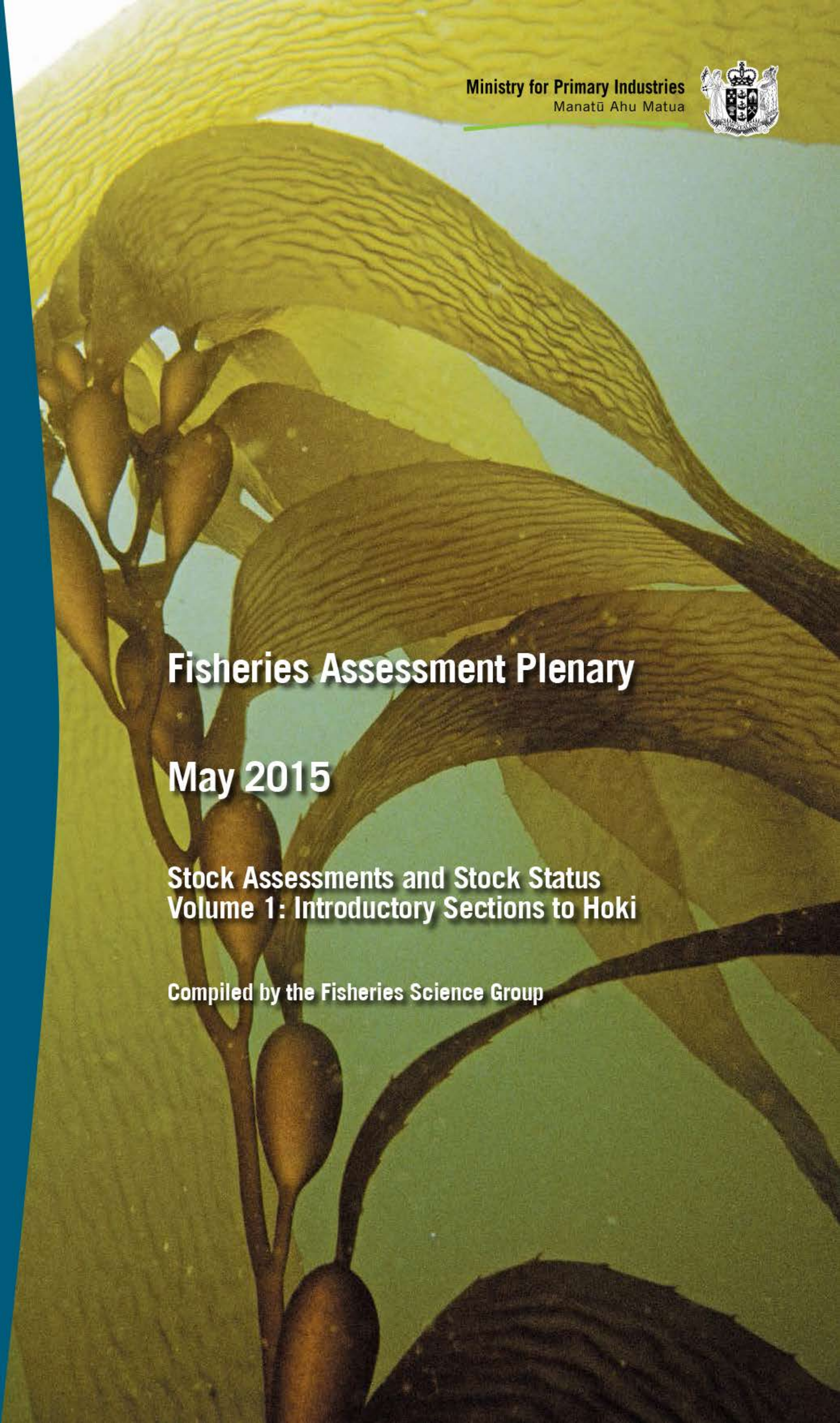

Ministry for Primary Industries
Manatū Ahu Matua

Fisheries Assessment Plenary

May 2015

Stock Assessments and Stock Status
Volume 1: Introductory Sections to Hoki

Compiled by the Fisheries Science Group

Ministry for Primary Industries
Fisheries Science Group

Fisheries Assessment Plenary:
Stock Assessments and Stock Status

May 2015

Volume 1: Introductory Sections to Hoki

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PREFACE

Fisheries Assessment Plenary reports have represented a significant annual output of the Ministry for Primary Industries and its predecessors, the Ministry of Fisheries and the Ministry of Agriculture and Fisheries, for the last 31 years. The Plenary is now more than 2000 pages long and is split into five volumes, three of which are produced in May and two in November of each year. However, the Plenary reports only provide summaries of the available information and are in turn supported by 70–100 more detailed, readily available publications per year.

The May 2015 Plenary summarises fishery, biological, stock assessment and stock status information for 83 of New Zealand's commercial fish species or species groups in a series of Working Group or Plenary reports. Each species or species group is split into 1–10 stocks for management purposes. In addition, the mid-year Plenary that is produced each November for species that operate on different management cycles includes 17 Working Group and Plenary summaries for Highly Migratory Species (HMS), 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. This year, Working Groups have continued the effort to populate the Status of the Stocks summary tables, developed in 2009 by the Stock Assessment Methods Working Group. These tables have several uses: they provide comprehensive summary information about current stock status and the prognosis for these stocks and their associated fisheries, they are used to evaluate fisheries performance relative to the 2008 Harvest Strategy Standard for New Zealand Fisheries and other management measures, and they rank the quality of stock assessment inputs and outputs based on the 2011 Research and Science Information Standard for New Zealand Fisheries.

The Plenary reports take into account the most recent data and analyses available to Fisheries Assessment Working Groups (FAWGs) 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 FAWGs or the Plenary.

I would like to recognise and thank the large number of research providers and scientists from research organisations, academia, the seafood industry, marine amateur fisheries, environmental NGOs, Maori customary and the Ministry for Primary Industries; along with all other technical and non-technical participants in present and past FAWG 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 the Ministry's past and present Science Officers who put tireless effort into checking and collating each Plenary report. The Science Officer for this report was Annie Galland.

I am pleased to endorse this document as representing the best available scientific information relevant to stock and fishery status, as at 31 May 2015.

Pamela Mace

Dr Pamela Mace
Principal Advisor Fisheries Science
Ministry for Primary Industries

CONTENTS

Page

Introduction…… 1

Glossary…… 3

Terms of Reference for Fisheries Assessment Working Groups…… 13

Fisheries Assessment Working Groups: Membership 2014–15…… 23

Guide to Biological Reference Points for Fisheries Assessment Meetings…… 27

Guidelines for Status of the Stocks Summary Tables…… 35

Alfonsino (BYX)…… 41
Anchovy (ANC)…… 51
Arrow squid (SQU)…… 55
Barracouta (BAR)…… 70
Black cardinalfish (CDL)…… 82
Bladder kelp attached (KBB G) …… 100
Blue cod (BCO)…… 114
Blue mackerel (EMA)…… 160
Blue moki (MOK)…… 169
Blue warehou (WAR)…… 176
Bluenose (BNS)…… 184
Butterfish (BUT)…… 205

Cockles (COC)

  COC Introduction …… 212
  COC 1A…… 217
  COC 3…… 227
  COC 7A…… 237
Deepwater (King) clam (PZL) …… 246
Elephant fish (ELE) …… 250
Flatfish (FLA) …… 272
Freshwater eels (SFE, LFE)…… 300
Frostfish (FRO) …… 341
Garfish (GAR) …… 350
Gemfish (SKI) …… 355

Ghost shark

  Dark ghost shark (GSH)…… 375
  Pale ghost shark (GSP)…… 390
Giant spider crab (GSC)…… 399
Green-lipped mussel (GLM)…… 403
Grey mullet (GMU)…… 407
Groper (HPB) …… 413
Hake (HAK) …… 424
Hoki (HOK) …… 450
Horse mussel (HOR)…… 486
Jack mackerels (JMA) …… 489
John dory (JDO)…… 511
Kahawai (KAH) …… 537
Kina (SUR) …… 562
King crab (KIC) …… 570

Kingfish (KIN) 574
Knobbed whelk (KWH) 585
Leatherjacket (LEA) 589
Ling (LIN) 599
Lookdown dory (LDO) 639

Orange roughy (ORH)

ORH Introduction 650
ORH 1 665
ORH 2A/2B/3A 673
ORH 3B 697
ORH 7A 729
ORH 7B 743
ORH ET 749

Oreos (OEO)

OEO Introduction 756
OEO 3A 770
OEO 4 785
OEO 1 and 6 799
Paddle crabs (PAD) 821
Parore (PAR) 827

Paua (PAU)

Paua Introduction 832
PAU 2 841
PAU 3 850
PAU 4 864
PAU 5A 869
PAU 5B 888
PAU 5D 901
PAU 7 918
Pilchard (PIL) 930
Pipis (PPI) 937
PPI 1A 942
Porae (POR) 949
Prawn killer (PRK) 953
Queen scallops (QSC) 956
Redbait (RBT). 960
Red cod (RCO) 963
Red crab (CHC) 976
Red gurnard (GUR) 979
Red snapper (RSN) 1 012
Ribaldo (RIB) 1 016
Rig (SPO) 1 028
Rubyfish (RBY) 1 061
Scampi (SCI) 1 069
School shark (SCH) 1 104
Sea cucumber (SCC) 1 135
Sea perch (SPE) 1 140
Silver warehou (SWA) 1 155

Skates

Rough Skate (RSK) 1 167
Smooth Skate (SSK) 1 176
Snapper (SNA) 1 185
Southern blue whiting (SBW) 1 257
Spiny dogfish (SPD) 1 288

Sprat (SPR) …… 1 305
Stargazer (STA)…… 1 309
Surf Clams
- Surf Clams Introduction. …… 1 335
- Deepwater tuatua (PDO) …… 1 340
- Fine (Silky) dosinia (DSU)…… 1 345
- Frilled venus shell (BYA)…… 1 349
- Large trough shell (MMI)…… 1 353
- Ringed dosinia (DAN)…… 1 358
- Triangle shell (SAE) …… 1 363
- Trough shell (MDI) …… 1 368

Tarakihi (TAR) …… 1 373
Toothfish (TOT) …… 1 405
Trevally (TRE) …… 1 433
Trumpeter (TRU) …… 1 451
Tuatua (TUA) …… 1 459
White warehou (WWA)…… 1 464
Yellow-eyed mullet (YEM)…… 1 471

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) that have relevance to fishery management have been incorporated for selected species. Paragraph 11 (page 14) 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, page 21) specifies that "For species, populations, habitats, or systems for which new assessments are not conducted in the current year, to review and update any existing Fisheries Assessment Plenary report text in order to determine whether the latest reported status summary is still relevant; else to revise the evaluations 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 2015. 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 some 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 Ministry's Fisheries website in a searchable database.

Environmental Effects of Fishing

Fisheries 2030 specifies a single goal for the New Zealand fisheries sector. That goal is to have "*New Zealanders maximising benefits from the use of fisheries within environmental limits*". To support the goal, Fisheries 2030 includes the desired environment outcome, that "*The capacity and integrity of the aquatic environment, habitats and species are sustained at levels that provide for current and future use, including:*

- *biodiversity and the function of ecological systems, including trophic linkages are conserved*
- *habitats of special significance to fisheries are protected*
- *adverse effects on protected species are reduced or avoided*
- *impacts, including cumulative impacts, of activities on land, air or water on aquatic ecosystems are addressed*."

The scientific information to assess the environmental effects of fishing and enable this outcome comes primarily from research commissioned by the Ministry 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). The Ministry has recently (2011) 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 fishery-specific summaries have been progressively included in this report since 2005, starting with hoki. These fishery-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 35–40. Beginning in 2012, selected 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, selected 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 the commercial fishery 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 the fishery (=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 **TACC's** (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 the fishery. 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**).

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.

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: virgin biomass**.

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 (see page 26). 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.

DWWG: The Deepwater (Science) Working Group.

ECER: Eel Catch-Effort Return.

ECELR: Eel Catch-Effort Landing Return.

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 fishery 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 the fishery. 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.

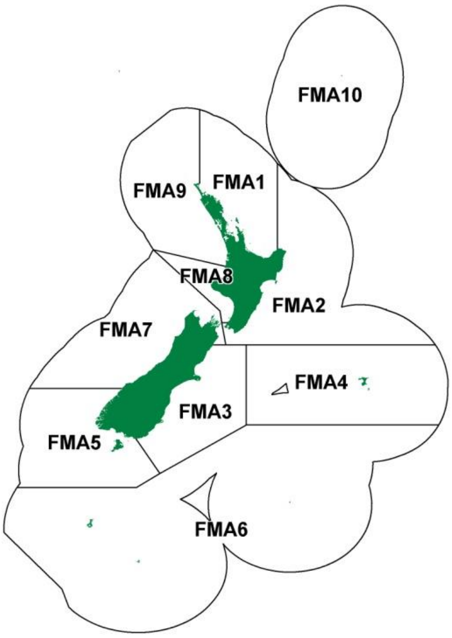
FAWGs: Fisheries Assessment (Science) Working Groups.

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}.

Growth overfishing: Growth overfishing occurs when the **fishing mortality rate** is above 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.

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 the commercial fishery 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 when 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 while 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: is 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 the fishery. .

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.

NINS: 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.

PCER: Paua Catch-Effort 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).

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 the fishery).

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 fishery 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 the fishery; 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.

RTWG: Marine Recreational Fisheries Technical Working Group, a sub group of the Marine Recreational Fisheries Working Group.

SAMWG: Stock Assessment Methods (Science) Working Group.

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.

SINS: 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 the 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.

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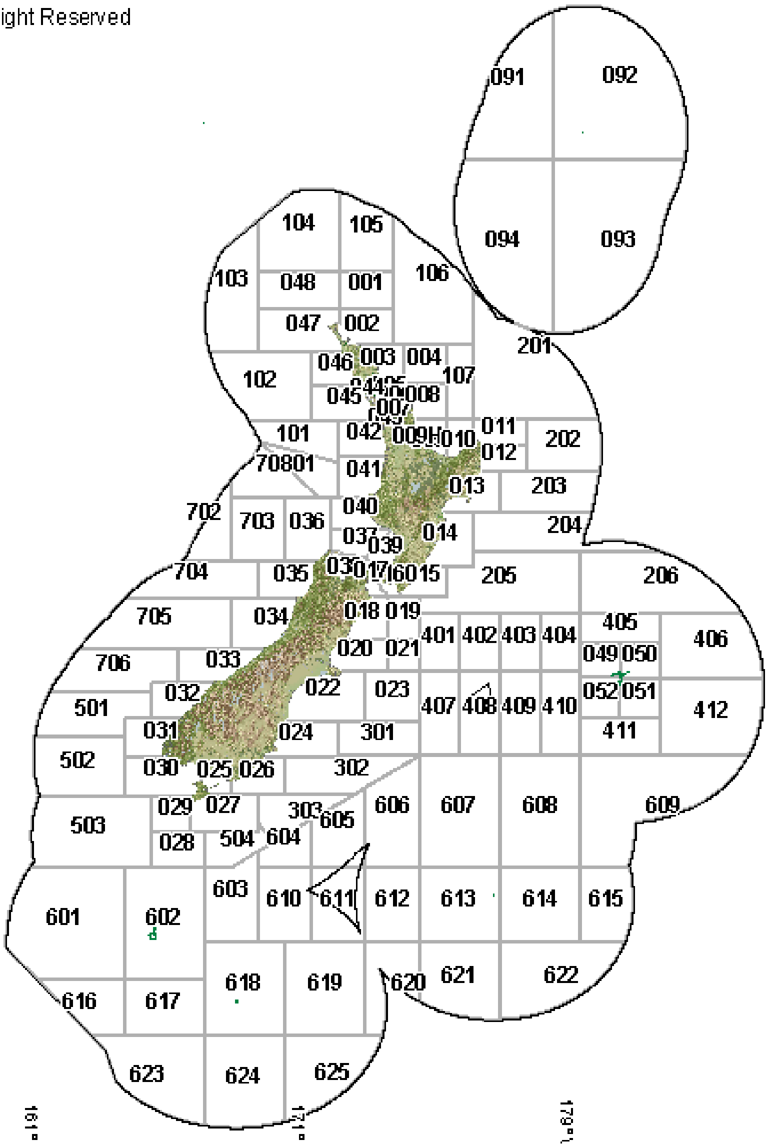
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179°W
169°W

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% B_0. A steepness value greater than about 0.9 is considered to be high, while 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. B_{MSY} and/or 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 B_{MSY} or B_0 or F_{MSY} or $F_{\%SPR}$. For example, the current biomass may be said to be above or below B_{MSY} or to be at some percentage of B_0. Similarly, fishing mortality may be above or below F_{MSY} or $F_{\%SPR}$.

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 be comprised of 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 fishery and **stock** attributes at a constant level simultaneously, thus sustainable fishing does not imply that the fishery and **stock** will persist in a constant **equilibrium** state. Because of natural variability, even if F_{MSY} could be achieved exactly each year, **catches** and **stock biomass** will oscillate around their average ***MSY*** and 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 Maori interests, recreational fishery 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.

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

$U_{40\%B0}$: The **exploitation rate** associated with a biomass of 40% 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

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

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 the fishery. 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 2015

Overall purpose

For fish stocks managed within the Quota Management System, as well as other important fisheries in which New Zealand engages:

to assess, based on scientific information, the status of fisheries and fish stocks relative to MSY-compatible reference points and other relevant indicators of stock status; to conduct projections of stock size under alternative management scenarios; and to review results from relevant research projects.

Fisheries Assessment Working Groups (FAWGs) evaluate relevant research, determine the status of fisheries and fish stocks and evaluate the consequences of alternative future management scenarios. They do not make management recommendations or decisions (this responsibility lies with MPI 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), MPI fisheries scientists will produce a list of stocks/issues for which new stock assessments or evaluations are likely to become available prior to the next scheduled sustainability rounds. FAWG Chairs will determine the final timetables and agendas.

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

Technical objectives

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

4. To estimate appropriate MSY-compatible reference points[1] for selected fish stocks 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 in order 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. In addition to determining the status of fish stocks relative to MSY-compatible reference points, and particularly where the status is unknown, FAWGs should explore the potential for using

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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: http://fs.fish.govt.nz/Page.aspx?pk=104

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/TACCs are maintained, or if fishers or fisheries managers are considering modifying them in other ways.

7. Where appropriate and practical, to conduct projections of likely future stock status using alternative fishing mortality (or exploitation) rates or catches and 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 are not conducted in the current year, to review the existing Fisheries Assessment Plenary report text on the "Status of the Stocks" in order 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, Maori 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 before setting a TAC or TACC.

11. To provide information and advice on other management considerations (e.g. area boundaries, by-catch 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 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" sections of 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 template provided on pages 34–36 of the 2014 May Plenary document, following the associated instructions on pages 34–39 (or, equivalently, pages 32–37 in the November 2014 Plenary).

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. 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 Principal Advisor Fisheries Science 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 a base case, (ii) the assessment is the first for a particular stock or the methodology has been substantially altered since the last assessment, and (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

Working Group chairs

17. The Ministry will select and appoint the Chairs for Working Groups. The Chair will be an MPI fisheries 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 focussing 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) and the criteria for peer review (pages 12–16) in the Standard;
    - requesting and documenting the affiliations of participants at each Working Group meeting that have the potential to be, or to be perceived to be, a conflict of interest of relevance to the research under review (refer to page 15 of the Research Standard). Chairs are responsible for managing conflicts of interest, and ensuring that fisheries management 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 decisions 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 Working Group reports and, where appropriate, in Status of Stock summary tables;

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[3] Link to the Research Standard: http://www.fish.govt.nz/en-nz/Publications/Research+and+Science+Information+Standard.htm

- 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 MPI Principal Advisor Fisheries Science, relevant MPI fisheries management staff, and other key stakeholders.

Working Group members

18. Working Groups will consist of the following participants:
    - MPI fisheries 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 analytical assessments to act in a peer review capacity;
    - representatives of relevant MPI fisheries management teams; and
    - any interested party who agrees to the standards of participation below.

19. Working Group participants must commit to:
    - participating appropriately in the discussion;
    - 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.

20. 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.

21. Working Group participants are expected to 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 reviewing the quality 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.

22. Participants in specific Working Groups will have access to the corresponding Science Working Group website and the Working Group papers and other information provided on the website. Although membership in Science Working Groups is open to a wide range of interested parties, access to Science Working Group websites will generally be restricted to those who have a

reasonable expectation of attending at least one meeting of a given Science Working Group each year.

23. Working Group members who do not adhere to the standards of participation (paragraph 19), or who use Working Group papers and related information inappropriately (see paragraph 25), 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.

Working Group papers and related information

24. Working Group papers will be posted on the MPI-Fisheries 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 many papers will be tabled 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 for written comments from Working Group members.

25. Working Group papers are "works in progress" whose role is to facilitate the discussion of 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 never 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.

26. From time to time, MPI commissions external reviews of particular 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

27. Meetings will take place as required, generally January–April and July–November for FAWGs and throughout the year for other Working Groups (AEWG, BRAG, Marine Amateur Fisheries and Antarctic Working Groups).

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

29. The Chair is responsible for deciding, with input from the entire Working Group, but focussing 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 Working Group reports;
- choice of base case 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.

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

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

32. A record of recommendations, conclusions and action items will be posted on the MPI-Fisheries website after each meeting has taken place.

33. Data upon which analyses presented to the Working Groups are based must be provided to MPI in the appropriate format and level of detail in a timely manner (i.e. the data must be available and accessible to MPI; however, data confidentiality concerns mean that such data are not necessarily available to Working Group members).

34. The outcome of each Working Group round will be evaluated, with a view to identifying opportunities to improve the Working Group process. The Terms of Reference may be updated as part of this review.

35. MPI fisheries scientists and science officers will provide administrative support to the Working Groups.

Information Quality Ranking

36. Science Working Groups are required to rank the quality of research and science information that is intended or likely to inform fisheries management 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 decisions 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 must 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

37. 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 Fishstock or species or environmental issue under the purview of the Working Group, for use in subsequent research planning processes.

Terms of Reference for the Aquatic Environment Working Group (AEWG) in 2015

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, aquaculture, and enhancement 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 of bottom fisheries on benthic biodiversity, species, and habitat;
- effects on biodiversity, including genetic diversity;
- changes to ecosystem structure and function from fishing, including trophic effects; and
- effects of aquaculture and fishery enhancement on the environment and on fishing.

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 assesses the effects of fishing or environmental status, and may evaluate the consequences of alternative future management scenarios. AEWG does not make management recommendations or decisions (this responsibility lies with MPI fisheries managers and the Minister responsible for Fisheries).

MPI 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 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.

Preparatory tasks

1. Prior to the beginning of AEWG meetings each year, MPI fisheries scientists will produce a list of issues for which new assessments or evaluations are likely to become available prior to the next scheduled sustainability round or decision process. AEWG Chairs 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, MPI-Fisheries or standards managers will alert MPI-Fisheries science managers and the Principal Advisor Fisheries Science, at least three months prior to the required AEWG meetings to other cases for which assessments or evaluations are urgently needed.

Technical objectives

3. To review any new research information on fisheries impacts, 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. For species, populations, habitats, or systems for which new assessments are not conducted in the current year, to review and update any existing Fisheries Assessment Plenary report text in order to determine whether the latest reported status summary is still relevant; else to revise the evaluations based on new data or analyses, or other relevant information.

Working Group input to annual Aquatic Environment and Biodiversity Review

10. To include in contributions to the Aquatic Environment and Biodiversity 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, by-catch 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 Principal Advisor Fisheries Science, about issues of particular importance that may require review by a plenary meeting or summarising in the AEBAR, and issues that are not believed to warrant such review. The general criterion for determining which issues should be discussed by a wider group or summarised 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.

Fisheries Assessment Working Groups: Membership 2014–15

Northern and Southern Inshore Working Group

Convenor: Marc Griffiths

Members: Mike Beentjes, Nokome Bentley, Richard Bian, Glen Carbines, Bill Chisholm, Ian Doonan, Alistair Dunn, Laura Furneaux, Malcolm Francis, Annie Galland, Mark Geytenbeek, Vivian Haist, Steve Halley, Bruce Hartill, Jeremy Helson, Ian Henderson, John Holdsworth, Rosie Hurst, Nicholas Jones, Terese Kendrick, Adam Langley, Pamela Mace, Dan MacGibbon, Graeme McGregor, Jeremy McKenzie, Alicia McKinnon, David Middleton, Richard O' Driscoll, Steve Parker, Darren Parsons, Nathan Reed, Pat Reid, Carol Scott, Paul Starr, Michael Stevenson, Kevin Sullivan, John Taunton-Clarke, Alison Undorf-Lay, Jenny Oliver, Adam von Opzeeland, Cameron Walsh.

Species:

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

Shellfish Working Group

Convenor: Julie Hills

Members: Ed Abraham, Jason Baker, Roger Belton Michelle Beritzhoff-Law, Erin Breen, Paul Breen, Mitch Campbell, Jeremy Cooper, Patrick Cordue, Martin Cryer, Alistair Dunn, Buz Faulkner, Jack Fenaughty, Rich Ford, Allen Frazer, Dan Fu, Vivian Haist, Mark Janis, Pamela Mace, Tom McCowan, Andrew McKenzie, Keith Michael, David Middleton, Reyn Naylor, Philip Neubauer, Matthew Pawley, Marine Pomarede, Darryn Shaw, Peter Sopp, Storm Stanley, Geoff Tingley, Ian Tuck, James Williams, John Willmer, Graeme Wright.

Species:

Cockles
Deepwater crab
Dredge oysters
Deepwater (king) clam (Geoduc)
Green-lipped mussel
King crab
Frilled venus shell
Knobbled whelk
Sea cucumber
Kina
Paddle crab
Paua
Pipi
Red crab
Queen scallops
Deepwater tuatua
Giant spider crab
Trough shell
Large trough shell
Triangle shell
Ringed dosinia
Fine (Silky) dosinia
Scallop
Scampi
Surf clam
Toheroa
Tuatua
Horse mussel

Deepwater Working Group

Convenors: Kevin Sullivan, Geoff Tingley

Members: Owen Anderson, John Annala, Neil Bagley, Sira Ballara, Michael Batson, Nokome Bentley, Michelle Beritzhoff-Law, Tiffany Bock, Malcolm Clark, George Clement, Patrick Cordue, Paul Crozier, Damian Diack, Ian Doonan, Adam Dunford, Alistair Dunn, Matt Dunn, Charlie Edwards, Jack Fenaughty, David Foster, Dan Fu, Annie Galland, Vivian Haist, Ian Hampton, Stuart Hanchet, Peter Horn, Rosie Hurst, Rudy Kloser, Yoann Ladroit, Kath Large, Pamela Mace, Dan MacGibbon, Vidette McGregor, Andy McKenzie, Adrian McNabb, Peter McMillan, David Middleton, Richard O'Driscoll, Graham Patchell, Vicky Reeve, Jim Roberts, Marie-Julie Roux, Tim Ryan, Andy Smith, Mike Soule, Paul Starr, Darren Stevens, Rob Tilney, 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: Mike Beentjes, Jacques Boubee, Bill Chisholm, Shannan Crow, Bruno David, Alistair Dunn, Allen Frazer, Tom Hollings, Mike Holmes, Mark James, John Jameson, Don Jellyman, Doug Jones, Mark Kuijten, Terry Lynch, Mike Martin, Duncan Petrie, Lan Pham, Michael Pingram, Garry Pullan, Hamish Quested, Taroi Rawiri, Tui Shortland, Travis Stull, Vic Thompson, Erina Watene-Rawiri, Dale Walters, Phillip Walters, David West, John Wilkie, Erica Williams, Kevin Wood.

Species: Freshwater eels

Stock Assessment Methods Working Group

Convenor: Pamela Mace

Members: Nokome Bentley, Michelle Beritzoff-Law, Tiffany Bock, Paul Breen, Patrick Cordue, Ian Doonan, Alistair Dunn, Matt Dunn, Charles Edwards, Chris Francis, Dan Fu, Marc Griffiths, Vivian Haist, Stuart Hanchet, Rosie Hurst, Adam Langley, Cath Large, Murdoch Macalister, Vidette McGregor, Andy McKenzie, David Middleton, Sophie Mormede, Vicky Reeve, Paul Starr, Kevin Stokes, Kevin Sullivan, Geoff Tingley, D'Arcy Webber.

Fisheries Data Working Group

Convenor: Kim George

Members: Edward Abrahams, Nokome Bentley, Alistair Dunn, David Fisher, Andrew France, Rosie Hurst, Pamela Mace, David Middleton, John Moriarty, Brian Sanders, Neville Smith, Paul Starr, Kevin Sullivan, Daryl Sykes, Finlay Thompson.

Aquatic Environment Working Group

Convenors: Rich Ford, Martin Cryer

Members: Blake Abernethy, Ed Abraham, Owen Anderson, Ian Angus, William Arlidge, Louise Askin, Karen Baird, Suze Baird, Barry Baker, Sira Ballara, Andrew Baxter, Brett Beamsley, Andrew Bell, Michelle Beritzhoff-Law, Katrin Berkenbusch, Tiffany Bock, Lesley Bolton-Ritchie, Laura Boren, Christine Bowden, Paul Breen, Stuart Brodie, Niall Broekhuizen, Bruno Brosnan, Martin Cawthorn, Alastair Childs, Steve Chiswell, David Clark, Malcolm Clark, Tom Clark, Rebecca Clarkson, Katie Clemens, Deanna Clement, Chris Cornelisen, Paul Crozier, Rohan Currey, Steve Dawson, Igor Debski, Ian Doonan, Matt Dunn, Adele Dutilloy, Charlie Edwards, Jack Fenaughty, Malcolm Francis, Charmaine Gallagher, Sarah Gardiner, Hilke Giles, Mark Gillard, Paul Gillespie, Neil Hartstein, Jeremy Helson, Judi Hewitt, Julie Hills, Deborah Hoffstra, Stephanie Hopkins, Rosie Hurst, Aaron Irving, Colin Johnston, Nigel Keeley, Dan Kluza, Ben Knight, Anna Kraack, Laws Lawson, Mary Livingston, Carolyn Lundquist, Dave Lundquist, Pamela Mace, Darryl MacKenzie, Lucy Manning, Rob Mattlin, Vidette McGregor, David Middleton, Rosemary Millar, Jodi Milne, Michael Neilsen, Tracey Osborne, Milena Palka, Matt Pinkerton, Irene Pohl, Marine Pomarede, Steve Pullan, Kris Ramm, Will Rayment, Vicky Reeve, Yvan Richard, Graham Rickard, Paul Sagar, Carol Scott, Liz Slooten, Tony Stafford, Kevin Stokes, Katrina Subedar, Alex Thompson, Findlay Thompson, Geoff Tingley, Di Tracey, Ian Tuck, Ben Tuckey, Nathan Walker, Bill Wallace, Barry Weeber, Richard Wells, John Wilmer, Hamish Wilson, John Wilson, Brent Wood.

Ministry for Primary Industries
Manatū Ahu Matua

MPI management teams and primary species managed

New Zealand Government

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
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*

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 the fishery 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 fishery, reasons) so that to get the best yield from a fishery 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 the fishery.

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***.

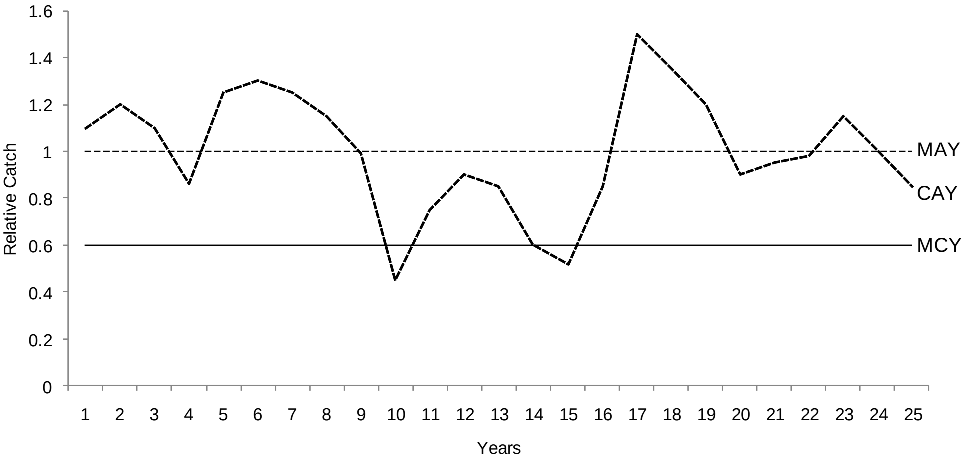

Figure 1: Relationship between *CAY, MCY* and *MAY*.

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) Maori 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 fishery is 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*** tones”.

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 $0.5MB_0$ (Gulland 1971). However various authors (including Beddington & Cooke 1983; Getz et al 1987; Mace 1988a) have shown that $0.5MB_0$ 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 $F_{0.1}B_0$ may be somewhat higher or somewhat lower than **0.25**. This depends primarily on the steepness of the assumed stock recruitment relationship (*see* Mace and 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 B_{AV} is the average historical recruited biomass, and the fishery is believed to have been fully exploited (i.e., fishing mortality has been near the level that would produce ***MAY***). This formulation assumes that $F_{0.1}$ approximates the average productivity of a stock.

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

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

$$MCY = 2/3MSY$$

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

$$MCY = 2/3CSP$$

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 c is the natural variability factor (defined above) and 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 ***MAY***), then the method should provide a good estimate of ***MCY***. In this case, $Y_{AV} = MAY$. If the population was under-exploited the method gives a conservative estimate of ***MCY***.

Familiarity with stock demographics and the history of the fishery is necessary for the determination of an appropriate period on which to base estimates of 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 ***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 ***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 ***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 the Ministry of Fisheries 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 ***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. ***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, ***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 ***CAY*** is given by

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

Where $\boldsymbol{B_{BEG}}$ is the projected stock biomass at the beginning of the fishing year for which the ***CAY*** is to be calculated and $\boldsymbol{F_{REF}}$ 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 $\boldsymbol{F_{REF}}$ 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: http://fs.fish.govt.nz/Page.aspx?pk=113&dk=23758.

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	2015
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_{2014} was estimated to be 50% B_0; Very Likely (> 90%) to be at or above the target
Status in relation to Limits	B_{2014} 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	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 (2005–2012) 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 (2011–12) 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: 2015	Next assessment: 2016
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.

Fishery Interactions
Main bycatch species are hake, ling, silver warehou and spiny dogfish, with lesser bycatches of ghost sharks, white warehou, sea perch and stargazers. Incidental interactions and associated mortalities are noted for New Zealand fur seals and seabirds. Low productivity species taken in the fishery include basking sharks and deepsea skates.

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 fishery 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 fishery status in relation to reference points.
3 – Qualitative Evaluation: A fishery characterisation with evaluation of fishery 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 fishery 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 Ministry will implement processes that rank the quality of research and science information used in support of fisheries management decisions. 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 Ministry’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 by-catch species, non-QMS by-catch 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.

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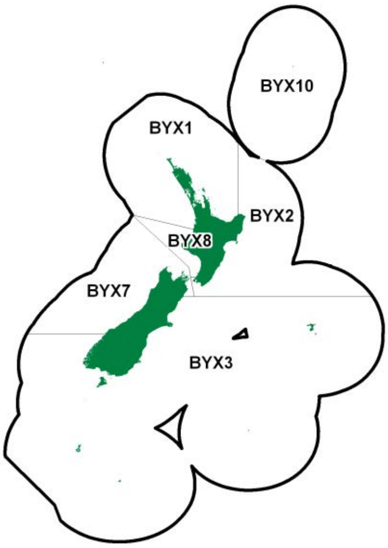
New Zealand Ministry of Fisheries (2011b) Operational Guidelines for New Zealand's Harvest Strategy Standard Revision 1. 78 p. Available at http://fs.fish.govt.nz/Doc/22847/Operational_Guidelines_for_HSS_rev_1_Jun_2011.pdf.ashx.

ALFONSINO (BYX)

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



1. FISHERY SUMMARY

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

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

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

The alfonsino fishery is essentially confined to BYX 2 & 3. Alfonsino has supported a major mid-water target trawl fishery off the lower 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 1, while Figure 1 shows the historical landings and TACC values for the main BYX stocks.

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.

Increasing volumes of alfonsino are taken as bycatch in the gemfish trawl fishery, which has exploited new grounds in QMA 2. Alfonsino is also taken as bycatch in the orange roughy and hoki fisheries in QMA 2.

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 under caught since then.

The TACC for BYX 2 was reduced from 1630 to 1274 t during the 1989–90 fishing year but has increased since then to 1575 t as a result of decisions by the Quota Appeal Authority. The TACC for BYX 2 was consistently overcaught by up to 300 t between 1992–93 and 2000–01, only in 2001–02 were the landings less than the TACC, and this was by only 1 t. The TACC in BYX 2 has been over-caught every year between 2002–03 and 2011–12 except two, the 2003–04 and 2007–08 fishing years.

The TACC for BYX 3 was increased for the 1987–88 fishing year from 220 t to 1000 t but annual landings remained low until 1993–94. Since 1995–96, landings have exceeded 900 t, reaching a peak of 1197 t in 2001–02 (187 t over the TAC). The 2002–03 catch of 1118 was also substantially larger than the 1010 t TACC. The marked increase in BYX 3 landings since 1994–95 (Table 2) is due mainly to the development of a target trawl fishery exploiting new grounds in BYX 3, and the discovery of new grounds south-east of the Chatham Islands (where a longline fishery for alfonsino, groper and ling has developed). Most of the BYX 3 catch is taken from the target bottom trawl fishery, operating on a complex of underwater features to the south-east of the Chatham Islands. The target fishery is comprised of a small number of vessels targeting alfonsino during the summer period. The remainder of the BYX 3 catch is taken as a small bycatch of the hoki, orange roughy, and hake target trawl fisheries. The target trawl fishery has an associated bycatch of bluenose (Langley & Walker 2002).

Fishing new grounds in BYX 7 resulted in increased catches in the mid 1990s and total landings of up to 77 t were recorded in 1996–97. However, landings have declined substantially since that time, fluctuating between 7 t and 32 t after 1999–2000.

Table 2: Reported domestic landings (t) of alfonsino by Fishstock from 1985–86 to 2013–14 and actual TACCs (t) from 1986–87 to 2013–14. 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
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

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
2011–12	45	300	1 603	1 575	1 037	1 010	14	81
2012–13	22	300	1605	1575	1013	1010	39	81
2013-14	29	300	1551	1575	930	1010	58	81

Table 2: Reported domestic landings (t) of alfonsino by Fishstock from 1985–86 to 2013–14 and actual TACCs (t) from 1986–87 to 2013–14. QMS data from 1986–present.

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

*FSU data.

‡ Excludes catches taken outside the New Zealand EEZ.

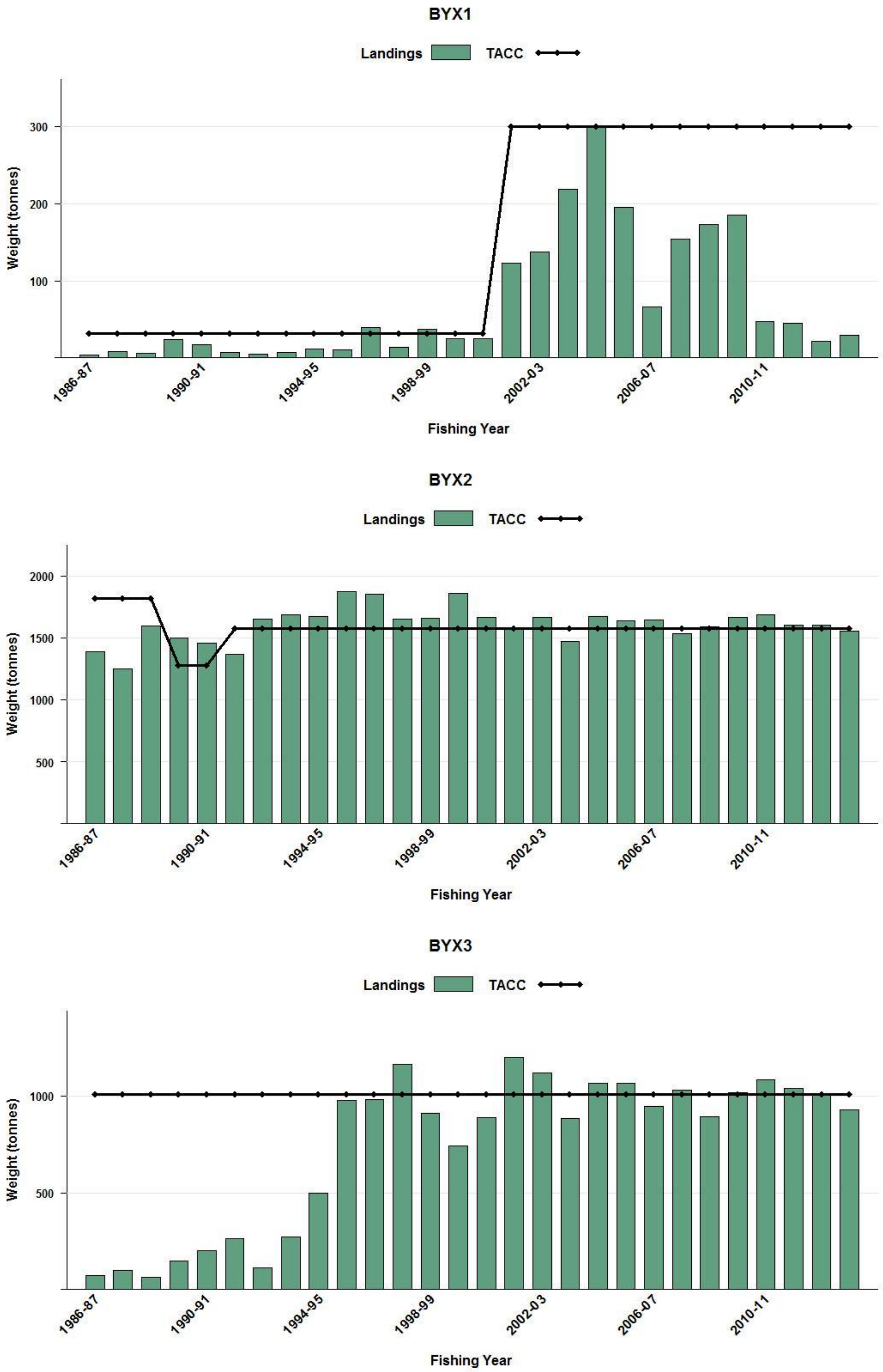


Figure 1: Reported commercial landings and TACC for the four main BYX stocks. Above: BYX 1 (Auckland) BYX 2 (Central East), BYX 3 (South East Coast, South East Chatham Rise, Sub Antarctic, Southland), Note that these figures do not show data prior to entry into the QMS. [Continued on next page].

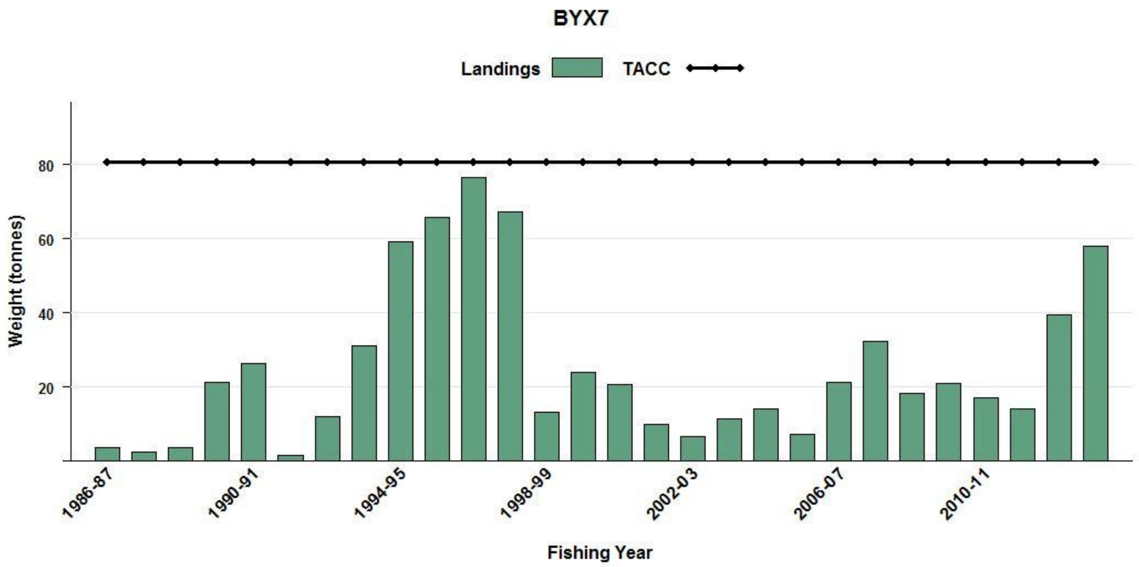


Figure 1 [Continued]: Reported commercial landings and TACC for the four main BYX stocks. BYX 7 (Challenger). Note that these figures do not show data prior to entry into the QMS.

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

Both species of *Beryx* occur throughout the world's tropical and temperate waters, in depths from 25 to 1200 m. 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. Red bream is taken mainly in BYX 1 but the biology of this species is poorly known. For the purposes of yield assessment, productivity parameters for alfonsino have been based on *B. splendens*. These species are primarily associated with undersea structures such as the seamounts that occur off the lower east coast of the North Island and on the Chatham Rise, in depths from 300–600 m.

Alfonsino have a maximum recorded age of 17 years and females grow faster than males. Pre-spawning alfonsino have been recorded in New Zealand waters but spawning grounds are unknown. Summer-autumn spawning activity has been noted in the North and South Atlantic and North Pacific Oceans. Juvenile alfonsino have been reported from near New Caledonia, associated with oceanic gyre systems. It is likely that the New Zealand stocks utilise similar pelagic water systems for reproduction and juvenile development. 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.
Estimates of *M* from catch curve analysis are not available due to the likelihood that age-specific migration precludes the sampling of the whole population. *M* was estimated using the equation *M* = log

$_e$100/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, *M* equalled 0.23.

Biological parameters relative to the stock assessment are shown in Table 3.

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)
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)

3. STOCKS AND AREAS

There are no new data which would alter the stock boundaries given in previous assessment documents. 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

There are no new data which would alter the yield estimates given in the 1996 Plenary Report. Yield estimates are based on commercial CPUE data.

4.1 Estimates of fishery parameters and abundance

i) BYX 1

BYX 1 is largely taken by bottom trawl (BT) (61%), with the remaining catch taken by mid-water trawl (MW) (25%) and bottom longline (BLL) (12%). The primary target species are alfonsino (81%) and cardinalfish (12%) for bottom trawl; alfonsino (55%), bluenose (21%) and rubyfish (21%) for mid-water trawl; and bluenose (95%) for bottom longline.

BT / MW trawl indices were not considered in 2010, and the BLL indices were updated using the same models as used in 2008. Standardised bottom longline CPUE series were considered by the AMP WG in 2010 to provide credible indices of abundance for BYX 1 in East Northland (EN) and Bay of Plenty (BoP), particularly after 2001–2. The two bluenose/hapuku/bass targeted BLL series show similar trends with both series increasing to peaks soon after introduction to the AMP (2002–03 for the BoP and 2003–04 in EN) then declining by 37% (BoP) to 2008–09 (Figure 2). The BoP index is considered to be more reliable as the fishery accounts for most of the longline catch and fishing has been more consistent. BLL is the least important method taking BYX 1 and there are questions regarding how representative these indices are of the BYX 1 stock, or of the size distribution of fish caught in the BT fishery. These CPUE indices are believed to be less reliable prior to 2001–02.

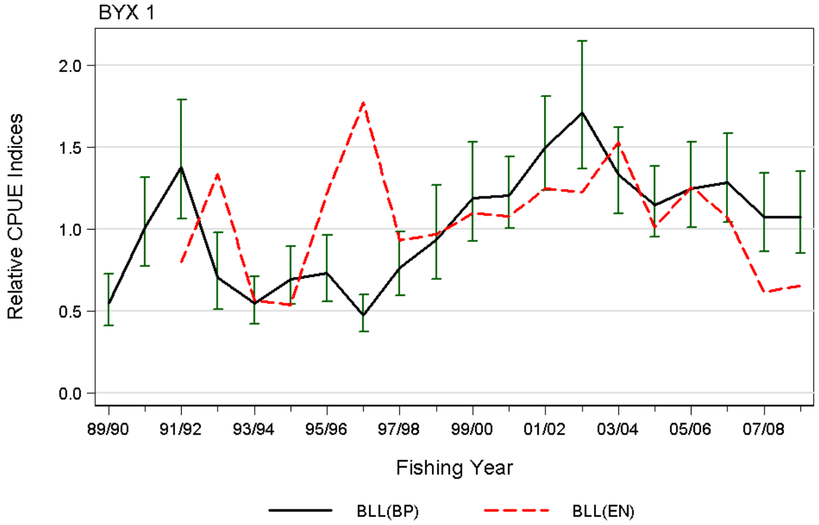


Figure 2: Comparison of the lognormal indices from the two bottom longline CPUE series for BYX 1: a) BLL[EN]: target bluenose/hapuku in East Northland; b) BLL[BP]: target bluenose/hapuku in Bay of Plenty. Each series is scaled so that the geometric mean = 1 (Starr et al 2010).

Given the very low catches prior to implementation of the AMP, the WG considered that the stock was lightly fished, and highly unlikely to have been below B_{MSY}, at the time of entry into the AMP. Noting that one index is currently at average levels, and the other about one-third below average levels, the WG considered that it was unlikely that the stock was below B_{MSY}, assuming that B_{MSY} is in the range of 30% to 50% of B_0. The WG noted that data being collected for this fishery are unlikely to ever be adequate to accurately determine stock status in relation to B_{MSY}.

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 (2002). 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

Biomass estimates are discussed in the section on estimation of MCY. Estimates of current biomass are not available.

4.3 Yield estimates and projections

Estimation of Maximum Constant Yield (*MCY*)

i) BYX 2
MCY was estimated at 1110–1200 t in 1991 using a stock reduction model based on an unstandardised CPUE index (Stocker & Blackwell 1991) and has not been updated. Subsequent CPUE analyses (Blackwell 2000) were not accepted as a measure of abundance for BXY 2 and as a result these estimates of yield may be unreliable.

These estimates of *MCY* have not changed since the 1991 Plenary Report.

The level of risk to the stock by harvesting the population at the estimated *MCY* value cannot be determined.

ii) Other areas
MCY cannot be determined.

Estimation of Current Annual Yield (*CAY*)
No estimates of current biomass are available for any stock and it is not possible to estimate *CAY*.

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 the two estimates of M (Table 3). $F_{0.1}$ 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 is 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 expected to increase in BYX 3 due to the discovery of new grounds. However, the potential for expansion may be constrained by the availability of BNS 3 quota to cover likely bluenose bycatch.

Yield estimates are summarised in Table 4.

Table 4: Yield estimates (t).

Parameter	Fishstock	Estimate
MCY	BYX 2	1 110–1 200
$F_{0.1}$ yield	BYX 2	1 320–1 800
CAY	All	Cannot be determined

5. STATUS OF THE STOCKS

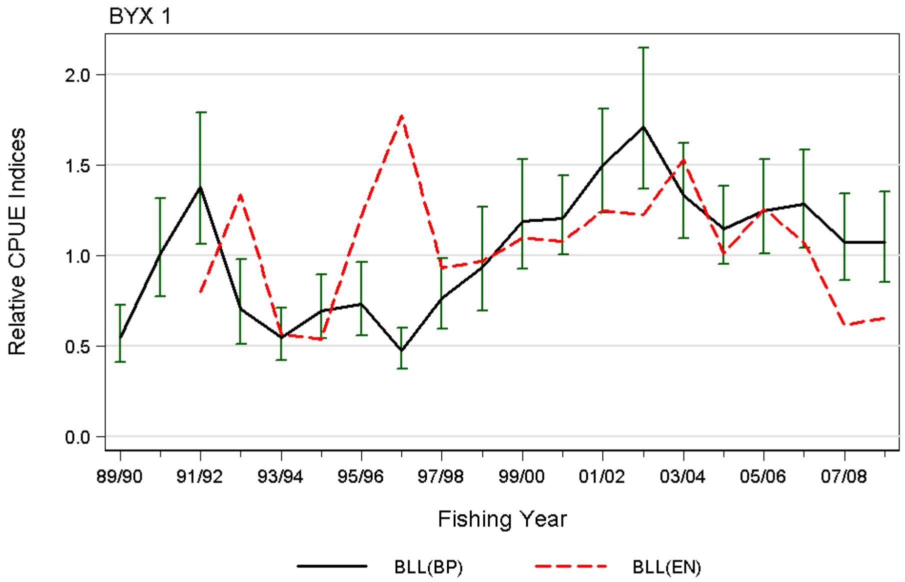
BYX 1

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. The BYX administrative fishstocks also consist of landings of more than one species (alfonsino *Beryx splendens* and red bream *B. decadactylus*). Information in this summary is provided for an assumed alfonsino Fishstock across FMA 1.

Stock Status	
Year of Most Recent Assessment	2010
Reference Points	Target: B_{MSY} Soft Limit: 20% B_0

	Hard Limit: 10% B_0
Status in relation to Target	Likely (> 60%) to be at or above B_{MSY}, assuming that B_{MSY} is in the range of 30–50% B_0
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below the Soft Limit Hard Limit: Very Unlikely (< 10%) to be below the Hard Limit

Historical Stock Status Trajectory and Current Status



Comparison of the lognormal indices from the two bottom longline CPUE series for BYX 1: a) BLL[EN]: target bluenose/hapuku in East Northland; b) BLL[BP]: target bluenose/hapuku in Bay of Plenty. Each series is scaled so that the geometric mean = 1.

Fishery and Stock Trends

Recent Trend in Biomass or Proxy	Standardised bottom longline (BLL) CPUE series were considered to provide credible indices of abundance for BYX 1 in East Northland and BoP, particularly after 2001–02. The two bluenose/hapuku/bass targeted BLL series show similar trends with both series increasing to peaks soon after introduction to the AMP (2002–03 for the BoP and 2003–04 in EN) then declining by 37% (BoP) to 2008–09. The BoP index is considered to be more reliable as the fishery accounts for most of the longline catch and fishing has been more consistent.

Projections and Prognosis

Stock Projections or Prognosis	Stock size is Likely (> 60%) to decline towards B_{MSY} under current catches and TACCs.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unlikely (< 40%)

Assessment Methodology

Assessment Type	Level 2: Standardised CPUE abundance index	
Assessment Method	Standardised CPUE indices	
Main data inputs	- catch and effort data derived from Ministry catch reporting - length frequency data summarised from logbooks compiled under the industry Adaptive Management Programme	
Period of Assessment	Latest assessment: 2010	Next assessment: 2014
Changes to Model Structure and Assumptions	Bottom/midwater trawl indices were not considered in 2010, and the BLL indices were updated using the same models as used in 2008.	
Major Sources of Uncertainty	BLL is the least important method taking BYX 1 and there are	

	questions regarding how representative these indices are of the BYX 1 stock, or of the size distribution of fish caught in the BT fishery. These CPUE indices are believed to be less reliable prior to 2001–02.
Qualifying Comments	
Catches have declined to below 50 tonnes since 2010 when this assessment of stock status was reported.	

Fishery Interactions
Bottom and mid water trawl fisheries that target bluenose, black cardinalfish and rubyfish also catch alfonsino. The bluenose target bottom longline fishery has alfonsino as a small bycatch.

BYX 2

Annual landings from 1986 to 2012–13 have remained reasonably stable at or above the level of the TACC. Catch at this level appears to be sustainable in the short to medium term.

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.

Yield estimates and reported landings are summarised in Table 5.

Table 5: Summary of yield estimates (t), TACCs (t) and reported landings (t) for alfonsino for the most recent fishing year.

					2013–14	2013–14
Fishstock		FMAs	*MCY*	$F_{0.1}$ yield	Actual TACC	Reported landings
BYX 1	Auckland (East) (West)	1 & 9	-	-	300	29
BYX 2	Central (East)	2	1 110–1 200	1 480–1 610	1 575	1 551
BYX 3	South-East (Coast) Southland & Sub-Antarctic	3, 4, 5, & 6		-	1 010	930
BYX 7	Challenger	7	-	-	81	58
BYX 8	Central (West)	8	-	-	20	< 1
BYX 10	Kermadec	10	-	-	10	0
Total					2 996	2 679

6. FOR FURTHER INFORMATION

Blackwell, R (2000) Alfonsino (*Beryx splendens*) abundance indices from standardised catch per unit effort (CPUE) analysis for the east coast North Island (BYX 2) midwater trawl fishery 1989–90 to 1997–98. *New Zealand Fisheries Assessment Report 2000/53*. 40 p.

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Langley, A D (1995) Analysis of commercial catch and effort data from the QMA 2 alfonsino-bluenose trawl fishery 1989–94. New Zealand Fisheries Assessment Research Document 1995/18. 12 p. (Unpublished document held by NIWA library, Wellington.)

Langley, A D; Walker, N (2002a) Characterisation of the alfonsino (*Beryx splendens*) fishery in BYX 3. *New Zealand Fisheries Assessment Report 2002/29*. 49 p.

Langley, A D; Walker, N (2002b) CPUE analysis of the target BYX 3 alfonsino fishery and associated bluenose catch. *New Zealand Fisheries Assessment Report 2002/24*. 45 p.

Massey, B R; Horn, P L (1990) Growth and age structure of alfonsino (*Beryx splendens*) from the lower east coast, North Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research 24*: 121–136.

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Seafood Industry Council (SeaFIC) (2003) BYX 1 performance report to the 2003 Adaptive Management Programme Working Group.

Seafood Industry Council (SeaFIC) (2004) Report to the Adaptive Management Fishery Assessment Working Group: Performance of the BYX 1 Adaptive Management Programme. AMP-WG-2004/06. (Unpublished report held by the Ministry for Primary Industries.)

Seafood Industry Council (SeaFIC) (2005) Report to the Adaptive Management Fishery Assessment Working Group: Performance of the BYX 1 Logbook Programme. AMP-WG-2005/05. (Unpublished report held by the Ministry for Primary Industries.)

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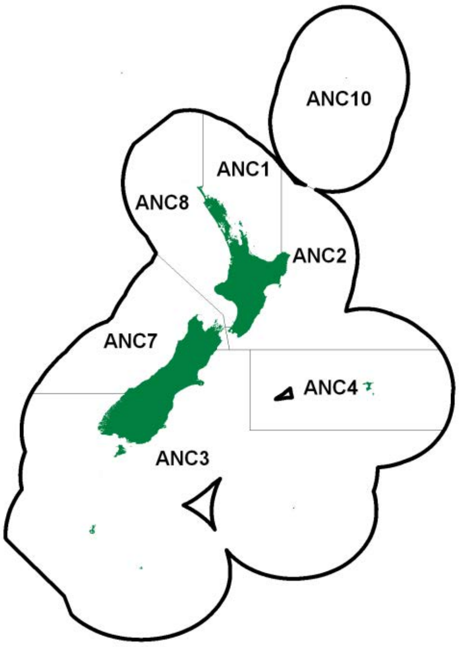
Starr, P J; Kendrick, T H; Lydon, G J (2006) 2006 Report to the Adaptive Management Programme Fishery Assessment Working Group: Full Term Review of the BNS 1 Adaptive Management Programme. AMP-WG-2006/03. 59 p. (Unpublished report available from Seafood New Zealand, Wellington.)

Stocker, M; Blackwell, R (1991) Biomass and yield estimates for alfonsino in BYX 2 for the 1991–92 fishing year. New Zealand Fisheries Assessment Research Document 1991/12. 12 p. (Unpublished document held in NIWA library, Wellington.)

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 and 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 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 2013–14 (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

† 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 2013–14 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	2013–14 Actual TACC	2013–14 Reported landings
ANC 1	Auckland (East)	1	200	2
ANC 2	Central (East)	2	100	0
ANC 3	South-east (Coast), Southland & sub-Antarctic	3, 5 & 6	50	< 1
ANC 4	South-east (Chatham)	4	10	0
ANC 7	Challenger	7	100	< 1
ANC 8	Central (West), Auckland (West)	8 & 9	100	< 1
ANC 10	Kermadec	10	0	0
Total			560	2

6. FOR FURTHER INFORMATION

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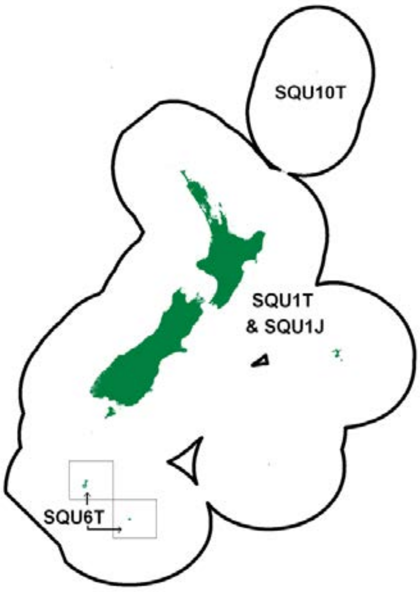
ARROW SQUID (SQU)

(*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 in 1983 to around 15 in 1994. The jig catch in SQU 1J declined from 53 872 t in 1988–89 to 4865 t in 1992–93 but increased significantly to over 30 000 t in 1994–95, before declining to just over 9000 t in 1997–98. The jig catch declined to low levels for the next four years but then increased back up to almost 9000 t in 2004–05, before declining again to 891 t in 2009–10. The 2010–11 and 2011–12 fishing years have seen an increase from this eight year low to 1811 t.

From 1987 to 1998 the trawl catch 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.
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 cost), 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. Note that the TACC automatically reverts to the original value at the end of the fishing year.

Table 1: Reported catches (t) and TACCs (t) of arrow squid from 1986–87 to 2013–14. 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	7483	44 741	7 403	32 369	0	10	15 053	127 332

* 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

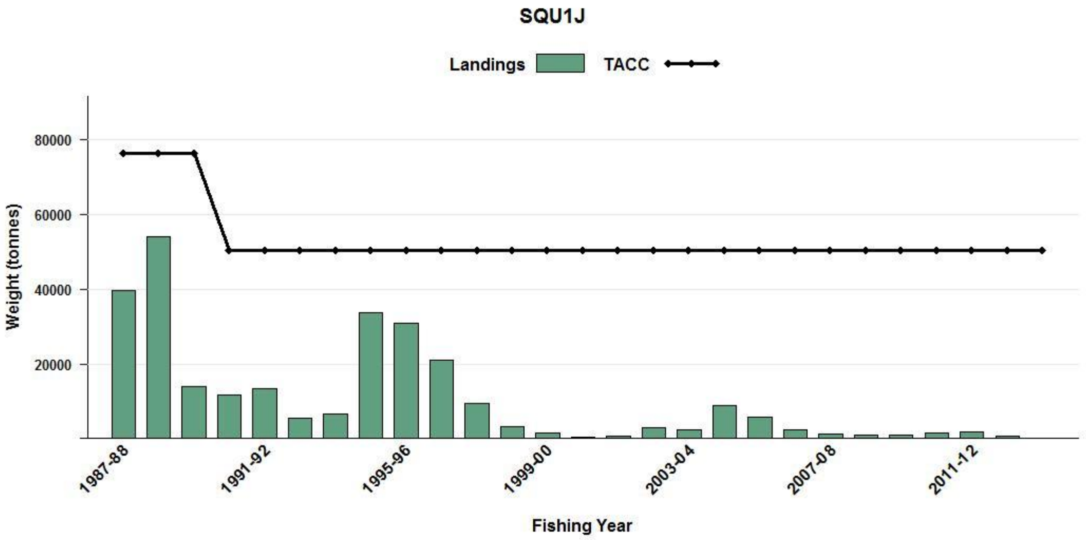
There is no quantitative information available on the level of illegal catch.

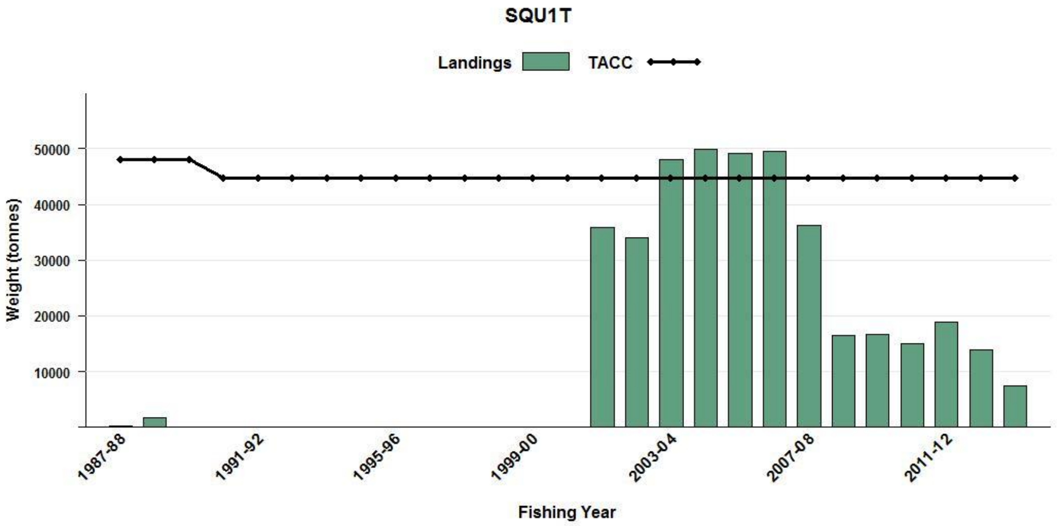
1.5 Other sources of mortality

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.





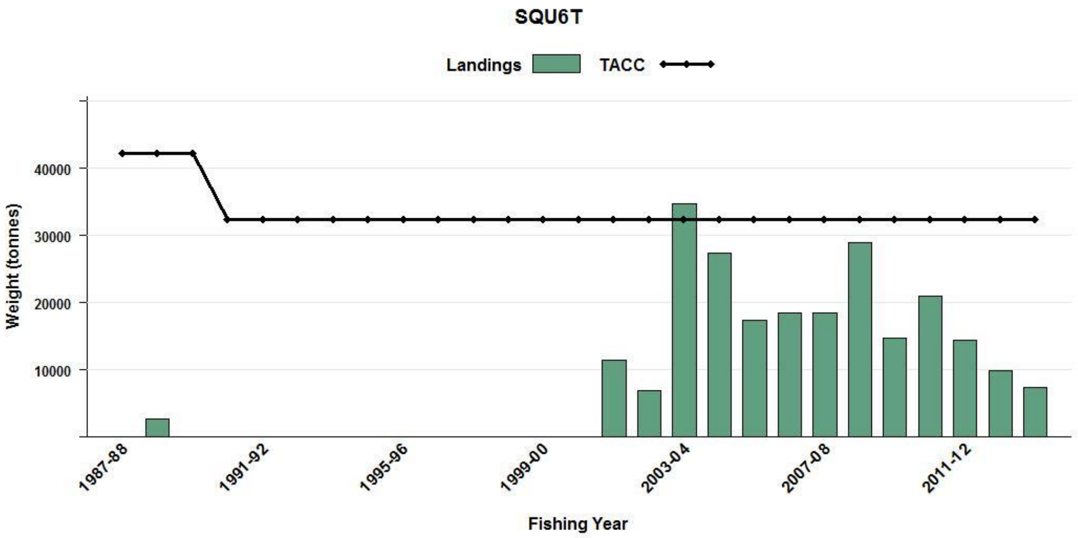


Figure 1: Reported commercial landings and TACC for the three main SQU stocks. Top to bottom: SQU 1J (All Waters Except 10T and 6T, Jigging), SQU 1T (All Waters Except 10T and 6T, All Other Methods) and SQU 6T (Southern Islands, All Methods). Note that these figures do not show data prior to entry into the QMS.

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	$L\infty$	
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, though 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

This section was last reviewed by the Aquatic Environment Working Group for the May 2012 Fishery Assessment Plenary. Tables were updated and minor corrections to the text were made for the May 2013 Fishery Assessment Plenary. This summary is from the perspective of the squid trawl fishery; a more detailed summary from an issue by issue perspective is available in the Aquatic Environment & Biodiversity Annual Review (www.mpi.govt.nz/Default.aspx?TabId=126&id=1644).

4.1 Role in the ecosystem

Arrow squid are short-lived and 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 NZ 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 Incidental catch (fish and invertebrates)

Based on models using observer and fisher-reported data, total bycatch in the arrow squid trawl fishery ranged from 4500 to 25 000 t per year between 1991 and 2010–11 (Anderson 2013). Over that time period arrow squid comprised about 80% of the total estimated catch recorded by observers in this fishery (Figure 2). The remainder of the observed catch comprised mainly the commercial fish species barracouta (8.5%), spiny dogfish (1.7%), and jack mackerel (1.1%). Invertebrate species made up a much smaller fraction of the bycatch overall (about 1%), but crabs (0.8%), especially the smooth red swimming crab (*Nectocarcinus bennetti*, 0.5%), were frequently caught.

Estimated total annual discards ranged from just over 200 t in 1995–96 to about 5500 in 2001–02 and, like bycatch, peaked in the early 1990s and were at relatively low levels after 2006–07 (Anderson 2013). Most discards were QMS species (about 62% over all years), followed by non-QMS species (19%), invertebrate species (11%), and arrow squid (7%). Absolute levels of discards increased in all categories over the 21-year period; this increase was strongly significant for non-QMS species and total discards, and also marginally significant for QMS species and invertebrates. The species discarded in the greatest amounts were spiny dogfish, redbait, rattails, and silver dory. Discards peaked at 0.13 kg of discarded fish for every 1 kg of arrow squid caught in the early 1990s and declined to 0.02–0.07 kg after 2002–03.

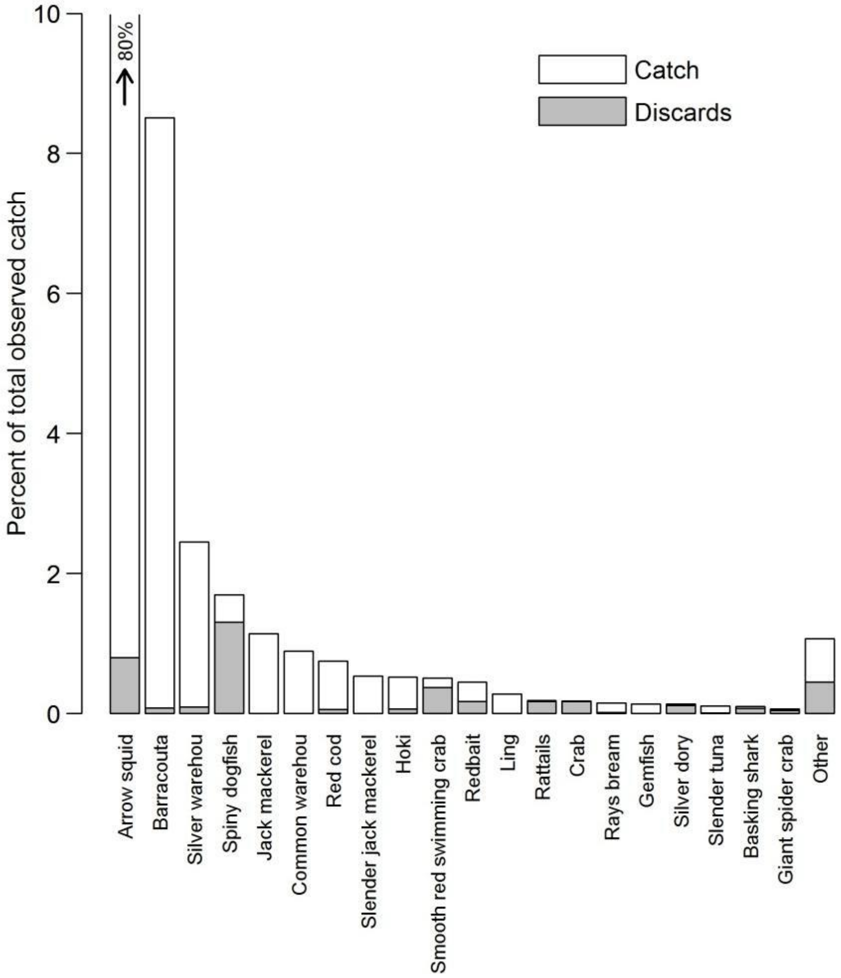


Figure 2: Percentage of the total catch contributed by the main bycatch species (those representing 0.05% or more of the total catch) in the observed portion of the arrow squid fishery, and the percentage discarded. The Other category is the sum of all bycatch species representing less than 0.05% of the total catch (Anderson 2013).

4.3 Incidental catch (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 NZ sea lion interactions

The New Zealand (or Hooker's) sea lion was classified in 2008 as "Vulnerable" by the International Union for Conservation of Nature (IUCN) and in 2010 as "Nationally Critical" under the NZ Threat Classification System (Baker et al 2010). Pup production at the main Auckland Island rookeries shows a steady decline since the late 1990s.

NZ sea lions are sometimes caught by vessels trawling for arrow squid (Smith & Baird 2005a, 2007a & b, Thompson & Abraham 2010a, Abraham & Thompson 2011). The trend in observed and estimated captures is downwards. Until recently, captures occurred most frequently in the SQU 6T fishery around the Auckland Islands, and a limit on the number of fishery-related mortalities in this fishery has been set since 1992 (Table 3). These limits have been determined using various approaches, but the current approach is to limit the number of sea lions estimated to have been captured using control rules calculated using the number of pups born in the previous two years. Estimated captures for a year are calculated from the estimated strike rate per tow and the number of tows. The average length of tows has increased substantially over the past decade, but this should be incorporated in the estimated strike rate per tow, albeit with high uncertainty. The likely performance of candidate control rules has been tested using an integrated population and fishery model (Breen et al 2010). Candidate rules are assessed against management criteria developed and agreed in 2003 by a Technical Working Group comprising

Ministry of Fisheries, DOC, NIWA, squid industry representatives, and environmental groups (details can be found in the Aquatic Environment and Biodiversity Annual Review 2012).

Sea Lion Exclusion Devices (SLEDs) were introduced into the SQU 6T fishery in 2001–02 and were in widespread use by 2004–05 leading to a sharp drop in observed incidental captures (Table 4). SLEDs are designed to allow sea lions to escape from a trawl and consist of a grid of steel bars that prevents sea lions entering the codend and an escape hole. From their introduction, SLEDs were subject to continuous design improvements for 10–15 years and, since 2007, a standard Mark 3/13 version has been used by all vessels in the SQU 6T fishery. Tows undertaken using an approved SLED receive a discount on the pre-determined sea lion strike rate, based on the assumption that some sea lions that encounter a trawl equipped with a SLED that would have drowned in the absence of a SLED will survive. This discount was originally set at 20%, was increased to 35% in 2007–08, and further increased to 82% in August 2012. The recent increase in discount rate was made to acknowledge recent research indicating that a high proportion of sea lions encountering a SLED are likely to survive the encounter (summarised in Abraham 2011). There is some remaining uncertainty, including the unknown probability that a sea lion that enters a net but is not subsequently captured will exceed its breath holding limit and die after exiting the trawl via the SLED or the front of the net. This uncertainty is discussed in the 2012 Aquatic Environment and Biodiversity Annual Review (MPI 2012).

Smaller numbers of NZ sea lions are captured in the squid trawl fishery on the Stewart-Snares shelf (SQU 1T, Table 5). Formal estimates of total captures in this fishery have not been calculated but captures across all trawl fisheries on the Stewart-Snares shelf were estimated by Thompson & Abraham (2010a) to vary from 3 to 9 sea lions each year.

Table 3: Fisheries-related mortality limit (FRML) from 1991 to 2012 (♀ = 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%	

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 Thompson et al (2013) and available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Data for 1995–96 to 2001–02 and all estimated strike rates data are from Thompson at al 2013). Data for 2002–03 to 2011–12 are based on data version 20130304 and provisional data for 2012–13 are based on data version 20140131.

			Obs. captures		Est. captures		Est. interactions		Est. strike rate	
Year	Tows	% obs.	No.	Rate	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
1995–96	4 467	12	13	2.4	131	69–226	131	67–244	2.9	1.6–5.0
1996–97	3 716	19	28	3.9	142	91–208	142	89–210	3.8	2.6–5.5
1997–98	1 441	22	13	4.2	60	33–102	60	31–104	4.2	2.5–6.9
1998–99	402	38	5	3.2	14	7–27	15	5–29	3.6	2.1–5.9
1999–00	1 206	36	25	5.7	69	45–107	69	41–108	5.8	4.0–8.6
2000–01	583	99	39	6.7	39	39–40	61	39–87	10.4	8.6–13.1
2001–02*	1 648	34	21	3.7	43	30–64	73	43–116	4.4	3.0–6.6
2002–03	1 466	28	11	2.6	19	13–28	46	24–77	3.2	2.0–5.1
2003–04	2 594	31	16	2.0	40	26–60	200	98–370	7.5	4.0–13.5
2004–05^	2 693	30	9	1.1	31	17–53	165	73–320	5.9	2.7–11.1
2005–06	2 459	22	10	1.8	27	15–45	149	63–309	6.0	2.7–12.5
2006–07	1 317	41	7	1.3	16	9–26	89	28–200	6.6	2.3–14.8
2007–08	1 265	47	5	0.9	12	6–21	116	21–489	8.0	1.6–30.9
2008–09	1 925	40	2	0.3	7	3–16	97	12–441	4.6	0.7–18.4
2009–10	1 188	26	3	1.0	13	5–26	124	19–508	9.0	1.7–33.6
2010–11	1 583	34	0	0.0	4	0–11	60	4–278	3.5	0.4–14.9
2011–12	1 281	45	0	0.0	2	0–7	43	2–206	-	-
2012–13†	1 027	86	3	0.3	-	-	-	-	-	-

* SLEDs were introduced. ^ SLEDs were standardised and in widespread use. † Provisional data, no model estimates available.

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 2011–12. 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 Thompson et al (2013) and available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Data for 2002–03 to 2011–12 are based on data version 20130304 and provisional data for 2012–13 are based on data version 20140131.

		Fishing effort		Observed captures		Estimated interactions		
	Tows	No. obs	% obs	Captures	Rate	Mean	95% c.i.	% included
2002–03	3 281	506	15.4	0	0.00	2	0–5	100.0
2003–04	4 534	957	21.1	1	0.10	3	1–7	100.0
2004–05	5 861	1 581	27.0	3	0.19	6	3–11	100.0
2005–06	4 481	537	12.0	1	0.19	4	1–8	100.0
2006–07	2 925	706	24.1	1	0.14	2	1–5	100.0
2007–08	2 412	864	35.8	0	0.00	1	0–3	100.0
2008–09	1 809	531	29.4	0	0.00	1	0–3	100.0
2009–10	2 259	764	33.8	1	0.13	2	1–4	100.0
2010–11	2 177	685	31.5	0	0.00	1	0–3	100.0
2011–12	1 983	800	40.3	0	0.00	1	0-2	100.0
2012–13†	1 529	1 343	87.8	0	0.00	0	0-1	100.0

† Provisional data, no model estimates available.

4.3.2 NZ 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 NZ Threat Classification System.

Vessels targeting arrow squid incidentally catch fur seals (Baird & Smith 2007a, Smith & Baird 2009, Thompson & Abraham 2010b, Baird 2011), mostly off the east coast South Island, on the Stewart-

Snares shelf, and close to the Auckland Islands. In the 2012–13 fishing year there were six observed captures of New Zealand fur seal in squid trawl fisheries. In the 2011–12 fishing year, there were 25 (95% c.i.: 12–53) estimated captures, with the estimates made using a statistical model (Thompson et al 2013, Table 6). Total estimated captures in squid trawl fisheries varied from 21 to 168 between 2002–03 and 2011–12, representing about 9% of the total estimated captures in trawl fisheries over those years (noting that less than 50% of all trawl effort is included in the estimates, except for the most recent year). The rate of capture over this period varied from 0.08 to 0.96 captures per hundred tows without obvious trend (Table 6), a rate that is about 40% of the rate for all trawl

Table 6: Number of tows by fishing year and observed and model-estimated total NZ fur seal captures in squid trawl fisheries, 2002–03 to 2012–13. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows, % inc, percentage of total effort included in the statistical model. Estimates are based on methods described in Thompson et al (2013) and available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Data for 2002–03 to 2011–12 are based on data version 20130304 and provisional data for 2012–13 are based on data version 20140131

		Observed				Estimated		
	Tows	No. obs	% obs	Captures	Rate	Captures	95% c.i.	% inc.
2002–03	8 410	1 308	15.6	8	0.61	56	27 – 108	100.0
2003–04	8 336	1 771	21.2	17	0.96	89	46 – 166	100.0
2004–05	10 486	2 511	23.9	16	0.64	155	82 – 284	100.0
2005–06	8 575	1 103	12.9	4	0.36	96	43 – 192	100.0
2006–07	5 906	1 289	21.8	8	0.62	42	20 – 83	100.0
2007–08	4 236	1 457	34.4	6	0.41	33	14 – 67	100.0
2008–09	3 867	1 298	33.6	1	0.08	19	6 – 45	100.0
2009–10	3 789	1 070	28.2	8	0.75	33	15– 66	100.0
2010–11	4 214	1.261	29.9	8	0.63	23	12 – 42	100.0
2011–12	3 505	1 380	39.4	8	0.58	23	11 – 48	100.0
2012-13	2 646	2 273	85.9	6	0.26	8	6– 17	-

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.

In the 2012–13 fishing year there were 450 observed captures of birds in squid trawl fisheries. In the 2011–12 fishing year, there were 327 (95% c.i.: 261–422) estimated captures, with the estimates made using a statistical model (Table 7).

Table 7: Number of tows by fishing year and observed and model-estimated total bird captures in squid trawl fisheries, 2002–03 to 2011–12. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows, % inc, percentage of total effort included in the statistical model. Estimates are based on methods described in Abraham et al (2013) and are available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Estimates from 2002–03 to 2010–11 are based on data version 20120531 and preliminary estimates for 2011–12 are based on data version 20130304.

		Observed				Estimated		
	Tows	No. obs	% obs	Captures	Rate	Captures	95% c.i.	% inc.
2002–03	8 410	1 308	15.6	159	12.16	929	761 – 1 227	100.0
2003–04	8 336	1 771	21.2	204	11.52	857	717 – 1027	100.0
2004–05	10 486	2 511	23.9	384	15.29	1 442	1 236 – 1 710	100.0
2005–06	8 575	1 103	12.9	200	18.13	1 203	947 – 1 568	100.0
2006–07	5 906	1 289	21.8	127	9.85	573	440 – 767	100.0
2007–08	4 236	1 457	34.4	162	11.12	540	425 – 705	100.0
2008–09	3 867	1 298	33.6	259	19.95	624	523 – 764	100.0
2009–10	3 789	1 070	28.2	92	8.60	401	311 – 521	100.0
2010–11	4 214	1 261	29.9	141	11.18	600	468 – 779	100.0
2011–12	3 505	1 380	39.4	106	7.68	344	277 – 438	100.0
2012–13†	2 646	2 273	85.9	450	19.78	505	477 – 553	100.0

† Provisional data, no model estimates available

Total estimated seabird captures in squid trawl fisheries varied from 327 to 1397 between 2002–03 and 2011–12 at a rate of 8.6 to 20.0 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 ten years is about 13.79 birds per 100 tows, a high rate relative to trawl fisheries for scampi (5.57 birds per 100 tows) and hoki (2.16 birds per 100 tows) over the same years. The squid fishery accounted for about 58% of seabird captures in the trawl fisheries modelled by Abraham et al (2013).

