses were undertaken for the six largest catching areas in GMU 1. The analysis was based on setnet catch and effort data for the years 1990–91 to 2005–06 (McKenzie & Vaughan 2008), and updated to 2010–11 (Kendrick & Bentley 2012). However, internal and anecdotal evidence suggest that method is being misreported in these fisheries and that standardized CPUE is unlikely to reflect relative abundance for GMU. CPUE was therefore rejected as an index of relative abundance for all sub-areas within GMU 1.

4.2 Biomass estimates

West coast GMU 1

A stock assessment was undertaken for the west GMU 1 substock using a stochastic dynamic age-structured observation-error time series model (Breen & McKenzie 1998), but this did not prove to be robust and the results were rejected by the Working Group.

4.3 Yield estimates and projections

There is insufficient information with which to revise the yield estimates of either the West or East coast GMU 1 substocks. The *MCY* estimate derived in 1986 using the equation $MCY = cY_{AV}$ (Method 4) remains the accepted yield estimate for GMU 1.

Annual landings of grey mullet in the Auckland QMA for the period 1974–84 showed an increasing trend to a maximum in 1984. There were some fluctuations throughout this period. A general increase in fishing effort occurred during this time. Fishing effort between 1983–84 and 1985–86 appeared relatively constant, and catches during these years were averaged to estimate Y_{AV}. The constant '*c*' was set at 0.8. This is not consistent with the maximum observed age of 14 years, which equates with an estimate of $M = 0.33$ and $c = 0.7$. However, it is believed that they live to older ages in unexploited populations. Therefore, the accuracy of *MCY* derived for grey mullet is uncertain. The estimate of *MCY* for GMU 1 is shown in Table 5. *MCY* cannot be estimated for the other fish stocks.

Table 5: Estimate of *MCY* (t) rounded to the nearest 5 t.

Fishstock	QMA	Y_{AV}	*MCY*
GMU 1	Auckland 1 & 9	1 030	825

The level of risk to the stock by harvesting the population at the estimated *MCY* level cannot be determined. No estimates of current biomass, fishing mortality, or other information are available which would permit the estimation of *CAY*.

4.5 Other Factors

The minimum legal mesh size for use in the grey mullet fishery is 89 mm. However, fishers typically use mesh larger than 89 mm when fishing for grey mullet (Fisheries New Zealand data). There are no data available to compare the selectivity characteristics of different mesh sizes. It is possible that a significant fraction of the grey mullet stock comprising larger older fish is poorly selected by the fishery. If this is true then the von Bertalanffy parameter estimates, which are based on random samples from the 1997–98 setnet landings, are likely to be biased: L_∞ will be biased low, K biased high.

Grey mullet have been exploited by customary, commercial, and recreational fishers for over a hundred years. They are found predominantly in harbours and these environments have undergone considerable change over this period due to a range of anthropogenic sources. The impact of these changes on potential carrying capacity and productivity are not understood and this potentially has impacts on the yields of GMU.

Characterisation shows an overall trend away from set netting towards ring netting, and, within the nominal setnet method, a trend towards shorter nets; a trend that is not seen in flatfish setnet fisheries in the same areas. This suggests there have been systematic changes in fishing strategy that are not captured by the CELR form. Anecdotal information from interviews of net fishers suggests that fishers use the various net method codes interchangeably, and that the methods describe differences in strategy rather than in gear, from passive fishing to spotting and encircling schools of fish. While the passive form of set netting is an appropriate sampling tool, any contamination by ring net or similarly 'directed' fishing could mask trends in the abundance of the underlying population.

The Working Group agreed that given the misreporting issues and its consequences, that standardized CPUE is unlikely to reflect relative abundance for GMU.

5. STATUS OF THE STOCKS

Given the misreporting of method and its consequences, standardized CPUE is unlikely to reflect relative abundance for GMU. CPUE was therefore rejected as an index of relative abundance for all sub-areas within GMU 1.

Yields, TACCs and reported landings are summarised in Table 6.

Table 6: Summary of yields (t), TACCs (t), and reported landings (t) of grey mullet for the most recent fishing year.

Fishstock	QMA	*MCY*	2018–19 Actual TACC	2018–19 Reported landings
GMU 1	Auckland (East) (West) 1 & 9	825	926	851
GMU 2	Central (East) (West) 2 & 8	-	20	<0.1
GMU 3	South-East (Coast) (Chatham) 3, 4, Southland and Sub-Antarctic 5 & 6	-	30	<0.1
GMU 7	Challenger 7	-	20	0
GMU 10	Kermadec 10	_	10	0
Total		-	1 006	851

6. FOR FURTHER INFORMATION

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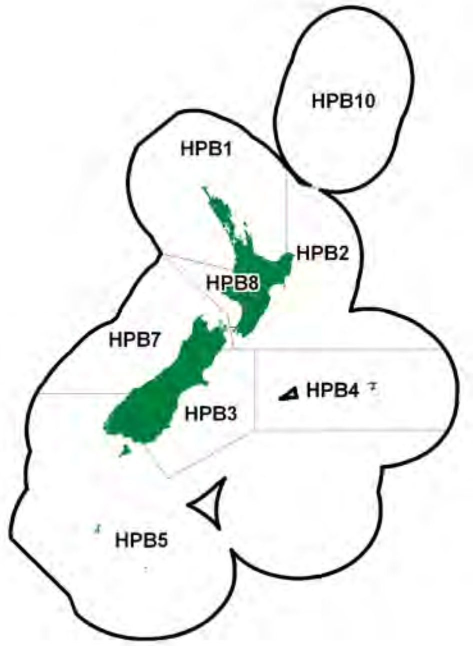
GROPER (HPB)

(*Polyprion oxygeneios*, *Polyprion americanus*)
Hāpuku, Moeone



1. FISHERY SUMMARY

1.1 Commercial fisheries

Both groper species, *Polyprion oxygeneios* (hāpuku) and *P. americanus* (bass), occur in shelf and slope waters of the New Zealand mainland and offshore islands, from the Kermadecs to the Auckland Islands. The groper fishery takes both species, but in different proportions by region, depth, fishing method and season, and these have changed over time. Reported landings generally do not distinguish between species, and published data combine them. In earlier years, bluenose (*Hyperoglyphe antarctica*) landings were sometimes also combined with groper. In this document, groper is used as collective term for hāpuku and bass. Historical estimated and recent reported groper landings and TACCs are shown in Tables 1, 2 and 3, while Figure 1 shows the historical and recent landings and TACC values for the main groper stocks.

Table 1: Reported total New Zealand landings (t) of groper from 1948 to 1983.

Year	Landings	Year	Landings	Year	Landings	Year	Landings
1948	1 665	1957	1 368	1966	1 222	1975	1 422
1949	1 969	1958	1 532	1967	1 314	1976	1 512
1950	1 709	1959	1 310	1968	1 073	1977	1 942
1951	1 396	1960	1 223	1969	1 122	1978	1 488
1952	1 430	1961	1 203	1970	1 499	1979	2 078
1953	1 403	1962	1 173	1971	1 346	1980	2 435
1954	1 364	1963	1 194	1972	1 120	1981	2 379
1955	1 305	1964	1 370	1973	1 312	1982	2 218
1956	1 399	1965	1 249	1974	1 393	1983	2 511

Reported foreign catches are included from 1974.
Source: Fisheries data.

The main fishery comprises a number of domestic fishers working small to medium sized vessels - longliners, setnetters and trawlers, at a variety of depths (according to method) out to 500 m (Paul 2002a). Over 90% of early (to 1950) total groper catches were taken by longline. Trawl catches rose from 5–10% during this period to 20–30% by the late 1970s. A setnet fishery developed in the late 1970s and early 1980s, mainly at Kaikoura, taking 14% in 1983 and then subsequently declining. From 1950 to the mid-1980s, line-fishing took 70–80% of the catch. After the introduction of the QMS in 1986, the proportion of the catch taken by lines appeared to drop.

The Cook Strait region has always supported the main groper fishery, followed by the Canterbury Bight; both show the same slow decline from 1949 to 1986 (equivalent regional data from subsequent years are not available). Northland, Bay of Plenty and Hawke Bay fisheries developed at different rates during the 1960s and 1970s. In most other areas, the groper fishery has been small and/or variable.

The first recorded landings of about 1 500 t in 1936 were typical of the range of catches (1 000–2 000 t) from then until 1978. After a decrease during the war when effort was restricted, landings in the total fishery slowly declined from almost 2 000 t in 1949 to about 1 300 t in the mid-1970s. They then increased sharply to 2 700 t in 1983–84 (Tables 1 and 2). Figure 1 shows the historical landings and TACC values for the main HPB stocks.

Landings and TACCs for all Fishstocks are given in Table 3. Total landings of groper were relatively stable throughout the mid-1990s, remaining below 1 500 t until 1998–99. From 1999–2000 onwards, landings have generally ranged between 1 200 t and 1 700 t. Although the TACC in HPB 3 has been exceeded in some years, landings have generally remained within the quotas for individual Fishstocks and have never exceeded the total TACC.

For the 1991–92 fishing year the conversion factor for headed and gutted groper was increased from 1.40 to 1.45, for fish landed in this state (about 75% of the total), which resulted in a reduction in removals from the stock of 3.5% for the same nominal quota.

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	HPB 1	HPB 2	HPB 3	HPB 4	Year	HPB 1	HPB 2	HPB 3	HPB 4
1931–32	231	0	207	2	1957	133	380	419	23
1932–33	201	276	242	0	1958	115	473	458	30
1933–34	198	330	173	25	1959	147	406	350	54
1934–35	204	304	212	57	1960	122	394	331	48
1935–36	179	201	146	70	1961	135	369	348	50
1936–37	129	445	115	12	1962	163	355	298	40
1937–38	119	523	315	15	1963	197	315	321	56
1938–39	90	621	479	8	1964	224	397	365	41
1939–40	118	502	409	12	1965	212	368	325	68
1940–41	120	444	286	9	1966	213	415	315	4
1941–42	80	450	302	10	1967	229	448	275	0
1942–43	69	287	315	9	1968	139	357	264	0
1943–44	59	316	271	8	1969	197	454	220	0
1944	55	332	286	9	1970	259	670	239	2
1945	106	311	271	3	1971	191	562	289	4
1946	154	326	409	7	1972	401	370	188	0
1947	98	401	563	5	1973	419	481	215	0
1948	111	450	526	11	1974	356	457	208	2
1949	174	498	547	7	1975	227	315	213	18
1950	141	423	555	9	1976	183	220	350	107
1951	104	353	381	19	1977	277	301	265	87
1952	112	368	373	35	1978	348	470	194	10
1953	105	349	431	33	1979	620	487	355	147
1954	156	355	397	32	1980	956	376	414	40
1955	142	351	419	26	1981	693	373	457	59
1956	106	404	439	32	1982	957	336	402	26

Year	HPB 5	HPB 7	HPB 8	Year	HPB 5	HPB 7	HPB 8
1931–32	130	13	13	1957	92	246	76
1932–33	91	98	53	1958	96	250	109
1933–34	99	127	53	1959	68	198	87
1934–35	115	106	56	1960	100	150	77
1935–36	33	109	33	1961	82	139	80
1936–37	29	156	50	1962	101	142	75
1937–38	29	148	52	1963	75	159	71
1938–39	75	156	50	1964	76	193	74
1939–40	59	155	43	1965	48	176	52
1940–41	54	142	41	1966	49	163	62
1941–42	46	150	44	1967	49	228	85

Table 2 [Continued]

Year	HPB 5	HPB 7	HPB 8	Year	HPB 5	HPB 7	HPB 8
1942–43	44	115	35	1968	67	176	70
1943–44	42	112	42	1969	30	138	84
1944	60	188	117	1970	54	175	97
1945	65	173	128	1971	41	181	78
1946	83	229	190	1972	29	99	33
1947	142	250	175	1973	30	136	32
1948	140	275	151	1974	43	140	72
1949	142	364	236	1975	55	379	62
1950	116	281	184	1976	101	445	37
1951	102	267	171	1977	47	575	113
1952	100	281	162	1978	59	280	67
1953	96	252	137	1979	113	276	71
1954	77	235	112	1980	199	315	105
1955	82	197	88	1981	218	381	166
1956	114	227	77	1982	133	256	46

Notes:

1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data includes both foreign and domestic landings.

Table 3: Reported landings (t) of groper by Fishstock from 1983–84 to present and actual TACCs (t) from 1986–87 to present. QMS data from 1986–present. [Continued on next page].

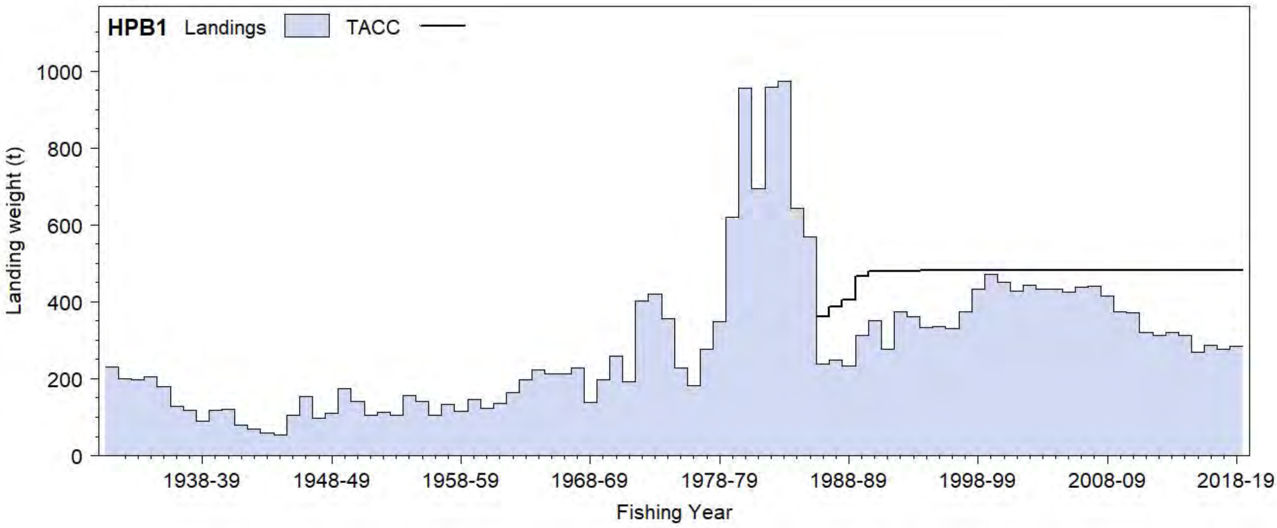
Fishstock	HPB 1		HPB 2		HPB 3		HPB 4		HPB 5	
FMA (s)	1 & 9		2		3		4		5 & 6	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84*	974	-	493	-	505	-	55	-	395	-
1984–85*	642	-	388	-	418	-	52	-	228	-
1985–86*	569	-	270	-	391	-	53	-	126	-
1986–87	238	360	179	210	260	270	42	300	131	410
1987–88	248	388	202	219	268	286	43	315	91	414
1988–89	231	405	187	248	259	294	49	315	70	425
1989–90	310	465	179	263	283	318	40	322	127	430
1990–91	350	480	225	263	311	326	77	323	120	436
1991–92	277	480	252	263	298	326	58	323	112	446
1992–93	375	480	273	264	299	327	68	323	128	446
1993–94	363	480	287	264	306	330	90	323	147	446
1994–95	334	481	259	264	274	335	149	323	161	451
1995–96	335	481	214	264	321	335	173	323	144	451
1996–97	331	481	234	264	301	335	131	323	149	451
1997–98	375	481	260	266	329	335	88	323	91	451
1998–99	433	481	256	266	348	335	121	323	97	451
1999–00	471	481	229	266	385	335	66	323	169	451
2000–01	450	481	220	266	381	335	45	323	188	451
2001–02	427	481	226	266	343	335	82	323	169	451
2002–03	442	481	273	266	350	335	79	323	212	451
2003–04	433	481	281	266	335	335	87	323	166	451
2004–05	433	481	263	266	371	335	147	323	208	451
2005–06	425	481	280	266	406	335	185	323	167	451
2006–07	483	481	245	266	394	335	222	323	157	451
2007–08	439	481	253	266	341	335	241	323	138	451
2008–09	415	481	253	266	391	335	138	323	153	451
2009–10	374	481	249	266	358	335	213	323	152	451
2010–11	371	481	222	266	322	335	231	323	128	451
2011–12	312	481	193	266	336	335	265	323	158	451
2012–13	314	481	206	266	337	335	156	323	140	451
2013–14	319	481	224	266	301	335	169	323	143	451
2014–15	314	481	180	266	280	335	156	323	126	451
2015–16	270	481	143	266	315	335	144	323	143	451
2016–17	287	481	162	266	342	335	152	323	156	451
2017–18	276	481	159	266	344	335	142	323	158	451
2018–19	283	481	173	266	347	335	137	323	168	451

	HPB 7		HPB 8		HPB 10		Total	
	7		8		10			
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84*	174	-	46	-	0	-	2 698	-
1984–85*	207	-	33	-	0	-	2 039	-
1985–86*	199	-	25	-	0	-	1 697	-
1986–87	149	210	35	60	0	10	1 036	1 830
1987–88	158	215	66	76	0	10	1 076	1 923
1988–89	132	226	39	78	1	10	968	2 001
1989–90	119	229	43	80	0	10	1 098	2 117
1990–91	128	235	48	80	23#	10	1 282	2 153
1991–92	175	235	50	80	83#	10	1 319	2 163
1992–93	186	236	62	80	22#	10	1 405	2 165

Table 3 [Continued]

	HPB 7		HPB 8		HPB 10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1993–94	193	236	69	80	0	10	1 455	2 167
1994–95	192	236	68	80	0	10	1 437	2 179
1995–96	214	236	78	80	0	10	1 479	2 179
1996–97	186	236	71	80	15	10	1 418	2 179
1997–98	147	236	60	80	33#	10	1 406	2 181
1998–99	218	236	78	80	3#	10	1 562	2 181
1999–00	165	236	65	80	0#	10	1 561	2 181
2000–01	171	236	64	80	0#	10	1 519	2 181
2001–02	204	236	62	80	< 1	10	1 514	2 181
2002–03	233	236	72	80	0	10	1 661	2 181
2003–04	239	236	66	80	0	10	1 607	2 181
2004–05	240	236	80	80	0	10	1 742	2 181
2005–06	207	236	56	80	0	10	1 728	2 181
2006–07	206	236	66	80	0	10	1 773	2 181
2007–08	195	236	44	80	0	10	1 651	2 181
2008–09	207	236	71	80	0	10	1 628	2 181
2009–10	221	236	66	80	0	10	1 633	2 181
2010–11	191	236	80	80	0	10	1 543	2 181
2011–12	173	236	61	80	0	10	1 187	2 181
2012–13	209	236	75	80	0	10	1 436	2 181
2013–14	182	236	63	80	0	10	1 401	2 181
2014–15	132	236	67	80	0	10	1 254	2 181
2015–16	148	236	73	80	0	10	1 236	2 181
2016–17	141	236	69	80	0	10	1 309	2 181
2017–18	110	236	61	80	0	10	1 250	2 181
2018–19	105	236	47	80	0	10	1 260	2 181

* FSU data.
\# Values in HPB 10 included catches taken under exploratory permit.



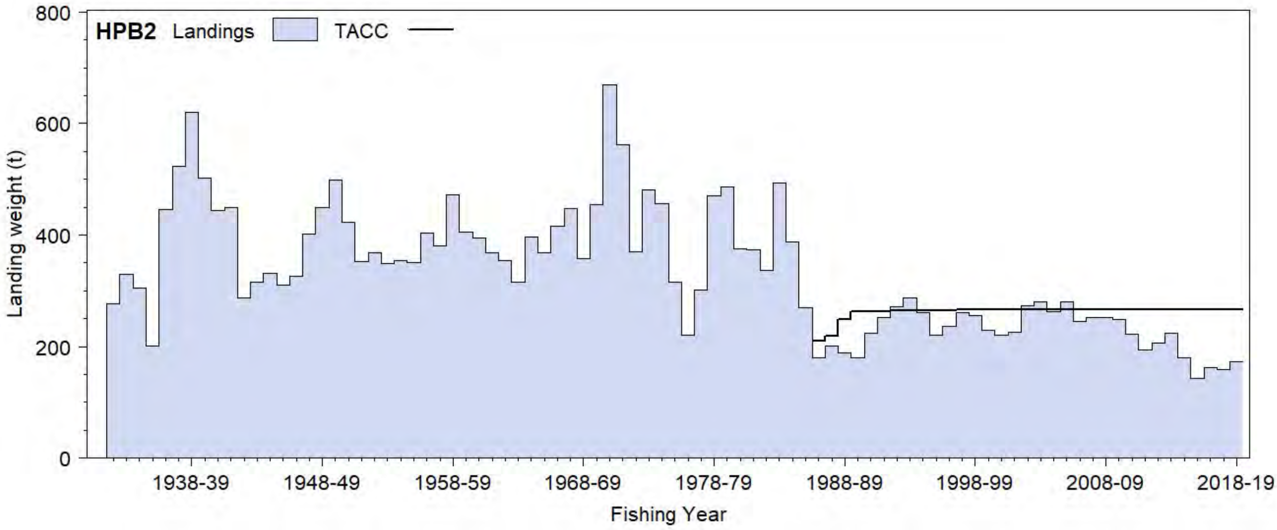
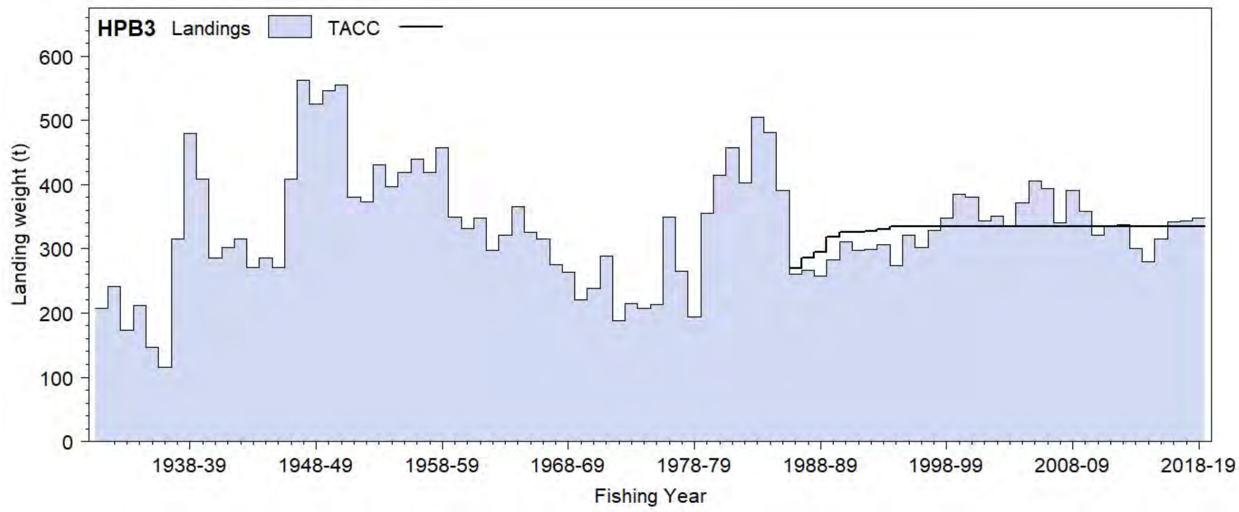
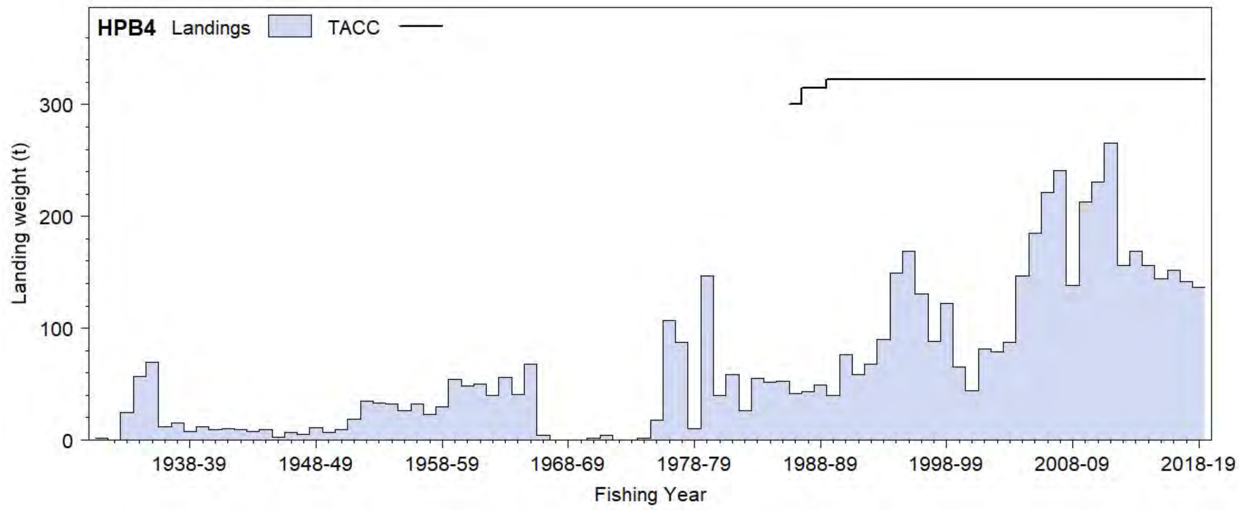


Figure 1: Total reported landings and TACC for the seven main HPB stocks. From top to bottom: HPB 1 (Auckland) and HPB 2 (Central East) [Continued on the next page].





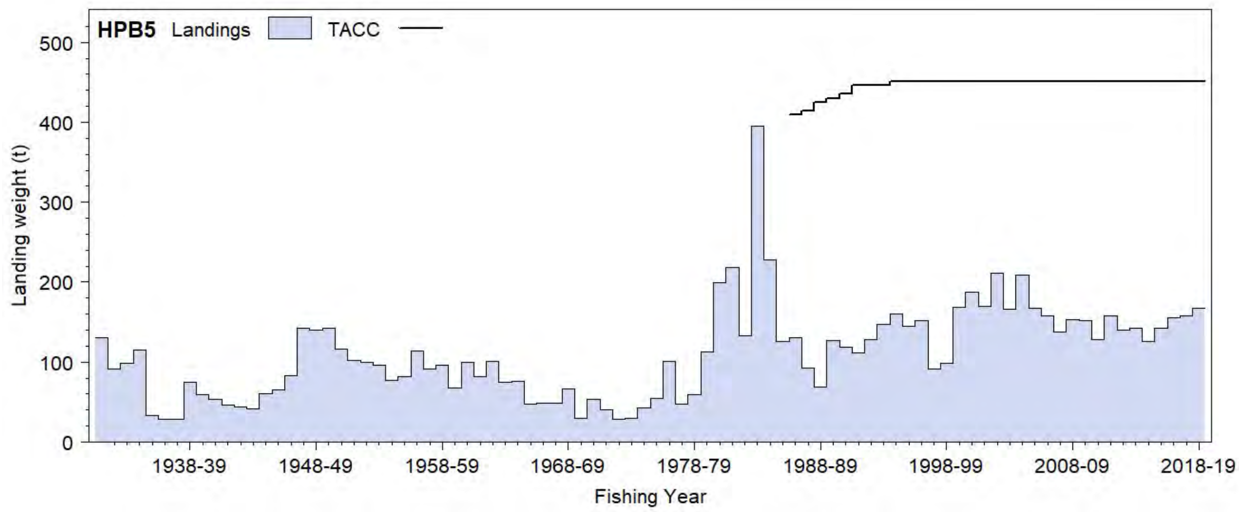
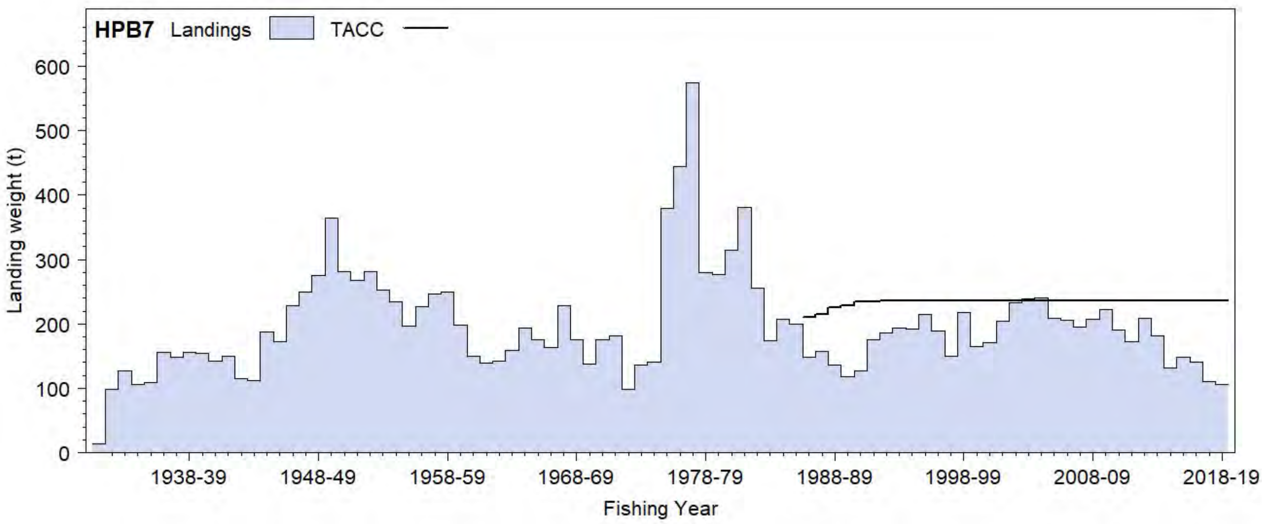


Figure 1 [Continued]: Total reported landings and TACC for the seven main HPB stocks. From top to bottom: HPB 3 (South East Coast), HPB 4 (Chatham Rise), and HPB 5 (Southland, Sub-Antarctic). [Continued on next page].



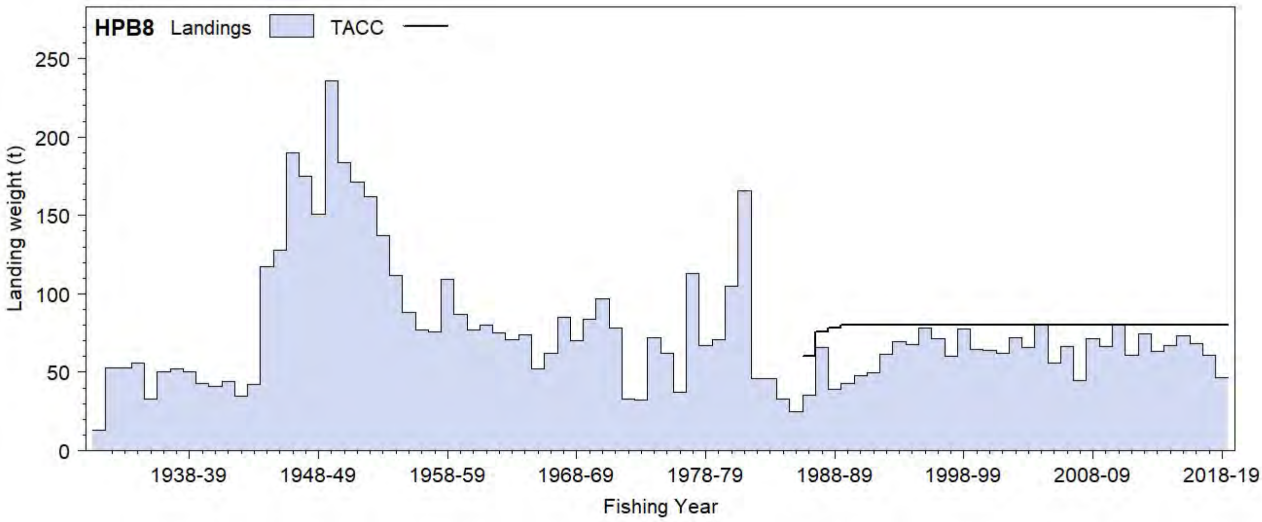


Figure 1 [Continued]: Total reported landings and TACC for the seven main HPB stocks. From top to bottom: HPB 7 (Challenger) and HPB 8 (Central).

1.2 Recreational fisheries

Groper are taken by handline and setline, and to a lesser extent by setnets. Recreational catch estimates from surveys undertaken in the 1990s are given in Tables 4–6.

Table 4: Estimated number of groper harvested by recreational fishers by Fishstock and survey, the corresponding estimated survey harvest and the estimated Fishstock harvest. Surveys were carried out in different years in the MAF Fisheries regions: South in 1991–92, Central in 1992–93 and North in 1993–94 (Teirney et al 1997).

		Total		
Fishstock	**Survey**	**Number**	**CV (%)**	**Survey harvest (t)**
HPB 1	North	22 000	17	190–220
HPB 2	North	1 000	-	5–10
HPB 2	Central	10 000	37	45–85
HPB 3	Central	3 000	-	10–30
HPB 3	South	4 000	40	10–30
HPB 5	Central	7 000	36	20–40
HPB 5	South	2 000	-	5–15
HPB 7	Central	12 000	40	45–115
HPB 8	Central	1 000	-	5−10

Table 5: Results of a national diary survey of recreational fishers in 1996, indicating estimated number of groper harvested by recreational fishers by Fishstock and the corresponding harvest tonnage. The mean weights used to convert numbers to catch weight are considered the best available estimates. Estimated harvest is also presented as a range to reflect the uncertainty in the estimates (from Bradford 1998).

Fishstock	Number caught	CV (%)	Harvest range (t)	Point Estimate (t)
HPB 1	11 000	17	40–60 ⎫	49
HPB 2	23 000	22	75–125 ⎭	100
HPB 3	4 000	-	-⎫	-
HPB 5	2 000	-	-⎭	-
HPB 7	9 000	-	-⎫	-
HPB 8	< 500	-	-⎭	-

Table 6: Results of the 1999–2000 national diary survey of recreational fishers (Dec 1999–Nov 2000). Estimated number of groper harvested by recreational fishers by Fishstock, and the corresponding harvest tonnage. Estimated harvest is presented as a range to reflect the uncertainty in the estimates (Boyd & Reilly 2002).

Fishstock	Number caught	CV (%)	Harvest range (t)	Point estimate (t)
HPB 1	60 000	39	209–476	342
HPB 2	56 000	33	307–608	457
HPB 3	52 000	50	97–293	195
HPB 5	6 000	70	14–80	47
HPB 7	17 000	37	79–172	125
HPB 8	2 000	67	6–32	19

The harvest estimates provided by telephone-diary surveys between 1993 and 2001 are no longer considered reliable for various reasons. A Recreational Technical Working Group concluded that these harvest estimates should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries. In response to these problems and the cost and scale challenges associated with onsite methods, a National Panel Survey was conducted for the first time throughout the 2011–12 fishing year. The panel survey used face-to-face interviews of a random sample of 30 390 New Zealand households to recruit a panel of fishers and non-fishers for a full year (Wynne-Jones et al 2019). The panel members were contacted regularly about their fishing activities and harvest information collected in standardised phone interviews. The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly comparable results (Wynne-Jones et al 2019). Recreational catch estimates from the two national panel surveys are given in Table 7. Note that national panel survey estimates do not include recreational harvest taken under s111 general approvals.

Table 7: Recreational harvest estimates for groper stocks (Wynne-Jones et al 2014, 2019). Mean fish weights were obtained from boat ramp surveys (Hartill & Davey 2015, Davey et al 2019).

Stock	Year	Method	Number of fish	Total weight (t)	CV
HPB 1	2011/12	Panel survey	14 264	83.5	0.37
HPB 2	2011/12	Panel survey	10 179	59.6	0.28
HPB 3	2011/12	Panel survey	6 383	37.4	0.31
HPB 5	2011/12	Panel survey	138	0.8	1.00
HPB 7	2011/12	Panel survey	2 163	12.7	0.41
HPB 8	2011/12	Panel survey	4 376	25.6	0.54
HPB 1	2017/18	Panel survey	12 250	73.1	0.21
HPB 2	2017/18	Panel survey	9 175	54.7	0.29
HPB 3	2017/18	Panel survey	8 474	50.5	0.36
HPB 5	2017/18	Panel survey	1 389	8.3	0.42
HPB 7	2017/18	Panel survey	5 937	35.4	0.35
HPB 8	2017/18	Panel survey	1 047	6.2	0.49

1.3 Customary non-commercial fisheries

Groper (hāpuku and bass) were certainly taken by early Maori, and would have been available in greater numbers at shallower depths than is the case at present. Traditional groper grounds are known in several regions. Quantitative information on the current level of customary non-commercial catch is not available.

1.4 Illegal catch
Quantitative information on the level of illegal catch is not available.

1.5 Other sources of mortality
None are apparent.

2. BIOLOGY

Both hāpuku and bass are widely distributed around New Zealand, generally over rough ground from the central shelf (about 100 m) to the shelf edge and down the upper slope. Their lower limits are ill-defined, but hāpuku extends to at least 300 m and bass to 500 m.

Hāpuku mature sexually between 10 and 13 years old and may live in excess of 60 years (Francis et al 1999). Cook Strait hāpuku mature over a wide size range, with the size at 50% maturity at 80–85 cm total length (TL) and 85–90 cm TL for males and females respectively (Paul 2002d). Spawning occurs during winter, anecdotally earlier in the north of New Zealand than in the south, but running ripe fish are seldom caught and spawning grounds are unknown. The smallest juveniles are virtually unknown, but are mottled, pelagic and epi-pelagic, perhaps schooling in association with drifting weed.

The size range of commercially caught hāpuku is 50–140 cm TL, with a broad mode between 70 and 100 cm TL. Bass are slightly larger at 60–150 cm TL, with a mode at 80–110 cm TL, but much bulkier and heavier at equivalent lengths.

There appear to be some regional differences in the size structure of populations. Trawl-caught hāpuku on the Stewart-Snares Shelf are mainly 50–80 cm, modal length 60 cm, and therefore juveniles. Trawl-caught hāpuku on the Chatham Rise are slightly larger, 50–100 cm, modal length 70 cm, with those on the shelf around the islands having their main mode at 60–75 cm; most of these fish are also juveniles. These offshore regions may be important nurseries.

Both groper species are assumed to be long-lived. Natural mortality in the past was assumed to be 0.2, however, a study of a South American (Juan Fernandez) population suggested that it may be lower (0.13–0.16) (Pavez & Oyarzun 1985). Furthermore, preliminary unvalidated ageing in New Zealand has indicated that maximum age may be greater than 40 years, and that M may be 0.1 or less (Francis et al 1999). This value of M will be retained until clearer information becomes available from ageing. Parker et al (2011) compared regional differences in the catch composition from observer collected data. This report noted that the proportion of age 10+ fish in the catch in the Kermadec and Northeastern regions (FMA 2) was greater than that of Southland.

Migration patterns are also little known, but are probably related to spawning. Tagging of mostly immature fish in Cook Strait has shown a high level of site fidelity, but about 5% of these fish have moved up to 160 km north and south. Other information is largely anecdotal and speculative. It is known that good fishing grounds, particularly pinnacles and reefs or ledges, can be quickly fished out and take some time to recover, suggesting a high level of residency (except, perhaps, for during the spawning season). On the other hand, trawlers sometimes catch groper on the flat and clear seafloor, and it is not known whether this represents their normal habitat, whether they are simply dispersing by travelling from one rough ground to another, or whether they are on a purposeful spawning migration.

Hāpuku and bass prey on a wide variety of fish and invertebrates, including red cod, tarakihi, blue cod, hoki and squid. In Cook Strait, they are preyed upon by sperm whales, although probably neither heavily nor selectively. Biological parameters relevant to stock assessment are shown in Table 8.

Table 8: Estimates of biological parameters of groper.

Fishstock	Estimate		Source
1. Natural mortality (*M*)			
All	*M* = 0.1		Francis et al (1999)
2. Weight = a (length)^b (Weight in g, length in cm fork length)			
	Both sexes combined		
BAS 1	a = 0.2734	b = 2.382	Johnston (1993)
HAP 1	a = 0.0142	b = 3.003	Johnston (1993)
HAP 2	a = 0.0242	b = 2.867	Johnston (1993)
HAP 7, 8	a = 0.0142	b = 2.998	Johnston (1983)

(HAP = hāpuku, BAS = bass groper)

3. STOCKS AND AREAS

Tagging studies reveal considerable mixing of hāpuku between Otago, South Canterbury and Cook Strait. Fishstock boundaries in Cook Strait separate Cook Strait hāpuku into three separate "stocks" (HPB 2, HPB 7, and HPB 8), none of which include Otago-Canterbury fish (HPB 3). Current Fishstock boundaries appear inappropriate for the management of Cook Strait and South Island hāpuku. Current stock boundaries are based on QMAs and do not reflect biological stocks. Existing data cannot describe the stock structure of New Zealand groper (Paul 2002b). Electrophoretic studies suggest that separate stocks of hāpuku could occur. However, the genetic heterogeneity of Cook Strait hāpuku, seasonal movements of hāpuku through this area, moderately long-distance movements of some tagged hāpuku, the presence of both species on open ground and the eventual recovery of heavily exploited reefs, suggest that either each stock is moderately mobile or that there is essentially only one stock (of each species) with some small geographic or temporal genetic differences.

4. STOCK ASSESSMENT

Yield estimates for HPB 4 and HPB 5 have been removed because the previous method used is now considered obsolete. The yield estimates for the other Fishstocks have been revised based on a revision of the estimate of *M*.

4.1 Estimates of fishery parameters and abundance

Estimates of fishery parameters and abundance are not available. Paul (2002c) found that CPUE indices could not be developed for hāpuku and bass either separately or in combination.

4.2 Biomass estimates

Estimates of current and reference biomass are not available. Data for hāpuku from the East Coast South Island trawl surveys have moderate CVs (average over all years = 28.17; range 19–35) and although the survey does not extend to the entire habitat range, the survey may be monitoring settled juveniles (Figure 2).

4.4 Yield estimates and projections

Current biomass cannot be estimated, so *CAY* cannot be determined. Yield estimates are summarised in Table 9.

Table 9: Yield estimates (t).

Parameter	Fishstock	Estimate
	HPB 4	Cannot be determined
	HPB 5	Cannot be determined
	Total	Cannot be determined
CAY	All	Cannot be determined

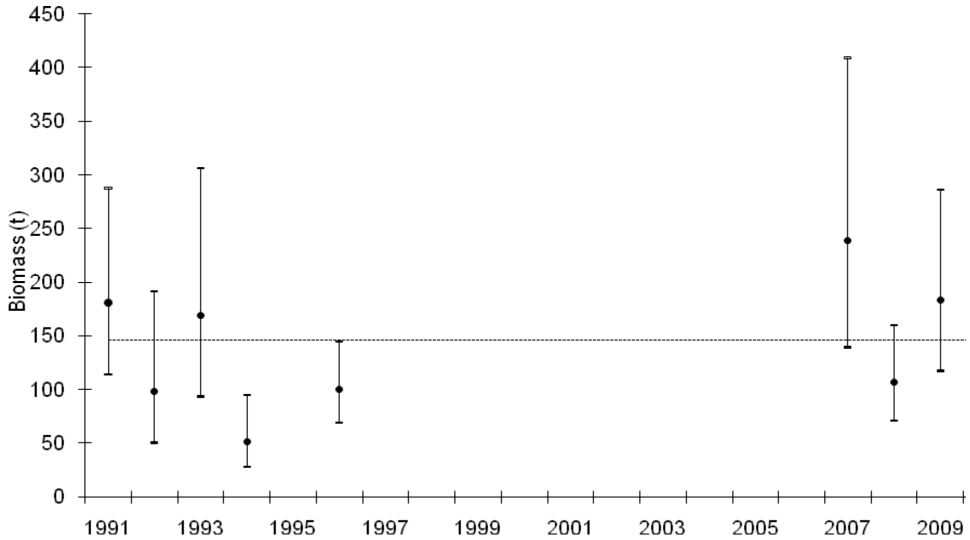


Figure 2: Biomass estimates ±95% CI (estimated from survey CV's assuming a lognormal distribution) and the time series mean (dotted line) from the East Coast South Island trawl survey.

4.5 Other factors

Although no distinct stocks of either groper species have been identified, results from trawl surveys suggest that there are reasonably large but dispersed populations over the Stewart-Snares Shelf and the Chatham Rise. The relationship between these "offshore" and the more traditionally fished "inshore" populations is not known due to the lack of information on groper movements. Little is known of the species composition and population structure of groper on the rough bottom shelf and ridges extending northwards from New Zealand.