Observed seabird captures since 2002–03 have been dominated by four species: white-capped and southern Buller's albatrosses make up 85% and 9% of the albatrosses captured, respectively; and white-chinned petrels and sooty shearwaters make up 48% and 45% of other birds, respectively, the total and fishery risk ratios presented in Table 8. Most captures occur on the Stewart-Snares shelf (60%) or close to the Auckland Islands (37%). 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 SLL fisheries (grouped by vessel size) and all fisheries included in the level two risk assessment, 2002–03 to 2011–12, showing seabird species with a risk ratio of at least 0.001 of PBR$_1$. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Potential Biological Removals, PBR$_1$ (from Richard and Abraham 2013 where full details of the risk assessment approach can be found). PBR$_1$ applies a recovery factor of 1.0. Typically a recovery factor of 0.1 to 0.5 is applied (based on the state of the population) to allow for recovery from low population sizes as quickly as possible. This should be considered when interpreting these results. The DOC threat classifications are shown (Robertson et al 2013 at http://www.doc.govt.nz/documents/science-and-technical/nztcs4entire.pdf).

		Risk ratio			
Species name	**PBR$_1$ (mean)**	**Squid target trawl**	**TOTAL**	**Risk category**	**DoC Threat Classification**
Salvin's albatross	975	0.035	2.756	Very high	Threatened: Nationally Critical
Flesh-footed shearwater	590	0.001	1.321	Very high	Threatened: Nationally Vulnerable
Southern Buller's albatross	513	0.292	1.292	Very high	At Risk: Naturally Uncommon
Chatham Island albatross	159	0.004	1.291	Very high	At Risk: Naturally Uncommon
NZ white-capped albatross	4 044	0.229	0.700	Very high	At Risk: Naturally Uncommon
Northern Buller's albatross	617	0.002	0.678	High	At Risk: Naturally Uncommon

Table 8 [Continued]

Species name	PBR_1 (mean)	Risk ratio Squid target trawl	 TOTAL	Risk category	DoC Threat Classification
Gibson's albatross	260	0.018	0.467	High	Threatened: Nationally Critical
Cape petrel	840	0.007	0.303	High	At Risk: Naturally Uncommon
Antipodean albatross	295	0.005	0.301	High	Threatened: Nationally Critical
Northern royal albatross	396	0.011	0.271	Medium	At Risk: Naturally Uncommon
Southern royal albatross	441	0.012	0.264	Medium	At Risk: Naturally Uncommon
Westland petrel	241	0.003	0.263	Medium	At Risk: Naturally Uncommon
Northern giant petrel	217	0.008	0.215	Medium	At Risk: Naturally Uncommon
White-chinned petrel	7 925	0.066	0.211	Medium	At Risk: Declining
Campbell black-browed albatross	1 017	0.002	0.189	Medium	At Risk: Naturally Uncommon
Grey petrel	2 172	0.001	0.114	Medium	At Risk: Naturally Uncommon
Light-mantled sooty albatross	237	0.002	0.028	Low	At Risk: Declining
Grey-headed albatross	333	0.001	0.018	Low	Threatened: Nationally Vulnerable
Sooty shearwater	348 096	0.002	0.005	Low	At Risk: Declining

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).

In the four complete fishing years after mitigation was made mandatory, the average rate of capture for white-capped albatross (90% of albatross captures in this fishery) was 3.2 birds per 100 tows compared with 7.9 per 100 tows in the three complete years before mitigation was made mandatory. This trend is masked in Table 7 by continued captures of smaller birds, mostly in trawl nets as opposed to on trawl warps (where mitigation is focused).

4.4 Benthic interactions

Between 1989–90 and 2004–05, 131 973 trawl tows for squid on or within 1 m of the seabed were reported, comprising 13.7% of all trawl tows on or within 1 m of the seabed reported on TCEPR forms in those years (range 8–23% by year, Baird et al 2011). Black et al (2013) estimated that hoki arrow squid has accounted for 13.5% of all tows reported on TCEPR forms since 1989–90. Between 2006–07 and 2010–11, 95% of arrow squid catch was reported on TCEPR forms. The great majority of tows are conducted on the Stewart-Snares shelf or north and east of the Auckland Islands, with smaller numbers off the east coast of the South Island and the Chatham Rise. Tows were located in Benthic Optimised Marine Environment Classification (BOMEC, Leathwick et al 2009) classes E (outer shelf), F, H (upper slope), I, J, L, and M (mid-slope) (Baird & Wood 2012), and 92% were between 100 and 300 m depth (Baird et al 2011). Tables 4–7 show that the number of trawl tows for squid varies between years, largely without trend and presumably in response to variations in the abundance of squid and management measures to limit the number of sea lions caught. The average duration of trawls has increased over this time so the trend in aggregate swept area will not be the same.

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 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 2012 Aquatic Environment and Biodiversity Annual Review.

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 2013–14 fishing year are summarised in Table 9.

Table 9: Summary of TACCs (t) and reported landings (t) of arrow squid for the most recent fishing year.

Fishstock	2013–14 Actual TACC	2013–14 Reported landings
SQU 1J	50 212	167
SQU 1T	44 741	7 483
SQU 6T	32 369	7 403
SQU 10T	10	0
Total	127 332	15 503

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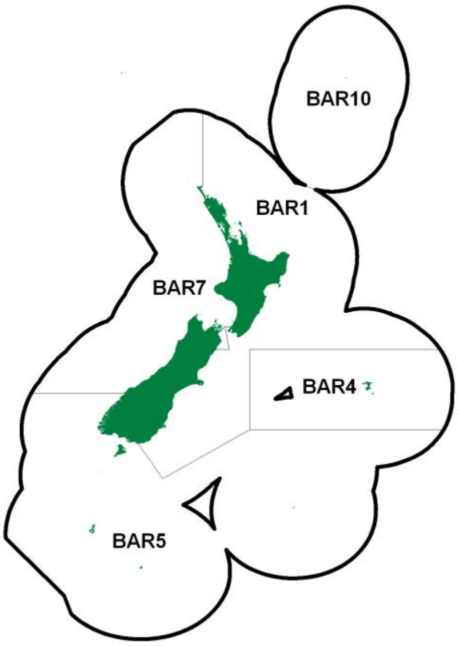
BARRACOUTA (BAR)

(*Thyrsites atun*)
Manga, maka



1. FISHERY SUMMARY

1.1 Commercial fisheries

Barracouta are caught in coastal waters around mainland New Zealand, The Snares and Chatham Islands, down to about 400 m and have been managed under the Quota Management System since 1 October 1986. Catches by New Zealand vessels increased significantly in the late 1960s and total annual catch peaked at about 47 000 t in 1977, with the addition of foreign vessels around New Zealand. Between 1983–84 and 2013–14, catches fluctuated between 18 000 and 29 000 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) 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 and on the east coast of the South Island. Barracouta also comprise a significant proportion of the bycatch in the west coast North Island jack mackerel and The Snares squid fisheries. Catches have increased in recent years in BAR 1 to the level of the TAC, but have dropped in BAR 4 in the last three years. The TACC in BAR 5 was reduced from 9282 t to 7470 t on 1 October 1998 with a 2 t customary and 3 t recreational allocation and a TAC of 7475 t. Recent catches have fluctuated about the new TAC in this fishery. In BAR 7 the catch limit was exceeded from 2004–05 to 2006–07 (catches nearly reached 15 000 t in 2006–07), but catch has decreased since, to well below the TAC.

Table 2: 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 3: Reported landings (t) of barracouta by Fishstock from 1983–84 to 2012–13 and actual TACCs (t) from 1986–87 to 2013–14. QMS data from 1986-present.

Fishstock		BAR 1		BAR 4		BAR 5		BAR 7
FMAs		1, 2, 3		4		5 & 6		7, 8, 9
	Landings	TACC	Landings	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

Table 3 [continued]

Fishstock		BAR 1		BAR 4		BAR 5		BAR 7
FMAs		1, 2, 3		4		5 & 6		7, 8, 9
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
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 4832	3 019	6 886	7 470	6 637	11 173

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	0	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

* FSU data.

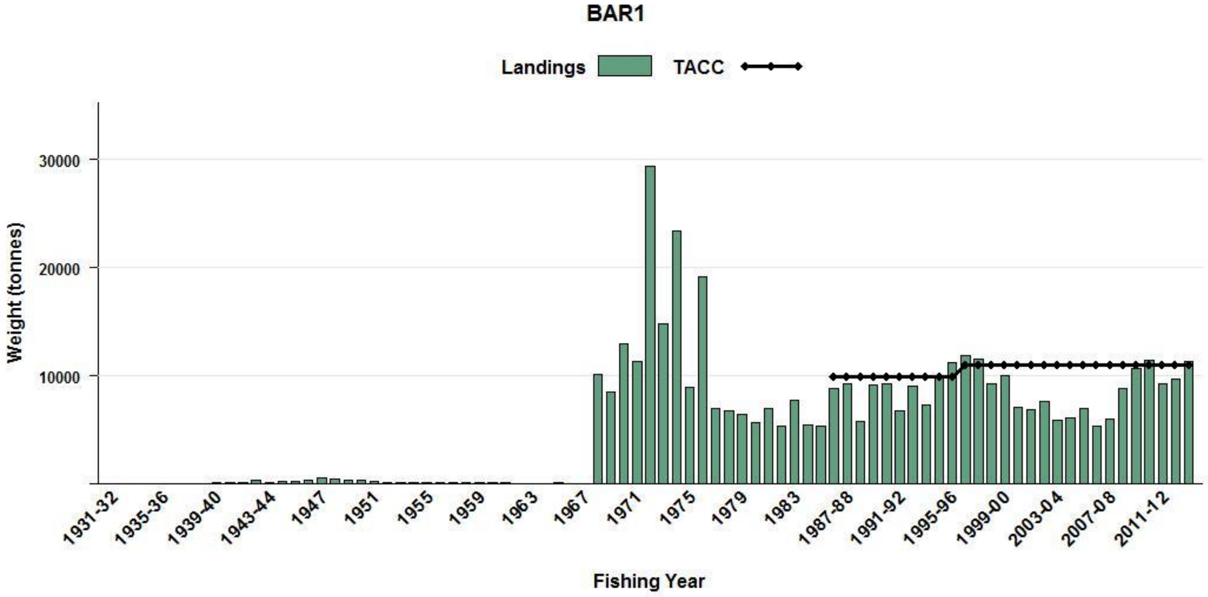
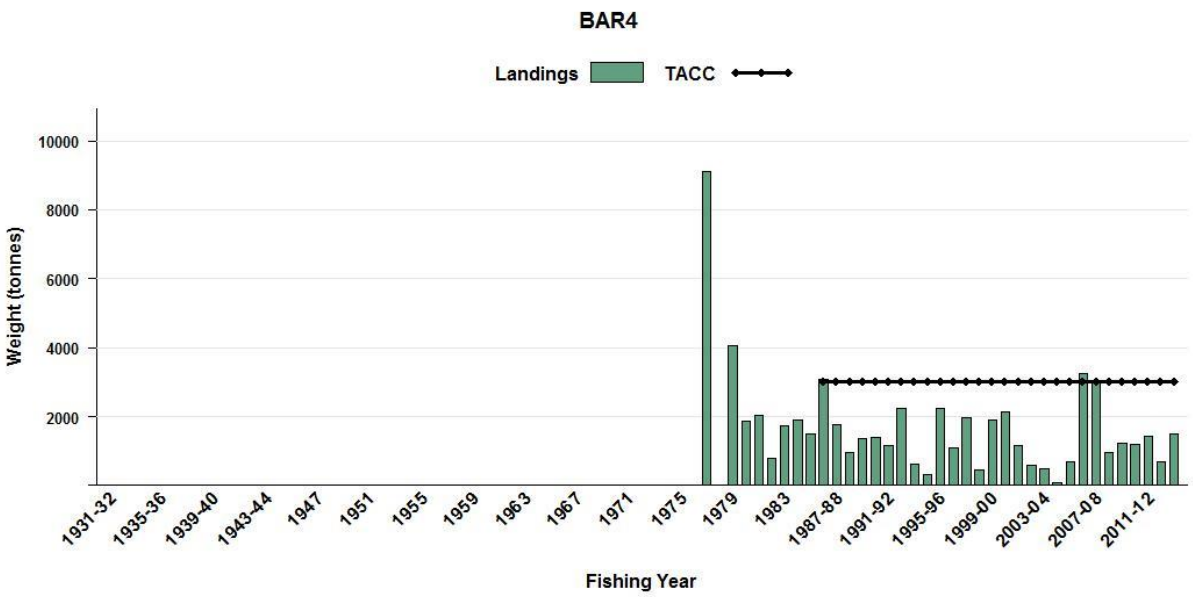
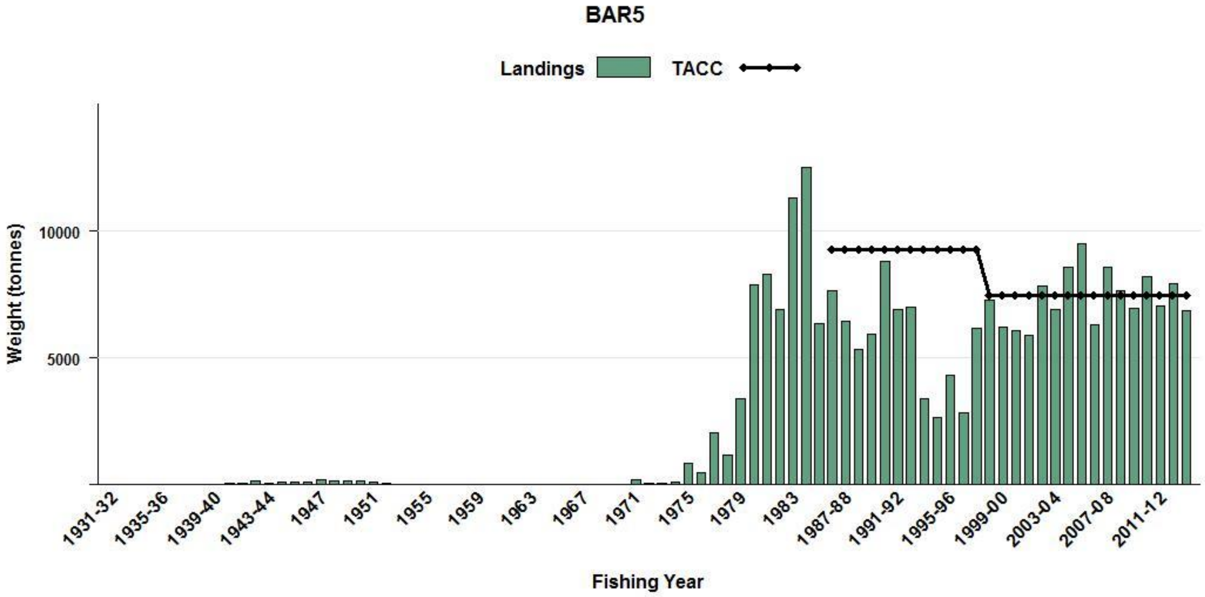


Figure 1: Reported commercial landings and TACC for the four main BAR stocks. BAR 1 (Auckland East), [Continued on next page].





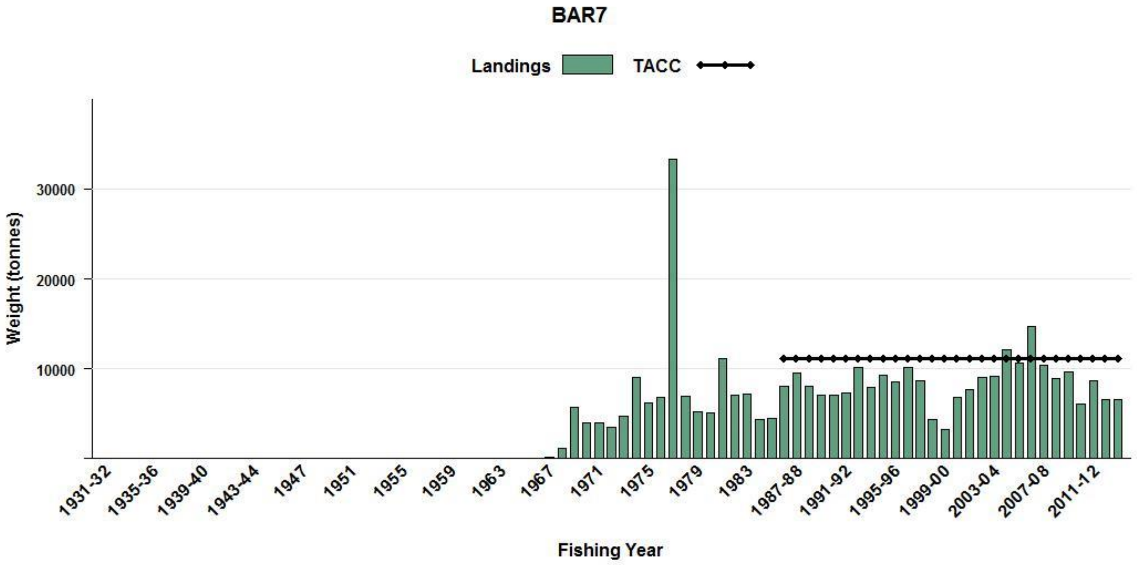


Figure 1: [Continued] Reported commercial landings and TACC for the four main BAR stocks. From top to bottom: BAR 4 (Chatham Rise), and BAR 5 (Southland), BAR7 (Challenger).

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%).

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 2005. The harvest estimates provided by these telephone diary surveys (Table 3) 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. Note that the national panel survey estimate does not include recreational harvest taken under s111 general approvals. Recreational catch estimates from the national panel survey are given in Table 4.

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 survey ran through the October to September fishing year but is denoted by the January calendar year. A mean weight of 2.14kg was used for the national panel survey.

Fishstock		Survey	Number	CV	Total 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	22 224		47.7
BAR 5	2012	Panel survey	666		1.4
BAR 7	2012	Panel survey	16 743		35.9
All combined	2012	Panel survey	39 652	18%	85.05

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) on 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. 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 on the west coast of the South Island. Adult fish are found down to about 400 m depth. Tagged barracouta have moved considerable distances to spawn (up to 500 nautical miles).

No age data is 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. Data have been validated for fish up to 3 years old by following modal progressions over time.

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)		

3. STOCKS AND AREAS

There are no new data which would alter the stock boundaries given in previous assessment documents.

Four barracouta management areas were established in 1983, based on knowledge at the time: EEZ areas E + F, G + H, B + C and D. Stock boundaries are not well understood, but the Chatham Islands stock is probably separate. However, 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 is 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. For BAR 4, 5 and 7, McGregor (in prep.) characterised the fisheries and estimated CPUE indices for the fisheries on the WCNI and WCSI (BAR 7) and the sourthern Snares fishery (BAR 5). In BAR 4 the fishery has been highly variable and no standardised analysis is possible.

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 200m) and Sub-Antarctic (deeper than 300m) 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

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 elephantfish and red gurnard which were included in the list of target species. Only 2007, 2012, and 2014 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) (Table 6, Figure 2). Biomass has been steadily increasing and in 2014 was more than four-fold larger than the average biomass of the early 1990s. The additional biomass captured in the 10–30 m depth range accounted for 15% and 6% of the biomass in the core plus shallow strata (10–400 m) for 2007 and 2012 respectively, but was less than 1% in 2014, however shallow strata should continue to be monitored for this species (Table 5, Figure 2).

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, 25 cm, and 50 cm (combined males, females, and unsexed) consistent with ages of 0+, 1+, and 2+. 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). The addition of the 10–30 m depth range does not change the shape of the length distributions.

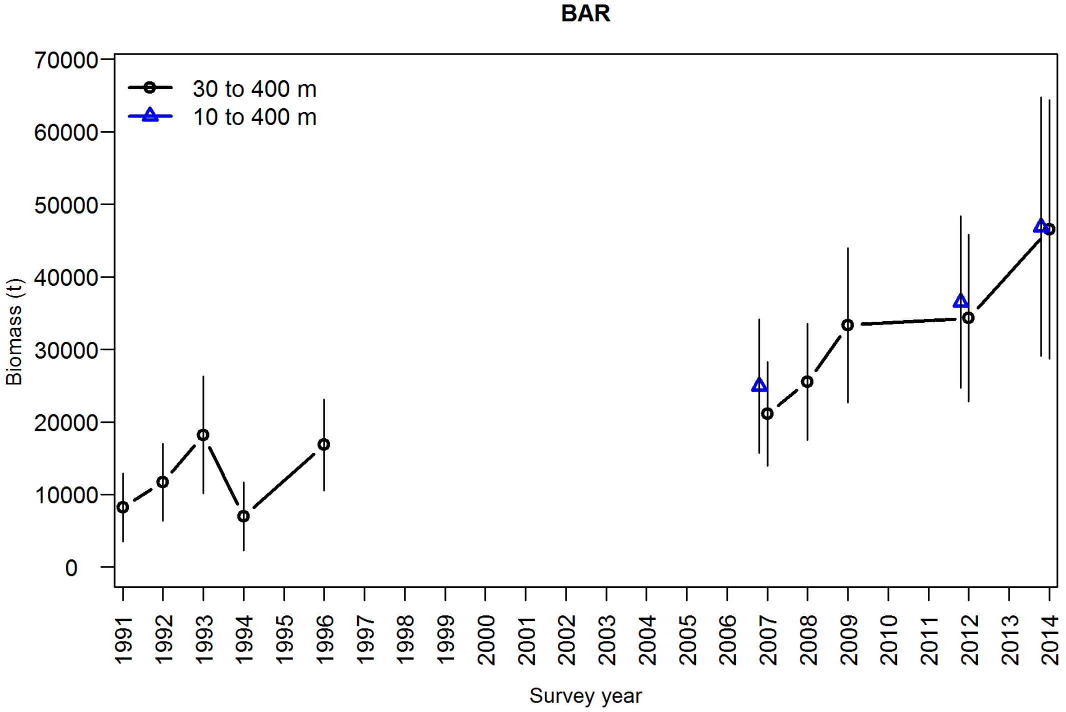


Figure 2: Barracouta total biomass and 95% confidence intervals for the all ECSI winter surveys in core strata (30–400 m), and core plus shallow strata (10–400 m) in 2007, 2012, and 2014

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
ECNI	BAR 1	1993	KAH9304	2 673	15	-	-
		1994	KAH9402	8 433	33	-	-
		1995	KAH9502	2 103	29	-	-
		1996	KAH9602	2 495	23	-	-

Table 6 [Continued]

Region	Fishstock	Year	Trip number	Total Biomass	CV (%)	Total	CV (%)
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	-	-
Southland	BAR 5	1993	TAN9301	11 587	18	-	-
		1994	TAN9402	6 151	20	-	-
		1995	TAN9502	4 539	17	-	-
		1996	TAN9604	7 693	19	-	-

4.2 BAR 5 Southland, Sub-Antarctic

4.2.1 CPUE indices

McGregor (in prep.) used merged (stratified) and unmerged (tow level) data to fit CPUE indices for the southern Snares fishery. The WG considered that the trip level CPUE was an adequate time series of CPUE to monitor this stock. After being flat for a long period the CPUE shows a recent increase since 2008 possibly from a recent recruitment pulse. The current stock status is unknown.

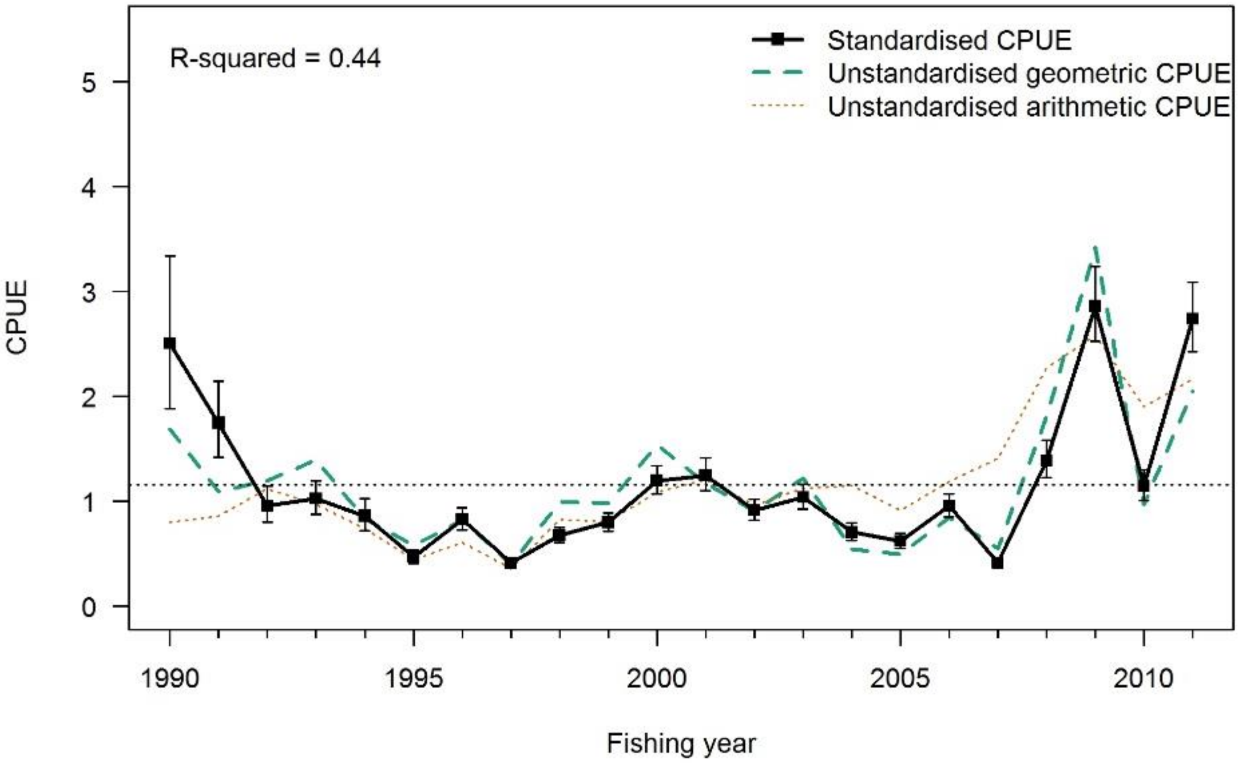


Figure 3 : South CPUE Model 1a (South) Arithmetic, geometric, and standardised CPUE indices for BAR 1990-2011.

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

4.3.1 CPUE indices

McGregor (in prep.) looked at the separate fisheries on the WCNI and WCSI. The three CPUE options for the WCNI all gave similar patterns to the inshore *Kaharoa* WCSI trawl survey. The WG considered that the tow level CPUE was the best data to use to monitor this stock. The CPUE shows an increasing trend from 2000 to 2004 and then generally flat (Figure 4).

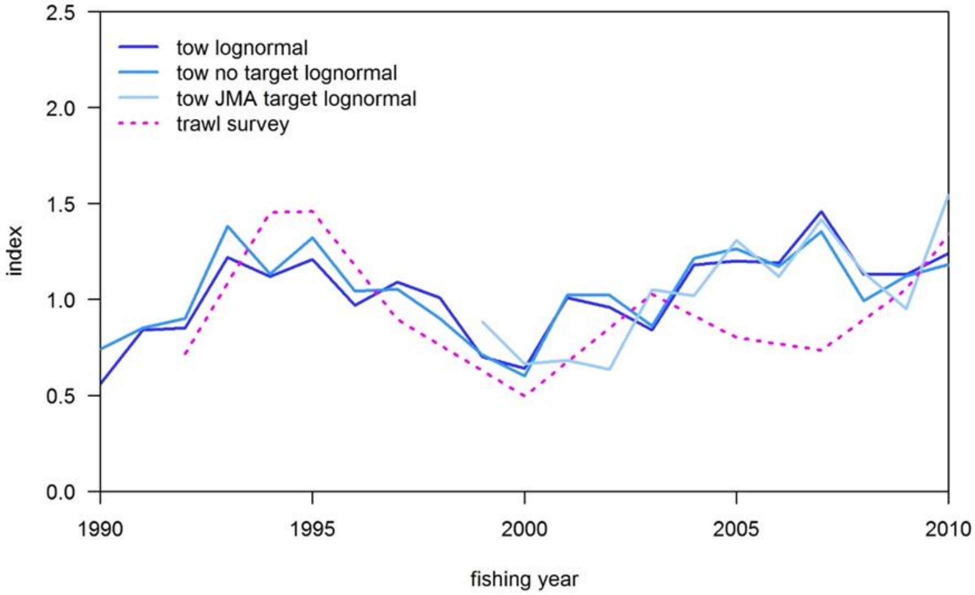


Figure 4: West Coast CPUE for Models 2b (tow level), 3 (JMA target) and 4 (no target) and Trawl Survey abundance index for calendar years 1990-2010. Model 3 (JMA target) is actually based on fishing years, months Nov-May, whereas the other models here are calendar year, Jun-Nov. Trawl survey is based on fishing year.

The WCSI data series shows a similar increase from 2000 and then generally flat, for the tow level CPUE based on all target from June to October (Figure 5).

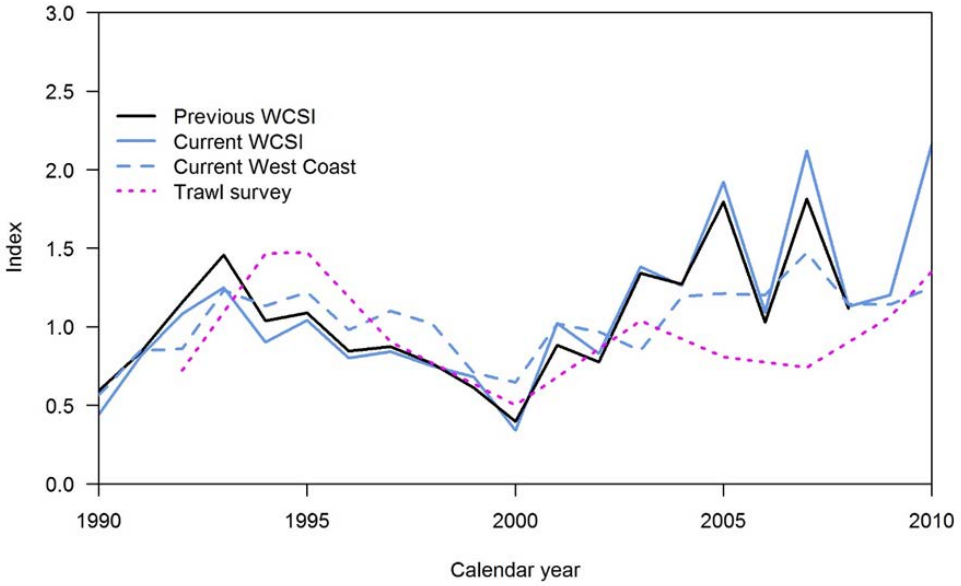


Figure 5: West Coast South Island current and previous CPUE, West Coast North Island CPUE and trawl survey abundance index for calendar years 1990-2010. Trawl survey is based on fishing year.

4.4 Yield estimates and projections

It is not feasible to estimate *MCY* from commercial landings data for most Fishstocks (except for BAR 1), as the amount of effort has varied considerably since the beginning of the fishery in the late 1960s i.e., foreign licensed access has declined, effort was encouraged by subsidies in 1979 and 1981, an unknown amount of fish has been and may still be dumped, and effort is related to the availability of more preferred, higher value species. These, and other factors, also result in CPUE data being of limited use.

Estimates of current biomass are not available and *CAY* cannot be estimated.

4.4.1 Auckland (East), Central (East) and South-East (Coast) (BAR 1)

MCY was estimated using the equation $MCY = cY_{AV}$ (Method 4), where Y_{AV} average estimated catch from 1968–1975 and $c = 0.7$. The estimated average catch includes 2000 t which is assumed to have been caught and either dumped or not reported. Fishing activity is assumed to have been on the total stock, even though the entire area was not fished. Due to problems with QMA boundaries not corresponding to the fishing history boundaries, 500 t is subtracted and added to BAR 7.

$$MCY = 0.7 * (12\,000 \text{ t} - 500 \text{ t}) = 8050 \text{ t}.$$

The level of risk to the stock by harvesting the population at the estimated *MCY* value cannot be determined. However, the risk is probably low given the sustainability of catches at about the *MCY* level since 1970.

MCY has not been determined for the other Fishstocks.

4.5 Other factors

The relationship of the southern area stock to the east and west coast South Island stocks is uncertain, so these areas have been treated separately as in the past. However, if fish from BAR 5 overlap significantly with other South Island stocks, then the *MCY*s for all Fishstocks on the South Island may all need adjusting downward.

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 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 efficiency of the two vessels.

5. STATUS OF THE STOCKS

Estimates of current and reference biomass are not available for any barracouta stocks and therefore it is not known if current TACCs and recent catches are sustainable or whether they are at levels which will allow the stocks to move towards a size that will support the maximum sustainable yield.

Yield estimates and reported landings are summarised in Table 7.

Table 7: Summary of yields (t), TACCs (t), and reported landings (t) for barracouta for the most recent fishing year.

Fishstock		FMAs	*MCY*	2013–14 Actual TACC	2013–14 Reported landings
BAR 1	Auckland (East), Central (East), South-East (Coast)	1, 2, & 3	8 050	11 000	11 309
BAR 4	South-East (Chatham)	4	-	3 019	1 482
BAR 5	Southland, Sub-Antarctic	5 & 6	-	7 470	6886

Table 7 [Continued]

Fishstock		FMAs	*MCY*	2013–14 Actual TACC	2013–14 Reported landings
BAR 7	Challenger, Central (West), Auckland (West)	7, 8, & 9	-	11 173	6 637
BAR 10	Kermadec	10	-	10	0
Total				32 672	26314

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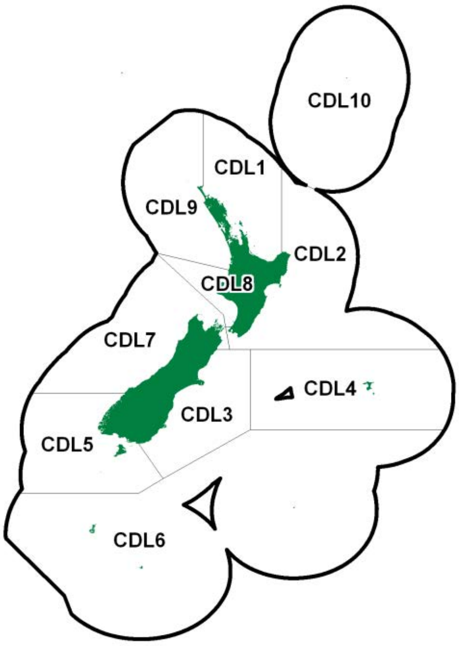
BLACK CARDINALFISH (CDL)

(*Epigonus telescopus*)
Akiwa



1. FISHERY SUMMARY

Black cardinal fish was introduced into the Quota Management System on 1 October 1998 with the following TACs, TACCs and allowances (Table 1).

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

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other sources of mortality	TACC	TAC
CDL 1	0	0	120	1200	1320
CDL 2	0	0	20	440	460
CDL 3	0	0	-	196	196
CDL 4	0	0	-	22	22
CDL 5	0	-	79	3955	4036
CDL 6	0	0	-	1000	1000
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	6856	7077

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 pro-rated 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. Landings from the Bay of Plenty (QMA 1) have fluctuated since 1988. The relatively large landings in 1990–91 were a combination of bycatch of the orange roughy fishery and target fishing for black cardinalfish. Between 1991–92 and 2005–06 occasional large catches were taken from outside the EEZ on the northern Challenger Plateau and the Lord Howe Rise.

Table 2: Reported landings (t) of black cardinalfish by QMA and fishing year (1 October to 30 September) from 1982–83 to 2013–14. The data in this table has been updated from that published in previous Plenary Reports by using the data through 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.

	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	-	-	-	-	-
1997–98	995	-	1 176	-	40	-	351	-	-	-	-	-
1998–99	24	1 200	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

Table 2 [Continued]

	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	4	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		

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 to 66 t and in CDL 5 to 22 t. In these stocks landings were above the TACC for a number of years and the TACCs have been 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 100 t respectively. Figure 1 shows the historical landings and TACC values for the main CDL stocks.

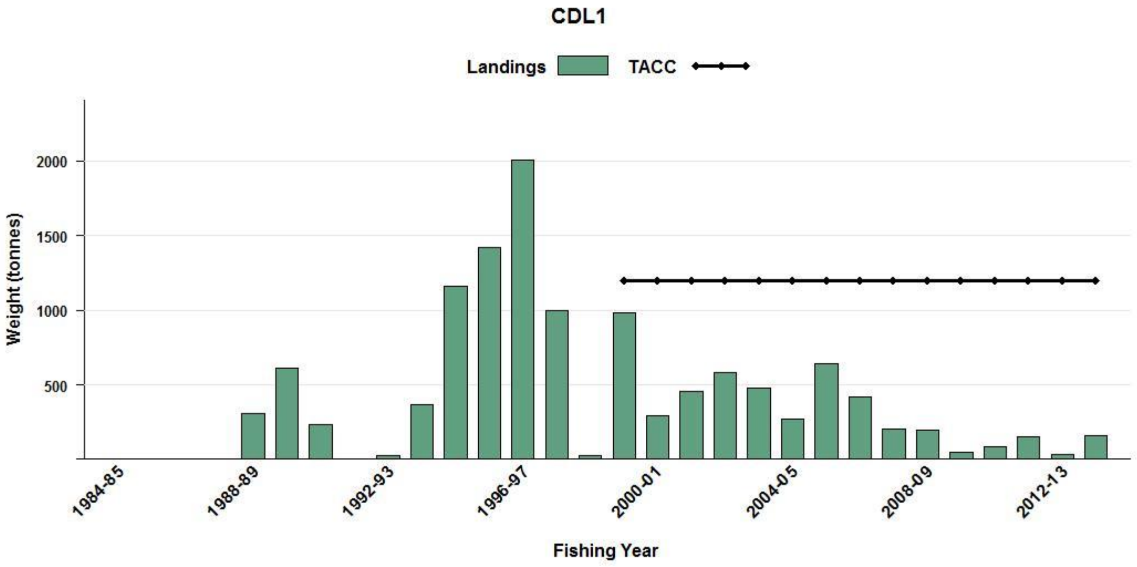


Figure 1: Reported commercial landings and TACC for the two main CDL stocks. CDL 1 (Auckland East).

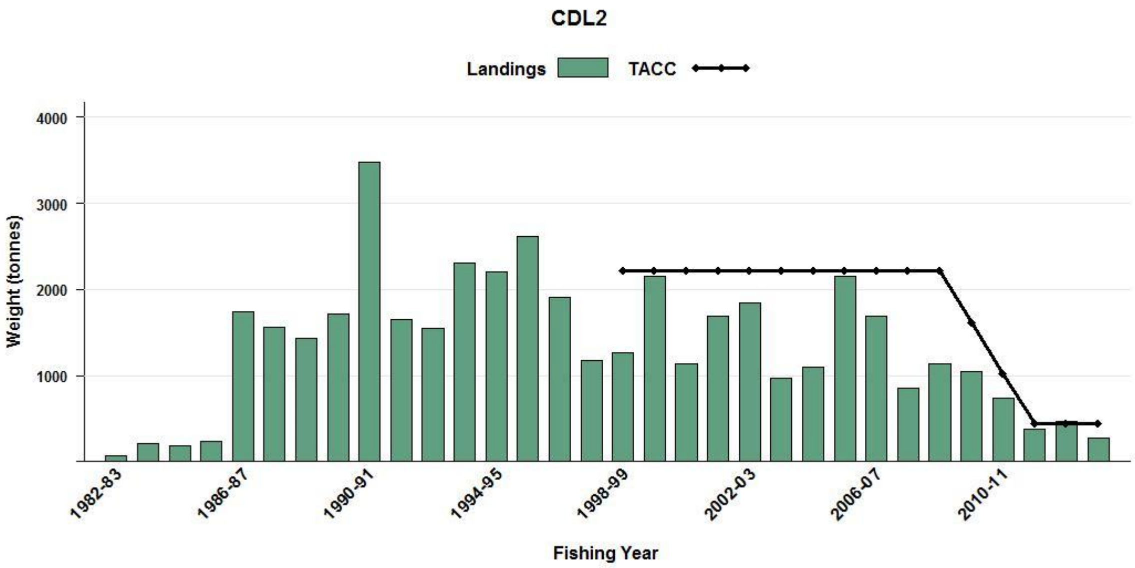


Figure 1:[Continued]: Reported commercial landings and TACC for the two main CDL stocks. CDL 2 (Central East).

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.

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	Over-run	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
1990–01	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 2013 Fishery Assessment Plenary after review by the Aquatic Environment Working Group. A more detailed summary from an issue-by-issue perspective is available in the 2012 Aquatic Environment and Biodiversity Annual Review (www.mpi.govt.nz/Default.aspx?TabId=126&id=1644).

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) 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).

4.2 Incidental catch (fish and invertebrates)

Incidental catch and discards have not been estimated for the black cardinalfish target fishery. Anderson (2009, 2011) summarised the bycatch and discards from the target orange roughy and oreo trawl fisheries from 1999–2000 to 2004–05 and 2005–06 to 2008–09 respectively. 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 Catch (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 Marine mammal interactions

Trawlers targeting orange roughy or oreos occasionally catch New Zealand fur seal (which were classified as “Not Threatened” under the NZ Threat Classification System in 2010, Baker et al 2010). Between 2002–03 and 2011–12, there were 14 observed captures of NZ fur seal in orange roughy, oreo, and black cardinalfish trawl fisheries. In the 2010–11 fishing year there were no observed captures (Table 5) but there were 2 (95% c.i.: 0–13) estimated captures, with the estimates made using a statistical model (Thompson et al 2013). All observed fur seal captures occurred in the Sub-Antarctic region, and suggest a reduced probability of fur seal capture in the black cardinalfish fishery which is carried out in central and northern New Zealand. The average rate of capture for these years was 0.08 per 100 tows (range 0 to 0.25). This is a low rate compared with that in the hoki fishery (1.29 to 5.63 per 100 tows).

Table 5: Number of tows by fishing year and observed and model-estimated total NZ fur seal captures in orange roughy, oreo, and cardinalfish trawl fisheries, 2002–03 to 2011–12. No. Obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows, % inc, percentage of total effort included in the statistical model. Estimates are based on methods described in Thompson et al (2013), available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Estimates from 2002–03 to 2010–11 are based on data version 20120531 and preliminary estimates for 2011–12 are based on data version 20130304.

		Observed				Estimated		
	Tows	No.obs	%obs	Captures	Rate	Captures	95%c.i.	%inc.
2002–03	8 872	1 378	15.5	0	0.00	4	0–16	99.9
2003–04	8 007	1 261	15.7	2	0.16	7	2–21	99.9
2004–05	8 418	1 617	19.2	4	0.25	17	4–79	99.8
2005–06	8 304	1 293	15.6	2	0.15	9	3–32	99.8
2006–07	7 368	2 321	31.5	2	0.09	3	2–7	99.9
2007–08	6 731	2 812	41.8	4	0.14	7	4–17	100.0
2008–09	6 134	2 373	38.7	0	0.00	3	0–14	100.0
2009–10	6 011	2 132	35.5	0	0.00	2	0 –10	100.0
2010–11	4 179	1 205	28.8	0	0.00	2	0–13	99.9
2011–12†	3 630	897	24.7	0	0.00	-	-	-

† Provisional data, no model estimates available.

4.3.2 Seabird interactions

Annual observed seabird capture rates ranged from 0.1 to 3.5 per 100 tows in orange roughy, oreo, and cardinalfish trawl fisheries between 1998–99 and 2007–08 (Baird 2001, 2004 a, b, 2005, Baird and Smith 2004, Abraham & Thompson 2009, Abraham et al 2009, Abraham & Thompson 2011). However, capture rates have not been above 1 bird per 100 tows since 2004–05 and have fluctuated without obvious trend at this low level (Table 6). In the 2011–12 fishing year there were 2 observed captures of birds in orange roughy, oreo, and cardinalfish trawl fisheries at a rate of 0.22 birds per 100 observed tows (Abraham et al 2012). No estimates of total captures were made. The average capture rate in orange roughy, oreo, and cardinalfish trawl fisheries over the last eight years is only 0.42 birds per 100 tows, a low rate relative to trawl fisheries for squid (12.56 birds per 100 tows), scampi (5.1 birds per 100 tows) and hoki (2.35 birds per 100 tows) over the same period.

Table 6: Number of tows by fishing year and observed seabird captures in orange roughy, oreo, and cardinalfish trawl fisheries, 2002–03 to 2011–12. 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 Thompson et al (2013) and available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Estimates from 2002–03 to 2010–11 are based on data version 20120531 and preliminary estimates for 2011–12 are based on data version 20130304.

	Fishing effort			Observed captures		Estimated captures		
	Tows	**No. obs**	**% obs**	**Captures**	**Rate**	**Mean**	**95% c.i.**	**% included**
2002–03	8 871	1 378	15.5	0	0.00	56	21–138	100.0
2003–04	8 005	1 261	15.8	3	0.24	47	21–104	100.0
2004–05	8 417	1 617	19.2	20	1.24	76	45–135	100.0
2005–06	8 305	1 294	15.6	7	0.54	54	29–99	100.0
2006–07	7 367	2 323	31.5	1	0.04	22	10–42	100.0
2007–08	6 730	2 811	41.8	5	0.18	28	14–50	100.0
2008–09	6 131	2 373	38.7	8	0.34	27	16–43	100.0
2009–10	6 011	2 133	35.5	19	0.89	44	28–79	100.0
2010–11	4 179	1 205	28.8	6	0.50	26	13–46	100.0
2011–12†	3 630	897	24.7	2	0.22	-	-	-

† Provisional data, no model estimates available.

Table 7: Number of observed seabird captures in orange roughy, oreo, and cardinalfish fisheries, 2002–03 to 2011–12, by species and area. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Potential Biological Removals, PBR (from Richard & Abraham 2013 where full details of the risk assessment approach can be found). It is not an estimate of the risk posed by fishing for jack mackerel. Other data, version 20130304.

Species	Risk Ratio	Chatham Rise	East Coast South Island	Sub-Antarctic	Stewart Snares Shelf	West Coast South Island	Total
Salvin's albatross	Very high	11	2	4	0	0	17
Southern Buller's albatross	Very high	3	0	0	0	0	3
Chatham Island albatross	Very high	7	0	1	0	0	8
NZ White capped albatross	Very high	5	0	0	0	1	6
Gibson's albatross	High	1	0	0	0	0	1
Northern royal albatross	Medium	1	0	0	0	0	1
Total albatrosses	**N/A**	**28**	**2**	**5**	**0**	**1**	**36**
Cape petrel	High	10	10	0	0	0	20
Northern giant petrel	Medium	1	0	0	0	0	1
White chinned petrel	Medium	0	1	0	0	0	1
Grey petrel	Medium	2	0	1	0	0	3
Sooty shearwater	Very low	1	3	0	1	0	5
Common diving petrel	-	2	0	0	0	0	2
Storm petrels	-	0	0	1	0	0	1
White-faced storm petrel	-	2	0	0	0	0	2
Total other birds	N/A	**18**	**14**	**2**	**1**	**0**	**35**

Salvin's albatross was the most frequently captured albatross (47% of observed albatross captures) but six different species have been observed captured since 2002–03. Cape petrels were the most frequently captured other taxon (57%, Table 7). 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.

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).

4.4 Benthic interactions

Cardinalfish, orange roughy, and oreos are taken using bottom trawls and collectively accounted for about 14% of all tows reported on TCEPR forms to have been fished on close to the bottom between 1989–90 and 2004–05 (Baird et al 2011). These tows were located in Benthic Optimised Marine Environment Classification (BOMEC, Leathwick et al 2009) classes J, K (mid-slope), M (mid-lower slope), N, and O (lower slope and deeper waters) (Baird & Wood 2012), and 94% were between 700 and 1200 m depth (Baird et al 2011). Deepsea corals in the New Zealand region are abundant and diverse and, because of their fragility, are at risk from anthropogenic activities such as bottom trawling (Clark & O'Driscoll 2003, Clark & Rowden 2009, Williams et al 2010). All deepwater hard corals are protected under Schedule 7A of the Wildlife Act 1953. Rowden et al (2012) mapped the likely coral distributions using predictive models, and concluded that fisheries that pose the most risk to protected corals are these deepwater trawl fisheries.

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 2012 Aquatic Environment and Biodiversity Annual Review 2012.

The NZ EEZ contains 17 Benthic Protection Areas (BPAs) that are closed to bottom trawl fishing and include about 52% of all seamounts greater than 1500 m elevation and 88% of identified hydrothermal vents.

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, 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) although work is currently underway to generate one. 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 cases, 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 catches adjusted by overruns (Table 9), two CPUE indices (Table 8), 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. Whilst 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 3. 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.

- 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 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.

- 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.

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
M0.027	0.027	Estimated separately
M0.06	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 formula. 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 M0.027 run resulting in a larger and less productive stock, and the M0.06 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 (Table 10).

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

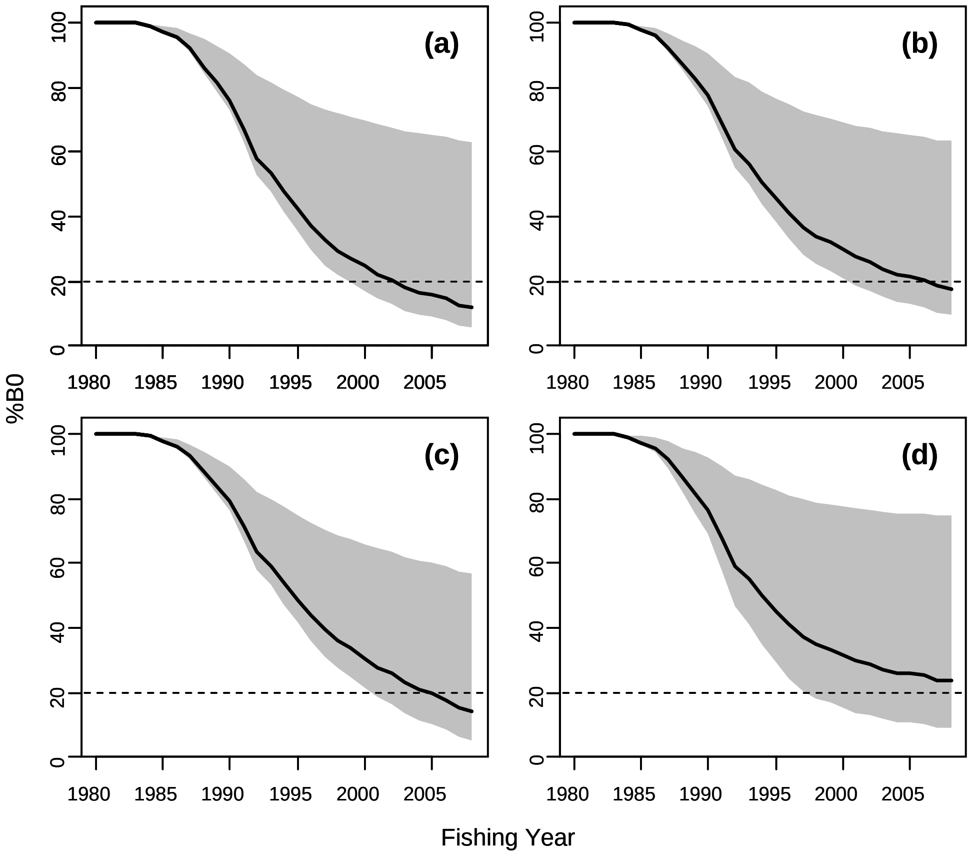


Figure 2: Estimated biomass trajectories (solid line) and 95% confidence intervals (shaded area) for the model runs (a) Base, (b) mat&sel, (c) *M*0.027, (d) *M*0.06. The horizontal broken line indicates 20% B_0.

5.4 Sensitivity analyses

Several sensitivity analyses were conducted (reported in more detail in Dunn 2009). The assessment was found to be relatively insensitive to the assumed catch over-runs. When over-runs 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 to 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 parenthesis 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
M0.027	$\%B_0$ (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
M0.06	$\%B_0$ (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, draft). 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.

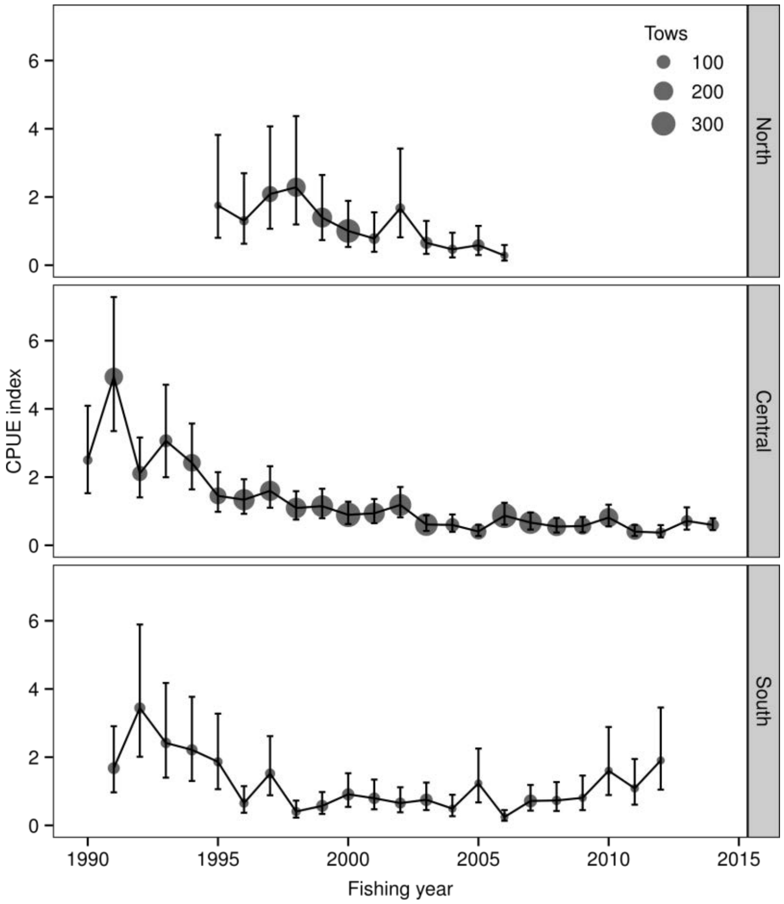


Figure 3: CPUE indices by region (see text for definitions of regions). Region/year combinations with less than 30 tows are not shown. Error bars indicate +/- one standard error. Fishing years are indicated by the later calendar year.

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.

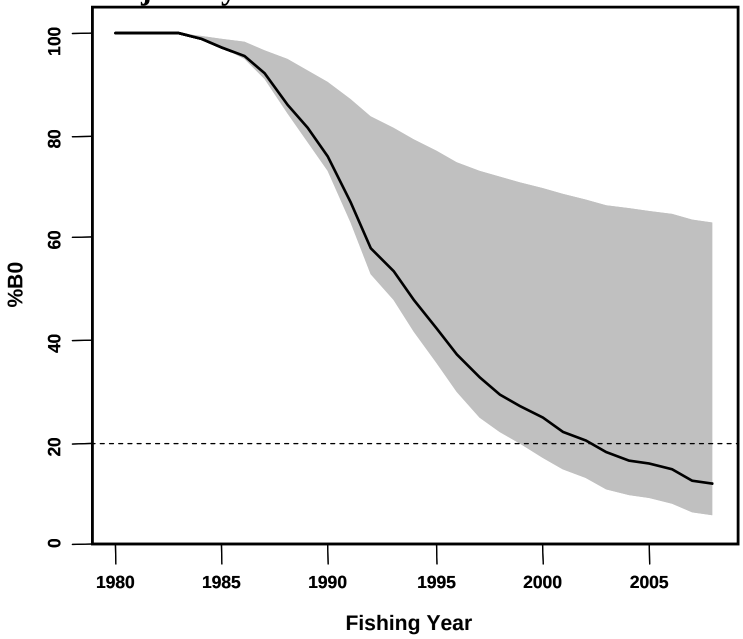
There is evidence that a spawning stock exists in CDL 2, with three geographically close spawning locations identified, on Tuaheni High, Ritchie Bank, and Rockgarden (Dunn 2009). Juveniles of less than 30 cm have been infrequently identified in CDL 2, and more frequently found on the northern flanks 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 2223 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 Tmin). CPUE since 2008 has been flat.

Fishery Interactions
Main associated species are orange roughy, alfonsino and, to a lesser extent, hoki.

Other QMAs

There is no information on the status of cardinalfish stocks in other QMAs.

TACCs and reported landings for the 2013–14 fishing year are summarised in Table 13.

Table 13: Summary of TACCs (t) and reported landings (t) for black cardinalfish for the most recent (2013–14) fishing year.

Fishstock	QMA	FMA	2013–14 Actual TACC	2013–14 Reported landings
CDL 1	Auckland (East)	1	1 200	160
CDL 2	Central (East)	2	440	440
CDL 3	South-east (Coast)	3	196	196
CDL 4	South-east (Chatham)	4	66	66
CDL 5	Southland	5	22	22
CDL 6	Sub-Antarctic	6	1	1
CDL 7	Challenger	7	39	39
CDL 8	Central (West)	8	0	0
CDL 9	Auckland (West)	9	4	4
CDL 10	Kermadec	10	0	0
Total			1 968	542

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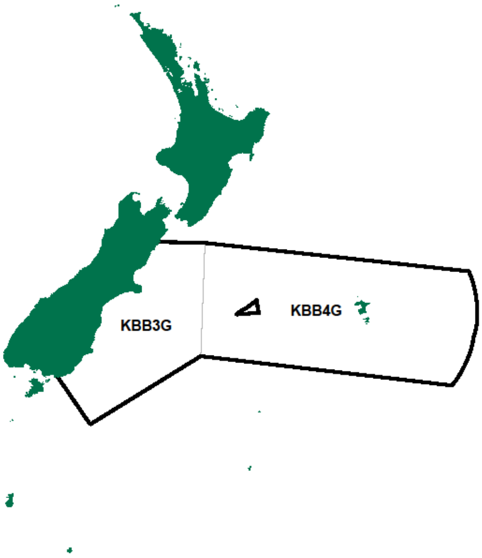
BLADDER KELP ATTACHED (KBB G)

(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, and which remain unchanged, are presented in Table 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. MPI 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 only to attached bladder kelp.

Table 1: Total Allowable Catch (TAC, t), Total Allowable Commercial Catches (TACC, t), customary non-commercial (t), recreational, and other mortality allowances 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	1 236	0.1	0.1	1
KBB 4G	274	272	0.1	0.1	

1.1 Commercial fisheries

Bladder kelp has been used as a dietary supplement, fertilizer, cultivation for bioremediation purposes, as well as abalone and sea urchin feed (Buschmann et al 2006, Gutierrez et al 2006). There is current research evaluating the utilization of bladder kelp as feed for other aquaculture species such as shrimps (Buschmann et al 2006, Cruz-Suárez et al 2006), 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, MPI considered the bladder kelp resource requires active management to ensure its sustainable use, and that management under the QMS was the most appropriate mechanism.

The season for commercial harvest of KBB G has been established between 1 October and 30 September, and catch is measured in greenweight (t).

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, compared to the Californian fishery, 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; details can be found in the Minister's letter on the MPI website.

Harvest of KBB G mainly occurs in QMA3 and has varied since 2001–02 from 3 to 105 t (Table 2). Landings of KBB G in QMA 4 are minimal, with 2.47 t reported in the last 13 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	TACC KBB 3G	TACC 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		1 236	272
2011–12	34.25		1 236	272
2012–13	35.00		1 236	273
2013-14	94	0	1 236	273

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 harvest of bladder kelp by customary Maori 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

Since introducing KBB G into the QMS, there is no quantitative or qualitative measure of illegal catch for bladder kelp.

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 et al 1984, 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 2000).

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, while spring recoveries were negatively correlated with sea surface temperature. On interannual 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, while 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 locales.

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, while *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 sake of this document, the four previously recognized 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 Castle Point 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 interannual 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.

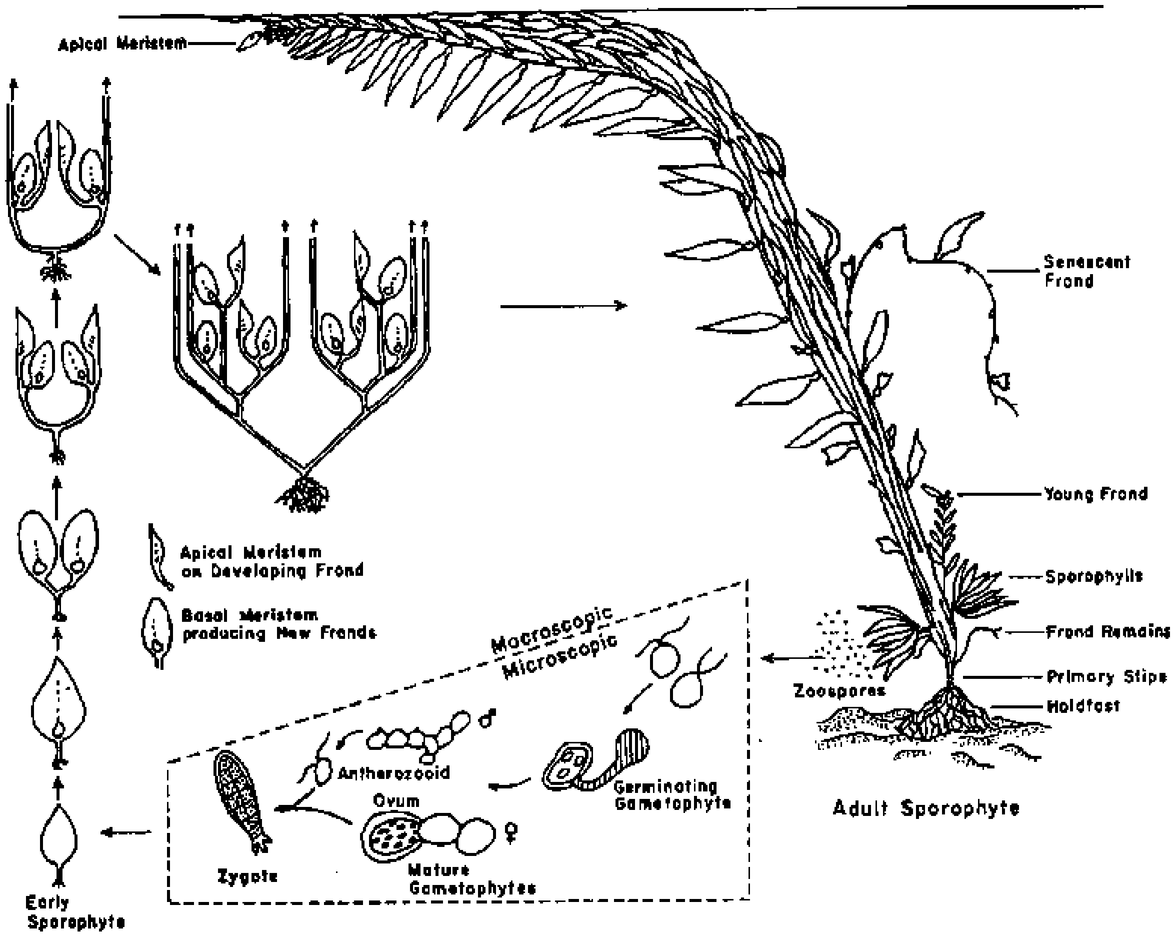

Apical Meristem
Senescent Frond
Young Frond
Sporophylls
Frond Remains
Primary Stipe
Holdfast
Zoospores
Adult Sporophyte
Apical Meristem on Developing Frond
Basal Meristem producing New Fronds
Macroscopic
Microscopic
Antherozooid
♂
Ovum
Germinating Gametophyte
♀
Zygote
Mature Gametophytes
Early Sporophyte

Figure 1: 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 ca two years old, standing in 10 m of water depth, and liberating haploid zoospores; (below center) development of haploid gametophytes from settled zoospores, proceeding to gametogenesis, and fertilization yielding the zygote and, thence, a diploid embryonic sporophyte. From North (1986).

Bladder kelp is a large perennial kelp (individuals persist for up to 5 years in California; North 1994) with a life history progressing from planktonic zoospores (less than 3 days longevity) to microscopic benthic gametophytes (7–30 days longevity) and finally macroscopic benthic sporophytes (the large plants we see along the coast) (Figure 1). 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 1). 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 1). 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 1). 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).

A floating surface canopy consisting of numerous vegetative fronds characterizes 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, giant 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 supports 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 giant 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 tradeoff 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.

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}

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 RGR's 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.

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 is 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 mid-water 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 colonizes each of these three components. Holdfasts are primarily colonised by algae and invertebrates and encrusted with bryozoans and sponges. The mid-water fronds and surface canopies are host to a variety of sessile and mobile invertebrates (e.g., amphipods, top and turban snails), encrusting bryozoans, and hydroids. Juvenile and adult fishes may also associate with mid-water 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 radiata, Evechinus chloroticus* (kina) and *Haliotis iris* (paua) 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 in California, Chile, Macquarie Island, South Georgia and Tasmania, have shown that holdfasts, mid-water 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,b,c, Smith 2002, Macaya et al 2005, Thiel & Gutow 2005a,b). 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, with New Zealand and Californian studies demonstrating 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 1980, 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, MPI is 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) (Pirker et al 2000). 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 per square metre biomass estimates for entire bladder kelp plants from 247 sites within 43 locations across the North and South Islands (Figure 2) between 1999 and 2005. 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 as 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.

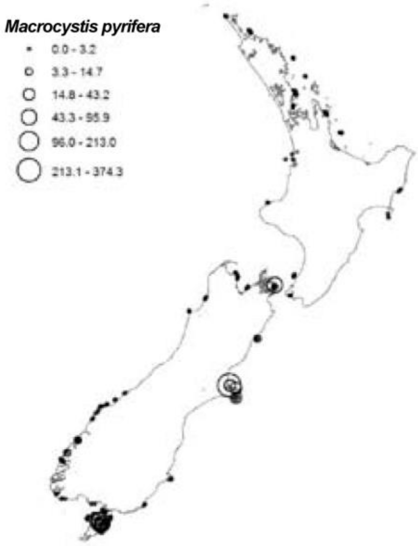


Figure 2: Mean biomass (g ash free dry weight m^{-2}) of attached bladder kelp at all sites, averaged across 4 depth categories from < 2 m to > 10 m depth. From Shears & Babcock (2007).

5.3 Yield estimates and projections

As absolute biomass has not been estimated, MCY cannot be 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 33 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.

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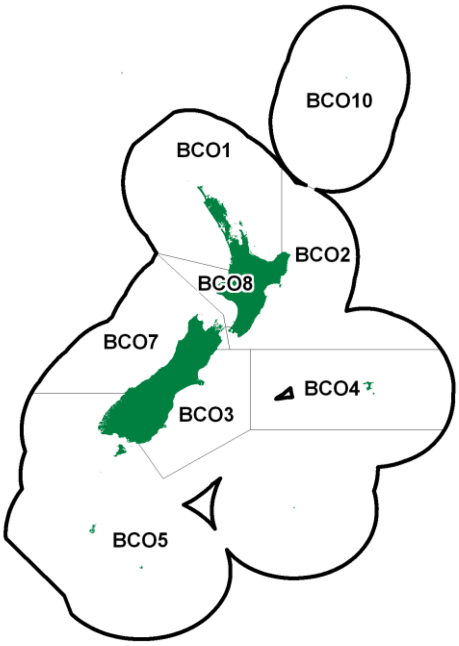
BLUE COD (BCO)

(Parapercis colias)
Rawaru



1. FISHERY SUMMARY

Allowances, TACCs and TACs in Table 1.

Table 1: Recreational and Customary non-commercial allowances, other mortality, TACCs and TACs 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 3000 t were reported in the 1930s and catches of 2500 t were sustained for many years in the 1950s and 1960s. 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 fishstocks 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 built up to a peak 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. Recent reported landings are shown in Table 3 and historical landings in Table 4, while Figure 1 shows the historical landings and TACC values for the five main BCO fish stocks.

Since 1994-95, total landings have exceeded 2000 t annually, peaking at 2501 t in 2003-04. Historically, the largest catches of blue cod have been taken in BCO 5 (1556 t in fishing year 2003-04). The total catch from this fishery remained relatively stable from 1982 to 1993 and subsequently increased to approach the level of the TACC in 1995-96. Catches have remained stable at this higher level in recent years.

Since 1989-90, a large proportion of the total catch from the BCO 5 fishery has been taken from Foveaux Strait (statistical area 025) and catches from this area have remained relatively stable. The recent increase in total catch has been attributed to an increase in catch from the western approaches to Foveaux Strait (stat area 030) and, to a lesser extent, from off eastern Stewart Island (statistical area 027). In BCO 3, catches have consistently fluctuated around the TACC of 163 t exceeding it in most years since 1997-98. In other Fishstocks, landings have generally been lower than the TACC. In BCO 7, commercial landings declined in response to a reduction in TACC (to 70 t) implemented in 1995-96, but from 2000-01 annual landings in this QMA have increased steadily.

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982

Year	BCO 1	BCO 2	BCO 3	BCO 4
1931-32	29	0	55	148
1932-33	12	0	59	111
1933-34	24	5	26	1055
1934-35	17	5	23	1306
1935-36	18	23	34	1197
1936-37	3	7	27	755
1937-38	2	8	31	793
1938-39	2	3	19	686
1939-40	1	4	33	715
1940-41	3	7	39	320
1941-42	2	5	30	189
1942-43	3	5	20	204
1943-44	4	12	31	212
1944	3	10	38	216
1945	8	6	45	102
1946	11	9	43	175
1947	8	22	81	278
1948	7	24	74	623
1949	37	6	98	390
1950	5	5	66	485
1951	4	9	51	494
1952	5	7	53	543
1953	7	20	62	682
1954	5	9	84	603
1955	4	8	83	355
1956	1	7	86	636
1957	2	5	63	1185
1958	2	4	57	892
1959	1	2	51	1158
1960	1	4	48	903
1961	1	2	43	871
1962	1	9	37	550
1963	1	12	46	633
1964	1	107	83	495
1965	1	18	55	742
1966	1	395	35	13
1967	1	437	34	0
1968	1	312	69	0
1969	6	232	92	8
1970	0	402	70	39
1971	1	105	81	36
1972	0	137	60	3
1973	1	127	65	4
1974	0	67	61	1
1975	0	5	42	2
1976	0	103	72	17
1977	2	3	21	46
1978	0	9	49	14
1979	0	17	74	13
1980	1	1	89	1
1981	1	2	69	40
1982	7	0	62	13

Table 2 [Continued]

Year	BCO 5	BCO 7	BCO 8	Year	BCO 5	BCO 7	BCO 8
1931-32	719	4	4	1957	581	61	2
1932-33	726	1	5	1958	542	71	2
1933-34	792	3	2	1959	492	71	1
1934-35	1057	0	4	1960	757	65	2
1935-36	284	44	2	1961	590	55	3
1936-37	113	61	0	1962	668	65	3
1937-38	172	81	0	1963	621	60	4
1938-39	94	57	0	1964	462	70	3
1939-40	135	68	0	1965	296	59	2
1940-41	177	72	0	1966	337	79	6
1941-42	128	54	0	1967	518	74	5
1942-43	139	65	0	1968	494	105	2
1943-44	221	80	0	1969	361	60	1
1944	552	88	0	1970	432	70	8
1945	634	109	0	1971	375	44	2
1946	715	116	2	1972	194	63	1
1947	955	153	1	1973	571	68	11
1948	852	88	2	1974	486	61	16
1949	929	82	3	1975	232	58	14
1950	1005	94	1	1976	254	58	17
1951	873	74	2	1977	208	87	19
1952	889	95	3	1978	197	104	12
1953	414	114	2	1979	217	98	16
1954	385	112	2	1980	403	62	18
1955	405	79	3	1981	494	79	23
1956	656	77	2	1982	356	68	34

Table 3: Reported landings (t) of blue cod by Fishstock from 1983 to 2012-13 and actual TACCs (t) from 1986-87 to 2012-13. QMS data from 1986-present. FSU data 1983-1986. [Continued on next page].

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

Fishstock	**BCO 7**		**BCO 8**		**BCO 10**			
FMA (s)	7		8		10			
	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

Table 3 [Continued]

Fishstock	BCO 7			BCO 8		BCO 10		
FMA (s)		7						
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	**TACC**
1989-90	75	136	34	74	0	10	1527	2 666
1990-91	63	136	28	74	0	10	1 752	2667
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

Table 4: Reported total New Zealand landings (t) of blue cod for the calendar years 1970 to 1983. Sources MPI 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

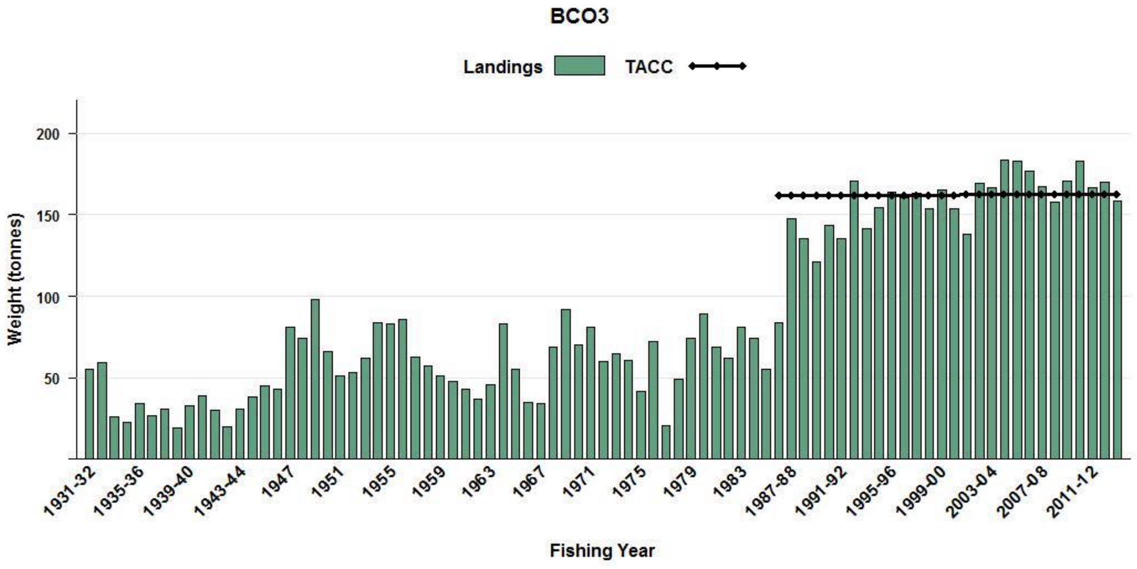


Figure 1: Reported commercial landings and TACC for the five main BCO stocks. From top: BCO3 (South East Coast) [Continued on next page].

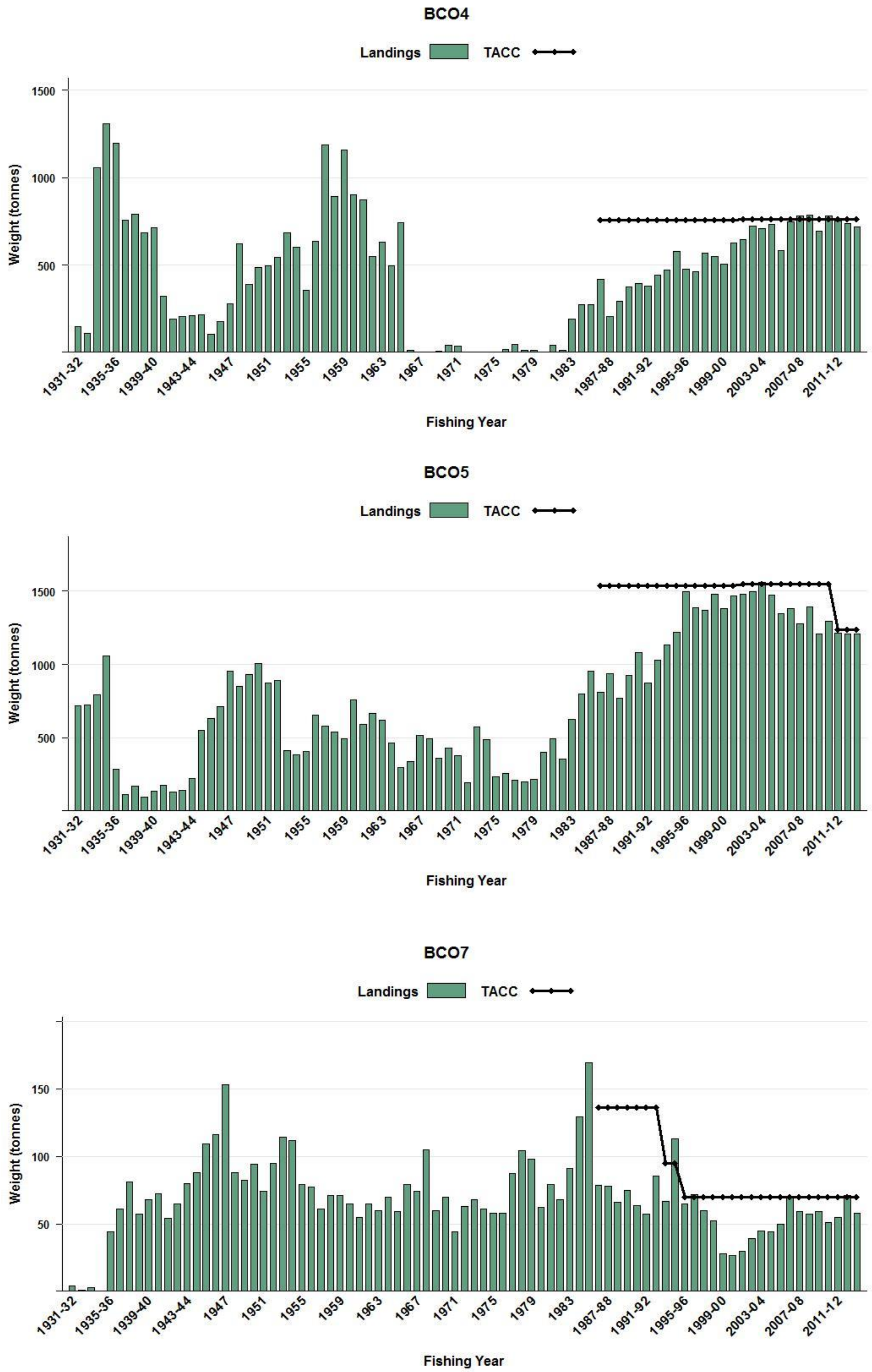


Figure 1: Reported commercial landings and TACC for the five main BCO stocks. From top: BCO4 (South East Chatham Rise), BCO5 (Southland), BCO7 (Challenger). [Continued on next page].

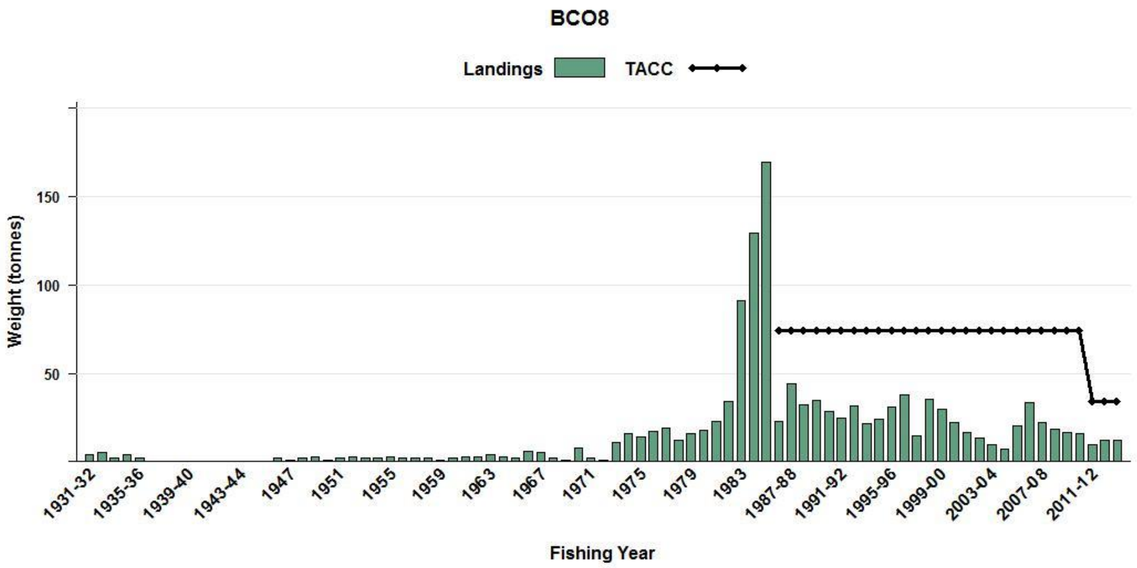


Figure 1 [Continued]: Reported commercial landings and TACC for the five main BCO stocks. BCO8 (Central Egmont).

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), a slot limit on size, method restrictions and daily bag limits. Both of these have changed over time and vary by Fishstock (Table 5).

Table 5: Changes to minimum legal size (MLS in cm) and amateur maximum daily limits (MDL) of blue cod by Fishstock from 1986 to present.*

Fishstock	BCO 1		BCO 2		BCO 3		BCO 4		BCO 5		Sub area provisions:	
QMA(s)	1&9		2		3		4		5 &6		Paterson Inlet	
	MLS	MDL	MLS	MDL	MLS	MDL	MLS	MDL	MLS	MDL	MLS	MDL
1986	30	30	30	30	30	30	30	30	30	30	30	30
1993	33	20	33	20	30	30	33	30	33	30	33	30
1994	33	20	33	20	30	30	33	30	33	30	33	15
	-	-	-	-	-	*30	*10	-	-	-	-	-

Fishstock	BCO 7		BCO 7		BCO 8		BCO 10	
QMA(s)	7		Marlborough Sounds		8		10	
	MLS	MDL	MLS	MDL	MLS	MDL	MLS	MDL
1986	30	30	30	12	30	30	30	30
1993	33	20	33	10	33	20	33	20
1994	33	20	28	6	33	20	33	20
2001	33	10	-	-	-	-	-	-
2003			30	3				
2011			SLOT 30-35	2				

All maximum daily limits are restricted within mixed species maximum daily bag limits which may vary between areas - (for the in north Canterbury area only).

During 1992-93, the amateur bag limit for blue cod was reduced and the minimum size increased from 30 cm to 33 cm for both amateur and commercial fishers (except for BCO 3). However, this was amended in 1993-94 for the Marlborough Sounds where the size limit was reduced to 28 cm. Bag limits were also reduced for the Marlborough Sounds and Paterson Inlet (Stewart Island), in 2003 the minimum legal size and daily bag limit in the Marlborough Sounds was changed to 30 cm and 3 per person per day respectively. In April 2011 a slot limit of 30-35cm and a bag limit of two blue cod per person per day were introduced for the Marlborough Sounds.

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 2005) 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 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 are likely to be an underestimate due to less sampling coverage than planned for two key reasons. Less flights occurred than planned for the outer Marlborough Sounds due to poor flying conditions (low cloud), and sampling of harvest at boat ramps was not as complete as intended due to the higher than anticipated proportion of fishers who departed and returned to a bach/crib within BCO 7, or Wellington, without being intercepted at a boat ramp within BCO 7.

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.

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 survey ran through the October to September fishing year but is 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	8	0.20
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
BCO 3	1996	Telephone/diary	217, 000	151	11
	2000	Telephone/diary	1, 026, 000	752	0.29
	2012	Panel survey	212, 184	101	0.20
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
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	75	0.17
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

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 Estimate (t)
BCO 1	430	18	2 500	2.4
BCO 2	34	50	300	0.2
BCO 3	17 272	29	72 000	58
BCO 5	16 750	36	63 000	51
BCO 7	32 026	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 traditionally 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.

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, whilst in the Marlborough Sounds it is reached at 21-26 cm (TL) at 3-6 years. In Southland, the fish become mature between 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 (Carbines 2004b). The maximum recorded age for this species is 32 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 unfished stock. Using the maximum age of 32 years, (Carbines *et al.* 2007) M was calculated to be 0.14. This estimate seems feasible as in lightly fished areas such as the offshore Banks Peninsula Z is thought to approximate M and was calculated at 0.14 to 0.15 (Beentjes 2012)

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 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 the survival of these fish is good if they are caught using large hooks (6/0) and returned to the sea quickly.