The relative quantity of groper taken as target and non-target catch has not been investigated, but is likely to have varied both spatially and temporally. Groper have been taken by the foreign licensed, chartered and New Zealand-owned trawlers working offshore grounds; although being regarded as a small bycatch they were not accurately reported before 1986. The *MCY* may therefore be under-estimated.

There are three regions where the groper catch has been substantially lower than the TACC.

HPB 1 - Three features of the fishery appear to explain the under-catch of the TACC. (i) A considerable part of the fishing effort which had generated the high catches in the early 1980s left the fishery. (ii) The allocated quota is widely distributed in small units among fishers who appear to use only a modest proportion of it to cover bycatch. (iii) The fishers who hold larger amounts of quota generally also use only a proportion of it to land high-quality fish (in contrast to the earlier bulk landings of lower-quality fish).

HPB 4 and 5 - The original yield estimates made before the introduction of the QMS and the original TAC were based on trawl surveys, not catch histories. The TACCs for these Fishstocks can only be economically targeted around the Chatham Islands in HPB 4, and a few localities in HPB 5. Elsewhere, it is used to cover a small bycatch from trawlers. A moderate quantity of quota is held, unused, by companies which would require it should they resume target fishing for ling and associated species.

5. STATUS OF THE STOCKS

No estimates of current biomass are available. An estimate of B_{AV} is available for HPB 5.

It is not known if current catches or the TACCs are sustainable or at levels that will allow the stocks to move towards a size that will support the maximum sustainable yield.

Yield estimates, TACCs and reported landings are summarised in Table 10.

Table 10: Summary of TACCs (t) and reported landings (t) of groper for the most recent fishing year.

Fishstock	QMA	FMAs	2018–19 Actual TACC	2018–19 Reported Landings
HPB 1	Auckland (East, West)	1 & 9	481	283
HPB 2	Central (East)	2	266	173
HPB 3	South-east (Coast)	3	335	347
HPB 4	South-east (Chatham)	4	323	137
HPB 5	Southland, Sub-Antarctic	5 & 6	451	167
HPB 7	Challenger	7	236	105
HPB 8	Central (West)	8	80	47
HPB 10	Kermadec	10	10	0
Total			2 181	1 260

6. FOR FURTHER INFORMATION

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HAKE (HAK)

(Merluccius australis)
Tiikati

1. FISHERY SUMMARY

1.1 Commercial fisheries

Hake was introduced into the Quota Management System on 1 October 1986. Hake are widely distributed throughout the middle depths of the New Zealand EEZ, mostly south of 40° S. Adults are mainly distributed from 250–800 m, but some have been found as deep as 1200 m, whereas juveniles (0+) are found in inshore regions shallower than 250 m. Hake are taken mainly by large trawlers, often as bycatch in hoki target fisheries, although hake target fisheries do exist.

The largest fishery has been off the west coast of the South Island (HAK 7) with the highest catch (17 000 t) recorded in 1977, immediately before the establishment of the EEZ. The TACC for HAK 7 is the largest, at 5064 t out of a total for the EEZ of 10 575 t. The WCSI hake fishery has generally consisted of bycatch in the much larger hoki fishery, but it has undergone a number of changes over time (Devine 2009). These include changes to the TACCs of both hake and hoki, and changes in fishing practices such as gear used, tow duration, and strategies to limit hake bycatch. In some years there has been a hake target fishery in September after the peak of the hoki fishery is over; more than 2000 t of hake were taken in this target fishery during September 1993 (Ballara 2015). High bycatch levels of hake early in the fishing season have also occurred in some years (Ballara 2015). From 1 October 2005 the TACC for HAK 7 was increased to 7700 t within an overall TAC of 7777 t. This new catch limit was set equal to average annual catches over the previous 12 years. From 1 October 2017 the TACC for HAK 7 was reduced to 5064 t. This new catch limit was set equal to the average annual catches over the previous five years. HAK 7 landings have been well below the TACC since the 2017–18 fishing year (referred to as the 2018 fishing year).

On the Chatham Rise and in the Sub-Antarctic, hake have been caught mainly as bycatch by trawlers targeting hoki (Devine 2009). However, significant targeting for hake has occurred in both areas, particularly in Statistical Area 404 (HAK 4), and around the Norwegian Hole between the Snares and Auckland islands in the Sub-Antarctic. Increases in TACCs from 2610 t to 3632 t in HAK 1 and from 1000 t to 3500 t in HAK 4 from the 1991–92 fishing year allowed the fleet to increase their reported landings of hake from these fish stocks. TACCs were further increased to 3701 t in HAK 1 from the 2001–02 fishing year. Reported catches rose over a number of years to the levels of the new TACCs in both HAK 1 and HAK 4. In HAK 1, annual catches remained relatively steady (generally between 3000 t and 4000 t) up to 2004–05, but were generally less than 3000 t from 2005–06 until 2009–10, and generally less than 2000 t since then. In 2018–19 landings less than 1000 t were recorded for the first time in HAK 1 since the mid-1980s. Landings from HAK 4 declined erratically from over 3000 t in 1998–99 to a low of 161 t in 2011–12. From 2004–05, the TACC for HAK 4 was reduced from 3500 t to 1800 t. Annual landings have been markedly lower than the new TACC since then, and lower than 300 t in all but one year since 2009–10.

An unusually large aggregation of possibly mature or maturing hake was fished on the western Chatham Rise, west of the Mernoo Bank (HAK 1) in October 2004. Over a four-week period, about 2000 t of hake were caught from that area. In previous years, catches from this area have typically been between 100 t and 800 t. These unusually high catches resulted in the TACC for HAK 1 being over-caught during the 2004–05 fishing year (4795 t against a TACC of 3701 t) and a substantial increase in the landings (more than 3700 t) associated with the Chatham Rise. Fishing on aggregated schools in the same area also occurred during October–November 2008 and 2010 (Ballara 2015).

Reported catches from 1975 to 1987–88 are shown in Table 1. Reported landings for each Fishstock since 1983–84 and TACCs since 1986–87 are shown in Table 2. Figure 1 shows the historical landings and TACC values for the main hake stocks.

Table 1: Reported hake catches (t) from 1975 to 1987–88. Data from 1975 to 1983 from MAF; data from 1983–84 to 1985–86 from FSU; data from 1986–87 to 1987–88 from QMS.

	New Zealand			Foreign licensed				
Fishing year	**Domestic**	**Chartered**	**Total**	**Japan**	**Korea**	**USSR**	**Total**	**Total**
1975 [1]	0	0	0	382	0	0	382	382
1976 [1]	0	0	0	5 474	0	300	5 774	5 774
1977 [1]	0	0	0	12 482	5 784	1 200	19 466	19 466
1978–79 [2]	0	3	3	398	308	585	1 291	1 294
1979–80 [2]	0	5 283	5 283	293	0	134	427	5 710
1980–81 [2]				No data available				
1981–82 [2]	0	3 513	3 513	268	9	44	321	3 834
1982–83 [2]	38	2 107	2 145	203	53	0	255	2 400
1983 [3]	2	1 006	1 008	382	67	2	451	1 459
1983–84 [4]	196	1 212	1 408	522	76	5	603	2 011
1984–85 [4]	265	1 318	1 583	400	35	16	451	2 034
1985–86 [4]	241	2 104	2 345	465	52	13	530	2 875
1986–87 [4]	229	3 666	3 895	234	1	1	236	4 131
1987–88 [4]	122	4 334	4 456	231	1	1	233	4 689

1. Calendar year.
2. April 1 to March 31.
3. April 1 to September 30.
4. October 1 to September 30.

Table 2: Reported landings (t) of hake by Fishstock from 1983–84 to 2018–19 and actual TACCs (t) for 1986–87 to 2018–19. FSU data from 1984–1986; QMS data from 1986 to the present. [Continued on next page]

Fish stock	**HAK 1**		**HAK 4**		**HAK 7**		**HAK 10**			
FMA(s)	**1, 2, 3, 5, 6, 8 & 9**		**4**		**7**		**10**		**Total**	
	Landings	**TACC**	**Landings**	**TACC**	**Landings**	**TACC**	**Landings**	**TACC**	**Landings**	**TACC**
1983–84 [1]	886	–	180	–	945	–	0	–	2 011	–
1984–85 [1]	670	–	399	–	965	–	0	–	2 034	–
1985–86 [1]	1 047	–	133	–	1 695	–	0	–	2 875	–
1986–87	1 022	2 500	200	1 000	2 909	3 000	0	10	4 131	6 510
1987–88	1 381	2 500	288	1 000	3 019	3 000	0	10	4 689	6 510
1988–89	1 487	2 513	554	1 000	6 835	3 004	0	10	8 876	6 527
1989–90	2 115	2 610	763	1 000	4 903	3 310	0	10	7 781	6 930
1990–91	2 603	2 610	743	1 000	6 148	3 310	0	10	9 494	6 930
1991–92	3 156	3 500	2 013	3 500	3 027	6 770	0	10	8 196	13 780
1992–93	3 525	3 501	2 546	3 500	7 154	6 835	0	10	13 225	13 846
1993–94	1 803	3 501	2 587	3 500	2 974	6 835	0	10	7 364	13 847
1994–95	2 572	3 632	3 369	3 500	8 841	6 855	0	10	14 782	13 997
1995–96	3 956	3 632	3 466	3 500	8 678	6 855	0	10	16 100	13 997
1996–97	3 534	3 632	3 524	3 500	6 118	6 855	0	10	13 176	13 997
1997–98	3 810	3 632	3 524	3 500	7 416	6 855	0	10	14 749	13 997
1998–99	3 845	3 632	3 324	3 500	8 165	6 855	0	10	15 334	13 997
1999–00	3 899	3 632	2 803	3 500	6 898	6 855	0	10	13 599	13 997
2000–01	3 628	3 632	2 784	3 500	7 698	6 855	0	10	14 111	13 997
2001–02	2 870	3 701	1 424	3 500	7 519	6 855	0	10	11 813	14 066
2002–03	3 336	3 701	811	3 500	7 433	6 855	0	10	11 580	14 066
2003–04	3 466	3 701	2 275	3 500	7 945	6 855	0	10	13 686	14 066
2004–05	4 795	3 701	1 264	1 800	7 317	6 855	0	10	13 377	12 366
2005–06	2 742	3 701	305	1 800	6 905	7 700	0	10	9 952	13 211
2006–07	2 025	3 701	899	1 800	7 668	7 700	0	10	10 592	13 211
2007–08	2 445	3 701	865	1 800	2 620	7 700	0	10	5 930	13 211
2008–09	3 415	3 701	856	1 800	5 954	7 700	0	10	10 226	13 211
2009–10	2 156	3 701	208	1 800	2 352	7 700	0	10	4 716	13 211
2010–11	1 904	3 701	179	1 800	3 754	7 700	0	10	5 837	13 211
2011–12	1 948	3 701	161	1 800	4 459	7 700	0	10	6 568	13 211
2012–13	2 079	3 701	177	1 800	5 434	7 700	0	10	7 690	13 211
2013–14	1 883	3 701	168	1 800	3 642	7 700	0	10	5 693	13 211

Table 2 [Continued]

Fish stock	HAK 1		HAK 4		HAK 7		HAK 10			
FMA(s)	1, 2, 3, 5, 6, 8 & 9		4		7		10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2014–15	1 725	3 701	304	1 800	6 219	7 700	0	10	8 248	13 211
2015–16	1 584	3 701	274	1 800	2 864	7 700	0	10	4 722	13 211
2016–17	1 175	3 701	268	1 800	4 701	7 700	0	10	6 144	13 211
2017–18	1 349	3 701	267	1 800	3 086	5 064	0	10	4 702	10 575
2018-19	896	3 701	183	1 800	1 563	5 064	0	10	2 642	10 575

[1] FSU data

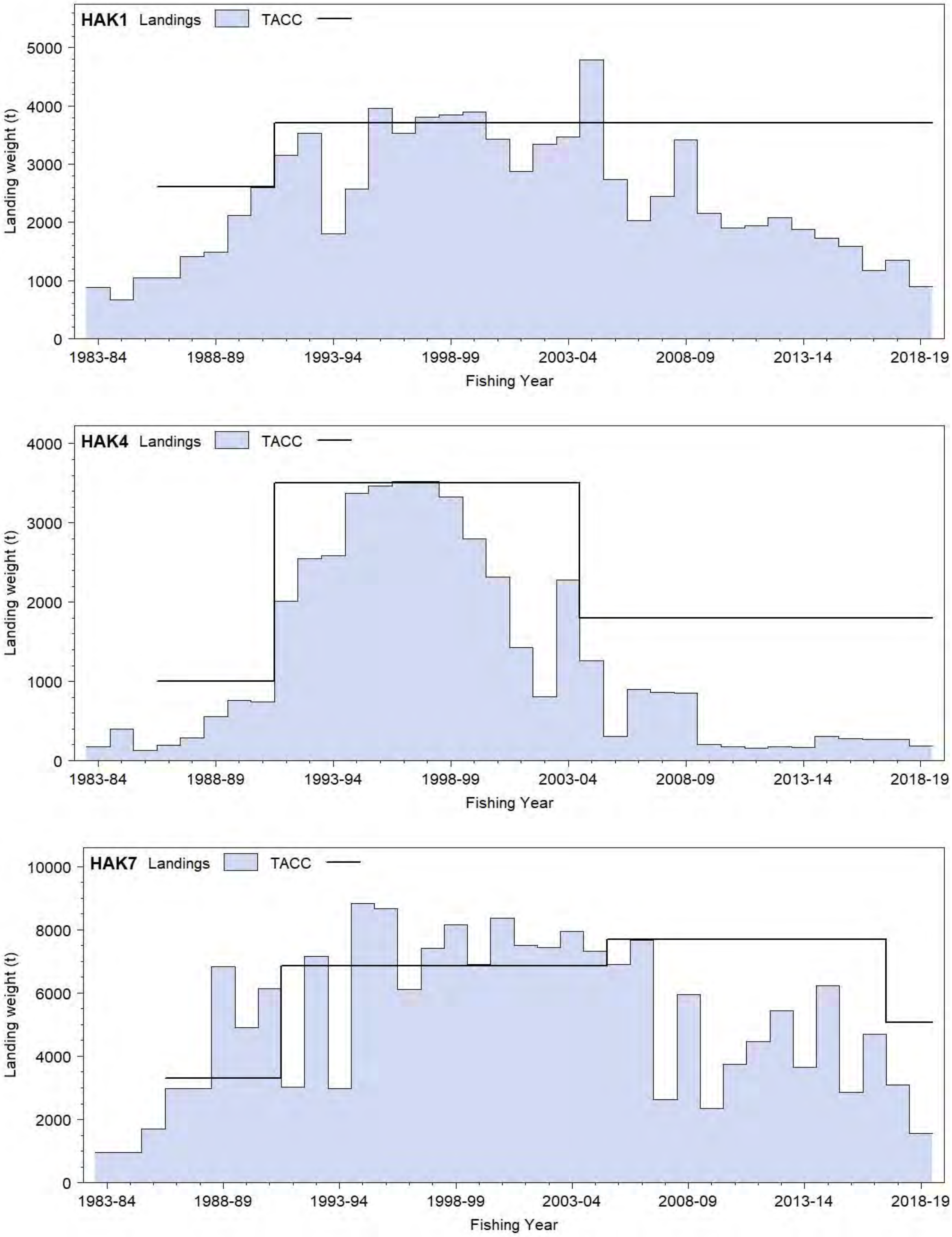

Figure 1: Reported commercial landings and TACC for the three main HAK stocks. From top: HAK 1 (Sub-Antarctic and part of Chatham Rise), HAK 4 (eastern Chatham Rise), and HAK 7 (Challenger).

1.2 Recreational fisheries
The recreational fishery for hake is negligible.

1.3 Customary non-commercial fisheries
The amount of hake caught by Māori is not known but is believed to be negligible.

1.4 Illegal catch
In late 2001, a small number of fishers admitted misreporting of hake catches between areas, pleading guilty to charges of making false or misleading entries in their catch returns. As a result, the reported catches of hake in each area were reviewed in 2002 and suspect records identified. Dunn (2003) provided revised estimates of the total landings by stock, estimating that the level of hake over-reporting on the Chatham Rise (and hence under-reporting off the West Coast South Island) was between 16 and 23% (700–1000 t annually) of landings between 1994–95 and 2000–01, mainly in June, July, and September. Probable levels of area misreporting prior to 1994–95 and between the West Coast South Island and Sub-Antarctic were estimated as small (Dunn 2003). There is no evidence of similar area misreporting since 2001–02 (Devine 2009, Ballara 2015).

In earlier years, before the introduction of higher TACCs in 1991–92, there is some evidence to suggest that catches of hake were not always fully reported. Comparison of catches from vessels carrying observers with those not carrying observers, particularly in HAK 7 from 1988–89 to 1990–91, suggested that actual catches were probably considerably higher than reported catches. For these years, the ratio of hake to hoki in the catch of vessels carrying observers was significantly higher than in the catch of vessels not carrying observers (Colman & Vignaux 1992). The actual hake catch in HAK 7 for these years was estimated by multiplying the total hoki catch (which was assumed to be correctly reported by vessels both with and without observers) by the ratio of hake to hoki in the catch of vessels carrying observers. Reported and estimated catches for 1988–89 were respectively 6835 t and 8696 t; for 1989–90, 4903 t reported and 8741 t estimated; and for 1990–91, 6189 t reported and 8246 t estimated. More recently, the level of such misreporting has not been estimated and is not known. No such corrections have been applied to either the HAK 1 or HAK 4 fishery.

For the purposes of stock assessment, the Chatham Rise stock was considered to include the whole of the Chatham Rise (including the western end currently forming part of the HAK 1 management area). Therefore, catches from this area were subtracted from the Sub-Antarctic stock and added to the Chatham Rise stock. The revised landings for 1974–75 to 2017–18 are given in Table 3.

Table 3: Revised landings from fishing years 1975 to 2018 (t) for Sub-Antarctic and Chatham Rise stocks and 1975–2018 fishing years for the West Coast South Island. Note, these relate to biological stocks, not QMAs.

Fishing year	West Coast S.I.	Sub-Antarctic	Chatham Rise
1974–75	71	120	191
1975–76	5 005	281	488
1976–77	17 806	372	1 288
1977–78	498	762	34
1978–79	4 737	364	609
1979–80	3 600	350	750
1980–81	2 565	272	997
1981–82	1 625	179	596
1982–83	745	448	302
1983–84	945	722	344
1984–85	965	525	544
1985–86	1 918	818	362
1986–87	3 755	713	509
1987–88	3 009	1 095	574
1988–89	8 696	1 237	804
1989–90[1]	8 741	1 927	950
1990–91[1]	8 246	2 370	931
1991–92	3 010	2 750	2 418
1992–93	7 059	3 269	2 798
1993–94	2 971	1 453	2 934
1994–95	9 535	1 852	3 271
1995–96	9 082	2 873	3 959
1996–97	6 838	2 262	3 890
1997–98	7 674	2 606	4 074
1998–99	8 742	2 796	3 589
1999–00	7 031	3 020	3 174

Table 3 [Continued]

Fishing year	West Coast S.I.	Sub-Antarctic	Chatham Rise
2000–01	8 346	2 790	2 962
2001–02	7 498	2 510	1 770
2002–03	7 404	2 738	1 401
2003–04	7 939	3 245	2 465
2004–05	7 298	2 531	3 518
2005–06	6 892	2 557	489
2006–07	7 660	1 818	1 081
2007–08	2 583	2 202	1 096
2008–09	5 912	2 427	1 825
2009–10	2 282	1 958	391
2010–11	3 462	1 288	951
2011–12	4 299	1 892	194
2012–13	5 171	1 863	344
2013–14	3 387	1 830	187
2014–15	5 966	1 630	348
2015–16	2 733		
2016–17	4 599		
2017–18	2 968		267

[1] West Coast South Island revised estimates for 1989–90 and 1990–91 are taken from Colman & Vignaux (1992) who corrected for underreporting in 1989–90 and 1990–91, and not from Dunn (2003) who ignored such underreporting.

The fisheries in the Sub-Antarctic and on the Chatham Rise largely take place in September and October and catch histories used in the assessment models adjust the fishing year to reflect this (see Tables 5 and 11).

1.5 Other sources of mortality

There is likely to be some mortality associated with escapement from trawl nets, but the level is not known and is assumed to be negligible.

2. BIOLOGY

The New Zealand hake reach a maximum age of at least 25 years. Males, which rarely exceed 100 cm total length (TL), do not grow as large as females, which can grow to 120 cm TL or more. Horn (1997) validated the use of otoliths to age hake and produced von Bertalanffy growth parameters. Growth parameters were updated by Horn (2008) using both the von Bertalanffy and Schnute growth models. The Schnute model was found to better fit the data. Chatham Rise hake reach 50% maturity at about 5.5 years for males and 7 years for females, Sub-Antarctic hake at about 6 years for males and 6.5 years for females, and WCSI hake at about 4.5 years for males and 5 years for females (Horn & Francis 2010, Horn 2013a).

Estimates of natural mortality (*M*) and the associated methodology are given by Dunn et al (2000); *M* is estimated as 0.18 y^{-1} for females and 0.20 y^{-1} for males. Colman et al (1991) previously estimated *M* as 0.20 y^{-1} for females and 0.22 y^{-1} for males from the maximum age (i.e., the maximum ages at which 1% of the population survives in an unexploited stock were estimated at 23 years for females and 21 years for males). Recent assessment models for all hake stocks have either assumed a constant *M* (0.19 yr^{-1} for both sexes), estimated a constant *M*, or have estimated age-dependent ogives for *M* (because true *M* is likely to vary with age).

Data collected by observers on commercial trawlers and data from trawl surveys suggest that there are at least three main spawning areas for hake (Colman 1998). The best known area is off the west coast of the South Island, where the season can extend from June to October, usually with a peak in September. Spawning also occurs to the west of the Chatham Islands during a prolonged period from at least September to January. Spawning on the Campbell Plateau, primarily to the north-east of the Auckland Islands, occurs from September to February with a peak in September–October. Spawning fish have been recorded occasionally on the Puysegur Bank, with a seasonality that appears similar to that on the Campbell Plateau (Colman 1998).

An aggregation of medium size hake fished on the western Chatham Rise in October 2004 may have comprised either spawning or pre-spawning fish. Fishing on aggregated schools in the same area also occurred during October–November 2008 and 2010. Also, the trawl survey took high catches of young, mature fish in this area in January 2009. It is possible that young, mature hake spawn on the western Chatham Rise and slowly move east, towards the main spawning area, as they age.

Juvenile hake have been taken in coastal waters on both sides of the South Island and on the Campbell Plateau. They reach a length of about 15–20 cm TL at one year old, and about 35 cm TL at 2 years (Colman 1998).

Dunn et al (2010) found that the diet of hake on the Chatham Rise was dominated by teleost fishes, in particular Macrouridae. Macrouridae accounted for 44% of the prey weight and consisted of at least six species, of which javelin fish, *Lepidorhynchus denticulatus*, was most frequently identified. Hoki were less frequent prey, but being relatively large accounted for 37% of prey by weight. Squid were found in 7% of the stomachs and accounted for 5% of the prey by weight. Crustacean prey were predominantly natant decapods, with pasiphaeid prawns, occurring in 19% of the stomachs.

The biological parameters relevant to the stock assessments are given in Table 4.

Table 4: Estimates of biological parameters.

Parameter				**Estimate**		**Source**
1. Natural mortality						
	Males	$M = 0.20$				(Dunn et al 2000)
	Females	$M = 0.18$				(Dunn et al 2000)
	Both sexes	$M = 0.19$				(Horn & Francis 2010)
2. Weight = a·(length)^b (Weight in t, length in cm)						
Sub-Antarctic	Males	$a = 2.13 \times 10^{-9}$	$b = 3.281$			(Horn 2013a)
	Females	$a = 1.83 \times 10^{-9}$	$b = 3.314$			(Horn 2013a)
	Both sexes	$a = 1.95 \times 10^{-9}$	$b = 3.301$			(Horn 2013a)
Chatham Rise	Males	$a = 2.56 \times 10^{-9}$	$b = 3.228$			(Horn 2013a)
	Females	$a = 1.88 \times 10^{-9}$	$b = 3.305$			(Horn 2013a)
	Both sexes	$a = 2.00 \times 10^{-9}$	$b = 3.288$			(Horn 2013a)
WCSI	Males	$a = 2.85 \times 10^{-9}$	$b = 3.209$			(Horn 2013a)
	Females	$a = 1.94 \times 10^{-9}$	$b = 3.307$			(Horn 2013a)
	Both sexes	$a = 2.01 \times 10^{-9}$	$b = 3.294$			(Horn 2013a)
3. von Bertalanffy growth parameters						
Sub-Antarctic	Males	$k = 0.295$	$t_0 = 0.06$	$L_\infty = 88.8$		(Horn 2008)
	Females	$k = 0.220$	$t_0 = 0.01$	$L_\infty = 107.3$		(Horn 2008)
Chatham Rise	Males	$k = 0.330$	$t_0 = 0.09$	$L_\infty = 85.3$		(Horn 2008)
	Females	$k = 0.229$	$t_0 = 0.01$	$L_\infty = 106.5$		(Horn 2008)
WCSI	Males	$k = 0.357$	$t_0 = 0.11$	$L_\infty = 82.3$		(Horn 2008)
	Females	$k = 0.280$	$t_0 = 0.08$	$L_\infty = 99.6$		(Horn 2008)
4. Schnute growth parameters ($\tau_1 = 1$ and $\tau_2 = 20$ for all stocks)						
Sub-Antarctic	Males	$y_1 = 22.3$	$y_2 = 89.8$	$a = 0.249$	$b = 1.243$	(Horn 2008)
	Females	$y_1 = 22.9$	$y_2 = 109.9$	$a = 0.147$	$b = 1.457$	(Horn 2008)
	Both sexes	$y_1 = 22.8$	$y_2 = 101.8$	$a = 0.179$	$b = 1.350$	(Horn 2013a)
Chatham Rise	Males	$y_1 = 24.6$	$y_2 = 90.1$	$a = 0.184$	$b = 1.742$	(Horn 2008)
	Females	$y_1 = 24.4$	$y_2 = 114.5$	$a = 0.098$	$b = 1.764$	(Horn 2008)
	Both sexes	$y_1 = 24.5$	$y_2 = 104.8$	$a = 0.131$	$b = 1.700$	(Horn & Francis 2010)
WCSI	Males	$y_1 = 23.7$	$y_2 = 83.9$	$a = 0.278$	$b = 1.380$	(Horn 2008)
	Females	$y_1 = 24.5$	$y_2 = 103.6$	$a = 0.182$	$b = 1.510$	(Horn 2008)
	Both sexes	$y_1 = 24.5$	$y_2 = 98.5$	$a = 0.214$	$b = 1.570$	(Horn 2011)

5. Maturity ogives (proportion mature at age)

	Age	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
SubAnt	Males	0.01	0.04	0.11	0.30	0.59	0.83	0.94	0.98	0.99	1.00	1.00	1.00
	Females	0.01	0.03	0.08	0.19	0.38	0.62	0.81	0.92	0.97	0.99	1.00	1.00
	Both	0.01	0.03	0.09	0.24	0.49	0.73	0.88	0.95	0.98	0.99	1.00	1.00
Chatham	Males	0.02	0.07	0.20	0.44	0.72	0.89	0.96	0.99	1.00	1.00	1.00	1.00
	Females	0.01	0.02	0.06	0.14	0.28	0.50	0.72	0.86	0.94	0.98	0.99	1.00
	Both	0.02	0.05	0.13	0.29	0.50	0.70	0.84	0.93	0.97	0.99	0.99	1.00
WCSI	Males	0.01	0.05	0.27	0.73	0.95	0.99	1.00	1.00	1.00	1.00	1.00	1.00
	Females	0.02	0.07	0.25	0.57	0.84	0.96	0.99	1.00	1.00	1.00	1.00	1.00
	Both	0.01	0.06	0.26	0.65	0.90	0.97	0.99	1.00	1.00	1.00	1.00	1.00

3. STOCKS AND AREAS

There are three main hake spawning areas; off the west coast of the South Island, on the Chatham Rise, and on the Campbell Plateau. Juvenile hake are found in all three areas. There are differences in size frequencies of hake between the west coast and other areas, and differences in growth parameters between all three areas (Horn 1997). There is good evidence, therefore, to suggest that at least three separate stocks may exist in the EEZ.

Analysis of morphometric data (Colman unpublished data) shows little difference between hake from the Chatham Rise and hake from the east coast of the North Island, but shows highly significant differences between these fish and those from the Sub-Antarctic, Puysegur, and off the west coast. No studies have been done on morphometric differences of hake across the Chatham Rise. The Puysegur fish are most similar to those from the West Coast South Island, although, depending on which variables are used, they cannot always be distinguished from the Sub-Antarctic hake. Hence, the stock affinity of hake from this area is uncertain.

Present management divides the fishery into three Fishstocks: (a) the Challenger FMA (HAK 7), (b) the Chatham Rise FMA (HAK 4), and (c) the remainder of the EEZ comprising the Auckland, Central, Southeast (Coast), Southland, and Sub-Antarctic FMAs (HAK 1). An administrative fishstock (with no recorded landings) exists for the Kermadec FMA (HAK 10).

4. STOCK ASSESSMENT

The stock assessments reported here were completed in 2018 for the Sub-Antarctic stock (Dunn 2019) and in 2020 for the Chatham Rise stock (Holmes in prep) and in 2019 for the West Coast South Island stock (Kienzle et al 2019). In stock assessment modelling, the Chatham stock was considered to include the whole of the Chatham Rise (including the western end currently forming part of the HAK 1 management area). The Sub-Antarctic stock was considered to comprise the Southland and Sub-Antarctic management areas. Although fisheries management areas around the North Island are also included in HAK 1, few hake are caught in these areas.

4.1 HAK 1 (Sub-Antarctic stock)

The 2018 stock assessment was carried out with data up to the end of the 2016–17 fishing year, implemented as a Bayesian model using the general-purpose stock assessment program CASAL v2.30 (Bull et al 2012). The assessment used research time series of abundance indices (trawl surveys of the Sub-Antarctic from 1991 to 2016), catch-at-age from the trawl surveys and the commercial fishery since 1990–91, and estimates of biological parameters. A trawl fishery CPUE series was used in a sensitivity run.

4.1.1 Model structure

The model had a single area, and was single-sex and age-structured, partitioned into age groups 1–30 with the last age group considered a plus group. Maturity was fixed and estimated outside of the model.

The model was initialised assuming an equilibrium age structure at an unfished equilibrium biomass (B_0), i.e., with constant recruitment set equal to the mean of the recruitments over the period 1974–2014. The selectivity for the fishery was assumed to be logistic, and the selectivities were domed (double normal) for each of the November–December and April–May trawl survey series (with the September 1992 survey assumed to have a selectivity equal to the April–May series). Selectivities were assumed constant across all years in the fishery and the surveys, and hence there was no allowance for possible annual changes in selectivity. Growth was assumed to be constant and fixed. Natural mortality was estimated as a constant. Year class strengths were estimated.

Model parameters were estimated using Bayesian estimation implemented using the CASAL software (Bull et al 2012). For final model runs, the full posterior distribution was sampled using Markov Chain Monte Carlo (MCMC) methods, based on the Metropolis-Hastings algorithm.

4.1.2 Fixed biological parameters and observations

There were five main data sources: the catch history; research trawl survey biomass indices from November–December 1992–2017, April–May 1992–98, and September 1992; catch-at-age estimates from the research surveys; catch-at-age estimates from the commercial fishery 1990–2017; and a commercial CPUE biomass index 1991–2017 (sensitivity run only).

Catch history

To more closely align with the seasons of the fishery, the model year was set as September to August, rather than the fishing year (October to September). The catch history was modified accordingly (Table 5). The catch history includes the revised estimates of catch reported by Dunn (2003).

Table 5: Commercial catch history (t) for the Sub-Antarctic stock. Note that from 1990 totals by model year differ from those for fishing year (see Table 3) because the September catch has been shifted from the fishing year into the following model year. Model year landings from 2018 assume catch to be the same as the previous year.

Model year	Total	Model year	Total
1975	120	1997	1 915
1976	281	1998	2 958
1977	372	1999	2 854
1978	762	2000	3 108
1979	364	2001	2 820
1980	350	2002	2 444
1981	272	2003	2 777
1982	179	2004	3 223
1983	448	2005	2 592
1984	722	2006	2 541
1985	525	2007	1 711
1986	818	2008	2 329
1987	713	2009	2 446
1988	1 095	2010	1 927
1989	1 237	2011	1 319
1990	1 897	2012	1 900
1991	2 381	2013	1 859
1992	2 810	2014	1 800
1993	3 941	2015	1 600
1994	1 596	2016	1 464
1995	1 995	2017	1 033
1996	2 779	2018	1 033

Biological parameters

All biological parameters other than natural mortality rate *M* were estimated outside of the model. Estimated and assumed values for biological parameters used in the assessments are given in Table 4.

Growth was constant and followed the Schnute parameterisation. *M* was constant and estimated with an informed prior (Table 6). A Beverton-Holt stock recruitment relationship was used with an assumed steepness *h* of 0.8. Year class strengths were estimated for the period 1974–2014, following the Haist parameterisation, with a lognormal prior. Ageing error was assumed (with CV = 0.08). All mature fish were assumed to spawn every year.

Table 6: The assumed priors for key distributions (when estimated) for the Sub-Antarctic stock assessment. The parameters are mean (in natural space) and CV for lognormal.

Parameter description	Distribution	Parameters		Bounds	
B_0	Uniform-log	–	–	5 000	600 000
Year class strengths	Lognormal (μ, cv)	1.0	1.1	0.01	100
Trawl survey q[1]	Lognormal (μ, cv)	0.16	0.79	0.01	0.4
CPUE q	Uniform-log	–	–	1e-8	1e-3
Selectivities	Uniform	–	–	1	20–200[2]
M	Normal (μ, sd)	0.19	0.05	0.05	0.40

[1] Three trawl survey q values were estimated, but all had the same priors.
[2] A range of maximum values was used for the upper bound.

Research trawl surveys

The biomass estimates from the research trawl surveys are given in Table 7.

Table 7: Research survey indices (and associated CVs) for the Sub-Antarctic stock.

Fishing		Nov–Dec series [1]		Apr–May series [2]		Sep series [2]	
Year	**Vessel**	**Biomass (t)**	**CV**	**Biomass (t)**	**CV**	**Biomass (t)**	**CV**
1989*	*Amaltal Explorer*	2 660	0.21				
1992	*Tangaroa*	5 686	0.43	5 028	0.15	3 760	0.15
1993	*Tangaroa*	1 944	0.12	3 221	0.14		
1994	*Tangaroa*	2 567	0.12				
1996	*Tangaroa*			2 026	0.12		
1998	*Tangaroa*			2 554	0.18		
2001	*Tangaroa*	2 657	0.16				
2002	*Tangaroa*	2 170	0.20				
2003	*Tangaroa*	1 777	0.16				
2004	*Tangaroa*	1 672	0.23				
2005	*Tangaroa*	1 694	0.21				
2006	*Tangaroa*	1 459	0.17				
2007	*Tangaroa*	1 530	0.17				
2008	*Tangaroa*	2 470	0.15				
2009	*Tangaroa*	2 162	0.17				
2010	*Tangaroa*	1 442	0.20				
2012	*Tangaroa*	2 004	0.23				
2013[4]	*Tangaroa*	2 428	0.23				
2015	*Tangaroa*	1 477	0.25				
2017[3,4]	*Tangaroa*	1 373	0.34				
2019	*Tangaroa*	1675	0.25				

* Not used in the reported assessment.

Notes: (1) Series based on indices from 300–800 m core strata, including the 800–1000 m strata in Puysegur, but excluding Bounty Platform. (2) Series based on the biomass indices from 300–800 m core strata, excluding the 800–1000 m strata in Puysegur and the Bounty Platform. (3) Due to bad weather, the core survey strata were unable to be completed in 2017; biomass estimates were scaled-up using factors based on the proportion of hake biomass in those strata in previous surveys from 2000 to 2014. This introduced additional uncertainty into the 2017 biomass estimate (O'Driscoll et al 2018). (4) The 2018 HAK1 stock assessment incorrectly used core only rather than core + Puysegur values for 2013 and 2017 resulting in a slightly more pessimistic assessment.

The priors for survey qs were estimated by assuming that q was the product of areal availability, vertical availability, and vulnerability. A simple simulation was conducted that estimated a distribution of possible values for the relativity constant by assuming that each of these factors was uniformly distributed. A prior was then determined by assuming that the resulting sampled distribution was lognormally distributed. Values assumed for the parameters were: areal availability (0.50–1.00), vertical availability (0.50–1.00), and vulnerability (0.01–0.50). The resulting (approximate lognormal) distribution had mean 0.16 and CV 0.79, with bounds assumed to be (0.01–0.40) (Table 6). Note that the values of survey relativity constants are dependent on the selectivity parameters, and the absolute catchability can be determined by the product of the selectivity by age and sex, and the relativity constant q. All trawl qs were estimated as free (not nuisance) parameters.

Biomass indices were fitted with lognormal likelihoods with assumed CVs set equal to the sampling CV. The CVs (for observations fitted with lognormal likelihoods) are assumed to have allowed for sampling error only. Additional variance, assumed to arise from differences between model simplifications and real world variation, was added to the sampling variance for all observations in all model runs. Process error of 0.2 was added to all survey biomass indices following the recommendation by Francis et al (2001). For the CPUE index, the process error CV was assumed to be 0.25.

Catch-at-age

Catch-at-age observations were available for each trawl survey of the Sub-Antarctic and for the commercial fisheries from observer data. A plus group for all the catch-at-age data was set at 21 with the lowest age set at 3. Catch-at-age distributions were fitted assuming multinomial errors, with an effective sample size set following Francis (2011) (Table 8).

Table 8: Catch-at-age data for the Sub-Antarctic stock, giving the multinomial effective sample sizes assumed for each sample. The effective sample size is proportional to the weight given to the data in the model fit.

	Research survey			
Fishing year	**Nov-Dec**	**Apr-May**	**Sep**	**Commercial catch-at-age**
1990	19			7
1991				
1992	21	16	17	17
1993	30	16		14
1994	36			5
1995				
1996		12		10
1997				
1998		13		16
1999				31
2000				49
2001	58			14
2002	46			21
2003	52			10
2004	38			18
2005	30			6
2006	40			21
2007	51			6
2008	49			16
2009	59			18
2010	45			31
2011				48
2012	49			42
2013	60			16
2014				47
2015	22			18
2016				31
2017				31

4.1.3 Model estimation

In the base model, the main parameters estimated were: virgin (unfished, equilibrium) biomass (B_0), trawl survey selectivity, fishery selectivity, natural mortality rate, and year class strengths (YCS) from 1974 to 2014.

A wide range of sensitivity models were run. Sensitivity models reported here were run to investigate the effect of estimating *M* as an age-dependent ogive while assuming a double normal selectivity for the fishery (to match the assumptions of the previous assessment) and alternative assumptions for the prior on year class strength. Additional sensitivity models not reported included one that used only data from the commercial fishery (CPUE series and catch-at-age).

The fits to the biomass indices were acceptable (Figure 2). Fits to the catch-at-age were generally good, although relatively strong recruitment from around 1992 apparent in the observer samples was not well fitted (Figure 3); this recruitment was not apparent in the research survey samples (Figure 4).

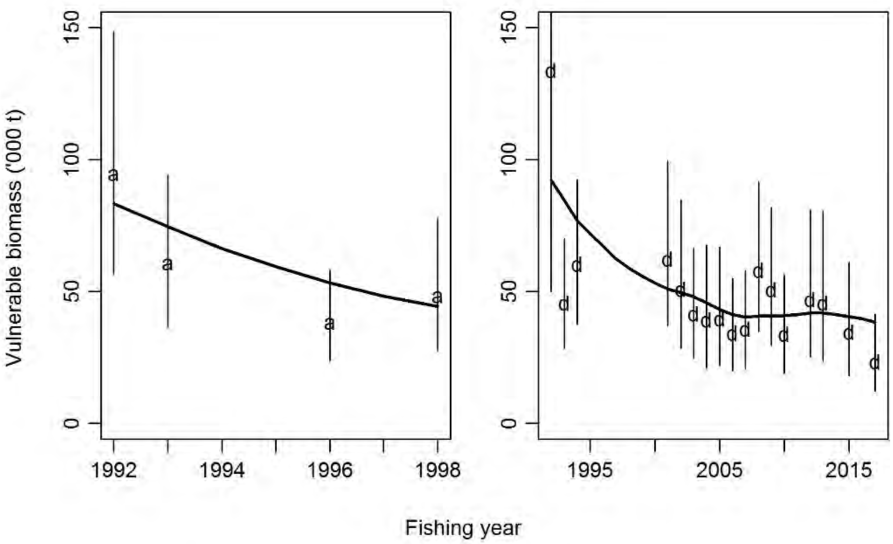

Figure 2: Fits of the base model for the Sub-Antarctic stock (solid lines) to the April–May (a) and November–December (d) research trawl biomass indices. Vertical lines indicate the 95% CI.

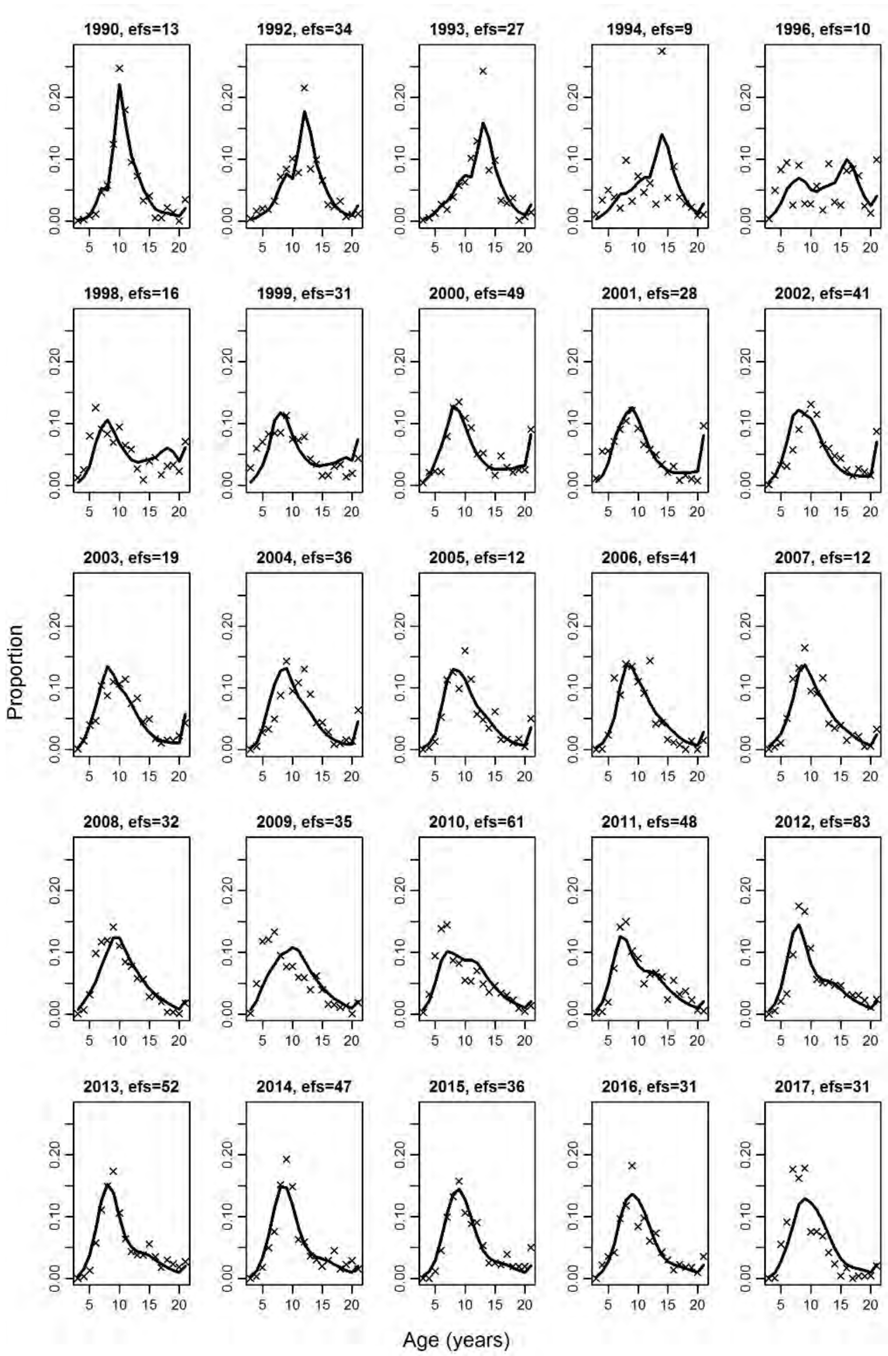

Figure 3: Model fit (solid lines) to the catch-at-age observations from the observer commercial fishery samples (×) for the base model run for the Sub-Antarctic stock. EFS, multinomial effective sample size.