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 < 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

Fishstock	**Estimate**	**Source**
1. Natural mortality (*M*)		
All	0.14	Estimated from the maximum age in Carbines *et al.* 2007, using Hoenig's (1983) method.

2. Von Bertalanffy growth parameters

	Females			Males			
	L_∞	k	t_0	L_∞	k	t_0	
Banks Peninsula (inshore)	45.8	0.128	-0.7	47.0	0.152	-0.1	Carbines & Haist 2012a
Banks Peninsula (offshore)	46.7	0.089	-1.8	56.7	0.085	-1.6	Carbines & Haist 2012a
Kaikoura	45.2	0.082	-2.9	53.5	0.089	-1.5	Carbines & Haist 2012b
Motunau	40.0	0.114	-2.0	50.7	0.088	-1.9	Carbines & Haist 2012b
Paterson Inlet	47.3	0.109	-1.4	63.7	0.070	-2.0	Carbines & Haist 2014a
Southland (Sub area 025)	34.5	0.4	1.2	41.6	0.3	1.2	Carbines (1998)
Queen Charlotte Sound (Over all)	32.2	0.3	-0.70	*	*	*	Carbines (1998)
Inner Queen Charlotte Sound	†	†	†	41.4	0.1	-5.2	Carbines (2000)
Outer Queen Charlotte Sound	†	†	†	33.7	0.4	1.07	Carbines (2000)
Extreme Outer Queen Charlotte Sound	†	†	†	50.2	0.1	-1.9	Carbines (2000)
Pelorus Sound (Over all)	33.2	0.2	-2.0	*	*	*	Carbines (2000)
Outer Pelorus Sound	†	†	†	36.8	0.27	-0.3	Carbines (2000)
Extreme Outer Pelorus Sound	†	†	†	40.8	0.22	-0.3	Carbines (2000)

3. Weight = a(length)^b (Weight in g, length in cm total length).

Area	Year	Sex	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	

† Sub areas showed no significant difference from pooled area growth estimates

* Pooled area growth estimates showed significant differences from sub areas.

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 isolated from each other and there may be several distinct populations within each management area.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

4.1.1 South Island blue cod potting surveys

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 and Carbines 2012). A new survey in 2013 used the same strata as 2010 (Beentjes et al in prep). 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 and Carbines 2012). The 1995 and 1996 surveys, similarly, have been reanalysed as part of the 2013 survey analyses (Beentjes et al in prep). 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 and Francis 2011). In 2010, a suite of random locations were added to the fixed sites in selected strata. Random sites may have any location (single latitude and longitude) and are generated randomly within each stratum. In 2013, full random and full fixed site surveys were conducted. However, only the fixed site component of the 2010 and 2013 surveys are considered comparable to the earlier surveys.

Throughout the 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 (Figures 2 to 5)(Table 9). In Queen Charlotte Sound catch rates progressively declined from 2.1 to 1.1 kg.pot^{-1} (CVs range 16 to 26%) between 1995 and 2007 before increasing markedly in 2010 to 1.75 kg.pot^{-1} (Figure 2). 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} (CVs range 7 to 19%) over the same period, before increasing 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 and Pelorus Sounds and east D'Urville. The 2013 survey was carried out two years after the slot limit management regime had been in place, with total blue cod catch rates for both Queen Charlotte and Pelorus Sounds declining compared to 2010, 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 (Figures 2 and 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} (CVs range 8 to 18%) (Figure 4). D'Urville was not closed to fishing in October 2008, but was included in the management area where the "slot limit" has been applicable since April 2011. Cook Strait has had only two comparable surveys (which used a random design) (2010 and 2013) with the first survey in 2008 being a fixed site survey which was not comparable. Total blue cod catch rates

from the random survey years were 1.1 kg.pot^{-1} in 2010, declining to 0.70 kg.pot^{-1} in 2013. There have been no closures or slot limit management measures for this region in 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, while 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).

No ageing results, including estimates of total mortality (*Z*) and spawner biomass per recruit, are presented for Marlborough Sounds as there have been inconsistencies in the ageing of blue cod from this area. An ageing protocol is currently being developed for blue cod, and the age dependant results for the Marlborough Sounds survey will be presented once the otoliths have been read using the new protocol.

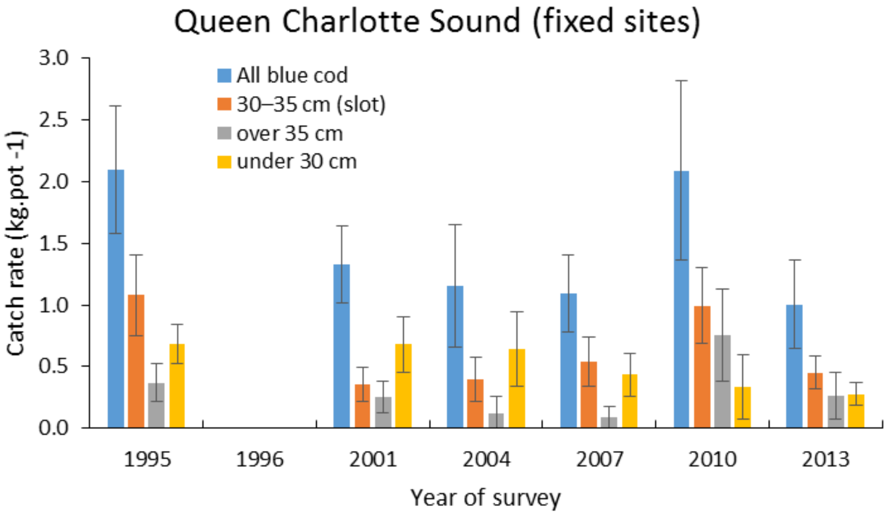


Figure 2: Scaled catch rates of blue cod from Queen Charlotte Sound fixed sites from 1995 to 2013. Catch rates are shown for all blue cod, slot limit blue cod (30–35 cm), blue cod above the slot limit (over 35 cm) and for pre-recruited blue cod (under 30 cm). Error bars are 95% confidence intervals.

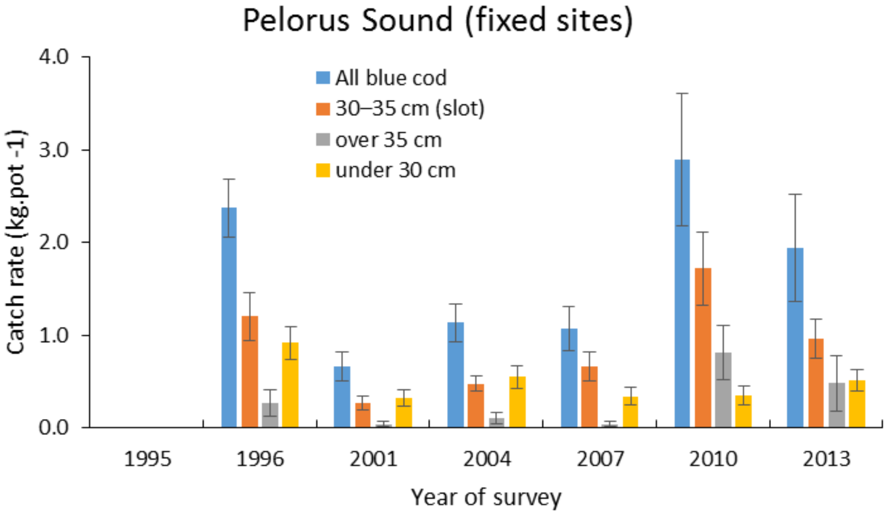


Figure 3: Scaled catch rates of blue cod from Pelorus Sound fixed sites from 1996 to 2013. Catch rates are shown for all blue cod, slot limit blue cod (30–35 cm), blue cod above the slot limit (over 35 cm) and for pre-recruited blue cod (under 30 cm). Error bars are 95% confidence intervals.

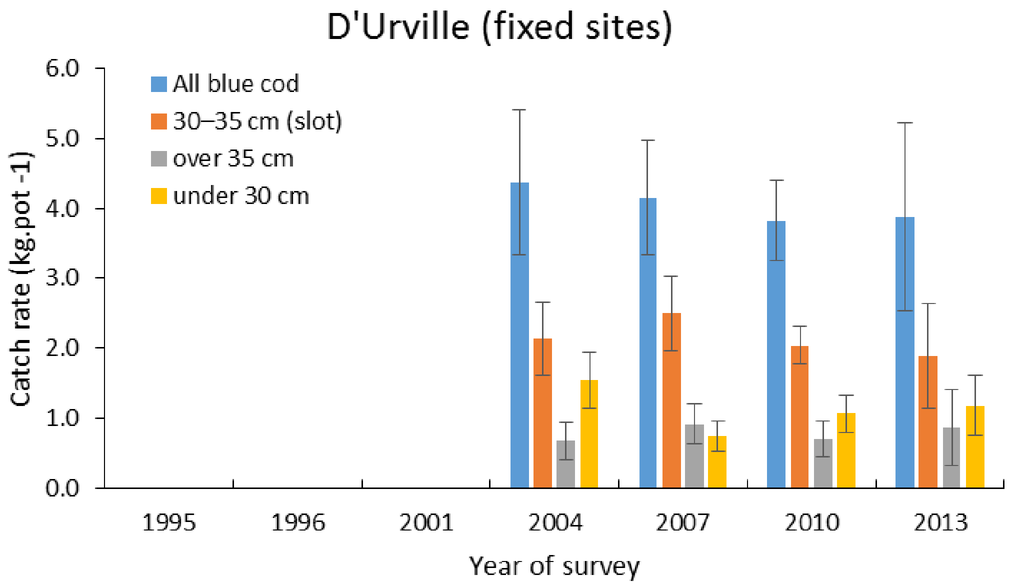


Figure 4: Scaled catch rates of blue cod from D'Urville region fixed sites from 2004 to 2013. Catch rates are shown for all blue cod, slot limit blue cod (30–35 cm), blue cod above the slot limit (over 35 cm) and for pre-recruited blue cod (under 30 cm). Error bars are 95% confidence intervals.

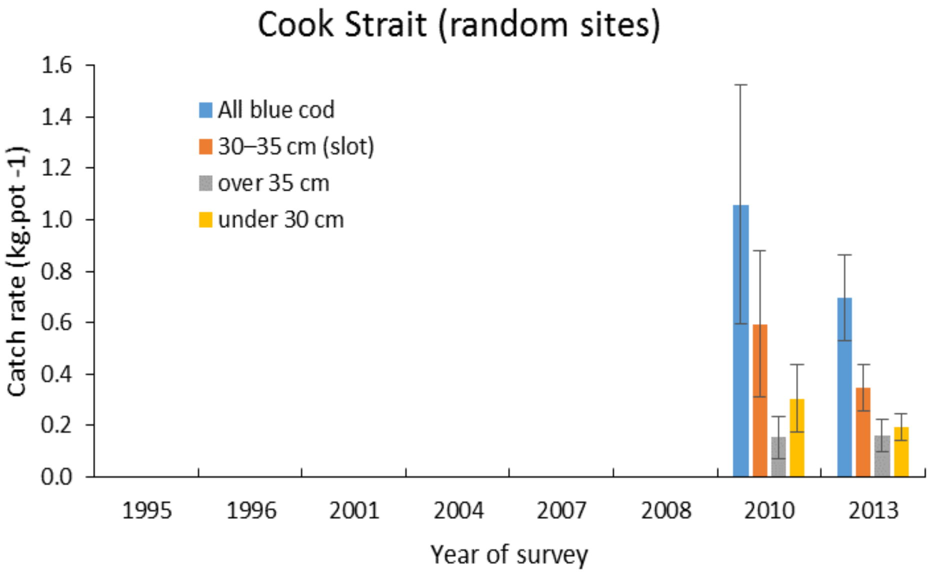


Figure 5: Scaled catch rates of blue cod from Cook Strait region random sites in 2010 and 2013. Catch rates are shown for all blue cod, slot limit blue cod (30–35 cm), blue cod above the slot limit (over 35 cm) and for pre-recruited blue cod (under 30 cm). Error bars are 95% confidence intervals.

Table 9: Summary statistics from standardised blue cod potting surveys in the Marlborough Sounds up to 2013 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 All surveys were fixed site except Cook Strait in 2010 and 2013 which were random. QCH, Queen Charlotte Sound; PEL, Pelorus Sound; DUR, D'Urville; CKST, Cook Strait.

			Mean length (cm)		CPUE (kg.pot^{-1})		
Region	Year	Site type	Male	Female	Overall	range (CV)	Sex ratio (% 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	0–2.60(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%
PEL	1995	–	–	–	–	–	–
	1996	Fixed	29.8	26.2	2.4	1.0–3.3 (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	1.6–3.86(13%)	87%
	2013	Fixed	31.3	27.2	1.95	3.3–4.94(15%)	89%
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%
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%

Banks Peninsula

Results from a fishery independent fixed site potting survey off Banks Peninsula (part of BCO 3) in 2002 estimated total mean catch rates for all blue cod of 2.13 kg/pot hour (CV = 10.8%). This ranged from 0.04 kg/pot hour near Akaroa Harbour entrance to 4.74 kg/pot hour for the offshore stratum located over Pompeys Rock (Beentjes & Carbines 2003). The Banks Peninsula fixed site survey was repeated in 2005 and the estimated total mean catch rate for all blue cod was 4.43 kg/pot hour (CV = 5.7%), strata ranging from 1.02 to 7.27 kg/pot hour (Beentjes & Carbines 2004). The fixed site survey was repeated again in 2008 (Beentjes & Carbines 2009) and the mean catch rates of blue cod (all sizes) ranged from 0.07 kg per pot hour in stratum 2 (Akaroa Harbour entrance), to 5.80 kg per pot hour for offshore stratum 6 located over Le Bons Rocks. Overall mean catch rate and CV were 2.59 kg per pot per hour and 7.7%. For blue cod 30 cm and over (minimum legal size), highest catch rates were also in stratum 6 (5.74 kg per pot hour) and lowest catch rates in stratum 2 (0.04 kg per pot hour). Overall mean catch rate and CV for blue cod 30 cm and over were 2.30 kg per pot hour and 8.3% respectively. In 2008 the sex ratio for inshore strata (1-5) was 2.4:1 (male:female), for offshore strata (6 and 7) 0.98:1, and overall 1.5:1.

In 2012 the fixed site survey was repeated along with a concurrent random stratified site survey (Carbines & Haist 2012a). From fixed sites the mean catch rates of blue cod (all sizes) ranged from 0.60 kg per pot per hour in stratum 2 (Akaroa Harbour entrance), to 6.28 kg per pot per hour for offshore stratum 7 (Pompeys Rocks). Overall mean catch rate and CV were 4.32 kg per pot per hour and 18.09%. For blue cod 30 cm and over, highest catch rates were also in stratum 7 (6.02 kg per pot per hour) and lowest catch rates in stratum 2 (0.32 kg per pot per hour). Overall mean catch rate and CV for blue cod 30 cm and over at fixed sites were 4.08 kg per pot per hour and 19.54% respectively. From random sites the mean catch rates of blue cod (all sizes) ranged from 0.33 kg per pot per hour in stratum 5 (Le Bons Bay area), to 4.09 kg per pot per hour for offshore stratum 6 (Le Bons Rocks). Overall mean catch rate and CV at random stratified sites were 2.97 kg per pot per hour and 31.28%. For blue cod 30 cm and over, highest catch rates were also in stratum 6 (4.30 kg per pot per hour) and lowest catch rates

in stratum 5 (0.28 kg per pot per hour). Overall mean catch rate and CV for blue cod 30 cm and over at random stratified sites were 2.79 kg per pot per hour and 33.59% respectively.
In 2012 at fixed sites the sex ratio for inshore strata (1-5) was 2.1:1 (male:female), for offshore strata (6 and 7) 1.3:1, and overall 1.6:1. Mortality was markedly greater for blue cod inshore compared to those offshore. Estimates are consistent with those from 2002, 2005 and 2008 fixed site surveys. At random stratified sites in 2012 the sex ratio for inshore strata (1-5) was 2.0:1 (male:female), for offshore strata (6 and 7) 1.4:1, and overall 1.8:1. Mortality was also markedly greater for blue cod inshore compared to those offshore.

North Canterbury
A fishery independent fixed site potting survey of blue cod in North Canterbury (part of BCO 3) in 2004/05 produced an overall mean catch rate for all blue cod of 2.45 kg/pot (CV = 8.7%) for Kaikoura and 10.19 kg/pot (CV = 7.3%) for Motunau. The catch rate of blue cod ≥ 30cm was 1.91 kg/pot hour (CV = 7.9%) for Kaikoura and 5.97 kg/pot (CV = 9.8%) for Motunau (Carbines & Beentjes 2006a).

In 2008 (Carbines & Beentjes 2009) mean catch rates of blue cod (all sizes) in the Kaikoura ranged from 1.94 to 20.45 kg per pot per hour. Overall mean catch rate and CV were 5.00 kg per pot per hour and 8.2%. Overall mean catch rate and CV for blue cod 30 cm and over were 4.01 kg per pot per hour and 9.2%. The overall sex ratio was 0.7:1 (male:female), although the two strata with the lowest catches of blue cod were biased in favour of males (1.4:1). Total mortality (*Z*) for Kaikoura blue cod populations in 2007 was estimated between 0.31 and 0.47 and was higher than estimates from the 2004 survey.

In 2008 (Carbines & Beentjes 2009) mean catch rates of blue cod (all sizes) in Motunau ranged from 4.11 to 8.86 kg per pot per hour. Overall mean catch rate and CV were 5.50 kg per pot per hour and 8.8%. For blue cod 30 cm and over (minimum legal size), catch rates ranged from 2.10 to 4.93 kg per pot per hour. Overall mean catch rate and CV for blue cod 30 cm and over were 3.33 kg per pot per hour and 15.7%. The overall sex ratio was 3.2:1 (male:female) and the bias toward males was consistent for all strata. Total mortality (*Z*) for Motunau blue cod populations in 2008 was estimated between 0.53 and 1.12 and remained consistent with the 2005 survey.

The substantial decrease in catch rates in all Motunau strata in 2008 compared to 2005 could not be explained by the relatively weak cohort in 2005; or catchability, as environmental conditions at Motunau were similar for both surveys. The relatively high estimates of mortality and the overall 44% decline in catch rates of legal sized blue cod in Motunau since the 2005 potting survey is of concern.

In 2011/12 the Kaikoura and Motunau fixed site survey were repeated along with concurrent random stratified site surveys (Carbines & Haist 2012b). From the 2011 Kaikoura fixed site survey the overall mean catch rates and CV of blue cod (all sizes) were 3.96 kg per pot per hour and 14.99% (set based estimates). Overall mean catch rate and CV for blue cod 30 cm and over at fixed sites were 2.79 kg per pot per hour and 13.33% respectively. In 2011 the overall mean catch rate and CV from random stratified sites were 2.62 kg per pot per hour and 16.71%. Overall mean catch rate and CV for blue cod 30 cm and over at random stratified sites were 1.72 kg per pot per hour and 16.39% respectively.

From the 2012 Motunau fixed site survey the overall mean catch rates and CV of blue cod (all sizes) were 5.53 kg per pot per hour and 11.95% (set based estimates). Overall mean catch rate and CV for blue cod 30 cm and over at fixed sites were 3.01 kg per pot per hour and 16.62% respectively. In 2012 the overall mean catch rate and CV from random stratified sites in Motunau were 2.97 kg per pot per hour and 20.13%. Overall mean catch rate and CV for blue cod 30 cm and over at Motunau random stratified sites were 1.56 kg per pot per hour and 22.60% respectively.

North Otago
An initial fishery independent fixed site potting survey of blue cod was done in North Otago (also part of BCO 3) in 2005, it produced an overall mean catch rate for all blue cod of 10.14 kg/pot (CV =

5.4%). The catch rate of blue cod 30 cm and over (minimum legal size) was 8.22 kg/pot hour (CV = 5.3%) (Carbines & Beentjes 2006). In 2009 a second fixed site potting survey (Carbines & Beentjes 2011) in North Otago produced mean catch rates of blue cod (all sizes) from 6.21 to 19.88 kg per pot per hour. Overall mean catch rate and CV were 11.51 kg per pot per hour and 6.0%, which was consistent with the 2005 survey catch rates. Overall mean catch rate and CV for blue cod 30 cm and over were 8.89 kg per pot per hour and 6.7%, also similar to the 2005 survey results. The overall sex ratio in 2009 was 2.7:1 (male:female), maintaining the bias toward males observed in 2005. Total mortality (*Z*) for North Otago blue cod populations in 2009 was estimated between 0.25 and 0.36, and were lower than retrospective estimates of Z from the 2005 survey.

In the 2013 North Otago fixed site potting survey (Carbines & Haist 2014b) mean catch rates of blue cod (all sizes) ranged from 2.72 to 8.07 kg per pot per hour. Overall mean catch rate and CV were only 4.96 kg per pot per hour and 12.6%. For blue cod 30 cm and over (minimum legal size), catch rates ranged from 2.02 to 6.42 kg per pot per hour. Overall mean catch rate and CV for blue cod 30 cm and over had dropped to 3.94 kg per pot per hour and 13.7%. The overall sex ratio was 3.3:1 (male:female) and the bias toward males remained consistent for all strata. *Z* for North Otago blue cod populations in 2013 was estimated between 0.22 and 0.36 and remained consistent with the 2009 survey. The substantial decrease in catch rates in 2013 compared to 2005 and 2009 is of concern. Estimates of Z (0.26, recruitment at 6 years) and percent spawner biomass per recruit (F%SPR=34.11%) for the 2013 North Otago fixed site survey are also of some concern.

In the concurrent 2013 North Otago stratified random site potting survey (Carbines & Haist 2014b) mean catch rates of blue cod (all sizes) ranged from 0.94 to 7.46 kg per pot per hour. Overall mean catch rate and CV were 4.16 kg per pot per hour and 13.9%, similar to concurrent fixed sites. For blue cod 30 cm and over, catch rates ranged from 0.46 to 5.28 kg per pot per hour. Overall mean catch rate and CV for blue cod 30 cm and over were 3.01 kg per pot per hour and 14.4%, also similar to fixed sites. The overall sex ratio was 2.13:1 (male:female) and comparatively less bias toward males at random sites. Estimates of *Z* (0.27, recruitment at 6 years) and F%SPR (35.73%) for the 2013 North Otago stratified random site survey were consistent with equivalent estimates from the concurrent fixed site survey.

South Otago

A comparison of fixed and random stratified site potting survey designs was done in three strata off South Otago (also part of BCO 3) in 2009 (Beentjes & Carbines 2011) with similar results. In 2013 a fully stratified random site potting survey of blue cod was done in six strata off South Otago and produced an overall mean catch rate for all blue cod of 6.24 kg/pot (CV = 19.8%) (Carbines & Haist 2014c). The catch rate of blue cod ≥ 30cm was 5.06 kg/pot hour (CV = 23.03%). The overall sex ratio was 1.22:1 (male:female), with the bias toward males occurring mainly inshore, and some offshore strata having up to 58% females. Total mortality estimates for South Otago blue cod populations in 2013 were 0.22 for inshore sites (age of recruitment 9 years) and 0.18 for offshore sites (age of recruitment 8 years). Subsequent estimates of F%SPR were 57.34% for inshore sites and 74.23% for offshore sites.

Paterson Inlet

A fixed site potting survey of blue cod in Paterson Inlet (BCO 5) in 2006 produced an overall mean catch rate for all blue cod of 4.77 kg/pot and CV of 11.9% (set based estimates excluding the marine reserve). The catch rate of blue cod ≥ 33cm (minimum legal size), was 2.91 kg/pot hour (CV = 12.3%). In 2010 the fixed site survey was repeated along with a concurrent random stratified site survey (Carbines & Haist 2014). The overall mean catch rate for all blue cod was 4.21 kg/pot and CV of 11.1% from fixed sites, and 0.82 kg/pot and CV of 24.2% from random stratified sites. The overall mean catch rate for ≥ 33cm blue cod was 3.08 kg/pot and CV of 11.3% from fixed sites, and 0.4 kg/pot and CV of 23.4% from random stratified sites.

Total mortality, estimated from Z-analyses derived from age composition distributions, reduced from 2006 to 2010 at fixed sites. In 2010 higher mean lengths at fixed sites resulted in lower mortality estimates than at random sites, suggesting that comparing mortality estimates between fixed and random stratified site surveys may not be appropriate. Further fixed site and random stratified site surveys were carried out in 2014 and the results are pending.

Dusky Sound

A fixed site potting survey of blue cod in Dusky Sound (part of BCO 5) in 2002 produced an overall mean catch rate for all blue cod of 2.69 kg.pot^{-1} (CV = 6.7%). The catch rate of blue cod ≥ 30 cm was 2.23 kg/pot hour (CV = 7.2%). Catch rates for all blue cod and for fish ≥ 30 cm were highest on the open coast (i.e., at the entrance to the Sound), being 8.42 and 5.46 kg.pot^{-1} respectively (Carbines & Beentjes 2003). A fixed site survey in 2008 resulted in catch rates of 4.2 kg.pot^{-1} (CV = 5.8%) for all blue cod, considerably higher than in 2002 and again highest catch rates were in the open coast stratum (Carbines & Beentjes 2011). Full fixed site and full random site surveys were carried out in 2014 and the results are pending.

Other potting survey analyses

Carbines *et al.* (2007) and Beentjes (2012) have generated age frequency distributions using age length keys derived from otolith collected during potting surveys. Using catch-at-age, estimates of total mortality (Z) and Spawner Biomass per Recruit (at a range of age-at-full recruitment) were calculated and compared in conjunction with relative abundance estimates (CPUE [kg.pot^{-1}]) from potting surveys conducted in Kaikoura, Motunau, Banks Peninsula, North Otago, Foveaux Strait, Paterson Inlet and Dusky Sound (Tables 10-13).

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.

Table 10: Summary statistics from standardised blue cod potting surveys done in the northeast coast of the South Island (BCO 3). CPUE – catch per unit effort (kg/pot); CV – coefficient of variation; *Z* – Total mortality; $F_{\%SPR}$ estimated for age at full recruitment = 6 years and *M* = 0.14. Mean length, mean age and *Z* are from population scaled length and age. Mean length, mean age, *Z* and $F_{\%SPR}$ from Beentjes (2012). CPUE taken from Carbines & Beentjes (2006; 2009).

	Mean length		Mean age		Survey CPUE kg.pot^{-1}	CPUE range (CV) CV is pot based or set based*	Mean Z (MWCV around age) * revised are at full recruitment	$F_{\%SPR}$
Area/Year	Female	Male	Female	Male				
				North Canterbury				
Kaikoura								
2004 (fixed sites)	30.3	32.5	8.4	7.8	2.45	0.60 – 7.97 (8.7%)	0.30 (26%)	36.9%
2007 (fixed sites)	29.8	32.5	7.0	6.9	5.0	1.91–20.45 (8.2%)	0.35 (24%)	16.1%
2011 (fixed sites)	27.4	29.2	9.1	8.1	3.96	2.14 – 11.44 (15.0%*)	0.27 (19%) *11	51.8%
2011 (random sites)	28.4	29.4	9.9	8.2	2.62	0.61 – 8.22 (16.7%*)	0.26 (17%) *11	52.2%
Motunau								
2005 (fixed sites)	25.7	29.6	5.7	6.3	10.2	9.53 – 15.37 (7.3%)	0.80 (42%)	13.6%
2008 (fixed sites)	25.2	29.3	5.1	6.2	5.5	4.1–8.9 (8.8%)	0.60 (18%)	30.3%
2012 (fixed sites)	24.5	28.8	6.4	8.0	5.53	4.43–8.704 (12.0%*)	0.39 (18%) *11	45.4%
2012 (random sites)	23.4	28.3	5.9	7.6	2.97	1.81–6.95 (20.1%*)	0.42 (19%) *11	43.5%
				Banks Peninsula				
All strata								
2002	32.3	31.6	9.1	7.4	2.1	0.04 –4.74	–	–
2005	32.4	35.5	8.9	8.6	4.4	1.02-7.27(5.7%)		

Table 10 [Continued]

Area/Year	Mean length Female	Mean length Male	Mean age Female	Mean age Male	Survey CPUE kg.pot^{-1}	CPUE range (CV) CV is pot based or set based*	Mean Z (MWCV around age) * revised are at full recruitment	$F_{\%SPR}$
					Banks Peninsula			
2008	32.5	35.5	9.2	8.0	2.6	0.07-5.80 (7.7%)		
2012 (random sites, excl. MR)	27.9	31.6			1.29	0.33 –2.89 (16.3%*)	0.13 (15%) *9	100%
Inshore								
2002	25.4	28.3	5.0	5.6	*	0.04 – 2.61	0.69 (23%)	13.8%
2005	27.2	32.7	5.8	6.9	*	1.02 – 4.16	0.48 (24%)	19.7%
2008	25.5	29.8	4.5	5.1	*	0.07 – 2.3	0.54 (23%)	18.0%
2012 (fixed sites, excl. MR)	24.7	28.8	5.4	6.6	1.33	0.60 – 1.81 (13.2%*)	0.62 (21%) *8	24.5%
2012 (random sites, excl. MR)	23.0	27.6	4.9	6.1	1.29	0.33 – 2.89 (16.3%*)	0.61 (22%) *8	24.8%
Offshore								
2002	36.6	37.6	11.6	10.9	*	2.04 - 4.74	0.14 (45%)	100%
2005	37.4	41.2	11.7	12.1	*	5.68 - 7.27	0.17 (45%)	90.6%
2008	35.6	41.8	11.7	11.9	*	3.13 – 5.80	0.15 (47%)	90.8%
2012 (fixed sites, excl. MR)	33.0	36.9	11.4	12.0	5.74	3.49 – 6.28 (20.0%*)	0.15 (14%) *9	92.4%
2012 (random sites, excl. MR)	34.1	39.3	12.7	13.4	3.77	3.69 – 4.09 (36.3%*)	0.12 (15%) *9	100%

* The overall CPUE value for Banks Peninsula were not reported specifically for these inshore and offshore strata but, for all strata combined (Beentjes & Carbines 2003; 2006; 2009).

Table 11: Summary statistics from standardised blue cod potting surveys done in the southeast coast of the South Island (BCO 3). CPUE – catch per unit effort (kg/pot); CV – coefficient of variation; *Z* – Total mortality; $F_{\%SPR}$ estimated for age at full recruitment = 6 years and M= 0.14. Mean length, mean age and *Z* are from population scaled length and age. North Otago survey - mean length, mean age, *Z* and $F_{\%SPR}$ from Beentjes (2012) and Carbines & Haist (2014b), CPUE from Carbines & Beentjes (2006; 2011) and Carbines & Haist (2014b). South Otago survey - 2009 from Beentjes & Carbines (2011) and 2013 from Carbines & Haist (2014c).

Area/Year	Mean length Female	Mean length Male	Mean age Female	Mean age Male	Survey CPUE (kg.pot^{-1})	CPUE range (CV) CV is pot-based or set-based*	Mean Z (MWCV around age)	$F_{\%SPR}$
					North Otago			
2005 (no stratum 6) (fixed sites)	27.8	32.8	6.2	7.5	10.1	7.45 - 14.5 (5.4%)	0.44 (19%)	18.7%
2009 (incl. stratum 6) (fixed sites)	27.4	32.3	7.0	8.3	11.5	6.21 – 19.88 (*6.8%)	0.30 (23%)	31.7%
2013 (incl. stratum 6) (fixed sites)	26.9	31.6	7.9	8.6	5.0	2.72 – 8.07 (*12.6.8%)	0.46 (25%)	34.1%
2013 (incl. stratum 6) (random sites)	27.6	30.7	7.9	8.1	4.2	0.94 – 7.46 (*13.9%)	0.43 (23%)	35.7%
					South Otago			
2009** (fixed sites)	29.4	33.6	8.7	9.7	9.7	3.3–16.9 (*17.1%)	0.23 (23%)	50.3%
2009 (random sites)	23.7	29.0	6.0	7.8	4.4	1.2 – 6.0 (*17.8%)	0.28 (26%)	39.4%
2013 (random sites)	25.5	31.9	6.3	8.4	6.2	0.8 – 7.4 (*19.9%)	0.21 (27%)	74.2%

Table 12: Summary statistics from standardised blue cod potting surveys done in the south and southwest coast of the South Island (BCO 5). CPUE – catch per unit effort (kg/pot); CV – coefficient of variation; *Z* – Total mortality; $F_{\%SPR}$ estimated for age at full recruitment = 6 years and $M = 0.14$. Mean length, mean age and Z are from population scaled length and age. Foveaux Strait survey- all results from Carbines & Beentjes 2012; Paterson Inlet survey -all results from Carbines 2007, Carbines & Haist 2014; Dusky Sound survey - mean length, mean age, *Z*, and $F_{\%SPR}$ from Beentjes (2012) and CPUE from Carbines & Beentjes (2003; 2011).

	Mean length		Mean age		CPUE (kg.pot^{-1})	CPUE range (CV) CV is pot-based or set-based*	Mean Z (MWCV around age) * revised are at full recruitment	$F_{\%SPR}$
Area/Year	Female	Male	Female	Male				
					Foveaux Strait			
2010 (random sites)	27.8	30.5	6.9	7.1	4.8	1.17 – 14.14 (*11.3%)	0.41 (23%)	35.3%
					Paterson Inlet			
2006 (fixed sites) (excl. marine reserve)	26.9	32.8	6.4	7.9	4.8	1.47 – 8.42 (*11.9%)	0.63 *8	22.1%
2010 (fixed sites) (excl. marine reserve)	27.5	32.2	6.9	8.5	3.2	1.43 – 3.29 (11.3%)	0.37 *8	40.4%
2010 (random sites) (excl. marine reserve)	25.9	29.0	6.2	7.1	0.4	0.22 – 0.53 (24.2%)	0.43 *8	36.9%
					Dusky Sound			
2002 (fixed sites)	29.9	34.7	7.0	7.7	2.69	1.28–8.42 (6.7%)	0.32 (17%)	34.3%
2008 (fixed sites) (excl. marine reserve)	32.2	37.9	7.9	10.1	4.20	2.49 – 8.13 (*5.5%)	0.27 (24%)	42.4%

Table 13: Total mortality estimates (*Z*) and 95% confidence intervals (CI) of blue cod for each blue cod potting survey, and corresponding spawner per recruit estimates ($F_{SPR\%}$). Fishing mortality (*F*) is calculated from $F = Z - M$ where natural mortality (*M*) is set at 0.14. MR, marine reserve; ageR, age-at-full recruitment to the fishery; –, no estimate made (Beentjes 2012) [Continued on next page].

Survey Area	**Year**	**Age R**	**Z**	**lowCI**	**upCI**	**F**	***F%SPR***
Dusky Sound	2002	5	0.30	0.23	0.40	0.16	$F_{37.1\%}$
		6	0.32	0.24	0.41	0.18	$F_{34.3\%}$
		7	0.31	0.23	0.4	0.17	$F_{35.7\%}$
		8	0.28	0.21	0.37	0.14	$F_{40.4\%}$
		9	0.23	0.17	0.29	0.09	$F_{51.9\%}$
		10	0.23	0.17	0.30	0.09	$F_{51.0\%}$
Dusky Sound (excl. MR)	2008	5	0.22	0.17	0.29	0.08	$F_{55.5\%}$
		6	0.27	0.2	0.35	0.13	$F_{42.4\%}$
		7	0.29	0.21	0.38	0.15	$F_{38.8\%}$
		8	0.32	0.23	0.41	0.18	$F_{34.4\%}$
		9	0.36	0.27	0.46	0.22	$F_{30.0\%}$
		10	0.35	0.26	0.46	0.21	$F_{31.0\%}$
Dusky (MR)		5	0.19	0.14	0.24	0.05	$F_{66.7\%}$
		6	0.22	0.16	0.28	0.08	$F_{55.1\%}$
		7	0.24	0.17	0.31	0.1	$F_{49.2\%}$
		8	0.28	0.2	0.36	0.14	$F_{40.5\%}$
		9	0.33	0.24	0.44	0.19	$F_{33.2\%}$
		10	0.36	0.26	0.47	0.22	$F_{30.0\%}$

Table13 [Continued]

Survey Area	Year	Age R	Z	lowCI	upCI	F	*F%SPR*
North Otago	2005	5	0.35	0.25	0.47	0.21	$F_{25.1\%}$
		6	0.44	0.31	0.58	0.3	$F_{18.7\%}$
		7	0.47	0.33	0.63	0.33	$F_{17.3\%}$
		8	0.54	0.38	0.75	0.4	$F_{14.8\%}$
		9	0.62	41%	0.89	0.48	$F_{12.8\%}$
		10	0.52	0.33	0.76	0.38	$F_{15.4\%}$
North Otago	2009	5	0.25	0.18	0.34	0.11	$F_{41.2\%}$
		6	0.30	0.22	0.4	0.16	$F_{31.7\%}$
		7	0.35	0.25	0.45	0.21	$F_{25.6\%}$
		8	0.41	0.29	0.54	0.27	$F_{20.9\%}$
		9	0.50	0.36	0.67	0.36	$F_{16.6\%}$
		10	0.56	0.39	0.77	0.42	$F_{14.7\%}$
North Otago	2013	5	0.22	0.16	0.30	0.08	$F_{62.3\%}$
		6	0.26	0.19	0.35	0.12	$F_{52.9\%}$
		7	0.31	0.22	0.44	0.17	$F_{45.2\%}$
		8	0.36	0.26	0.50	0.22	$F_{40.3\%}$
		9	0.39	0.29	0.54	0.25	$F_{38.2\%}$
		10	0.46	0.33	0.66	0.32	$F_{34.1\%}$
South Otago	2013	5	0.17	0.13	0.24	0.03	$F_{76.8\%}$
		6	0.18	0.14	0.25	0.04	$F_{70.9\%}$
		7	0.20	0.15	0.27	0.06	$F_{63.6\%}$
		8	0.21	0.16	0.28	0.07	$F_{61.0\%}$
		9	0.21	0.16	0.29	0.07	$F_{60.1\%}$
		10	0.24	0.18	0.33	0.10	$F_{50.1\%}$
Banks Peninsula (all strata) (fixed sites)	2002	5	0.22	0.16	0.28	0.08	$F_{52.6\%}$
		6	0.19	0.14	0.25	0.05	$F_{64.6\%}$
		7	0.18	0.13	0.23	0.04	$F_{69.8\%}$
		8	0.17	0.13	0.23	0.03	$F_{75.7\%}$
		9	0.18	0.14	0.24	0.04	$F_{69.8\%}$
		10	0.19	0.14	0.26	0.05	$F_{64.6\%}$
inshore (fixed sites)	5		0.65	0.43	0.93	0.51	$F_{14.6\%}$
	6		0.69	0.45	0.96	0.55	$F_{13.8\%}$
	7		0.47	0.3	0.69	0.33	$F_{20.1\%}$
	8		0.59	0.34	0.89	0.45	$F_{16.0\%}$
	9		0.60	0.33	1	0.46	$F_{15.8\%}$
	10		0.78	0.38	1.4	0.64	$F_{12.5\%}$

Table13 [Continued]

Survey Area	**Year**	**Age R**	**Z**	**lowCI**	**upCI**	**F**	***F%SPR***
offshore		5	0.14	0.11	0.18	0	$F_{100\%}$
(fixed sites)		6	0.14	0.1	0.18	0	$F_{100\%}$
		7	0.15	0.11	0.2	0.01	$F_{90.6\%}$
		8	0.15	0.11	0.2	0.01	$F_{90.6\%}$
		9	0.17	0.13	0.22	0.03	$F_{75.7\%}$
		10	0.18	0.14	0.24	0.04	$F_{69.8\%}$
Banks Peninsula (all strata)	2005	5	0.23	0.16	0.29	0.09	$F_{49.4\%}$
(fixed sites)		6	0.23	0.17	0.3	0.09	$F_{49.4\%}$
		7	0.23	0.17	0.31	0.09	$F_{49.4\%}$
		8	0.23	0.17	0.31	0.09	$F_{49.4\%}$
		9	0.23	0.16	0.3	0.09	$F_{49.4\%}$
		10	0.21	0.15	0.28	0.07	$F_{56.1\%}$
inshore		5	0.43	0.31	0.58	0.29	$F_{22.2\%}$
(fixed sites)		6	0.48	0.33	0.67	0.34	$F_{19.7\%}$
		7	0.53	0.36	0.75	0.39	$F_{17.7\%}$
		8	0.62	0.41	0.89	0.48	$F_{15.2\%}$
		9	0.63	0.39	0.91	0.49	$F_{15.0\%}$
		10	0.64	0.36	0.99	0.5	$F_{14.8\%}$
offshore		5	0.13	0.1	0.17	0.01	$F_{100\%}$
(fixed sites)		6	0.15	0.11	0.19	0.01	$F_{90.6\%}$
		7	0.16	0.12	0.21	0.02	$F_{82.6\%}$
		8	0.18	0.13	0.23	0.04	$F_{69.8\%}$
		9	0.18	0.13	0.24	0.04	$F_{69.8\%}$
		10	0.19	0.13	0.24	0.05	$F_{64.6\%}$
Banks Peninsula (all strata)	2008	5	0.17	0.13	0.22	0.03	$F_{76.1\%}$
(fixed sites)		6	0.16	0.12	0.20	0.02	$F_{82.9\%}$
		7	0.17	0.12	0.22	0.03	$F_{76.1\%}$
		8	0.17	0.12	0.22	0.03	$F_{76.1\%}$
		9	0.16	0.12	0.21	0.02	$F_{82.9\%}$
		10	0.17	0.13	0.23	0.03	$F_{76.1\%}$
inshore		5	0.54	0.36	0.76	0.40	$F_{18.0\%}$
(fixed sites)		6	0.54	0.35	0.80	0.40	$F_{18.0\%}$
		7	0.69	0.43	1	0.55	$F_{14.4\%}$
		8	0.74	0.4	1.20	0.60	$F_{13.6\%}$
		9	0.58	0.29	1.07	0.44	$F_{16.8\%}$
		10	0.86	0.35	1.9	0.72	$F_{12.1\%}$

Table13 [Continued]

Survey Area	Year	Age R	Z	lowCI	upCI	F	*F%SPR*
offshore		5	0.14	0.1	0.17	0	$F_{100\%}$
(fixed sites)		6	0.15	0.11	0.19	0.01	$F_{90.8\%}$
		7	0.15	0.11	0.19	0.01	$F_{90.8\%}$
		8	0.16	0.12	0.21	0.02	$F_{82.7\%}$
		9	0.17	0.12	0.21	0.03	$F_{76.1\%}$
		10	0.17	0.13	0.22	0.03	$F_{76.1\%}$
Kaikoura	2004	5	0.27	0.20	0.36	0.13	$F_{42.1\%}$
		6	0.30	0.22	0.39	0.16	$F_{36.9\%}$
		7	0.30	0.22	0.40	0.16	$F_{36.9\%}$
		8	0.28	0.20	0.37	0.14	$F_{40.2\%}$
		9	0.26	0.19	0.35	0.12	$F_{44.1\%}$
		10	0.27	0.19	0.37	0.13	$F_{42.1\%}$
Kaikoura	2007	5	0.31	0.22	0.42	0.17	$F_{35.1\%}$
		6	0.35	0.25	0.47	0.21	$F_{30.3\%}$
		7	0.43	0.31	0.59	0.29	$F_{23.9\%}$
		8	0.47	0.32	0.63	0.33	$F_{21.8\%}$
		9	0.41	0.27	0.57	0.27	$F_{25.2\%}$
		10	0.33	0.22	0.46	0.19	$F_{32.5\%}$
Banks Peninsula (all strata,excluding marine reserve)	2012	5	0.15	0.12	0.20	0.01	$F_{90.5\%}$
(fixed sites)		6	0.16	0.13	0.22	0.02	$F_{82.5\%}$
		7	0.17	0.13	0.23	0.03	$F_{78.2\%}$
		8	0.16	0.13	0.22	0.02	$F_{82.4\%}$
		9	0.15	0.11	0.20	0.01	$F_{92.4\%}$
		10	0.16	0.12	0.21	0.02	$F_{87.9\%}$
inshore(excluding marine reserve)		5	0.39	0.27	0.56	0.25	$F_{35\%}$
(fixed sites)		6	0.47	0.33	0.70	0.33	$F_{29.9\%}$
		7	0.60	0.40	0.91	0.46	$F_{25.2\%}$
		8	0.62	0.42	0.93	0.48	$F_{24.5\%}$
		9	0.46	0.30	0.70	0.32	$F_{30.6\%}$
		10	0.47	0.30	0.74	0.33	$F_{29.7\%}$
offshore		5	0.13	0.10	0.17	0.00	$F_{100\%}$
(fixed sites)		6	0.15	0.11	0.20	0.01	$F_{95.9\%}$
		7	0.15	0.12	0.21	0.01	$F_{88.8\%}$
		8	0.15	0.12	0.21	0.01	$F_{89.4\%}$
		9	0.15	0.12	0.20	0.01	$F_{92.4\%}$
		10	0.16	0.12	0.21	0.02	$F_{86.7\%}$
Banks Peninsula (all strata,excluding marine reserve)	2012	5	0.14	0.10	0.18	0.00	$F_{100\%}$
(random sites)		6	0.14	0.11	0.19	0.00	$F_{97\%}$
		7	0.15	0.11	0.20	0.01	$F_{94.8\%}$

Table13 [Continued]

Survey Area	Year	Age R	Z	lowCI	upCI	F	*F%SPR*
Banks peninsula [Continued]		8	0.14	0.11	0.19	0.00	$F_{100\%}$
		9	0.13	0.10	0.17	0.00	$F_{100\%}$
		10	0.13	0.10	0.18	0.00	$F_{100\%}$
Inshore (excluding marine reserve)		5	0.42	0.29	0.63	0.28	$F_{32.5\%}$
(random sites)		6	0.48	0.34	0.71	0.34	$F_{29.1\%}$
		7	0.61	0.41	0.91	0.47	$F_{24.8\%}$
		8	0.61	0.41	0.93	0.47	$F_{24.8\%}$
		9	0.44	0.29	0.69	0.30	$F_{31.2\%}$
		10	0.49	0.31	0.78	0.35	$F_{28.9\%}$
Offshore		5	0.11	0.09	0.15	0.00	$F_{100\%}$
(random sites)		6	0.12	0.09	0.16	0.00	$F_{100\%}$
		7	0.13	0.10	0.17	0.00	$F_{100\%}$
		8	0.13	0.10	0.16	0.00	$F_{100\%}$
		9	0.13	0.10	0.17	0.00	$F_{100\%}$
		10	0.13	0.10	0.17	0.00	$F_{100\%}$
Kaikoura	2004	5	0.27	0.20	0.36	0.13	$F_{42.1\%}$
(fixed sites)		6	0.30	0.22	0.39	0.16	$F_{36.9\%}$
		7	0.30	0.22	0.40	0.16	$F_{36.9\%}$
		8	0.28	0.20	0.37	0.14	$F_{40.2\%}$
		9	0.26	0.19	0.35	0.12	$F_{44.1\%}$
		10	0.27	0.19	0.37	0.13	$F_{42.1\%}$
Kaikoura	2007	5	0.31	0.22	0.42	0.17	$F_{35.1\%}$
(fixed sites)		6	0.35	0.25	0.47	0.21	$F_{30.3\%}$
		7	0.43	0.31	0.59	0.29	$F_{23.9\%}$
		8	0.47	0.32	0.63	0.33	$F_{21.8\%}$
		9	0.41	0.27	0.57	0.27	$F_{25.2\%}$
		10	0.33	0.22	0.46	0.19	$F_{32.5\%}$
Kaikoura	2011	5	0.23	0.17	0.33	0.09	$F_{59.4\%}$
(fixed sites)		6	0.24	0.17	0.34	0.10	$F_{57.3\%}$
		7	0.27	0.20	0.37	0.13	$F_{51.3\%}$
		8	0.27	0.19	0.38	0.13	$F_{51.5\%}$
		9	0.24	0.18	0.33	0.10	$F_{57.1\%}$
		10	0.25	0.18	0.35	0.11	$F_{54.2\%}$
		11	0.27	0.19	0.39	0.13	$F_{51.8\%}$
Kaikoura	2011	5	0.21	0.15	0.29	0.07	$F_{65.8\%}$
(random sites)		6	0.22	0.16	0.30	0.08	$F_{62.7\%}$
		7	0.24	0.18	0.33	0.10	$F_{57.2\%}$
		8	0.25	0.18	0.33	0.11	$F_{55.9\%}$
		10	0.25	0.18	0.35	0.11	$F_{55.0\%}$
		11	0.26	0.19	0.37	0.12	$F_{52.2\%}$
Motunau	2005	5	0.53	0.33	0.77	0.39	$F_{19.5\%}$
(fixed sites)		6	0.80	0.47	1.23	0.66	$F_{13.6\%}$
		7	0.74	0.41	1.17	0.6	$F_{14.5\%}$

Table13 [Continued]

Survey Area	Year	Age R	Z	lowCI	upCI	F	*F%SPR*
Motunau		8	0.73	0.41	1.26	0.59	$F_{14.6\%}$
(fixed sites)		9	1.34	0.63	2.26	1.2	$F_{9.0\%}$
		10	1.13	0.48	2.13	0.99	$F_{10.8\%}$
Motunau	2008	5	0.53	0.37	0.72	0.39	$F_{18.2\%}$
(fixed sites)		6	0.60	0.42	0.83	0.46	$F_{16.1\%}$
		7	0.71	0.48	0.98	0.57	$F_{13.8\%}$
		8	0.79	0.49	1.16	0.65	$F_{12.6\%}$
		9	0.95	0.52	1.49	0.81	$F_{11.0\%}$
		10	1.12	0.50	2.29	0.98	$F_{9.8\%}$
Motunau	2012	5	0.29	0.21	0.41	0.15	$F_{53.9\%}$
(fixed sites)		6	0.34	0.23	0.48	0.20	$F_{49.1\%}$
		7	0.33	0.23	0.48	0.19	$F_{49.6\%}$
		8	0.38	0.27	0.54	0.24	$F_{46.1\%}$
		9	0.37	0.26	0.54	0.23	$F_{46.4\%}$
		10	0.45	0.31	0.64	0.31	$F_{42.2\%}$
		11	0.39	0.28	0.55	0.25	$F_{45.4\%}$
Motunau	2012	5	0.31	0.22	0.44	0.17	$F_{52.1\%}$
(random sites)		6	0.33	0.23	0.49	0.19	$F_{49.4\%}$
		7	0.32	0.22	0.46	0.18	$F_{51.1\%}$
		8	0.35	0.24	0.52	0.21	$F_{47.8\%}$
		9	0.36	0.25	0.53	0.22	$F_{47.2\%}$
		10	0.43	0.30	0.62	0.29	$F_{42.8\%}$
		11	0.42	0.28	0.60	0.28	$F_{43.5\%}$

4.2 BCO 3

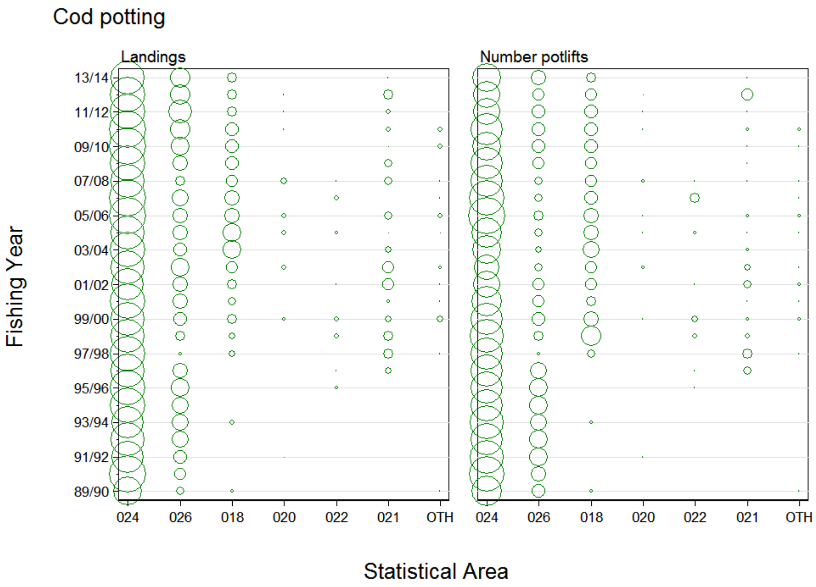


Figure 6: Distribution of landings and number of potlifts for the cod potting method by statistical area and fishing year from trips which landed BCO 3. Circles are proportional within each panel: [catches] largest circle = 95 t in 10/11 for 024; [number potlifts] largest circle = 9641 pots in 05/06 for 024 (Starr & Kendrick in prep).

A standardised CPUE analysis was conducted in 2015 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 25 years from 1989–90 to 2013–14, 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 25 years (Figure 6). As found in the previous 2010 analysis, 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.

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. Two data sets were prepared: one which defined the data set by only selecting trips which fished exclusively in the Areas 018–024 & 026 (designated “statarea”) and the other restricted to trips which exclusively landed BCO 3 (designated “Fishstock”). There was no difference in the CPUE trends estimated by these two data sets. Each 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 68 vessels representing 85% of the landings for the “statarea” data set). 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. Because there was also an estimated catch of blue cod recorded with nearly every effort record, it was also possible to repeat the standardised analysis based on estimated catch as well as the landed catch. This was done to provide a check on the methods used to groom the landing data of the spurious RCO 3 landing data. Only a lognormal model based on successful catch records was used as there were too few unsuccessful fishing events to justify pursuing a binomial model.

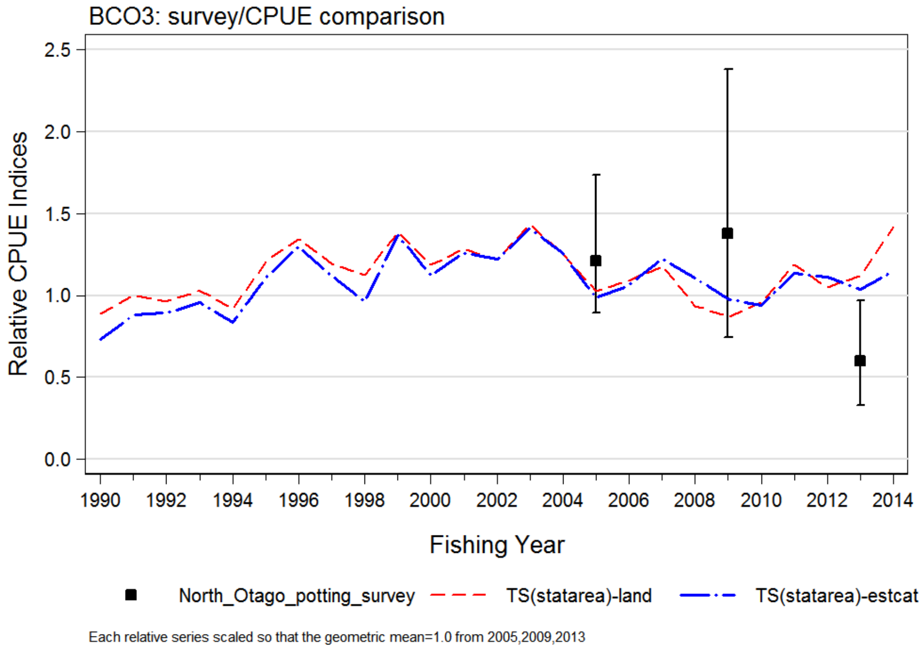


Figure 7: Comparison of BCO 3 standardised series based on landed greenweight catch data and estimated catch with the three observations from the North Otago potting survey (Starr & Kendrick in prep).

The lognormal standardised model for BCO 3 (Figure 7) showed a declining trend in commercial CPUE from 2002-03 to 2008–09 after a relatively long period of stability, followed by an increasing trend to 2013–14. 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 WG agreed in 2015 that the series based on landed catch was more reliable and consistent with other CPUE analyses done for the Southern Inshore WG.

During the period 2002–03 to 2013–14, commercial catches in all of BCO 3 exceeded the TACC by 5%. As 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), both the CPUE and catch trends for BCO 3 are strongly influenced by the catches in these areas. Therefore, the Working Group agreed that the CPUE trend presented for the Daily Landed Catch analysis in Figure 7 is representative of the southerly portion of BCO 3 (Areas 024 and 026) and is not applicable to those parts of BCO 3 north of Area 024.

Establishing BMSY compatible reference points

The Working Group accepted 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 (Bentley & Kendrick in prep). The analysis was based on a Weibull model of positive allocated landed catches from a core fleet of vessels. This methodology differs from the previous CPUE standardisation (Kendrick & Bentley 2011) which used a standardisation model with the assumption of a lognormal error distribution. 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. 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 to, the indices from the latter part of the series.

Overall, the annual indices from the standardisation model have fluctuated without trend since the late 1990s (Figure 8). From 2006/07 to 2012/13 there was a decline in the index, although this was almost fully reversed by a large increase in the index in 2013/14 The indices from the 1990s are lower than those during the latter part of the series and for the aforementioned reasons may not be fully comparable.

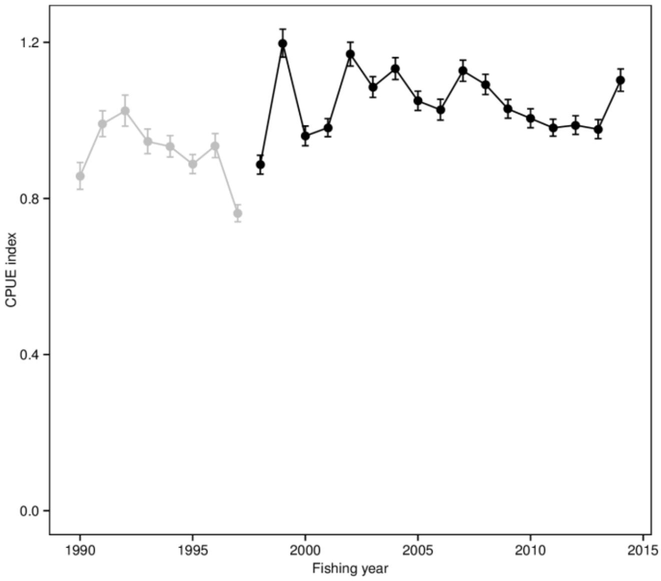


Figure 8: Standardised CPUE index for BCO 4 based on records of positive BCO catch by core vessels , 1989-90 to 2013-14 (Bentley & Kendrick 2015). The indices for the fishing years up to, and including, 1996/97 are considered to be less reliable due to possible changes in fleets, fishing methods and/or reporting practices and may not be comparable to the latter part of the series.

4.4 BCO 5 (Southland)

The first fully quantitative stock assessment for blue cod in BCO 5 was carried out in 2013. A custom-built length-based model, which used Bayesian estimation, was fitted separately to data from Statistical Areas 25, 27 and 30.

4.4.1 Methods

4.4.1.1 Model structure

The stock assessment model is length-based and sex-specific, using growth transition matrices calculated from the von Bertalanffy growth models to transition fish through size bins. This approach is similar to that used for New Zealand rock lobster (Haist et al. 2009).

The model is conditioned on the landings for the three modelled fisheries (commercial line, commercial pot, and recreational line), using a Newton-Raphson algorithm to calculate fishing mortality rates for each sex, length bin and fishery. Each fishery is modelled with a selectivity ogive and a retention ogive (Table 14). Catch and catch LFs are a function of the selectivity ogive and landings and landings LFs are a function of the product of selectivity and retention ogives. Separate pre-1993 and post-1992 commercial and recreational fishery retention functions account for the change in minimum legal size (MLS) in 1993. Separate pre-1993 and post-1993 commercial fishery selectivity functions account for change in mesh size regulation at that time, with the assumption that the selectivity change was gradual over 5 years. Discard mortality is assumed for fish that are caught but not landed.

Sex change is modelled as a dynamic process, with the proportion of females (at length) transitioning to males a function of male depletion. Spawning stock biomass (SSB) is measured as the total mature biomass.

A Beverton-Holt stock recruitment relationship is assumed. The standard deviation of recruitment residuals (log-scale) is fixed at 0.6 and the steepness prior is beta distributed (mean= 0.75, std. dev.=0.10). Recruitment residuals are estimated for 1980 to 2010. Fish recruit to the model at age 0+ with 65% of fish recruiting as females.

Natural mortality is modelled assuming a normal prior distribution with a mean of 0.14 and a standard deviation of 0.015. The majority of the prior density is in the range of 0.11 to 0.17, which is the range of uncertainty considered in blue cod potting survey analyses (Beentjes & Francis, 2011).

The populations are initialised at unexploited equilibrium conditions in 1900.

The assumed prior distributions for model parameters are given in Table 15.

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. DHN = double half normal.

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 <=1992	DHN	Mesh size trial LF
Commercial pot fishery >=1997	Logistic	Logbook & Shed sampling LF
Recreational fishery	DHN	Recreational catch LF
Survey	DHN	Survey LF
Retention		
Commercial line fishery	Knife-edge	MLS (330 mm)
Commercial pot fishery <=1992	Knife-edge	MLS
Commercial pot fishery >=1993	Knife-edge	MLS
Recreational fishery <=1992	Logistic	Recreational landings LF
Recreational fishery >=1993	Logistic	Shifted +3 cm from <=1992 retention curve

Table 15: Assumed prior distributions for model parameters.

Model parameters	Distribution	Parameters
M	Normal	Mean: 0.14 Std. dev: 0.015
S-R steepness	Beta (defined on 0.2 – 1.0)	Mean: 0.75 Std. dev: 0.10
Recruitment variation	Normal-log	Std. dev: 0.60
1995 sex-change *dmax*	Normal-log	Mean: ln(410) Std. dev: 0.05

4.4.1.2 Data

Separate data sets were compiled and analysed for Statistical Areas 25, 27, and 30. The data available for each of these areas differs, and little data are available for the remainder of the BCO 5 Statistical Areas. Combined, Statistical Areas 25, 27 and 30 represent 92% of the recent commercial fishery landings. The general categories of data used in the stock assessment models include: catch and landings; fishery and survey length frequency data (LFs); abundance indices; and biological information on growth, maturation, and sex change.

Historical time series of BCO 5 landings were constructed for 3 gear types: commercial hand line fishing, commercial pot fishing, and recreational 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.

Commercial landings data are available beginning in 1931 (Warren et al. 1997) and these were linearly decreased 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 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 through 2011. The shed sampling was sex-specific while the logbook sampling was not. It is unclear whether samples collected for shed sampling were of the entire catch or of landings. Mean size of fish from the shed samples were smaller than those from the logbook program (for Areas 25 and 27, there were not shed samples from Area 30), which may have resulted because the shed samples were not representative of the entire fishing area. The shed and logbook LF data are each fitted to model predictions of the average commercial catch size distribution for 2009 through 2011.

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, and Halfmoon Bay) and a logbook survey of charter and recreational vessels. Blue cod measured through the boat ramp program were assumed to represent the landings and fish measured through the logbook program were assumed to represent the catch.

Length frequency data from a blue cod mesh size selectivity study, conducted by MAF in 1986 at Bluff and Stewart Island, were available. The LFs 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 prior to the 1992 and 1994 pot regulation changes. In the model, this data is fitted to the predicted average size distribution of the 1985 through 1992 potting fishery.

LF data is also available from random stratified potting surveys conducted in Areas 25 and 30 in 2010. These surveys provide not only length frequency data, but also are one of the few information sources

about the population sex structure. These data are fitted in the model assuming domed survey selectivity.
Three sets of data are available that can inform stock abundance estimates: fishery-based standardised CPUE estimates (Table 16), survey-based estimates of total mortality (*Z*), and a drift underwater video survey (DUV) estimate of absolute stock abundance.

Z estimates were derived from the 2010 Area 25 and Area 30 random-stratified potting survey data using standard methods described in Beentjes and Francis (2011). The distributions of Z estimates are approximately lognormal and are fitted with lognormal priors in the stock assessment model. The mean Z estimate for Area 30 (0.377) is slightly lower than that for Area 25 (0.465).

A DUV survey was conducted in Area 25 in 2010, surveying a number of the random-stratified sites that were sampled during the potting survey. The survey estimate of the mean density of legal-sized blue cod was extrapolated to the total Area 25 area to generate a total abundance estimate. This was fitted to model-predicted 2010 legal-sized blue cod abundance.

The data fitted in the models for each Statistical Area are shown in Table 16 and the assumed error structure of each data series is shown in Table 17.

4.4.1.3 Further assumptions

Sex-specific von Bertalanffy growth parameters are available from Area 25 and Area 30 random-stratified potting surveys (refs.). The Area 25 growth models were assumed for Area 27. Both male and female blue cod are assumed to mature at a length of 280 mm (Carbines 2004).

Sex-change data was available from a 1995 Foveaux Strait study that characterised blue cod by state: male, female, or transitional (Carbines 2004). The proportions of transitional females by length bin were fitted with a parametric relationship to describe the sex-change process. The maximum proportion transitional was observed at 410 mm.

Assuming that sex-change is a function of the relative abundance of mature males was found to result in fewest model convergence issues. The length at 50% sex change (*dmax*) is modelled as a function of the ratio of mature male biomass in year $y \left(B_y^M \right)$ relative to mature male biomass in the virgin state $\left(B_0^M \right)$:

$$dmax = \lambda \left({B_y^M}/{B_0^M} \right)^{\delta},$$

where the parameters λ and δ are estimated through the model fitting. In practice, only λ was estimated and δ was fixed. This model results in the form of the sex-change relationship remaining the same except that it is shifted along the length-axis. With this parameterisation it is not possible to fix the 1995 length at 50% sex change (to 410 mm, as observed in the sex transition data set collected in 1995), so a penalty function is used to encourage that value.

Table 16: Standardised CPUE indices for Statistical Areas 25, 27 and 30.

Fishing Year	Area 25	Area 27	Area 30
1990	0.803	0.603	0.925
1991	0.748	0.607	0.860
1992	0.815	0.665	1.026
1993	0.854	0.835	0.846
1994	0.847	0.648	0.689
1995	0.808	0.796	0.669
1996	0.943	1.022	0.657
1997	1.043	1.241	1.011
1998	1.084	1.116	1.141
1999	0.972	1.152	1.224
2000	1.034	1.292	1.185
2001	1.143	1.466	1.098
2002	1.160	1.743	1.453
2003	1.256	1.532	1.422
2004	1.145	1.602	1.359
2005	1.283	1.219	1.262
2006	1.253	1.127	1.172
2007	1.035	0.881	1.093
2008	1.017	0.888	0.924
2009	1.023	0.894	0.939
2010	0.984	0.901	0.961
2011	1.006	0.888	0.839
2012	0.998	0.940	0.819

Table 17: Data series fitted in the stock assessments for Areas 25, 27, and 30.

Data type	Series	Area 25	Area 27	Area 30
LF data:	Shed	✓	✓	-
	Logbook	✓	✓	✓
	Survey	✓	-	✓
	Mesh sel. trials	data common to all areas		
	Rec. landings	data common to all areas		
	Rec. catch	data common to all areas		
Abundance Index:	CPUE	✓	✓	✓
	Survey Z	✓	-	✓
	DUV abundance	✓	-	-

Table 18: Assumed distributions for data fitted in the models.

Data type	Distribution	Parameters
Logbook LF	Multinomial	N: 100
Shed samples LF	Multinomial	N: 100
Mesh size trials LF	Multinomial	N: 100
Recreational catch LF	Multinomial	N: 100
Recreational landings LF	Multinomial	N: 100
Survey LF	Multinomial	N: 100
CPUE	Normal-log	Std. dev: 0.20
Survey Z –Area 25	Normal-log	Mean: -0.782 Std. dev: 0.178
Survey Z –Area 30	Normal-log	Mean: -0.991 Std. dev: 0.173
DUV LegalN	Normal-log	Mean: 15.163 Std. dev: 0.300

4.4.1.4 Calculation of fishing intensity and B_{MSY}

Fishing intensity is measured as the spawning biomass per recruit (SPR). $F_{\%SPR}$ is the ratio of spawning biomass per recruit at a given level of fishing mortality relative to the spawning biomass per recruit in the absence of fishing. This metric was selected to represent fishing intensity because estimates for the entire BCO 5 stock can readily be calculated from the Statistical Area estimates.

MSY statistics are calculated assuming deterministic recruitment and the final years' selectivity and retention ogives. The recreational and customary fisheries are held fixed at the current levels, and only the commercial fishery varied to determine MSY. B_{MSY} is measured as total mature biomass and MSY is presented as the commercial catch at B_{MSY}.

Caution about the interpretation of B_{MSY} estimates

There are several reasons why B_{MSY}, as calculated in this way, is not a suitable target for management of blue cod fisheries. First, it assumes a harvest strategy that is unrealistic in that it involves perfect knowledge (current biomass must be known exactly in order to calculate the target catch) and annual changes in TACC (which are unlikely to happen in New Zealand and not desirable for most stakeholders). Second, it assumes perfect knowledge of the stock-recruit relationship, which is actually very poorly known. Third, it makes no allowance for extended periods of low recruitment. Fourth, it would be very difficult with such a low biomass target to avoid the biomass occasionally falling below 20% B_0, the default soft limit according to the Harvest Strategy Standard.

4.4.1.5 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 estimate the mode of the posterior distribution). Their purpose was to decide which sets of assumptions should be carried forward to the final runs. The final runs were fully Bayesian, estimating posterior distributions for all quantities of interest.

The modelling assumptions and approaches investigated though the exploratory model runs included: the dynamics of sex-change; what assumptions to make about LF data from the logbook and shed sampling programs; the magnitude of recruitment variation; the magnitude of error in fits to the CPUE data; the form of the survey and recreational fishery selectivity; and sensitivity to alternative assumptions about recreational catch, bait usage, and discard mortality rates.

Four final runs were chosen by the Working Group: a *base case* and three sensitivities to the *base case*. The sensitivity runs each modify a single assumption of the *base case*. The sex-change power parameter (delta in equation above) is fixed at 0.4 for the *base case*. Two of the sensitivity runs modify this parameter to values of 0.2 and 0.6. The third sensitivity run reduces the recreational catch time series by 50%.

Label	Description
1.1	Base case
1.2	Sex-change power parameter=0.2
1.3	Sex-change power parameter=0.6
1.4	Recreational catch reduced by 50%

Bayesian posterior distributions were estimated for each of these runs 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 summing across Areas 25, 27, and 30. B_{MSY} and *MSY* are calculated assuming these areas account for 92% of the BCO 5 stock.

The model estimates are summarised in Table 19 (estimates of spawning biomass and *MSY*), Figure 9 (biomass trajectories), Figure 10 (current biomass distribution), Figure 11 (fishing intensity trajectories), and Figure 12 (recruitment trajectories).

The runs with the higher sex-change power parameter (run 1.3) have higher male and lower female spawning abundance in the unfished populations and runs with the lower sex-change power parameter (run 1.2) have lower male and higher female initial abundance. Current biomass and the combined male and female B_0 do not differ much among the runs. Assuming lower recreational catch (run 1.4) results in a slightly lower B_0 estimate and slightly higher current biomass. Area 25 is somewhat more depleted than Areas 27 and 30.

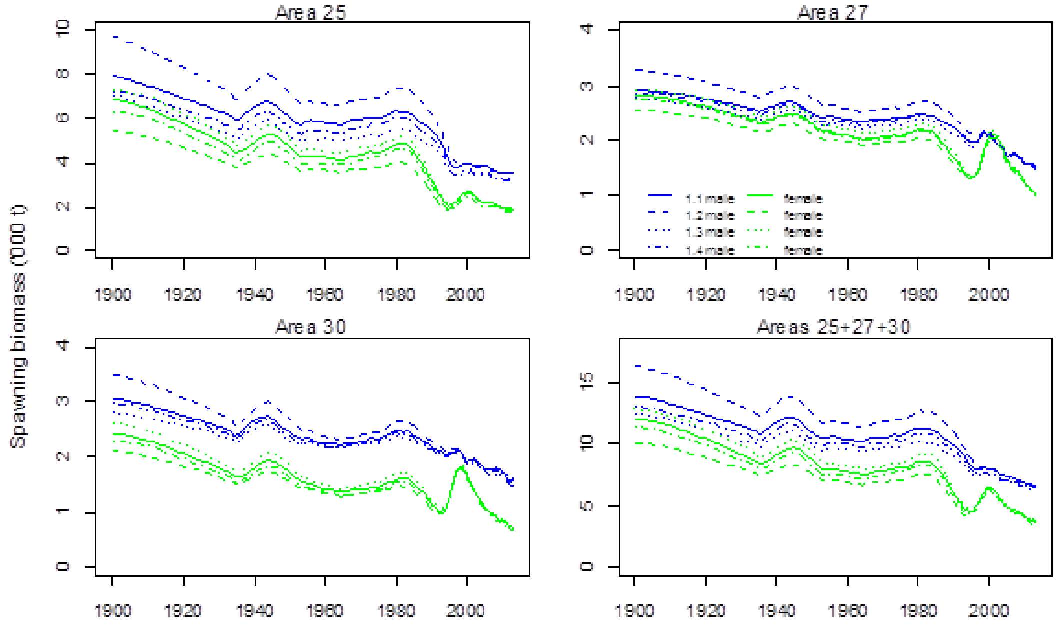


Figure 9: Median estimates of Area 25, Area 27, Area 30, and Areas combined male and female spawning biomass for the base case and sensitivity runs, 1900 – 2012.

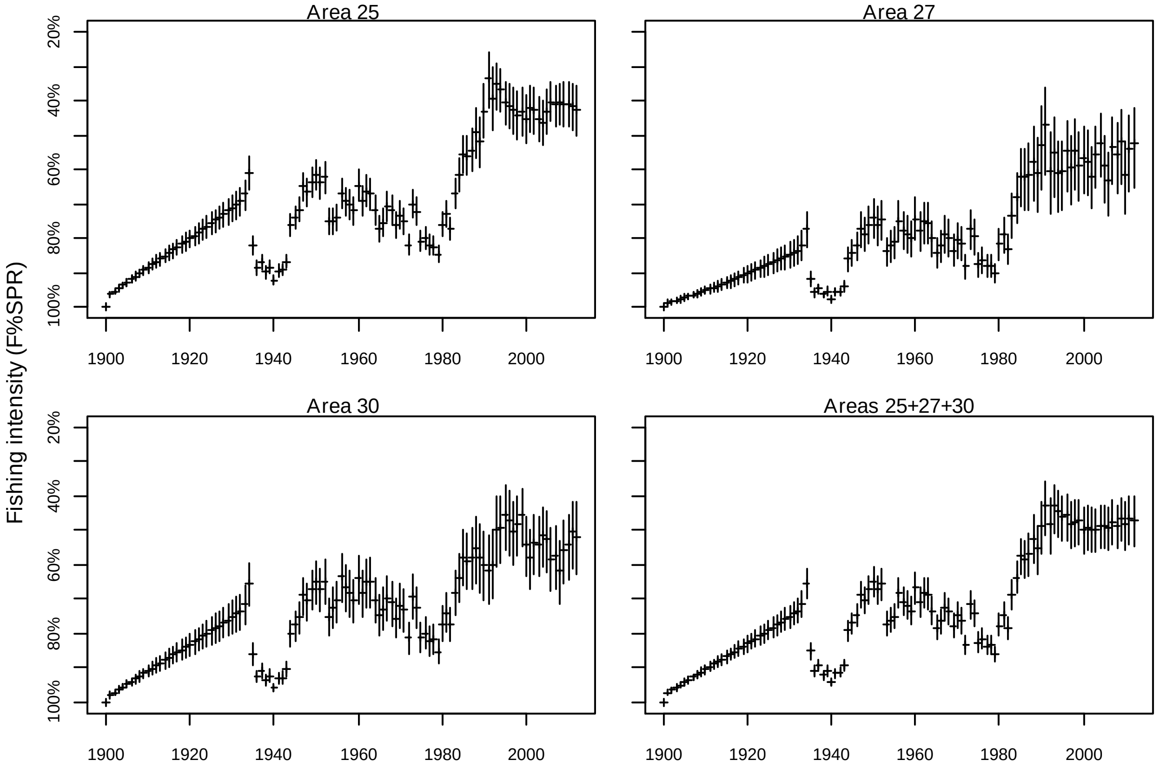


Figure 10: Fishing intensity ($F_{\%SPR}$) estimates from the base case runs for Areas 25, 27, 30, and the Areas combined, 1900-2012. The horizontal lines show the median and the vertical lines show the 90% confidence intervals.

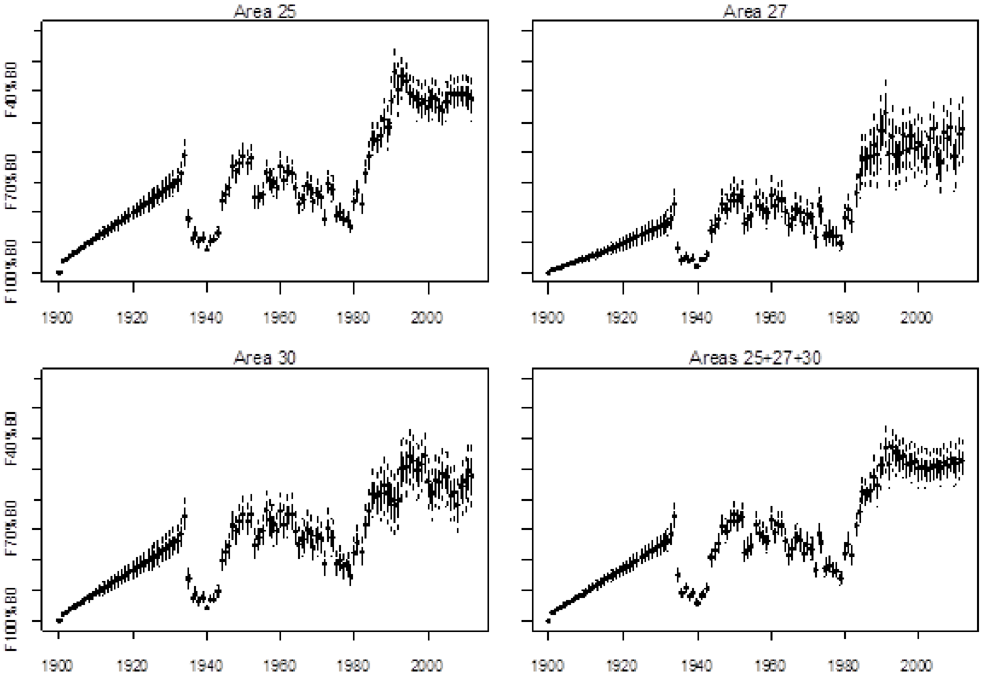


Figure 11: Fishing intensity (*F*$_{\%SPR}$) estimates from the base case runs for Areas 25, 27, 30, and the Areas combined, 1900-2012. The solid boxes show the interquartile range and the whiskers show the 90% confidence limits.

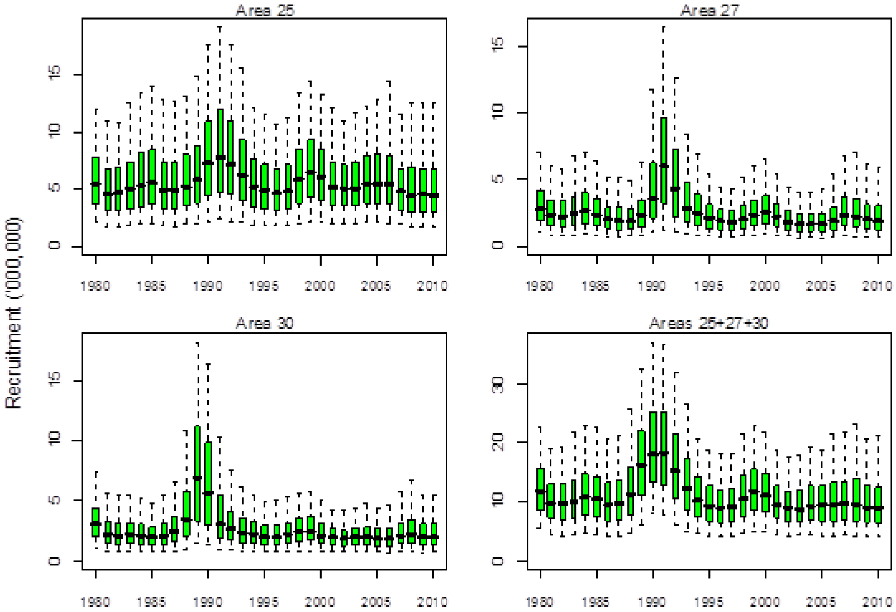


Figure 12: Recruitment estimates from the base case runs for Areas 25, 27, 30, and the Areas combined, 1980-2010. The boxes show the interquartile range, the whiskers show the 90% confidence limits, and the bars show the medians.

Fishing intensity has remained below *F*$_{40\%SPR}$, except in Area 25 for a brief period in the 1990s. Recruitment has been slightly below average in all three Areas over the last decade.

Table 19: Estimates of BCO 5 spawning stock biomass, *MSY* and B_{MSY} for final runs (medians of marginal posterior distributions, with 90% confidence intervals in parentheses). B_0 and *MSY* are calculated assuming Areas 25, 27 and 30 represent 92% of the BCO 5 blue cod stock.

Run	B_0 (,000 t)	$B_{current}$ (%B_0)	*MSY*	B_{MSY}(%B_0)
1.1	28(25,31)	39(31,51)	1336(1092,1589)	31(29,35)
1.2	28(26,31)	39(30,50)	1316(1088,1569)	32(29,35)
1.3	27(24,31)	39(30,50)	1345(1114,1607)	31(28,34)
1.4	26(24,29)	40(31,51)	1335(1115,1615)	31(29,35)

4.4.1.6 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.

Commercial catch levels were based on the current TACC and the average BCO 5 Statistical Area catch split over the past 10 years. Although only 90% of the BCO 5 TACC was caught on average over the past 10 years, with the reduction of the TACC to 1239 t in 2011-12, over 98% of the allowable catch was caught that year. Therefore stock projections based on the full TACC being caught appears reasonable. Alternative catch scenarios were simulated with commercial catch increased and reduced by 20%. Recreational and customary catch was assumed to remain constant at the 2011-12 levels.

Recruitment was simulated by randomly re-sampling (with replacement) from the time series of recruitment deviations, applied to the stock-recruitment relationship. Two alternative recruitment scenarios were simulated: recent recruitments were re-sampled from the 2001 through 2010 recruitment deviations and long-term recruitments were re-sampled from the 1980 through 2010 recruitments.
Summary statistics were calculated for the BCO 5 FMA by summing B_0, B_{msy} and projection biomass estimates across the three Statistical Areas.

The projections indicate that under the assumptions of commercial catch at the current TACC and recruitment at recent levels the BCO 5 biomass is unlikely to change much over the next 10 years (Figure 13). Recruitments closer to the long-term average or a reduction in catch from the current TACC results in slight increases in biomass and an increase in catch above the TACC results in a slight decrease in biomass. 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, the target of 40% B_0, and 25%, 50% and 100% of B_{MSY} are presented in Table 22, for the base case model with recent or long-term recruitment and 3 catch levels and for the sensitivity runs with recent recruitment and commercial catch at the current TACC. With catches at the current TACC, the probability of the stock being less than either the soft or hard limit over the next five years is negligible.

There are no time series of length frequency observations for the BCO 5 stock assessment. So, while the assessment indicates a BCO 5 recruitment pulse in the early 1990s, the information to support this pulse comes solely from the CPUE data, and hence may be spurious.

The sex change predictions also need to be viewed with caution as there are few data to inform the parameters and the form of the equation.

Table 20: Median estimates of the proportion male in the 1900, 2013, 2018 and 2023 BCO 5 spawning stock at alternative recruitment and catch levels for the *base case* and sensitivity stock projections.

Run	1.1						1.2	1.3	1.4
Recruitment	Recent	Recent	Recent	Long-term	Long-term	Long-term	Recent	Recent	Recent
Catch Level	TACC	1.2·TACC	0.8·TACC	TACC	1.2·TACC	0.8·TACC	TACC	TACC	TACC
1900	0.41	0.41	0.41	0.41	0.41	0.41	0.47	0.39	0.41
2013	0.51	0.51	0.51	0.51	0.51	0.51	0.49	0.51	0.51
2018	0.48	0.51	0.51	0.47	0.51	0.51	0.50	0.48	0.49
2023	0.51	0.52	0.49	0.49	0.51	0.48	0.49	0.52	0.51

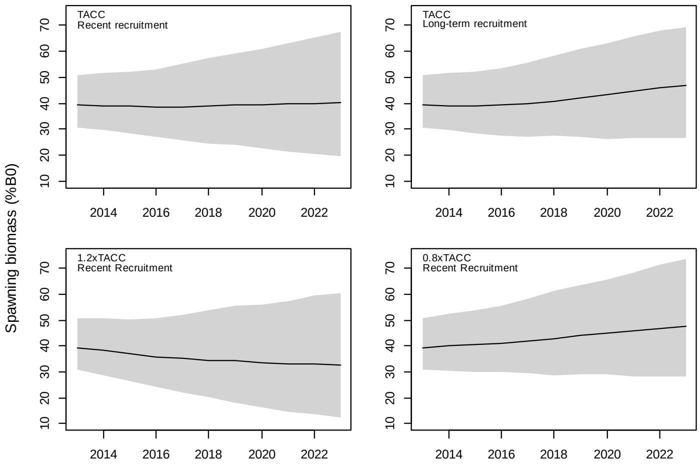


Figure 13: Projected BCO 5 spawning biomass (%B_0) assuming recent or long-term recruitment and catch at current TACC or increased/decreased by 20% for the base case run. Median estimates are shown as solid lines and 90% confidence intervals as shaded polygons.

Table 21: Probabilities of SSB being below B_0 and B_{msy} reference levels in 2013, 2018 and 2023 at alternative recruitment and catch levels for the *base case* and sensitivity stock projections.

Run	1.1						1.2	1.3	1.4
Recruitment	Recent	Recent	Recent	Long-term	Long-term	Long-term	Recent	Recent	Recent
Catch Level	TACC	1.2·TACC	0.8·TACC	TACC	1.2·TACC	0.8·TACC	TACC	TACC	TACC
$P(B_{2013} < 0.1\ B_0)$	0	0	0	0	0	0	0	0	0
$P(B_{2013} < 0.2\ B_0)$	0	0	0	0	0	0	0	0	0
$P(B_{2013} < 0.4\ B_0)$	0.538	0.538	0.538	0.538	0.538	0.538	0.576	0.549	0.532
$P(B_{2013} < 0.25\ B_{msy})$	0	0	0	0	0	0	0	0	0
$P(B_{2013} < 0.5\ B_{msy})$	0	0	0	0	0	0	0	0	0
$P(B_{2013} < B_{msy})$	0.095	0.095	0.095	0.095	0.095	0.095	0.116	0.091	0.078
$P(B_{2018} < 0.1\ B_0)$	0.001	0.002	0	0	0.001	0	0	0	0
$P(B_{2018} < 0.2\ B_0)$	0.010	0.048	0.002	0.003	0.024	0	0.012	0.007	0.015
$P(B_{2018} < 0.4\ B_0)$	0.543	0.694	0.379	0.470	0.622	0.288	0.578	0.578	0.605
$P(B_{2018} < 0.25\ B_{msy})$	0	0.002	0	0	0	0	0	0	0
$P(B_{2018} < 0.5\ B_{msy})$	0.002	0.014	0	0	0.006	0	0.004	0.002	0.005
$P(B_{2018} < B_{msy})$	0.230	0.377	0.114	0.153	0.294	0.069	0.249	0.215	0.262
$P(B_{2023} < 0.1\ B_0)$	0.003	0.024	0.002	0	0.005	0	0.007	0.004	0.006
$P(B_{2023} < 0.2\ B_0)$	0.053	0.173	0.008	0.019	0.077	0	0.052	0.051	0.074
$P(B_{2023} < 0.4\ B_0)$	0.498	0.681	0.271	0.289	0.533	0.110	0.491	0.505	0.553
$P(B_{2023} < 0.25\ B_{msy})$	0.001	0.014	0	0	0.002	0	0.004	0.003	0.002

Table 21 [continued]

$P(B_{2023} < 0.5\ B_{msy})$	0.021	0.107	0.004	0.009	0.037	0	0.025	0.018	0.040
$P(B_{2023} < B_{msy})$	0.256	0.473	0.105	0.113	0.306	0.030	0.272	0.257	0.305

4.5 Other factors

The target blue cod fishery is chiefly a pot fishery and there are few significant bycatch problems. However, in recent years bycatch associated with the inshore fleet of trawlers has increased in BCO 3 and BCO 7. Blue cod is only a very minor bycatch of the offshore fleet.

Before the introduction of the QMS, blue cod landings were affected by factory limits imposed in some parts of Southland, and there were economic constraints to the development of the fishery at the Chatham Islands (BCO 4).

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 handline 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. Large areas are currently not heavily fished and there are some areas such as the Mernoo Bank, the Puysegur Bank and South Traps which are potentially productive fisheries. 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.

5. STATUS OF THE STOCKS

For BCO 1 and 8 recent commercial catch levels are considered sustainable. The status of the remaining fishstocks is summarised below.

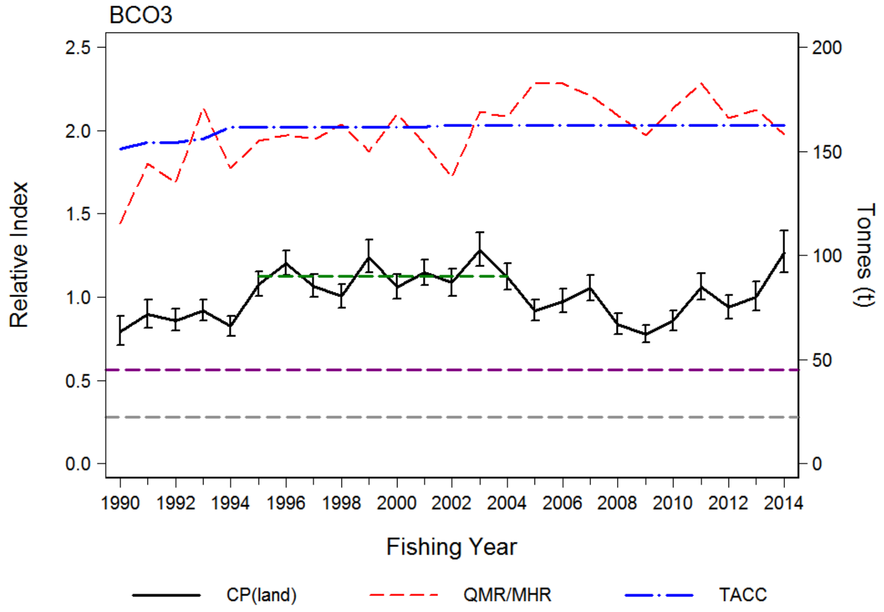
BCO 3 (Stat areas 24 and 26)

Stock Structure Assumptions

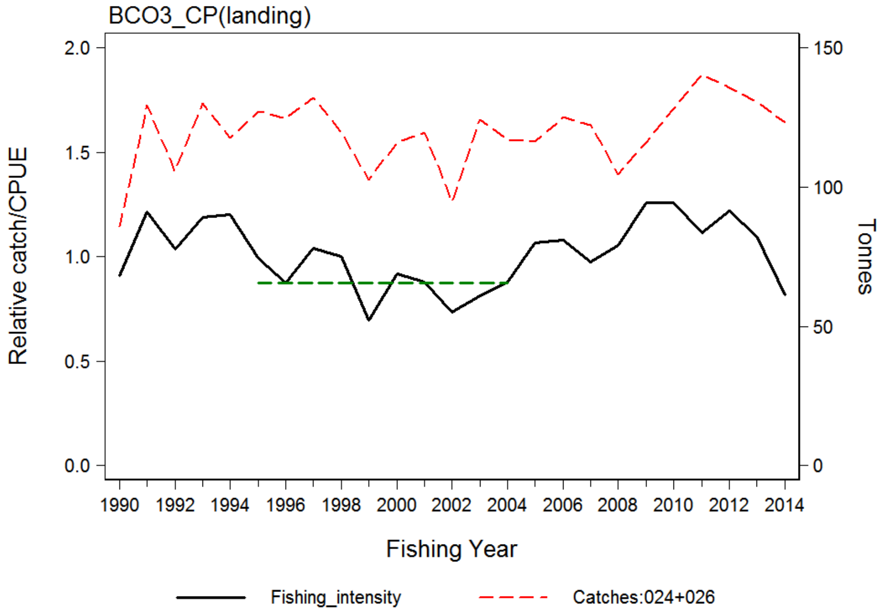
Tagging experiments suggest that blue cod populations may be isolated from each other and there may be several distinct populations within management areas. For the purposes of this summary, BCO 3 is split into two sub-areas along the Stat Area 022 and 024 boundary.

Stock Status	
Year of Most Recent Assessment	2015 (CPUE analysis)
Assessment Runs Presented	Potting survey CPUE index based on landed catch
Reference Points	Target: B_{msy} proxy based on mean CPUE for the period 1994–95 to 2003–04 Soft Limit: 50% B_{MSY} Hard Limit: 25% B_{MSY} Overfishing Threshold: F_{MSY} proxy based on mean relative exploitation rate for the period 1994–95 to 2003–04
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.



Relative Fishing Intensity (catch/CPUE) for BCO 3 (where CPUE=CP(land) and catch=Sum(024 & 026).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass has increased in four of the five years since a nadir reached in 2008–09. It is now near the highest level in the series.
Recent Trend in Fishing Mortality or Proxy	Relative exploitation rate declined since 2011–12, and 2013–14 was below the overfishing threshold.
Other Abundance Indices	The North Otago potting survey has only three index values which do not form a trend and do not match the CP CPUE series very well. The South Otago potting survey has only two index values.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis		
Stock Projections or Prognosis	Stock abundance, as monitored with cod potting CPUE, has fluctuated around a mean level since the early 1990s at levels of commercial catch averaging near 160 t/year. Recreational catch trends are not well known, but there seems to be little cause for concern as long as catches remain near current levels.	
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Very Unlikely (< 10%)	
Assessment Methodology		
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: 2015	Next assessment: 2017
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	3 – Low Quality: insufficient data points to describe trends and inconsistencies with BCO ageing have reduced the quality of age-based mortality estimates
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.

Fishery Interactions
Over 2/3 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

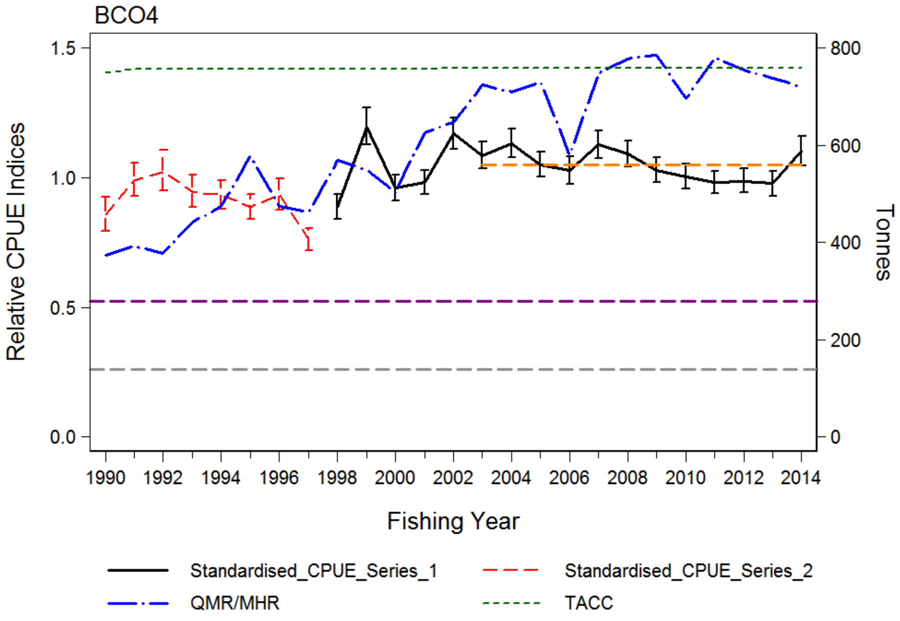
Stock Structure Assumptions

For the purposes of this summary BCO 4 is considered to be a single management unit.

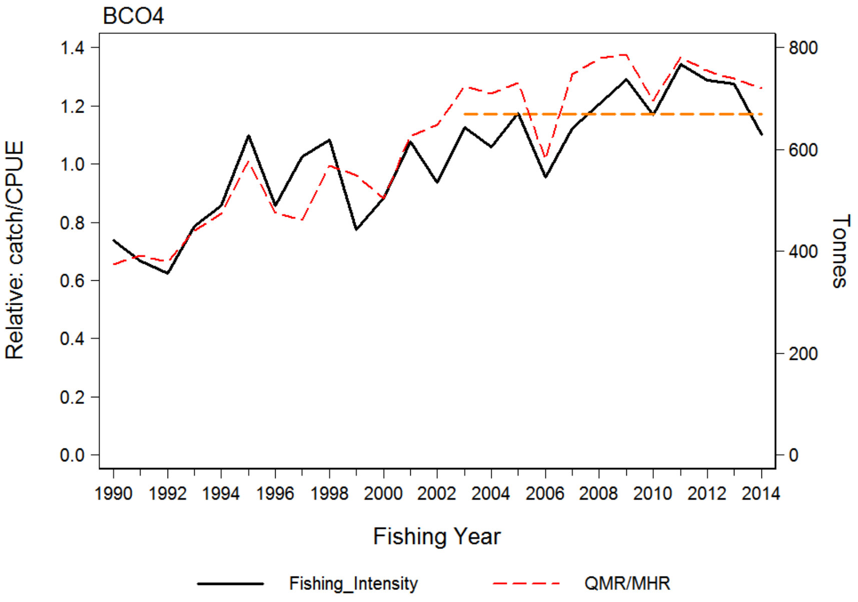
Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	CPUE index based on landed catch
Reference Points	Interim Target: B_{MSY} proxy based on mean CPUE for the period 2002–03 to 2013–14 (a period with high yield when both catch and CPUE were stable) Soft Limit: 50% B_{MSY} proxy 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	About as Likely as Not (40–60%) 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 plotted as two series: 1990–1997 and 1998–2014, representing greater confidence in the latter series. Also plotted are the QMR/MHR landings and the BCO 4 TACC. The orange line represents the interim B_{MSY} proxy of mean CPUE from 2003–2014. 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].



BCO 4 fishing intensity (=catch/CPUE) plot based on the standardised CPUE series and the QMR/MHR landings. Horizontal orange line represents the mean 2003–2014 fishing intensity associated with the interim *Bmsy*_proxy.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE has fluctuated without trend since 1997–98
Recent Trend in Fishing Mortality or Proxy	Relative exploitation rate has declined since 2010–11 and in 2013–14 was below 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 decline below Limits	Soft Limit: Very Unlikely (< 10%) Hard Limit: Very Unlikely (< 10%)	
Assessment Methodology		
Assessment Type	Level 2: Partial Quantitative Stock Assessment	
Assessment Method	Fishery characterisation and standardised CPUE analysis	
Assessment Dates	Latest assessment: 2015	Next assessment: 2019
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and Effort 1997–98 to 2013–14 - Catch and Effort 1989–90 to 1996–97	1 – High Quality 2 – Medium or Mixed Quality: compromised by changes in fleet composition and reporting practices
Data not used (rank)	N/A	
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.

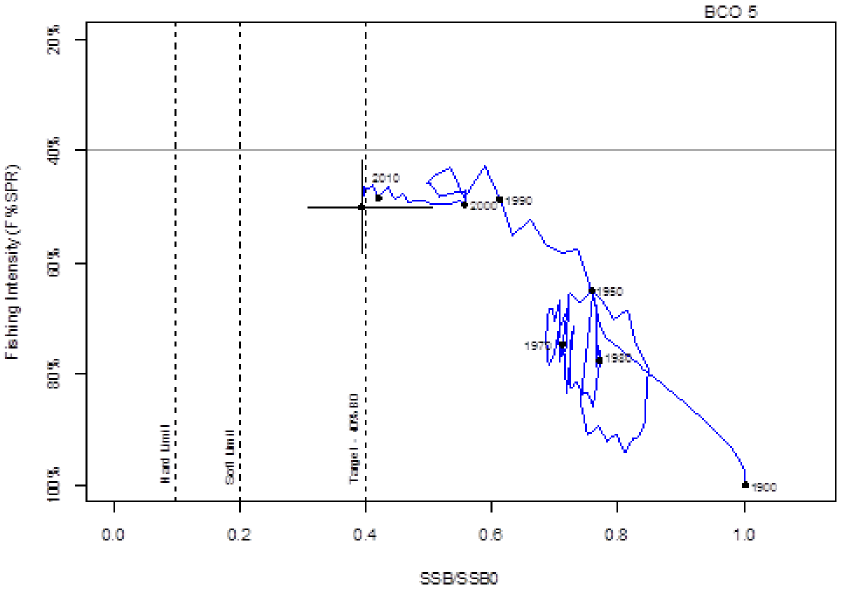
BCO 5

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, BCO 5 is treated as a unit stock.

Stock Status	
Year of Most Recent Assessment	2013
Assessment Runs Presented	One base case model was used to evaluate BCO 5 stock status in this assessment. Three sensitivity runs are also presented.
Reference Points	Interim Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: F_{MSY}
Status in relation to Target	B_{2013} was estimated to be 39.4% of B_0; About as Likely as Not (40–60%) to be at or above the Interim Management Target
Status in relation to Limits	B_{2013} 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	Unlikely (< 40%) that overfishing is occurring

Historical Stock Status Trajectory and Current Status



Trajectory of fishing intensity ($F_{\%SPR}$) and spawning biomass ($\%B_0$) for BCO 5 from the start of the assessment period in 1990 to 2012. The vertical lines at 10%*B_0*, 20%*B_0* and 40%*B_0* represent the soft limit, the hard limit and the target, respectively, and the shaded area shows the *B_{MSY}* 90% CI. Estimates are based on MCMC medians and the 2012 90% CI is shown by the crossed lines

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass has been slowly decreasing since 2000.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity is estimated to have been relatively constant since 2000.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Recent recruitment (2002 – 2010) is estimated to be slightly below the long-term average.

Projections and Prognosis	
Stock Projections or Prognosis	BCO 5 biomass is expected to stay steady over the next 5 to 10 years at the 2012 TACC which approximates the 2012 catch.
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 assessment	
Assessment Method	Length-based model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2013	Next assessment: 2018
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- CPUE time series - Proportion at length data from surveys and commercial catch - Estimates of biological	1 – High Quality 1 – High Quality

	parameters - DUV survey absolute biomass estimate - Potting survey Z estimates	1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	-	-
Changes to Model Structure and Assumptions	New model	
Major Sources of Uncertainty	Degree to which CPUE reflects abundance; the age, size and sex structure of the population; relationship between abundance and sex change dynamics	

Qualifying Comments
-

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.

Research needs
Research into the sex change dynamics of blue cod would assist in improving the information that goes into the BCO 5 stock assessment. Histological analysis of gonads from the randomly stratified surveys would be a useful approach to assess sex change dynamics. Catch sampling should be undertaken in BCO 5 and needs to be scheduled as part of the medium term research plan.

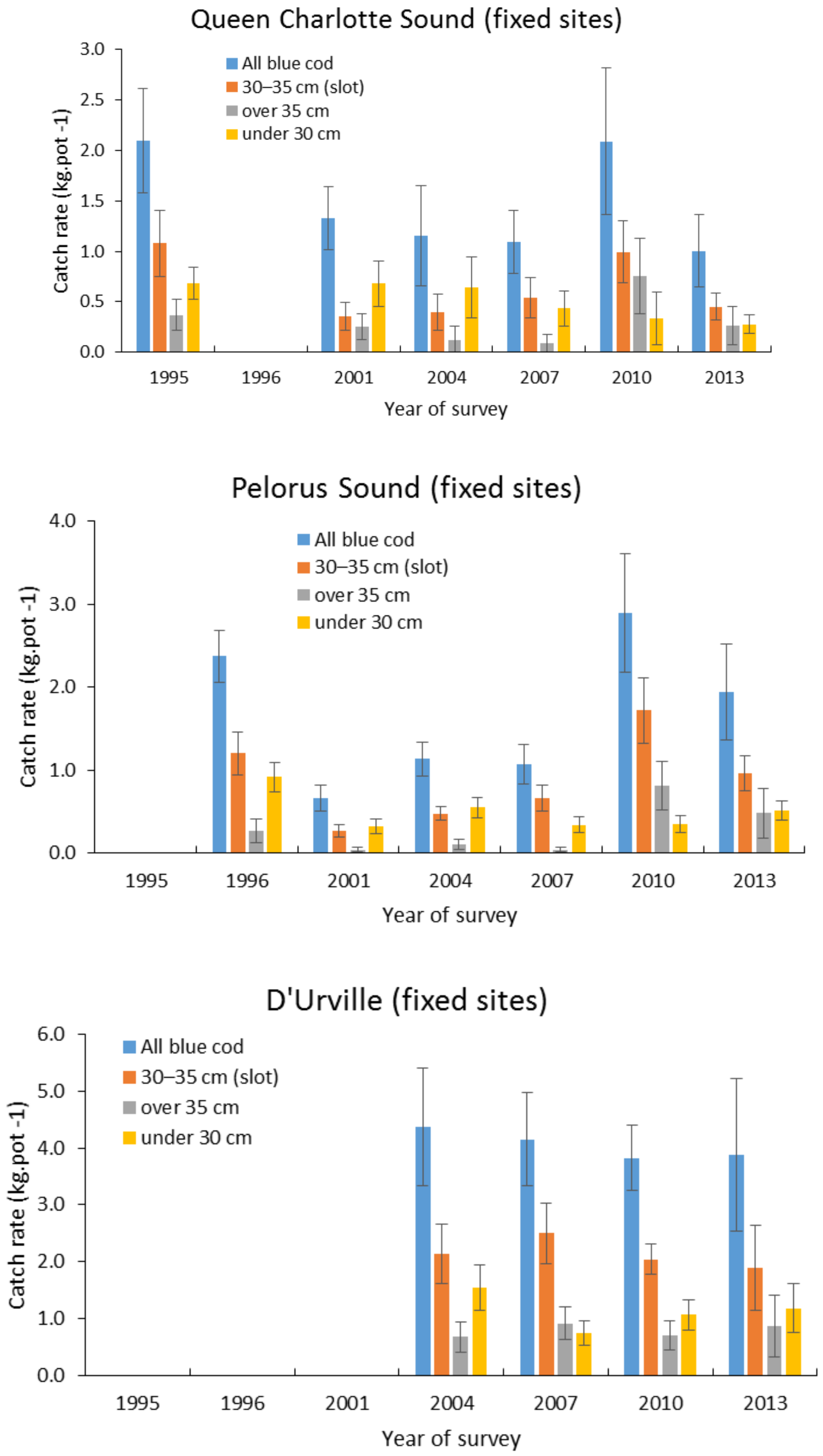
BCO 7 - Marlborough Sounds only

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	2014
Assessment Runs Presented	Catch rates from the fixed site Marlborough Sounds potting survey
Reference Points	Target: B_{MSY}-compatible proxy based on the Marlborough Sounds potting survey (to be determined) Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: F_{MSY}-compatible proxy (to be determined)
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



Scaled catch rate rates by size category from the fixed site potting surveys in the Marlborough Sounds for Queen Charlotte Sound, Pelorus Sound and D'Urville regions. Error bars are 95% confidence intervals.

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 same areas 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 in April 2011 and the estimated 2013 survey abundance in those regions declined, but no change was observed in DUR.
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. It is not known if the mortality in 2014 is higher or lower than that which existed when the fishery was closed in 2008.
Other Abundance Indices	The mean length of catches taken during the 2010 blue cod potting survey tended to be larger than those observed in previous surveys. Mean length declined for the 2013 survey in QCH and PEL.
Trends in Other Relevant Indicators or Variables	Sex ratio is strongly skewed in favour of males.

Projections and Prognosis	
Stock Projections or Prognosis	It is unknown whether biomass will continue to decline under current management controls.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology and Evaluation		
Assessment Type	2 – Partial Quantitative Stock Assessment	
Assessment Method	Fishery-independent potting survey. Fixed sites in QCH, PEL, DUR, and random sites in CKST.	
Assessment Dates	Latest assessment: 2014	Next assessment: 2017
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Potting survey catch rates - Length	1 – High Quality 1 – High Quality
Data not used (rank)	-Age -$F_{\%SPR}$	3 – Low Quality: Age has been determined by several otolith readers across time, and otolith interpretation varies greatly between readers. 3 – Low Quality: $F_{\%SPR}$ was not used due to the frequent regulatory changes for this fishery resulting in inconsistent fishing mortality over the lifetime of recent cohorts. Issues regarding age determination have also created problems with mortality estimation.
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- The total removals from the recreational sector and the distribution of recreational effort are not well estimated in most years.	

Qualifying Comments
The survey is moving from a fixed site to a random site stratified potting survey, in the interim both survey types will be undertaken simultaneously so that the random survey can be calibrated to the historic data. The 2010 survey comprised a full fixed site survey along with a partial random site survey in selected strata, whereas 2013 included full fixed and full random site surveys carried out simultaneously.
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	Actual TACC	2013-14 Reported landings
BCO 1	Auckland	1 & 9	46	9
BCO 2	Central (East)	2	10	8
BCO 3	South-East (Coast)	3	163	159
BCO 4	South-East (Chatham Rise)	4	759	720
BCO 5	Southland and Sub-Antarctic	5 & 6	1 239	1 208
BCO 7	Challenger	7	70	58
BCO 8	Central (Egmont)	8	34	12
BCO 10	Kermadecs	10	10	0
Total			2 332	2 174

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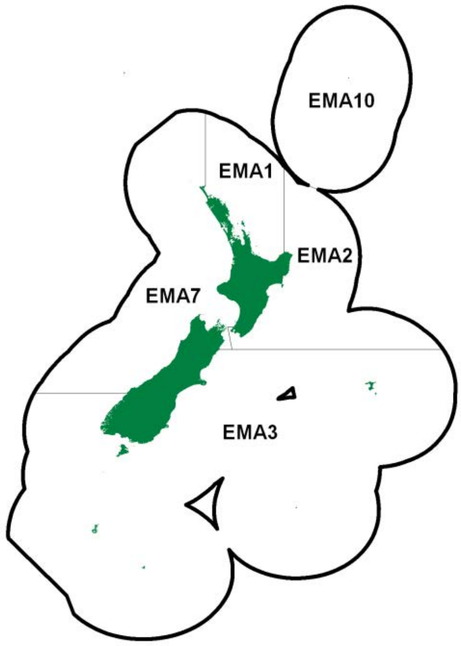
BLUE MACKEREL (EMA)

(*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, including bottom longline, bottom pair trawl, beach-seine, bottom trawl, drift net, dip net, Danish seine, handline, lampara, mid-water trawl, purse seine, lobster pot, ring net, surface longline, setnet, and troll. However, for many of these methods the catch is very low. Most catch is taken north of latitude 43° S (Kaikoura). 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. Historical estimated and recent reported blue mackeral 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.

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. Total catches 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 1998–99 (13 500 t), 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 and 2011–12. The purse seine fishery accounted for 92% of the total EMA 1 landings in 2004–05.

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 2013–14. 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	7213	3	100	2 401	0	0	9 716
2013-14	6 860	4	29	1 200	0	0	8 092

* FSU data, # Landings reported from QMA 10 are probably attributable to Statistical Area 010 in the Bay of Plenty (i.e., QMA 1).

The 2004–05, 2005–06, and 2008–09 EMA 7 landings also exceeded the TACC. By contrast, landings in these years from EMA 2 and EMA 3 were well below the TACC and at levels near the lowest recorded since 1983–84. There was an increase in catch from EMA 3 since 2005–06, but to levels still well below the TACC. The blue mackerel catch from EMA 7 is principally non-target catch from the jack mackerel mid-water trawl fishery and, in 2004–05, represented about 85% of total landings in that Fishstock with most of the balance taken by purse seine (12%).

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.

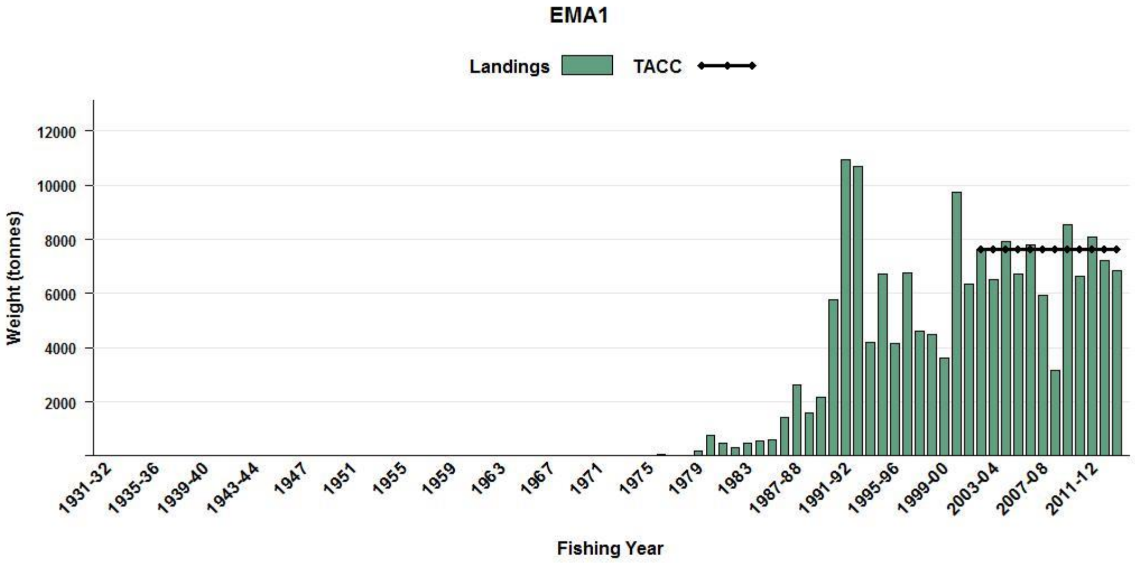
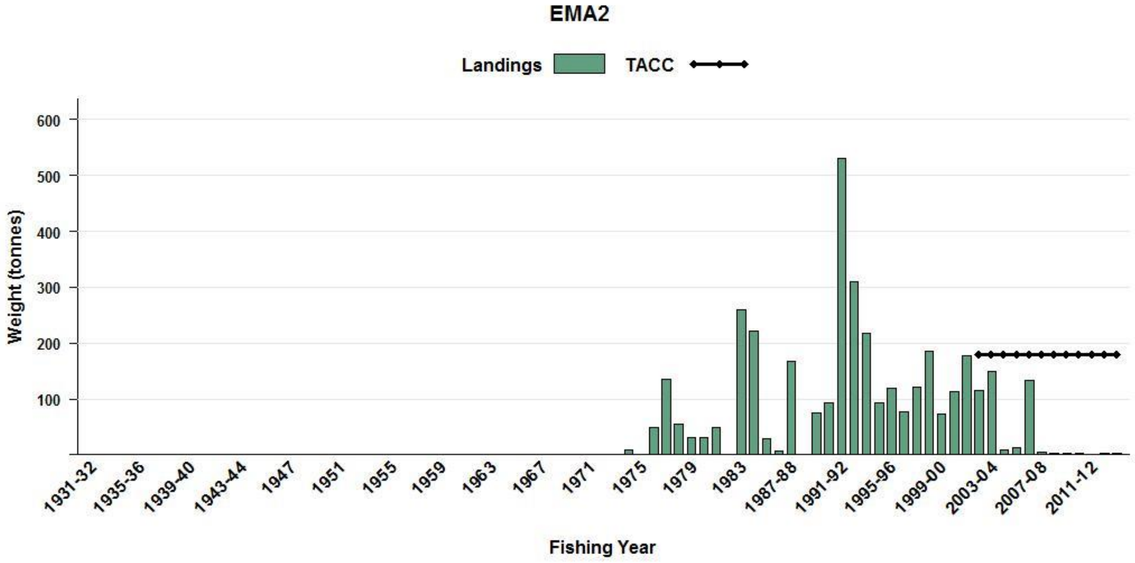


Figure 1: Reported commercial landings and TACC for the three main EMA stocks. EMA 1 (Auckland East) [Continued on next page]



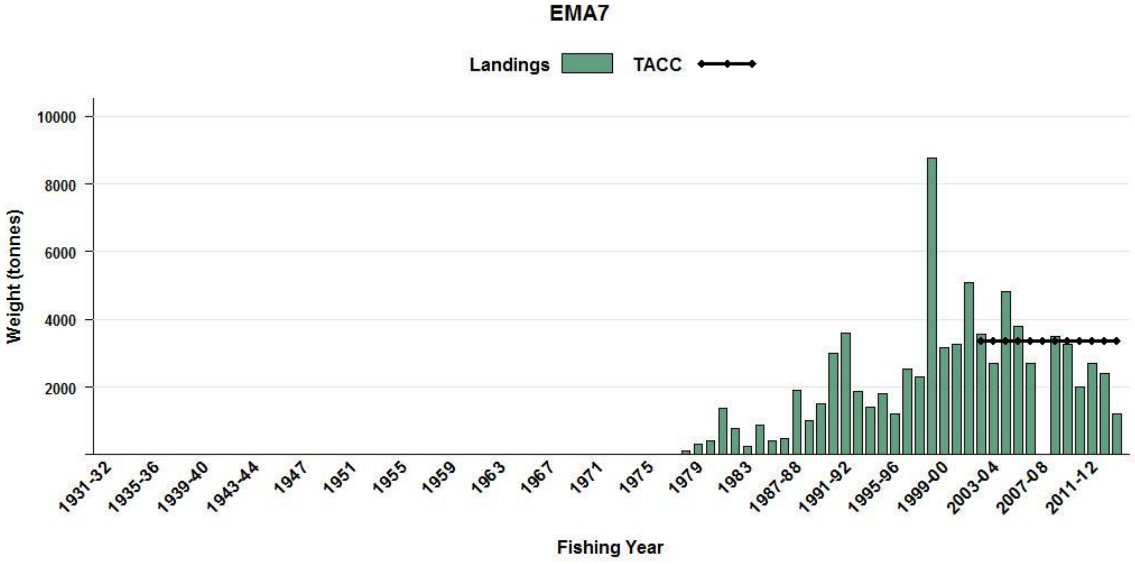


Figure 1: [Continued] Reported commercial landings and TACC for the three main EMA stocks. From top left: EMA 1 (Auckland East), EMA 2 (Central East), and EMA 7 (Challenger to Auckland West).

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. The harvest estimates from the diary surveys 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.

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.

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 otter 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 4. 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 (lavender) oil, whereas the New Zealand method is based on otolith thin-sections. 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 4: 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 standard and validated age estimation method for blue mackerel is an important topic of future research in New Zealand.

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, blue mackerel are sub divided into at least three stocks in New Zealand fisheries waters: EMA 1, EMA 2, and EMA 7.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

Analysis of aerial sightings data for east Northland 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.

A standardised CPUE analysis for EMA 7 was carried out in 2006–07 using TCEPR tow by tow data from the mid-water trawl jack mackerel target fishery in which blue mackerel form a significant and important bycatch. Tows that targeted jack mackerel but did not report any blue mackerel catch were considered to be a zero tow.

Estimates of relative year effects were obtained using a forward stepwise multiple regression method, where the data were fitted using binomial-lognormal model structure. The data used for the CPUE analyses consisted of catch and effort by core vessels that targeted jack mackerel; core vessels were those vessels that had more than five non-zero tows of blue mackerel catches for at least three years.

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 2004–05 using catch and effort by 7 core vessels.

For the early time series (Table 5), the residual deviance explained were 19% for the binomial models and 33% for the lognormal model. For the late time series, the residual deviance explained were 18% for the binomial models and 30% for the lognormal model. For both data series, the main terms selected by the models are statistical area, vessel, and month.

The combined indices produced for the early time series dropped to the lowest in 1992–93, recovered in 1994–95, and then fluctuated to 1997–98. The indices produced for the late time series fluctuated to 1999–2000, declined through the years to a level in 2004–05 about 15% that of 1996–97.

Table 5: Standardised CPUE indices for EMA 7 from the binomial-lognormal model fitted to the early time series (1989–90 to 1997–98, vessels 1–12) and the late time series (1996–97 to 2004–05, vessels 13–19); Year 1999 demotes fishing year 1998–99.

Year		Vessels 1–12 1990 to 1998			Vessels 13–19 1997 to 2005	
	Binomial	Lognormal	Combined	Binomial	Lognormal	Combined
1990	1.00	1.00	1.00	-	-	-
1991	1.17	1.43	1.51	-	-	-
1992	0.65	1.65	1.39	-	-	-
1993	0.30	1.04	0.57	-	-	-
1994	0.27	1.20	0.61	-	-	-
1995	0.65	1.63	1.37	-	-	-
1996	1.01	1.31	1.31	-	-	-
1997	0.65	1.75	1.47	1.00	1.00	1.00
1998	0.74	1.46	1.30	1.06	0.80	0.83
1999	-	-	-	1.29	0.98	1.14
2000	-	-	-	1.46	0.81	1.01
2001	-	-	-	1.14	0.62	0.67
2002	-	-	-	1.20	0.62	0.68
2003	-	-	-	0.52	0.34	0.22
2004	-	-	-	0.65	0.16	0.12
2005	-	-	-	0.94	0.14	0.14
2004	-	-	-	0.65	0.16	0.12
2005	-	-	-	0.94	0.14	0.14

Due to the significant area / year interactions estimated in the analysis, and the large interannual variation in catches and CPUE in some areas, the PELWG agreed that it was is premature to make conclusions about trends in abundance based on these indices at this time.

Using market and catch sampling data collected during 2004–05, estimated numbers-at-length and numbers-at-age were calculated based on all available groomed length and length-at-age data. These were done separately by sex and scaled to estimates of the total catch from each of the three main blue mackerel fisheries. Results showed that the EMA 1 and 7 purse seine fisheries were composed of fish between 2–21 and 2–24 years of age respectively, although most were between 5 and 15 years in both cases. Catch-at-age in the EMA 7 mid-water trawl TCEPR bycatch (jack mackerel target) fishery appeared somewhat broader, 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.

4.2 Biomass estimates

No biomass estimates are available.

4.3 Yield estimates and projections

It is not feasible to estimate *MCY*. There are no estimates of biomass or reference fishing mortalities and recent fishing effort has been interdependent on several small pelagic species. A large proportion of catch is by purse seine, and catch restrictions for kahawai (which traditionally received greater effort) first set in the early 1990s, shifted fishing effort towards blue mackerel. A significant component of the catch is also taken as non-target catch when targeting other small pelagic species.

Estimates of current biomass are not available and *CAY* cannot be determined.

4.4 Other factors

Recent catch sampling indicates 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, suggest that blue mackerel may be capable of sustaining current commercial fishing mortality in EMA 1.

5. STATUS OF THE STOCKS

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. It is not known if recent catch levels are sustainable or at levels that will allow the stocks to move towards a size that will support the *MSY*.

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

The broad spread of age classes seen in the catch from the trawl fishery is not consistent with the large decline in CPUE from 1999 to 2005. The Working Group agreed that it was premature to make conclusions about trends in abundance based on the CPUE indices, due to the significant area/year interactions in the analysis.

Table 6: Summary of reported landings (*t*) and TACCs by QMA for the most recent fishing year.

Fishstock	FMA	2013–14 TACC	2013–14 Reported Landings
EMA 1	1	7 630	6 860
EMA 2	2	180	4
EMA 3	3–6	390	29
EMA 7	7–9	3 350	1 200
EMA 10	10	0	0
TOTAL		11 550	8 092

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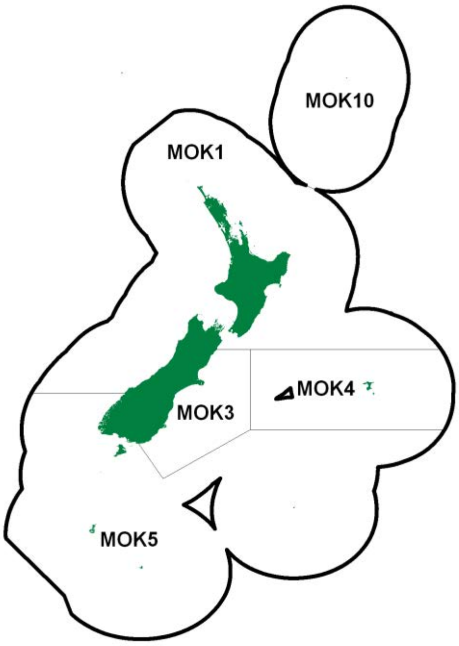
BLUE MOKI (MOK)

(*Latridopsis ciliaris*)
Moki



1. FISHERY SUMMARY

1.1 Commercial fisheries

Most blue moki landings are taken by setnet or trawl on the east coast between the Bay of Plenty (BoP) and Kaikoura, although small quantities are taken in most New Zealand coastal waters. While the proportions of the total commercial landings taken by setnet and trawl have varied over time, setnetting has been the predominant method (60%) since 1979.

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. Landings of blue moki peaked in 1970 and 1979 at about 960 t. Since 1993–94, total landings have been around 500 t i.e., approximately 100 t below the aggregated TACC. Reported landings and TACCs are given in Tables 1 and 2, while an historical record of landings and TACC values for the two main MOK stocks are depicted in Figure 1.

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 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.

1.2 Recreational fisheries

Popular with recreational fishers, blue moki are taken by beach anglers, setnetting and spearfishing. Annual estimates of recreational harvest were obtained from diary surveys in 1991–94, 1996 and 1999–2000 (Tables 3 and 4).

Table 2: Reported landings (t) and actual TACCs (t) of blue moki by Fishstock from 1986–87 to 2013–14. Source – QMS data. MOK 10 is not tabulated; no landings have ever been reported from MOK 10.

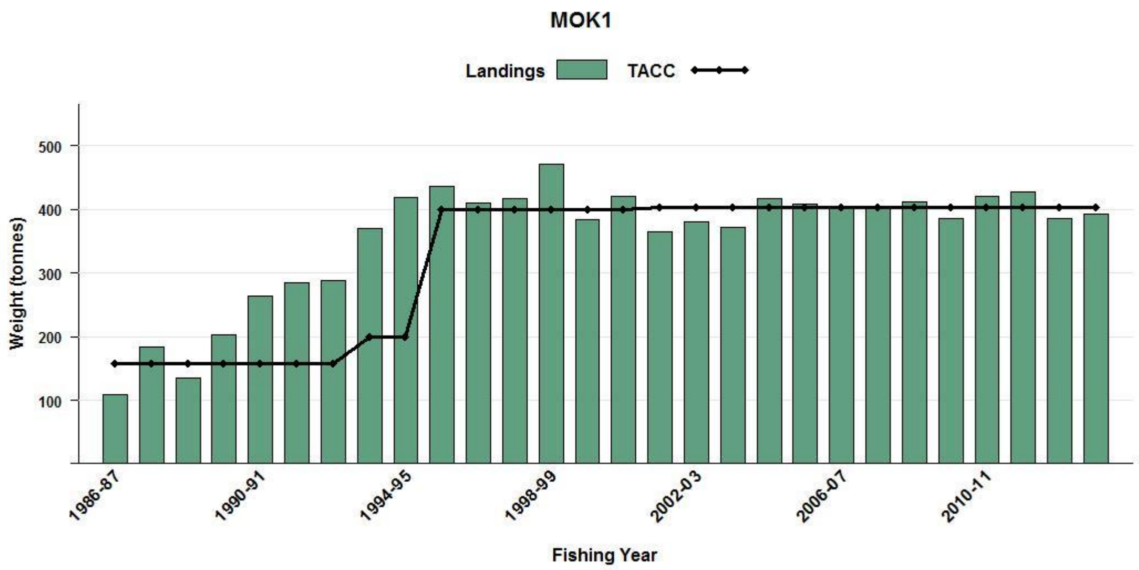
Fishstock	MOK 1		MOK 3		MOK 4		MOK 5			
FMA (s)	1,2,7,8,9		3		4		5 & 6		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1986–87	109	130	52	60	0	20	3	40	164	260
1987–88	183	142	95	62	0	20	2	40	280	274
1988–89	134	151	121	64	0	20	3	40	258	285
1989–90	202	156	89	65	11	25	1	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

Table 3: 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 4: Estimates of annual number and weight of blue moki harvested by recreational fishers from national diary surveys in 1996 (Bradford 1998) and Dec1999–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	9000	-	-	-
				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



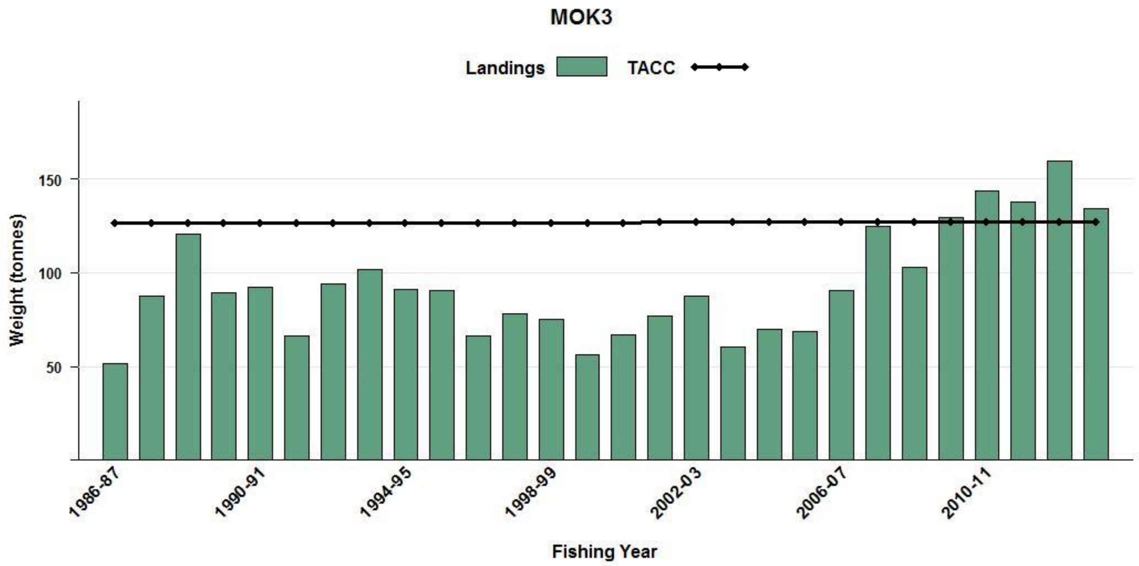


Figure 1: Reported commercial landings and TACC for the two main MOK stocks. Left to right: MOK 1 (Auckland, Central, and Challenger) and MOK 3 (South East Coast). Note: these figures do not show data prior to entry into the QMS.

The MOK 1 recreational harvest estimated during the 1999–2000 survey was around a third (34%) of the commercial catch during that period. However, the Recreational Technical Working Group concluded that the harvest estimates from the diary surveys 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.

1.3 Customary non-commercial fisheries

A traditional Maori fishery exists in some areas, particularly the eastern BoP 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 setnetting 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. While little information is available, this practice appears to have been most common in Stewart Island and the Chatham Islands, and may have accounted for about 45 t and 60 t in Stewart and Chatham 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, while 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 $M = \log_e 100/\text{maximum age}$, is 0.1. Note 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

There are no new data which would alter the yield estimates given in the 1996 Plenary Report. The yield estimates are based on commercial landings data only and have not changed since the 1992 Plenary Report.

4.1 Estimates of fishery parameters and abundance

Standardised CPUE analyses (using both loglinear indices of non-zero catches and negative binomial indices or the proportion of zero catches) were undertaken for blue moki caught in four separate fisheries operating between Banks Peninsula and East Cape: blue moki setnet fishery, blue warehou setnet fishery, tarakihi setnet fishery and tarakihi bottom trawl fishery (Langley & Walker 2004).

Setnet CPUE trends, particularly those for the target component, proved to be the most promising candidates for future monitoring of the fishery. However, because of the poor quality of the data collected up to 2002 the current trends were not thought to track abundance. The recently implemented setnet data-form requires higher spatial resolution of catch and effort data, thus promising to provide data of sufficient quality to monitor the fishery in the future.

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 setnet 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 a 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 Biomass estimates

Estimates of current and reference biomass are not available.

4.3 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.

4.4 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. An analysis of MOK 1 CPUE data indicates that annual catch rates remained relatively constant between 1989–90 and 1993–94, despite an increase in the total commercial catch during the same period.

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	2008
Assessment Runs Presented	
Reference Points	Target: Not established but $F = M$ assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	F is Very Likely (> 90%) to be below M
Status in relation to Limits	Soft Limit: Unlikely Hard Limit: Unlikely (< 40%) to be below
Historical Stock Status Trajectory and Current Status	-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	-
Recent Trend in Fishing Mortality or Proxy	Low estimates of fishing mortality in 2005–06 and stable catches over the previous 14 years suggest that fishing mortality has been low for more than two decades.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Catch curve analysis from recent catch sampling (2004–05 and 2005–06) indicates that total mortality is low, with fishing mortality well below natural mortality. The fishery is comprised of fish across a broad range of ages across both sexes. Given that the MOK 1 catch has been fairly stable since 1993–94, and that catches have been near the TACC since 1995–96, stock size is Likely (> 60%) to remain above the limit reference points under current catches and TACCs, in the short to medium term.

Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unlikely (< 40%)

Assessment Methodology		
Assessment Type	Level 2 - Partial Quantitative stock assessment	
Assessment Method	Estimates of total mortality using Chapman-Robson estimator	
Main data inputs	-Age structure of setnet and trawl catches of blue moki made between Kaikoura and East Cape in 2004–05 and 2005–06 -Instantaneous rate of natural mortality (*M*) of 0.10 based on a maximum age of 44 years	
Period of Assessment	Latest assessment: 2008	Next assessment: 2017
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	Uncertainty in the estimate of *M*	

Qualifying Comments
-
Fishery Interactions
-

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*	2013–14 Actual TACC	2013–14 Reported landings
MOK 1	Auckland (East) (West), Central (East) (West), Challenger 1, 2, 7, 8 & 9	-	403	385
MOK 3	South East (Coast) 3	-	127	159
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	608	549

6. FOR FURTHER INFORMATION

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Manning, M J; Stevenson, M L; Dick, C M (2009) The length and age composition of the commercial catch of blue moki (*Latridopsis ciliaris*) in MOK 1 during the 2004/05 and 2005/06 fishing years including total and fishing mortality estimates. *New Zealand Fisheries Assessment Report* 2010/34. 65 p.

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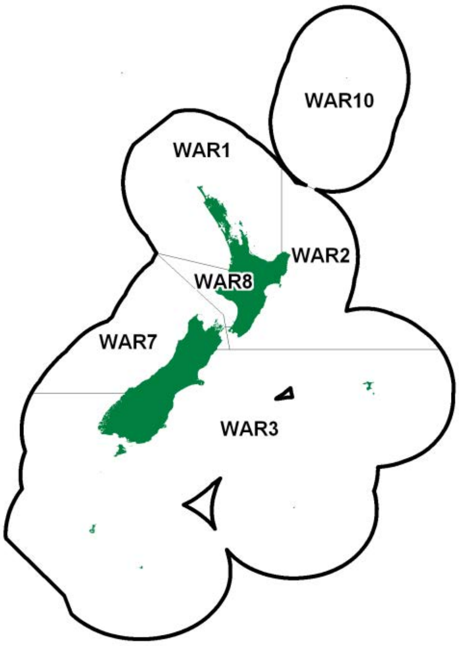
BLUE WAREHOU (WAR)

(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 1). Figure 1 shows the 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. In all other areas landings are below the TACCs.

Table 1: Reported landings (t) of blue warehou by Fishstock 1983–84 to 2013–14 and actual TACCs (t) from 1986–87 to 2013–14. QMS data from 1986–present.

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

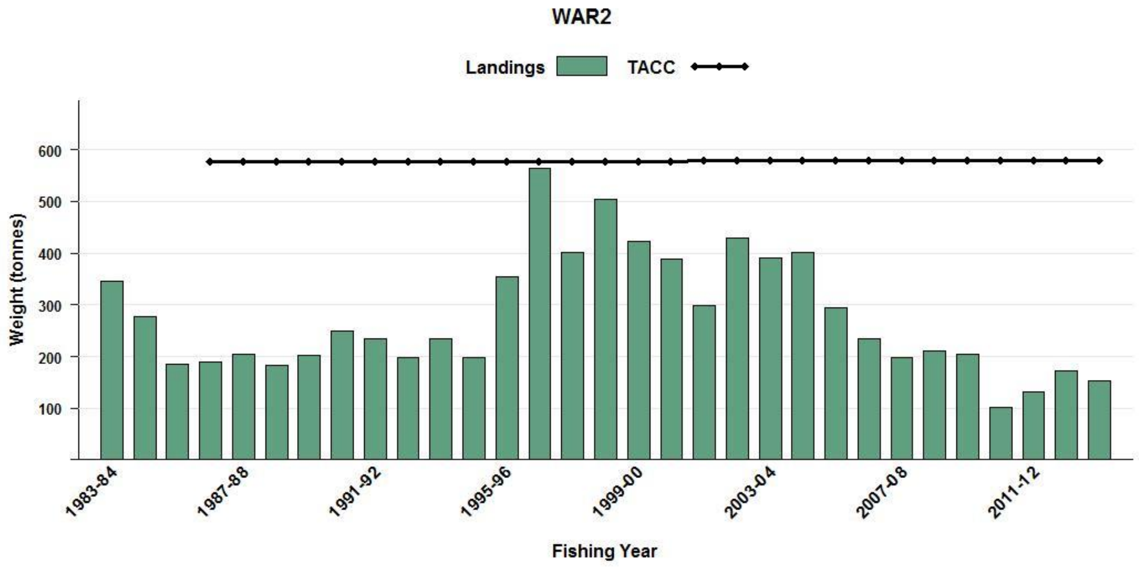
Fishstock	WAR 8		WAR 10			
FMA	8		10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC
1983–84*	104	-	0	-	4 387	-
1984–85*	91	-	0	-	2 165	-
1985–86*	43	-	0	-	2 782	-
1986–87	40	210	0	10	2 347	4 850
1987–88	43	218	0	10	1 915	5 014
1988–89	44	231	0	10	1 466	5 162
1989–90	57	233	0	10	1 696	5 459
1990–91	113	233	0	10	3 232	4 499
1991–92	132	233	0	10	3 905	4 499
1992–93	152	233	0	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	< 1	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
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

* FSU data.

‡ Includes landings from unknown areas before 1986–87.

1.2 Recreational fisheries

Estimates of recreational catch in the MAF Fisheries Central and South regions are shown in Table 2. Surveys in the North region in 1993–94 indicated that blue warehou were not caught in substantial quantities.



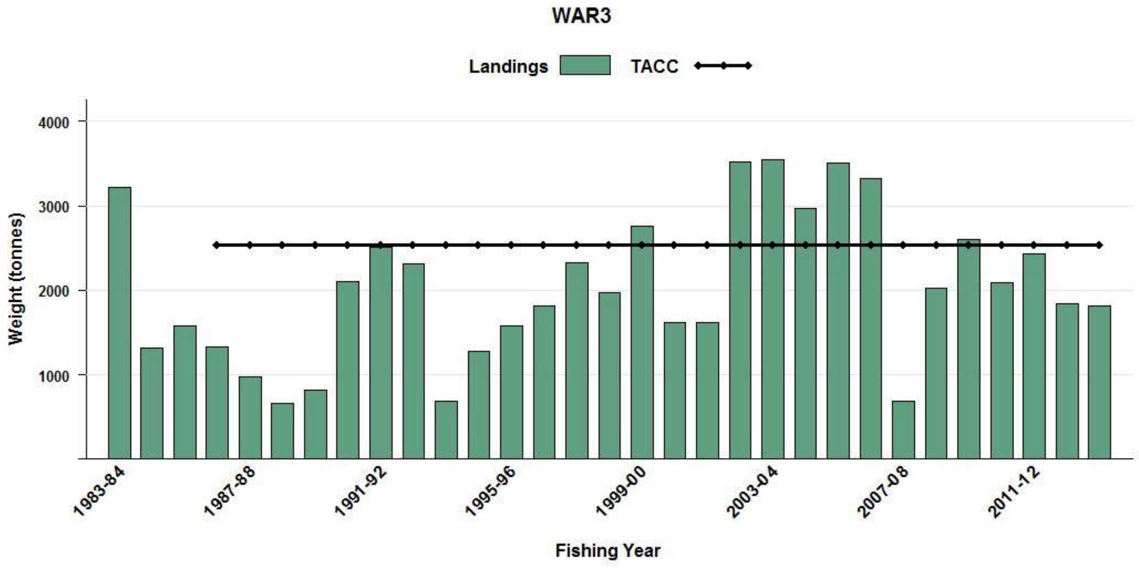
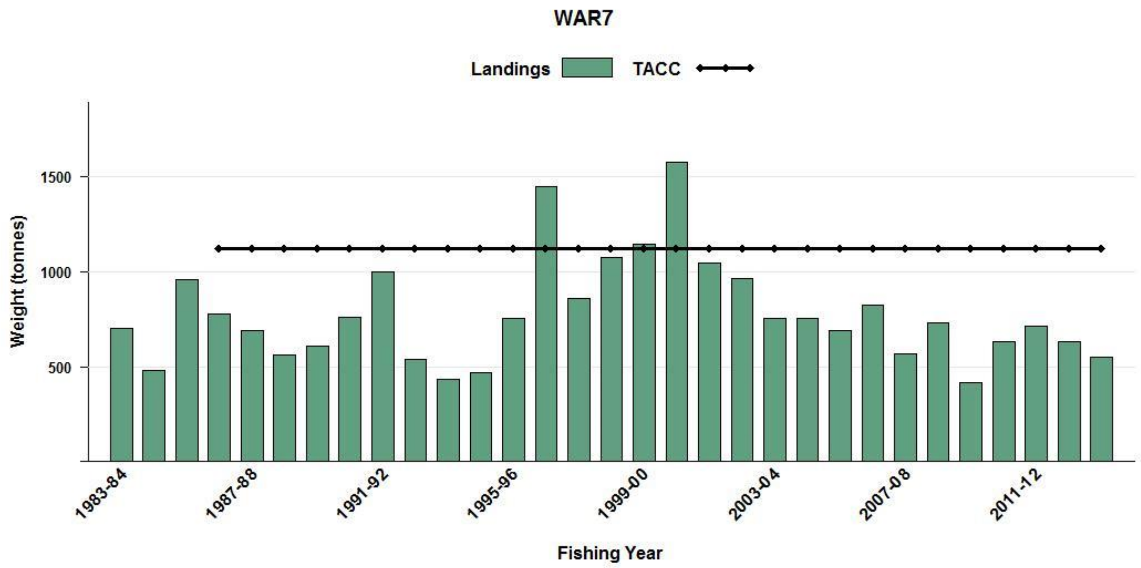


Figure 1: Reported commercial landings and TACC for the four main WAR stocks. From top to bottom: WAR 2 (Central East) and WAR 3 (South East Coast). [Continued on next page].



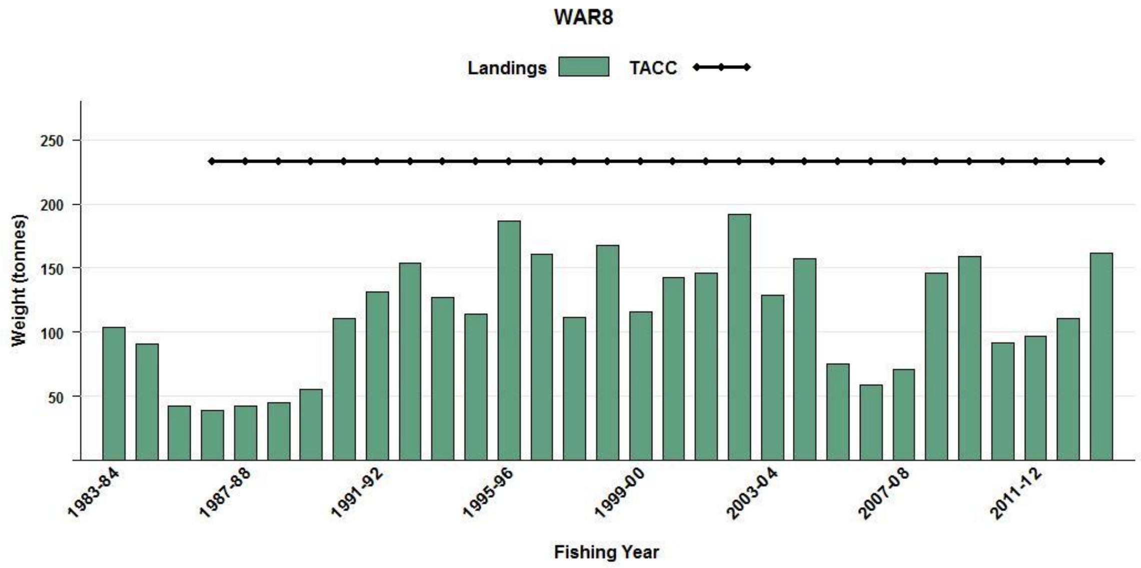


Figure 1 [Continued]: Reported commercial landings and TACC for the four main WAR stocks. WAR 7 (Challenger) and WAR 8 (Central Egmont).

Table 2: 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	62%
WAR 7	Central	1.7	65%
WAR 8	Central	0.6	102%

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, and the estimates are not considered reliable.

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 Hawkes 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 3.

Table 3: 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 4) 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 4: 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.

$$\begin{aligned} MCY &= 0.8 * (300\text{–}350 \text{ t}) \\ &= 240\text{–}280 \text{ t} \end{aligned}$$

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

$$\begin{aligned} MCY &= 0.8 * 2040 \text{ t} \\ &= 1630 \text{ t} \end{aligned}$$

Challenger (WAR 7)

The catches from 1983–84 to 1985–86 were considered to be a sustainable level of catch. Y_{AV} = 710 t.

$$\begin{aligned} MCY &= 0.8 * 710 \text{ t} \\ &= 570 \text{ t} \end{aligned}$$

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.

$$MCY = 80 \text{ t}$$

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 2012–13 fishing year are summarised in Table 5.

Table 5: Summary of yield estimates (t), TACCs (t) and reported landings (t) for blue warehou for the most recent fishing year.

Fishstock		FMAs	*MCY*	2013–14 Actual TACC	2013–14 Reported landings
WAR 1	Auckland (East) (West)	1 & 9	240–280	41	8
WAR 2	Central (East)	2		578	172
WAR 3	South-east (Coast) (Chatham), Southland & Sub-Antarctic	3,4,5 & 6	1 630	2 531	1 847
WAR 7	Challenger	7	570	1 120	632
WAR 8	Central West)	8	80	233	111
WAR 10	Kermadecs	10	0	10	0
Total				4 512	2 770

6. FOR FURTHER INFORMATION

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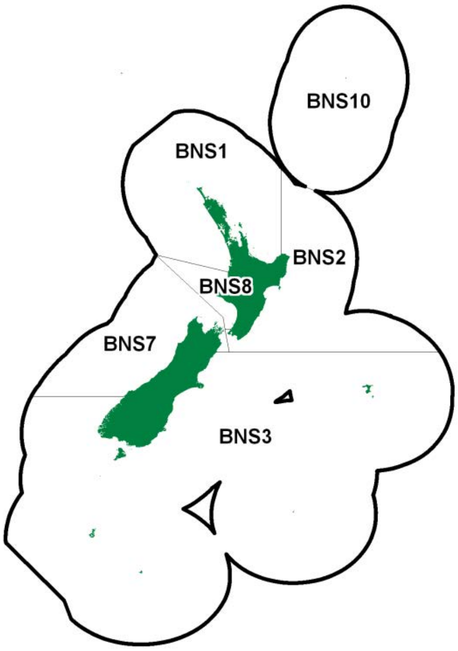
BLUENOSE (BNS)

(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 below.

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	400	425
BNS 2	25	2	9	438	474
BNS 3	18	2	3	171	194
BNS 7	3	2	2	62	69
BNS 8	2	1	1	29	33
BNS 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 on the lower east cost of the North Island developing after 1983, initially as a bycatch of the alfonsino fishery (Horn 1988). 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 (BoP) and off Northland (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 focussed on the eastern Chatham Rise where bottom longline catches were historically a bycatch of ling and häpuku 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 mid-water trawl fishery in BNS 3 since the early 2000s. The bottom trawl fishery in BNS 3 has diminished. A small amount of target setnet fishing for bluenose occurred in the Bay of Plenty until 1999 and has occurred again since 2012. Target bluenose setnet fishing also occurs sporadically in the Wairarapa region of BNS 2. Setnet catches and off the east coast of the South Island have been a mix of target and bycatch in ling and häpuku target sets.

Reported landings and TACCs since 1981 are given in Table 2, while 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 2013-14 and actual TACCs (t) from 1986–87 to 2013-14. QMS data from 1986-present.

Fish stock		BNS 1		BNS 2		BNS 3		BNS 7		BNS 8
FMA (s)		1 & 9		2		3, 4, 5 & 6				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

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
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

Table 2 [Continued]

Fish stock		BNS 10		
FMA (s)		10	Total	
2011–12	0	10	1 218	1 590
2012–13	0	10	1 142	1 110
2013-14	0	10	1 190	1110

* 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 1 175 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 area that 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 (BNS 1), 902 (BNS 2), 505 (BNS 3), 89 (BNS 7) and 43 (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 (BNS 1), 629 (BNS 2), and 248 (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 (BNS 1), 438 (BNS 2), 171 (BNS 3), 62 (BNS 7) and 29 (BNS 8). The 2011 rebuild plan included a third phase of TACC reductions. This phase has been delayed pending further evaluation.

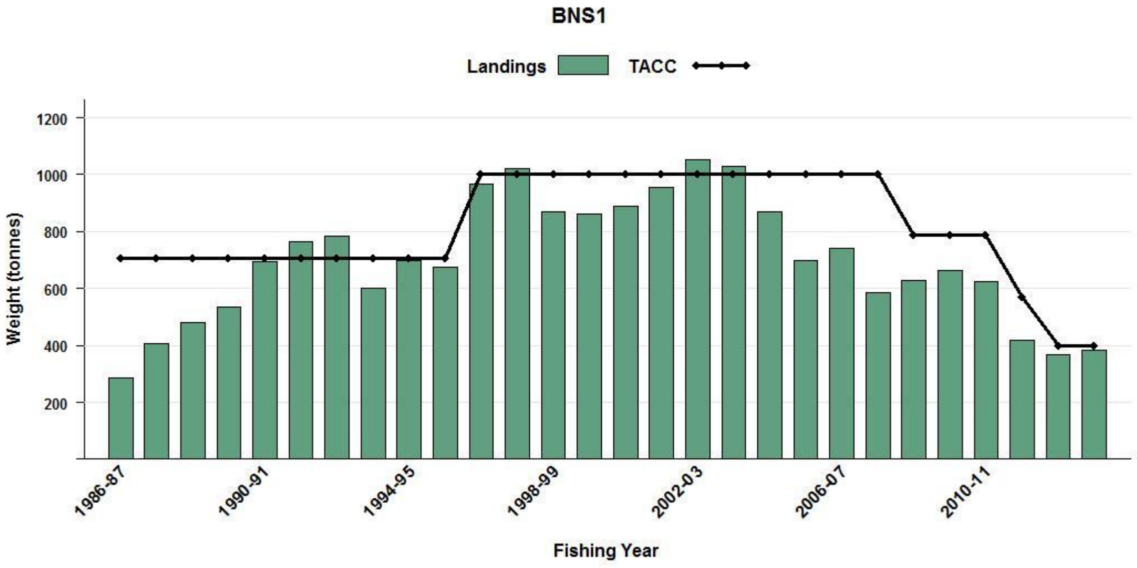
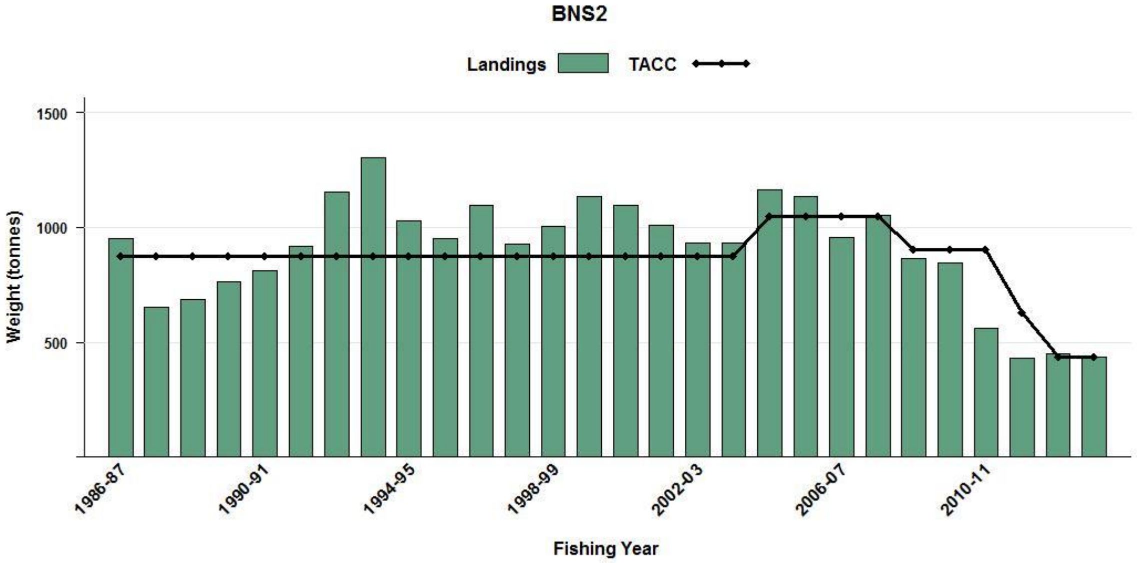
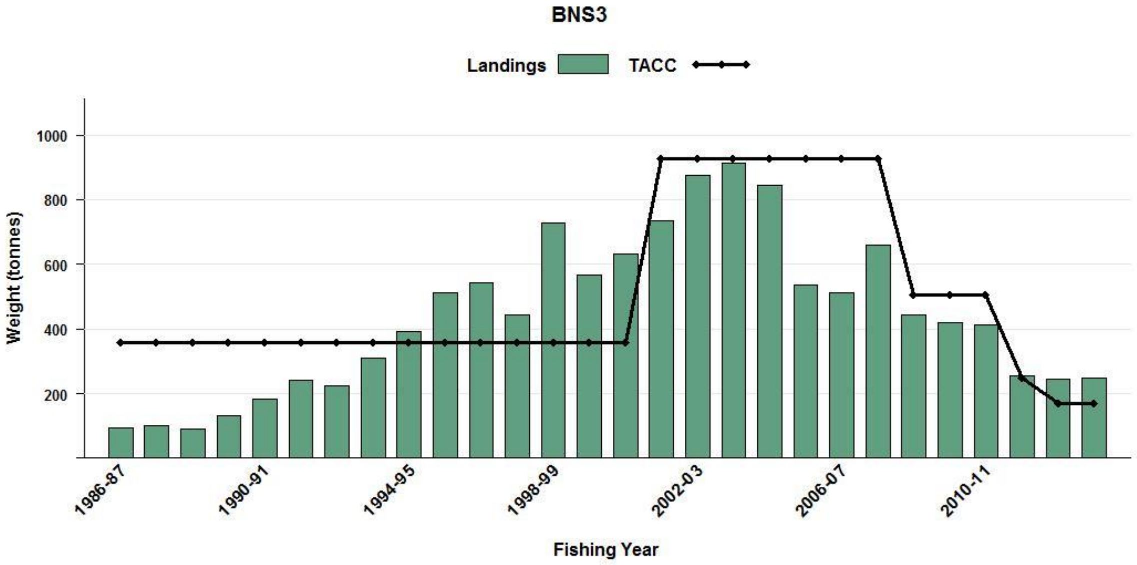


Figure 1: Reported commercial landings and TACC for the five main BNS stocks. BNS1 (Auckland East) [Continued on next page].





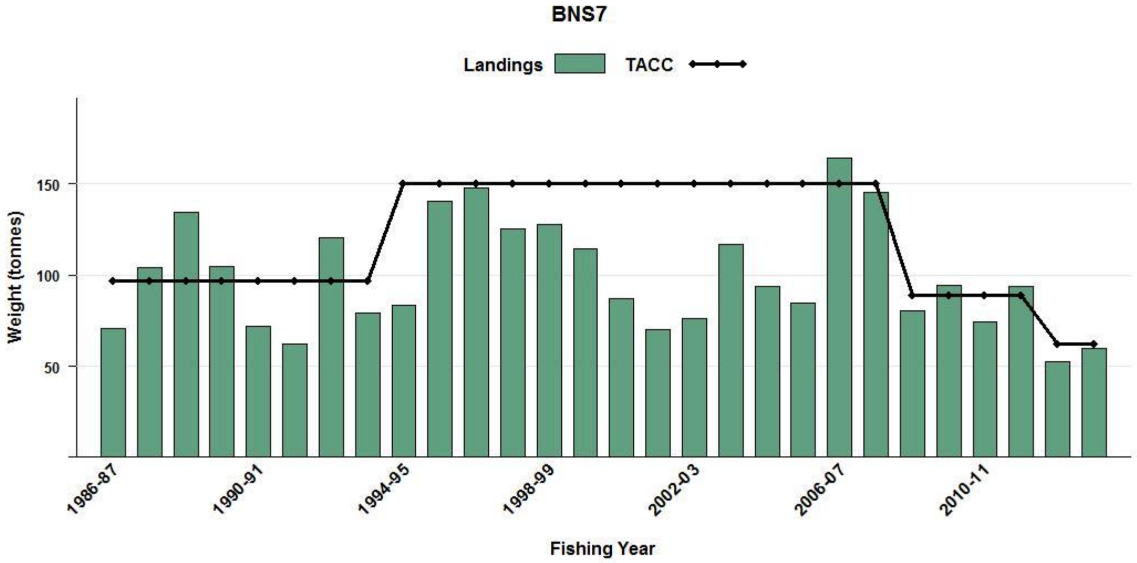


Figure 1: [Continued] Reported commercial landings and TACC for the five main BNS stocks. Top to bottom: BNS2 (Auckland East), BNS3 (Central East), BNS7 (Challenger) [Continued on next page].

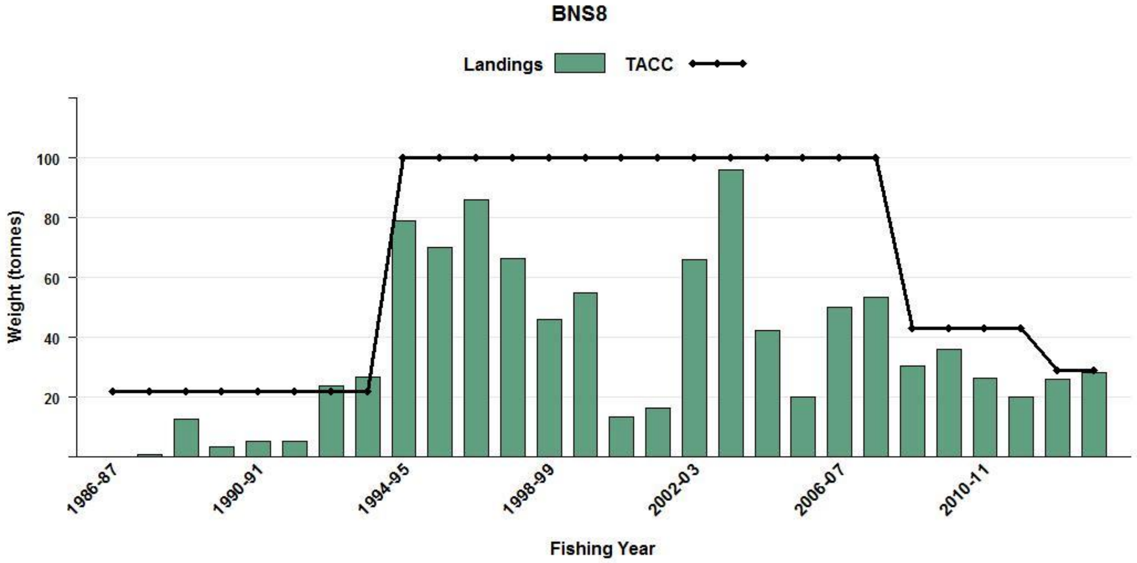


Figure 1 [Continued]: Total commercial catch and TACC for the five main BNS stocks. BNS8 (Central Egmont).

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, before the reduction from 2008-09 to 2335 t. 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 20% (average landings 2602 t / year) from 2004-05 to 2007-08. The reduced TACC of 2335 t was under-caught by 12% in 2008-09 and 2009-10.

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 shown in Table 1.

1.2.1 Management controls

From 2010 on the catch limit for recreational fishers in all areas is 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 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 2005) 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 2 000 fish in 1993–94 (Teirney *et al*. 1997), 5000 fish in 1996 (Bradford 1998) and 11 000 fish in 1999–00 (Boyd & Reilly 2005). 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. Note that the national panel survey estimate does not include recreational harvest taken Recreational catch estimates from the national panel survey are given in Table 3.

Table 3: Recreational harvest estimates for bluenose stocks (Wynne-Jones et al. 2014). Mean fish weights were obtained from boat ramp surveys; for bluenose the value used was 4.473 kg (Hartill and Davey 2015).

Stock	Year	Method	Number of fish	Total weight (t)	CV
BNS 1	2011/12	Panel survey	6,287	28.15	0.40
BNS 2	2011/12	Panel survey	444	1.99	0.48
BNS 3	2011/12	Panel survey	461	2.05	0.92
BNS 7	2011/12	Panel survey	456	2.02	1.00
BNS 8	2011/12	Panel survey	137	0.61	1.03

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 1 200 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 <100 m to about 1 000 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, while 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 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 1988). 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 *et al.* (2010) estimated a maximum age of 76 years, approximately twice the previous maximum age estimate. 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 appears 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 (2011) recorded a maximum age of 71 years for BNS 1, and estimated natural mortality (*M*) to be in the range 0.09-0.15, based on 1% of the unfished population living to 30- 50 years. Given the maximum recorded age, they commented that estimates of *M* less than 0.09 may be appropriate as bluenose live to at least 71 years and older fish may be poorly sampled by the line fishery. From the range of estimates resulting from recent ageing, the working group concluded that *M* for bluenose was unlikely to be > 0.1.

Instantaneous total mortality was estimated for five BNS 1 line fishery samples (Horn & Sutton 2011). The best estimates of *Z* ranged from 0.13 to 0.17, indicating that *F* was probably lower than *M*. This result was unexpected given recent strong declines in bluenose CPUE and the dramatic increase in targeting beginning in the mid-1980s. It was concluded that *Z* was underestimated, probably because the sampled fishing grounds did not hold closed populations, resulting in large or old fish being over-represented in the catch.

Maturity and reproduction

Biological parameters relevant to stock assessment are summarised in Table 4.

Table 4: Estimates of biological parameters for bluenose.

Fishstock						Estimate	Source
1. Natural mortality (*M*)							
BNS						0.09-0.15	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}			17	15			Horn & Sutton (2011)

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 commercial logbook programmes, primarily in BNS 1, 7 & 8, indicate that spawning probably peaks from February to April annually. No distinct spawning grounds have been identified for bluenose in New Zealand waters. The logbook programmes have sampled reproductively active fish around the North Island from East Cape to west of Cook Strait, and off the south west coast of the South Island. Observer data includes a small number of observations of spawning fish, but these extend from the southern half of FMA 10 to the Stewart-Snares shelf.

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, BoP, 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, causing 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.

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). Standardised catch per unit effort (CPUE) indices were updated in 2015.

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.

Table 5: The three alternative catch (t) histories used in the BNS model runs. Trawl catch prior to 1970 was assumed to be zero.

	Line				Line				Trawl		
	Low	Mid	High		Low	Mid	High		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

Table 5 [continued]

	Line		
	Low	Mid	High
1949	0	95	189
1950	0	89	177
1951	0	74	147
1952	0	71	142
1953	0	70	141
1954	0	69	137
1955	0	66	132
1956	0	69	138
1957	0	69	138
1958	0	75	149
1959	0	68	137
1960	0	62	124
1961	0	60	121
1962	0	59	118

	Line		
	Low	Mid	High
1976	618	692	767
1977	821	913	1004
1978	1	81	161
1979	9	92	176
1980	15	98	180
1981	235	300	365
1982	469	511	554
1983	730	755	780
1984	951	956	962
1985	1013	1013	1013
1986	982	982	982
1987	744	744	744
1988	752	752	752
1989	797	797	797

	Trawl		
	Low	Mid	High
1976	0	112	211
1977	0	385	1505
1978	0	0	0
1979	0	0	0
1980	0	0	0
1981	0	0	0
1982	0	0	0
1983	0	0	0
1984	324	324	324
1985	372	372	372
1986	605	605	605
1987	667	667	667
1988	522	522	522
1989	623	623	623

	No variation	
	Trawl	Line
1990	763	777
1991	577	1192
1992	549	1414
1993	733	1573
1994	860	1459
1995	904	1382
1996	811	1503
1997	1060	1765
1998	779	1728
1999	904	1871
2000	1022	1712
2001	1082	1638
2002	1345	1443
2003	1331	1671
2004	957	2133
2005	1114	1900
2006	710	1765
2007	424	2001
2008	500	2000
2009	300	1746
2010	300	1759
2011	300	1700

Two CPUE indices (Starr & Kendrick 2013) 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 as the estimated CVs for the CPUE indices are unrealistically low (as is typical for indices estimated using a GLM approach).

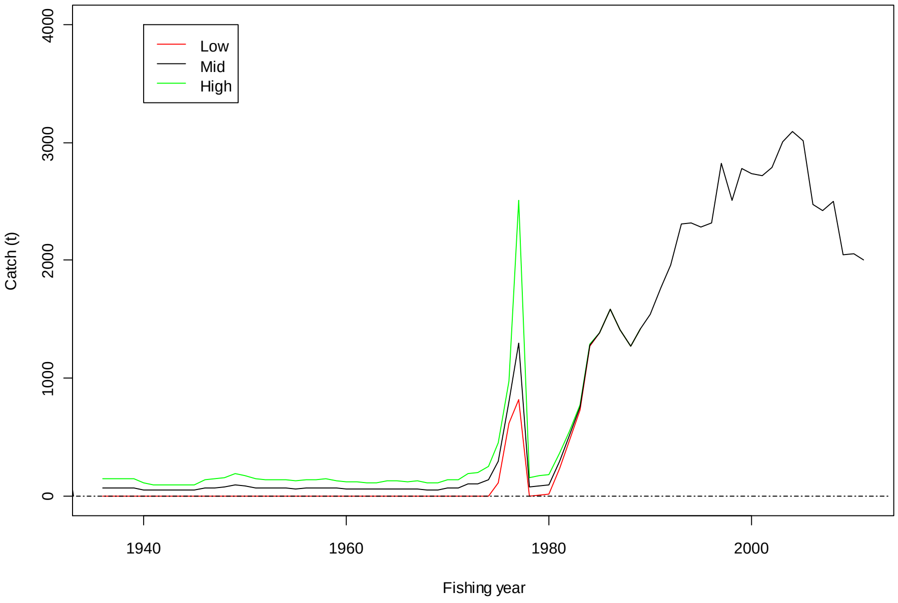


Figure 2: The three alternative catch histories used in BNS model runs.