Estimated selectivities for the surveys were not strongly domed (even though they were estimated using double normal parameterisation). Hake were fully selected by the November–December survey at age 4.5, by the April–May and September surveys at age 15, and by the fishery at about age 10.

Year class strength estimates suggested that the Sub-Antarctic stock was characterised by a group of above average year class strengths in the late 1970s, a very strong year class in 1980, followed by a period of average to less than average recruitment through to 2014 (Figure 5).

The absolute catchability of the Sub-Antarctic trawl surveys was estimated to be extremely low (Figure 6). Although catchability was expected to be higher, hake are believed to be relatively more abundant over rough ground (that is likely to be avoided during a trawl survey), and it is known that hake tend to school off the bottom, particularly during their spring-summer spawning season, hence reducing their availability to the bottom trawl.

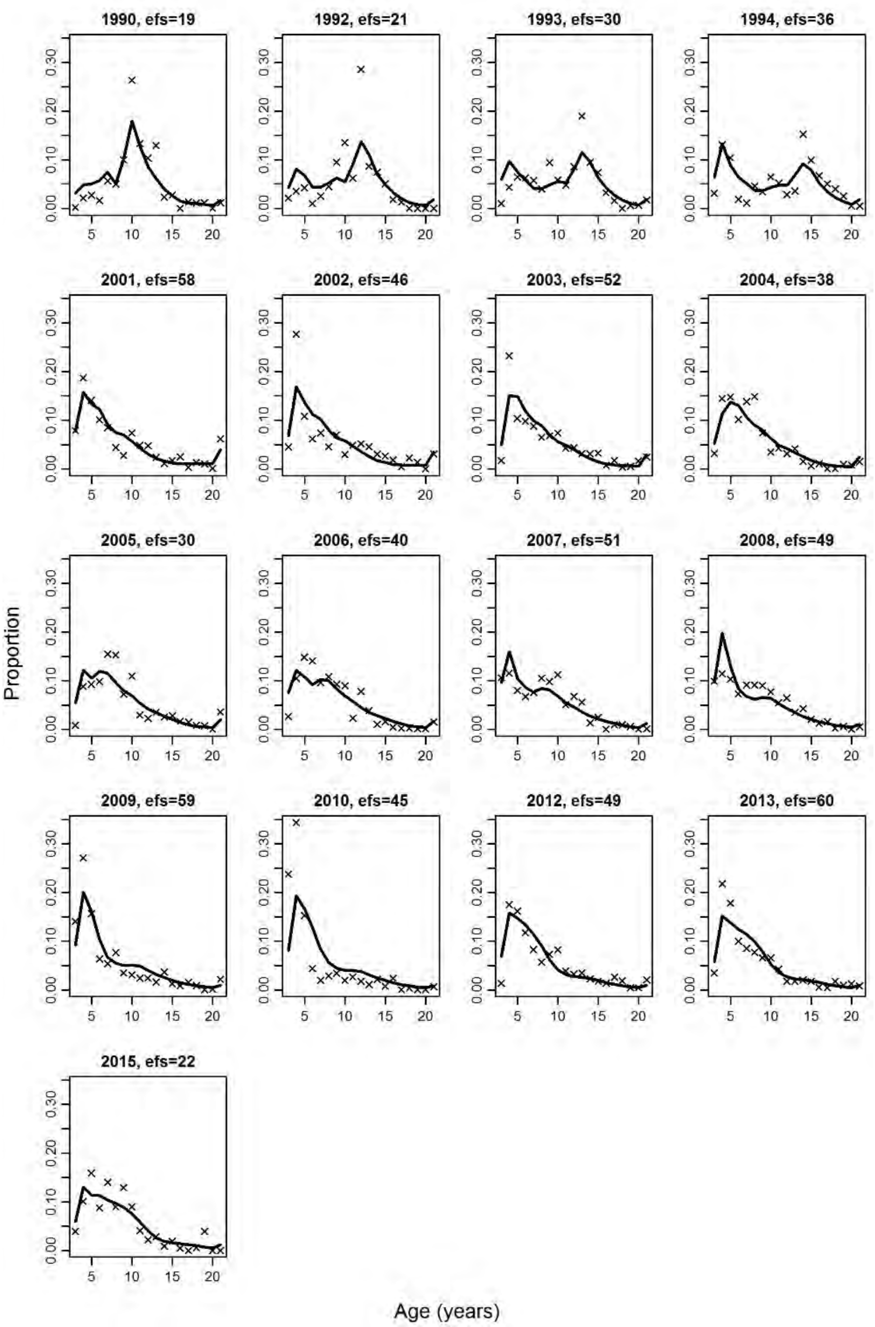

Figure 4: Model fit (solid lines) to the catch-at-age observations from the November–December research trawl survey samples (×) for the base model run for the Sub-Antarctic stock. EFS, multinomial effective sample size.

Biomass estimates for the stock appeared relatively healthy, with estimated current biomass from the base model at about 55% B_0 (Figure 7, Table 9). Annual exploitation rates (catch over vulnerable biomass) were low in all years as a consequence of the high estimated stock size relative to the level of catches (Figure 8).

A wide range of sensitivity runs was conducted, but in general these produced similar estimates of stock size and status. The 2018 assessment model was different to the previous (2014) model in assuming a logistic rather than domed selectivity for the fishery, and a constant rather than at-age natural mortality rate. However, the biomass estimates from the base model and previous model (run Previous) were similar (Table 9). The MPD model runs were found to be sensitive to the assumed prior on year class strengths (the CV, σ_R), but modifying σ_R to 0.7 made little difference to MCMC results (run Base 0.7). The sensitivity run using only commercial fishery data (run Commercial; CPUE and observer catch-at-age only) did not allow the observer catch-at-age to be better fitted and was not considered plausible.

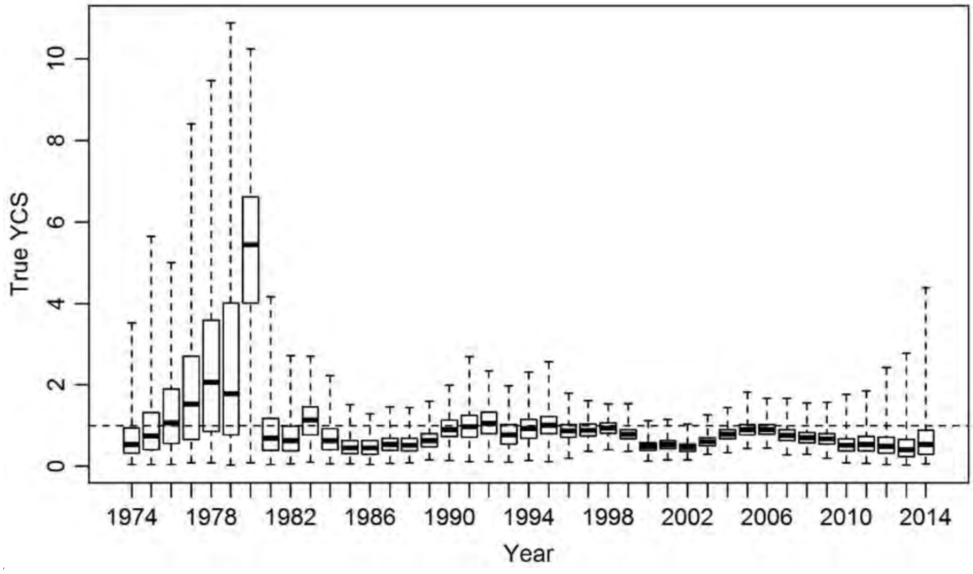

Figure 5: Estimated posterior distributions of year class strengths for the base case for the Sub-Antarctic stock. The dashed horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

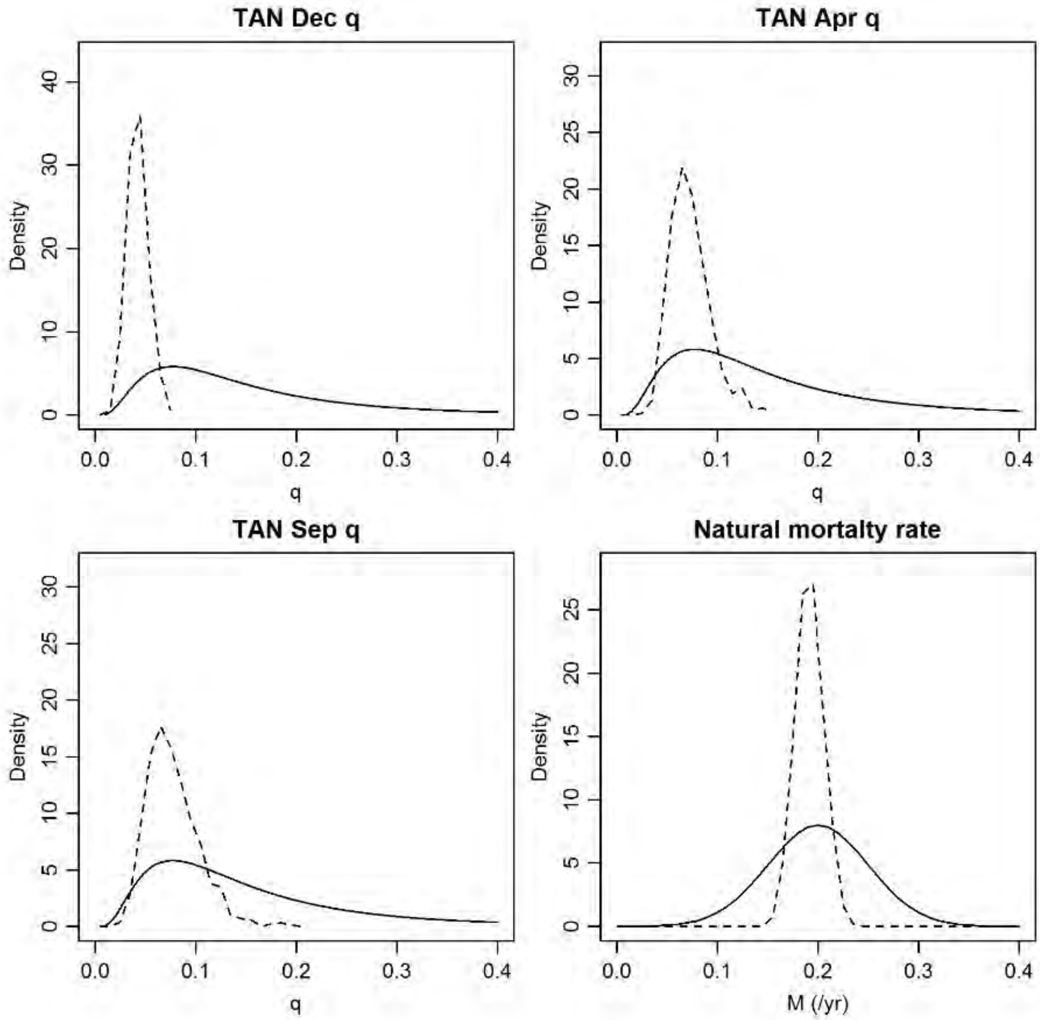

Figure 6: Estimated prior (solid lines) and posterior distributions (broken line) of catchability for the research trawl surveys, and natural mortality rate, for the base case for the Sub-Antarctic stock.

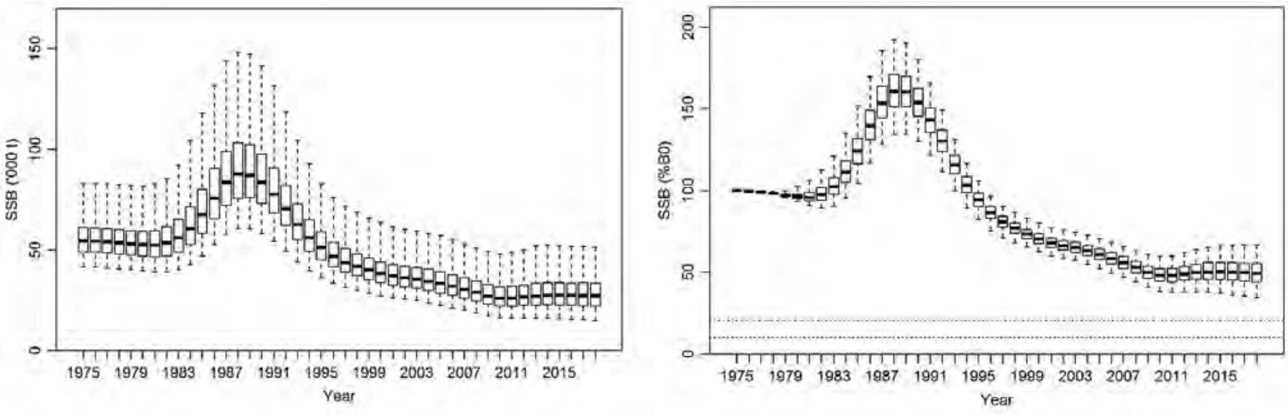

Figure 7: Estimated median trajectories (with 95% credible intervals shown as dashed lines) for the Sub-Antarctic stock base case model for absolute biomass and biomass as a percentage of B_0. The management target (40% B_0, solid horizontal line) and soft limit (20% B_0, dotted horizontal line) are shown on the right-hand panel.

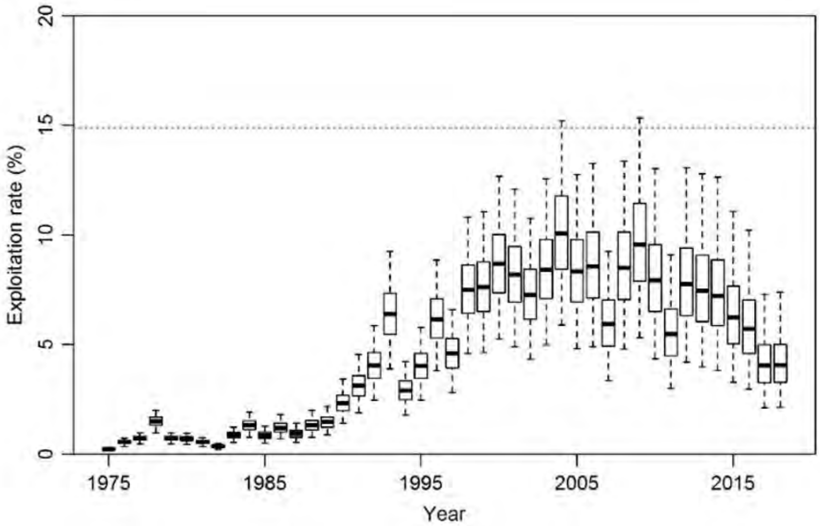

Figure 8: Exploitation rates (catch over vulnerable biomass) for the Sub-Antarctic stock base case model. The horizontal broken line indicates the exploitation rate at 40% B_0 (U_{40}; median derived from MCMC samples).

Table 9: Bayesian median (95% credible intervals) (MCMC) of B_0, B_{2018}, B_{2018} as a percentage of B_0, and the probability of B_{2018} being below the target (40% B_0), for the Sub-Antarctic base model and sensitivity runs.

Model run	B_0	B_{2018}	B_{2018} (%B_0)	P(B_{2018} > 0.4 B_0)
Base	54 600 (41 500–83 200)	27 200 (14 800–51 300)	49 (34–67)	0.11
Previous	54 400 (40 100–85 400)	31 700 (16 900–61 200)	57 (40–78)	0.03
Base 0.7	52 600 (41 700–80 100)	27 900 (16 100–52 100)	53 (38–70)	0.05

Projections

Five-year biomass projections were made for the Base model run assuming future catches in the Sub-Antarctic to be an average of the catch from the last three years (1366 t), or the TACC (3701 t). For each projection scenario, future recruitment variability was sampled from actual estimates between 1974 and 2012 (entire time series, where all year classes measured at least three times), or 2003 and 2012 (last ten years).

Table 10: HAK 1 Bayesian median and 95% credible intervals (in parentheses) of projected B_{2023}, B_{2023} as a percentage of B_0, and B_{2023}/B_{2018} (%) for the model runs.

Model run	Catch	B_{2023}	B_{2023} (%B_0)	B_{2023}/B_{2018} (%)	p(B_{2023} < 0.2 B_0)	p(B_{2023} < 0.1 B_0)
Base 1974–2012	1 366	28 800 (14 500–59 500)	52 (33–81)	104 (76–154)	0	0
	3 701	21 000 (7 000–51 800)	38 (16–71)	76 (40–131)	0.05	0.01
Base 2003–2012	1 366	26 200 (13 300–53 200)	47 (30–72)	95 (73–130)	0	0
	3 701	18 400 (5 600–46 100)	33 (12–61)	67 (34–103)	0.12	0.01

At the current catch (1366 t), SSB is predicted to remain stable over the next five years (Table 10). At a catch of the TACC (3701 t), SSB is predicted to decrease. At the current catch, the estimated probability of SSB falling below the soft or hard limits is zero. At the TACC, the probability of the SSB dropping below the soft limit is 5% if large year classes such as those seen around 1980 are possible, and 12% if year class strength remains at recent levels.

4.2 Chatham Rise stock (HAK 4 and HAK1 north of Otago peninsula)

The 2020 stock assessment was carried out up to the end of 2020 using data up to the end of the 2018–19 fishing year and an assumed catch of 436 t for the 2019–20 year. The assessment used research time series of abundance indices (trawl surveys of the Chatham Rise from 1992 to 2020), catch-at-age from the trawl survey series and the commercial fishery since 1990–91, a CPUE series from the eastern trawl fishery, and estimates of biological parameters.

To more closely align with the seasons of the fishery, the model year was set as September to August, rather than the fishing year (October to September). The catch history was modified accordingly (Table 11). The catch history includes the revised estimates of catch reported by Dunn (2003).

4.2.1 Model structure

The base case model partitioned the Chatham Rise stock population into unsexed age groups 1–30 with the last age group considered a plus group. No CPUE was included and a constant M was used. The models were initialised assuming an equilibrium age structure at an unfished equilibrium biomass (B_0), i.e., with constant recruitment set equal to the mean of the recruitments over the period 1975–2017. Commercial fishing was split into two fisheries, east and west (split at latitude 178.1° E). Double-normal selectivity-at-age ogives were used for the west commercial fishing selectivity and a survey selectivity for the Chatham Rise January trawl survey series. In a change to the previous assessment base case a logistic selectivity-at-age ogive was used for the east commercial fishing selectivity. Selectivities were assumed constant across all years in both fisheries and the survey, and hence there was no allowance for possible annual changes in selectivity. The age at full selectivity for the trawl survey series was strongly encouraged to be in the range 8±2 years. This range was determined by visual examination of the at-age plots and was implemented because unconstrained selectivity resulted in age at full selectivity being older than most of the fish caught in the survey series.

4.2.2 Fixed biological parameters and observations

Estimates and assumed values for biological parameters used in the assessments are given in Table 4. Variability in the Schnute age-length relationship was assumed to be lognormal with a constant CV of 0.1.

Catch-at-age observations were available for each survey on the Chatham Rise, and for commercial trawl fisheries on the eastern and western Chatham Rise in some years, from observer data. The catch histories assumed in all model runs (Table 11) include the revised estimates of catch reported by Dunn (2003). Resource survey abundance indices are given in Table 12.

4.2.3 Model estimation

Model parameters were derived using Bayesian estimation implemented using the general-purpose stock assessment program CASAL v2.30 (Bull et al 2012). For final runs, the full posterior distribution was sampled using Markov Chain Monte Carlo (MCMC) methods, based on the Metropolis-Hastings algorithm.

The error distributions assumed were multinomial for the proportions-at-age and lognormal for all other data. Biomass indices had assumed CVs set equal to the sampling CV, with additional process error of 0.15 retained from the previous assessment (process error estimated from an MPD run was very similar). A process error CV of 0.20 for the CPUE series estimated following Francis (2011) was also retained from the previous assessment. The multinomial observation error effective sample sizes for the at-age data were adjusted using the reweighting procedure of Francis (2011). Ageing error was assumed to occur for the observed proportions-at-age data, by assuming a discrete normally distributed error with a CV of 0.08.

Table 11: Commercial catch history (t) by fishery (East and West) and total, for the Chatham Rise stock. Note that from 1990 totals by model year differ from those for fishing year (see Table 3) because the September catch has been shifted from the fishing year into the following model year.

Model year	West	East	Total	Model year	West	East	Total
1975	80	111	191	1998	1 424	1 124	2 547
1976	152	336	488	1999	1 169	3 339	4 509
1977	74	1 214	1 288	2000	1 155	2 130	3 285
1978	28	6	34	2001	1 208	1 700	2 908
1979	103	506	609	2002	454	1 058	1 512
1980	481	269	750	2003	497	718	1 215
1981	914	83	997	2004	687	1 983	2 671
1982	393	203	596	2005	2 585	1 434	4 019
1983	154	148	302	2006	184	255	440
1984	224	120	344	2007	270	683	953
1985	232	312	544	2008	259	901	1 159
1986	282	80	362	2009	1 084	838	1 922
1987	387	122	509	2010	275	134	409
1988	385	189	574	2011	777	165	942
1989	386	418	804	2012	108	101	209
1990	309	689	998	2013	249	117	366
1991	409	503	912	2014	109	96	205
1992	718	1 087	1 805	2015	139	83	222
1993	656	1 996	2 652	2016	249	209	458
1994	368	2 912	3 280	2017	302	124	426
1995	597	2 903	3 500	2018	228	173	401
1996	1 353	2 483	3 836	2019	364	93	457
1997	1 475	1 820	3 295	2020*	286	150	436

*2020 values are means of the 2016–2019 values for each area.

Table 12: Research survey indices (and associated CVs) for the Chatham Rise stock.