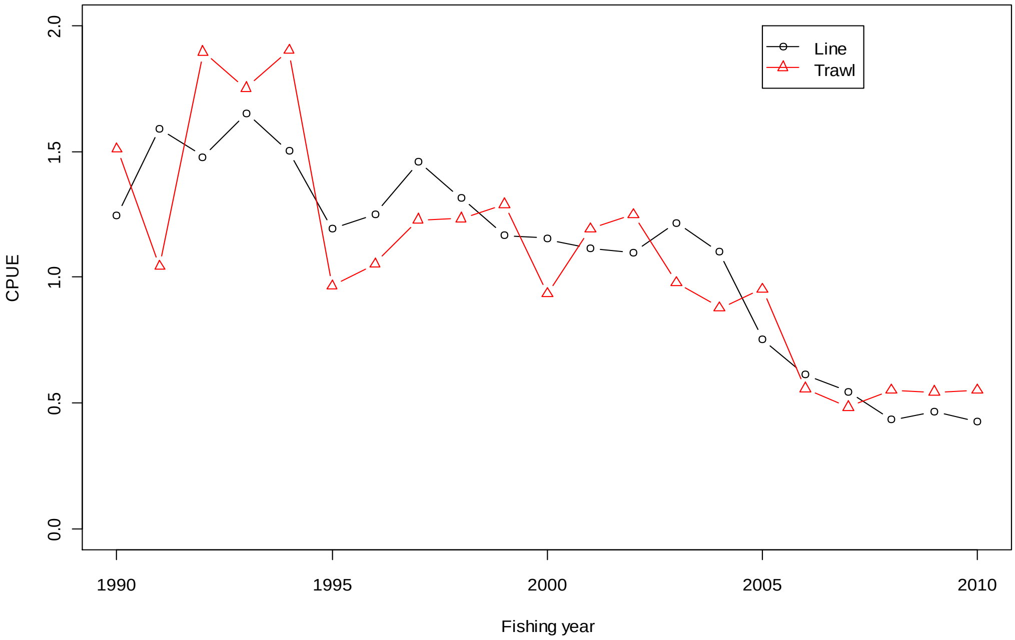


Figure 3: The line and trawl CPUE indices fitted in the 2011 BNS assessment model runs.

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 BoP 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).

Fixed parameters were assigned the following values:

	Male	**Female**	**Source**
Length-weight (cm, g)			
a	0.00963	0.00963	Plenary report
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, 0.9

The *M* values cover what the working group considered a plausible range. The default assumption of *h* = 0.75 was adopted, and h = 0.9 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. As 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).

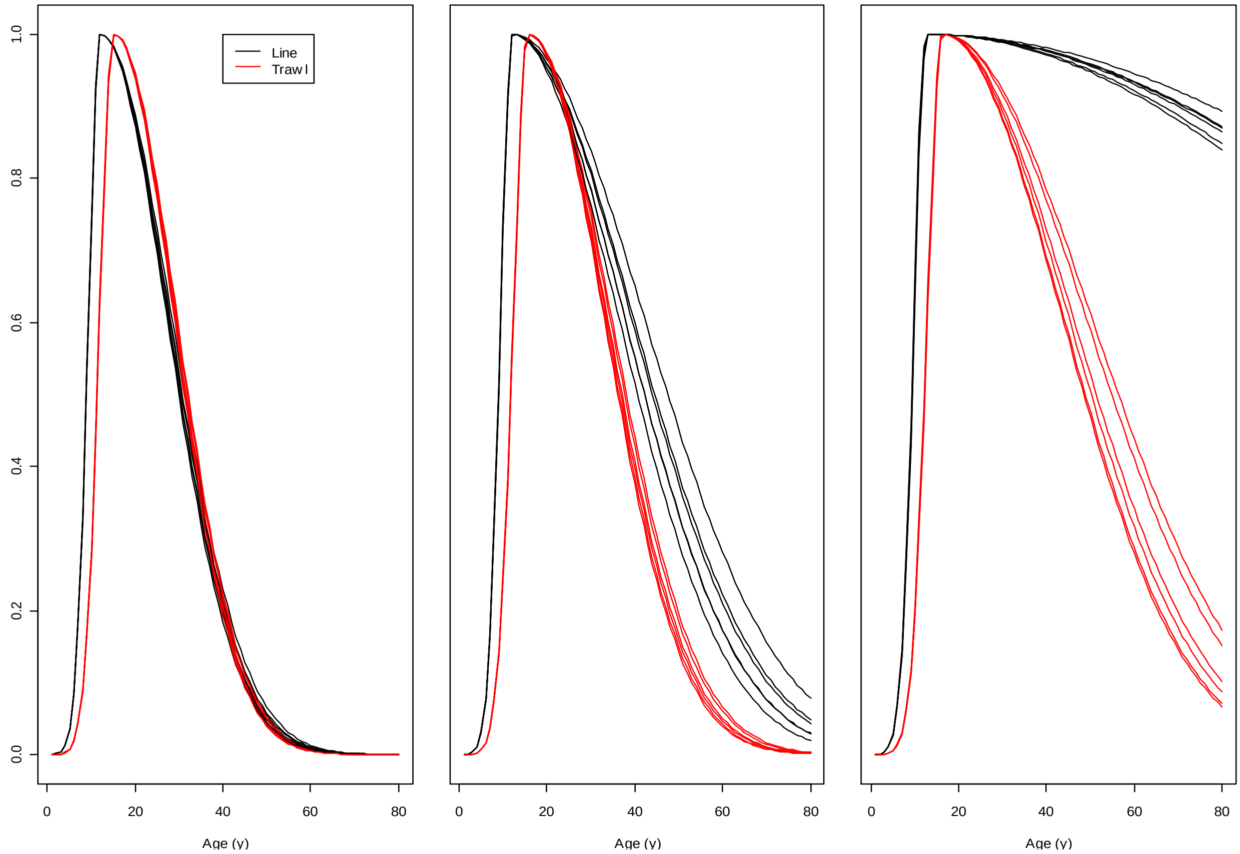


Figure 4: Estimated fishing selectivities for the trawl and line fisheries for the final 18 MPD runs. Each plot shows the results for six runs with the same value of *M* (which increases from 0.06 to 0.08 to 0.10 from left to right in the three plots).

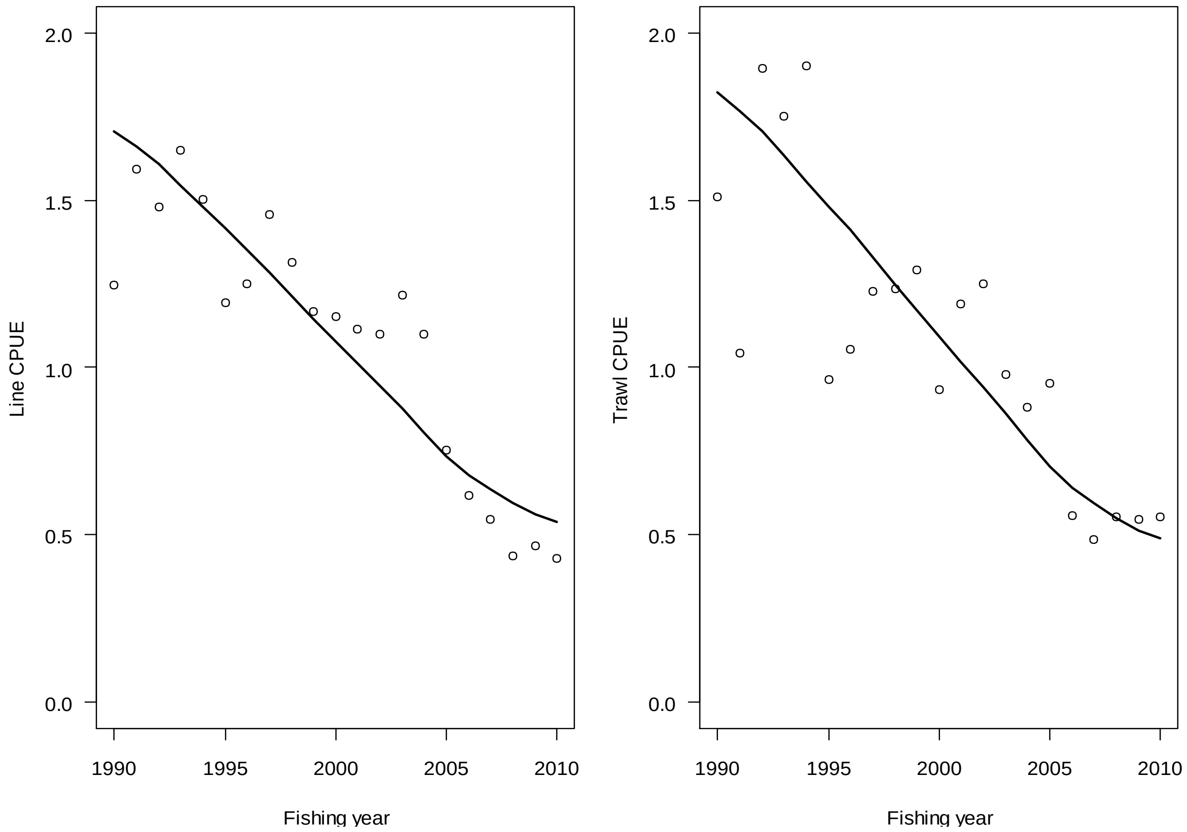


Figure 5: The model fits to the line and trawl CPUE for the run with mid catch, mid *M* and *h* = 0.75. The fits for the other runs were almost identical.

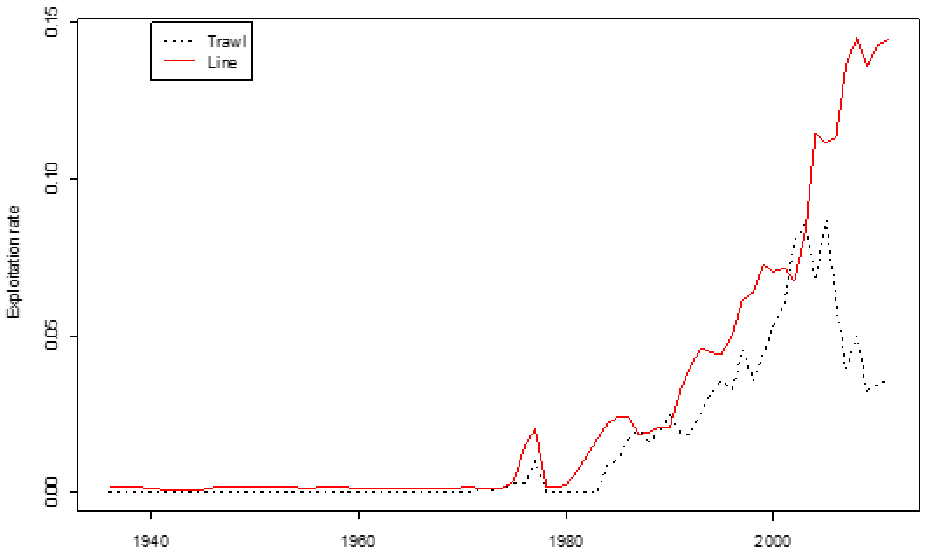


Figure 6: Exploitation rates (catch divided by beginning-of-year selected biomass) for the trawl and line fisheries for the run with mid catch, mid *M*, and *h* = 0.75.

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.

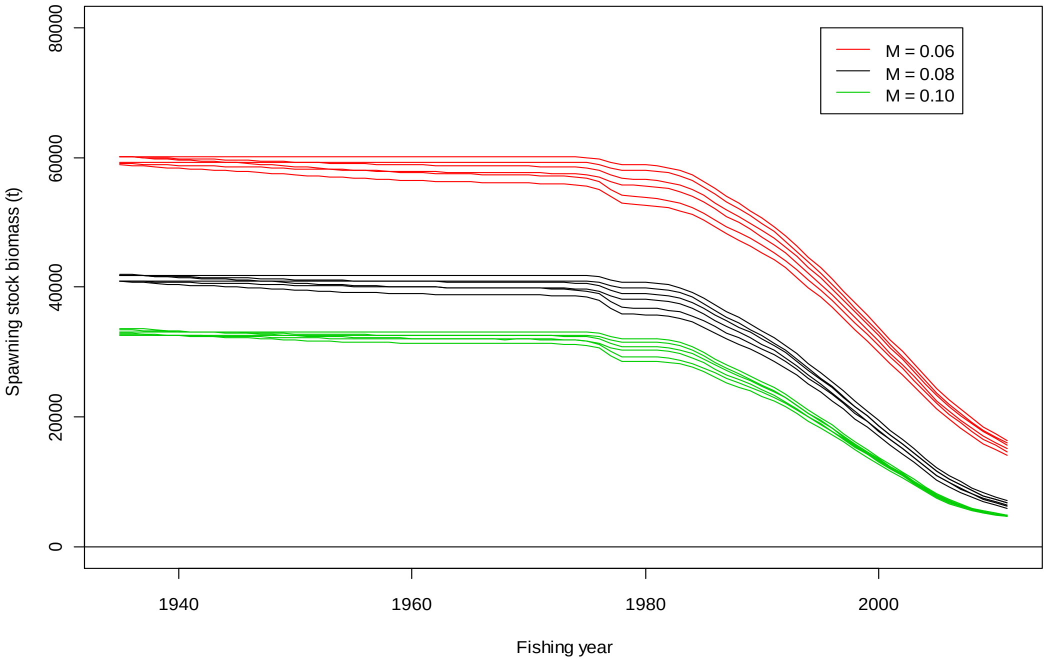


Figure 7: Biomass trajectories (t) for the final set of 18 MPD runs.

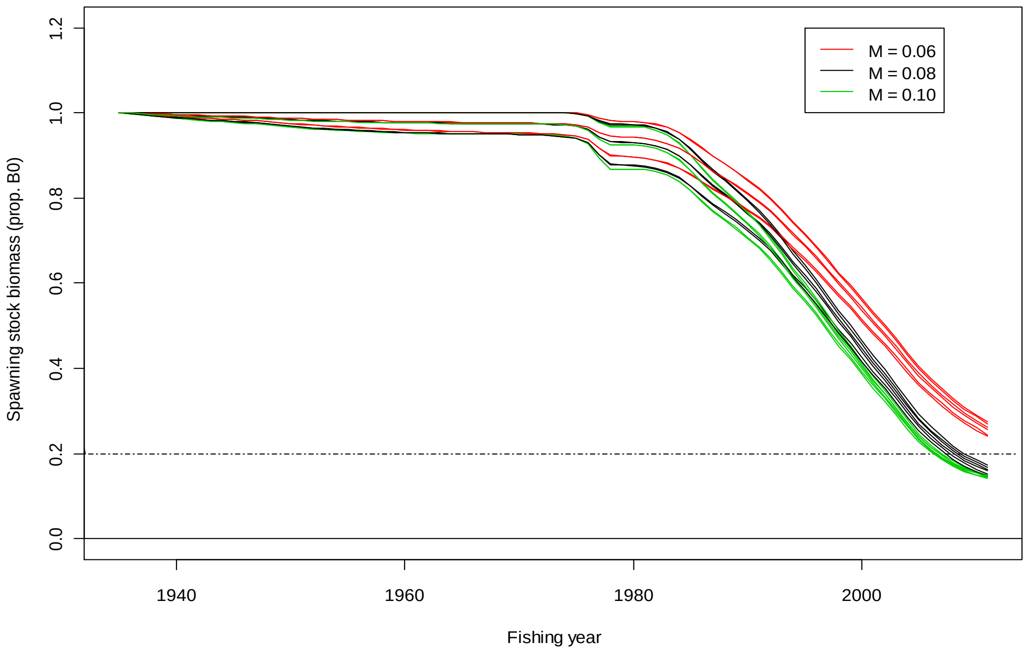


Figure 8: Biomass trajectories (proportion of B_0) for the final set of 18 MPD runs.

Biomass trajectories, as a proportion of B_0, all show a similar trend with a continuous decline from the late 1980s to 2011 (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 while 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.

Table 6: Estimates of B_0, B_{2011} and stock status (B_{2011}/B_0) for the final 18 runs. The range is given for the 6 runs at each value of M. B_0 and B_{2011} are mid-spawning season (after half the annual catch has been removed).

M	B_0 (000 t)	B_{2011} (000 t)	B_{2011}/B_0
0.06	60-60	15-16	0.24-0.27
0.08	42-42	6.3-7.0	0.15-0.17
0.10	33-34	4.8-5.0	0.14-0.15

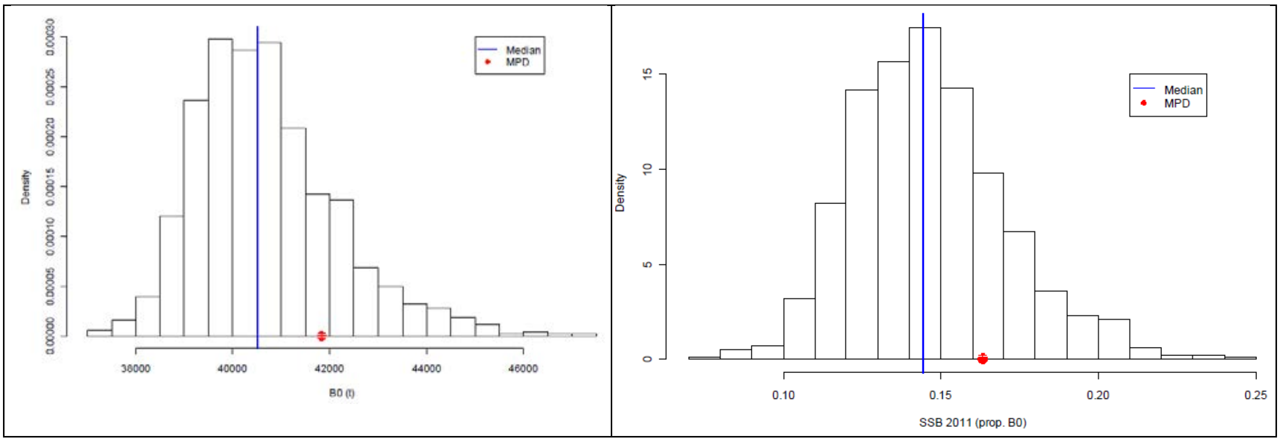


Figure 9: MCMC posteriors for B_0 and B_{2011}/B_0 for the mid catch, M = 0.08 and h = 0.75.

The MCMC run for the mid catch, $M = 0.08$ and $h = 0.75$ confirmed that the MPD and median of the posterior were similar for B_0 and stock status (Figure 9).

Assuming trawl and line catches remain in the same proportions as those used for 2010-11 in the model catch history, deterministic B_{MSY} was estimated as 25% B_0 when $h = 0.75$ and 15-18% B_0 when $h = 0.9$.

4.3 Projections

Deterministic projections to 2050 were carried out for a range of future constant catches, maintaining the 2009/10 ratio between catches from the line and trawl fisheries. Projections were carried out for the models fitted with the mid catch history only, as the different catch history scenarios had little effect on model estimates.

Catches at the level of the 2010/11 TACC or the 2009/10 catch (which was not much less than the TACC) were predicted to cause the stock to decline to very low abundance over the next 20 years (Figure 10). 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} range from 10 to 13 years (Table 7) and the maximum catches that allow a rebuild to 40% B_0 within twice T_{min} (the maximum rebuilding time under the Harvest Strategy Standard) range from 570–840 t (Table 8).

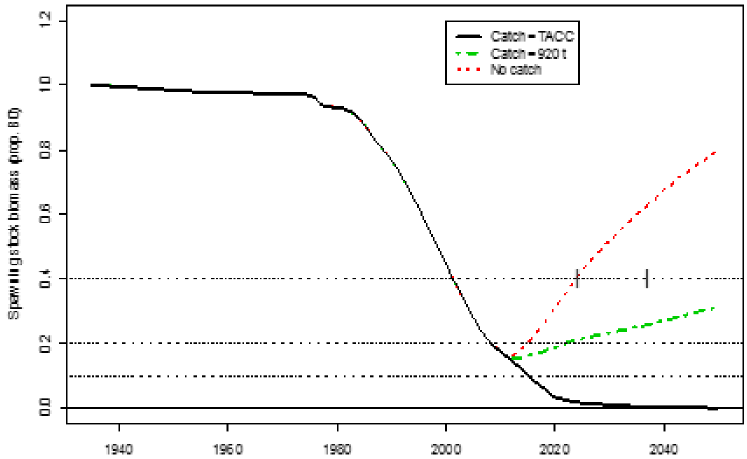


Figure 10: Projected SSB at different catch levels from the run with mid catch, M = 0.08 and h = 0.75. The two short vertical lines at 40% B_0 mark 2011 + T_{min} and 2011 + 2 T_{min}.

Table 7: The number of years before SSB reaches 40% B_0 when no future catch is taken. 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 catch (t) that allows SSB to rebuild to at least 40% B_0 within twice T_{min} for the six runs with mid catch.

	h	
M	**0.75**	**0.90**
0.06	600	720
0.08	570	770
0.10	600	840

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 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).

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 NZ EEZ, declined an average of 64% over the period 2001-02 to 2006-07.

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.

Information relating to bluenose stock structure is limited. In 2008, the AMP Working Group conducted full reviews of all bluenose Fishstocks which included separate CPUE abundance index standardisations for each Fishstock (Ministry of Fisheries 2008). The close coincidence between trends in the indices for all bluenose Fishstocks led the AMP Working Group to conclude that bluenose may constitute a single New Zealand-wide stock.

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.

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 2015. 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 as the high resolution data provides 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 x year interaction (Figure 11). 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.

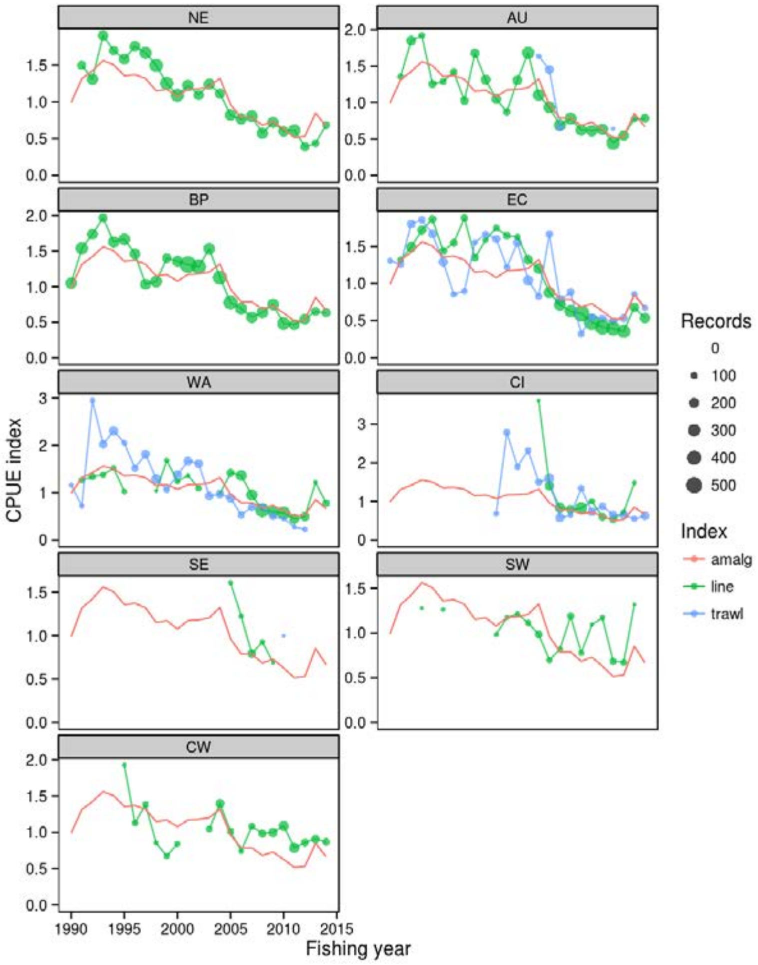


Figure 11: Zone-year indices for the line and trawl indices with the amalgamated national line index shown for reference. Zone-year combinations with less than 30 records are not shown.

The key bluenose target line and bluenose/alfonsino target trawl indices both showed an upturn in CPUE for 2012/13 (Figure 12). There is a decrease in both indices from 2012/13 to 2013/14 but they both remain above the 2011/12 nadir.

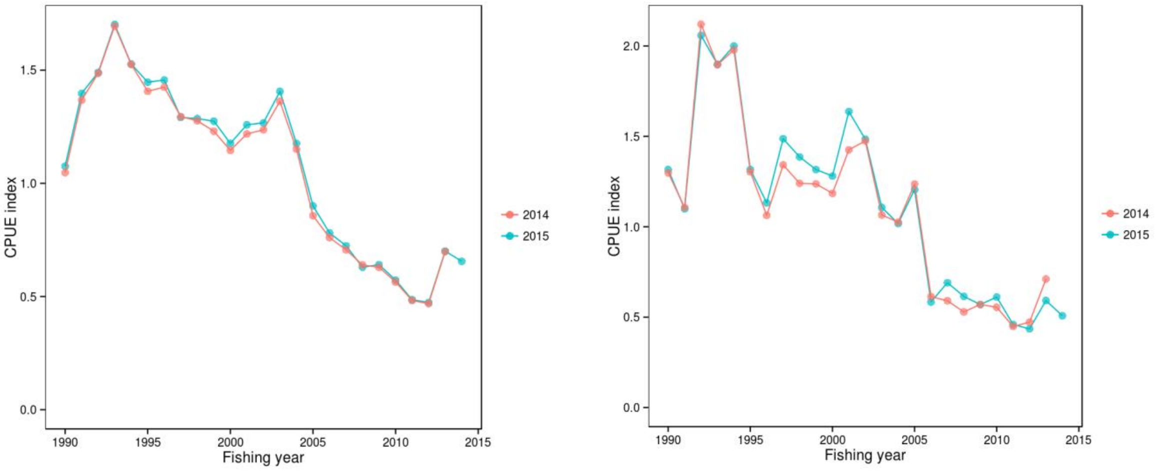


Figure 12: Standardised CPUE indices for bluenose in bluenose target longline (BLL.BNS) and bluenose/alfonsino target trawl (MW+BT.BYX+BNS). The updated 2015 indices with a new core vessel selection are shown in comparison to the 2014 estimated series.

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.

5. STATUS OF THE STOCKS

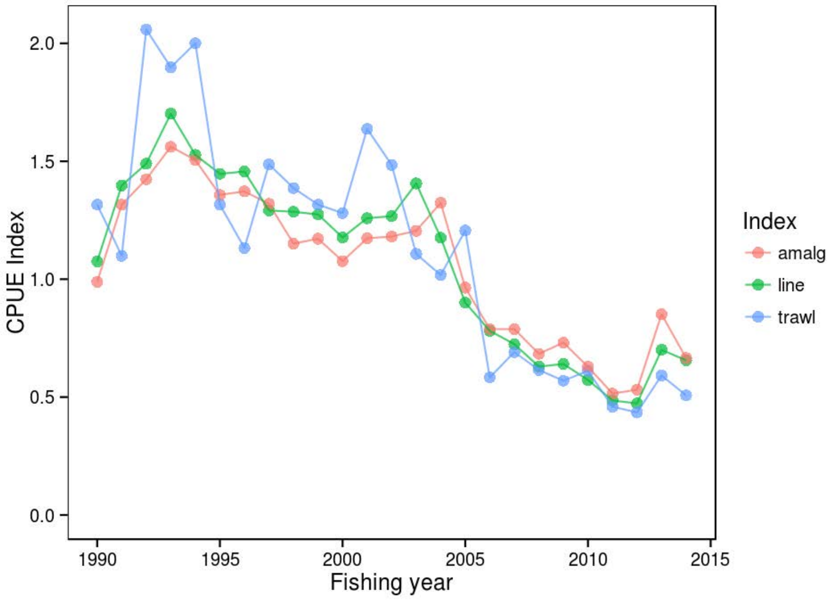
Stock Structure Assumptions

The assessment presented here assumes that bluenose in New Zealand waters comprise a single biological stock.

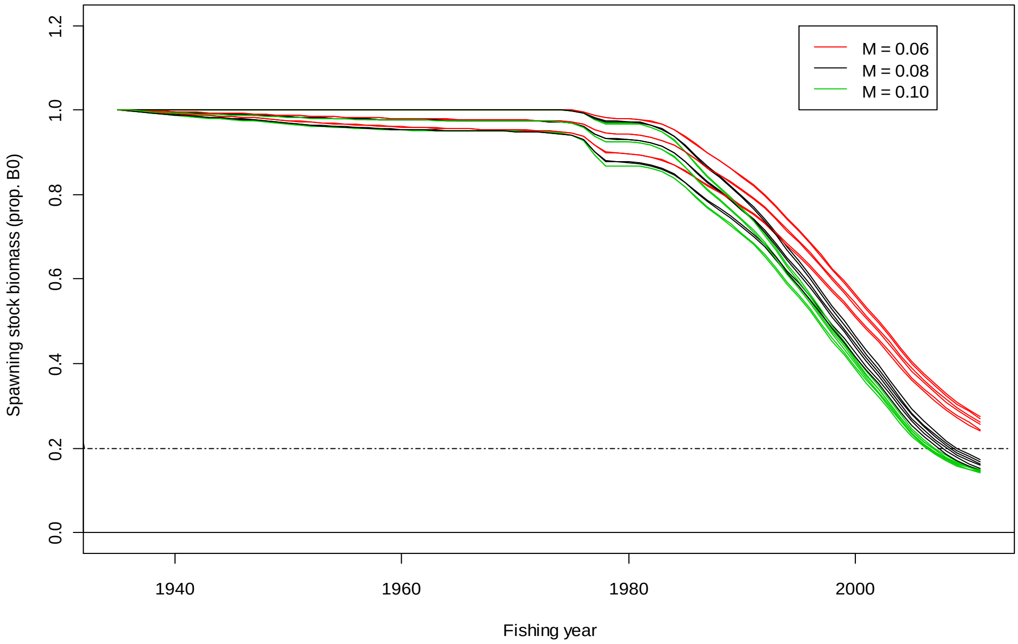
BNS 1, BNS 2, BNS 3, BNS 7, BNS 8, BNS 10

Stock Status	
Year of Most Recent Assessment	2011: Stock assessment 2015: CPUE update
Assessment runs presented	Assessment Eighteen MPD runs exploring a plausible range of catch history, natural mortality rate, and stock-recruitment steepness CPUE Standardised CPUE for bluenose target longline and bluenose/alfonsino target trawl
Reference Points	B_{MSY}: 15-25% B_0 Target: Not formally established; assumed to be 40% B_0 (based on Harvest Strategy Standard Operational Guidelines, low productivity stock) Soft Limit: 20% B_0 (HSS default) Hard Limit: 10% B_0 (HSS default)
Status in relation to Target	The New Zealand bluenose stock was assessed in 2011 to be Very Unlikely (< 10%) to be at or above the default target (MPD range B_{2011} = 14-27% B_0) but abundance indices have subsequently increased. Unlikely (< 40%) to be at or above the default 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

Historical Stock Status Trajectory and Current Status



CPUE for bluenose target longline and bluenose/alfonsino trawl. The amalgamated index is obtained by combining the individual zone line indices according to the area of bluenose habitat in each.



Spawning stock biomass trajectories (proportion of B_0) for the final set of 18 MPD. Runs.

Fishery and Stock Trends

Recent Trend in Biomass or Proxy	The MPD estimates of stock size in 2011 ranged from 14-27% B_0. Biomass was estimated to have declined continuously since the 1980s and to have been below the default target biomass since around 2000. Abundance indices showed a sharp increase in 2012/13.There was a decrease in the indices from 2012/13 to 2013/14 but they remain above the 2011/12 nadir.
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. Fishing mortality is therefore likely to have decreased.
Other Abundance Indices	A second BLL index based on bycatch of bluenose in the HPB fishery had a trend that was very similar to the target BNS series, but with a less pronounced increase in 2012/13. This series was not updated in 2015
Trends in Other Relevant Indicator or Variables	-

Projections and Prognosis		
Stock Projections or Prognosis	Deterministic projections 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 assumed target (40% B_0) under zero catches ranges from 10 to 13 years, depending on model assumptions. Within the range of model runs explored, the maximum catch (EEZ wide) that would rebuild the stock to the target within twice T_{min} was 570-600 t for $h = 0.75$ and 720-840 t for $h = 0.9$. A rebuilding plan to reduce catches and rebuild the stock to target levels within twice T_{min} was developed. Two stepped reductions in TACC were implemented and a third has been put on hold following a substantial increase in the standardised CPUE abundance indices.	
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		
Assessment Type	Level 1: Full Quantitative Stock Assessment (2011) Level 2: Partial Quantitative Assessment (2014)	
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: Stock Assessment: 2011; CPUE: 2015	Next assessment: 2016
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- CPUE indices derived from statutory catch and effort reporting	1 – High Quality
	- Length frequency data from sampling conducted under the Adaptive Management Programme, and from observer data	1 – High Quality
	- One age frequency distribution for each of the trawl and line fisheries	1 – High Quality

Data not used (rank)	-	
Changes to Model Structure and Assumptions	Stock Assessment The 2011 assessment was the first full quantitative assessment of bluenose and assumes a single NZ-wide stock. CPUE indices for longline and trawl fisheries were assumed to index abundance. CPUE The 2015 CPUE index for the longline fishery 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. Although some increase in BNS biomass is likely to have occurred as a result of the recent TACC reductions, the low productivity of BNS suggests that biomass is unlikely to have increased from 2011–12 to 2012–13 to the same degree as CPUE. Since bluenose aggregate on features, and CPUE is consequently likely to be hyper-stable, it is possible that smaller increases in abundance could be disproportionately reflected in CPUE. The increase in BNS CPUE was not nearly as pronounced when targeting HPB or LIN. The 2013–14 CPUE index was consistent with an increase in abundance.

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 NZ 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]

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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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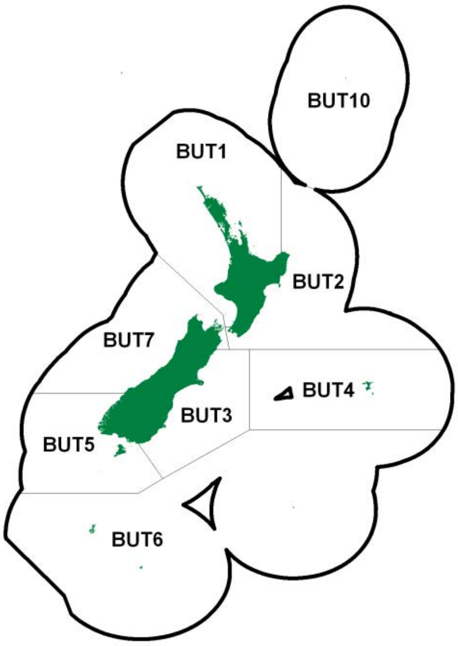
BUTTERFISH (BUT)

(*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. This effectively closed the butterfish fishery in FMA 5 and 7 but interim relief for butterfish fishers was granted in FMA 7 by the High Court in a review of the Ministers decision on 23 February 2010.

As a result of a judicial review, the High Court referred the decision not to exempt targeted butterfish commercial fishing from the closure of part of the east coast South Island to set net fishing, back to the Minister for Primary Industries for reconsideration.

Table 2: Reported domestic landings (t) and TACCs of butterfish by Fishstock from 2001–02 to 2013–14.

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

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

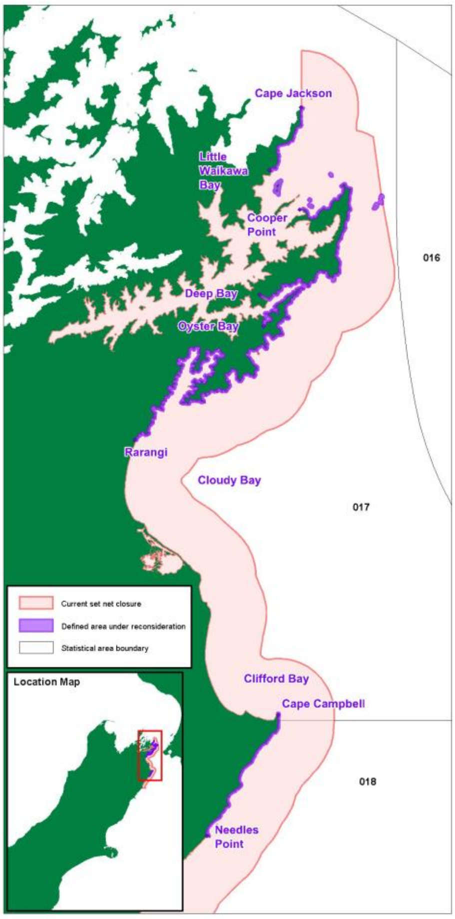

Cape Jackson
Little Waikawa Bay
Cooper Point
016
Deep Bay
Oyster Bay
Rarangi
Cloudy Bay
017
Current set net closure
Defined area under reconsideration
Statistical area boundary
Location Map
Clifford Bay
Cape Campbell
018
Needles Point

Figure 1: Map showing the setnet closures and areas that are under reconsideration.

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 (see Figure 1).

The Minister considers that there is an acceptable level of risk in terms of mortality from butterfish fishing by commercial fishers on the East Coast South Island given the type of fishing gear they use, the size of the area and the numbers of Hector's dolphins. The Minister also directed the Ministry to advise him whether an exemption may be warranted for recreational set net fishers targeting butterfish in the same defined area of the East Coast South Island where he granted the commercial exemption.

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 2 shows the historical landings and TACC values for the main BUT stocks.

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 & 7, and substantially higher in QMA 3 (Tables 3 and 4).

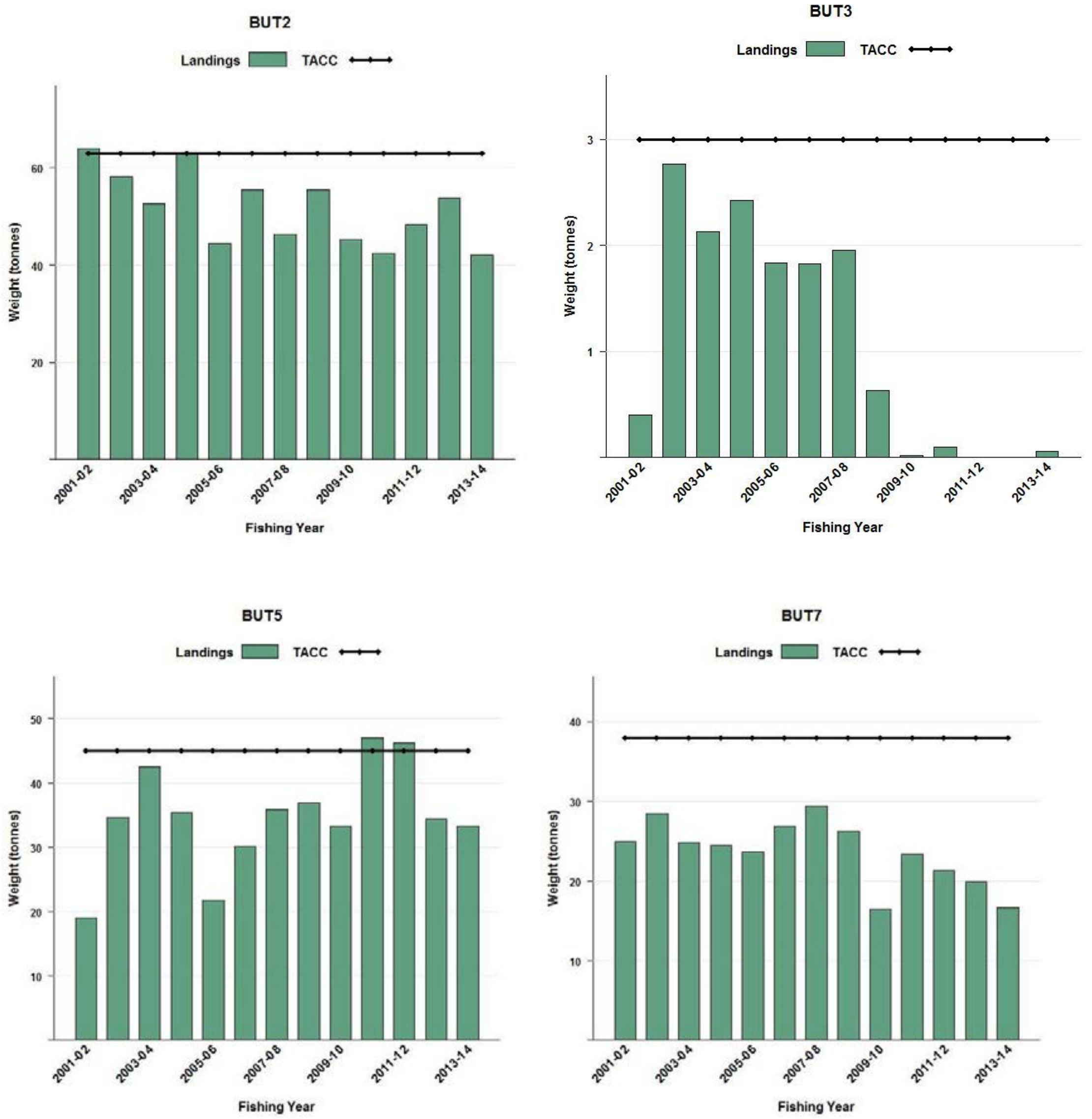


Figure 2: Reported commercial landings and TACC for the three main BUT stocks. BUT 2 (Central East), BUT 3 (South east coast), BUT 5 (Southland) and BUT 7 (Challenger).

Table 3: 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 4: Estimated number and weight of butterfish harvested by recreational fishers by Fishstock and survey. Surveys were carried out nationally in 1999–2000 (Boyd & Reilly 2005).

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

A key component of estimating recreational harvest from diary surveys is determining the proportion of the population that fish. The Recreational Working Group has concluded that the methodological framework used for telephone interviews produced biased results for the 1996 and previous surveys. Consequently the harvest estimates derived from these surveys are considered to be considerably underestimated. However, relative comparisons can be made between stocks within these surveys. The Recreational Working Group considered that the 2000 survey using face-to-face interviews better estimated eligibility and that the derived recreational harvest estimates are believed to be more accurate. FMA 2 catches were nevertheless considered to be an over-estimate, probably because of an unrepresentative diarist sample.

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 can be made.

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).

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 37–45 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.

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)

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	2013–14 Actual TACC	2013–14 Reported landings
BUT 1	Auckland (East)(West), Central (West)	1,8&9	3	3.0
BUT 2	Central (East)	2	63	42.0
BUT 3	South-east coast	3	3	0.1
BUT 4	Chatham	4	10	0.1
BUT 5	Southland	5	45	32.2
BUT 6	Sub-Antarctic	6	0	0
BUT 7	Challenger	7	38	16.7
BUT 10	Kermadec	10	0	0
TOTAL			162	95.1

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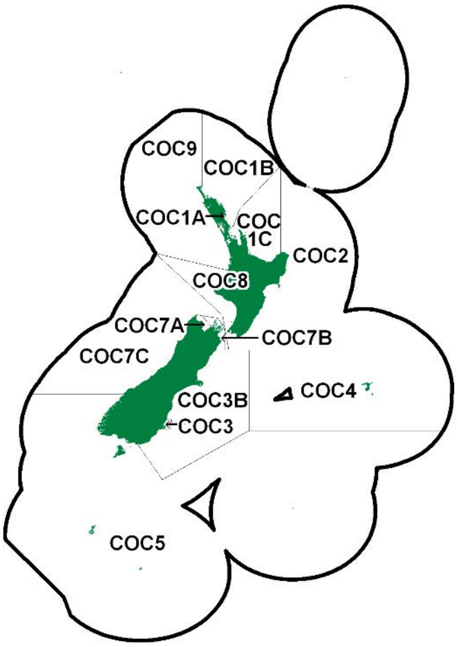
COCKLES (COC)

(*Austrovenus stutchburyi*)
Tuangi



1. INTRODUCTION

Cockles are important shellfish both commercially and for non-commercial fishers.

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 since August 2009 under a special permit from Otago Harbour. 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 are relatively stable since 2002–03; by contrast landings from COC 1A and COC 7A have generally declined over that time period.

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 MPI 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 MPI 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 allowances and TAC (t) for all cockle stocks.

Code	Description	TACC	Recreational allowance	Customary allowance	TAC
COC 1A	Whangarei Harbour	346	25	25	396
COC 1B	East Northland	0	22	22	44
COC 1C	Hauraki Gulf and Bay of Plenty	5	32	32	69
COC 2	Central	0	2	2	4
COC 3	Otago	1 470	10	10	1 490
COC 3B	Part South East Coast	1	27	27	55
COC 4	South East (Chatham Rise)	0	1	1	2
COC 5	Southland and Sub-Antarctic	2	2	2	6
COC 7A	Nelson Bays	1 390	85	25	1 500
COC 7B	Marlborough	0	5	5	10
COC 7C	Part Challenger	0	3	3	6
COC 8	Central (Egmont)	0	1	1	2
COC 9	Auckland (West)	0	6	6	12

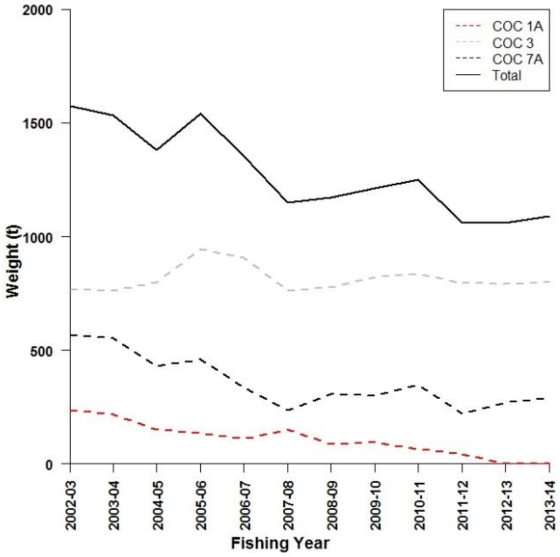


Figure 1: Commercial landings and the sum total (solid line) of the three main commercial COC stocks throughout time. Note that this figure does not show data prior to entry into the QMS.

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.

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[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

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 2 (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 (MPI 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 then 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 2). 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 2: 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	0.311	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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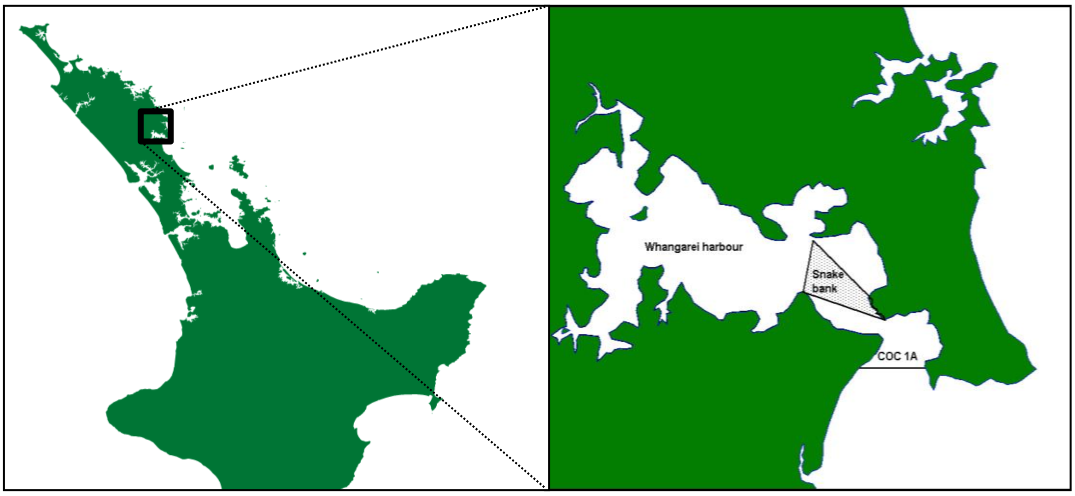
COCKLES (COC 1A) Snake Bank (Whangarei Harbour)

(*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 open 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 is now 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), and no landings have occurred since 2011-12, this closure (in November 2012) was due to low biomass.

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)
1986–87	114	584
1987–88	128	584
1988–89	255	584
1989–90	426	584
1990–91	396	584
1991–92	537	584
1992–93	316	584
1993–94	**566	584
1994–95	501	584
1995–96	495	584
1996–97	457	584
1997–98	439	584
1998–99	472	584
1999–00	505	584
2000–01	423	584
2001–02	405	584
2002–03	237	346
2003–04	218	346
2004–05	151	346
2005–06	137	346
2006–07	111	346
2007–08	151	346
2008–09	88	346
2009–10	93	346
2010–11	64	346
2011–12	43	346
2012–13	0	346
2013-14	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 relatively low catch in recent years 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 2006–7, 2007–8, 2008–9 and 2009–10 fishing years, respectively[1]. Figure 1 shows the recent landings and TACC values of COC 1A.

The mean length of the commercial harvest is about 29.5 mm and cockles smaller than 25 mm are less attractive to both commercial and non-commercial fishers.

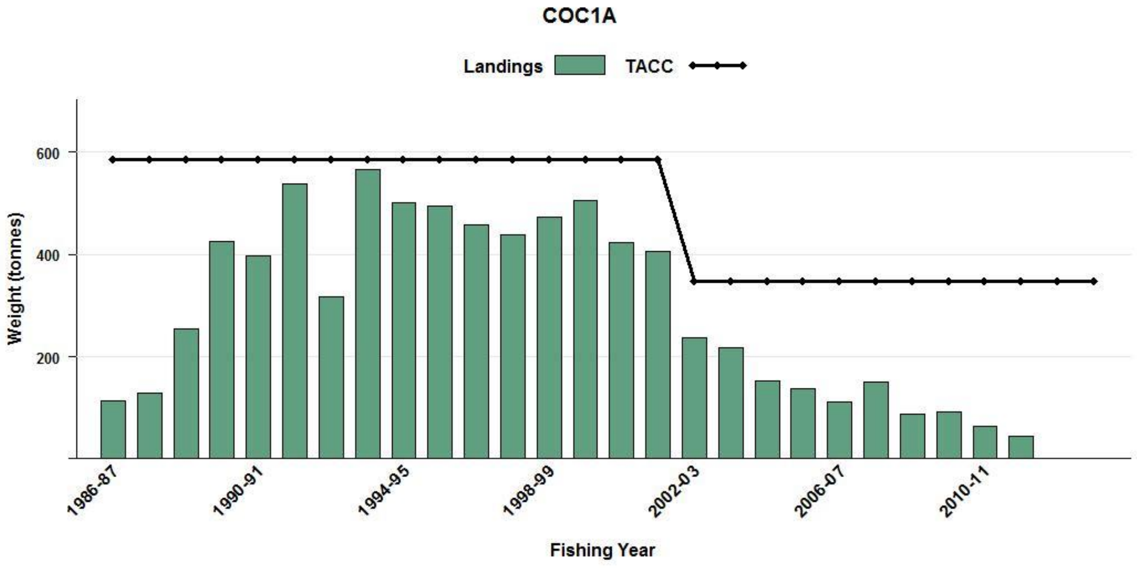


Figure 1: Reported commercial landings and TACC for COC 1A (Whangarei Harbour).

1.2 Recreational fisheries

The recreational fishery is harvested entirely by hand digging, and large cockles (30 mm shell length or greater) are preferred. A regional telephone and diary survey in 1993–94, and national recreational diary surveys in 1996, 1999–2000, and 2000–01 estimated the numbers of cockles harvested in QMA 1 to be 0.57–2.4 million (Table 2). It is not clear to what extent these estimates include customary take. No mean harvest weight for cockles was available, but an assumed mean weight of 25 g (as for cockles

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[1] Statistics supplied by New Zealand Food Safety Authority in Whangarei.

30 mm SL or more from the 1992 Snake Bank survey) leads to a QMA 1 recreational harvest of 14–59 t (Table 2). In 2004, the Marine Recreational Fisheries Technical Working Group reviewed the harvest estimates of these surveys and concluded that the 1993–94 and 1996 estimates were unreliable due to a methodological error. While the same error did not apply to the 1999–00 and 2000–01 surveys, it was considered the estimates may still be very inaccurate. No recreational harvest estimates specific to the Snake Bank fishery are available.

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 a telephone and diary survey in 1993–94, and from national recreational diary surveys in 1996, 1999–00, and 2000–01.

Year	QMA 1 harvest (number of cockles)	CV (%)	QMA 1 harvest (t)	Source
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)

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 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.

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

No quantitative information on the level of other sources of mortality is available. It has been suggested that some methods of harvesting such as brooms, rakes and “hand sorters” cause some mortality, particularly of small cockles, but this proposition has not been tested.

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.

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.

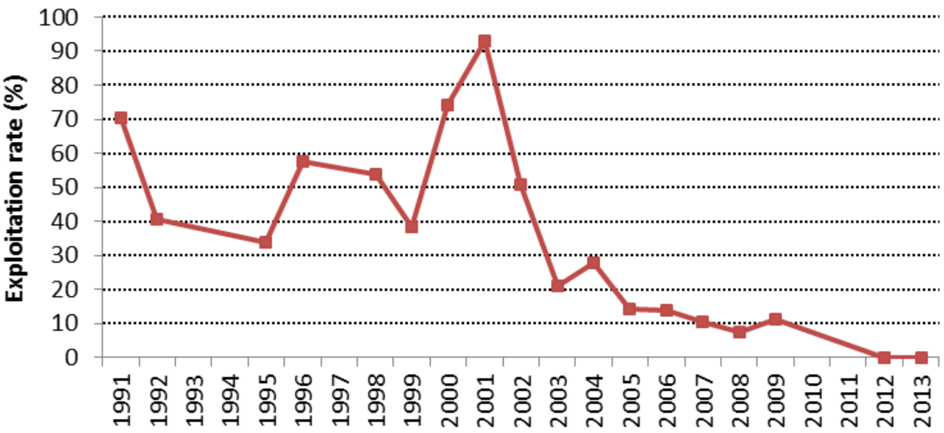


Figure 2: Exploitation rate (≥ 30 mm shell length).

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 and Eyre 2014), this is included as it gives a recent indication of biomass in the absence of commercial fishing.

Table 4: Estimates of biomass (t) of cockles on Snake Bank for surveys (*n*, number of stations) between 1982 and 20015.. 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	c.v.	Biomass	c.v.	Biomass	c.v.	Biomass	c.v.	
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							

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 (1825 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.

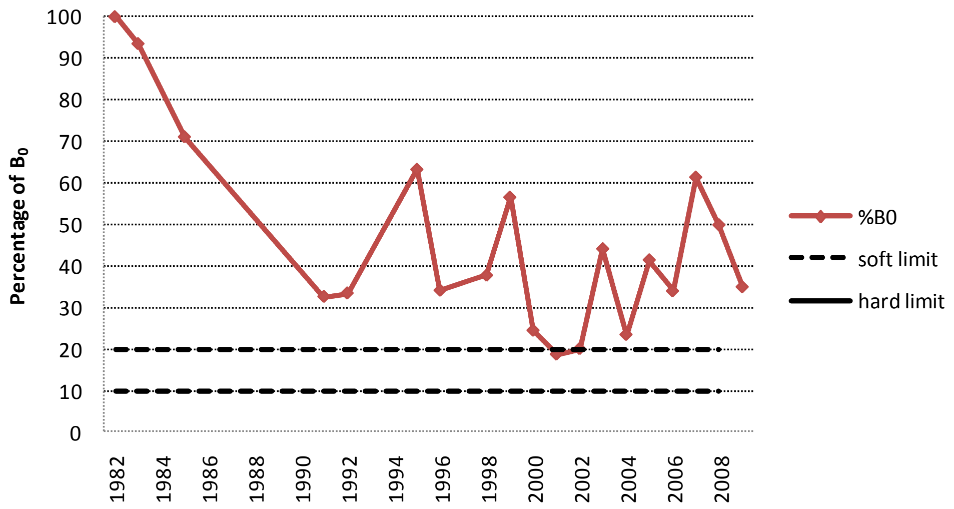


Figure 3: Recruited biomass (≥30 mm shell length) over time as a percentage of B_0 in relation to the hard and soft limits.

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

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.

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

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.

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).

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

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.

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 (Breen 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 2004). 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 (2004) 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 are being recovered and measured on a quarterly basis, and preliminary results suggest there may be strong seasonal variability in growth.

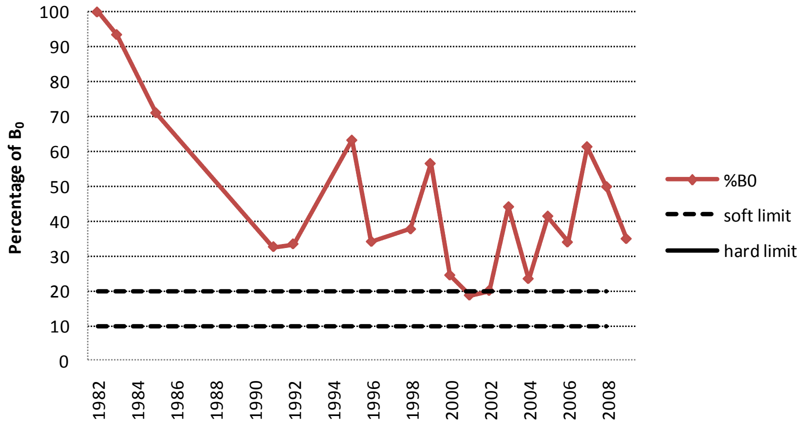
Although the Shellfish Working Group considered that the development of a length-based stock assessment model would be of considerable benefit to the stock assessment, the problems with the model were such that the current approach used to estimate yield for this fishery that had been agreed to by the Shellfish Fishery Assessment Working Group since 1992, would remain.

5. STATUS OF THE STOCKS

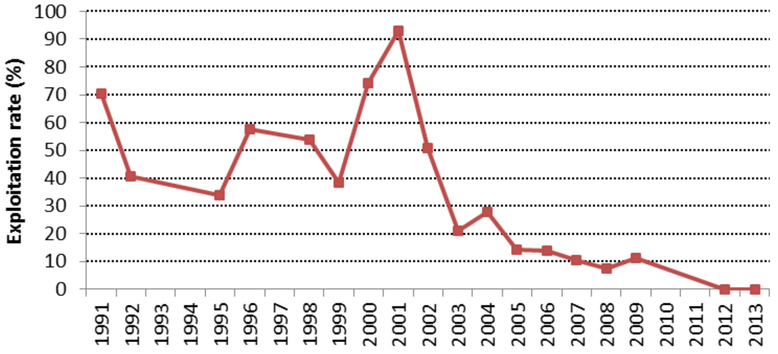
Stock structure assumptions

Snake bank is assumed to be a single stock.

COC 1A

<table>
<tr><th colspan="2">Stock Status</th></tr>
<tr><td>Year of Most Recent Assessment</td><td>2009</td></tr>
<tr><td>Assessment Runs Presented</td><td>Survey biomass estimate for ≥ 30 mm shell length</td></tr>
<tr><td>Reference Points</td><td>Target: Not defined, but B_{MSY} assumed
Soft Limit: 20% B_0
Hard Limit: 10% B_0</td></tr>
<tr><td>Status in relation to Target</td><td>About as Likely as Not (40–60%) to be at or above the target</td></tr>
<tr><td>Status in relation to Limits</td><td>Unlikely (< 40%) to be below both soft and hard limits</td></tr>
<tr><td colspan="2">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.</td></tr>
</table>

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The stock status in 2009 was at 35% of B_0 and has varied between 19 and 63% of B_0 since 1988, following a decline from 1982–1991.
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%). It is Exceptionally Unlikely (< 1%) that overfishing is occurring. 
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing decline below Limits	Fishing at present levels is Exceptionally unlikely (< 1%) to cause declines below soft or hard limits.

Assessment Methodology and Evaluation		
Assessment Type	Level 2: Partial quantitative stock assessment	
Assessment Method	Absolute biomass estimates from quadrant surveys	
Main data inputs (rank)	Abundance and length frequency information	
Period of assessment	Latest assessment: 2009	Next assessment: Unknown
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 recent years, e.g. the fishery was closed for 96 days in the 2009–10 year due to poor water quality. The $\%B_{recruited}$ and the exploitation rate are likely to be underestimate and overestimate, respectively as they are based on a 30 mm shell length and the size limit for commercial harvest is believed to have decreased from 30 to 28 mm over time.

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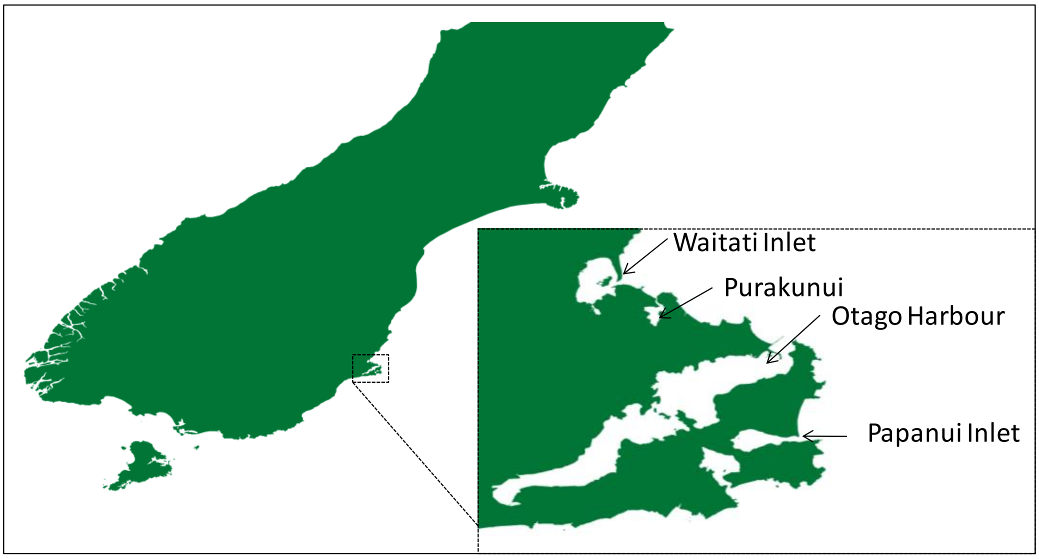
COCKLES (COC 3) Otago Peninsula

(*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 of 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 can be seen 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 (under a current special permit). 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. From 1992–93 to 1998–99, the catch limits were 90 t for Papanui Inlet and 252 t for Waitati Inlet. In April 2000, 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. Commercial landings from Papanui and Waitati Inlets are shown in Table 1. Since August 2009 cockles have been taken from Otago Harbour under a special permit in order to investigate the ecosystem effects of commercial cockle harvesting in this location. This permit states no explicit limit to the tonnage able to be taken but does delimit the area where harvest will be taken and currently expires on the 31st of December 2015.

In 1992, 35 mm shell length was the minimum size for commercial cockles. However, commercial fishers currently target cockles 28 mm or more, therefore 28 mm is used as the effective minimum size in yield calculations. CPUE data are available for this fishery, but have not been analysed.

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.

Amateur harvest levels in FMA 3 were estimated by telephone and diary surveys in 1993–94 (Teirney et al 1997), 1996 (Bradford 1998) and 2000 (Boyd & Reilly 2002), Table 2. Harvest weights are estimated using an assumed mean weight of 25 g (for cockles over 30 mm). In 2004, the Marine Recreational Fisheries Technical Working Group reviewed the harvest estimates of these surveys and concluded that the 1993–94 and 1996 estimates were unreliable due to a methodological error. While the same error did not apply to the 1999–00 and 2000–01 surveys, it was considered the estimates may still be very inaccurate. No recreational harvest estimates specific to the COC 3 commercial fishery areas are available.

Table 1: Reported landings (t) of cockles from Papanui and Waitati Inlets, Otago, combined (FMA 3), from 1986–87 to 2011–12 based on Licensed Fish Receiver Returns (LFRR). Catch splits are provided by Southern Clams Ltd and are partially from Stewart (2005). N/A = Not Applicable [Continued on other page].

Year	Papanui catch (t)	Papanui limit (t)	Waitati catch (t)	Waitati limit (t)	Otago Harbour catch (t)	Total catch (t)	Total 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	24	775	1 470
2009–10	–	N/A	379	N/A	441	820	1 470
2010–11	–	N/A	240	N/A	596	836	1 470
2011–12	–	N/A	358	N/A	437	795	1 470
2012-13						790	1 470
2013-14						800	1 470

*No catches have been taken from Papanui Inlet since 2006–07 because of water quality problems.

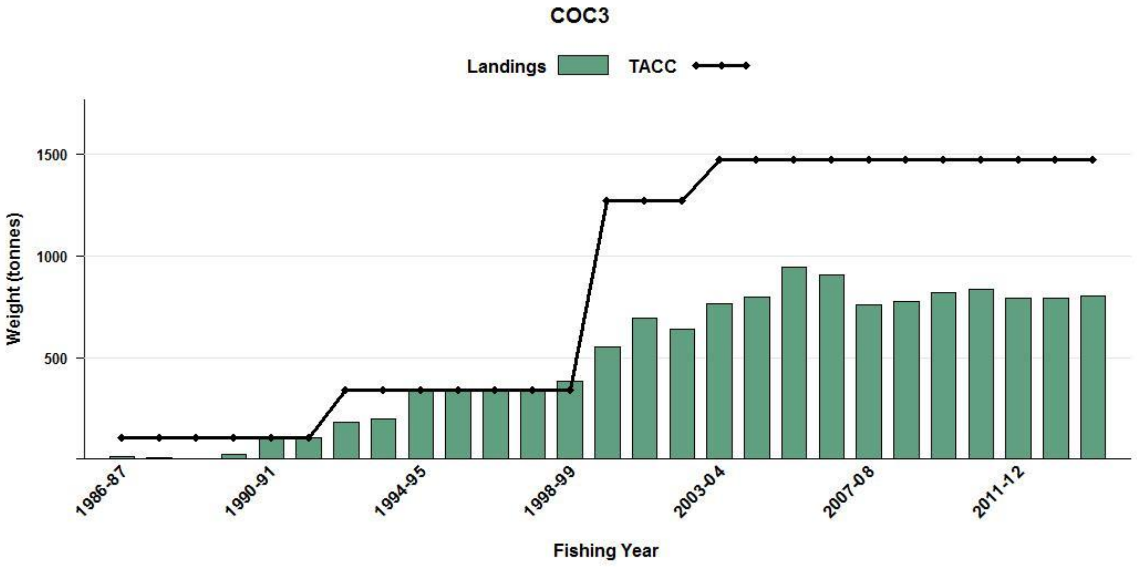


Figure 1: Reported commercial landings and TACC for COC 3 (Otago).

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 of cockles harvested under customary permits is given in Table 3, and is likely to be an underestimate of customary harvest.

Table 2: Estimated numbers of cockles harvested by recreational fishers in FMA 3, and the corresponding harvest tonnage. Figures were extracted from a telephone and diary survey in 1993–94, and the national recreational diary surveys in 1996 and 2000.

Fishstock	Survey	Harvest (*N*)	% CV	Harvest (t)
FMA 3	1993–94 South	106 000	51	2.7
FMA 3	1996	144 000	–	3.6
FMA3	2000	1 476 000	45	36.9

On 1 October 2010, on the recommendation of the Taiapure 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 Taiapure, 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. Larger cockles are preferred by both customary and recreational fishers. 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.

Table 3: Number of cockles harvested under customary fishing permits.

Year	Number of cockles
1998	750
1999	0
2000	1 109
2001	1 090
2002	0
2003	2 750
2004	4 390
2005	5 699

1.4 Illegal catch

No quantitative information is available on the magnitude of illegal catch but it is thought to be insignificant.

1.5 Other sources of mortality

No quantitative information is available on the magnitude of other sources of mortality. It has been suggested that some harvesting implements, such as brooms, rakes, "hand-sorters", bedsprings and "quickfeeds" cause some incidental mortality, particularly of small cockles, but this proposition has not been scientifically investigated. High-grading of cockles is also practised, with smaller sized cockles being returned to the beds. The mortality from this activity is unknown, but is likely to be low.

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[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.

2. STOCKS AND AREAS

Each inlet is assumed to be an independent fishery within the stock.

3. 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 (Annala et al 2003). Breen et al (1999) also estimated biomasses and yields for Otago Harbour and Purakanui. Stewart (2005, 2008a) estimated biomass and yields for Papanui and Waitati Inlets in 2004 and Waitati Inlet in 2007.

3.1 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 2005, 2008a, Jiang et al 2011). 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 below. Exploitation rate is below 7% for Waitati, Papanui Inlet and Otago harbour (Table 4a, 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	
			Waitati	Papanui
0.2	0.2321	0.2899	0.2600	0.2900
0.3	0.3412	0.3863	0.3900	0.4400
0.4	0.4767	0.5537	0.5300	0.6000

Table 4a: Exploitation rate % (for cockles ≥30 mm across each entire inlet)*

Year	Papanui	Waitati	Otago Hbr
1998	2	0	
2002	1	5	
2004	2	6	
2007	0	7	0
2011	0	2	4

* This measure is likely to overestimate exploitation as harvest occurs down to a size limit of 28mm.

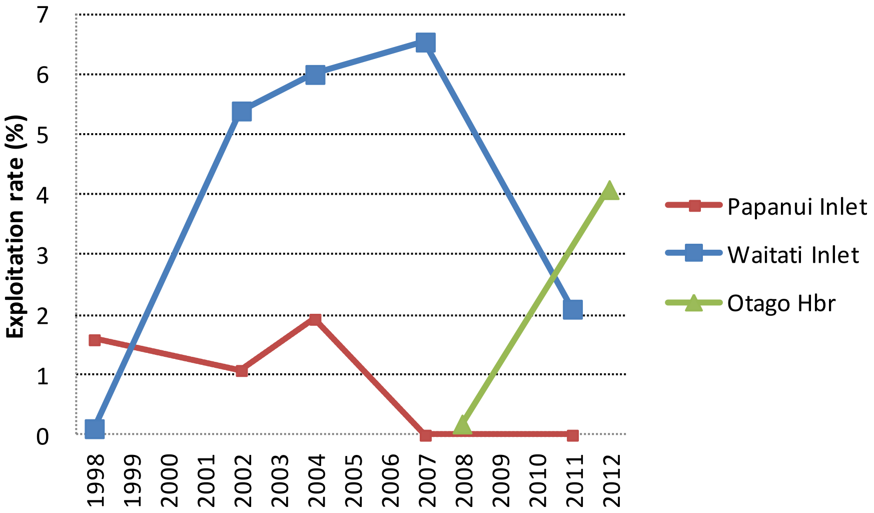


Figure 2: Exploitation rate as calculated by landings divided by biomass (≥30 mm) from whole inlets. Note: This measure is likely to overestimate exploitation as harvest occurs down to a size limit of 28 mm.

3.2 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 done cautiously.

The Spawning stock biomass (19 mm or more, shell length) has been stable around the level of virgin biomass in Waitati Inlet (Table 5, Figure 3). In Papanui Inlet the spawning stock biomass (19 mm or more shell length) has shown a trend of gradual decline from 1984 until 2011, when it was at 73% of virgin biomass (notably no commercial harvesting has occurred in Papanui Inlet since 2006-7). 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).

Table 5: Current (±95% CI) and previous biomass estimates from COC 3*.

Papanui Inlet

Size Class	1984	1992	1998	2002	2004 Total inlet	2004 Commercial area	2011 Total inlet
>2 to 18 mm (juveniles)	65	139	33	17 ± 1.7	36 ± 2.2	13 ± 1.3	8 ± 1.4
19 – 34 mm (adults)	3 705	3 721	3 435	1 970 ± 192	2 415 ± 151	825 ± 88	1 400 ± 168
≥35 mm	2 370	1 706	2 231	2 579 ± 252	2 301 ± 273	1 847 ± 208	3 048 ± 429
≥30 mm			3 990	3 860 ± 365	3 677 ± 367	2 420 ± 271	4 025 ± 542
Total (t)	6 140	5 567	5 699	4 565 ± 424	4 752 ± 425	2 685 ± 298	4 457 ± 601

Waitati Inlet**.

Size Class	1984	1992	1998	2002	2004 Total Inlet	2004 Commercial area	2007 Total Inlet	2007 Commercial area	2011 Total Inlet
>2 to 18 mm (juveniles)	619	1 210	304	153 ± 20	257 ± 14	77 ± 4	335 ± 26	102 ± 7.5	220 ± 14
19 to 34 mm (adults)	7 614	5 198	8 519	6 653 ± 652	7 272 ± 403	2 735 ± 129	7 673 ± 591	1 284 ± 95*^{3}	7 348 ± 501
≥35 mm	3 844	4 620	4 381	4 298 ± 298	4 535 ± 508	3 872 ± 384	3 941 ± 462		6 323 ± 643
≥30 mm			7 235	7 183 ± 463	7 993 ± 720	5 612 ± 681	7 107 ± 548	4 726 ± 352	11 441 ± 946
Total (t)	12 080	11 027	13 204	11 103 ± 848	12 064 ± 925	6 685 ± 517	11 948 ± 921	6 112 ± 456	13 892 ± 1149

Purkaunui Inlet			
Size Class	1998	2008	2012
(≥30 mm)	1 825		
Otago Harbour			
Size Class	1998	2008	2012
(≥30 mm)	32 975		
Otago Harbour (sanitation area, 1804)			
Size Class	1998	2008	2012
(≥30 mm)	8 901*	5 473	4 169
Otago Harbour (sanitation area 1805)			
Size Class	1998	2008	2012
, ≥30 mm	5 546*	3 526	4 093

*Wildish 1984a; Stewart et al 1992; Breen et al 1999; Wing et al 2002; Stewart, 2005; Stewart 2008a, Stewart 2008b; Jiang et al 2011; Stewart 2013. 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 survey of Breen et al 1999 covered a larger extent on these beds than the two subsequent surveys of Stewart 2008b and 2013.

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 2005, 2008a). These data were then used to generate length to weight relationships.

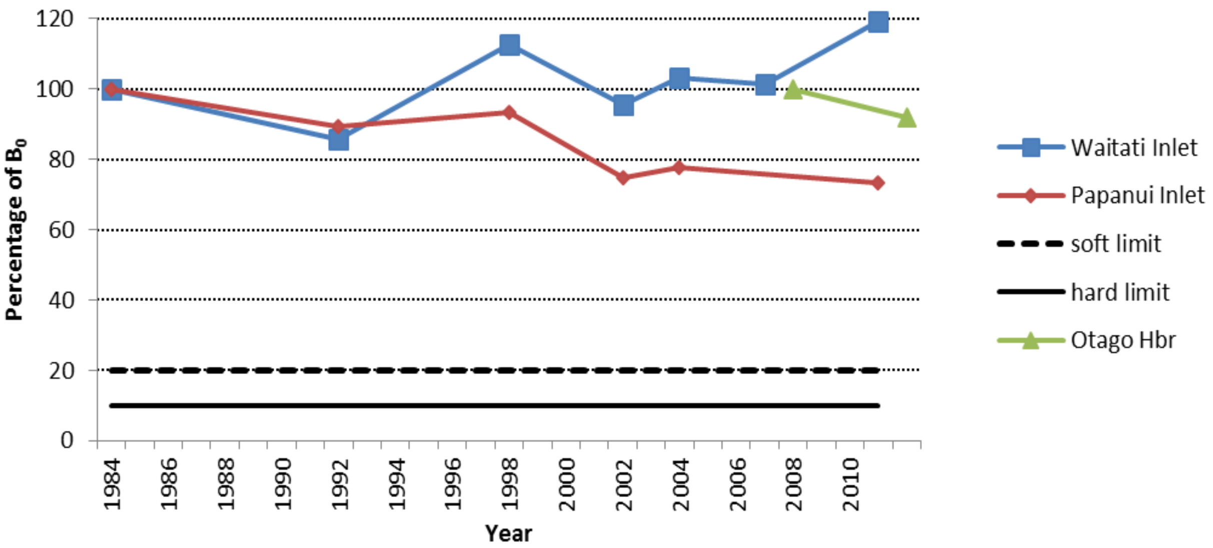


Figure 3: Biomass as a proportion of B_0 for Waitati and Papanui Inlets, this is estimated from biomass >19mm. Note: No catch has been taken from Papanui Inlet since 2006-07. Virgin biomass was taken from the Stewart 2008b survey for Otago harbour as this is the extent that has been subsequently surveyed.

3.3 Yield estimates and projections

Estimates of *MCY* are given in Table 6.

Table 6: Estimates of *MCY* (*t*) for COC 3 generated using Method 1 (Annala et al 2003) $MCY = 0.5F_{0.1}B_{AV}$, an average biomass ≥30 mm as B_0 and the 2011 estimates of $F_{0.1}$. This calculation is likely to underestimate the true *MCY*.

Location	M	1998	2002	2004	2007	2011
Waitati Inlet	0.2	941	934	1039	924	1487
Waitati Inlet	0.3	1411	1401	1559	1386	2231
Waitati Inlet	0.4	1917	1903	2118	1883	3032
Waitati Inlet (commercial)	0.2			730	614	894
Waitati Inlet (commercial)	0.3			1094	922	1342
Waitati Inlet (commercial)	0.4			1487	1252	1823
Papanui Inlet	0.2	579	560	533		584
Papanui Inlet	0.3	878	849	809		886
Papanui Inlet	0.4	1197	1158	1103		1208
Papanui Inlet (commercial)	0.2			351		259
Papanui Inlet (commercial)	0.3			532		392
Papanui Inlet (commercial)	0.4			726		535

For Waitati Inlet, *CAY* was estimated (Table 7) using Method 1 ($CAY = (F_{0.1} / Z)(1-\exp(-Z))B_{BEG}$) (Annala et al 2003) and biomass estimates at different times. *CAY* has been estimated at times for both the entire inlet area and a subset area where the commercial fishery has been operating for the past several years. This approach assumes that, between the start of the fishing year and when the biomass survey is started, productivity and catch cancel each other.

Table 7: *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.

				WI		WIc		PI		PIc		
Year	M	$F_{0.1}$	≥ SL (mm)	B_{beg}	CAY	B_{beg}	CAY	B_{beg}	CAY	B_{beg}	CAY	Reference
2011	0.2	0.26	30	11 441	2 385	6881	1434					Jiang et al 2011
2011	0.3	0.39	30	11 441	3 223	6881	1938					Jiang et al 2011
2011	0.4	0.53	30	11 441	3 948	6881	2374					Jiang et al 2011
2011	0.2	0.29	30					4 026	923	1784	409	Jiang et al 2011
2011	0.3	0.44	30					4 026	1 252	1784	555	Jiang et al 2011
2011	0.4	0.60	30					4 026	1 527	1784	677	Jiang et al 2011
2007	0.2	0.2899	28	8 378	1 920	5 261	1 206					Stewart 2008a
2007	0.3	0.3863	28	8 378	2 342	5 261	1 471					Stewart 2008a
2007	0.4	0.5537	28	8 378	2 990	5 261	1 878					Stewart 2008a
2007	0.2	0.2899	30	7 106	1 629	4 725	1 083					Stewart 2008a
2007	0.3	0.3863	30	7 106	1 986	4 725	1 321					Stewart 2008a
2007	0.4	0.5537	30	7 106	2 536	4 725	1 686					Stewart 2008a
2004	0.2	0.2321	30	9 399	1 771	6 081	1 146	4 119	776	2 454	462	Stewart 2005
2004	0.3	0.3412	30	9 399	2 367	6 081	1 532	4 119	1 038	2 454	618	Stewart 2005
2004	0.4	0.4767	30	9 399	2 984	6 081	1 930	4 119	1 308	2 454	779	Stewart 2005
2002	0.2	0.2017	30	7 183	1 193	5 364	891	3 860	641	2 322	386	Wing et al 2002
2002	0.3	0.3015	30	7 183	1 627	5 364	1 215	3 860	874	2 322	526	Wing et al 2002
2002	0.4	0.3956	30	7 183	1 960	5 364	1 464	3 860	1 053	2 322	634	Wing et al 2002
1999	0.2	0.258	30	7 235	1 498			3 990	826			Breen et al 1999
1999	0.3	0.357	30	7 235	1 848			3 990	1 019			Breen et al 1999
1999	0.4	0.457	30	7 235	2 221			3 990	1 225			Breen et al 1999

3.4 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. Estimates of yields have been estimated for size of recruitment at 28 mm; 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 very slight decrease in biomass recorded in the Stewart (2008a) survey suggests that the current level of harvest is sustainable. What is not known is if the decrease in biomass is the beginning of a long-term trend or simply the result of natural variability.

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.

4. STATUS OF THE STOCKS

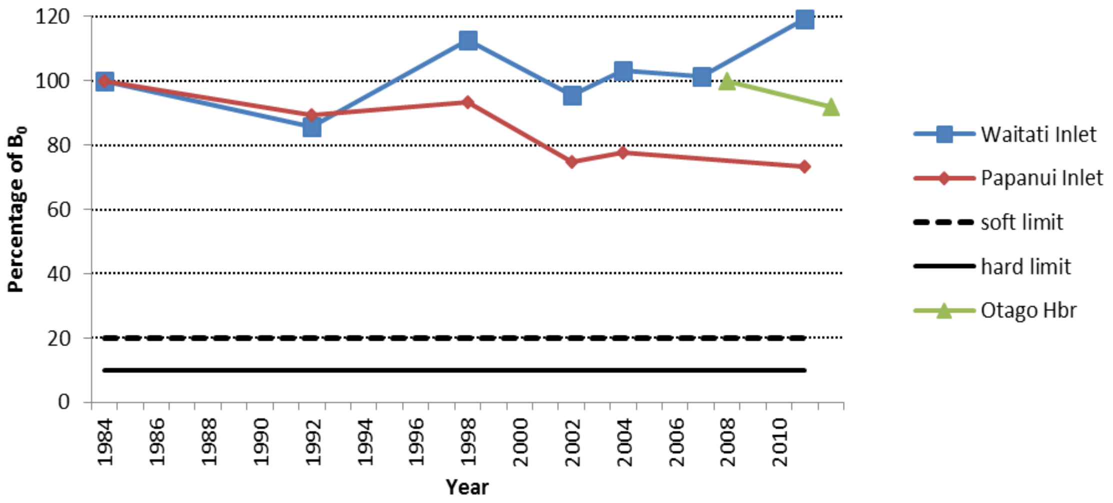
Stock structure assumptions

Each inlet is assessed separately.

COC 3

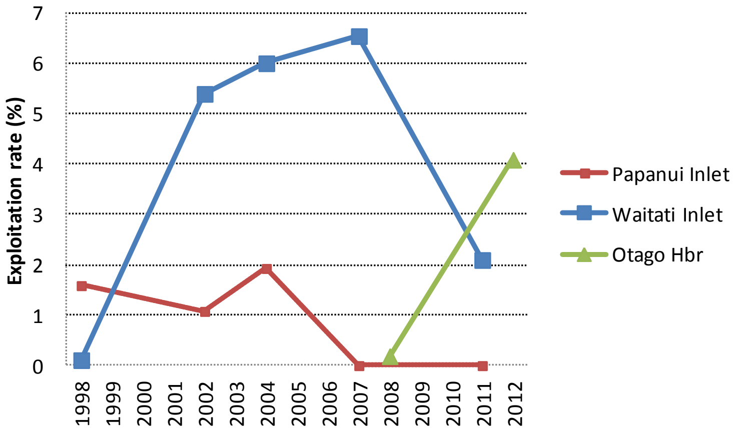
Stock Status	
Year of Most Recent Assessment	2011
Assessment Runs Presented	Survey biomass estimate for ≥ 19 mm shell length
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Likely (> 60%) to be at or above the target
Status in relation to Limits	Very Unlikely (< 10%) to be below both soft and hard limits

Historical Stock Status Trajectory and Current Status



Biomass as a proportion of B_0 for Waitati and Papanui Inlets, this is estimated from biomass > 19 mm. Note: No catch has been taken from Papanui Inlet since 2006-07. Virgin biomass was taken from the Stewart 2008b survey for Otago harbour as this is the extent that has been subsequently surveyed.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass at Waitati Inlet has been stable or increasing and has never decreased below 85% of 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 biomass has declined, but most of this occurred before harvesting starting.

Recent Trend in Fishing Mortality or Proxy	Exploitation rate has never exceeded 7% at any of the harvested sites. It is Very Unlikely (< 10%) that overfishing is occurring.  **Exploitation rate as calculated by landings divided by biomass (≥19 mm) from whole inlets (excluding Otago Harbour where it was taken from commercial beds only).**
Other Abundance Indices	
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing decline below Limits	Fishing at recent levels is Very Unlikely (< 10%) to cause declines below soft or hard limits

Assessment Methodology		
Assessment Type	Level 2: Partial quantitative stock assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Main data inputs	Abundance and length frequency information	
Period of Assessment	Latest assessment: 2010 or 2011 (depending upon location)	Next assessment: unknown
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 Papanui Inlet in recent years.

5. FOR FURTHER INFORMATION

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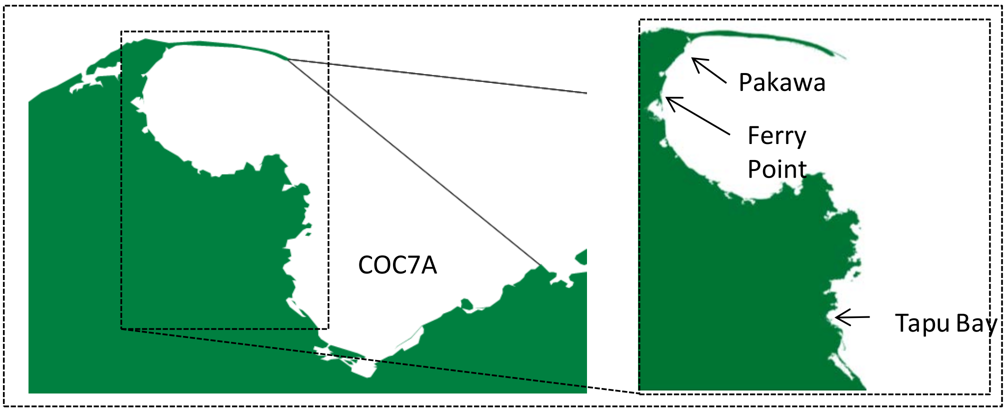
COCKLES (COC 7A) Tasman and Golden Bays

(*Austrovenus stutchburyi*)

Tuangi



1. FISHERY SUMMARY

COC 7A was introduced to the Quota Management System in October 2002 with a TAC of 1510 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 1390 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) are derived from company records and QMS returns. 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.

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

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.

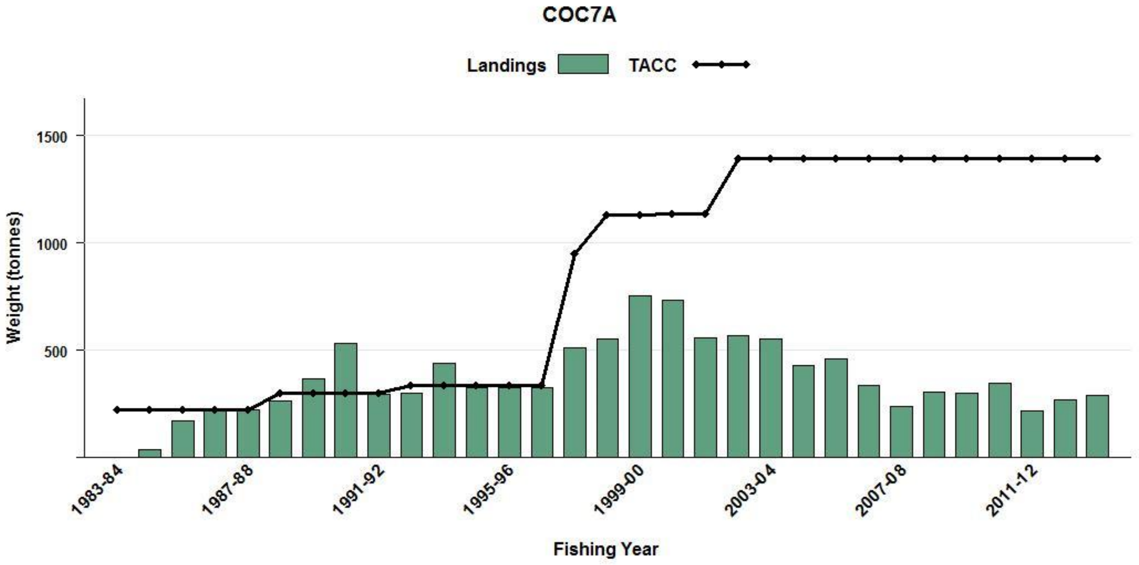


Figure 1: Total reported landings and TACC for COC 7A (Nelson Bays).

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.

Estimates of the amateur cockle harvest from QMA 7 are available (Table 2) from a telephone and diary survey in 1992–93 (Tierney et al 1997) and from national diary surveys in 1996 (Bradford 1998) and 2000 (Boyd & Reilly 2004). Harvest weights were estimated assuming a mean weight of 25 g per cockle. The 1992–93 and 1996 estimates are very uncertain and probably underestimate actual recreational catch. The 2000 survey is considered to be a more reliable estimate of recreational harvest.

Table 2: Estimated numbers of cockles harvested by recreational fishers in QMA 7, and the corresponding harvest tonnage. Data from both surveys were not sufficiently reliable to allow estimates of CVs.

Year	QMA 7 harvest	
	Number	(t)
1992–93	166 000	4
1996	325 000	8
2000	499 000	12.5

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).

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 earlier in this Plenary 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	Osborne (1992)
Pakawau Beach (1992)		0.000017	3.78	Forrest & Asher (1997)
Ferry Point (1996)		0.00020	3.153	Stark & Asher (1991)
Tapu Bay-Riwaka (1991)		0.000150	3.249	
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 modeled by the equation $y = 11.452\mathrm{Ln}(x) + 16.425$, 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 1988 and 1984 covered smaller areas still. The survey area was reduced in 2008 to remove areas that were observed over eight years to be consistently unsuitable habitat for cockles or cockle harvesting (sand banks, soft mud and *Zostera* areas). There is no apparent decline in biomass per unit area throughout the entire series of surveys. The eight comparable surveys show total and recruited biomass to have fluctuated, but with no consistent trend. Because harvesting is not permitted in areas of *Zostera*, additional estimates of recruited biomass available to harvesters are presented (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). Results from all these surveys are listed in Table 5 and shown in Figure 2. Biomass at Pakawau beach has generally increased over time and the biomass at Riwaka and Ferry Point have generally decreased over time.

Table 4: Estimates of biomass (t) with 95% confidence intervals (CI) where available, and mean density (kg/m^2) for cockles on Pakawau Beach. Values are given for the total and recruited (≥ 30 mm) biomass. Available biomass is recruited biomass not occurring in areas of *Zostera*. *n* = number of samples in the survey. Lines of data in italics represent results from the 1997–99 surveys, but using only those strata surveyed in 1992.

Date	Area	*n*	Total biomass			Recruited biomass		
	(ha)		*t*	CI	kg/m^2	*t*	CI	kg/m^2
1984	326	-	4 604	1 562	1.41	-	-	-
1988	510	-	5 640	-	1.11	-	-	-
Nov 1992#	421	230	5 540	824	1.32	5 299	836	1.26
May 1997#	421	224	7 846	1 588	1.86	7 422	1 665	1.76
Jun 1998#	421	227	6 838	1 245	1.62	6 285	1 252	1.49
Apr-99	421	228	6 920	1 154	1.64	6 388	1 091	1.52
Mar-00	421	205	6 357	1 184	1.51	5 966	1 140	1.42
Mar-01	421	190	8 942	1 570	2.12	8 160	1 460	1.94
Feb-04	421	268	9 432	1 200	2.24	8 803	1 164	2.09
Jan-08	407	180	8 968	1 662	2.2	8 285	1 599	2.04

# Prior to 1999, recruited biomass was calculated for size of ≥ 35 mm shell length and has been adjusted to biomass >30 mm using a length weight model.

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 biomasses, 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.

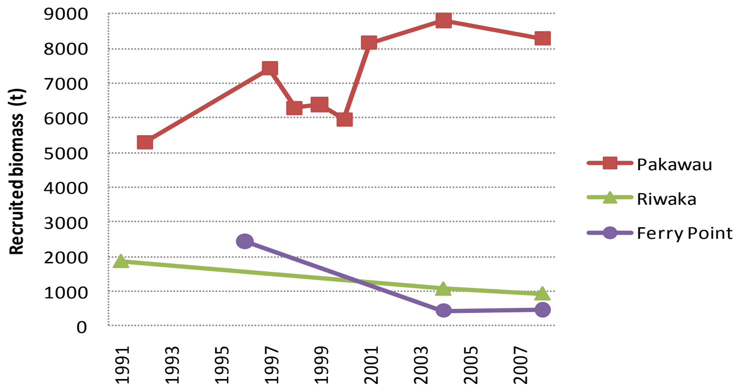


Figure 2: Recruited biomass (≥ 30 mm shell length) over time.

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.

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, *MCY* is as follows:

M	0.2	0.3	0.4
MCY	1 182	2 418	4 658

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	
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 F_{MAX} 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 estimates in Table 8.

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	2001	F_{MAX}	1 599	2 388	2 975	-
Pakawau Beach	2004	$F_{0.1}$	1 202	1 555	1 910	
Pakawau Beach	2008	$F_{0.1}$	1 161	1 501	1 845	
Ferry Point	1996	$F_{0.1}$	407	501	600	696
Ferry Point	1996	F_{MAX}	748	1 050	1 369	1 650
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: Estimates of $F_{0.1}$ and F_{MAX} using a range of *M* values and two minimum harvest sizes (MHS).

F_{REF}	MHS (mm)				M
		0.2	0.3	0.4	0.5
$F_{0.1}$	35	0.27	0.38	0.51	0.65
$F_{0.1}$	30	0.26	0.34	0.45	0.57
F_{MAX}	35	0.66	1.35	2.6	-
F_{MAX}	30	0.53	0.91	1.59	3.01

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

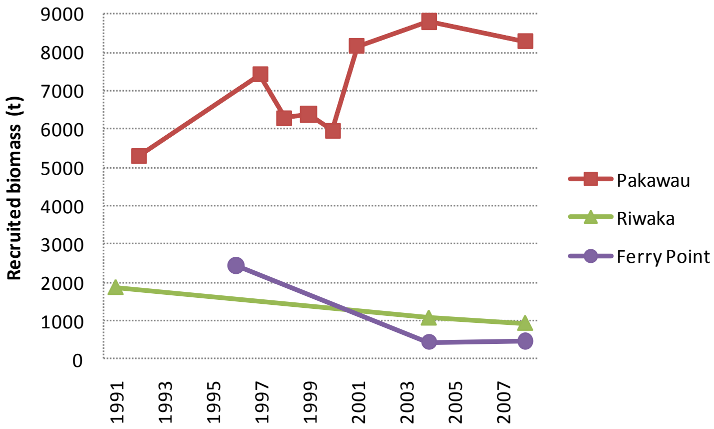
Little is known of the stock boundaries of cockles. Given differences in growth and mortality within and between different beds and in the absence of more detailed knowledge regarding larval connectivity, this commercial fishery area is managed as a discrete population.

COC 7A

Stock Status	
Year of Most Recent Assessment	2008

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
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

Historical Stock Status Trajectory and Current Status



Recruited biomass (≥ 30 mm shell length) over time.

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, with the lowest value in 1992 (5299 t) and the highest value in 2004 (8803 t). 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).
Recent Trend in Fishing Mortality or Proxy	Landings since 2004–05 are intermediate compared to the history of the fishery and have fluctuated without trend between 237 and 460 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 decline below Limits	Fishing at present levels is Very Unlikely (< 10%) to cause declines below the soft or hard limits.	
Assessment Methodology		
Assessment Type	Level 2: Partial quantitative stock assessment	
Assessment Method	Absolute biomass estimates from quadrant surveys	
Main data inputs	Abundance and length frequency information	
Period of Assessment	Latest assessment: 2008	Next assessment: Unknown
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
-

6. FOR FURTHER INFORMATION

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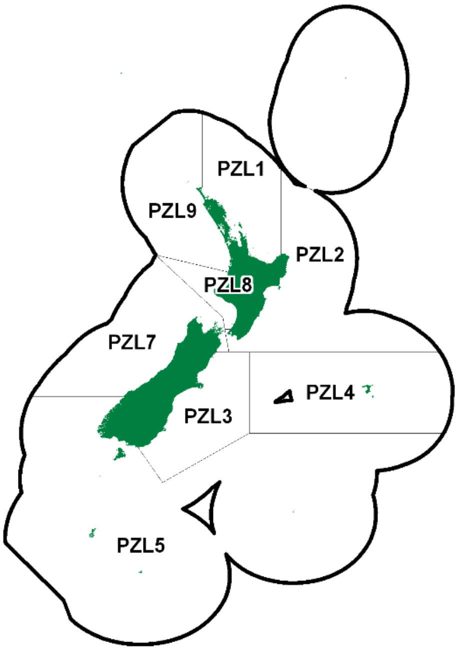
DEEPWATER (KING) CLAM (PZL)

(*Panopea zelandica*)



1. FISHERY SUMMARY

Deepwater clams (*Panopea zelandica*), commonly referred to as geoducs or geoducks, 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. Targetted 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 1993 (10.885 t) occurred in 2011–12 and was mainly taken from the Nelson-Marlborough region (Table 2).

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 1988–89 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	
Fishstock	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

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* and *P. smithae*, both of which are endemic and occur around the North, South and Stewart Islands. *P. smithae* has also been reported from the Chatham Islands. Their distributions overlap, but *P. zelandica* occurs mainly in shallow waters (5–25 m) in sand and mud off sandy ocean beaches, while *P. smithae* lives mainly at greater depths (110–130 m) on coarse shell bottoms, and is also thought to burrow deeper in the substrate. In samples of commercial and exploratory catches, *P. zelandica* is more abundant than *P. smithae*, and in the early 1990s it comprised 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 2004). Spawning may be temperature controlled because it occurred at the Coromandel and Wellington sites when water temperature reached approximately 15°C (Gribben et al 2004). 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 and Kennedy Bay 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 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 and 116.5 mm, respectively (Breen 1991, Gribben & Creese 2005)[1].

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 from 0.1 to 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

No stock assessments have been carried out for any deepwater clam stocks. Sustainable fishing rate estimates were made by Breen (1994).

4.1 Estimates of fishery parameters and abundance

No abundance estimates are available for any geoduc stocks. Sustainable fishing rate estimates were made by Breen (1994).

4.2 Biomass estimates

Biomass has not been estimated for any deepwater clam stocks.

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.

5. STATUS OF THE STOCKS

PZL 7 - *Panopea zelandica*

Stock Status	
Year of Most Recent Assessment	No formal assessment done for any stock
Assessment Runs Presented	-
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0
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	Very Unlikely (< 40%) to be below the soft or hard limit
Historical Stock Status Trajectory and Current Status	-

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[1] No confidence intervals were available for these estimates.

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 decline below Limits	Current catches are Unlikely (< 40%) to cause declines below soft or hard limits.

Assessment Methodology		
Assessment Type	-	
Assessment Method	-	
Main data inputs	-	
	Latest assessment: -	Next assessment: -
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
-

7. FOR FURTHER INFORMATION

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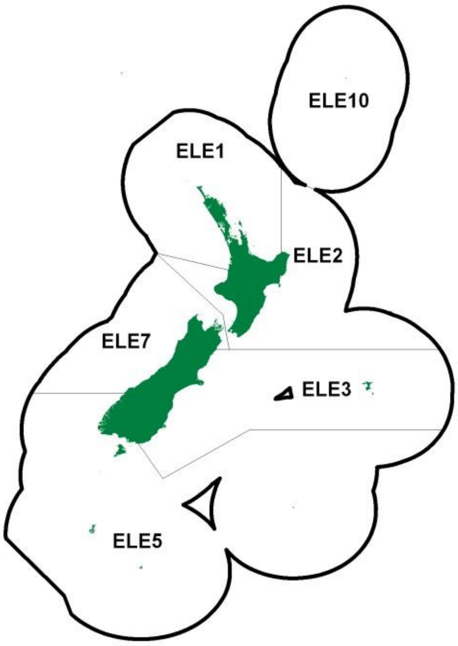
ELEPHANTFISH (ELE)

(*Callorhinchus milii*)
Reperepe



1.1 Commercial fisheries

From the 1950s to the 1980s, landings of elephantfish of around 1000 t/year were common. Most of these landings were from the area now encompassed by ELE 3, but fisheries for elephantfish 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 elephantfish dropped considerably in the early 1980s (between 1982–83 and 1994–96 they ranged between 500 and 700 t) but later increased to the point that they have annually exceeded 1000 t since the 1995–96 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 elephantfish 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, been consistently exceeded since 1986–87. The ELE 3 TACC was consequently 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 1000 t where it presently remains. 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 elephantfish 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 elephantfish, with the former fishery taking about 100 t/year and the latter between 40 and 70 t/year between 2008–09 and 2010–11.

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 have been increasing consistently since 1992–93, exceeding the TACCs since 1995–96. 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 has was increased by 17% up from 120 t to 140 t. The ELE 5 TACC was further increased to 170t in 2012–13. All AMP programmes ended on 30 September 2009.

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

Year	ELE 1	ELE 2	ELE 3	ELE 5
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	79	0
1937–38	0	0	183	0
1938–39	0	0	194	1
1939–40	0	1	190	1
1940–41	0	1	243	8
1941–42	0	0	220	1
1942–43	0	0	163	6
1943–44	0	0	219	1
1944	0	0	251	10
1945	0	2	205	3
1946	0	0	228	3
1947	0	2	176	0
1948	0	2	227	0
1949	0	1	296	2
1950	0	1	522	14
1951	0	2	585	6
1952	0	0	440	9
1953	0	3	514	13
1954	0	2	839	5
1955	0	3	771	4
1956	0	1	933	16
1957	0	2	992	28
1958	0	0	1140	47
1959	0	0	1066	37
1960	0	1	1099	38
1961	0	0	913	43
1962	0	4	1066	73
1963	0	2	976	111
1964	0	3	1109	107
1965	0	7	983	88
1966	0	1	985	99
1967	0	1	812	77
1968	0	1	757	54
1969	0	1	824	75
1970	0	3	987	87
1971	0	0	1243	103
1972	0	0	928	70
1973	0	0	864	73
1974	0	0	766	97
1975	0	1	557	55
1976	0	0	622	91
1977	0	0	601	114
1978	0	0	552	49
1979	0	0	661	63
1980	0	0	794	129
1981	0	1	543	114
1982	0	0	584	85

Table 2 [Continued].

Year	ELE 7	Year	ELE 7
1931–32	0	1957	46
1932–33	0	1958	51
1933–34	0	1959	44
1934–35	0	1960	27
1935–36	0	1961	27
1936–37	1	1962	14
1937–38	0	1963	8
1938–39	2	1964	16
1939–40	1	1965	34
1940–41	1	1966	27
1941–42	0	1967	45
1942–43	0	1968	52
1943–44	0	1969	33
1944	0	1970	53
1945	3	1971	37
1946	4	1972	15
1947	10	1973	21
1948	9	1974	41
1949	13	1975	28
1950	13	1976	52
1951	10	1977	45
1952	5	1978	26
1953	3	1979	18
1954	7	1980	34
1955	25	1981	16
1956	29	1982	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 elephantfish by Fishstock from 1983–84 to 2012–13 and actual TACCs (t) from 1986–87 to 2013–14. 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	1110	1000	173	170	96	102	1394	1304

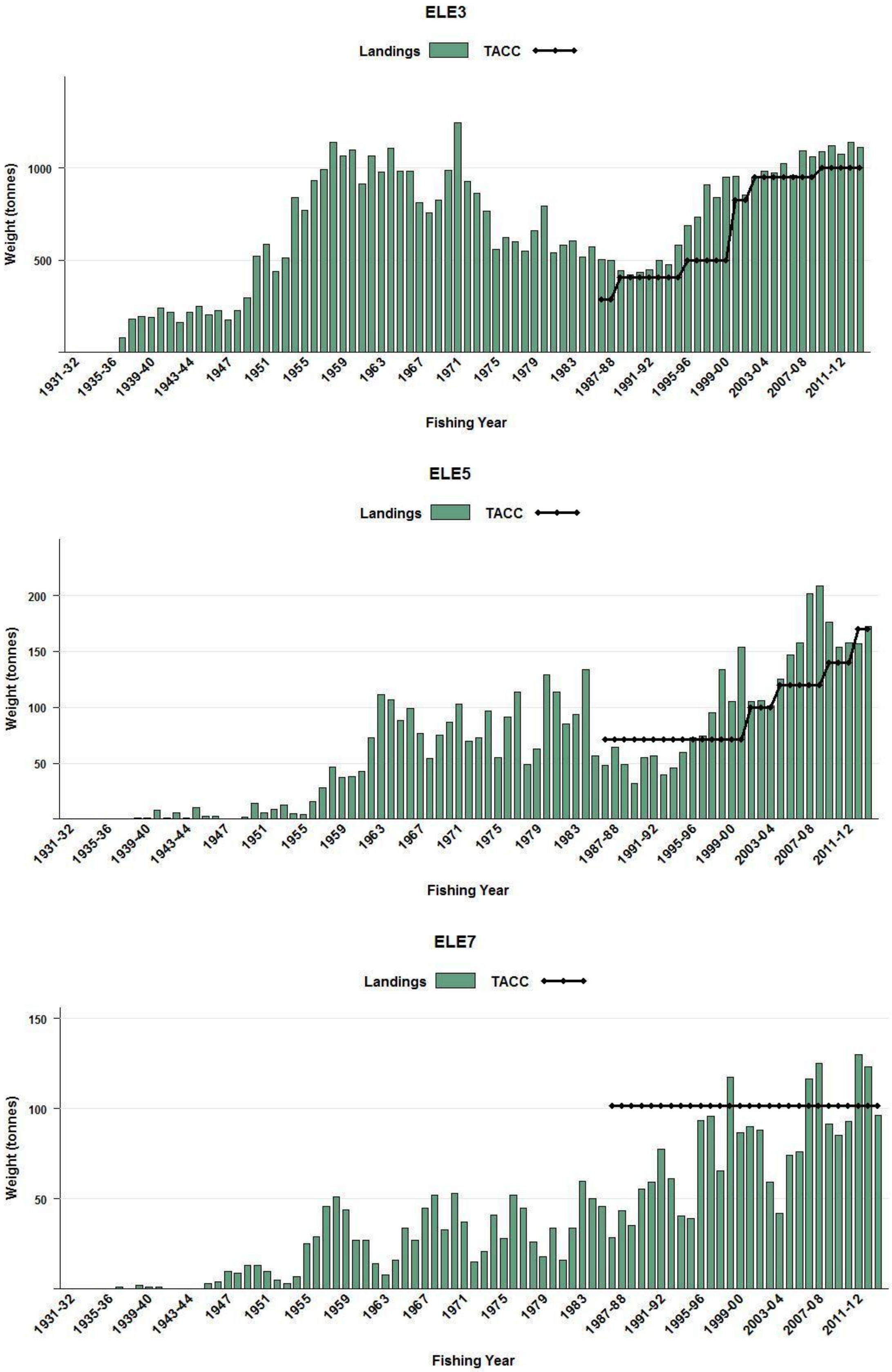


Figure 1: Reported commercial landings and TACC for the three main ELE stocks. From top left: ELE 3 (South East Coast and Chatham Rise), ELE 5 (Southland and Sub-Antarctic), and ELE 7 (Challenger).

1.2 Recreational fisheries

Catches of elephantfish by recreational fishers are low compared to those of the commercial sector. Recreational fishing surveys carried out by the MAF Fisheries in the early 1990s estimated the recreational catch of elephantfish in the South region of ELE 3 in 1991–92 at 3000 fish, 1000 fish in the central region of ELE 7 in 1992–93, and no catch was reported in the North region in 1993–94 (Teirney et al 1997). The national diary survey of recreational fishers in 1996 estimated that recreational catches of elephantfish were fewer than 500 fish in ELE 2, 1000 fish in ELE 3 and fewer than 500 fish in ELE 7 (Bradford 1998). Estimates from the 1999–2000 recreational survey were 1000 fish in ELE 2, 2000 fish in ELE 3 and fewer than 500 in ELE 7 (Boyd & Reilly 2002). Owing to biases inherent in telephone relative to face-to-face interviews, the 1999–2000 estimate is regarded to be the most accurate. The Recreational Technical Working Group concluded that the harvest estimates from the diary surveys 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.

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 elephantfish 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

Elephantfish 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 cannot be reliably estimated, but appears to be at least 9 years and may be as high as 15 years. The M value of 0.35 used is based on unvalidated ageing work indicating a maximum age of 13 years. 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 elephantfish 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.

Biological parameters relevant to the stock assessment are shown in Table 4. Provisional von Bertalanffy growth curves based on MULTIFAN are available for Pegasus Bay and Canterbury Bight in 1966–68 and 1983–88. Because the growth curves were based on a MULTIFAN analysis of length-frequency data, the ages of the larger fish were probably underestimated and the growth curves are only reliable to about 4–5 years. Fish appeared to grow faster in the 1980s than in the 1960s.

Table 4: Estimates of biological parameters for elephant fish.

Fishstock	Estimate				Source
1. Natural mortality (M)					
All	0.35				Francis (1997)
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					
		Pegasus Bay 1966–68		Canterbury Bight 1966–68	
	Males	Females	Males	Females	Francis (1997)
K (yr^{-1})	0.231 ± 0.002	0.096 ±0.001	0.089 ± 0.002	0.060 ± 0.001	
L_∞ (cm)	74.7 ± 0.12	156.9 ± 1.38	141.5 ± 2.28	203.6 ± 3.2	
t_0 (yr)	-0.78 ± 0.008	-0.87 ± 0.006	-0.96 ± 0.008	-1.06 ± 0.009	
		Pegasus Bay 1983–84		Canterbury Bight 1988	
	Males	Females	Males	Females	
K (yr^{-1})	0.473 ± 0.009	0.195 ±0.008	0.466 ± 0.008	0.224 ± 0.001	
L_∞ (cm)	66.9 ± 0.52	113.9 ± 2.89	62.7 ± 0.23	94.1 ± 0.26	
t_0 (yr)	-0.24 ± 0.017	-0.53 ± 0.023	-0.38 ± 0.015	-0.69 ± 0.006	

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 elephantfish 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

4.1.2 Biomass estimates

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 elephantfish and red gurnard which were included in the target species. Only the 2007, 2012, and 2014 surveys provide full coverage of the 10–30 m depth range.

Elephantfish total biomass in the east coast South Island winter surveys core strata (30–400 m) increased markedly in 1996 and although it has fluctuated since then it remained high with the 2014 biomass 8% below the post-1994 average of 1032 t (Table 4, Figure 2). The post 1994 average biomass was about three-fold greater than that of the early 1990s, indicating that the large increase in biomass between 1994 and 1996 was sustained. The proportion of pre-recruited biomass in the core strata varied greatly among surveys ranging from 50% in 2007 to only 5% in 2012, the latter value reflecting the high numbers of large fish present in 2012 (Table 4). In 2014 18% of the total biomass was pre-recruit fish. Similarly, the proportion of juvenile biomass (based on the length-at-50% maturity) in 2012 was the lowest of all surveys at 23% and in 2014 it increased to 28% (Figure 3).

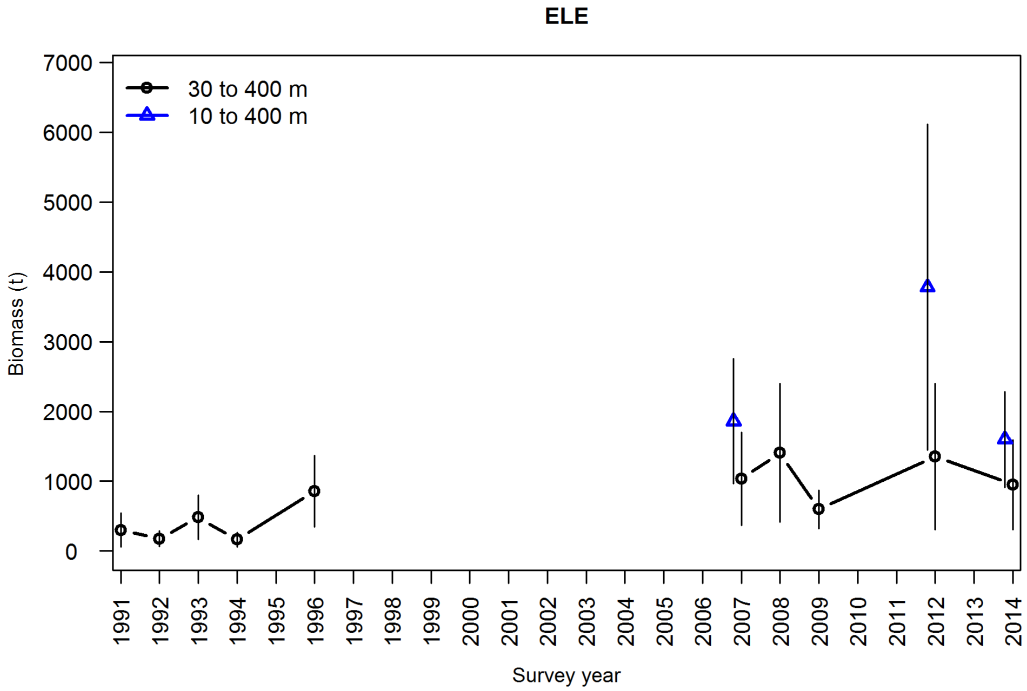


Figure 2: Elephantfish total biomass and 95% confidence intervals for all ECSI winter surveys in core strata (30–400 m), and core plus shallow strata (10–400 m) in 2007, 2012 and 2014.

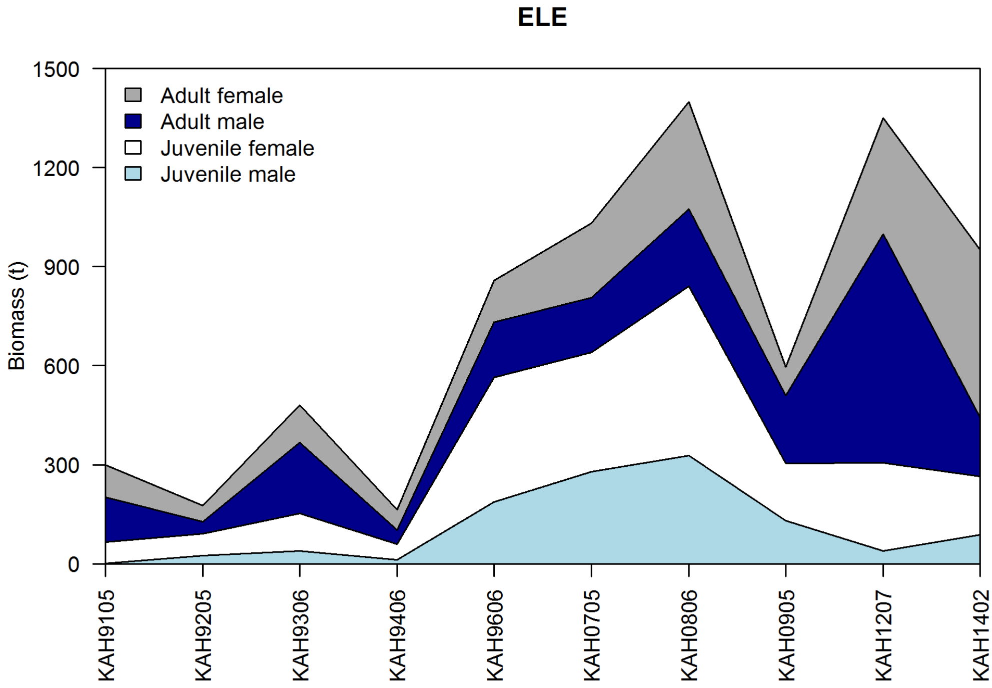


Figure 3: Elephantfish juvenile and adult biomass for ECSI winter surveys in core strata (30–400 m), where juvenile is below and adult is equal to or above the length at which 50% of fish are mature.

Biomass in the core plus shallow strata in 2014 was less than half that in 2012 (Figure 2). The additional elephantfish biomass captured in the 10–30 m depth range accounted for 44%, 64% and 41% of the biomass in the core plus shallow strata (10–400 m) for 2007, 2012 and 2014 respectively, indicating that it is essential to continue monitoring the shallow strata for elephantfish biomass (Table 4, 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 (Figure 5). The proportion of pre-recruit biomass in the core plus shallow strata was also greater than that of the core strata alone, a reflection of the larger numbers of smaller elephantfish found in the shallow strata (Table 5).

The distribution of elephantfish 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, elephantfish (ELE 7) total biomass estimates are variable between successive surveys and the biomass estimates are frequently imprecise, particularly for the higher biomass estimates (Table 5). 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 4). 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.

4.1.3 Length frequency distributions

The size distributions of elephantfish are inconsistent among the core strata (30–400 m) for the east coast South Island trawl surveys and generally characterised by a wide right hand tail of 3+ and older fish (up to about 10 years) and the occasional poorly represented 1+ and 2+ cohort modes (see 2007 and 2008 surveys, Figure 5). The time series of length frequency distributions in the shallow plus core strata (10–400) includes only the 2007, 2012 and 2014 surveys, and have similar modal distributions, but with higher proportions of juvenile cohorts.

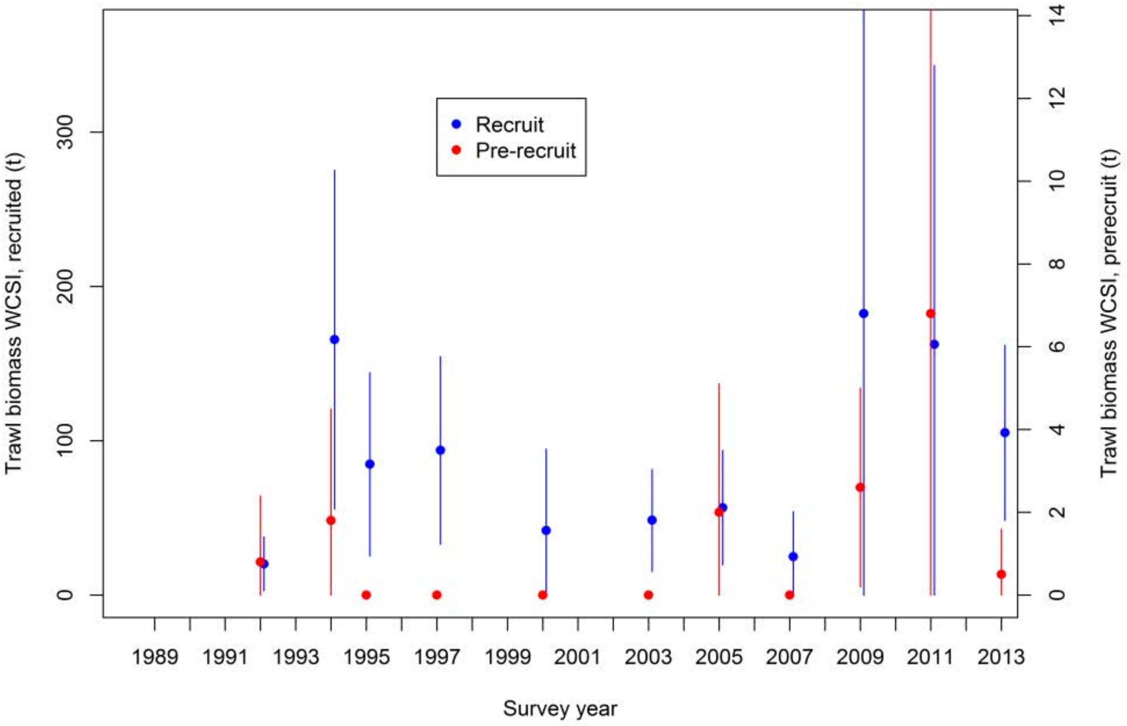


Figure 4: Elephantfish trawl survey pre-recruit and recruited biomass estimates for the west coast South Island area of the WCSI trawl survey, with associated confidence intervals. Recruited fish were defined as fish above 40 cm T.L.

Table 5: 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
ECSI(summer)	ELE 3	1996–97	KAH9618	1 127	31	-	-	-	-	-	-	-	-	-	-
		1997–98	KAH9704	404	18	-	-	-	-	-	-	-	-	-	-
		1998–99	KAH9809	1 718	28	-	-	-	-	-	-	-	-	-	-
		1999–00	KAH9917	1 097	25	-	-	-	-	-	-	-	-	-	-
								-	-	-	-	-	-	-	-
		2000–01	KAH0014	693	18	-	-	-	-	-	-	-	-	-	-
								-	-	-	-	-	-	-	-
WCSI	ELE 7	1992	KAH9204	38	42	-	-	-	-	-	-	-	-	-	-
		1994	KAH9404	167	33	-	-	-	-	-	-	-	-	-	-
		1995	KAH9504	85	35	-	-	-	-	-	-	-	-	-	-
		1997	KAH9701	94	33	-	-	-	-	-	-	-	-	-	-
		2000	KAH0004	42	63	-	-	-	-	-	-	-	-	-	-
		2003	KAH0304	49	34	-	-	-	-	-	-	-	-	-	-
		2005	KAH0503	59	33	-	-	-	-	-	-	-	-	-	-
		2007	KAH0704	28	53	-	-	-	-	-	-	-	-	-	-
		2009	KAH0904	185	83	-	-	-	-	-	-	-	-	-	-
		2011	KAH1104	170	53	-	-	-	-	-	-	-	-	-	-
		2013	KAH1305	110	26										
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.

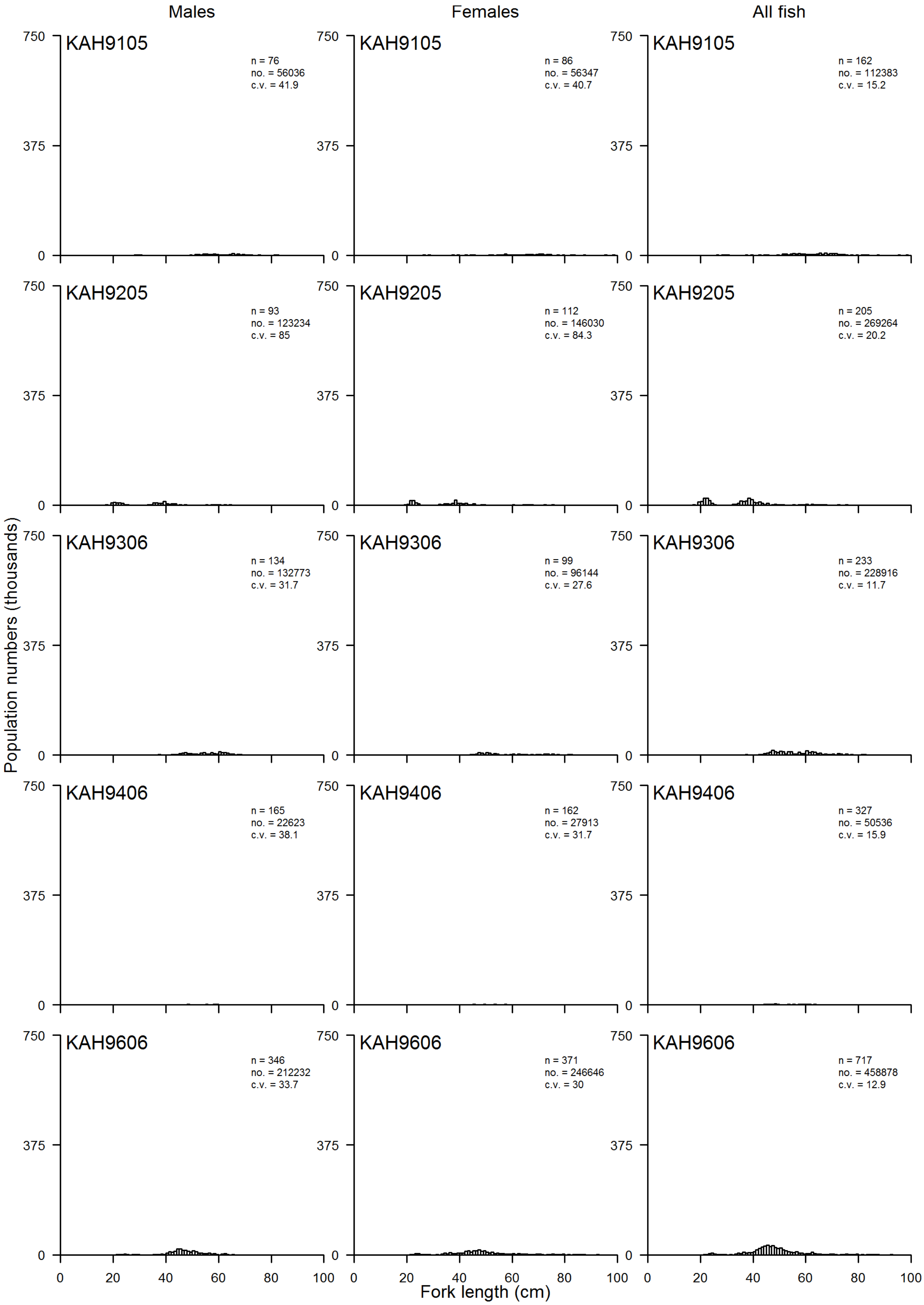


Figure 5 Scaled length frequency distributions for elephantfish in core strata (30–400 m) for all ten ECSI winter surveys. The length distribution is also shown in the 10–30 m depth strata for the 2007, 2012 and 2014 surveys overlaid (not stacked) in light grey. Population estimates are for the core strata only, in thousands of fish. Scales are the same for males, females and unsexed [Continued on next page]

ELEPHANT FISH (ELE)

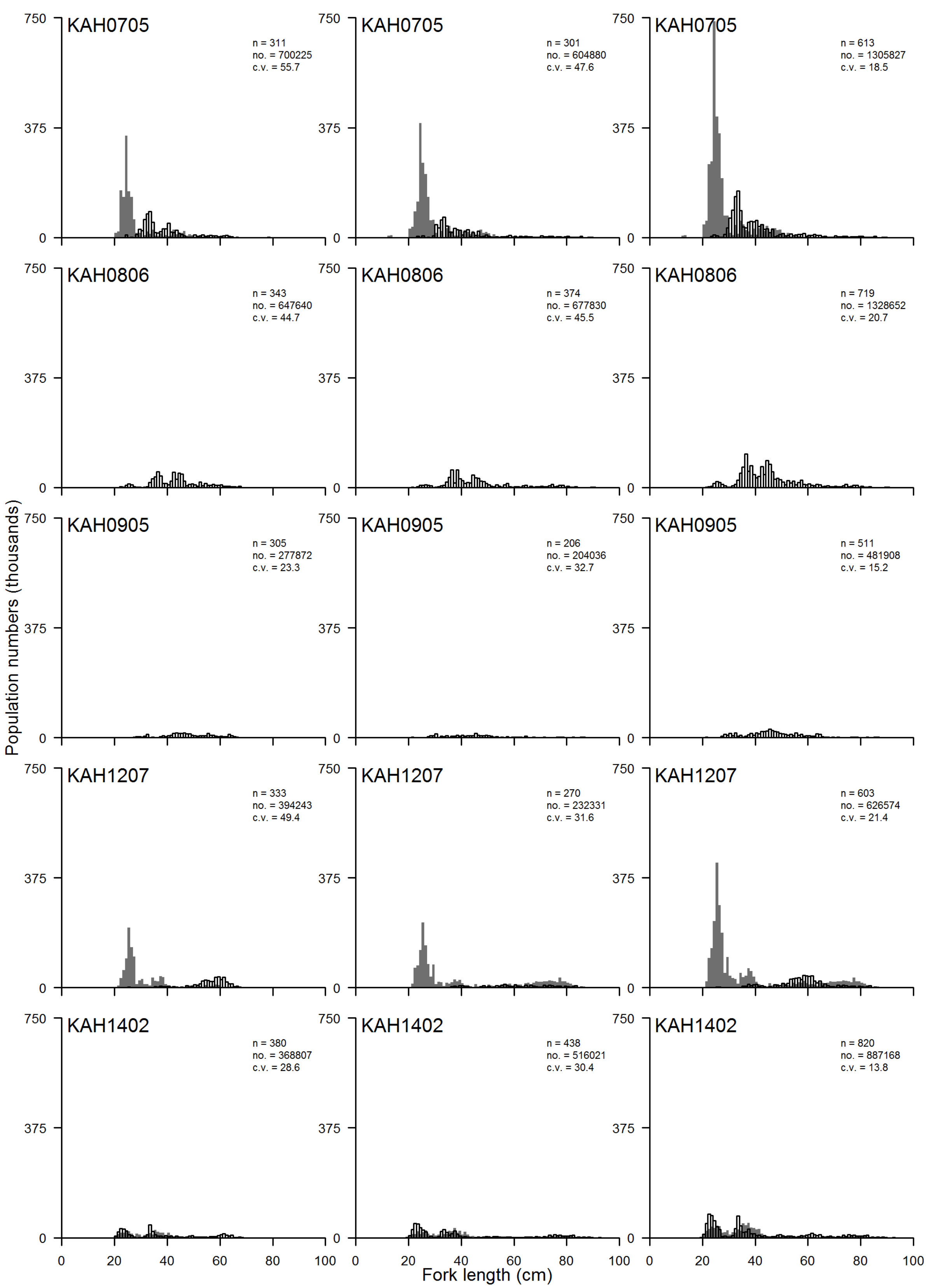


Figure 5 [continued]: Scaled length frequency distributions for elephantfish in core strata (30–400 m) for all ten ECSI winter surveys.The length distribution is also shown in the 10–30 m depth strata for the 2007, 2012 and 2014 surveys overlaid (not stacked) in light grey. Population estimates are for the core strata only, in thousands of fish. Scales are the same for males, females and unsexed

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 elephantfish in bottom trawl fisheries defined by different target species combinations. Initially, the Working Group accepted a series based solely on the bycatch of elephantfish 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. 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. Standardised CPUE has fluctuated without trend since 2009–10 and the 2012–13 data point is near the interim target (see below) (Figure 6).

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.

***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.

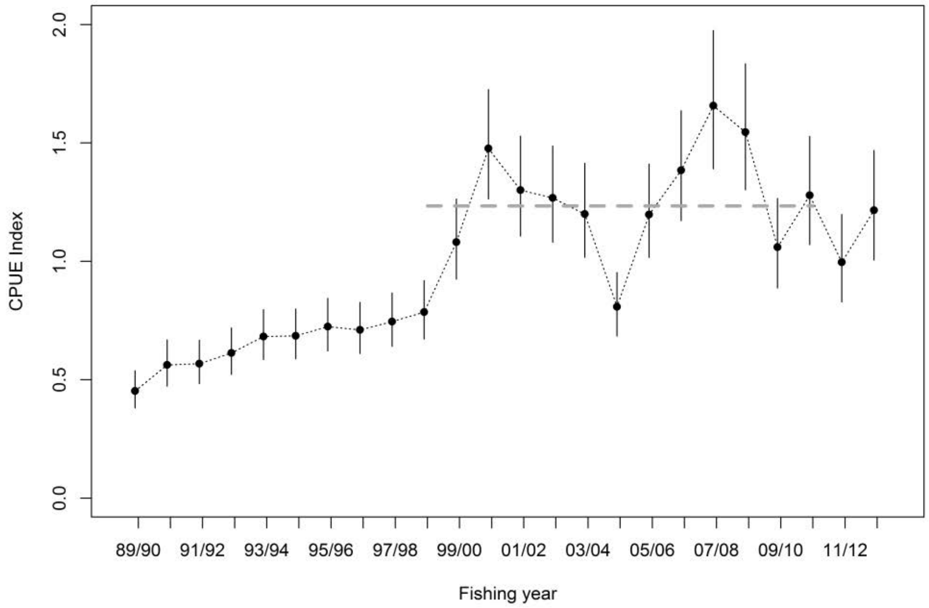


Figure 6: Standardised CPUE indices for the ELE 3 bottom trawl fisheries [ELE 3(MIX)]. The horizontal grey line is the mean of ELE 3(MIX) from 1998–99 to 2010–11 (B_{MSY} conceptual proxy). The CPUE series has been normalised to a geometric mean of 1.0. Error bars show 95% confidence intervals.

Two standardised CPUE series for ELE 5 were prepared for 2012 with each series based on the bycatch of elephantfish in the bottom trawl fisheries defined by target species combinations (Starr & Kendrick 2013). One of these series [ELE 5 (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 (MIX)-trip] was a trip-based analysis using the same target species selection method as described for ELE 3(MIX)-trip. The two sets of indices were very similar.

In 2014, the ELE 5(MIX) CPUE model was updated to include data from 2011–12 to 2012–13 (Langley 2014). 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 7). There are relatively broad confidence intervals associated with the individual CPUE indices and there is no strong trend in the CPUE indices during 2005–06 to 2012–13.

B_{MSY} conceptual proxy: The Working Group was unable to agree on an appropriate "B_{MSY} conceptual proxy" for ELE 5 because of the continually increasing nature of the series. CPUE would need to stabilise or decline before a suitable target could be established.

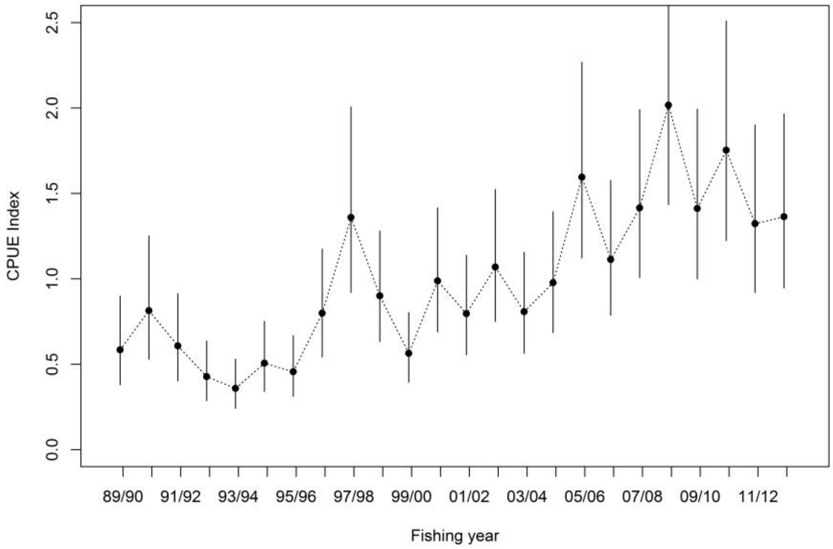


Figure 7: Standardised CPUE indices for a mixed target species ELE 5 bottom trawl fisheries [ELE 5- (MIX)]. Error bars show 95% confidence intervals.

ELE 7

A preliminary CPUE analysis of the catch of elephantfish 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 elephantfish. These target trawl fisheries encompass almost all the trawl fishing effort within the depth range that encompasses most of the catch of elephantfish 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 elephantfish 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 elephantfish 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, 1kg, 2kg and 5kg) 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 8). 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 (Figure 8). The SINS WG concluded that the TCER CPUE indices represented the best available information for monitoring trends in ELE 7 stock abundance.

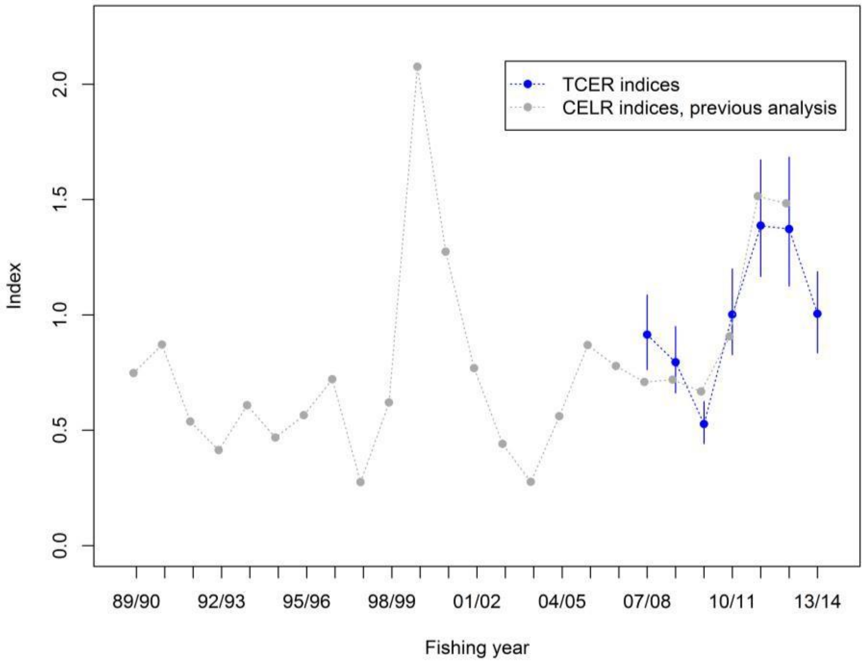


Figure 8. Standardised Delta-lognormal CPUE indices for the ELE 7 inshore WCSI trawl fishery for the entire time series configured in CELR data format and for indices derived from the location based TCER data set. Both sets of indices are normalised to the comparable time period (2007–08 to 2012–13). The error bars represent the 95% confidence interval.

4.2 Biomass Estimates

Estimates of current and reference absolute biomass are not available.

4.3 Yield estimates and projections

No other yield estimates are available.

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

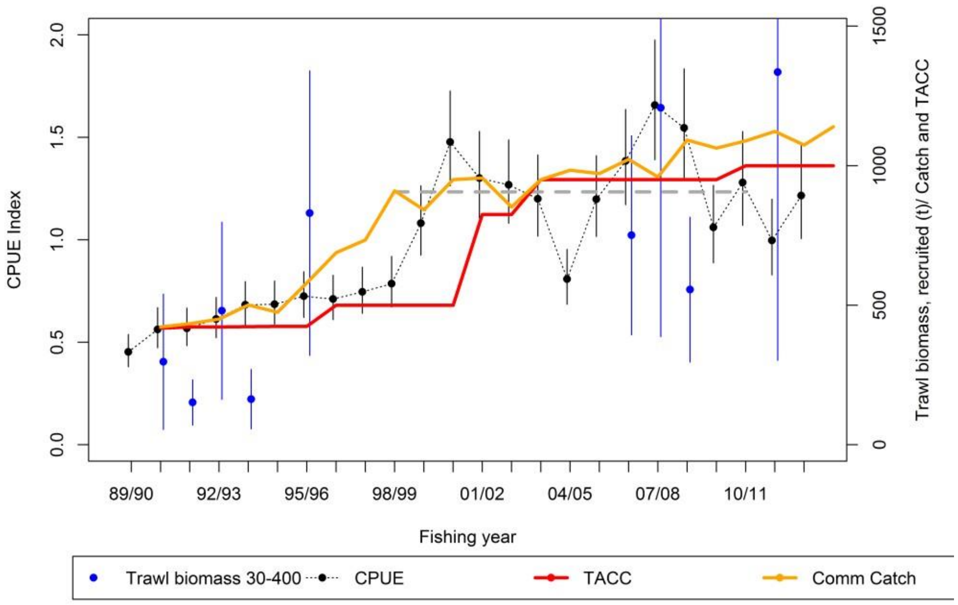
Stock Structure Assumptions

No information is available on the stock separation of elephantfish. The Fishstock ELE 3 is treated in this summary as a unit stock.

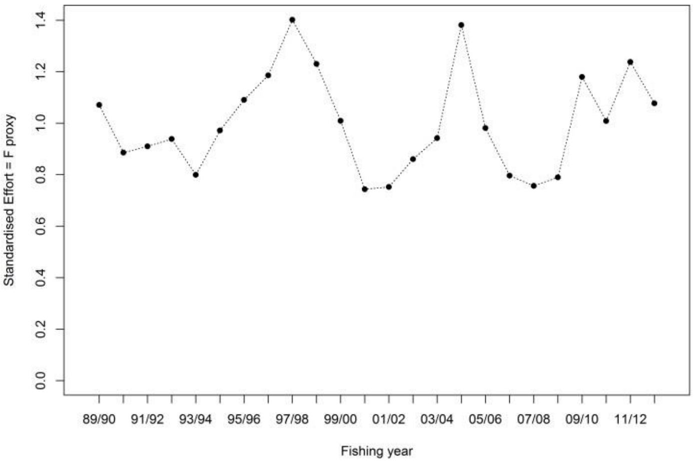
Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Update ELE 3 (MIX) CPUE series
Reference Points	(Proposed) Target: B_{MSY}-compatible proxy based on CPUE (average from 1998–99 to 2010–11 of the ELE 3(MIX) model as defined in Starr & Kendrick 2013) Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: F_{MSY} (assumed)
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 Unlikely (< 40%) 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 2012–13 and winter trawl survey estimates of recruited biomass (fish greater than 40 cm). The dashed line is the target.

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 Mortality or Proxy	 Fishing mortality proxy is Standardised Fishing Effort = Total catch/CPUE (normalised). Fishing mortality proxy has fluctuated about the average level and was above average in the most recent years.
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.
Trends in Other Relevant Indicator or Variables	Current landings (2007–08 to 2012–13) are at a similar level to those recorded in the 1960s and early 1970s. The stock was believed to be at low levels in the early 1980s.

Projections and Prognosis	
Stock Projections or Prognosis	Quantitative stock projections are unavailable.
Probability of Current Catch or TACC causing 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 Unlikely (< 40%) to cause overfishing.

Assessment Methodology and Evaluation		
Assessment Type	Level 2: Standardised CPUE abundance index and the winter ECSI trawl survey index.	
Assessment Method	Evaluation of agreed standardised CPUE indices which reflect changes in abundance as well as the trawl survey biomass indices.	
Assessment Dates	Latest assessment: 2014	Next assessment: 2015
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 - Trawl survey biomass indices and associated length frequencies	1 – High Quality 1 – High Quality

Data not used (rank)	Compass Rose trawl survey data Summer ECSI trawl survey data	3 – Low Quality: insufficient data 3 – Low Quality: variable catchability between years
Changes to Model Structure and Assumptions	None since 2012 assessment	
Major Sources of Uncertainty	- It is possible that discarding and management changes in this fishery have biased the CPUE trends reported for this fishery.	

Qualifying Comments
Elephantfish have shown good recovery since apparently being at low biomass levels in the mid-1980s. Good abundance of pre-recruit elephantfish was seen in the 2007 length frequencies from the resumed winter east coast South Island trawl survey. There are potentially enough data to undertake a quantitative stock assessment for ELE 3, but this would require ageing of spines collected by the trawl survey. This may allow the estimation of B_{MSY} and other reference points. With respect to the conceptual proxy, the Working Group and the Plenary has concerns about the reliability of this as a proxy and suggested that it only be used on an interim basis. 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. 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
Elephantfish in ELE 3 are taken as bycatch by bottom trawl fisheries targeting red cod, flatfish and barracouta. Targeting elephantfish in the bottom trawl fishery has increased to around a third 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, elephantfish, 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. This may have reduced juvenile and egg mortality in shallow water. Incidental captures of seabirds occur and there is a risk of incidental capture of Hector's dolphins. There is also a risk of incidental capture of sea lions from Otago Peninsula south.

ELE 5

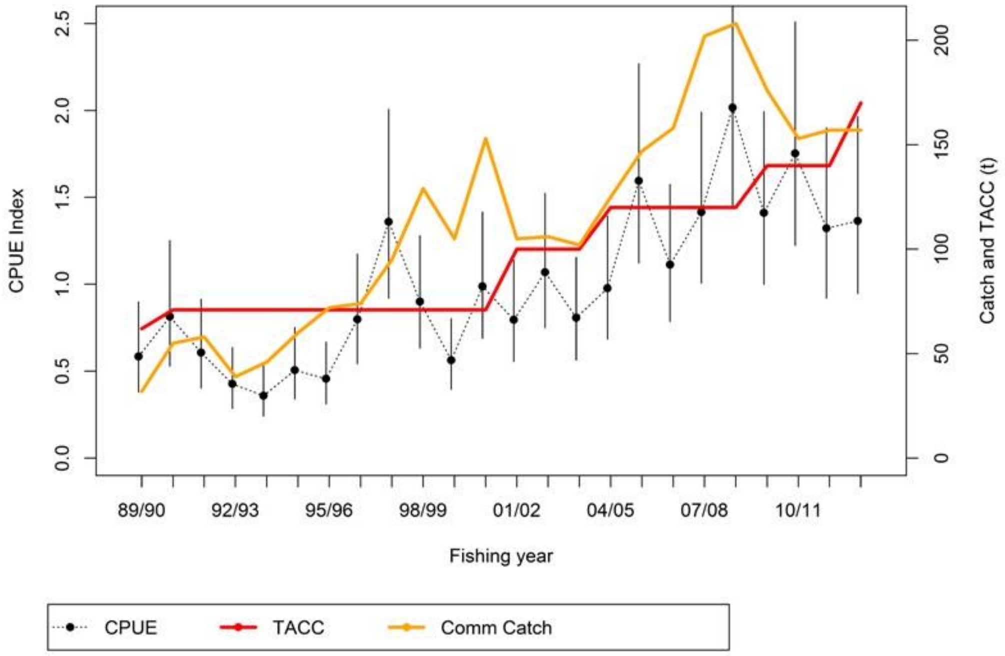
Stock Structure Assumptions

No information is available on the stock separation of elephantfish. The Fishstock ELE 5 is treated in this summary as a unit stock.

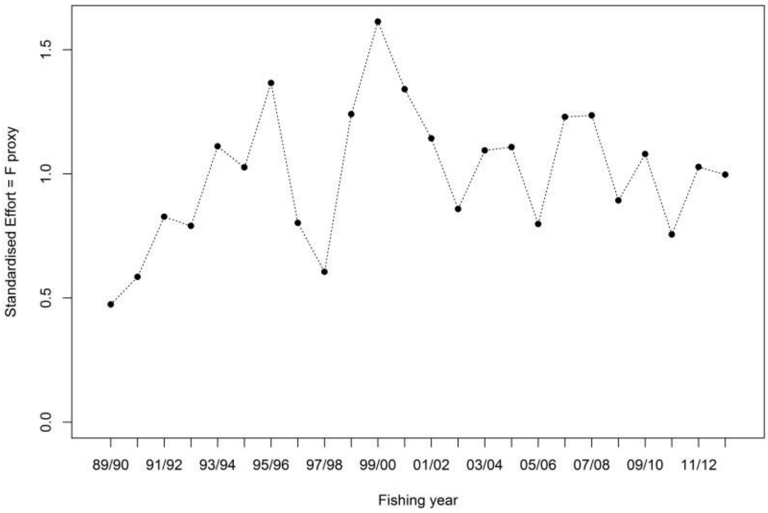
Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Update of CPUE indices only
Reference Points	Target: B_{MSY}-compatible proxy based on CPUE (to be determined) Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: F_{MSY} (assumed)
Status in relation to Target	Unknown

Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below 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



Comparison of the mixed target species bottom trawl CPUE series (ELE 5(MIX)) with the trajectories of catch (ELE 5(QMR/MHR)) and TACCs from 1989–90 to 2012–13.

Fishery and Stock Trends	
Recent trend in Biomass or Proxy	The ELE 5 (MIX) CPUE series increased up to 2005–06 and has fluctuated without trend since then.
Recent Trend in Fishing Mortality or Proxy	 Fishing mortality proxy is Standardised Fishing Effort = Total catch/CPUE (normalised). Fishing mortality proxy has remained relatively stable over the last 10 years, while total catches have increased.
Other Abundance Indices	-
Trends in Other Relevant Indicator or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	CPUE and catch in ELE 5 have both increased since the early 1990s.
Probability of Current Catch and TACC causing decline below Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Unlikely (< 40%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unlikely (< 40%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2: Partial Quantitative Stock Assessment	
Assessment Method	Evaluation of agreed standardised CPUE indices	
Assessment Dates	Latest assessment: 2014	Next assessment: 2016
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- ELE 5 (MIX) CPUE index	1 – High Quality: The Southern Inshore Working Group agreed that this index was a credible measure of abundance
	- Catch and effort data derived from the Ministry for Primary Industries compulsory catch reporting system	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	-	
Major Sources of Uncertainty	The index of abundance is based on relatively small amounts of data and consequently has relatively high uncertainty. It is possible that discarding and management changes in this fishery have biased the CPUE trends reported for this fishery.	

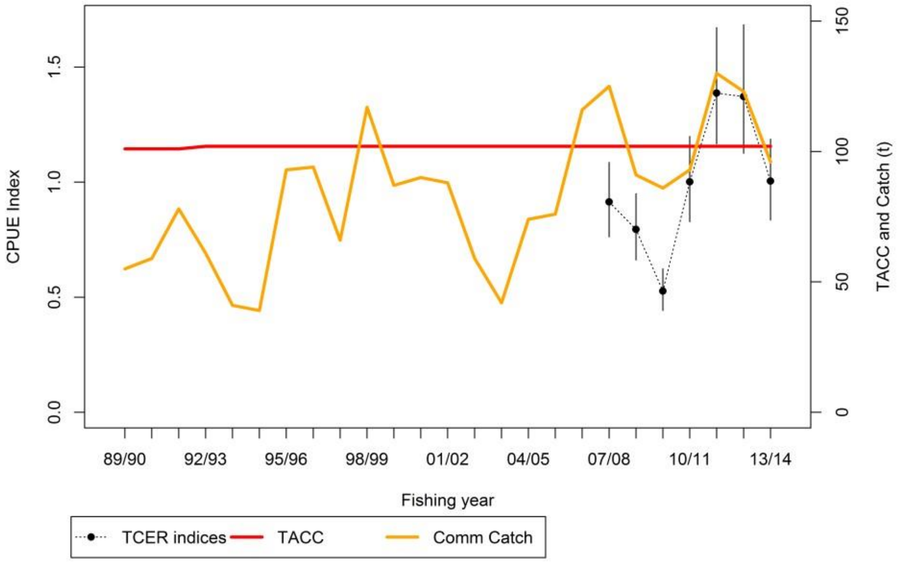
Qualifying Comments
Elephantfish have shown good recovery since apparently being at low biomass levels in the mid-1980s. The historical catches may be poorly estimated. Both current and historical estimates of landings exclude fish discarded at sea and the quantum of discards is unknown. Management interventions 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
Elephantfish in ELE 5 are taken by bottom trawl in fisheries targeted at flatfish and stargazer. Targeting elephantfish in the bottom trawl fishery was low (average 14% from 1989–90 to 2010–11) but has increased to about 20% of the landings since 2002–03. Around 12% of the ELE 5 landings are taken by setnet in a fishery targeted mainly at school shark. Both the trawl and setnet fisheries have been subject to management measures designed to reduce interactions with endemic Hector’s dolphins. Incidental captures of seabirds occur and there is a risk of incidental capture of Hector's dolphins.

ELE 7

Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	ELE 7 standardised CPUE based mixed target species in the bottom trawl fishery
Reference Points	Target: Not established but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: F_{MSY} (assumed)
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Very Unlikely (< 10%)
Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring

Historical Stock Status Trajectory and Current Status



Standardised TCER CPUE index for ELE 7 (black dots), commercial landings (yellow line) and TACC (red line).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE indices indicate biomass increased considerably from 2009–10 to 2011–12, remained at the higher level in 2012–13 and declined in 2013–14.
Recent Trend in Fishing Mortality or Proxy	Catches declined from a high in 1998–99 to a low in 2003–04 but have risen to and fluctuated around the level of the TACC since 2006–07.
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	CPUE indices and catches for 2011–12 and 2012–13 were relatively high levels (series beginning 1989–90), lower in 2013–14. Recent trawl survey biomass estimates are also relatively high.	
Probability of Current Catch or TACC causing 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 Unlikely (< 40%) to cause overfishing.	
Assessment Methodology		
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: 2015	Next assessment: 2017
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Standardised CPUE (MIX) (from 2007–08)	1 – High Quality: The SINSWG had more confidence in this part of the CPUE index as a credible measure of abundance
	- Standardised CPUE (MIX) (pre 2007–08)	2 – Medium or Mixed Quality: less catch (data) and lack of spatial resolution
	- Catch and effort data derived from the Ministry for Primary Industries compulsory catch reporting system	1 – High Quality
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. -The CPUE indices are derived from a data set with a high proportion of zero catch records and the indices may be sensitive to the treatment of zero catch records (although this was not apparent from a limited number of sensitivity analyses conducted).	
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 risk of incidental capture of Hector's dolphins.

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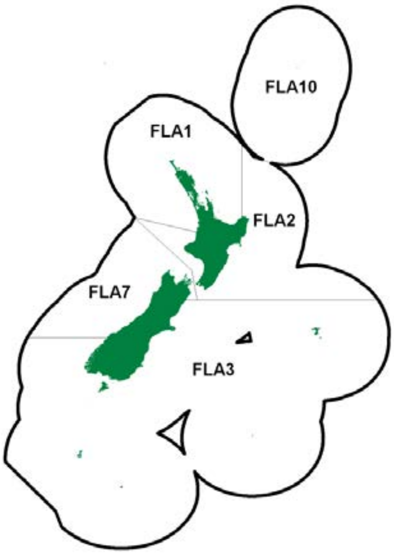
(FLA)

(*Colistium nudipinnis*, *Peltorhamphus novaezelandiae*, *Colistium guntheri*, *Rhombosolea retiaria*,
Rhombosolea plebeia, *Rhombosolea leporina*, *Rhombosolea tapirina*, *Pelotretis flavilatus*)
Patiki



SFL

GFL

BRI

YBF

ESO

BFL

TUR

LSO

1. FISHERY SUMMARY

1.1 Commercial fisheries

Flatfish Individual Transferable Quota (ITQ) provides for the landing of eight species of flatfish. These are: the yellow-belly 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. Set and drag net fishing are important in the northern harbours and the Firth of Thames. Important fishing areas are:

Yellow-belly flounder	-	Firth of Thames, Kaipara and Manukau harbours;
Sand flounder	-	Hauraki Gulf, Tasman/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 5160 t and 2750 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, and subsequently increased to a peak of 4051 t for the 2006–07 fishing year and have declined since to 2792 and 2672 t in 2012–13 and 2013–14 respectively. Historical estimated and recent reported flatfish landings and TACCs are shown in Tables 1 and 2, while Figure 1 shows the historical landings and TACC values for the main FLA stocks. From 1 October 2007 a TAC and allowances were set for the first time in FLA 3. The FLA 3 TACC was reduced by 47% to 1430 t as well as implementing a management procedure that recommends an in-season increase in the TACC if supported by early CPUE data (see Section 4.3 for a description of this procedure). All FLA fisheries have been put on to 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. The base TAC 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.

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. 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. 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 2012–13 and actual TACCs (t) from 1986–87 to 2013–14. QMS data from 1986–present.

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
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

Table 2 [Continued]

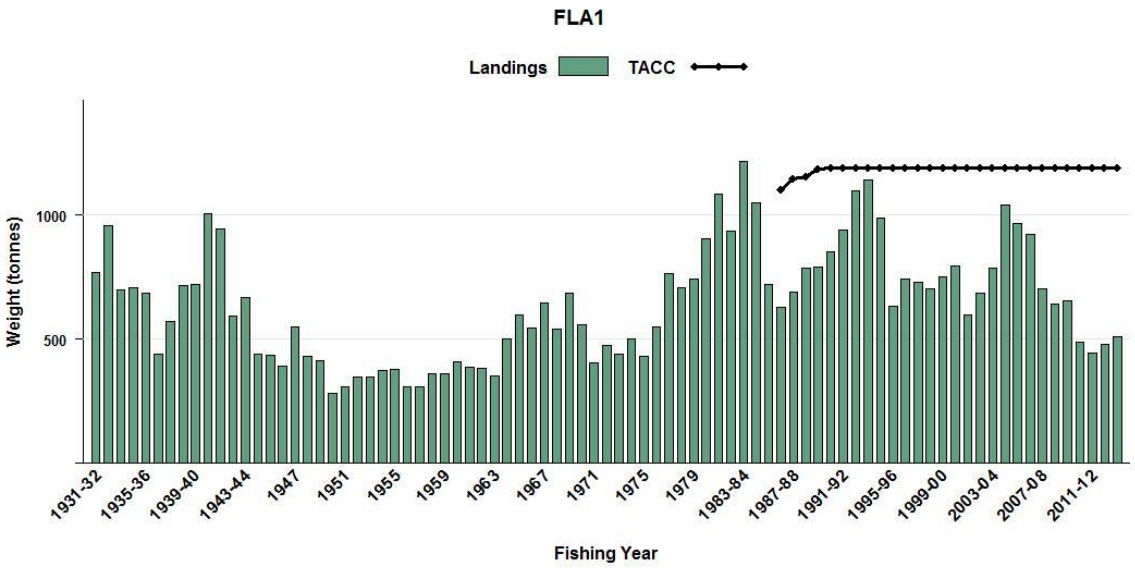
1995–96	628	1 187	481	726	2 298	2 681	1 163	2 066	1	10	4 571	6 670
1996–97	741	1 187	363	726	2 573	2 681	1 117	2 066	0	10	4 794	6 670
1997–98	728	1 187	559	726	2 351	2 681	1 020	2 066	0	10	4 657	6 670
1998–99	690	1 187	274	726	1 882	2 681	868	2 066	0	10	3 714	6 670
1999–00	751	1 187	212	726	1 583	2 681	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	5 409
2008–09	639	1 187	214	726	1 544	1 430	1 020	2 066	0	10	3 417	5 409
2009–10	652	1 187	212	726	1 525	**1 846	884	2 066	0	10	3 273	5 409
2010–11	486	1 187	296	726	1 027	**1 520	659	2 066	0	10	2 467	5 419
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	5 419
2013-14	511	1 187	216	726	1 377	1 430	568	2 066	0	10	2 672	5 419

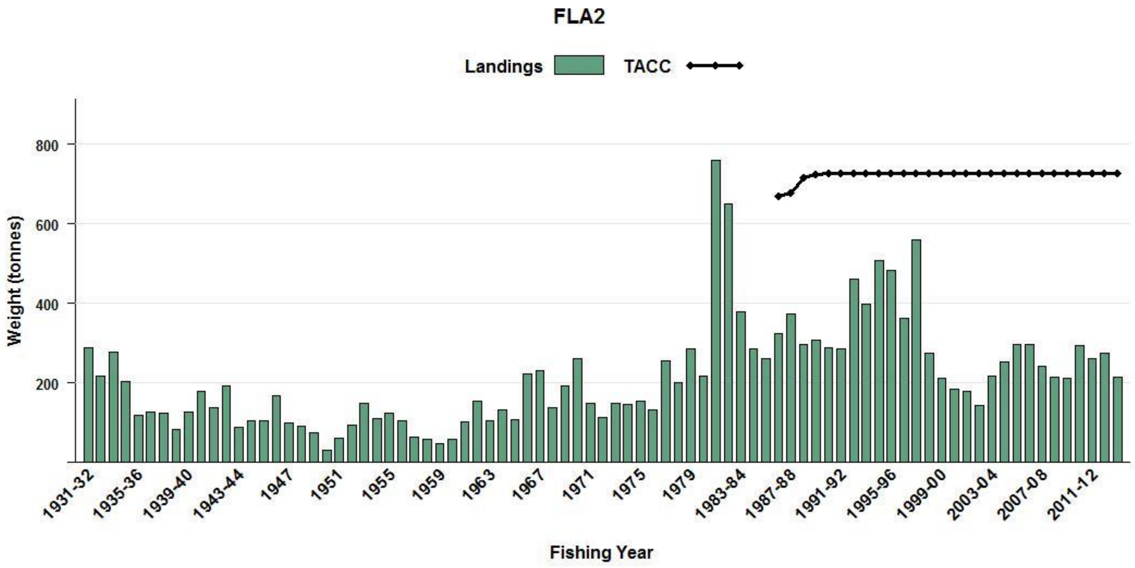
* FSU data.
‡ Includes 11 t Turbot, area unknown but allocated to QMA 7.
§ Includes landings from unknown areas before 1986–87.
** The TACC was increased in-season under Schedule 2 of the Fisheries Act (1996).

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. Although fishers are now instructed to use specific species codes when reporting estimated catches, they often use the generic FLA code. Beentjes (2003) showed that, for all QMAs combined between 1989–90 and 2001–02, about half of the estimated catch of flatfish was recorded using the generic species code FLA, and the remainder was reported using a combination of 12 other species codes (Table 3). Flatfish species that comprised a large proportion of the total estimated catch over the 13 year period included ESO (16%), LSO (12%), SFL (12%) and YBF (6%). Species that are important contributors to catch in each QMA are FLA 1: YBF, SFL, GFL; FLA 2: ESO, SFL; FLA 3: ESO, LSO, SFL, BFL, BRI; FLA 7: GFL, SFL, TUR (Table 4; codes provided in the caption to Table 3). Starr & Kendrick (in prep) have recently shown that trips which report catches in FLA 3 by species rather than using the generic FLA code accounted for greater than 80% of the estimated catches in 2012–13 and 2013–14.

Table 3: Percent estimated flatfish catch by species and fishing year in FLA 3 for "splitter" trips, which are trips which landed FLA 3 but which did not use the FLA code in the estimated catch section of the catch/effort form. Codes are arranged in descending order of total estimated catch: lemon sole (LSO), New Zealand sole (ESO), sand flounder (SFL), black flounder (BFL), brill (BRI), yellow belly flounder (YBF), Turbot (TUR), greenback flounder (GFL) (Starr & Kendrick in prep). Also shown is the proportion by weight of estimated catch defined in the "splitter" category.

Year	LSO	ESO	SFL	BFL	BRI	YBF	FLO	TUR	GFL	Other	"Splitters"
1990–91	14.7	32.1	22.2	18.1	5.2	4.5	0.0	1.3	1.9	0.0	44.9
1991–92	23.9	41.7	15.3	1.7	3.5	8.5	0.0	1.3	4.0	0.0	42.6
1992–93	23.6	42.9	20.3	0.4	3.2	4.5	0.0	0.4	4.8	0.0	44.1
1993–94	32.9	43.2	14.4	0.3	2.3	2.3	0.0	0.7	3.9	0.0	58.8
1994–95	34.8	35.4	16.3	3.5	2.0	2.8	0.0	1.1	3.6	0.5	60.9
1995–96	40.6	34.0	11.9	6.1	2.3	2.4	0.7	0.7	0.9	0.4	67.5
1996–97	38.2	36.8	14.6	2.4	2.0	1.2	2.4	0.7	1.6	0.1	61.5
1997–98	54.5	26.1	10.8	0.7	1.6	1.3	2.3	0.7	1.8	0.1	62.2
1998–99	57.2	22.4	8.9	1.3	2.7	2.0	2.4	1.6	1.4	0.1	67.0
1999–00	42.0	31.8	9.7	6.4	4.2	2.9	0.7	2.0	0.4	0.1	65.8
2000–01	36.4	37.3	9.7	3.5	3.2	2.9	1.1	1.9	0.2	3.8	67.8
2001–02	26.3	44.5	10.8	8.6	2.6	2.0	1.0	1.4	0.3	2.5	67.2
2002–03	33.0	40.2	11.2	2.2	4.1	4.3	1.3	1.8	0.2	1.7	59.0
2003–04	39.1	30.1	9.6	1.7	2.8	10.8	0.8	0.7	0.1	4.3	59.6
2004–05	33.9	27.0	12.7	13.4	2.9	3.6	1.1	1.2	0.3	3.9	59.3
2005–06	46.3	25.0	12.1	5.3	2.9	3.0	2.1	0.9	1.1	1.3	61.1
2006–07	52.0	20.6	15.9	0.1	2.5	4.6	1.8	1.2	0.5	0.8	65.3
2007–08	65.4	18.2	7.3	0.0	3.3	0.7	1.3	1.1	1.9	0.7	75.7
2008–09	54.9	25.6	10.2	0.0	3.0	0.7	1.8	1.9	1.5	0.4	71.7
2009–10	59.9	19.3	11.4	0.3	3.1	1.0	1.4	1.8	1.0	0.8	71.1
2010–11	54.7	14.4	16.8	2.4	4.7	0.4	2.0	2.4	0.9	1.4	65.8
2011–12	51.0	18.6	15.0	4.2	3.4	0.6	3.4	2.5	0.3	1.0	62.8
2012–13	46.4	20.7	16.9	2.4	3.3	1.9	3.2	2.4	0.6	2.0	83.8
2013–14	39.2	20.7	21.9	3.2	3.4	4.4	2.5	2.4	1.2	1.2	84.7
Total	42.7	29.6	13.3	3.4	3.0	2.8	1.5	1.4	1.4	1.1	61.3





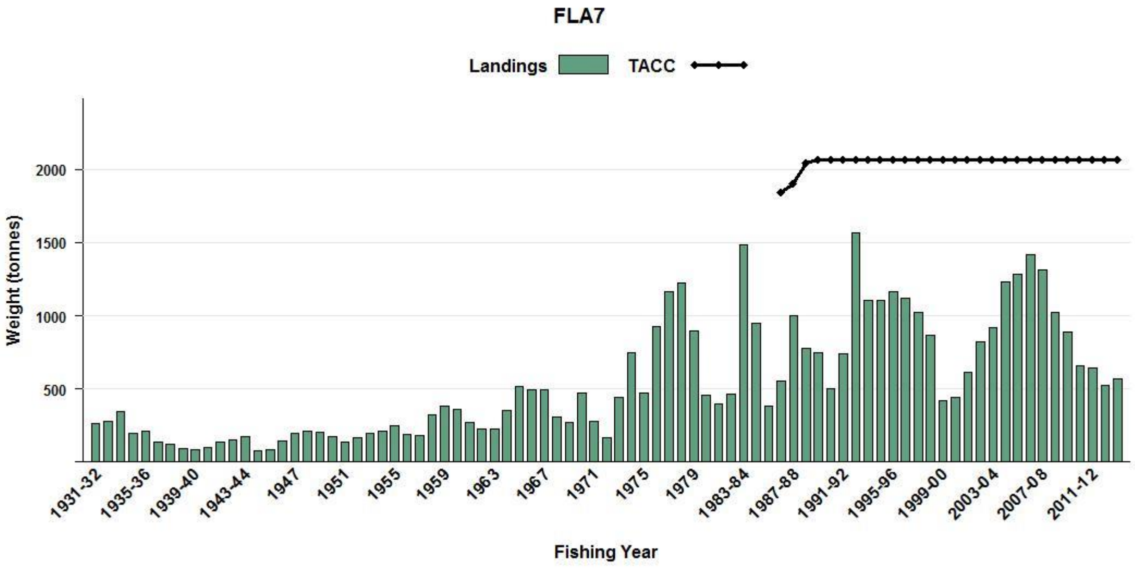


Figure 1: Historical landings and TACC for the four main FLA stocks. FLA 1 (Auckland), FLA 2 (Central), FLA 3 (South East Coast, South East Chatham Rise, Sub-Antarctic, Southland), and FLA 7 (Challenger).

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 setnetting, 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 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 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 2005. The harvest estimates provided by these telephone diary surveys (Table 3) 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. Note that the national panel survey estimate does not include recreational harvest taken under s111 general approvals. Recreational catch estimates from the various surveys are given in Table 4.

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 survey conducted 01 October 2011 through 30 September 2012, used a mean weight for flatfish of 0.41kg (Wynne-Jones et al 2014).

Fishstock	Survey	Number	CV%	Harvest range (t)	Point estimate (t)
1991–92					
FLA 1	South	3 000	-	-	-
FLA 3	South	15 200	31	50–90	-
FLA 7	South	3 000	-	-	-
1992–93					
FLA 1	Central	6 100	-	-	-
FLA 2	Central	73 000	26	20–40	-
FLA 7	Central	37 100	59	10–30	-
1993–94					
FLA 1	North	520 000	19	225–275	-
FLA 2	North	3 000	-	0–5	

Table 2 [Continued]

Fishstock	Survey	Number	CV%	Harvest range (t)	Point estimate (t)
1996					
FLA 1	National	308 000	11	95–125	110
FLA 2	National	67 000	19	13–35	24
FLA 3	National	113 000	14	30–50	40
FLA 7	National	44 000	18	10–20	16
1999–00					
FLA 1	National	702 000	25	203–336	-
FLA 2	National	380 000	49	82–238	-
FLA 3	National	395 000	33	128–252	-
FLA 7	National	114 000	53	23–73	-
2012					
FLA 1	Panel	64 999			26.7
FLA 2	Panel	12 885			5.3
FLA 3	Panel	53 475			21.9
FLA 7	Panel	12 259			5.0
All areas combined	Panel	143 619	21		58.9

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.