Year	Vessel	Biomass (t)	CV
1989*	*Amaltal Explorer*	3 576	0.19
1992	*Tangaroa*	4 180	0.15
1993	*Tangaroa*	2 950	0.17
1994	*Tangaroa*	3 353	0.10
1995	*Tangaroa*	3 303	0.23
1996	*Tangaroa*	2 457	0.13
1997	*Tangaroa*	2 811	0.17
1998	*Tangaroa*	2 873	0.18
1999	*Tangaroa*	2 302	0.12
2000	*Tangaroa*	2 090	0.09
2001	*Tangaroa*	1 589	0.13
2002	*Tangaroa*	1 567	0.15
2003	*Tangaroa*	890	0.16
2004	*Tangaroa*	1 547	0.17
2005	*Tangaroa*	1 049	0.18
2006	*Tangaroa*	1 384	0.19
2007	*Tangaroa*	1 820	0.12
2008	*Tangaroa*	1 257	0.13
2009	*Tangaroa*	2 419	0.21
2010	*Tangaroa*	1 700	0.25
2011	*Tangaroa*	1 099	0.15
2012	*Tangaroa*	1 292	0.15
2013	*Tangaroa*	1 877	0.15
2014	*Tangaroa*	1 377	0.15
2016	*Tangaroa*	1 299	0.19
2018	*Tangaroa*	1 660	0.34
2020	*Tangaroa*	1 037	0.20

Year class strengths were assumed known (and equal to one) for years before 1975 and after 2017, where inadequate or no catch-at-age data were available. Otherwise year class strengths were estimated under the assumption that the estimates from the model should average one.

MCMCs were estimated using a burn-in length of 3×10^6 iterations, with every 5000^{th} sample taken from a minimum of the next 5×10^6 iterations (i.e., a final sample of at least length 1000 was taken from the Bayesian posterior).

4.2.4 Prior distributions and penalty functions

The assumed prior distributions used in the assessment are given in Table 13. The priors for B_0 and year class strengths were intended to be relatively uninformed and had wide bounds. Priors for the trawl fishery selectivity parameters were assumed to be uniform. Priors for the trawl survey selectivity parameters were assumed to have a normal-by-stdev distribution, with a very tight distribution set for age at full selectivity, but an essentially uniform distribution for parameters *aL* and *aR*. The prior for the survey *q* was informative and was estimated using a simple simulation as described in section 4.1.2 above.

Penalty functions were used a) to constrain the model so that any combination of parameters that resulted in a stock size that was so low that the historical catch could not have been taken was strongly penalised, b) to ensure that all estimated year class strengths averaged 1, and c) to smooth the year class strengths estimated over the period 1975 to 1983.

Table 13: The assumed priors for key distributions (when estimated) for the Chatham Rise stock assessment. The parameters are mean (in natural space) and CV for lognormal and normal priors, and mean (in natural space) and standard deviation for normal-by-stdev priors.

Parameter description	Distribution	Parameters		Bounds	
B_0	Uniform-log	–	–	10 000	250 000
Year class strengths	Lognormal	1.0	1.1	0.01	100
Selectivity (fishery)	Uniform	–	–	1	25–200
Selectivity (survey, *a1*)	Normal-by-stdev	8	1	1	25
Selectivity (survey, *aL*, *aR*)	Normal-by-stdev	10	500	1	25–200
M	Normal	0.19	0.2	0.1	0.35

4.2.5 Model estimates

Estimates of biomass were produced for an agreed base case run (research survey abundance series, constant *M,* logistic selectivity for the eastern fishery) using the biological parameters and model input parameters described earlier. Sensitivity models were run to investigate the effects of estimating:

- ‘High M’: A higher fixed constant *M* (*M* raised from 0.19 to 0.23) (MPD only).
- ‘Low M’: A lower fixed constant *M* (*M* lowered from 0.19 to 0.15) (MPD only).
- ‘All double normal’: Selectivities for the survey and both fisheries were modelled as double normal.
- ‘CPUE’: the eastern CPUE series was included. The CPUE analysis for Chatham Rise hake investigated three CPUE series. The first used catch and effort data from the whole Chatham Rise. Two more were based on the catch and effort of the western and eastern fisheries data respectively. During the characterisation work for the stock it was concluded the Eastern CPUE demonstrated least conflict in abundance signal with the survey series.

Stock status from these four models was not markedly different to the base case. For all runs, MPD fits were obtained and qualitatively evaluated. MCMC runs were performed of the base case and all double normal and CPUE models. Base case MCMC estimates of the median posterior and 95% percentile credible intervals are reported for virgin, current, and projected biomass.

Estimated MCMC marginal posterior distributions from the base case model are shown for year class strengths (Figure 9) and biomass (Figure 10). The year class strength estimates suggested that the Chatham Rise stock was characterised by a group of relatively strong relative year class strengths in the late 1970s to early 1980s and again in the early 1990s, followed by a period of relatively poor recruitment since then (except for 2002 and 2011). Consequently, biomass increased slightly during the late 1980s, then declined to about 2006. The growth of the strong 2002 year class resulted in an upturn in biomass from about 2007, followed by a further upturn from 2016 as the 2011 year class began to recruit. Current stock biomass was estimated at about 55% of B_0 (see Figure 10 and Table 14). Annual exploitation rates (catch over vulnerable biomass) were low (less than 0.1) up to 1993 and since 2006, but moderate (although probably less than 0.25) in the intervening period (Figure 11).

The resource survey and fishery selectivity ogives all had relatively wide bounds after age at peak selectivity. The survey ogive was essentially logistic (even though fitted as double normal) and had hake fully selected by the research gear from about age 9. Recall that age at full selectivity for the trawl survey was strongly influenced by tight priors. Fishing selectivities indicated that hake were fully selected in the western fisheries by about age 7 years. For the eastern fishery, fitting the selectivity as logistic (as in the base case) resulted in wide bounds up to and beyond age of full selectivity which was not until age 14 or 15; this is logical given that the eastern fishery concentrates more on the spawning (i.e., older) biomass. If fitted as double normal the eastern fishery ogive was again essentially logistic.

Base case projections

Five-year biomass projections were made assuming future catches on the Chatham Rise were much higher (and assumed equal to the HAK 4 TACC of 1800 t) or the mean annual catch over the last six years (362 t). For the projections, estimated future recruitment variability was sampled in two ways: the first from actual estimates between 1975 and 2017, a period including the full range of recruitment successes; the second from actual estimates between 2008 and 2017 only. Restricting sampling to the more recent year class strengths (YCS) was in response to estimated YCS indicating a declining long-term trend in YCS decadal means.

Base case model projections assuming a future annual catch of 1800 t suggest that biomass will decline between 2021 and 2025 (Table 15). The rate of decline depends on whether recruitments are some combination of those from all estimated years or whether they remain at the level of the last decade. In either recruitment scenario there is little risk (i.e., < 1%) that the stock will fall below 20% B_0 in the next five years under this catch scenario. Note that 1800 t is higher than recent annual landings from the stock (they have averaged about 362 t in the last six years), but lower than what could be taken (if all the HAK 4 TACC plus some HAK 1 catch from the western Chatham Rise was taken). Under the assumption there has been no long-term decline in recruitment, future catches of 362 t per year will allow further stock rebuilding. If it is assumed recruitment will remain at the level of the last decade, future catches of 362 t per year are predicted to see SSB essentially unchanged over the next 5 years.

Table 14: Bayesian median and 95% credible intervals of B_0, B_{2020}, and B_{2020} as a percentage of B_0 for the Chatham Rise model runs.

Model run	B_0	B_{2020}	B_{2020} (%B_0)	P(B_{2020} > 0.4 B_0)
Base case	32 838 (28 280–42 721)	18 150 (13 204–27 258)	55.1 (45.7–65.9)	0.99
Double normal	32 859 (27 998–43 444)	18 237 (13 175–27 659)	55.4 (45.4–66.8)	0.996
CPUE	34 367 (29 504–44 113)	20 035 (15 096–28 979)	58.0 (49.6–68.1)	1.0

Table 15: Chatham Rise base model: Bayesian median and 95% credible intervals of projected biomass, probability (%) of being above target (40% B_0) and below soft limit (20% B_0) or hard limit (10% B_0) in each year to 2025.

Recruitment	Future catch (t)	Year	B	B (%B_0)	p(B > 0.4 B_0)	p(B < 0.2 B_0)	p(B < 0.1 B_0)
All YCS	1 800	2021	17 600 (11 700–29 200)	53.5 (42.0–68.4)	0.992	0	0
		2022	16 400 (10 700–28 100)	50.2 (37.6–66.8)	0.937	0	0
		2023	15 700 (9 800–27 800)	47.6 (34.1–65.6)	0.844	0	0
		2024	15 100 (8 900–27 700)	45.9 (31.2–66.1)	0.762	0	0
		2025	15 000 (8 400–27 500)	45.0 (29.1–66.8)	0.717	0.001	0
All YCS	362	2021	18 100 (12 300–29 800)	55.1 (43.9–69.6)	0.997	0	0
		2022	18 100 (12 300–29 800)	55.2 (43.4–71.2)	0.995	0	0
		2023	18 300 (12 600–30 500)	55.7 (43.2–73.0)	0.992	0	0
		2024	18 800 (12 600–31 500)	57.0 (43.4–76.0)	0.993	0	0
		2025	19 600 (13 000–32 400)	59.3 (44.1–79.8)	0.997	0	0
Recent YCS	1 800	2021	17 500 (11 700–29 100)	53.3 (41.8–68.2)	0.991	0	0
		2022	16 200 (10 400–27 900)	49.7 (36.7–66.4)	0.918	0	0
		2023	15 100 (9 200–27 800)	45.9 (32.1–66.2)	0.769	0	0
		2024	13 900 (8 000–27 400)	42.5 (27.7–65.9)	0.607	0.001	0
		2025	13 000 (6 900–27 000)	39.5 (23.0–65.5)	0.484	0.007	0
Recent YCS	362	2021	18 100 (12 200–29 700)	54.9 (43.7–69.6)	0.996	0	0
		2022	17 900 (12 100–29 500)	54.8 (42.7–71.2)	0.994	0	0
		2023	17 800 (11 900–30 600)	54.3 (41.4–74.1)	0.987	0	0
		2024	17 800 (11 800–31 300)	54.1 (40.0–75.5)	0.975	0	0
		2025	17 800 (11 500–32 000)	53.9 (39.1–77.7)	0.969	0	0

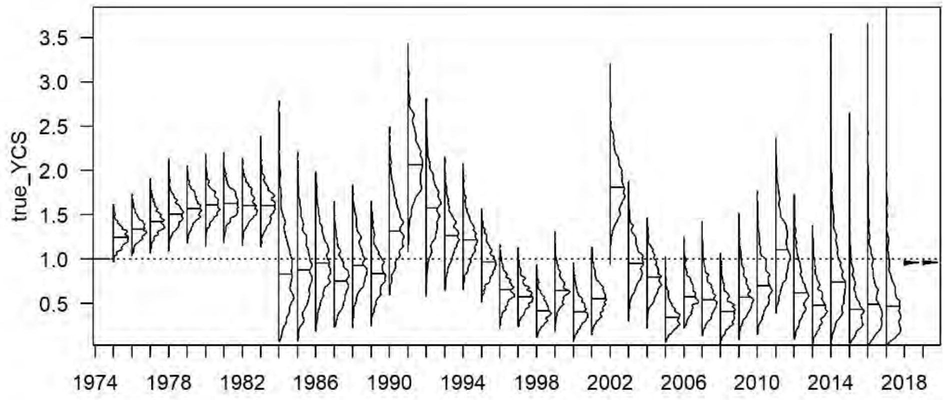

Figure 9: Estimated posterior distributions of year class strengths for the Chatham Rise base case. The dashed horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

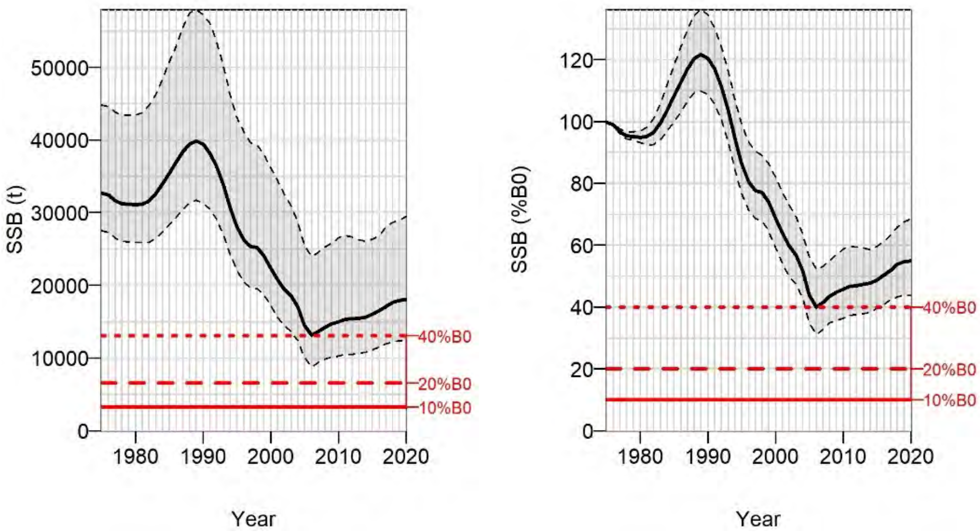

Figure 10: Estimated median trajectories (with 95% credible intervals shown as dashed lines) for the Chatham Rise base case model for absolute biomass and stock status (biomass as a percentage of B_0).

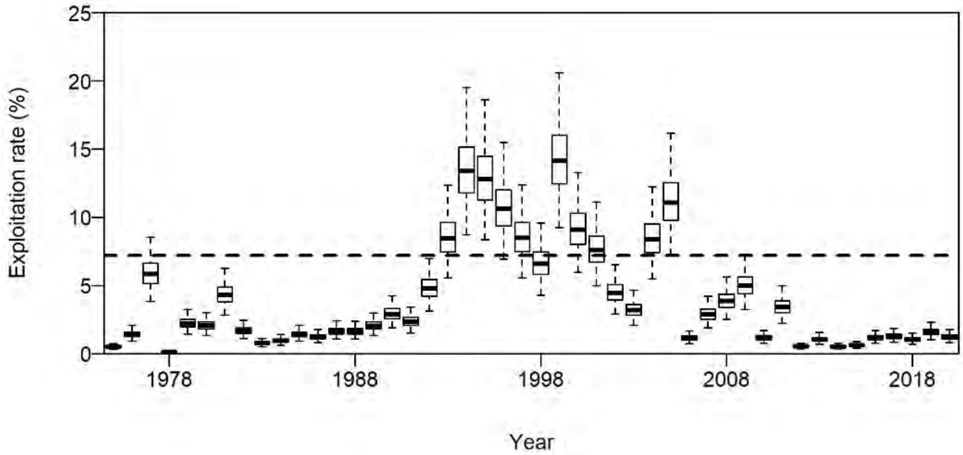

Figure 11: Exploitation rates (catch over vulnerable biomass) for the Chatham Rise stock base case model. Overall exploitation rate uses a catch weighted average of the component fishery exploitations.

4.3 HAK 7 (West Coast, South Island)

A new stock assessment for HAK 7 was accepted by the working group in 2019, building on previous assessments. Earlier work used standardised Catch Per Unit Effort (CPUE) as an index of abundance (Dunn 1998). Later, CPUE was included in the model in combination with a biomass index from a scientific survey conducted by RV *Tangaroa* (Horn 2011, 2013b). As additional survey data were collected over the period 2012–16 (Table 16), the trends in abundance provided by the CPUE and survey indices diverged to the point that they could not be reconciled within a single stock assessment model (Horn 2017). The 2019 assessment base case used the survey indices only (including the 2018 survey index). Results from the model using the CPUE index in place of the survey abundance index are presented as a sensitivity run.

The present assessment for HAK 7 modelled the fishery from 1974–75 to 2018–19. It used catches and catch age composition data from the commercial trawl fishery, research trawl survey biomass indices and age composition data, and biological parameters available in the scientific literature.

4.3.1 Model structure

The model assumed a single sex (male and females combined), having 30 unsexed age groups, with the last age group being a plus (accumulator) group. Natural mortality was assumed constant at M=0.19 per year. The model assumed two time steps: the first representing the period between October and May when recruitment occurred; and the second June to September, when the fishery and the survey took place. Selectivity ogives were assumed to follow logistic ogives for the commercial fishery, and double-normal with an estimated descending right-hand limb for the trawl survey. Models were explored using double-normal ogives for the commercial fishery, and the resulting estimated curves were almost logistic, with little difference to the model fits or results. Hake sexual maturation was set to occur according to an age-specific schedule informed by biological studies. The relation between spawning stock biomass and recruitment was assumed to follow a Beverton-Holt relationship with assumed fixed steepness equal to 0.84. The model was initialised assuming an equilibrium age structure at an unfished equilibrium biomass (B_0) in 1975, i.e., with constant recruitment set equal to the mean of the recruitments over the period 1975 to 2015.

4.3.2 Fixed biological parameters and observations

Estimates and assumed values for biological parameters used in the assessments are given in Table 4. Variability in the Schnute age-length relationship was assumed to be normal with a constant CV of 0.1.

Commercial fishery catch-at-age observations were available for 1979 (fishing by RV *Wesermünde*), and from observers from 1989–90 to 2017–18 (Figure 12). Until 2005, the most frequently caught age-groups of hake in the fishery were between 6 and 12 years old, and after 2005 between 5 and 9 years old.

The research trawl survey on the west coast of the South Island has been conducted since 2000. This survey initially covered an area from 300 m to 650 m depth north of Hokitika Canyon (‘core area’). Since 2012, the survey focus was changed by extending into both shallower and deeper water to more adequately cover the distribution of a number of species, including hake (covering an area referred to as ‘all areas’). The survey was initially extended from 200 to 800 m. An additional 800–1000 m deep stratum was added in 2016, to monitor shovelnose dogfish and ribaldo. However, the survey remains north of Hokitika Canyon and consequently does not monitor populations, including hake, which are in the canyon and south.

Due to variable estimates in the numbers of hake aged 1 and 2 observed in the survey, possibly from the changes in coverage over time, these age classes were excluded from the survey biomass estimates and survey age data used in the model.

The representativeness of the survey (either core or all) of the hake population on the WCSI is not well known and the survey may index a changing proportion of the population over time. This is because this survey does not monitor areas south of the Hokitika Canyon which are known to support hake in reasonable numbers.

Standardised CPUE indices are shown in Table 17. Because of concerns about changing fishing behaviour, including targeting and avoidance, advances in gear technology, and changes in fleet structure, the working group considered the CPUE to be a less reliable index of abundance than the fishery independent survey series

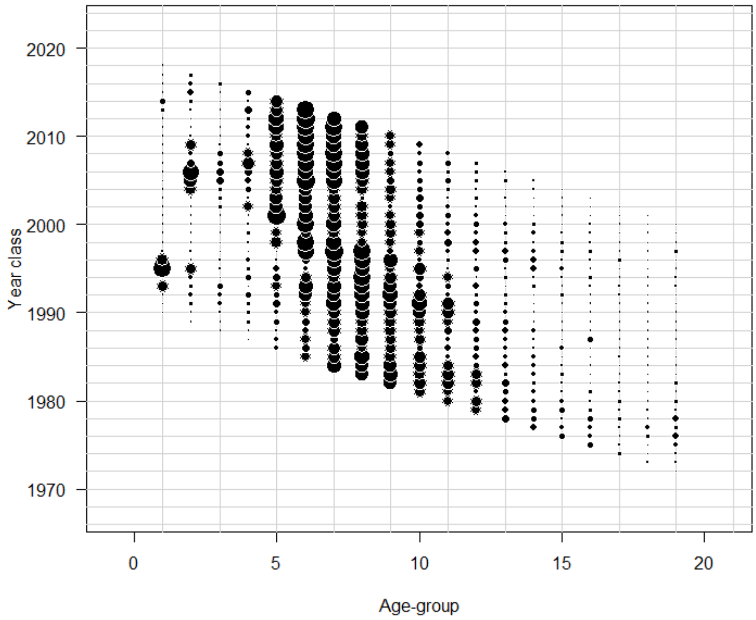

Figure 12: Proportion of hake estimated in the HAK 7 commercial trawl fishery by age-group (x-axis) and year class (y-axis) for data collected from 1990-2018.

Table 16: Research survey indices of abundance (biomass in tonnes) and associated CVs (in parentheses) for core and all survey areas.

Year	core	all
2000	803 (0.13)	NA
2012	579 (0.13)	1 096 (0.13)
2013	328 (0.17)	740 (0.22)
2016	208 (0.25)	316 (0.18)
2018	227 (0.33)	549 (0.18)

Table 17: Trawl fishery CPUE indices (and associated CVs) for the WCSI stock.

Year	Index	CV
2000–01	0.91	0.04
2001–02	2.56	0.03
2002–03	0.47	0.07
2003–04	1.20	0.03
2004–05	0.92	0.03
2005–06	1.03	0.03
2006–07	0.86	0.06
2007–08	0.39	0.05
2008–09	0.23	0.06
2009–10	0.46	0.06
2010–11	0.75	0.05
2011–12	0.82	0.03
2012–13	1.36	0.03
2013–14	0.88	0.03
2014–15	0.92	0.03
2015–16	0.89	0.03
2016–17	1.04	0.03
2017–18	1.34	0.03

The catch history assumed in the model runs is shown in Table 18.

Table 18: Revised landings (t) from fishing years 1975 to 2018 for the West Coast South Island. Note, these relate to biological stocks, not QMAs.

Fishing year	West Coast S.I.	Fishing year	West Coast S.I.
1974–75	71	1996–97	6 838
1975–76	5 005	1997–98	7 674
1976–77	17 806	1998–99	8 742
1977–78	498	1999–00	7 031
1978–79	4 737	2000–01	8 346
1979–80	3 600	2001–02	7 498
1980–81	2 565	2002–03	7 404
1981–82	1 625	2003–04	7 939
1982–83	745	2004–05	7 298
1983–84	945	2005–06	6 892
1984–85	965	2006–07	7 660
1985–86	1 918	2007–08	2 583
1986–87	3 755	2008–09	5 912
1987–88	3 009	2009–10	2 282
1988–89	8 696	2010–11	3 462
1989–90[1]	8 741	2011–12	4 299
1990–91[1]	8 246	2012–13	5 171
1991–92	3 010	2013–14	3 387
1992–93	7 059	2014–15	5 966
1993–94	2 971	2015–16	2 733
1994–95	9 535	2016–17	4 599
1995–96	9 082	2017–18	2 968

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4.3.3 Model estimation

Model parameters were derived using Bayesian estimation, implemented by using the general-purpose stock assessment program CASAL v2.30 (Bull et al 2012). For final model runs, the full posterior distribution was sampled using Markov Chain Monte Carlo (MCMC) methods.