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 as 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.

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 flat fish.

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.)
Yellow-belly 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)

3. STOCKS AND AREAS

There is evidence of many fairly localised stocks of flatfish. However, the inter-relationships of neighbouring populations have not been thoroughly 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 yellow-belly 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, no fish tagged in Tasman Bay or the Hauraki Gulf have 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 fairly 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

The standardised CPUE series previously presented for FLA 1 (Kendrick & Bentley 2012) were updated with an additional three years of data (Kendrick & Bentley in prep.), 2012. The Northern Inshore Working Group concluded that the accepted indices reflect abundance. Less than half of the estimated flatfish catch in each year is identified by species, but at least 90% of flatfish caught in FLA 1 West are likely to be yellow-belly flounder. This is supported by the fact that the preferred muddy bottom habitat of yellow-belly flounder dominates the west coast harbours.

Three quarters of the west coast catch is taken from Kaipara and Manukau Harbours. Standardised CPUE trends were derived for these two areas using estimated catches described as either YBF or FLA (assumed to be YBF). In spite of fluctuations, both the Manukau and Kaipara series show a long-term declining trend and are currently below the means for each series.

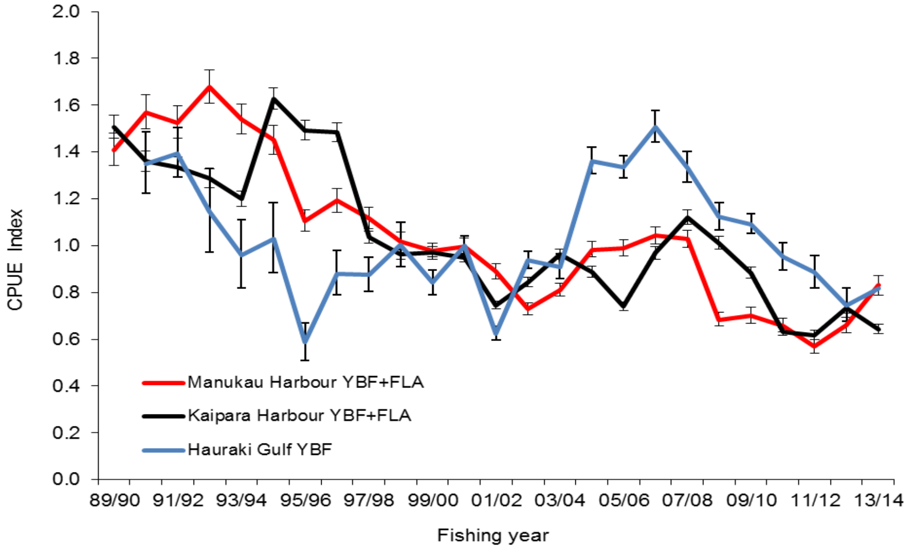


Figure 2: Comparison of standardised CPUE indices for yellowbelly flounder from models of catch rate in successful set net trips in Manukau Harbour, Kaipara Harbour (YBF or FLA) and in the Hauraki Gulf (YBF reported).

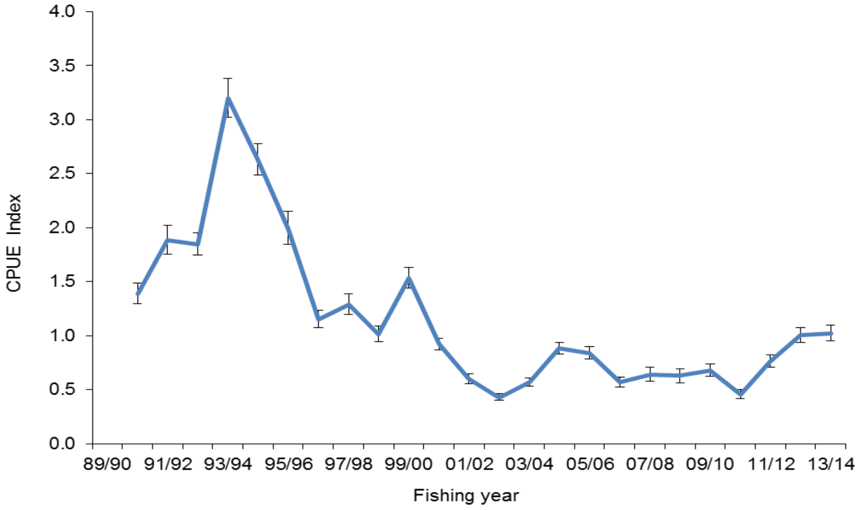


Figure 3: Standardised CPUE indices for sand flounder (SFL) from a lognormal model of catch rate in successful set net trips in the Hauraki Gulf.

Most 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. 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. The Hauraki Gulf yellowbelly CPUE index peaked in 2006-07 and has declined steadily since then. It currently sits below the long-term mean (Figure 2). The sand flounder index peaked between 1990–91 and 1993–94 and then declined steeply to its lowest point in 2002–03. Since then it has fluctuated without trend and is currently at about the mean for the series (Figure 3).

Coburn and Beentjes (2005) described a negative relationship between sea surface temperature and sand flounder abundance in the Firth of Thames, assuming a 2-year lag between egg production and recruitment. The abundance of yellowbelly flounder in the Firth of Thames did not appear to be related to temperature.

FLA 2

In 2014, Kendrick & Bentley (in press) provided standardised CPUE for FLA 2 (Figure 4) based on a model of positive catches from statistical areas 013 and 014 using a gamma error distribution, and a core fleet of 20 vessels that had completed at least five trips per year in at least five years. Characterisation done in 2014 suggests that the catch comprises mainly sand flounder (SFL) and English sole (ESO). Estimated catches were allocated to daily aggregated effort using methodology described in Langley (2014) to improve the comparability between the data collected from two different statutory reporting forms (CELR and TCER). The model adjusted for the recent positive influences of shifts in duration, an area x month interaction term, and vessel, and accounted for 37% of the variance in catch. A shorter time series based on TCEPR and TCER format data available since 2007–08, and analysed at tow by tow resolution closely resembles the mixed form series for the years in common (Figure 4).

The CPUE series exhibits moderate fluctuations around the longterm mean, with no overall trend up or down and appears currently to be in an increasing phase.

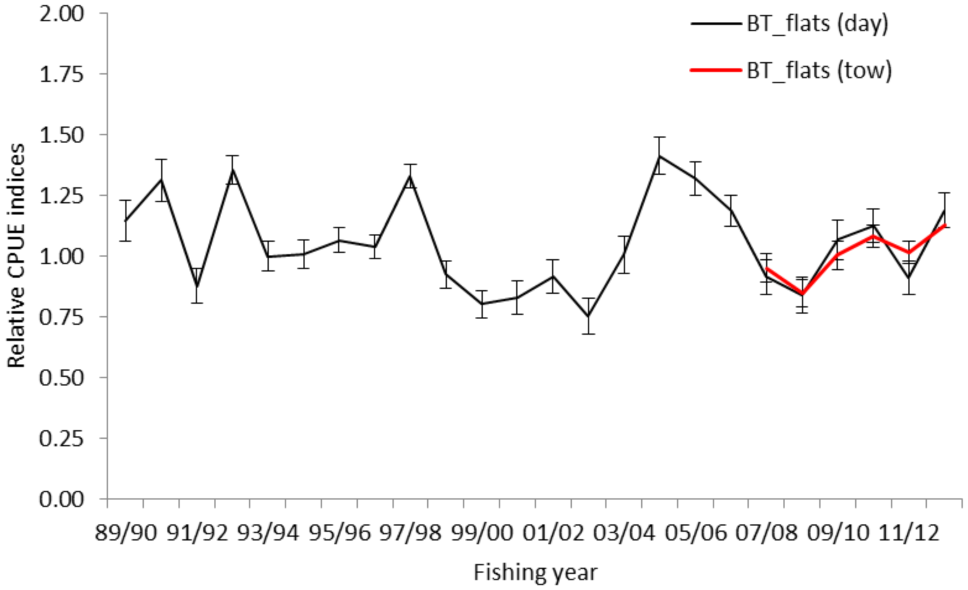


Figure 4: Standardised CPUE indices in FLA 2 for BT_targetting all species of flatfish, (aggregated to combine data across form types), and a shorter times series based on tow by tow resolution data (Kendrick & Bentley, in prep).

Establishing B_{MSY} compatible reference points

The Working Group accepted 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

As in 2010 (Kendrick & Bentley in prep), 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 estimated. The species-specific 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 also investigated, 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 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. Each analysis was confined to a set of core vessels which had participated consistently in the fishery for a reasonably long period (ESO, LSO and SFL: 5 trips for at least 5 years; TOT: 10 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.

These trends were used to evaluate the relative status of these species and to predict in-season abundance of FLA based on early harvest returns for the fishery. There are similarities in the fluctuations of the four standardised CPUE indices (Figure 5), with all indices increasing in the early 1990s and peaking at some point in the five years between 1989–90 and 1993–94. 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. The FLA, ESO and SFL indices show the greatest 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 5). The SFL index has continued to increase up to 2013–14 while the other three indices have dropped from peaks reached in 2009–10.

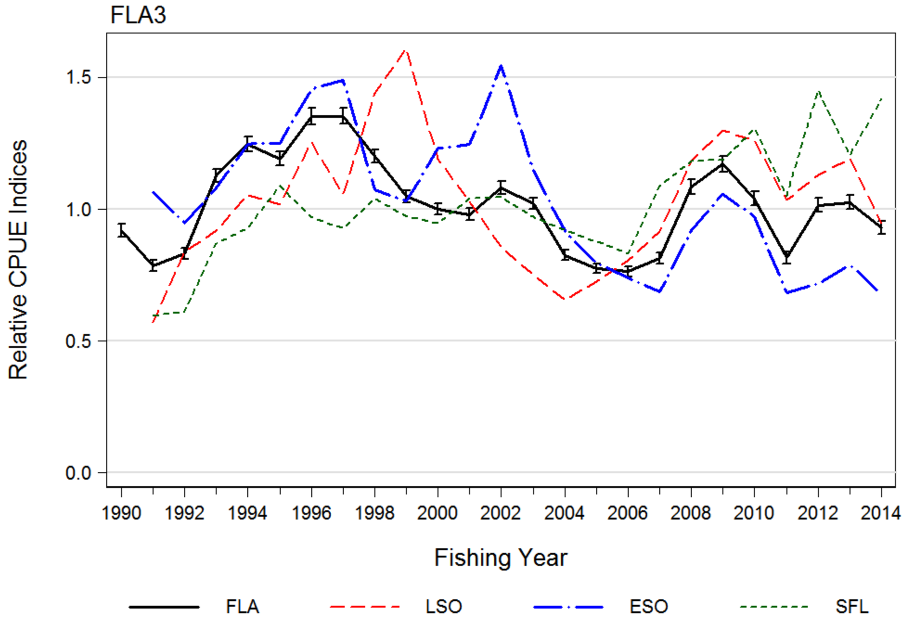


Figure 5: Comparison of standardised bottom trawl lognormal CPUE indices in FLA 3 for FLA (all flatfish species combined) LSO (lemon sole), ESO (New Zealand sole) and SFL (sand flounder). Note that only the FLA index is available for the 1989–90 fishing year because very little species composition data are available for that year (Starr & Kendrick, in prep).

ECSI trawl survey biomass estimates for LSO

Lemon sole biomass indices in the core strata (30–400 m) for the East Coast South Island trawl survey (Table 6) show no trend (Figure 6). Coefficients of variation are moderate to low, ranging from 18 to 33% (mean 24%). The additional biomass captured in the 10–30 m depth range accounted for only 4% and 1% of the biomass in the core plus shallow strata (10–400 m) for 2007 and 2012, respectively, indicating that the existing core strata time series in 30–400 m are the most important, but that shallow strata should also be monitored. A comparison of the two sets of LSO biomass indices shows that both series fluctuate without trend, with considerable variability (Figure 7). However, the correspondence between the two sets of indices is weak (rho= -0.294; R^2= 9%).

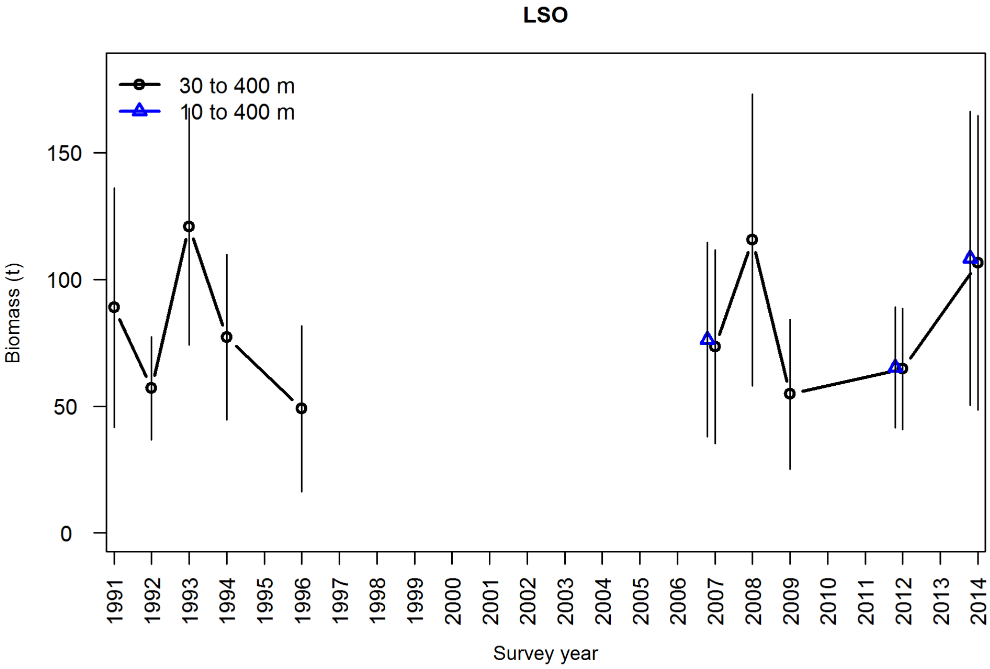


Figure 6: Lemon sole total biomass and 95 % confidence intervals for all ECSI winter surveys in core strata (30-400 m), and core plus shallow strata (10-400 m) in 2007, 2012 and 2014.

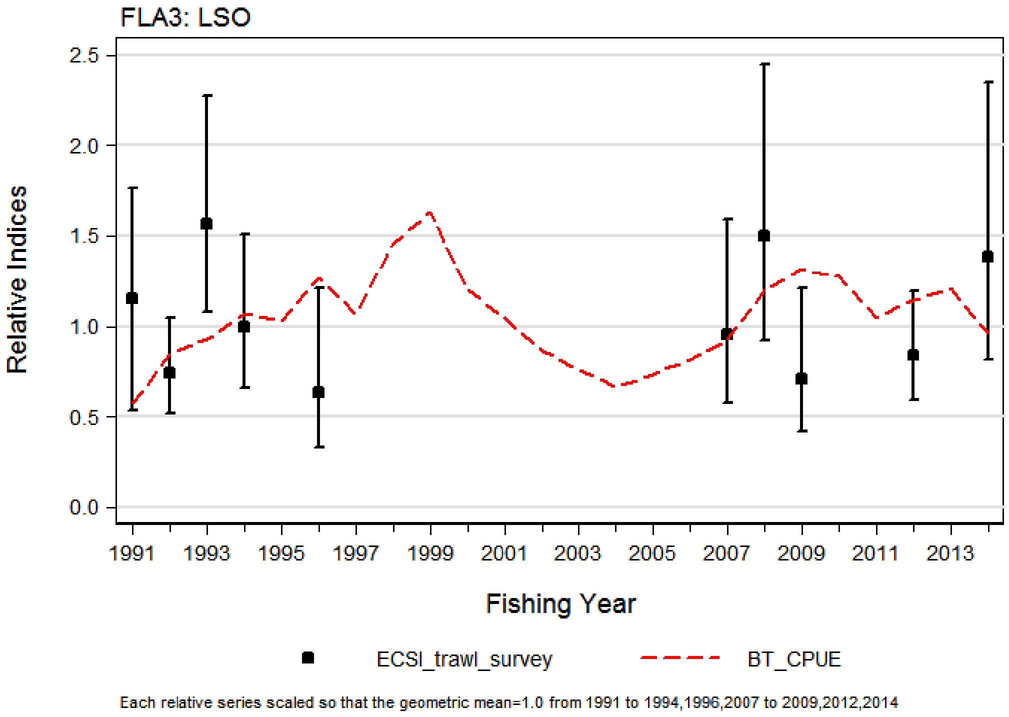


Figure 7: Lemon sole total biomass and 95% confidence intervals for the all ECSI winter surveys in core strata (30–400 m) plotted against the LSO bottom trawl CPUE series.

Table 6: Relative biomass indices (t) and coefficients of variation (CV) for lemon sole for the east coast South Island (ECSI) - winter survey area.

Region	Fishstock	Year	Trip number	Total Biomass estimate (t)	CV (%)
ECSI (winter)	FLA 3: LSO			30–400 m	
		1991	KAH9105	89	27
		1992	KAH9205	57	18
		1994	KAH9406	77	21
		1996	KAH9606	49	33
		2007	KAH0705	74	26
		2008	KAH0806	116	25
		2009	KAH0905	55	27
		2012	KAH1207	65	18
		2014	KAH1402	107	27

In-season Management Procedure

A 2010 Management Procedure (MP) used to inform in-season adjustments to the FLA 3 TACC (Kendrick & Bentley in prep.) was updated and revised in 2015 (Starr & Kendrick in prep). This MP 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 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 9).

The previous FLA 3 MP, adopted in 2010, 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 revised 2015 MP is 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 eligibiltiy 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).

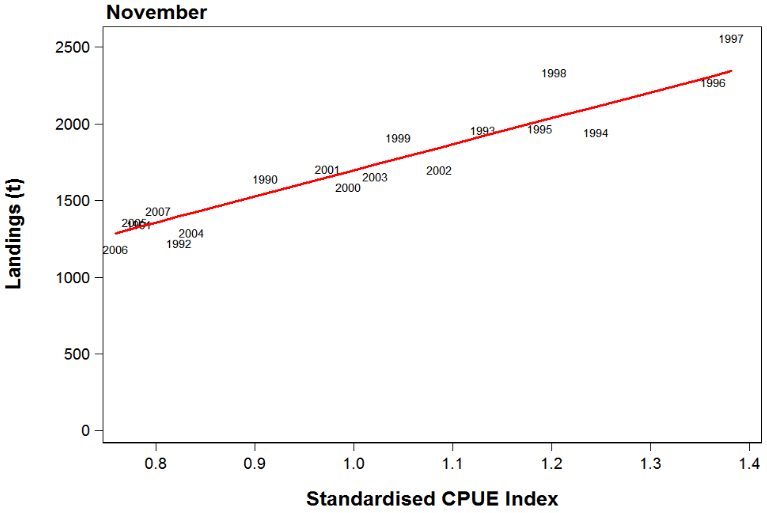


Figure 8: Relationship between annual FLA 3 CPUE (=FLA in Figure 5) and total annual FLA 3 QMR/MHR landings from 1989–90 to 2006–07.

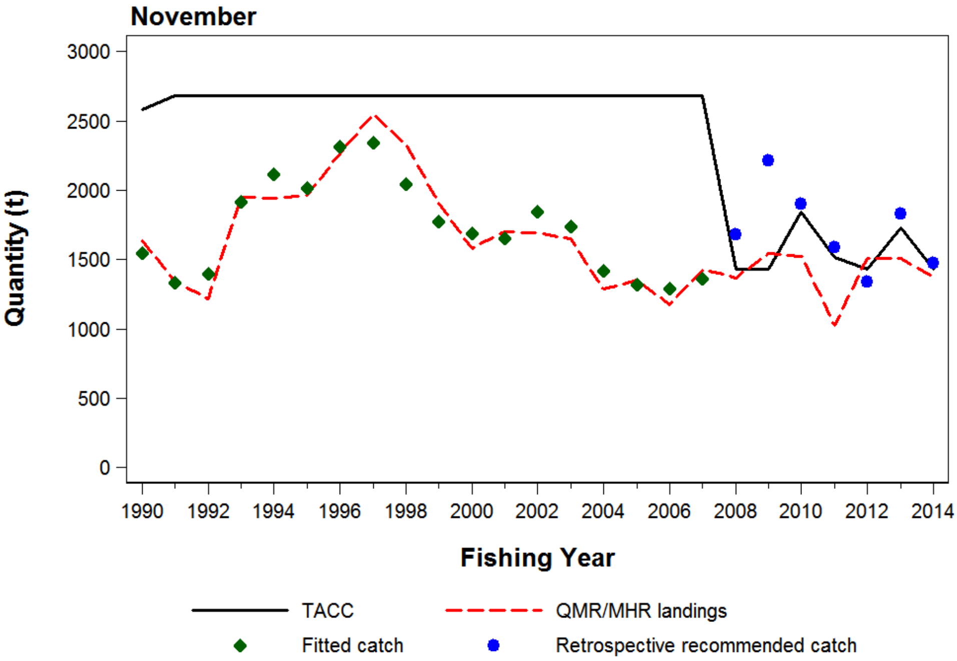


Figure 9:Operation of the 2015 FLA 3 MP, showing the relationship of the fitted catch estimates to the observed MHR/QMR landings and the annual recommended catches from 2008 onward based on the estimated standardised CPUE up to the end of November and only using the data available in the indicated year.

Establishing B_{MSY} compatible reference points

The Working Group accepted mean CPUE from the bottom trawl flatfish target series for the period 1989-90 to 2006-07 as a B_{MSY}-compatible proxy for FLA and 1990-01 to 2006/07 for LSO, SFL and ESO. These periods were chosen as catches were not constrained by the TACC. 1989-90 to 2006-07 was also the period used to determine average exploitation rate for the in season adjustment Management Procedure. 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.

4.2 Other Factors

The flatfish complex is comprised of 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 yellow belly 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.

4.2 Research needs

- Conduct CPUE analyses for brill and turbot, which are two of the longest-lived flatfish species and as such may be more susceptible to overfishing and depletion, particularly if they are caught in conjunction with other more productive species.

5. STATUS OF THE STOCKS

Estimates of current and reference biomass are not available.

- **Yellow-belly flounder in FLA 1**

Stock Structure Assumptions

Based on tagging studies, yellow-belly flounder appear to comprise localised populations, especially in enclosed areas such as harbours and bays.

<table>
<tr><th colspan="2">Stock Status</th></tr>
<tr><td>Year of Most Recent Assessment</td><td>2015</td></tr>
<tr><td>Assessment Runs Presented</td><td>CPUE in Manukau and Kaipara harbours, and the Hauraki Gulf</td></tr>
<tr><td>Reference Points</td><td>Target: Not established but B_{MSY} assumed
Soft Limit: 20% B_0
Hard Limit: 10% B_0
Overfishing Threshold: F_{MSY}</td></tr>
<tr><td>Status in relation to Target</td><td>Manukau: Unknown
Kaipara: Unknown
Hauraki Gulf: Unknown</td></tr>
<tr><td>Status in relation to Limits</td><td>Unknown</td></tr>
<tr><td>Status in relation to Overfishing</td><td>Unknown</td></tr>
<tr><th colspan="2">Historical Stock Status Trajectory and Current Status</th></tr>
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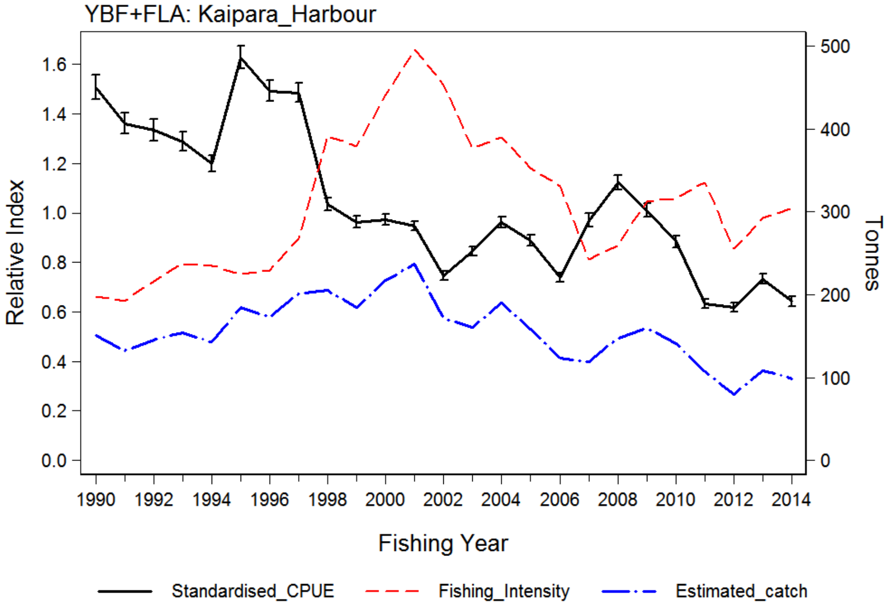

CPUE and total annual estimated catches for YBF in Kaipara Harbour. Also shown is the fishing intensity (catch/CPUE), standardised relative to the geometric mean. Fishing year designated by second year of the pair.
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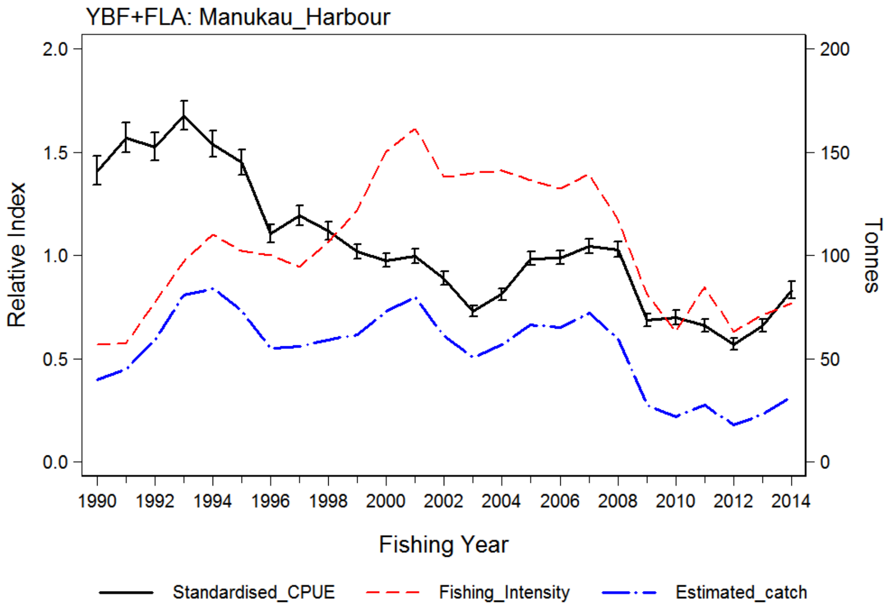
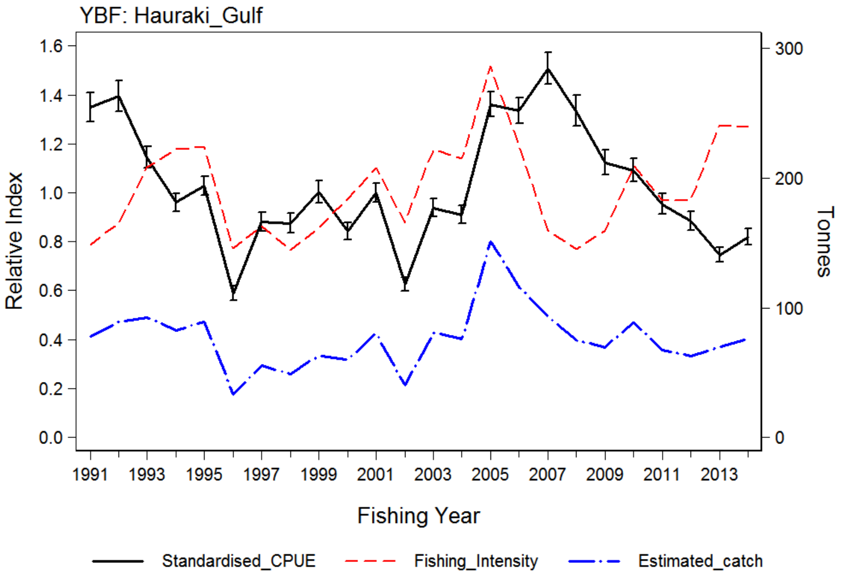


CPUE and total annual estimated catches for YBF in Manukau Harbour. Also shown is the fishing intensity (catch/CPUE), standardised relative to the geometric mean. Fishing year designated by second year of the pair.



CPUE and total annual estimated catches for YBF in 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 with a peak in 2006-07 being the highest point in the series, it has declined since then to currently sit at its lowest level since the mid-1990s.
Recent Trend in Fishing Intensity or Proxy	-
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: 2015	Next assessment: 2018
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 stock structure and relationship between CPUE and biomass	

Qualifying Comments
Work by NIWA (McKenzie et al 2013) in the Manakau 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 Manakau 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 protected species are believed to be low.

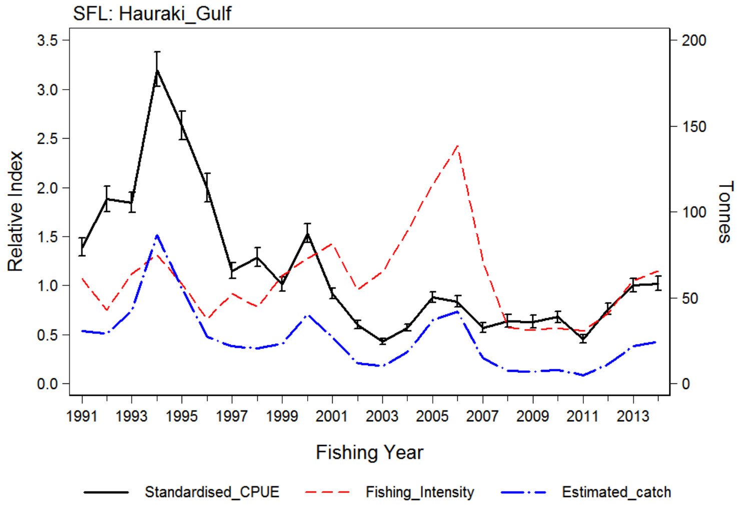
- **Sand flounder in FLA 1**

Stock Structure Assumptions

Based on tagging studies and morphological analysis, sand flounder appear to comprise localised populations, especially in enclosed areas such as harbours and bays.

Stock Status	
Year of Most Recent Assessment	2015
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
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 SFL 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 sand flounder index peaked from 1990–91 to 1993–94 and then declined steeply to its lowest point in 2002–03, after which it has fluctuated at or below the long term mean.
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	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: 2015	Next assessment: 2018
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 stock structure and relationship between CPUE and biomass	

Qualifying Comments
Coburn & Beentjes (2005) described a negative relationship between sea surface temperature and sand flounder abundance in the Firth of Thames, assuming a 2-year lag between egg production and recruitment to the fishery. The lack of species specific reporting for FLA stocks limits the ability to assess these stocks.

Fishery Interactions
Main QMS bycatch species is yellow belly flounder, especially on the east coast. FLA 1 species are mostly targeted with setnets in harbours. Interactions with protected species are believed to be low.

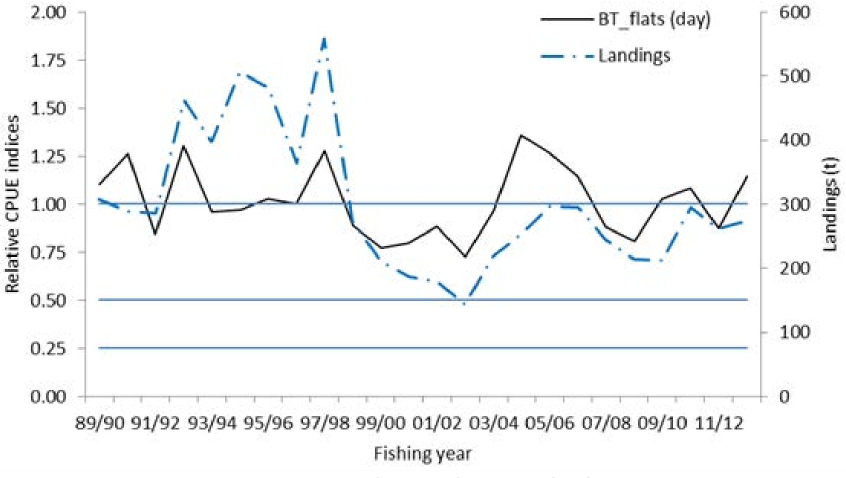
- **FLA 2**

Stock Structure Assumptions

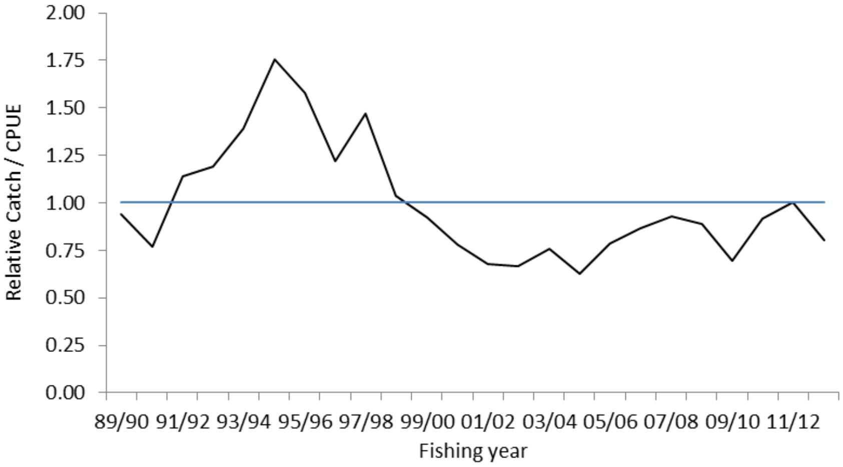
Sand flounder off the East Coast of North Island appear to be a single continuous population. The stock structure of New Zealand sole (ESO) is unknown.

Stock Status	
Year of Most Recent Assessment	2014
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: Very Unlikely (< 10%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Overfishing in 2013 was Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status



Standardised CPUE indices based on positive catches for BT_flats, (all flatfish species combined) at day resolution (Kendrick & Bentley, in prep). 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 above the target.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has be reasonably stable since 2001and is currently below the long term average
Other Abundance Indices	-
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: 2014	Next assessment: 2017
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
The lack of species specific reporting for FLA stocks limits the ability to assess these stocks on an individual basis. There is no indication that species composition has changed over the analysis period.

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 protected species are believed to be low. Incidental captures of seabirds occurs.

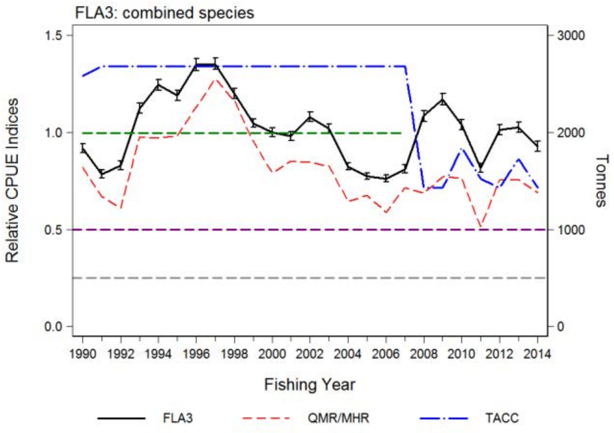
FLA 3 (all species combined)

Stock Structure Assumptions

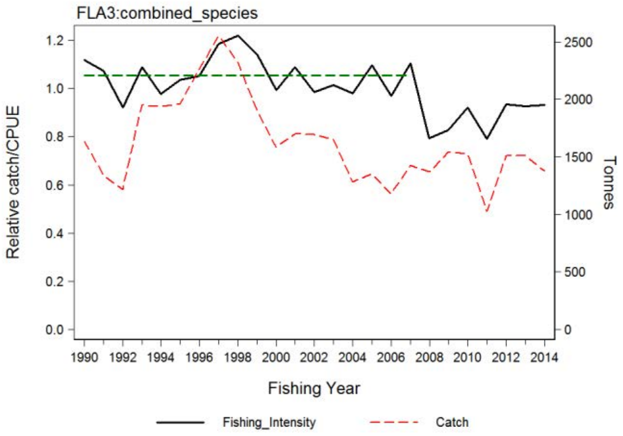
New Zealand sole and lemon sole appear to be a continuous population extending from Canterbury Bight to Foveaux Strait. Sand flounder off the East and South Coasts of South Island show localised concentrations that roughly correspond to the existing statistical areas. The stock relationships among these localised concentrations are unknown.

Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	Standardised lognormal bottom trawl CPUE for all flatfish combined in FLA 3
Reference Points	Interim Target: B_{MSY} proxy based on the mean standardised lognormal CPUE from 1989–90 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}
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	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, showing the agreed B_{MSY} proxy (green dashed line: average 1989–90 to 2006–07 CPUE index) and the associated Soft (purple dashed line) and Hard (grey dashed line) Limits (Starr & Kendrick in prep). Also shown are the QMR/MHR declared FLA 3 landings and the annual FLA 3 TACC. Fishing year designated by second year of the pair.



Fishing intensity (catch/CPUE), standardised relative to the geometric mean, plot over time for FLA 3 (combined species). Also shown are the trajectory of total QMR/MHR catches (t) and the mean fishing intensity from 1989–90 to 2006–07 (green line). 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 25-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 TACC variation and remains below the F_{MSY} proxy.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Stock managed with annual in-season adjustment procedure: expected 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 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: 2015	Next assessment: 2020
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 - the decline in fishing intensity in recent years is inconsistent with the increases for individual stock components	

Qualifying Comments
The lack of historical species specific reporting for FLA stocks limits the ability to assess the long-term trends in these stocks; there is evidence that reporting by flatfish species has substantially improved in FLA 3 in 2012–13 and 2013–14.

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 elephantfish. Interactions with protected species are believed to be low. Incidental captures of seabirds occur.

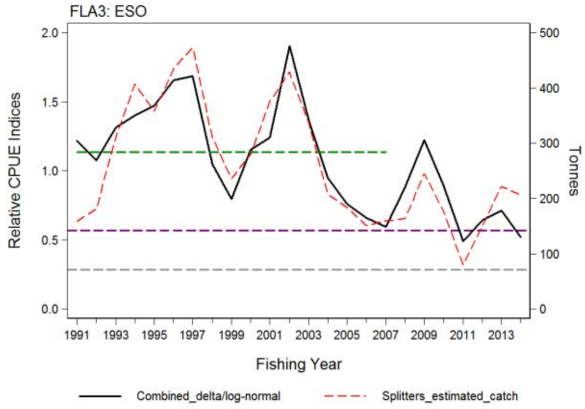
FLA 3: New Zealand (ESO) sole

Stock Structure Assumptions

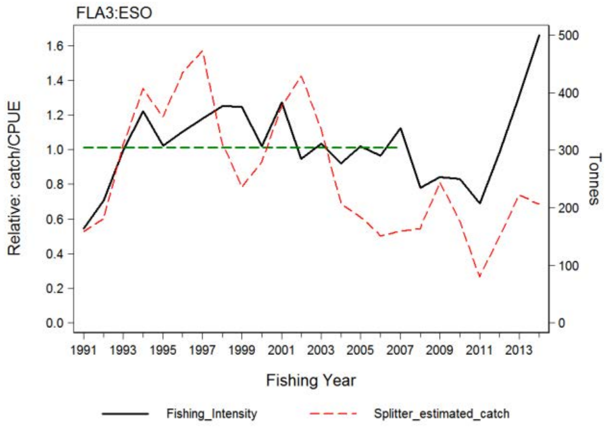
New Zealand sole appear to be a continuous population extending from Canterbury Bight to Foveaux Strait.

Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	Standardised combined delta-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 1989-90 to 2006-07
Status in relation to Target	Unlikely (< 40%) to be at or above target
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	Likely (> 60%) that overfishing is occurring

Historical Stock Status Trajectory and Current Status



Standardised CPUE indices based on combined delta-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 in prep). 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.



Fishing intensity (catch/CPUE, standardised relative to the geometric mean) plot over time for New Zealand sole (ESO) in FLA 3. Also shown are the trajectory of ESO estimated catches by trips that landed FLA 3 but which did not use the FLA code and the mean fishing intensity from 1990–91 to 2006–07 (green line). Fishing year designated by

second year of the pair.	
Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE has declined from a peak reached in 2001–02 and has been near the Soft Limit since 2010-11.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has increased since 2010/11 to more than 50% above the mean level.
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: About as Likely as Not (40–60%) for current catch Hard Limit: Unlikely (< 40%) for current catch
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Likely (> 60%) 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: 2015	Next assessment: 2020
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 evidence that reporting by flatfish species has substantially improved in FLA 3 in 2012–13 and 2013–14.

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: Lemon (LSO) sole**

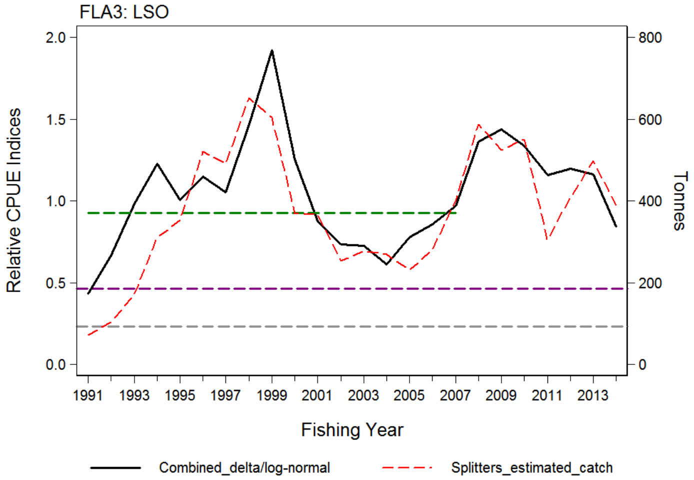
Stock Structure Assumptions

Lemon sole appear to be a continuous population extending from Canterbury Bight to Foveaux Strait.

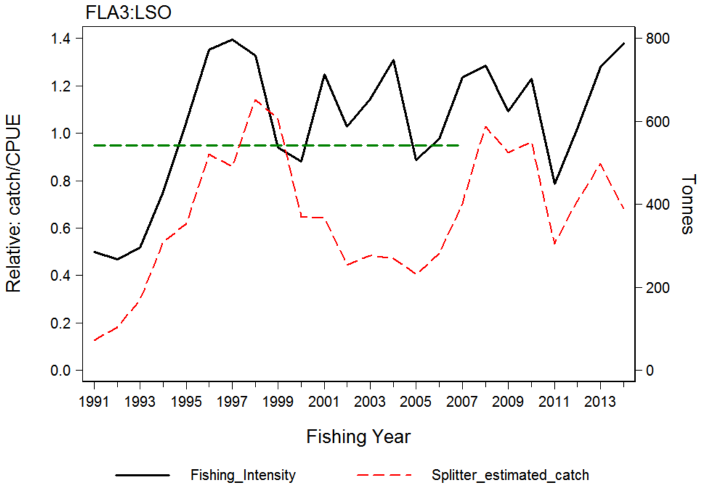
Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	Standardised combined delta-lognormal bottom trawl CPUE for LSO in FLA 3, based on trips which landed FLA 3 but which did not use the FLA species code
Reference Points	Interim Target: B_{MSY} proxy based on mean standardised 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 1989-90 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	Likely (> 60%) that overfishing is occurring

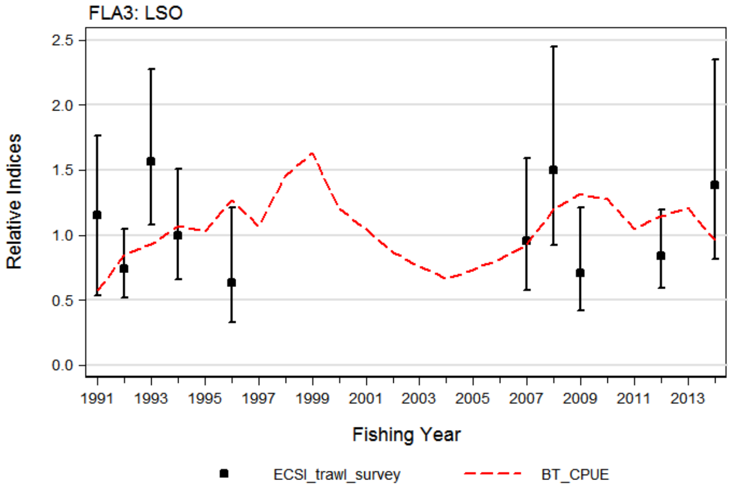
Historical Stock Status Trajectory and Current Status



Standardised CPUE indices based on combined delta-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 in prep). 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.



Fishing intensity (catch/CPUE, standardised relative to the geometric mean) plot over time for Lemon sole (LSO) in FLA 3. Also shown are the trajectory of LSO estimated catches by trips that landed FLA 3 but which did not use the FLA code and the mean fishing intensity from 1990–91 to 2006–07 (green line). Fishing year designated by second year of the pair.



Each relative series scaled so that the geometric mean=1.0 from 1991 to 1994,1996,2007 to 2009,2012,2014

Standardised CPUE indices based on combined delta-lognormal CPUE series for Lemon sole (ESO), shown with the 10 trawl survey LSO 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 high level in 2007–08 and has since declined to the long-term mean level.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has fluctuated, mostly above the F_{MSY} proxy since 1994-95, and in 2013-14 was nearly 40% above this level.
Other Abundance Indices	Relative abundance from the ECSI trawl survey has fluctuated without trend since 1991.
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: Unlikely (< 40%) Hard Limit: Very Unlikely (< 10%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Likely (> 60%)

Assessment Methodology		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches	
Assessment Dates	Latest assessment: 2015	Next assessment: 2020
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 evidence that that reporting by flatfish species has substantially improved in FLA 3 in 2012–13 and 2013–14.		

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.

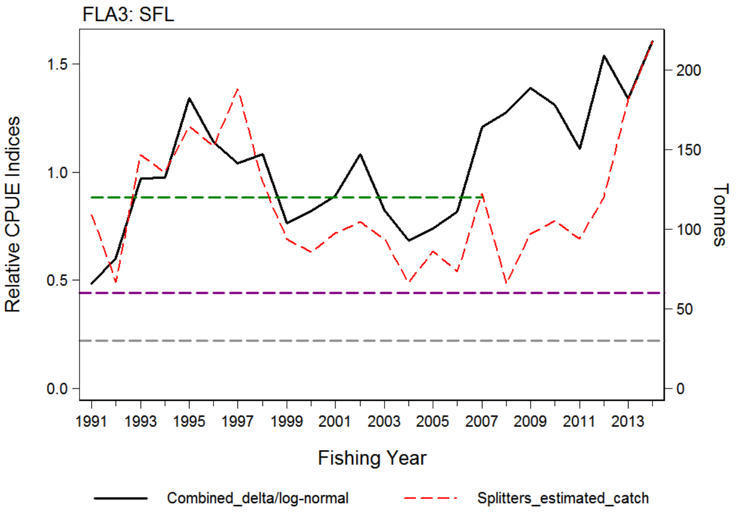
- **FLA 3: Sand Flounder (SFL)**

Stock Structure Assumptions

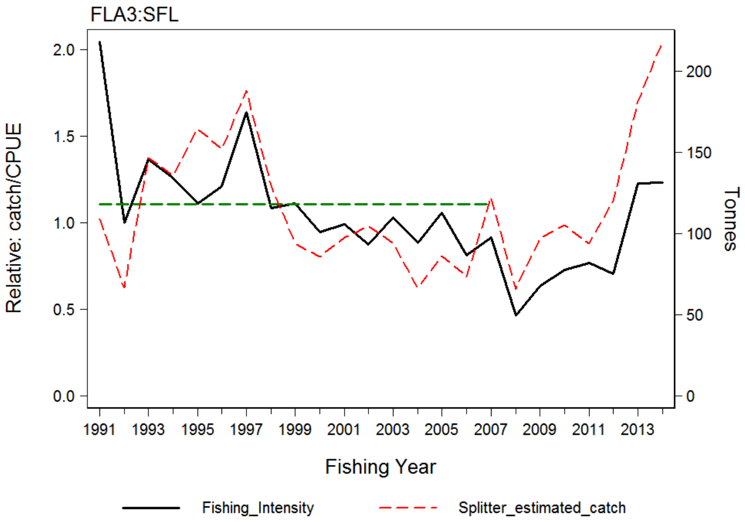
Sand flounder off the East and South Coasts of South Island show localised concentrations that roughly correspond to the existing statistical areas. The stock relationships among these localised concentrations are unknown.

Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	Standardised combined delta-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 1989-90 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	About as Likely as Not (40–60%) that overfishing is occurring

Historical Stock Status Trajectory and Current Status



Standardised CPUE indices based on combined delta-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 in prep). 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.



Fishing intensity (catch/CPUE, standardised relative to the geometric mean) plot over time for Sand flounder (SFL) in FLA 3. Also shown are the trajectory of SFL estimated catches by trips that landed FLA 3 but which did not use the FLA code and the mean fishing intensity from 1990–91 to 2006–07 (green line). Fishing year designated by second year of the pair.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE has been climbing steadily from a nadir in 2003–04.
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	-
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%) for current catch Hard Limit: Very Unlikely (< 10%) for current catch
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: 2015	Next assessment: 2020
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 evidence that reporting by flatfish species has substantially improved in FLA 3 in 2012–13 and 2013–14.

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.

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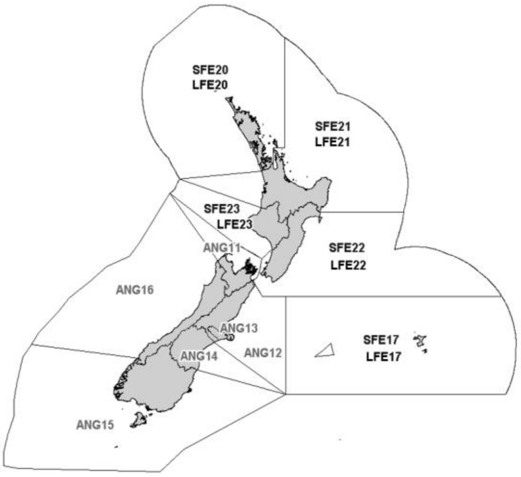
FRESHWATER EELS (SFE, LFE, ANG)

(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). The Australasian longfin eel is combined as part of the shortfin eel stocks in the Chatham and North Islands, as 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 31mm escapement tubes (equivalent to South Island regulation). The minimum legal diameter for escape tubes on the North Island was increased to 31mm 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 practise 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, 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 2011–12 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 2013–14 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	1978	1 583	1988–89	1 315	2001–02	978
1966	50	1979	1 640	1989–90	1 356	2002–03	808
1967	140	1980	1 395	1990–91	1 590	2003–04	729
1968	320	1981	1 043	1991–92	1 585	2004–05	708
1969	450	1982	872	1992–93	1 466	2005–06	771
1970	880	1983	1 206	1993–94	1 255	2006–07	718
1971	1 450	1984	1 401	1994–95	1 438	2007–08	660
1972	2 077	1985	1 505	1995–96	1 429	2008–09	518
1973	1 310	1986	1 166	1996–97	1 342	2009–10	560
1974	860	1987	1 114	1997–98	1 210	2010–11	626
1975	1 185	1988	1 281	1998–99	1 219	2011–12	755
1976	1 501			1999–00	1 133	2012–13	717
1977	906			2000–01	1 071	2013–14	678

MFish data, 1965–1982; FSU, 1983 to 1989–90; CELR, 1990–91 to 1999–00; ECLR 2000–01 to 2003–04; MHR 2004–05–present.

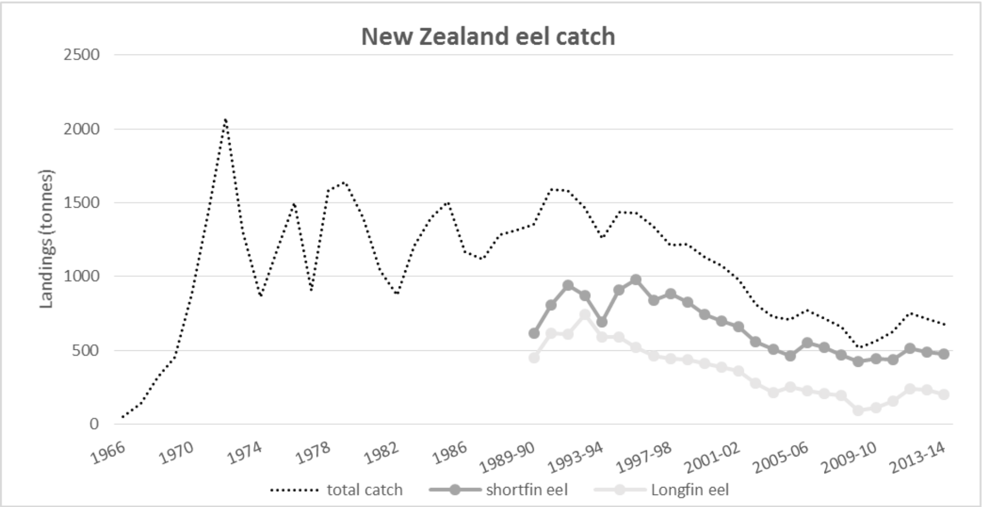


Figure 1: Total eel landings from 1965 to 2012–13, as well as separate shortfin and longfin landings from 1989–90 to 2012–13. The diamond points represent estimates for the period prior to the introduction of Eel Catch Landing Return (ECLR) forms, and were generated by pro-rating the unidentified eel catch by the LFE:SFE ratio (see below). Squares represent post QMS data based on Monthly Harvest Returns (MHR).

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 were further reduced during 2001–02 to 2004–05 as eel stocks were progressively introduced into the Quota Management System (QMS). While landings since 2007–08 were further affected by the reduction in TACCs for both species in the North Island on 1 Oct. 2007, eel catches have remained below the TACCs as a result of reduced international market demand, and since 2007–08 have ranged between 487 and 642 tonnes. For the period 1991–92 to 2013–14, the North Island provided on average 61% of the total New Zealand eel catch (Table 2).

Table 2: North and South Island eel catch (t) compiled from data from individual processors 1991–92 to 1999–00 and LFRR/QMR/MHR 2000–01 to 2011–12. Numbers in parentheses represent the percentage contribution from the North Island fishery.

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%)	_
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%)

Table 3: Total NZ eel landings (t) by species and fishing year. Numbers in bold represent data collected following the introduction of the ECLR forms, whereas all others are pro-rated as described above. 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%)

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. Pro-rating 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 pro-rated 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, as 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 ca 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. 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 come catchments to commercial fishing; and declining/fluctuating market demand.

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 are mostly comprised of 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 the period of 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
						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

*For the transition from a 1 0ctober 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.

Table 5: TACCs and commercial landings (t) for Chatham Island (SFE17) and North Island shortfin stocks from 2003–04 to 2013–14 (based on ECLR data).

Fishing	SFE17		SFE20		SFE21		SFE22		SFE23		Total
Year	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	landings
2003–04	10	< 1	-	-	-	-	-	-	-	-	-
2004–05	10	1.6	149	78.4	163	122.6	108	80.0	37	15.7	298
2005–06	10	2.6	149	92.0	163	143.3	108	106.7	37	29.9	374
2006–07	10	< 1	149	108.5	163	113.3	108	92.9	37	29.8	345
2007–08	10	0	86	77.5	134	126.7	94	81.6	23	15.3	301
2008–09	10	0	86	67.7	134	110.4	94	70.1	23	10.2	258
2009–10	10	< 1	86	62.0	134	121.7	94	69.1	23	18.1	271
2010–11	10	< 1	86	83.0	134	132.4	94	59.1	23	16.1	290
2011–12	10	< 1	86	85.4	134	139.7	94	94.8	23	20.6	340.4
2012–13	10	<1	86	77.4	134	124.8	94	79.9	23	14.5	296.6
2013–14	10	<1	86	70.2	134	138.2	94	82.2	23	13.9	304.5

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 2013–14. The annual landings are based on data recorded on ECLR forms, as 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 6: TACCs and commercial landings (t) for Chatham Island (LFE17) and North Island longfin stocks from 2003–04 to 2013–14 (based on ECLR data).

Fishing	LFE17		LFE20		LFE21		LFE22		LFE23		Total
Year	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	landings
2003–04	1	< 1	-	-	-	-	-	-	-	-	-
2004–05	1	< 1	47	27.1	64	52.9	41	23.6	41	26.4	130.0
2005–06	1	< 1	47	24.4	64	39.2	41	29.6	41	22.3	115.5
2006–07	1	0	47	27.0	64	30.4	41	25.7	41	14.9	98.0
2007–08	1	0	19	18.1	32	30.9	21	18.0	9	6.5	74.0
2008–09	1	0	19	11.5	32	22.5	21	7.3	9	2.5	44.0
2009–10	1	< 1	19	9.4	32	21.7	21	10.5	9	5.7	47.0
2010–11	1	< 1	19	12.3	32	16.7	21	8.0	9	7.4	44.0
2011–12	1	< 1	19	19.2	32	32.5	21	18.5	9	6.6	76.8
2012–13	1	<1	19	17.9	32	26.0	21	17.2	9	5.6	66.7
2013–14	1	0	19	14.9	32	26.6	21	15.6	9	5.2	62.3

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 Maori not taken under customary provisions. The extent of the recreational fishery is not known although the harvest by Maori might be significant.

1.3 Customary non-commercial fisheries

Eels are an important food source for use in customary Maori practices. Maori 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. Maori 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 Maori 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. Mätaitai 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 mätaitai 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.

Table 7: TACs, 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.

	ANG 11 Nelson/ Marlborough	ANG 12 North Canterbury	ANG 13 Te Waihora Lake Ellesmere	ANG 14 South Canterbury	ANG 15 Otago/Southland	ANG 16 West Coast
TAC	51	55	156	45	151	80
Customary Non-Commercial Allowance	10	11	31	9	30	16
Recreational Allowance	1	1	3	< 1	3	2

Table 8: TACs, and customary non-commercial, recreational, and other fishing-related mortality allowances (t) for the Chatham Island and North Island shortfin stocks.. Numbers in parentheses reflect the current TACs following a review of catch limits for October 2007 for all North Island eel stocks.

	SFE17	SFE20	SFE21	SFE22	SFE23
TAC	15	211 (148)	210 (181)	135 (121)	50 (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

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 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 statistical areas ANG 12 (North Canterbury) and ANG 13 (Te Waihora/Lake Ellesmere). Customary regulations were only extended to freshwaters of the Chatham and North Islands in November 2008.

Table 9: TACs, and customary non-commercial, recreational, and other mortality allowances (t) for the Chatham Island and North Island longfin eel fisheries. Numbers in parentheses reflect the current TACs following a review of catch limits for October 2007 for all North Island eel stocks.

	LFE17	LFE20	LFE21	LFE22	LFE23
TAC	3	67 (39)	92 (60)	54 (34)	66 (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

There is no information available on illegal catch. 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 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, is 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 on-going habitat modification brought about by irrigation, channelisation of rivers and streams and the reduction in littoral habitat. On-going 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 faciltative 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, while 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 and South Islands, 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, while 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 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 longfinned 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 has taken the unique opportunity that exist to monitor the relative abundance of elvers arriving at large in-stream barriers where established 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 2013–14 season, there are now up to 19 years of reliable and accurate elver catch information for some sites (Martin *et al.* 2014). These records show that the magnitude of the elver catches 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 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 analysis.

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. The consistently increasing catches at Piripaua, however, stand out at present (Figure 2a).

Variation in the distance of dam sites from the sea and catchment based elver migration rates has resulted in differences in the size (age) structure of elvers captured at the various sites. Martin et al. (2014) used the median age of elvers at key sites (Table 10b) to standardise the normal catch index so that it reflected the recruitment of glass eels (0yrs old) into each catchment.

The standardised recruitment indices indicate that there was a recruitment peak between 2004 and 2006 for both eel species (Figure 2b). Records from Patea and Wairua where elvers are younger than at any of the other monitored sites indicate that there may have been a second a peak in recruitment in 2013.

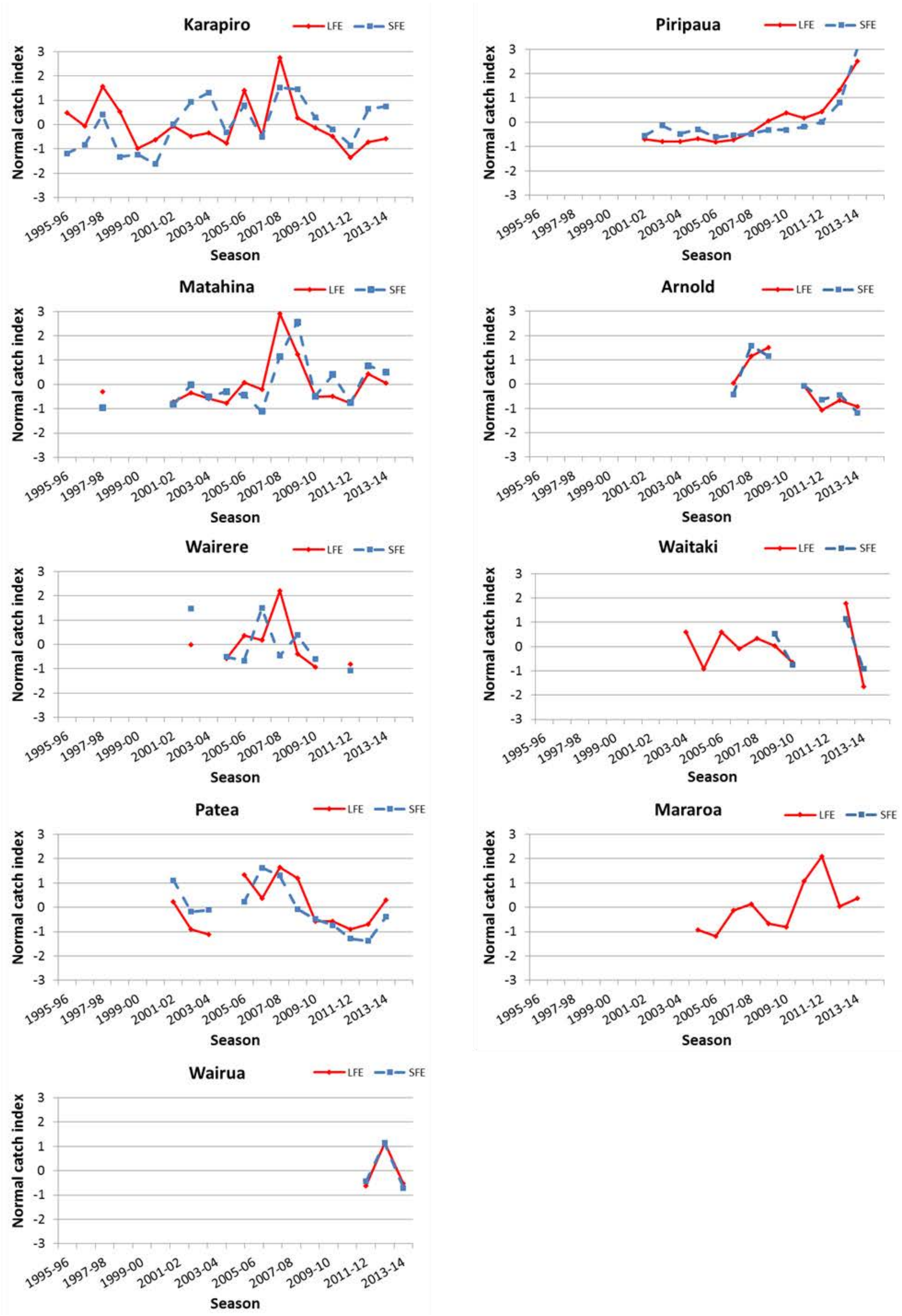


Figure 2a: Normal catch index for longfin and shortfin elvers at monitored sites from 1995–96 to 2013–14. (Notes: incomplete records for season have been omitted; 0 = mean index for entire monitoring period for each site; few shortfins recorded at Mararoa Weir). Mararoa has inconsistent fishing effort so the trend shown may reflect increased trapping efficiency rather than increased recruitment.

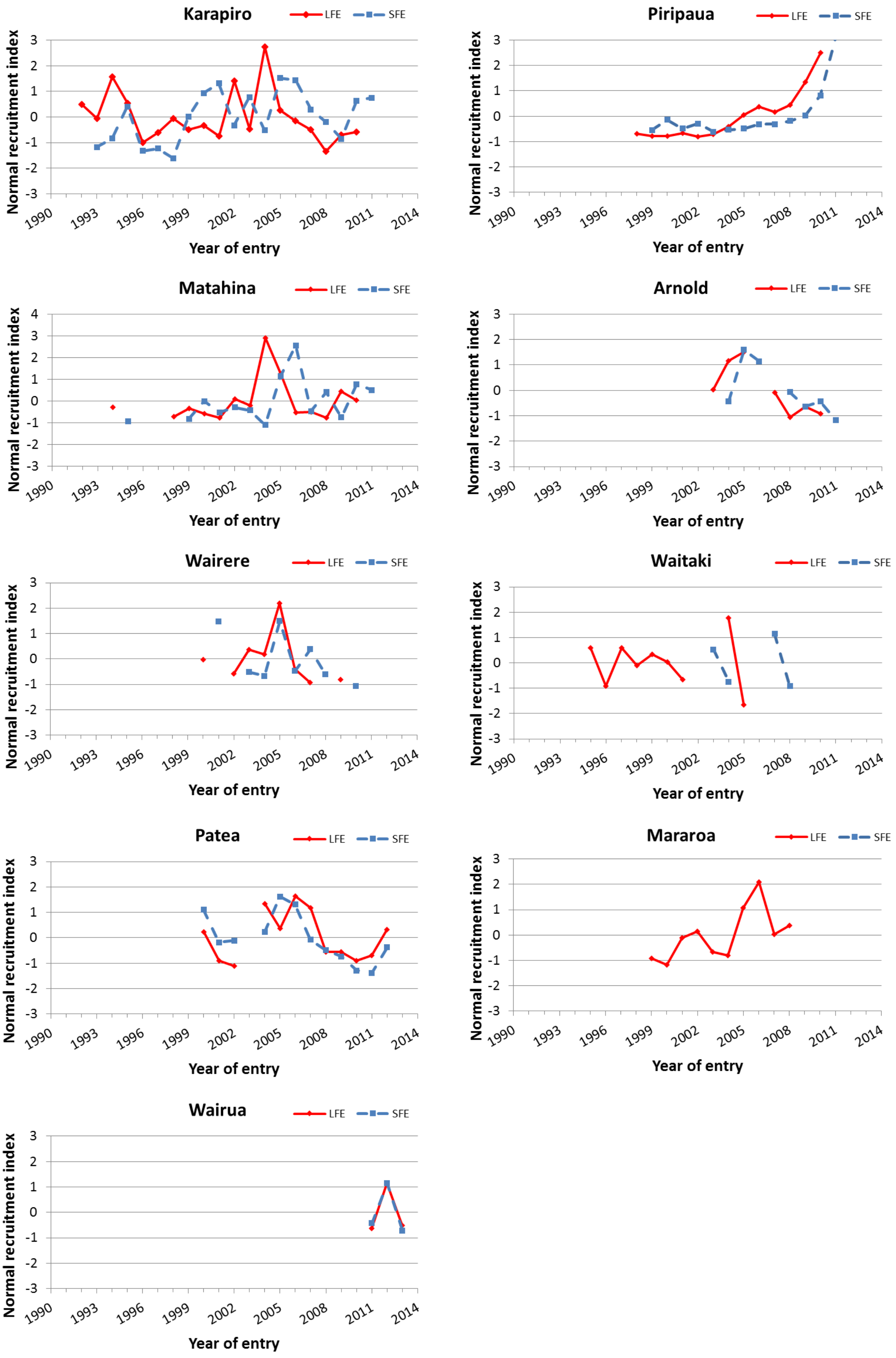


Figure 2b: Normal recruitment indices for longfin and shortfin elvers at the main monitored sites from 1995–96 to 2013–14 (0 = mean catch for entire monitoring period for each site). Mararoa has inconsistent fishing effort so the trend shown may reflect increased trapping efficiency rather than increased recruitment.

Eel larvae are thought to drift on sea currents to reach the New Zealand continental shelf and glass eels enter rivers and streams between August and December. 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). Specific 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 and Sykes 2004). 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). 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. There is some evidence of annual variation influenced by the El Nino Southern Oscillation (ENSO), with the arrival route of glass eels from the northwest being stronger during the La Nina phase and stronger from the northeast during the El Nino 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.

Table 10a: Estimated numbers (1000s) of all elvers and, in brackets, longfins only; trapped at key elver trap and transfer monitoring sites by season (Dec–April) 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. 2014 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

Table 10a [Continued]

Year	Wairua	Karapiro	Matahina	Wairere	Patea	Piripaua	Arnold	Waitaki	Roxburgh	Mararoa
		(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)

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. 2014).

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	0
	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	2
	SFE	295	93	91	153–74	0.9	0.8	3.9–0.4	2
Matahina	LFE	272	111	110	152–86	1.53	1.4	4.0–0.6	3
	SFE	750	97	96	133–75	0.96	0.9	2.9–0.4	2
Piripaua	LFE	166	115	112	188–90	1.7	1.5	8.7–0.8	3
	SFE	497	101	100	142–85	1.1	1.1	3.4–0.5	2
Patea	LFE	124	80	79	124–59	0.62	0.56	2.57–0.18	1
	SFE	1 247	74	73	121–57	0.46	0.43	1.95–0.16	1
Arnold	LFE	400	130	126	202–101	2.1	1.8	8.9–0.7	4
	SFE	418	111	108	175–90	1.1	1.0	4.3–0.5	3
Waitaki	LFE	53	196	200	260–118	10.0	8.65	22.1–1.7	11
	SFE	103	132	130	203–102	2.25	1.98	11.3–0.9	5
Roxburgh	LFE	16	159	163	210–120	4.38	4.34	7.5–2.3	8
Mararoa Weir	SFE	1 591	152	137	240–92	4.9	3.0	18.92–0.7	5
	LFE	15	108	104	150–92	1.34	0.99	3.8–0.6	3

[a] Fresh water age based on median lengths of elver at each site and nation-wide age vs length regression.

Spawning

As 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.

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) recently developed a length-structured longfin population model that generated New Zealand-wide estimates of the pre-exploitation female spawning stock biomass (approximately 1700 t) as well as the pre-exploitation biomass of legal-sized eels (16 000 t in all fished areas and 6000 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 noted that further analyses be conducted 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 commericial 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.

The commercial eel monitoring programme collects processor recorded data for each species based on size-grades (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) and is ongoing.

4.2 Catch-per-unit-effort analyses

Each species of eel comprises a single stock, and these can be more appropriately managed using an alternative to the maximum sustainable yield (*MSY*) approach, which is available under s.14 of the Fisheries Act 1996. To that end, 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 2011–12 for all North Island ESAs and from 1990–91 to 2012–13 for all South Island ESAs (Tables 12 to 13 and Figures 4–7).

North Island CPUE

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 2002 to 2007 (Table 12, Figure 4) (Beentjes & Dunn 2013b).

For longfin there were generally fewer data than for shortfin for most areas and indices were often more variable or associated with wider confidence intervals. In general, apart from Rangitikei-Whanganui (ESA AH) which showed a steadily declining CPUE trend throughout the time series, CPUE initially declined, and then was either flat with no clear trend or there was an increase in CPUE between 2005 and 2011. Most increases in CPUE were only slight (Table 13, Figure 5) (Beentjes & Dunn 2013b).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, as many fishers do not have ACE to cover all of their catch (larger longfins are more valuable than small and medium specimens). Industry were previously unaware of the fact that eels of legal size (220 g–4 kg) that are released are supposed to be recorded using the destination X code. CPUE of the large commercial size category of longfin eels, as previously recommended by the WG, would not be affected by this behaviour. CPUE of the large size category will be investigated when the North Island CPUE series are next updated.
2. The introduction of a maximum size of 4kg in 2007–08. Longfins > 4 kg were landed before this date. There is currently no legal requirement to record the catch of eels > 4 kg.
3. Avoidance of longfin habitat post 2006–07 in some statistical areas as there is currently insufficient quota to allow targeting of longfin eels. The QMA most affected is LFE 23 (current TACC is 9 tons). Almost all of the longfin TACC is leased to a fisher operating in the Taranaki statistical area 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.
4. Voluntary uptake of larger escape tubes (31mm) over the last two years (2010–11 and 2011–12) is expected to have resulted in a stepped drop in CPUE.

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

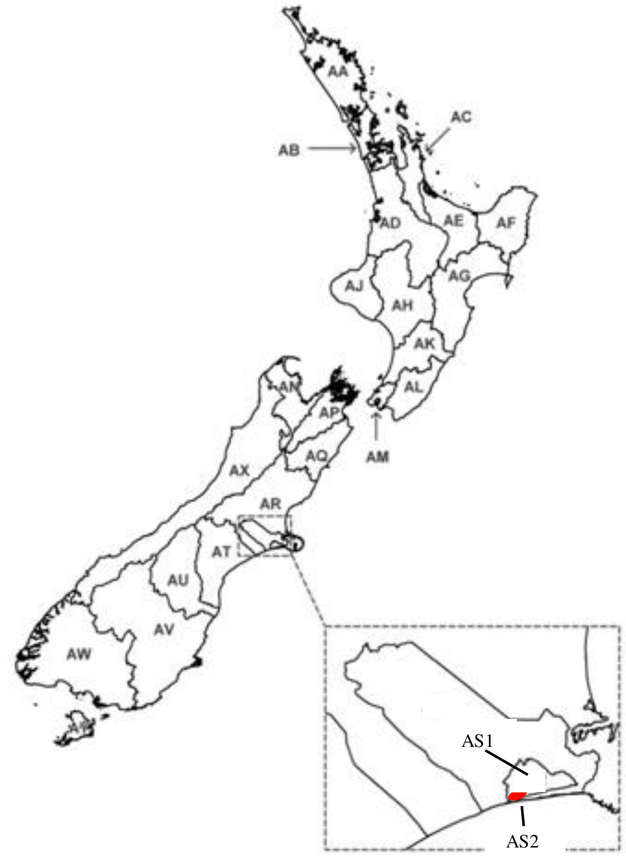


Figure 3: New Zealand Eel Statistical Areas (ESAs).

Avoidance of longfin habitat post 2006–07 in some statistical areas as there is currently insufficient quota to allow targeting of longfin eels. The QMA most affected is LFE 23 (current TACC is 9 t). Almost all of the longfin TACC is leased to a fisher operating in the Taranaki statistical area 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.

Voluntary uptake of larger escape tubes (31 mm) over the last two years (2010–11 and 2011–12) is expected to have resulted in a stepped drop in CPUE.

South Island CPUE

The Eel Working Group (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, as 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.

Table 12: CPUE indices for shortfin eels by Eel Statistical Area (ESA). For the South Island separate indices are presented for pre-QMS (1991–2000) and post-QMS (2001–2010). 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). [Continued on next page].

							Shortfin (North Island ESAs)			
Year	AA	AB	AC	AD	AE	AG	AH	AJ	AK	AL
1991	0.75	1.32	0.95	1	1.24	1.51	0.82	1.37	2.7	1.56
1992	0.7	0.83	0.91	1.16	0.83	1.54	0.75	1.48	4.8	1.62
1993	0.75	0.73	1.09	1.11	0.72	1.45	0.83	0.58	2.12	0.93
1994	0.68	0.85	1.04	1.22	0.83	1.37	0.94	0.53	0.67	1.2
1995	0.85	1	1.08	1.19	1.05	1.4	0.88	0.93	0.63	1.12
1996	0.9	1.09	1.11	1.21	1.17	1.06	1.37	0.92	0.52	0.94
1997	0.85	0.82	0.79	1.03	0.92	0.83	0.94	0.7	0.51	0.67
1998	1.05	1.03	0.71	1.1	0.57	0.66	0.89	0.82	0.71	0.91
1999	1.11	1.3	0.76	0.96	0.91	0.94	0.93	1.09	1.03	0.87
2000	1.2	0.95	0.88	0.81	0.49	0.8	0.73	0.95	0.6	0.71
2001	1.22	0.87	0.84	0.77	0.54	1.05	0.8	0.83	0.65	0.88
2002	0.97	0.69	1.13	0.79	0.42	0.54	0.61	0.84	0.77	0.48
2003	0.97	0.75	0.98	0.72	0.63	0.57	0.86	0.72	0.39	0.49
2004	1.01	0.82	1.08	0.89	0.72	0.75	0.4	0.71	1.39	0.36
2005	0.98	0.88	1	0.88	1.25	0.8	0.68	0.68	1.03	1.22
2006	1.03	0.99	1.04	0.96	1.24	1.08	1.23	1.11	1.17	1.14
2007	1.11	1.03	0.93	0.99	1.33	0.91	1.27	0.89	1.34	1.29
2008	1.14	1.36	0.96	1.03	1.6	0.96	1.62	1.3	1.49	1.5
2009	1.18	1.11	1.09	1.12	1.89	1.19	1.7	1.52	1.01	1.32
2010	1.42	1.31	1.11	1.18	1.89	1.23	1.6	2.16	1.2	1.58
2011	1.32	1.5	1.35	1.19	2.2	1.14	2	1.76	1.06	1.7
2012	1.29	1.29	1.51	0.97	2.11	1.17	1.93	1.78	0.89	1.27

								Shortfin (South Island ESAs)		
QMS status	Year	AN	AP_AQ	AR	AT	AU	AV	AW	AX	AS1
Pre-QMS	1991	-	2.36	1.13	2.09	1.7	1.51	1.3	0.96	–
	1992	–	1.94	1.09	1.07	1.46	1.2	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	0.9	–
	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	0.9	0.79	0.75	–
	1998	0.97	0.38	1	1.07	1.1	0.84	0.89	1.31	–
	1999	1.37	0.73	1.13	0.67	0.61	0.83	0.9	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	–	–	–	–	–	0.8	1.29	0.89	1.28
	2009	–	–	–	–	–	1.26	0.8	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 13: CPUE indices for longfin eels by Eel Statistical Area (ESA). For the South Island separate indices are presented for pre–QMS (1991–2000) and post QMS (2001–2010). 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).

								Longfin (North Island ESAs)		
Year	**AA**	**AB**	**AC**	**AD**	**AE**	**AG**	**AH**	**AJ**	**AK**	**AL**
1991	1.63	1.32	2.81	1.17	2.64	1.84	2.22	1.7	8.44	1.19
1992	1.44	2.13	2.57	1.48	2.15	1.89	2.49	2.06	1.91	1.9
1993	1.52	1.88	2.36	1.04	1.26	2.1	1.9	1.46	1.02	1.05
1994	1.47	1.78	1.21	1.23	1.44	1.99	2.12	1.29	0.76	1.84
1995	1.46	1.95	1.43	1.34	1.43	1.47	1.71	1.57	0.6	1.34
1996	1.7	1.74	1.33	1.12	0.89	1.45	1.69	1.47	0.8	1.7
1997	1.25	1.14	1.34	1.2	1.27	0.91	1.72	1.27	0.82	1.19
1998	1.65	1.26	1.04	0.86	1.3	1.09	1.09	1.12	2.28	1.16
1999	1.79	1.35	0.82	0.9	2.39	1.48	0.93	0.98	0.7	1.03
2000	1.27	1.46	1.05	1.04	0.84	1.53	1.04	0.89	1.4	1.02
2001	1.28	1.69	0.7	1.06	2.03	1.12	0.81	0.82	0.73	0.67
2002	0.93	1.03	0.91	0.88	0.85	0.76	0.75	0.75	0.67	0.56
2003	0.8	0.9	0.75	0.92	0.96	0.87	0.76	0.74	0.53	0.98
2004	0.98	1.05	0.69	0.93	1.03	0.56	0.65	0.88	0.64	0.64
2005	0.81	0.61	0.9	0.9	0.52	0.8	0.93	0.9	0.94	0.87
2006	0.68	0.59	0.84	0.84	0.68	0.79	1.05	0.95	0.95	0.92
2007	0.84	0.64	0.67	0.8	0.5	0.8	0.74	0.96	0.8	0.77
2008	0.69	0.61	0.77	0.8	0.63	0.66	0.75	0.83	0.77	0.63
2009	0.45	0.49	0.62	0.91	0.72	0.78	0.38	0.55	0.89	0.68
2010	0.48	0.47	0.48	0.89	0.42	0.33	0.6	0.47	1.12	1.21
2011	0.46	0.45	0.63	0.94	0.51	0.4	0.73	0.87	8.44	0.92
2012	0.55	0.47	0.86	1.05	0.77	0.99	0.31	0.88	1.91	1.19

							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	1.2	1.13	0.95
	1993	0.8	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	1.1
	1996	0.81	1.19	1.21	0.78	1.22	0.8	1	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	1.1	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

							Longfin (South Island ESAs)		
QMS status	**Year**	**AN**	**AP_AQ**	**AR**	**AT**	**AU**	**AV**	**AW**	**AX**
Post QMS	2001	–	–	–	–	–	–	–	–
	2002	–	–	–	–	–	0.91	1	0.8
	2003	–	–	–	–	–	0.84	1.09	0.79
	2004	–	–	–	–	–	0.92	0.85	0.93
	2005	–	–	–	–	–	1.11	1.1	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

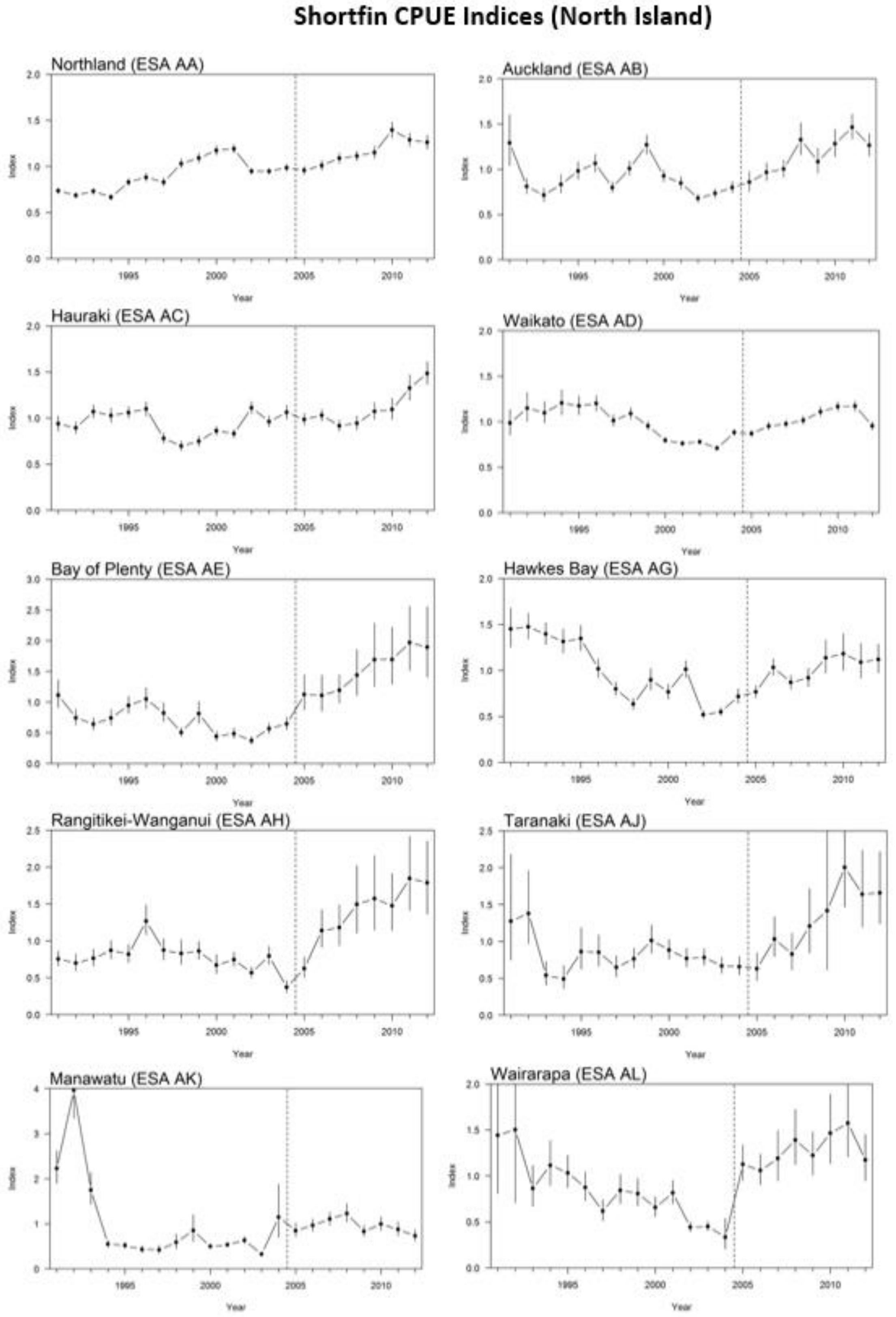


Figure 4: Trends in North Island shortfin CPUE indices for all North Island ESAs from 1990–91 to 2011–12, except Poverty Bay (AE) where there was insufficient data. Vertical dotted line indicates the introduction to the QMS in 2004–05.