The model was fitted to proportions-at-age using a multinomial probability distribution, and to the survey abundance index using a lognormal distribution. A process error of 0.10 was applied on the biomass index in addition to its measurement uncertainty (CVs in Table 16). A process error CV of 0.30 for the CPUE series was estimated following the recommendations of Francis (2011). The multinomial observation error effective sample sizes for the at-age data were adjusted using the reweighting procedure of Francis (2011). Ageing error was assumed to occur for the observed proportions-at-age data, by assuming a normally distributed error with a CV of 0.08.

Year class strengths were assumed known (and equal to one) for years before 1974–75 and after 2014–15, when inadequate or no catch-at-age data were available. Otherwise year class strengths were estimated under the assumption that the estimates from the model should average to one.

4.3.4 Prior distributions and penalty functions

The assumed prior distributions used in the assessment are given in Table 19. The priors for B_0 and year class strengths were intended to be relatively uninformed and had wide bounds. Priors for all selectivity parameters were assumed to be uniform. The prior for the survey q was informative and was estimated using the Sub-Antarctic hake survey prior as a starting point (see section 4.1.2) because the survey series in both areas used the same vessel and fishing gear. However, the WCSI survey area in the 200–800 m depth range comprised 12 928 km^2; seabed area in that depth range in the entire HAK 7 biological stock area (excluding the Challenger Plateau) is estimated to be about 24 000 km^2. Because the biomass survey coverage only includes 54% of the known WCSI hake habitat, the mean of the Chatham Rise prior was modified accordingly (i.e., $0.16 \times 0.54 = 0.09$), and the bounds were also reduced from [0.01, 0.40] to [0.01, 0.25]. The same prior was used for the 'core area'. Priors for all selectivity parameters were assumed to be uniform.

The prior on the year class strength was lognormal with mean equal to 1 and standard deviation (σ_R) equal to 1.1. A penalty function was used to constrain the model so that any combination of parameters that resulted in a stock size that was so low that the historical catch could not have been taken was strongly penalised.

Table 19: The assumed priors for key distributions (when estimated) for the WCSI stock assessment. The parameters are mean (in natural space) and CV for lognormal and normal priors.

Parameter description	Distribution	Parameters		Bounds	
B_0	Uniform-log	–	–	5 000	250 000
Year class strengths	Lognormal	1.0	1.1	0.01	100
Trawl survey *q*	Lognormal	0.09	0.79	0.01	0.25
CPUE *q*	Uniform-log	–	–	1e-8	1e-3
Selectivities	Uniform	–	–	0	20–200*

* A range of maximum values was used for the upper bound

4.3.5 Model sensitivities

Three model sensitivity models were developed. The 'CPUE' sensitivity model used CPUE to index abundance in place of the survey. The 'core' sensitivity model used the 'core' survey biomass index in place of the 'all' survey biomass index. The 'YCS c.v.' sensitivity model reduced the coefficient of variance (CV) on Year Class Strength (YCS) estimates from 1.1, as it is in the base model, to 0.8. A fourth sensitivity model assumed a single selectivity function, and the base case and the remaining selectivity runs estimated separate selectivity functions before and after 2005 because of the shift in the age composition of the catch described above in section 4.3.2.

4.3.6 Model estimates

Results from the base case assessment model (model 'survey all'), and four sensitivity models are presented here. The sensitivity models are: (1) the effect of a narrower prior on year class strength (i.e., the CV on the prior was 0.8 instead of 1.1); (2) using core survey areas instead of all survey areas (model 'survey core'); (3) using a single selectivity for the commercial fishery throughout the time series (model 'single sel'); and (4) replacing the survey index of abundance by a standardised CPUE index (model 'CPUE').

For all models, MPD fits were obtained and qualitatively evaluated. For all models except the single selectivity model, MCMC estimates of the median posterior and 95% percentile credible intervals were determined for current and virgin biomass, and projected states. The 'single sel' selectivity run was only run to the MPD level and is not reported in Table 20.

The base case stock assessment model estimated spawning stock biomass declined throughout the late 1970s (Figure 13) when there were relatively high catch levels. The biomass then increased through the mid-1980s, after which it steadily declined to a low point in 2018–19 because of higher levels of exploitation and below-average recruitment from 2000–01 to 2014–15 (Figure 14).

The model YCS prior with CV=0.8 produced similar trends in year class strength (Figure 14) and estimated SSB_{2019}/B_0 to be 19.1%, 2% higher than the base case model (Table 20). The base case model estimated the SSB in 2018–19 to be 17.0% of virgin biomass (B_0), with a 95% credible interval ranging from 9.7% to 28.5%.

The survey core sensitivity produced a better fit to the survey biomass index (Figure 15), and estimated stock status to be 1% greater than the base case run with wider credibility bounds (Table 19).

Table 20: Bayesian median (95% credible intervals) (MCMC) of SSB_0, SSB_{2019}, and SSB_{2019} as a percentage of B_0 for the WCSI models.

Model run	B_0		SSB_{2019}		SSB_{2019} (%B_0)	
Survey all	70 046	(65 945–75 588)	11 904	(6 636–20 977)	17.0	(9.7–28.5)
Survey core	70 430	(65 930–72 218)	13 068	(6 082–24 929)	18.5	(8.9–33.0)
YCS c.v.	70 586	(66 425–76 419)	13 442	(7 632–23 569)	19.1	(11.2–31.6)
CPUE	84 745	(76 048–99 139)	52 595	(31 309–88 696)	62.0	(40.5–90.8)

4.3.7 Model sensitivities

Three model sensitivity runs were developed. The 'CPUE' sensitivity model used CPUE to index abundance in place of the survey. The 'core' sensitivity model used the 'core' survey biomass index in place of the ‘all’ survey biomass index. The ‘YCS c.v.’ sensitivity model reduced the coefficient of variance (CV) on Year Class Strength (YCS) estimations from 1.1, as it is in the base model, to 0.8.

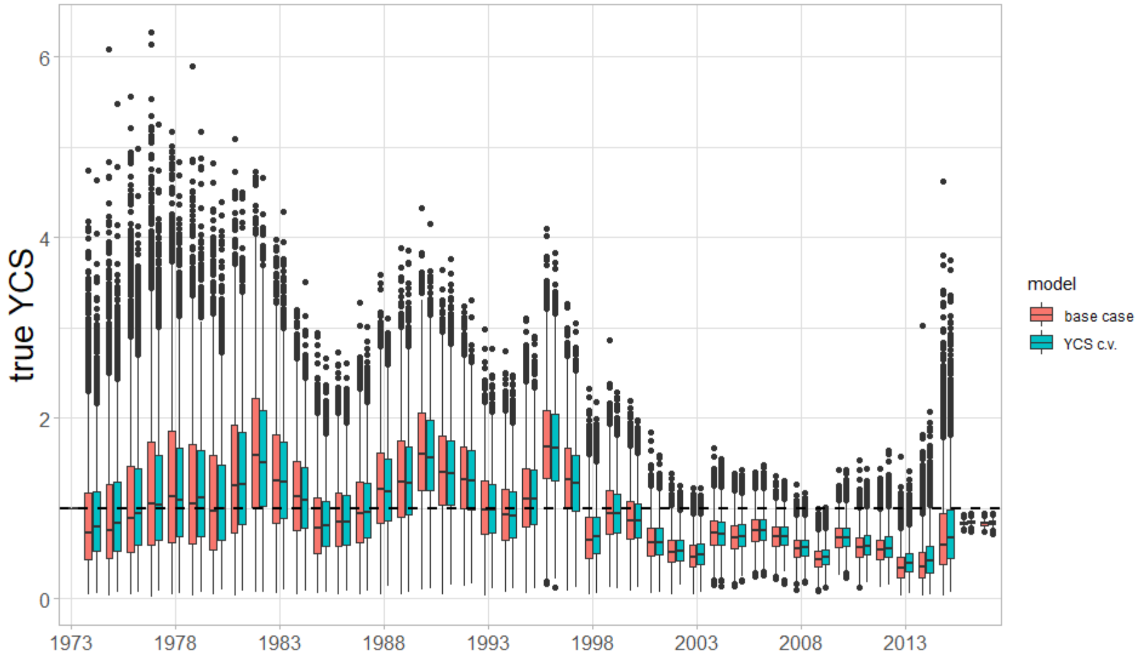


Figure 14: MCMC estimates of year class strength for the base case model and the sensitivity model investigating a narrower prior distribution (YCS c.v.=0.8 instead of 1.1).

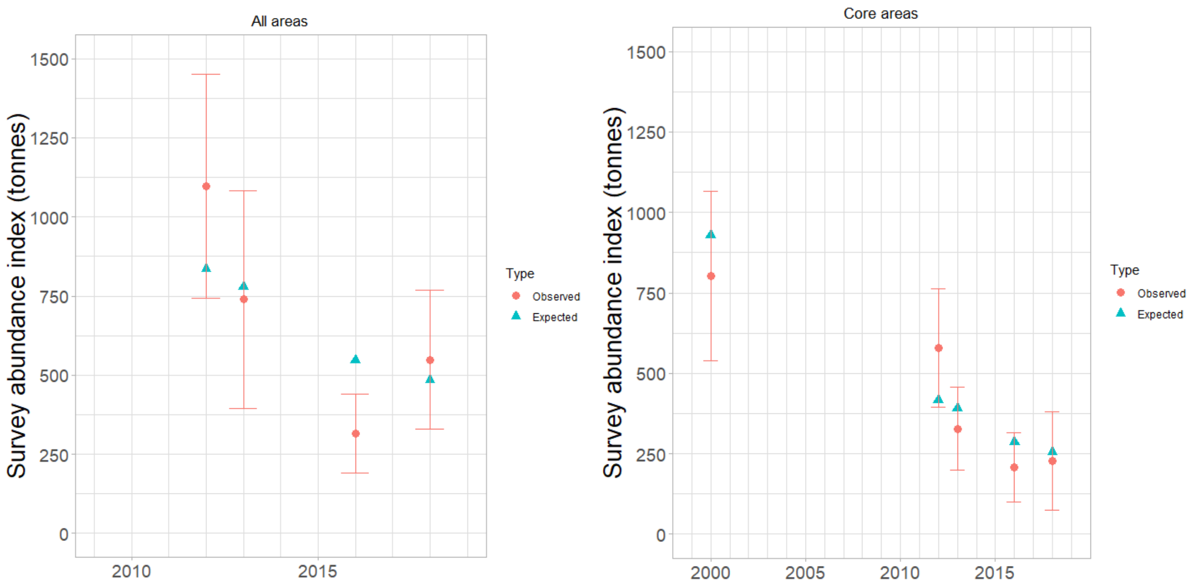


Figure 15: Fit of the base case model to the survey index of abundance from all areas (left) and fit of the sensitivity model to core survey area (right).

Base case MPD estimates from the logistic selectivity ogives (Figure 16) indicated that 8% of age 5 and 50% of age 7 hake were retained by the commercial trawl before 2005. After 2005, the proportion retained increased to 42% at age 5 and 96% at age 7. The ‘single sel’ model run estimated a selectivity ogive between these two, with 55% retention at age 6. The base case model fitted the proportion-at-age data better than the ‘single sel’ run and supports the assumption that selectivity changed around 2005.

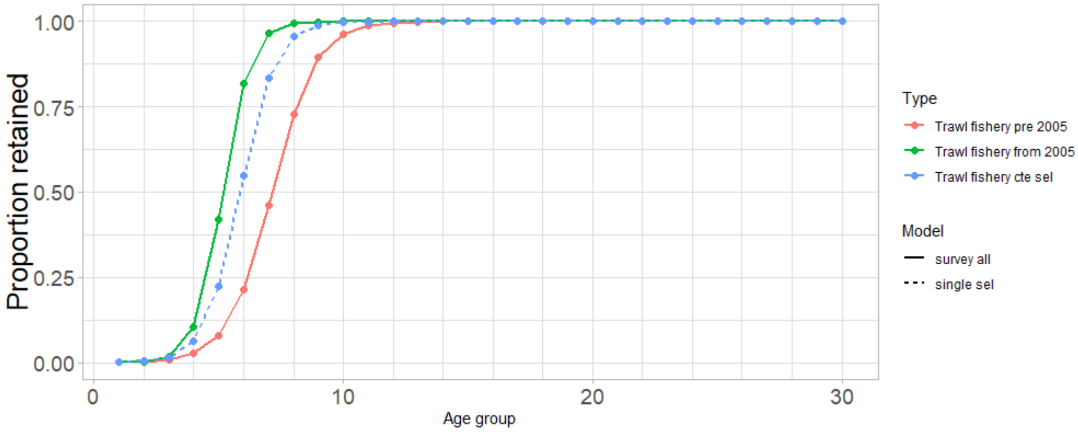


Figure 16: MPD estimated logistic commercial trawl gear selectivity estimated for the base case model (survey all) and the sensitivity model (single sel).

The CPUE sensitivity run estimated a substantially different trend in SSB (Figure 17), which increased after 2007–08 to a SSB_{2019}/B_0 of 62.0% (CI 40.5–90.8%).

For the base model, the exploitation rate was estimated to have first exceeded the exploitation rate that would result in the target biomass ($U_{40\%}$) in 1986–87, and then remained higher than $U_{40\%}$ until 2018–19 (Figure 18). $U_{40\%}$ was estimated at 9% for the base model, but would be 12% if future fishery selectivity returned to that estimated before 2004–05.

4.3.8 Yield estimates and projections

The biomass of HAK 7 was projected 5 years into the future (2019–2024), assuming two scenarios for future WCSI catches: (1) catches staying at 2017–18 levels (2968 t annually), and (2) catches at the TACC limit (5064 t annually). For each projection scenario, future recruitment deviates were sampled from two sets of recruitment estimates (1) recruitment estimates between 1973 and 2015 and (2) between 2006 and 2015. Note that the RV *Tangaroa* survey in 2018 and RV *Kaharoa* inshore survey in 2017 suggested that the 2016 year class was above average, but these data were not included in the projections.

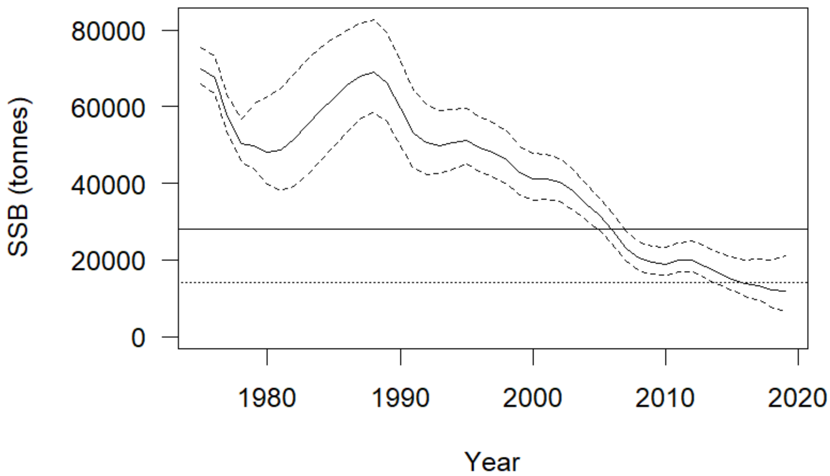


Figure 17: Estimated median trajectories (with 95% credible intervals shown as dashed lines) for the WCSI stock base case. The management target (40% B_0, solid horizontal line) and soft limit (20% B_0, dotted horizontal line) are shown as horizontal solid and dotted lines respectively.

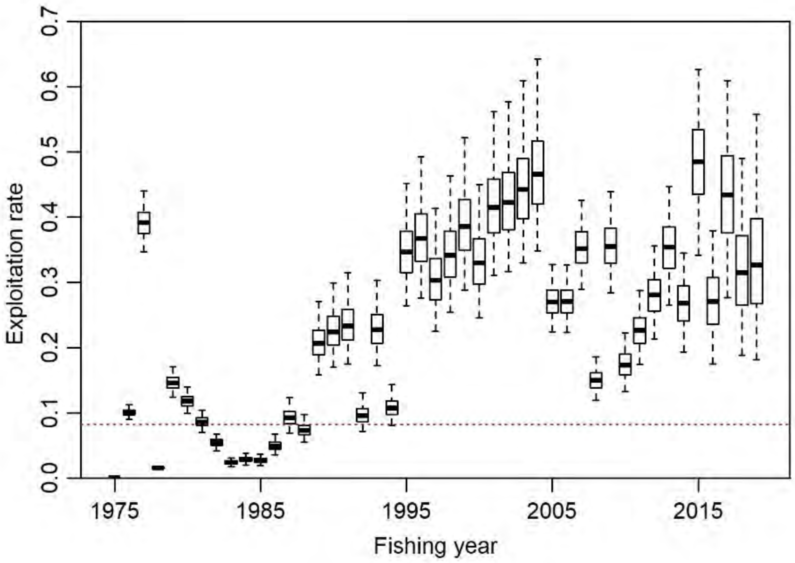


Figure 18: Exploitation rates (catch over vulnerable biomass) for the WCSI 'survey all' model. The horizontal broken line indicates the exploitation rate at 40% B_0 (U_{40}; median derived from MCMC samples).

Projections with the base case model ('survey all') using the 2006–2015 recruitment series, which is below average, indicated that spawning biomass will remain below 20% B_0 with catches equal to 2968 t (Table 21, Figure 19). If catches were to increase to the current TACC, the SSB in 2024 would drop to 8.8% B_0 (4.3–33.5%). When projections are made from average recruitment (1974–2015), the SSB is expected to increase at current level of catches and stay at a similar level if the TACC was caught.

Projections when assuming a narrower 'recruitment variability (YCS c.v.=0.8 model) estimated 2–4% increases to the projected biomass relative to the base case. The 'core survey' model also projected the stock status to be slightly greater than the base case model (1–3%). The CPUE model projected that the stock will remain above 40% B_0 in all scenarios.

Table 21: Bayesian median and 95% credible intervals of projected B_{2024}, B_{2024} as a percentage of B_0, and B_{2024}/B_{2019} (%) for the 'survey' and 'CPUE' models, under two future annual catch scenarios and two future recruitment scenarios.

Future catch (t)	Future YC	B_{2019}	B_{2024}	B_{2024} (% B_0)	B_{2024}/B_{2019} (%)
Survey all model					
2968	2006–2015	11 815 (6 513–20946)	13 127 (3 695–31 629)	18.7 (5.4–42.8)	110 (49–194)
5064		11 823 (6 499–20934)	6 167 (2947–24 967)	8.8 (4.3–33.5)	57 (32–140)
2968	1974–2015	11 891 (6 604–21 038)	21 271 (7 951–40 903)	30.4 (11.7–56.0)	174 86–320)
5064		11 912 (6 604–21 036)	13 427 (4 362–33 506)	19.0 (6.4–45.1)	110 (44–248)
YCS c.v.=0.8 model					
2968	2006–2015	13 362 (7 519–23 547)	15 846 (5 419–34 506)	22.4 (8.0–46.4)	116 (61–188)
5064		13 364 (7 526–23 547)	7 980 (3 469–26 319)	11.4 (5.1–35.2)	61 (34–134)
2968	1974–2015	13 430 (7 569–23 629)	23 244 (10 318–42 017)	32.9 (15.1–56.9)	166 (97–137)
5064		13 432 (7 629–23 554)	15 477 (5 107–34 909)	21.9 (7.5–47.9)	112 (47–224)
Survey core model					
2968	2006–2015	12 980 (5 954–24 835)	14 972 (3 540–39 555)	21.3 (5.2–51.9)	114 (49–202)
5064		12 972 (5 926–24 844)	7 376 (2 940–31 125)	10.5 (4.4–41.3)	62 (32–150)
2968	1974–2015	13 075 (5 997–24 947)	22 593 (8 253–45 522)	32.0 (12.1–61.0)	168 (90–321)
5064		13 080 (6 018–24 942)	14 839 (4 519–37 125)	21.0 (6.6–49.7)	111 (45–240)
CPUE model					
2968	2006–2015	52 796 (31 037–89 937)	62 224 (34 740–111 194)	73.5 (44.7–115)	118 (92–146)
5064		52 749 (31 106–89 799)	54 692 (27 220–104 575)	64.7 (34.8–109)	104 (76–133)
2968	1974–2015	52 504 (31 248–89 156)	57 544 (34 548–92 927)	67.9 (43.6–97.7)	109 (81–150)
5064		52 536 (31 118–89 203)	50 115 (26 927–84 105)	59.0 (34.5–89.3)	94 (68–133)

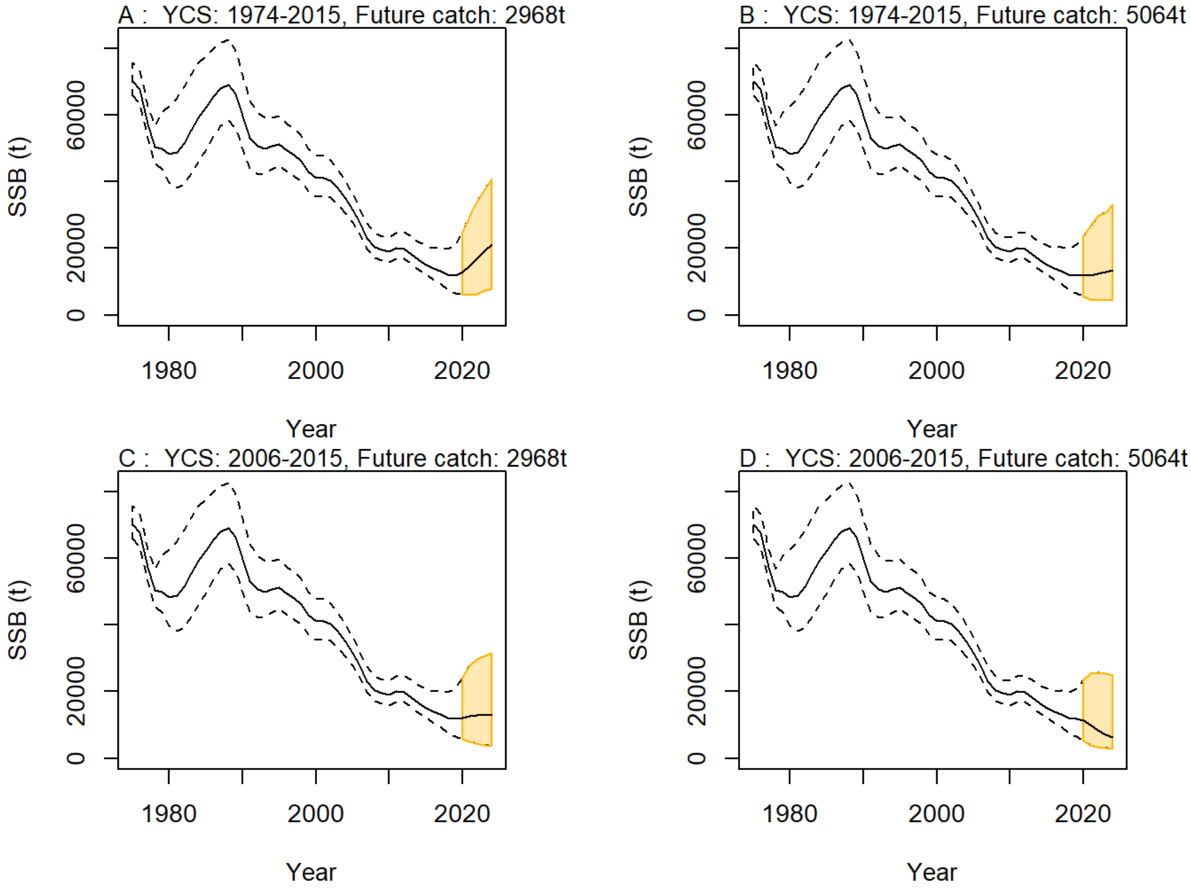


Figure 19: Spawning Stock Biomass (SSB) trajectories including projections from 2020–2024 for the Base model (Survey all), projected with catch of 2968 t (A, C) or TACC catch (B, D), with YCS sampled from all years (A, B) or most recent estimated 10 years (C, D).

Table 22: Probability of the stock being less than 10, 20 and 40% B_0 for the Base, Survey core, YCS c.v., and CPUE models, at 2019 and projected out to 2024 with either current catch (2968 tonnes) or TACC (5064 tonnes).

			2019				2024
Model	**P(<10%)**	**P(<20%)**	**P(<40%)**		**P(<10%)**	**P(<20%)**	**P(<40%)**
Base	0.038	0.74	1.00	**Current catch**	0.12	0.55	0.97
				TACC	0.58	0.88	0.99
Survey core	0.048	0.60	1.00	**Current catch**	0.11	0.44	0.92
				TACC	0.47	0.79	0.97
YCS c.v.				**Current catch**	0.054	0.39	0.94
	0.0098	0.58	1.00	**TACC**	0.43	0.80	0.99
CPUE	0.00	0.00	0.022	**Current catch**	0.00	0.00	0.011
				TACC	0.00	0.00	0.072

5. Status of the stocks

Stock Structure Assumptions

Hake are assessed as three independent biological stocks, based on the presence of three main spawning areas (eastern Chatham Rise, south of Stewart-Snares shelf, and WCSI), and some differences in biological parameters between these areas.

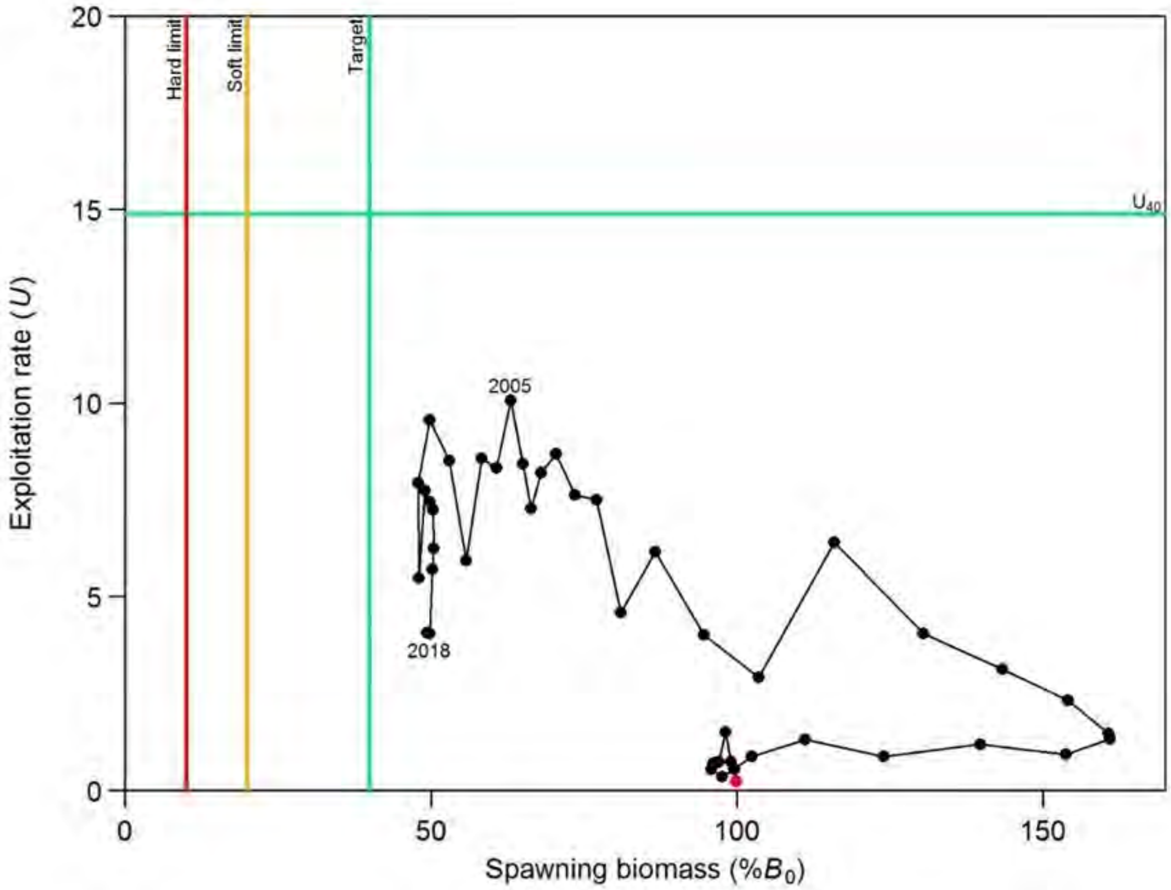
The HAK 1 Fishstock includes all of the Sub-Antarctic biological stock, part of the Chatham Rise biological stock, and all hake around the North Island (which are more likely part of either the WCSI or Chatham Rise stocks). The Sub-Antarctic stock is defined as all of Fishstock HAK 1 south of the Otago Peninsula; the Chatham Rise stock is all of HAK 4 plus that part of HAK 1 north of the Otago Peninsula; the WCSI stock is HAK 7.

- **Sub-Antarctic Stock (HAK 1 South of Otago Peninsula)**

Stock Status	
Year of Most Recent Assessment	2018
Assessment Runs Presented	Base case
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $U_{40\%}$
Status in relation to Target	B_{2018} was estimated at 49% B_0; Likely (> 60%) to be at or above the target
Status in relation to Limits	B_{2018} is Exceptionally Unlikely (< 1%) to be below both the Soft and Hard Limits
Status in relation to Overfishing	Overfishing is Exceptionally Unlikely (< 1%) to be occurring

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass is estimated to have been stable since 2010.
Recent Trend in Fishing Mortality or Proxy	Exploitation rate is estimated to have been low throughout the duration of the fishery.
Other Abundance Indices	A CPUE series showed a similar biomass trend to the research surveys.
Trends in Other Relevant Indicators or Variables	Recent year classes (since 2008) have been below average.

Historical Stock Status Trajectory and Current Status



Trajectory over time of exploitation rate (*U*) and spawning biomass (% B_0), for the HAK 1 stock base model from the start of the assessment period in 1974 (represented by a red point), to 2018. The red vertical line at 10% B_0 represents the hard limit, the orange line at 20% B_0 is the soft limit, and green lines are the %B_0 target (40% B_0) and the corresponding exploitation rate (U_{40}). Biomass and exploitation rate estimates are medians from MCMC results.

Projections and Prognosis (2019)	
Stock Projections or Prognosis	The biomass of the Sub-Antarctic stock was expected to remain stable at recent average catch levels. At the TACC, the stock biomass is expected to decline.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Exceptionally Unlikely (< 1%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Current catch: Extremely Unlikely (< 1%) TACC: Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2018	Next assessment: 2021
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Research time series of abundance indices (trawl survey: summer, autumn)	1 – High Quality
	- Proportions-at-age data from the commercial fisheries and trawl surveys	1 – High Quality
	- Estimates of biological parameters	1 – High Quality
Data not used (rank)	- Commercial CPUE (used in sensitivity run only)	2 – Medium Quality: potentially biased owing to changes in fishing practice and catch reporting
Changes to Model Structure and Assumptions	- This assessment now assumes constant *M* (rather than age-specific), and logistic selectivity for the fishery (rather than domed).	
Major Sources of Uncertainty	- The summer trawl survey series has shown a decline over time, but individual survey estimates are variable and catchability clearly varies between surveys. The general lack of contrast in this series (the main relative abundance series) makes it difficult to accurately estimate past and current biomass. - The assumption of a single Sub-Antarctic stock (including the Puysegur Bank), independent of hake in all other areas, is the most parsimonious interpretation of available information. However, this assumption may not be correct. - Uncertainty about the size of recent year classes affects the reliability of stock projections. - There are patterns in the residuals in the commercial catch-at-age data fitted by the model. - Although the catch history used in the assessment has been corrected for some misreported catch (see Section 1.4), it is possible that additional misreporting exists.	

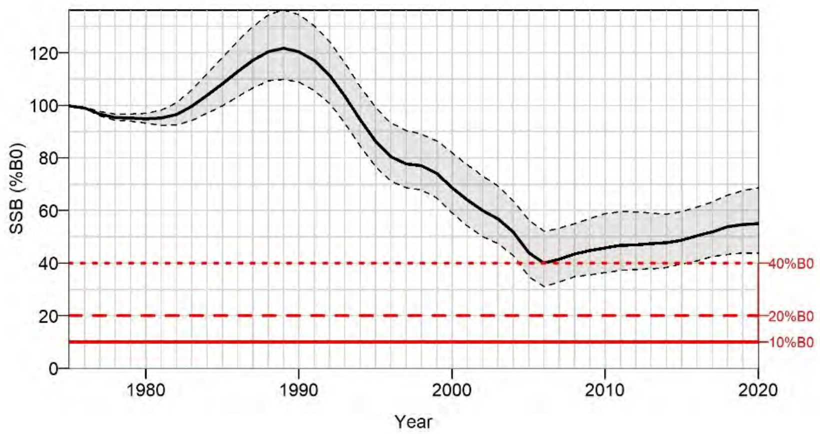
Qualifying Comments
-

Fishery Interactions
Hake are often taken as a bycatch in hoki target fisheries. Some target fisheries for hake do exist, with the main bycatch species being hoki, ling, silver warehou and spiny dogfish. Hake are a key predator of hoki. Incidental interactions and associated mortality have been recorded for some protected species, including New Zealand fur seals and seabirds.

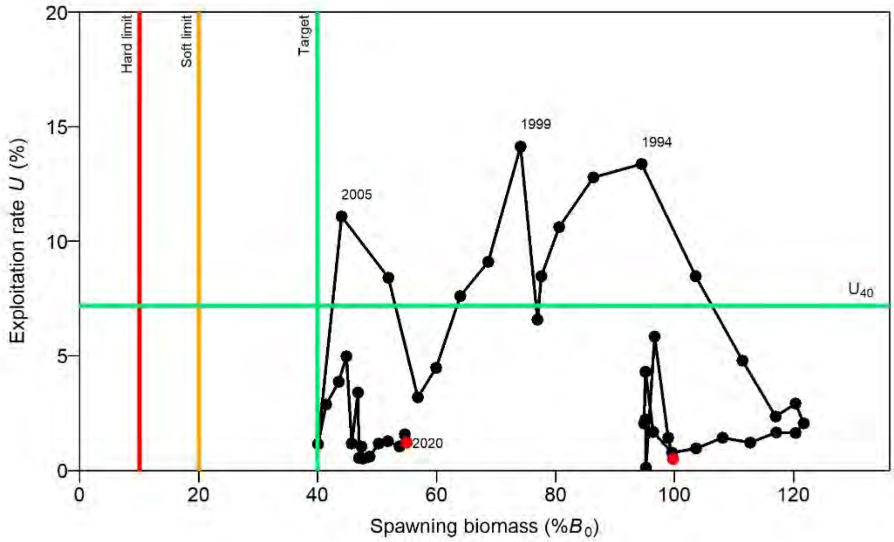
- **Chatham Rise Stock (HAK 4 plus HAK 1 north of Otago Peninsula)**

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	An agreed base case, fitted primarily to a research survey abundance series
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	B_{2020} was estimated to be about 55% B_0; Very Likely (> 90%) to be at or above target
Status in relation to Limits	B_{2020} is Exceptionally Unlikely (< 1%) to be below the Soft or Hard Limits
Status in relation to Overfishing	Overfishing is Exceptionally Unlikely (< 1%) to be occurring

Historical Stock Status Trajectory and Current Status



Trajectory over time of spawning biomass (% B_0, with 95% credible intervals shown as broken lines) for the Chatham Rise hake stock from the start of the assessment period in 1975 to 2020 (the final assessment year). The management target (40% B_0, short dash horizontal line) and soft limit (20% B_0, dashed horizontal line) and hard limit (solid line) are shown. Years on the x-axis indicate fishing year with "2005" representing the 2004–05 fishing year. Biomass estimates are based on MCMC results.



Trajectory over time of exploitation rate (U) and spawning biomass (% B_0), for the HAK 4 stock base model from the start of the assessment period in 1975 (represented by a red point), to 2020 (red and labelled). The red vertical line at 10% B_0 represents the hard limit, the orange line at 20% B_0 is the soft limit, and green lines are the %B_0 target (40% B_0) and the corresponding exploitation rate (U_{40}). Biomass and exploitation rate estimates are medians from MCMC results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Median estimates of biomass fell to 40% B_0 in 2006, but biomass has been slowly increasing since 2007.
Recent Trend in Fishing Intensity or Proxy	Fishing pressure is estimated to have been low since 2006 (relative to estimated fishing pressure in most years from 1994 to 2005).
Other Abundance Indices	The CPUE index for the eastern Chatham Rise has been increasing since 2012.
Trends in Other Relevant Indicators or Variables	Recruitment (1996–2013, but excluding 2002 and 2011) is estimated to be lower than the long-term average for this stock.

Projections and Prognosis	
Stock Projections or Prognosis	Expectations for the biomass of the Chatham Rise stock over the next 5 years depends on whether recruitment is assumed able to increase to levels from throughout the time series or assumed to be restricted to levels seen recently. If the former, then catch levels equivalent to those from recent years (i.e. about 360 t annually) are expected to result in an increase in SSB, but if recruitments are restricted to the levels of recent years SSB is expected to remain more or less constant. If future catches increase to the level of the full HAK 4 TACC of 1800 t, biomass is expected to decline under both recruitment scenarios with the median estimate reaching 40% B_0 in 2025 under the more pessimistic recruitment assumption.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Assuming recent recruitment and current catch (362 t): Soft Limit: Exceptionally Unlikely (< 1%) Hard Limit: Exceptionally Unlikely (< 1%) Assuming recent recruitment and future catches at 1800 t (based on the HAK 4 TACC): Soft Limit: Very Unlikely (< 10%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Assuming recent recruitment and future catches at the level of the current catch: Very Unlikely (< 10%) Assuming recent recruitment and future catches at 1800 t (based on the HAK 4 TACC): About as Likely as Not (40–60%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2020	Next assessment: 2023
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Research time series of abundance indices (trawl survey) - Proportions-at-age data from the commercial fisheries and trawl surveys	1 – High Quality 1 – High Quality
Data not used (rank)	- Commercial CPUE	2 – Medium or Mixed Quality: does not track stock biomass well, and was used in a sensitivity model

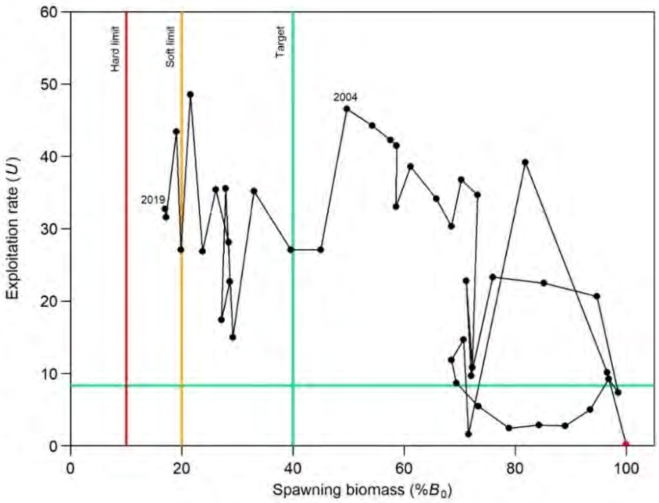
Changes to Model Structure and Assumptions	- Selectivity for the commercial fishery to the east of the Chatham Rise is modelled as logistic (double normal previously) - Catch history revised from 2009 onwards
Major Sources of Uncertainty	- Catch at age information from the commercial catch has not been available since 2016 due to declining catches - Although the catch history used in the assessment has been corrected for some misreported catch (see Section 1.4), it is possible that additional misreporting exists

Qualifying Comments
- In October 2004, large catches were taken in the western deep fishery (i.e. near the Mernoo Bank). This was repeated to a lesser extent in 2008 and 2010. There is no information indicating whether these aggregations fished on the western Chatham Rise were spawning; if they were then this might indicate that there is more than one stock on the Chatham Rise. However, the progressive increase in mean fish size from west to east is indicative of a single homogeneous stock on the Chatham Rise. - A pronounced reduction in average recruitment over 40 years may indicate a decline in the productivity of this stock.

Fishery Interactions
Hake are often taken as a bycatch catch in hoki target fisheries. Some target fisheries for hake do exist, with the main bycatch species being hoki, ling, silver warehou and spiny dogfish. Hake are a key predator of hoki. Incidental interactions and associated mortality have been recorded for some protected species, notably New Zealand fur seals and seabirds.

- **West Coast South Island Stock (HAK 7)**

Stock Status	
Year of Most Recent Assessment	2019
Assessment Runs Presented	One base case, and three sensitivity model runs
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	B_{2019} was estimated to be 17% B_0; Exceptionally Unlikely (< 1%) to be at or above the target
Status in relation to Limits	B_{2019} is About as Likely as Not (40–60%) to be below the Soft Limit and Very Unlikely (< 10%) to be below the hard Limit.
Status in relation to Overfishing	Overfishing in 2019 was Likely (> 60%) to be occurring.

Historical Stock Status Trajectory and Current Status

Trajectory over time of exploitation rate (*U*) and spawning biomass (% B_0), for the HAK 7 base model fitted to the survey biomass index, from the start of the assessment period in 1974 (represented by a red point), to 2018. The red vertical line at 10% B_0 represents the hard limit, the orange line at 20% B_0 is the soft limit, and green lines are the %B_0 target (40% B_0) and the corresponding exploitation rate (U_{40}). Biomass and exploitation rate estimates are medians from MCMC results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	- The 'all area' survey series shows a decreasing trend from 2012 until 2016, with the 2018 estimate higher than the 2016 estimate. - The 'core area' survey series shows a decreasing trend from 2000 until 2016, with the 2018 estimate similar to the 2016 estimate.
Recent Trend in Fishing Intensity or Proxy	Exploitation rate was estimated to have been high since 1989.
Other Abundance Indices	The CPUE index indicated an increasing biomass trend, but may not be a reliable index of abundance.
Trends in Other Relevant Indicators or Variables	Recent recruitment (2006–2015) is estimated to be lower than the long-term average for this stock.

Projections and Prognosis	
Stock Projections or Prognosis	The biomass of the WCSI stock is expected to remain constant under recent recruitment and current catch, and to increase under average recruitment and recent catch. Under catches equal to the TACC, the biomass is expected to decline with recent recruitment, and remain constant with average recruitment.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	For the Base model at current catches and recent average recruitment: Current catch: Soft Limit: About as Likely as Not (40–60%) Hard Limit: Unlikely (< 10%) TACC: Soft Limit: Very Likely (> 90%) Hard Limit: Likely (> 60%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	For the Base model at current catches and recent average recruitment: Current catch: Likely (> 60%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2019	2022
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Research trawl surveys (2000-2018 for ‘core area’, and 2012-2018 for ‘all area’)	1 – High Quality
	- Proportions-at-age data from the commercial fishery and research surveys	1 – High Quality
	- Estimates of fixed biological parameters	1 – High Quality
	- Trawl fishery CPUE	2 – Medium or Mixed Quality: may not track stock biomass
Data not used (rank)	- *RV Kaharoa* WCSI inshore trawl survey	Does not monitor the adult stock
Changes to Model Structure and Assumptions	- The model assumes two fishery selectivities rather than one. - The base case model used the ‘all area’ survey series.	
Major sources of Uncertainty	- Uncertainty about the size of recent year classes affects the reliability of stock projections. - The spatial and temporal representativeness of the survey of the hake stock on the WCSI is not known. - Although the catch history used in the assessment has been corrected for some misreported catch (see Section 1.4), it is possible that additional misreporting exists. - It is assumed in the assessment models that natural mortality is constant over all ages and years.	

Qualifying Comments
- CPUE from this stock has previously been considered too unreliable to be used as an abundance index, but a truncated series from 2001 was previously used as an alternative base run. The fisheries-independent abundance series is sparse (at most five comparable trawl surveys) and while the ‘all’ strata that more accurately samples hake for the base model has been used, the ‘core’ strata have been included as a sensitivity as this data extends back to include the year 2000. - The estimates of the 2016 year class (which is not included in projections) from the *RV Tangaroa* survey in 2018 and *RV Kaharoa* inshore survey in 2017 suggested that this year class may be above average.

Fishery Interactions
The main bycatch species of hoki-hake-ling-silver warehou-white warehou target fisheries are rattails, javelin fish, and spiny dogfish. Hake are a key predator of hoki. Incidental interactions and associated mortality have been recorded for protected species, including NZ fur seals and seabirds.

Table 23: Summary of TACCs (t) and reported landings (t) for the most recent fishing year.

Fishstock	QMA	2018–19 actual TACC	2018–19 reported landings
HAK 1	Auckland, Central Southeast, Southland, Sub-Antarctic (FMAs 1, 2, 3, 5, 6, 8, 9)	3 701	896
HAK 4	Chatham Rise (FMA 4)	1 800	183
HAK 7	Challenger (FMA 7)	5 064	1 563
HAK 10	Kermadec	10	0
Total		10 575	2 642

6. FOR FURTHER INFORMATION

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