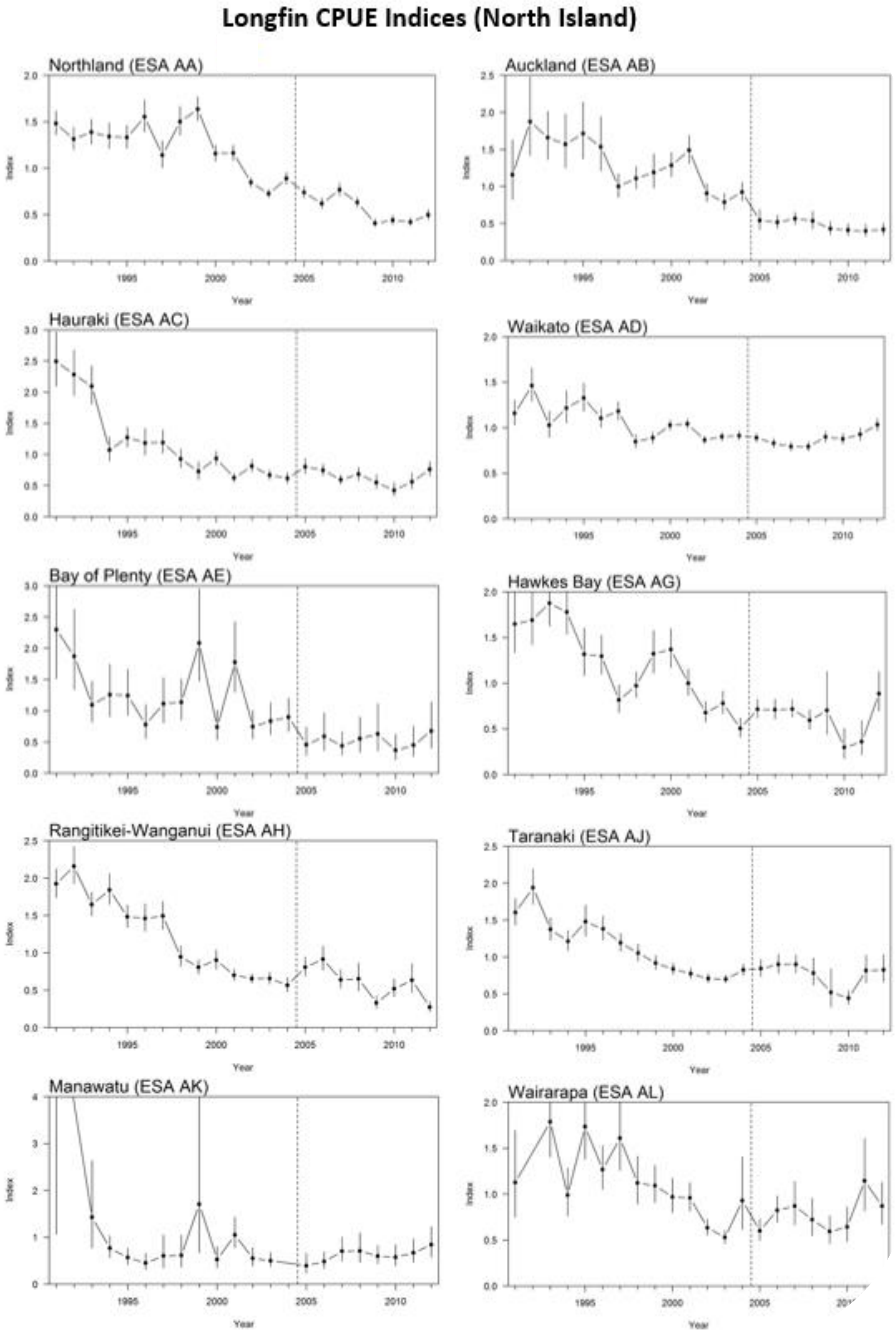


Figure 5: Trends in North Island longfin CPUE indices for all North Island ESAs from 1990–91 to 2011–12, except Poverty Bay (AE) where there was insufficient data. Vertical dotted line indicates the introduction to the QMS in 2004–05. (From Beentjes & Dunn 2013b).

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.

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 12 and 13, 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 12 and 13, 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 (Tables 12 and 13, 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 to 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).

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.

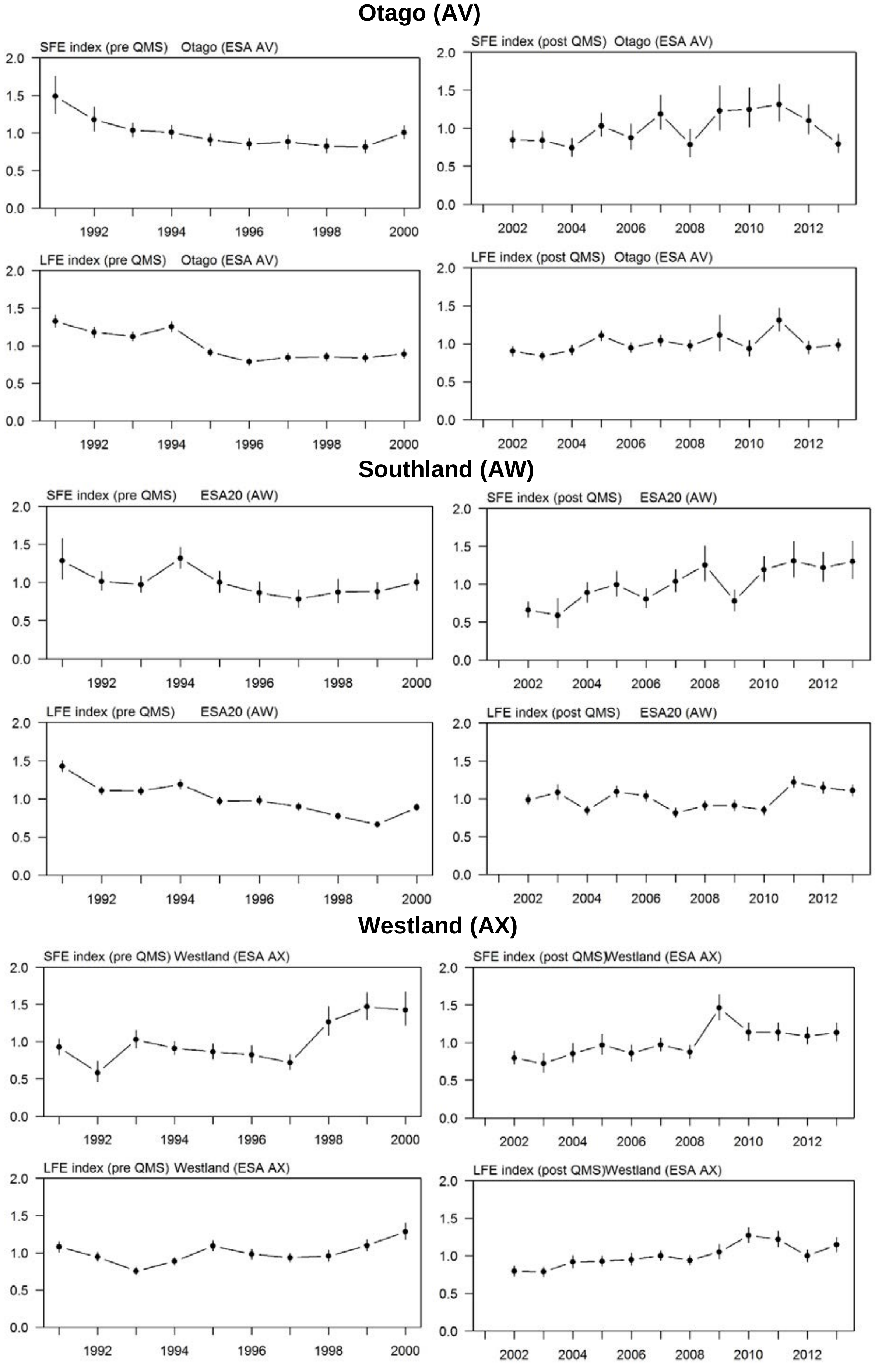


Figure 6: Trends in South Island shortfin and longfin CPUE indices for key ESAs: Otago (AV), Southland (AW), and Westland (AX). Separate indices are presented for pre-QMS (1991–2000) and post-QMS (2002–2013). (From Beentjes & Dunn 2015).

Te Waihora (AS1)

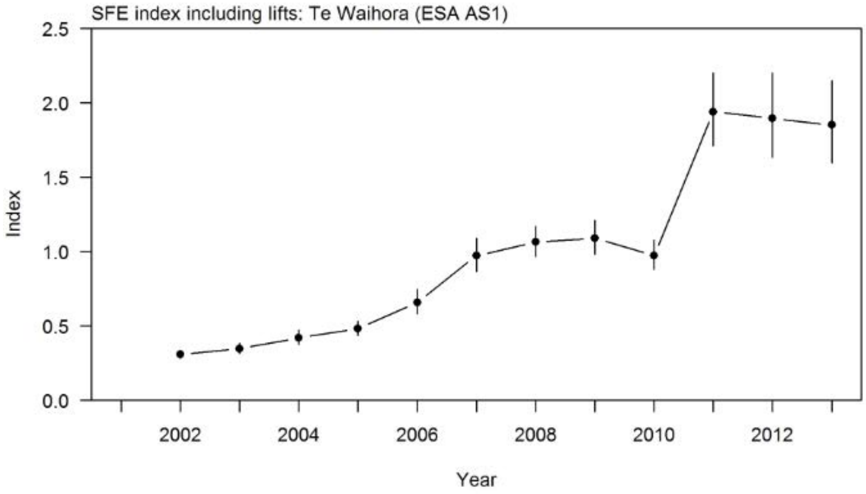


Figure 7: Te Waihora shortfin CPUE indices for AS1 (outside migration area) from 2001–02 to 2012–13. (From Beentjes & Dunn 2015).

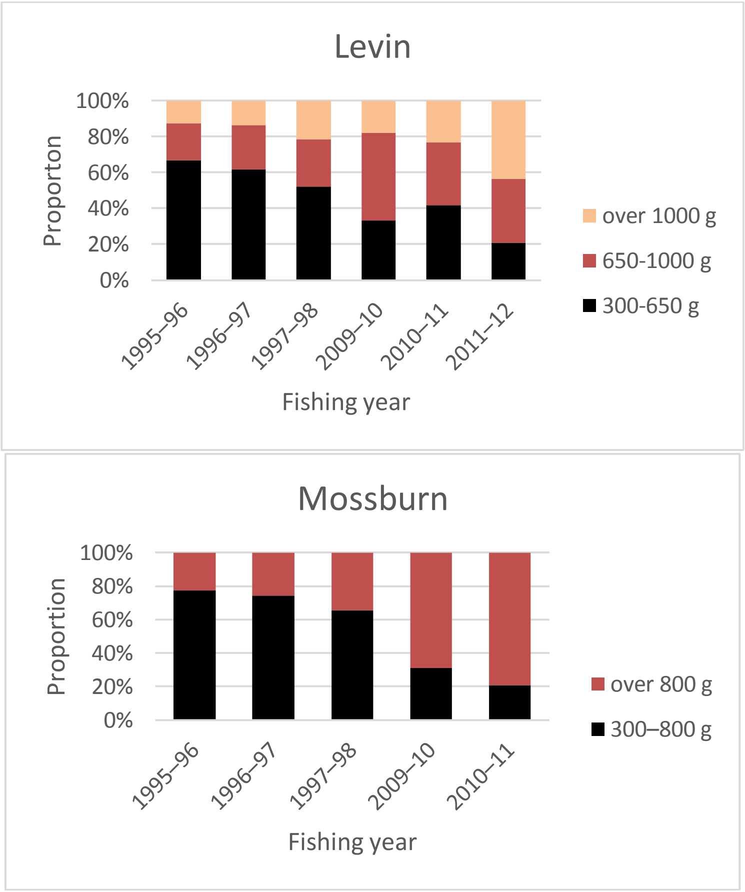


Figure 8: Size grade proportions of shortfin eels harvested from Te Waihora AS1 (lake) from eel processors Levin Eel Trading Ltd in 2009–10 to 2011–12, and Mossburn Enterprises Ltd in 2010–11 and 2011–12. The equivalent size grades have been estimated from the length of eels taken during commercial catch sampling of the commercial catch in 1995–96 to 1997–98 (from Beentjes & Dunn 2014).

4.4 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 stage 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).“The recent recruitment increase of some 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” (Dekker and Casselman 2014).

Based on GIS modelling it has been estimated that for longfin eels, 5% of 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 is 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 is 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 is either in a reserve or in rarely/non-fished areas (Graynoth *et al*. 2008).

Sex ratio

The shortfin fishery is based on the exploitation of immature female eels, as most shortfin male eels migrate before reaching the minimum size of 220 g. The exception being 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 and 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 Manapöuri 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 are 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 NEEDS

- The potential influence of zero catches should be considered in future CPUE analyses for the post-2002 period (when use of the EEU code ceased), and a combined index should be produced. In a number of instances, the proportion of zeros is high, and there is often a negative correlation between the proportion of zeros for longfin and shortfin.
- 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.
- The "core selection" should only be conducted for the catcher and not the permit holder, given that there can be more than one catcher per permit, some of which may not fish for many years.
- 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.

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, and information on spawner escapement allow for cautioned assessments of longfin and shortfin eels using Level 2 Partial Quantitative Stock Assessments.

Stock Structure Assumptions

Longfin and shortfin eels comprise 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 B_{MSY}, will ensure the entire (national) stock of each species is maintained at that level.

Status of North Island Eels

Given the potential negative impact of North Island regulation changes on CPUE as an index of abundance, only South Island longfin and shortfin eels have been assessed using Level 2 Partial Quantitative Stock Assessments. North Island eel populations will be assessed using Level 2 assessments when the standardized CPUE indices are next updated (in 2016). Approximately 30% of available longfin habitat in the North Island is either in reserves or in rarely/non-fished areas.

Status of South Island Eels

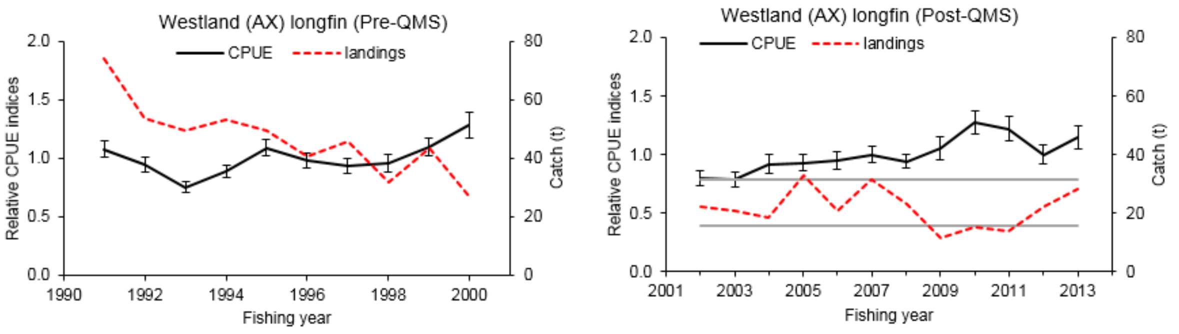
Level 2 Partial Quantitative Stock Assessments are conducted by statistical area and species, and are only possible where accepted indices of abundance are available; i.e. Westland, Otago, Southland and Te Waihora). Standardised CPUE provides information on the abundance of commercially harvested eels (300 g–4000 g) in areas that are fished commercially. Aproximately 34% of currently available longfin habitat on the South Island is either in reserves or in rarely/non-fished areas.

- **Westland (AX) longfin**

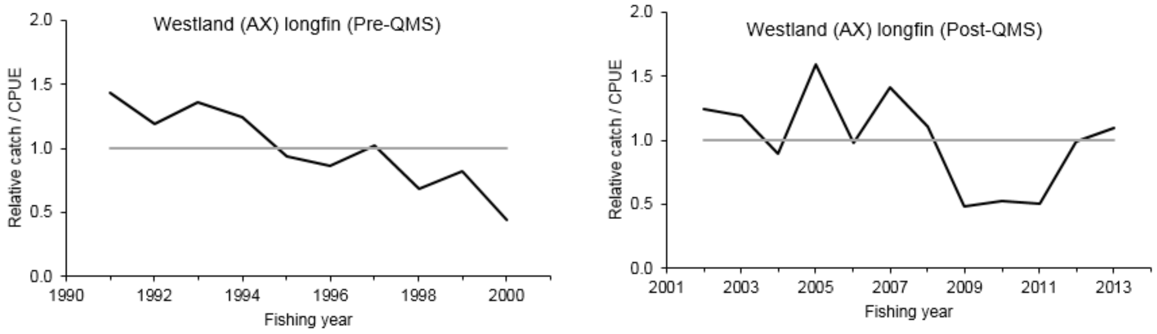
Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Standardised CPUE
Reference Points	Target: B_{MSY} assumed, but not estimated Interim Soft Limit: Mean CPUE from 2001–02 to 2002–03 Hard Limit: 50% of Soft Limit Overfishing threshold: F_{MSY} assumed, but not estimated

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.

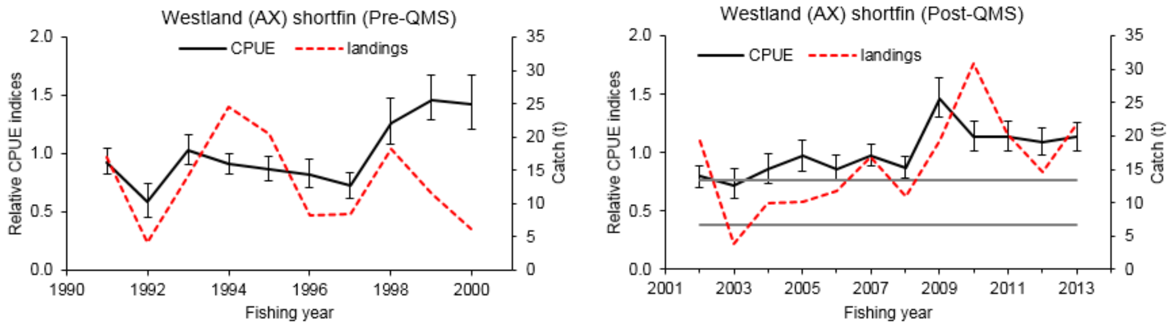
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown if catch remains at current levels Likely (> 60%) if catch were to increase to the level of the TACC	
Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from commercial fyke net	
Assessment Dates	Latest assessment: 2014	Next assessment: 2017
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
By catch 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.

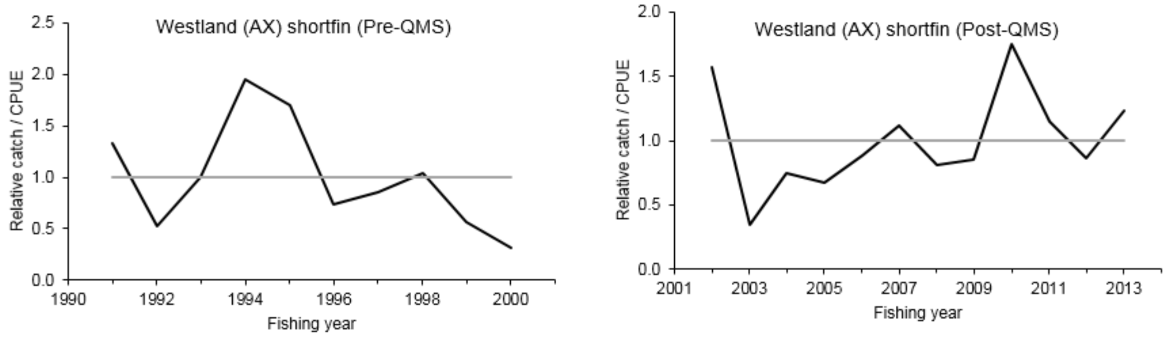
- **Westland (AX) shortfin**

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: 2017
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)	

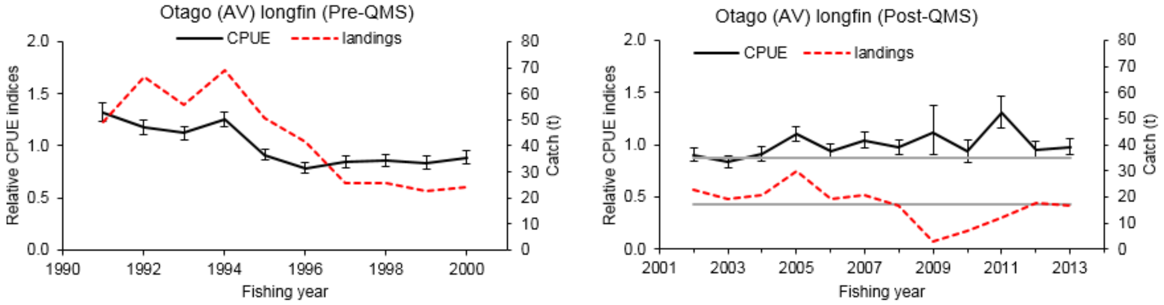
Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other 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
By catch 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.

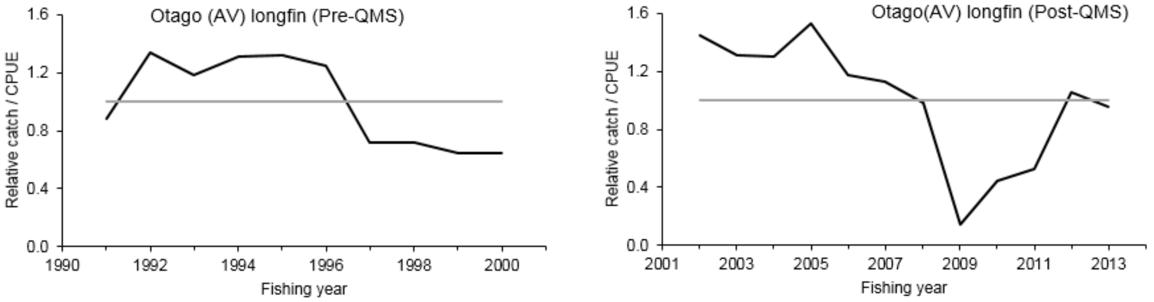
- **Otago (AV) longfin**

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: 2017

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)	

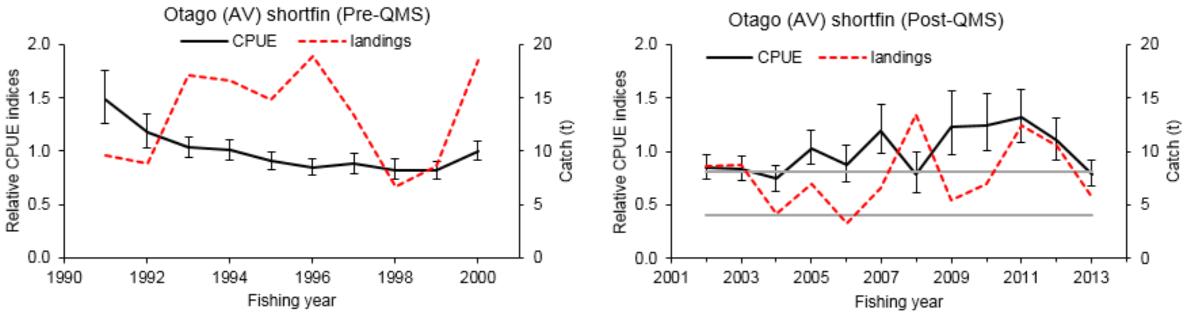
Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other 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
By catch 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.

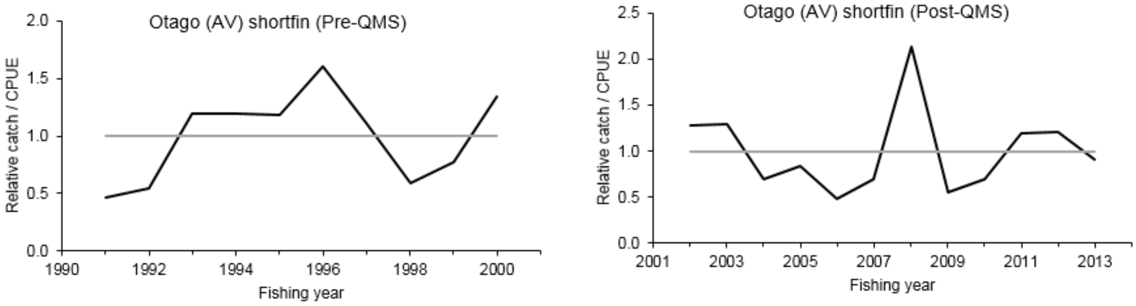
- **Otago (AV) shortfin**

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	Unknown
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 ANG15. 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: 2017
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)	

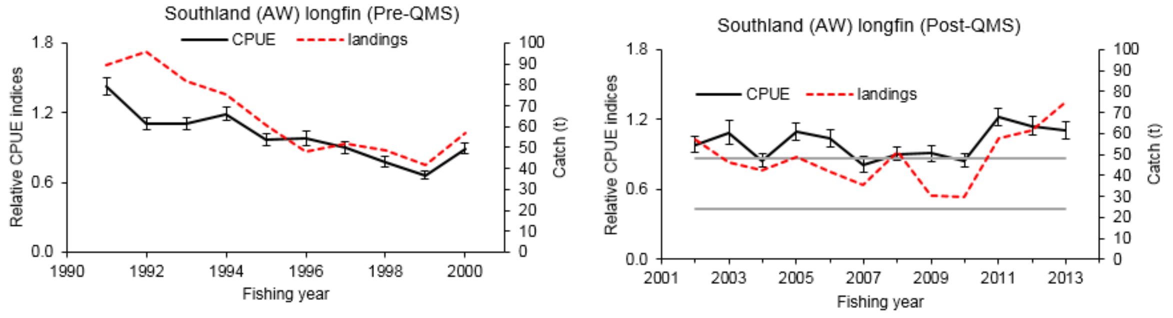
Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other 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
By catch of other species in the commercial eel fishery is low, and may include: brown trout, blackflounder, koura, yellow-eyed mullet, galaxiids, yellowbelly flounder, and bullies in order of amount caught. Bycatch species are usually returned alive.

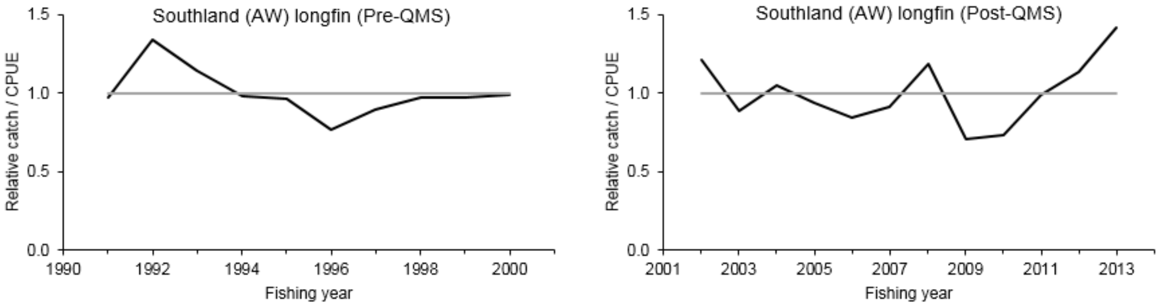
- **Southland (AW) longfin**

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: 2017
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)	

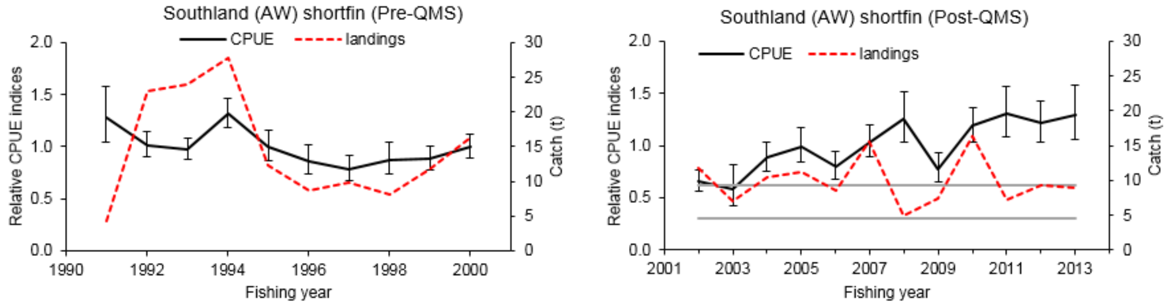
Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other 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
By catch 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.

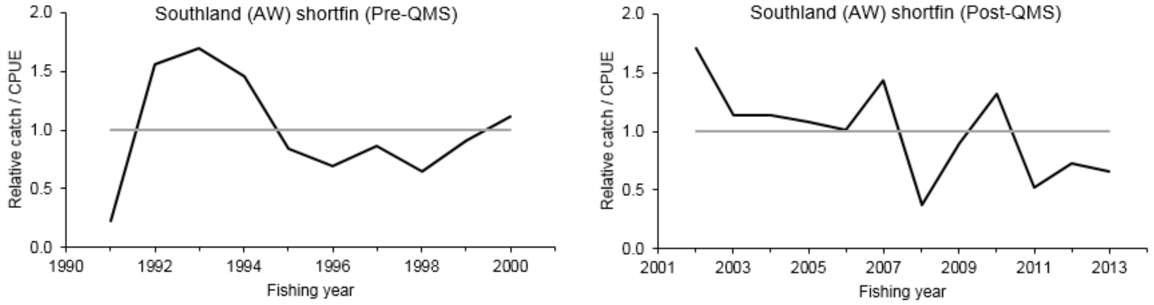
- **Southland (AW) shortfin**

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: 2017
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)	

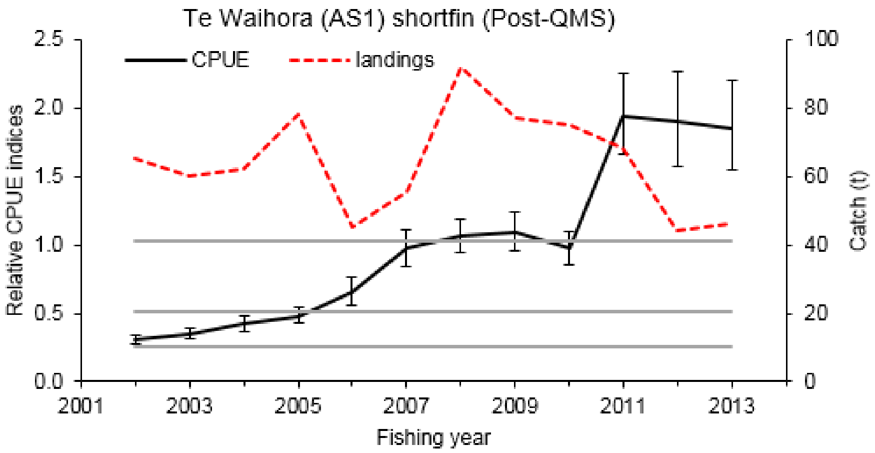
Qualifying Comments
Because the commercial eel fishery has had a long history (beginning in the late 1960s), and indices of abundance are only available from the early 1990s, it is difficult to infer stock status from recent abundance trends, and these should therefore be interpreted with caution. Other 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
By catch 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.

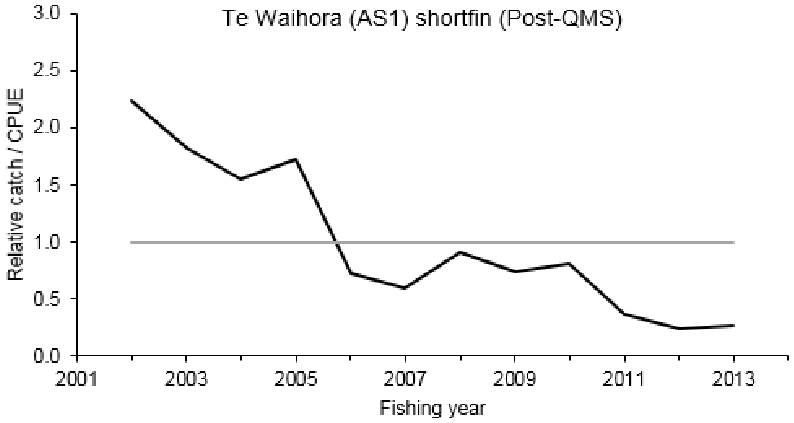
- **Te Waihora (AS1) shortfin**

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: 2017
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 culling (primarily 1930s to 1950s) and 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, blackflounder, 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.

6. FOR FURTHER INFORMATION

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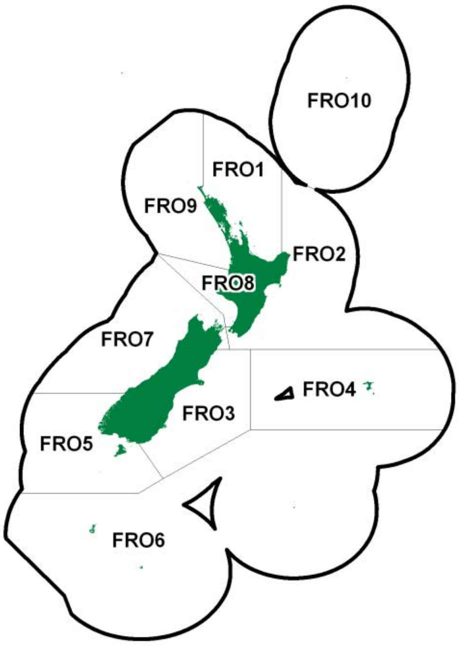
FROSTFISH (FRO)

(*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 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 have been recorded as frostfish by some specific vessels.

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 1 and 2, 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 have been increased to the average of the previous seven years plus an additional 10% (Table 2).

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.

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.

Year	FRO 1	FRO 2	FRO 3	FRO 4	FRO 5	Year	FRO 1	FRO 2	FRO 3	FRO 4	FRO5
1931-32	0	0	0	0	0	1957	0	0	0	0	0
1932-33	0	0	0	0	0	1958	0	0	0	0	0
1933-34	0	0	0	0	0	1959	0	0	0	0	0
1934-35	0	0	0	0	0	1960	0	0	0	0	0
1935-36	0	0	0	0	0	1961	0	0	0	0	0
1936-37	0	0	0	0	0	1962	0	0	0	0	0
1937-38	0	0	0	0	0	1963	0	0	0	0	0
1938-39	0	0	0	0	0	1964	0	0	0	0	0
1939-40	0	0	0	0	0	1965	0	0	0	0	0
1940-41	0	0	0	0	0	1966	0	5	0	0	0
1941-42	0	1	0	0	0	1967	0	0	0	0	0
1942-43	0	0	0	0	0	1968	0	0	0	0	0
1943-44	0	0	0	0	0	1969	0	0	0	0	0
1944	0	0	0	0	0	1970	0	0	0	0	0
1945	0	0	0	0	0	1971	0	0	0	0	0
1946	0	0	0	0	0	1972	0	0	0	0	0
1947	3	0	0	0	0	1973	0	0	0	0	0
1948	0	0	0	0	0	1974	0	0	0	0	0
1949	0	0	0	0	0	1975	0	0	0	0	0
1950	0	0	0	0	0	1976	0	0	0	0	0
1951	0	0	0	0	0	1977	0	0	0	0	0
1952	0	0	0	0	0	1978	1	4	2	0	0
1953	0	0	0	0	0	1979	1	14	4	19	1
1954	0	0	0	0	0	1980	0	0	2	20	7
1955	0	0	0	0	0	1981	0	0	6	25	3
1956	0	0	0	0	0	1982	4	0	0	8	13

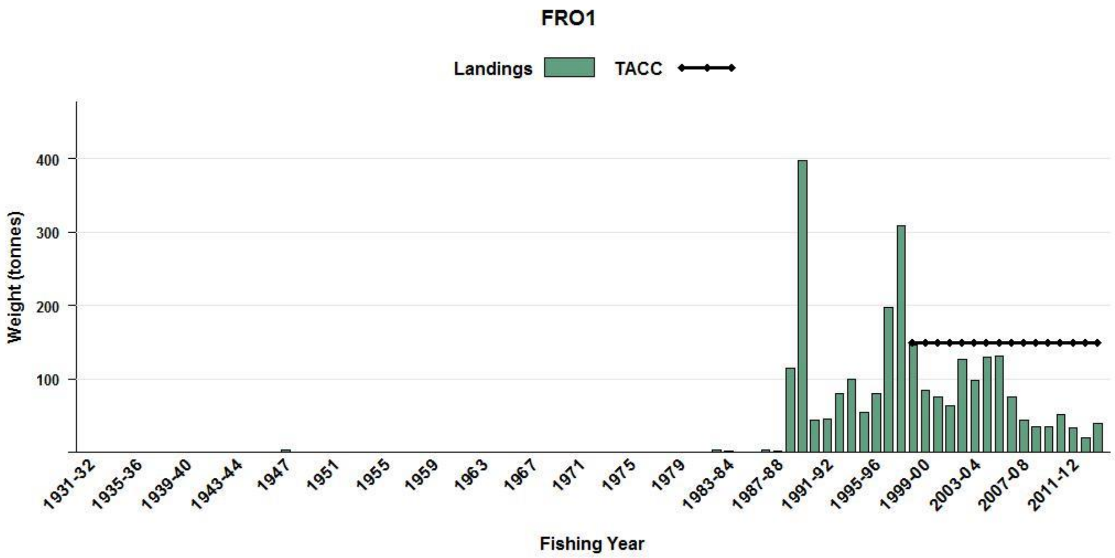
Year	FRO 6	FRO 7	FRO 8	FRO 9	Year	FRO 6	FRO 7	FRO 8	FRO 9
1931-32	0	0	0	0	1957	0	0	0	0
1932-33	0	0	0	0	1958	0	0	0	0
1933-34	0	0	0	0	1959	0	0	0	0
1934-35	0	0	0	0	1960	0	0	0	0
1935-36	0	0	0	0	1961	0	0	0	0
1936-37	0	0	0	0	1962	0	0	0	0
1937-38	0	0	0	0	1963	0	0	0	0
1938-39	0	0	0	0	1964	0	0	0	0
1939-40	0	0	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	1	0
1944	0	0	0	0	1970	0	0	1	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	1	1973	0	0	0	0
1948	0	0	0	0	1974	0	0	0	0
1949	0	0	0	0	1975	0	0	0	0
1950	0	0	0	0	1976	0	0	0	0
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

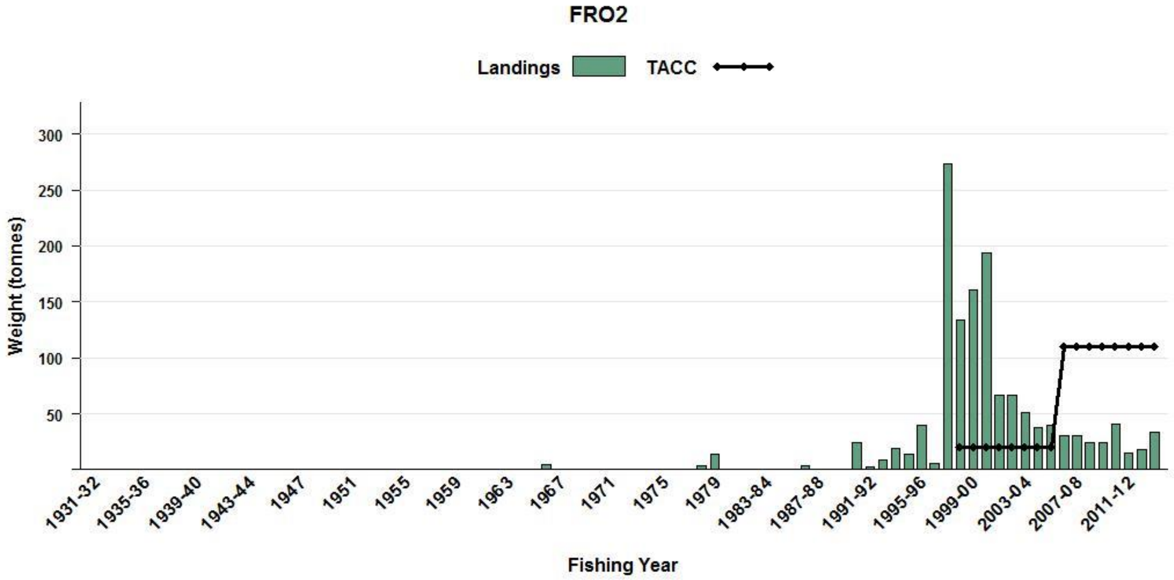
Notes:
The 1931–1943 years are April–March but from 1944 onwards are calendar years, Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports, Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a 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 2013–14. The data in this table has been updated from that published in previous Plenary Reports 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

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	2 989	3 858
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





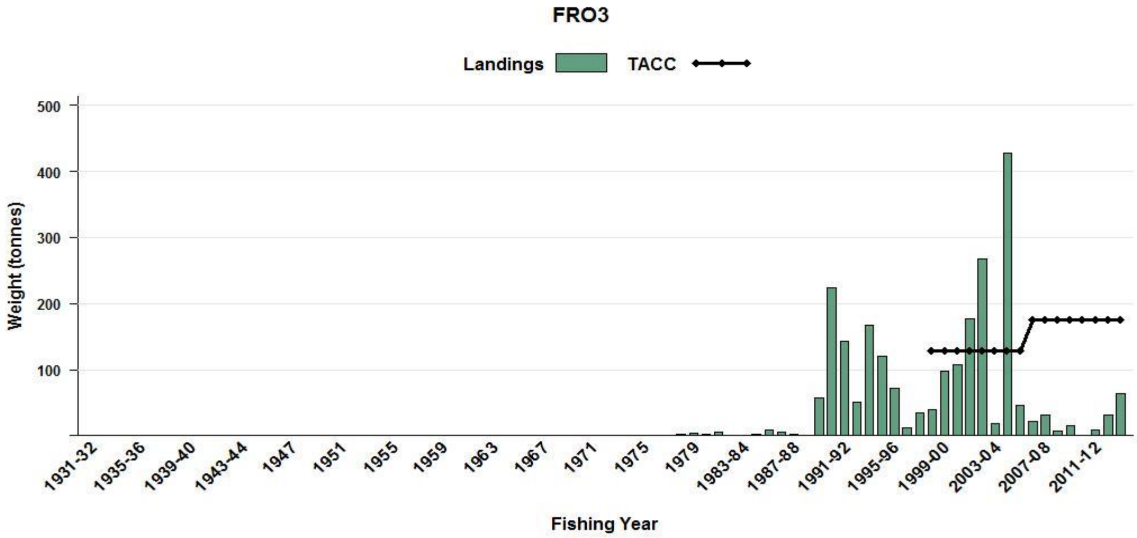


Figure 1: Reported commercial landings and TACC for the eight main FRO stocks. From top: FRO 1 (Auckland East), FRO 2 (Central East), FRO 3 (South East Coast), [Continued on next page].

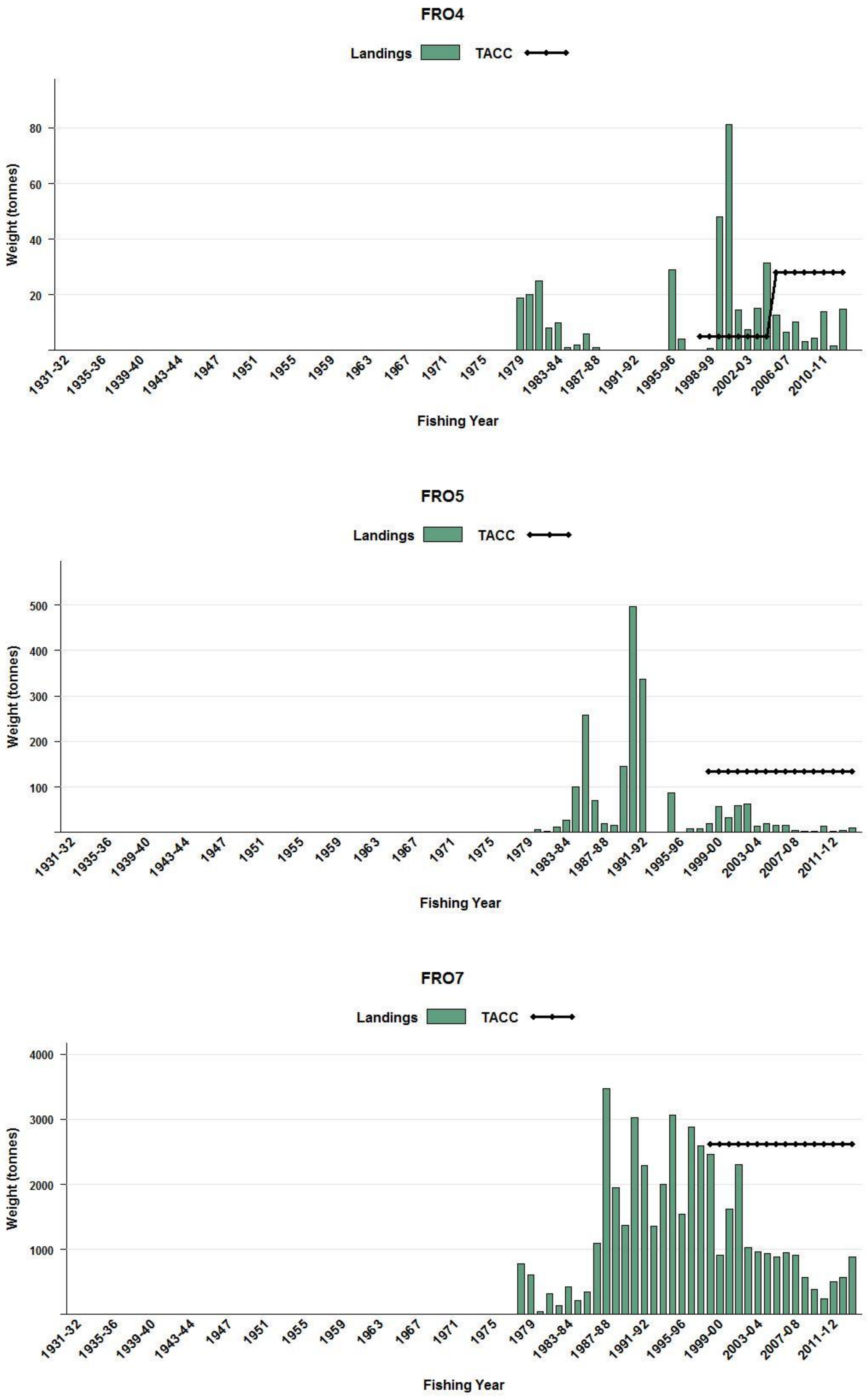
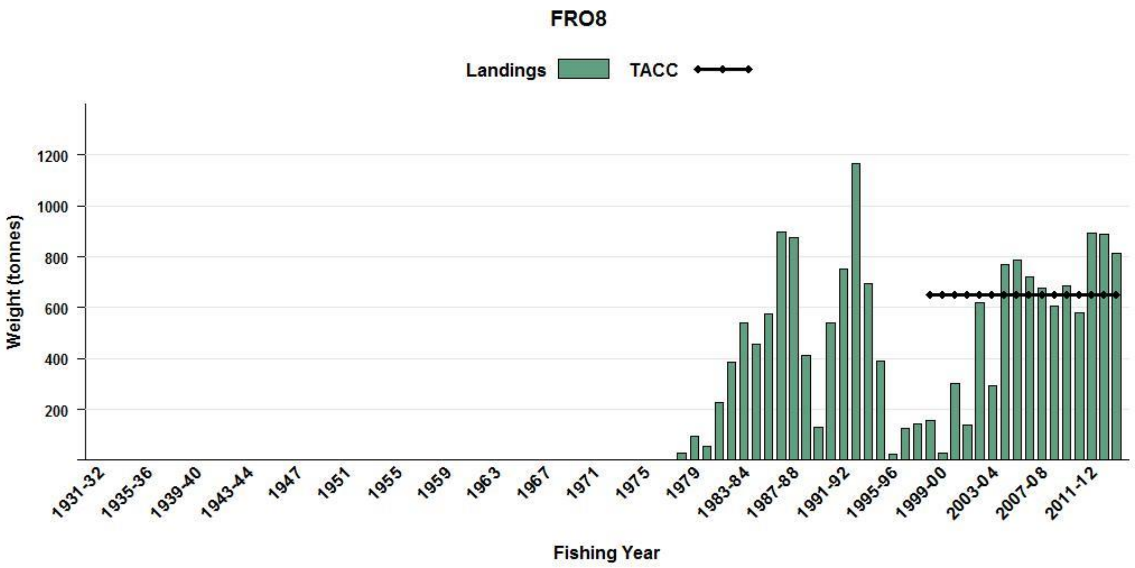


Figure 1: Reported commercial landings and TACC for the eight main FRO stocks. From top: FRO 4 (South East Chatham Rise), FRO 5 (Southland), and FRO 7 (Challenger). [Continued on next page].



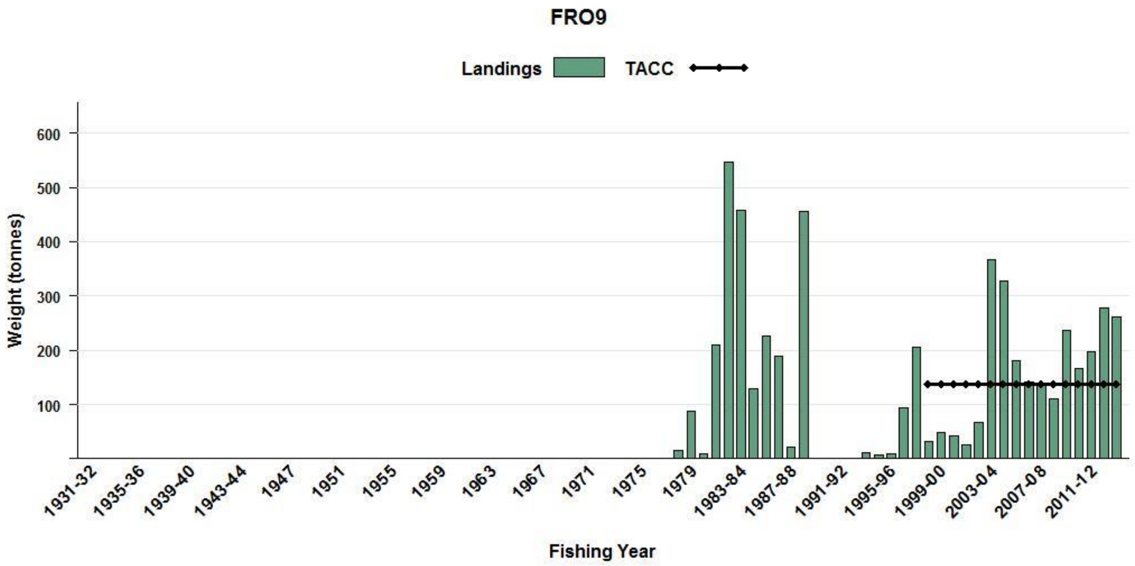


Figure 1 [Continued]: Reported commercial landings and TACC for the eight main FRO stocks. From top: FRO 8 (Central West), and FRO 9 (Auckland West). Note that these figures do not show data prior to entry into the QMS.

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 34°S to 49°S, but are most common between 36°S and 44°S. 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 16°C.
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 22.0°C (Robertson 1980).

No length-weight relationships or information on age or growth rates are available for New Zealand frostfish. However, these data are available for *Lepidopus caudatus* from the northwestern Mediterranean (Demestre et al 1993). These fish exhibit fast growth and attain a maximum age of 8 years. Von Bertalanffy growth parameters for the Mediterranean fish are given by Schofield et al (1998). Assuming that 8 years is the age reached by 1% of the virgin population gives an estimate of 0.58 for M. However, Mediterranean sampling was carried out on an already exploited stock and fish were aged using whole otoliths which may have resulted in underestimates of age for larger fish.

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).

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 4). 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 4: 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
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	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 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 2013–14 fishing year are summarised in Table 5.

Table 5: Summary of TACCs (t), and reported landings (t) of frostfish for the most recent fishing year.

Fishstock		FMA	2013–14 Actual TACC	2013–14 Reported landings
FRO 1	Auckland (East)	1	149	40
FRO 2	Central (East)	2	110	34
FRO 3	South-east (Coast)	3	176	63
FRO 4	South-east (Chatham)	4	28	15
FRO 5	Southland	5	135	11
FRO 6	Sub-Antarctic	6	11	< 1
FRO 7	Challenger	7	2 623	880
FRO 8	Central (West)	8	649	814
FRO 9	Auckland (West)	9	138	262
FRO 10	Kermadec	10	0	0
Total			4 019	2 220

6. FOR FURTHER INFORMATION

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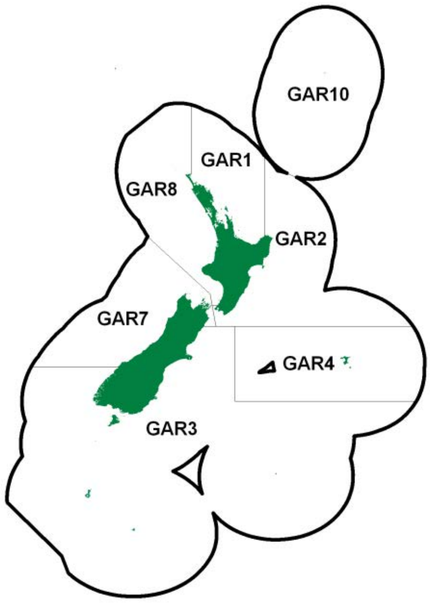
GARFISH (GAR)

(*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 have been of a similar order of magnitude although catches have declined since the 2000–01 fishing season (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. Total reported catches have been below 15 t for the last nine years.

Table 3: Reported catches or landings (t) of garfish by Fishstock from 1990–91 to 2013–14*. 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

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
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

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
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

* 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

There is a small and specific recreational fishery using beach seines, but no information on the size of catch.

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	2013–14 Actual TACC	2013–14 Reported Landings
GAR 1	Auckland (East)	1	–	25	15
GAR 2	Central (East)	2	–	5	0
GAR 3	South East (Coast), Southland, Sub-Antarctic	3, 5, 6	–	5	0
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	15

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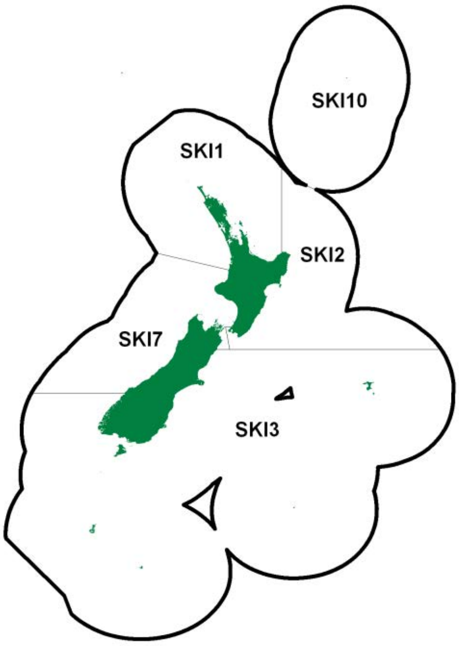
GEMFISH (SKI)

(*Rexea solandri*)
Maka-tikati



1. FISHERY SUMMARY

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 1 and 2, while 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 1). In the late 1980s, annual catches generally ranged from about 4200 to 4800 t per annum, but since then have steadily declined, with landings of less than 1000 t reported in six of the last eight years (Table 2). TACCs were reduced in SKI 3 and SKI 7 for the 1996–97 fishing year and have been progressively reduced in SKI 1 and SKI 2 since 1997–98. TACs and TACCs are 218 t and 210 t for SKI 1, and 248 t and 240 t for SKI 2, respectively. Both SKI 1 and SKI 2 were allocated customary and recreational allowances of 3 t and 5 t respectively.

Table 1: Reported gemfish catch (t) from 1978–79 to 1987–88. Source - MAF and FSU data.

Fishing year	New Zealand		Foreign Licensed			
Year	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 2 due to under-reporting to the FSU.
N/A Unknown.

Table 2: 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 3: Reported landings (t) of gemfish by Fishstock from 1983–84 to 2013–14 and actual TACs from 1986–87.

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	TAC	Landings	TAC	Landings	TAC	Landings	TAC	TAC	Landings	TAC
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
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
2011–12	212	210	155	240	11	300	260	300	†10	638	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

FSU data.

§ The totals do not match those in Table 1 as some fish were not reported by area (FSU data prior to 1986–87).

† No recorded landings

Table 4: Catch history for gemfish stocks, divided into pre-spawning and spawning seasons (t). N/A - not available.

Year	SKI 1 (spawn)			SKI 2	Total
	SKI 1E	SKI 1W	Total	(pre-spawn)	SKI 1 & 2
1952	5	0	5	50	55
1953	5	0	5	25	30
1954	5	0	5	60	65
1955	5	0	5	35	40
1956	5	0	5	35	40
1957	5	0	5	55	60
1958	5	0	5	30	35
1959	5	0	5	45	50
1960	5	0	5	85	90
1961	5	0	5	70	75
1962	5	0	5	60	65
1963	15	0	15	70	85
1964	15	0	15	65	80
1965	20	0	20	130	150
1966	15	0	15	140	155
1967	35	0	35	240	275
1968	40	0	40	250	290
1969	100	0	100	375	475
1970	95	0	95	400	495
1971	100	0	100	420	520
1972	130	0	130	400	530
1973	45	0	45	300	345
1974	35	0	35	230	265
1975	10	0	10	170	180
1976	30	0	30	190	220
1978	90	0	90	240	330
1979	120	0	120	200	320
1980	140	0	140	450	590
1981	120	0	120	500	620
1982	100	0	100	320	420
1983	360	0	360	730	1 090
1984	588	0	588	632	1 220
1985	388	0	388	381	769
1986	716	0	716	381	1 097
1987	773	0	773	896	1 669
1988	696	0	696	1 095	1 791
1989	1 023	0	1 023	1 011	2 034
1990	1 230	0	1 230	1 043	2 273
1991	1 048	10	1 058	949	2 007
1992	940	77	1 017	1 208	2 225
1993	1 137	155	1 292	1 020	2 312
1994	606	550	1 156	1 058	2 214
1995	438	594	1 032	906	1 938
1996	485	316	801	789	1 590
1997	385	580	965	978	1 943
1998	N/A	N/A	627	671	1 298
1999	N/A	N/A	413	335	748
2000	N/A	N/A	409	506	915
2001	N/A	N/A	335	330	665
2002	N/A	N/A	201	268	487
2003	N/A	N/A	206	313	519
2004	N/A	N/A	221	301	522
2005	N/A	N/A	234	259	493
2006	N/A	N/A	230	182	412
2007	N/A	N/A	215	317	532
2008	N/A	N/A	216	249	465
2009	N/A	N/A	191	191	382
2010	N/A	N/A	247	176	424
2011	N/A	N/A	226	300	525
2012	N/A	N/A	212	155	367
2013	N/A	N/A	182	140	322

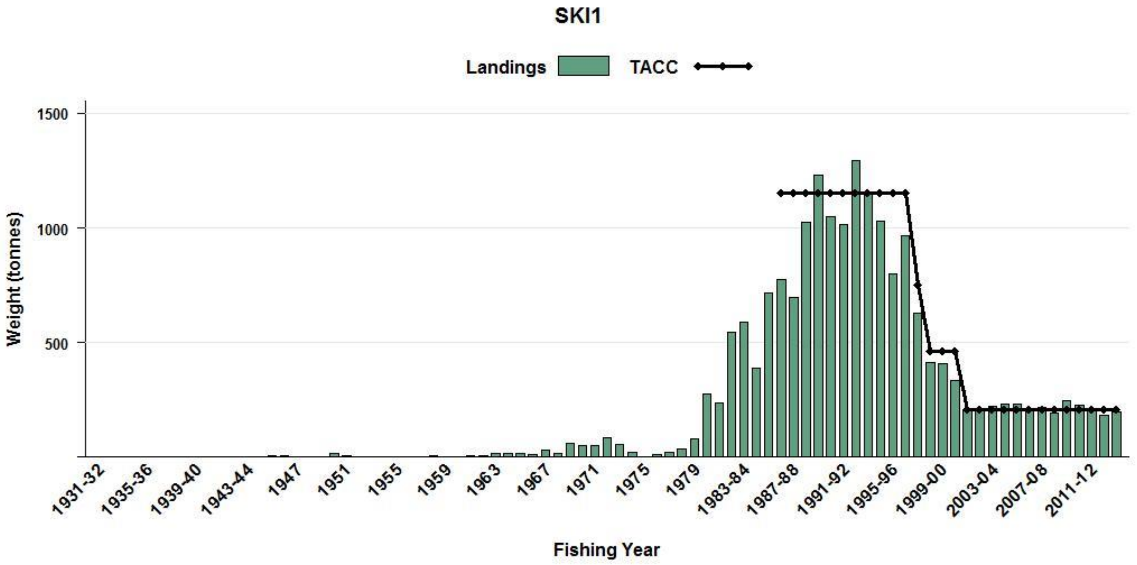


Figure 1: Reported commercial landings and TACC for the four main SKI stocks. SKI 1 (Auckland East). [Continued on next page].

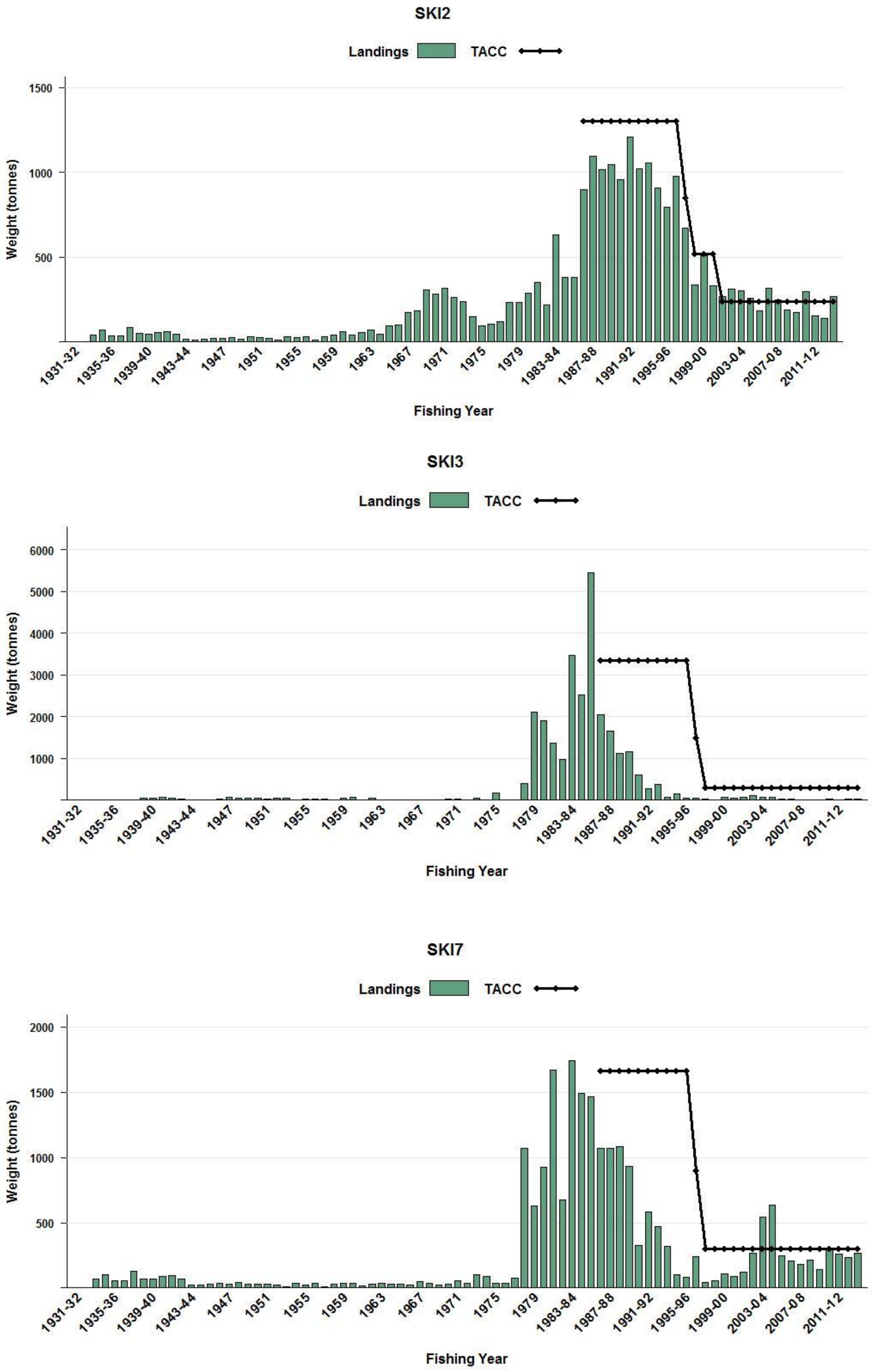


Figure 1: Reported commercial landings and TACC for the four main SKI stocks. From top to bottom right: SKI 1 (Auckland East), SKI 2 (Central East), SKI 3 (South East Coast) and SKI 7 (Challenger).

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 (Table 4), 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 last reduced. The west coast fishery has since virtually disappeared, as has the fishery off East Northland, each accounting for less than 10% of the SKI 1 catch since 2001–02. . The Bay of Plenty fishery has correspondingly increased, accounting for over 80% of the SKI 1 landings in the same period. While landings in SKI 1 are almost entirely concentrated in the months of May and June, landings in SKI 2 are spread fairly evenly from October to May. SKI 2 landings occur as a bycatch in a range of trawl fisheries, including tarakihi, barracouta, scampi and hoki, although over 80% of the SKI 2 landings are targeted at gemfish. Catches off the west and southern coasts of the South Island are primarily bycatch of hoki and squid target fisheries. Reported landings in SKI 7 increased from 2000, with 2005 being more than double the level of the TACC in 2004–05, but decreased to 144 t in the 2009–10 fishing year. Landings then increased to the TACC in 2010–11, followed by a slight drop in the 2011–12 fishing year. Landings in SKI 3 have remained at very low levels. Figure 1 shows the historical landings and TACC values for the main SKI stocks.

1.2 Recreational fisheries

There was no recreational catch reported in marine recreational fishing catch and effort surveys of the MAF Fisheries South and Central regions (1991–92 and 1992–93, respectively). However, there is known to be a target recreational fishery in the Bay of Plenty. The recently completed national panel survey of New Zealand recreational fishing gave an estimated total NZ harvest of just under 3000 fish (MPI unpublished data).

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 on the west coast of the South Island.

Ageing of southern gemfish indicate 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) and 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 has been correlated to wind and sea surface temperature patterns during the spawning season (Renwick et al 1998). 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 the stock assessment are shown in Table 5.

Table 5: Estimates of biological parameters for gemfish.

Fishstock						Estimate	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 (QMA 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 (QMA 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, 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 is 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 either 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 assessment for the SKI 1 and SKI 2 stock was updated in 2007 with new standardised CPUE indices and addition of catch-at-age data up to 2005–06. Further analysis was carried out in 2008 incorporating SKI 2 catch-at-age for 2006–07. A number of changes were made to the 2003 model including the use of age-based selectivities and differential natural mortality.

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, as results from previous assessments were similar to those from SKI 1 and SKI 2 combined. Estimates of virgin biomass (B_0) and current mature biomass are presented below.

The stock assessment model includes two fishery types, based on spawning activity. The first is on the home ground, SKI 2, where all age classes occur and where fishing is mainly in the non-spawning season. The second is on the spawning migrations, SKI 1, where only mature age classes occur and where fishing is in the winter months. The non-spawning (SKI 2) and spawning (SKI 1) season landings used in the assessment are given in Table 4. This table also shows the split between east and west coast catches in SKI 1 from 1991 to 1997. 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 used catch-per-unit-effort time series, catch-at-age from the commercial fishery, and estimates of biological parameters.

New information from the previous assessment included a revised catch history, new CPUE abundance indices, four years of catch sampling proportions-at-age data for SKI 2, and one year of catch sampling proportions-at-age data for SKI 1.

The assessment of the southern stock (SKI 3 & 7) was not updated, as there were no new indices of biomass or proportion at age available. The results of the 1997 assessment are summarised below.

4.1 Auckland (SKI 1) and Central East (SKI 2)

4.1.1 Age composition of commercial catches

Commercial catch-at-age data included in the models were: SKI 1E for 1989 to 1994, 1997 to 1999, 2002, and 2006; SKI 1W for 1996 to 1999, and 2002; and SKI 2 for 1996 to 2005, and 2007. Age data for SKI 1E and SKI 1W were combined for the stock assessment model.

4.1.2 Estimates of abundance

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 (Figures 2 and 3). The indices for TCEPR all gemfish catch (SKI 1 for 1990 to 2006, SKI 2 for 1994 to 2006) were used in the assessment (Table 6). The indices for SKI 1 are from SKI 1E and SKI 1W combined and for SKI 2 include both midwater and bottom trawl methods. Both time series show steep declines to the early 2000s, followed by marked increases in recent years.

In 2007, the WG considered year*area interactions in the CPUE model. This model was used to overcome the difference in timing of catch rate declines in different statistical areas of SKI 1. The catch rate in each statistical area had a different scale but a similar trend. Weighting of data would require relative population sizes (by area) to do correctly.

The WG thought at the time (2007) that the CPUE series should stop in 2001 when the quota was last reduced. Since then the indices are unlikely to be proportional to abundance in the stock given the changes observed in the fishery. The distribution of fishing in SKI 1 has shrunk to a small area in the Bay of Plenty and no fishing occurred on the WCNI in the last three years. In SKI 2 many vessels have left the area or have stopped targeting gemfish, therefore the CPUE series from 1994 to 2001 only should be used. The WG agreed in 2007 to use the CPUE indices from each fishery in the stock assessment based on TCEPR data including all SKI catch (Table 5).

Table 6: Standardised catch per unit effort indices and coefficient of variation (CV) for SKI 1 and SKI 2. The SKI 2 model is the combined mixed target species model (including SKI), based on daily effort data.

	SKI 1		SKI 2	
Year	Index	CV	Index	CV
1990	1.94	0.10	6.28	0.061
1991	1.71	0.12	3.18	0.056
1992	1.36	0.10	1.52	0.053
1993	1.48	0.07	1.65	0.052
1994	1.73	0.06	1.24	0.051
1995	1.65	0.07	1.25	0.053
1996	1.05	0.06	0.76	0.063
1997	1.20	0.06	0.51	0.067
1998	0.86	0.06	0.38	0.068
1999	0.68	0.07	0.55	0.071
2000	0.66	0.07	0.53	0.074
2001	0.56	0.08	0.54	0.070
2002	–	–	0.66	0.070
2003	–	–	0.84	0.062
2004	–	–	1.18	0.060
2005	–	–	0.62	0.065
2006	–	–	0.52	0.061
2007	–	–	0.98	0.057
2008	–	–	1.05	0.063
2009	–	–	0.86	0.060
2010	–	–	0.83	0.056
2011	–	–	1.74	0.052
2012	–	–	1.74	0.053
2013	–	–	1.15	0.060

4.1.3 2014 SKI 2 CPUE update

The SKI 2 CPUE series was updated in 2014 with data up to the end of 2012–13. The SKI 1 series was not updated because of the cessation of fishing in East Northland and SKI 1W. The SKI 2 CPUE series differed from the previous series 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. Sensitivity analyses included excluding target SKI records and repeating both analyses using only the event-level forms in their original tow-by-tow stratification. These data were used to prepare lognormal models based on positive catch records and binomial models based on the presence/absence of gemfish, which were subsequently combined into a single model using the delta-lognormal method. Gemfish landings from the scampi target fishery were analysed separately as another sensitivity, recognising that this fishery is quite different from the finfish fisheries used in the other analyses, using slower towing speeds and a very different type of net. These data were also analysed using two different data preparation methods: daily amalgamated data or original event-level (tow-by-tow) stratification.

These analyses appear to be extremely robust, with only small differences in the models that excluded or included SKI as a target category (Figure 3). There was also good correspondence with the 2007 CPUE series (even with the SKI 1 series), except at the beginning and the end of the series (Figure 4). The scampi target models were much more variable, given the much smaller data sets being used, but there was broad general agreement in the CPUE indices calculated from all three data sets.

The two daily amalgamated series show a precipitous drop in the first two years of data, followed by a long slow decline up to the end of the 1990s, when the fishery was severely curtailed (Table 3). Since then, there appears to have been gradual increase in relative CPUE, with current levels 3 to 4 times greater than the lowest value observed in 1998 (Table 6). The two tow-by-tow series show the same pattern as the daily effort series over the period of overlap, without the initial steep decline because there are insufficient tow-by-tow data in the years before 1994 (Figure 3).

4.1.3 Assessment model

The assessment model partitions 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 are four time steps in the model (Table 7). In the first time step, the 1 year-olds are recruited 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.

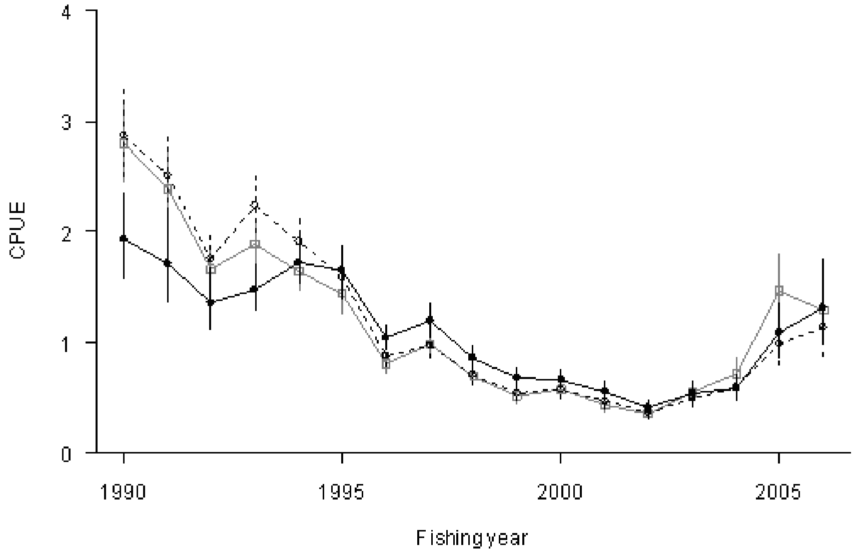


Figure 2: Standardised CPUE indices for the three fishery subgroups in SKI 1: "target catch", black solid; "all catch", black dotted; "TCEPR all catch", gray solid. Vertical bars represent 95% confidence interval.

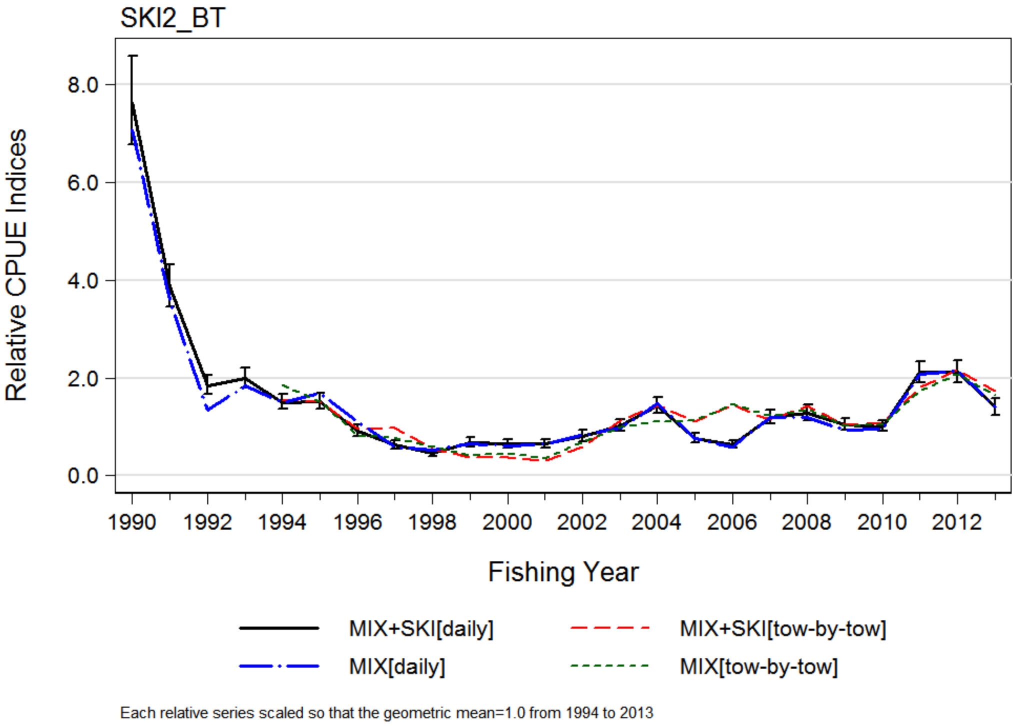
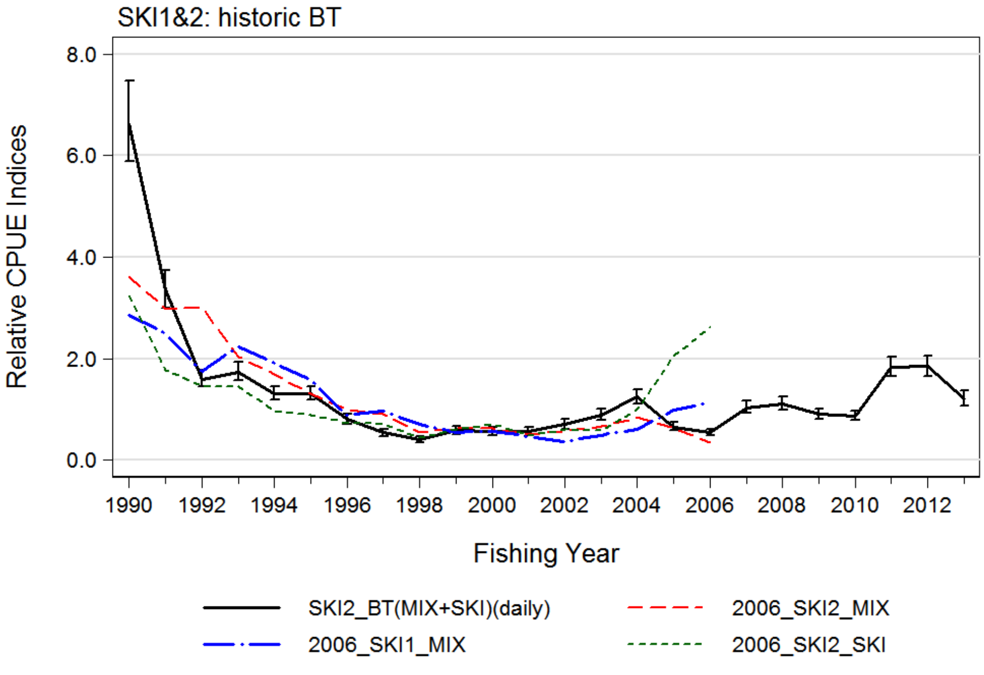


Figure 3: Comparison of the four main combined 2014 SKI 2 CPUE series: a) mixed target species model (including SKI) (daily effort data); b) mixed target species model (without SKI) (daily effort data); b) mixed target species model (including SKI) (tow-by-tow data); b) mixed target species model (without SKI) (tow-by-tow data).



Each relative series scaled so that the geometric mean=1.0 from 1990 to 2006

Figure 4: Comparison of the 2014 combined SKI 2 mixed target species model (including SKI) (daily effort data) with three of the 2006 SKI 1&2 CPUE models: SKI 1 mixed target species, SKI 2 mixed target species, SKI 2 target SKI.

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*	Description	%*M*
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.

The model used separate male and female age-based maturation ogives for SKI 1 and fishing ogives for SKI 2. The SKI 2 fishery was truncated into an early (before 2001) and a late period (after 2002), and separate fishing ogives were used. The SKI 1 fishing ogives were assumed known and were fixed at 1 for all ages.

The age-based fishing ogives for SKI 2 were assumed to be logistic, with male estimated relative to female. The model used logistic migration ogives, one for each sex to determine the rates that fish will mature.

The natural mortality was parameterised by the average of male and female, with the difference estimated within the model. A constant average natural mortality of 0.25 y^{-1} was used. The differential natural mortality, in conjunction with sex-specific fishing ogives were used to account for the between sex difference in proportions at age.

Maximum exploitation rates for gemfish were assumed to be 0.5 for SKI 2 and 0.7 for SKI 1. The choice of the maximum exploitation rate has the effect of determining the minimum possible virgin biomass allowed by the model. This value was set relatively high as there was little external information from which to determine this value.

Lognormal errors, with known CVs, were assumed for all relative biomass and proportions-at-age observations. The CVs available for the relative abundance and catch-at-age observations allow for sampling error only. However additional variance, assumed to arise from differences between model simplifications and real world variation, was added to the sampling variance. The additional variance, termed process error, was estimated in early runs of the model using all available data from MPD fits. Hence, the overall CV assumed in the initial model runs for each observation was calculated by adding process error and observation error. The process error added was a CV of 0.14 and 0.20 for the SKI 1 and SKI 2 CPUE series respectively, and 0.48, 0.40, and 0.14 for the SKI 1, SKI 2 early period, and SKI 2 late period proportions-at-age data (run $2006_{YCS2000}$, see Table 9).

Year class strengths were assumed known (and equal to one) for years prior to 1978 and after 2000 (run $2006_{YCS2000}$, see Table 9) when inadequate or no age data were available. Otherwise year class strengths were estimated under the assumption that the estimates from the model should average one.

The assumed prior distributions used in the assessment are given in Table 8. All priors were intended to be relatively uninformed, and were estimated with wide bounds.

Table 8: The assumed priors assumed for key distributions (when estimated). The parameters are mean (in natural space) and CV for lognormal.

Parameter description	Distribution	Parameters		Bounds	
		Mean	CV	Lower	Upper
B_0	uniform-log	-	-	2 500	250 000
SKI 1 CPUE *q*	uniform-log	-	-	$1\text{x}10^{-7}$	0.01
SKI 2 CPUE *q*	uniform-log	-	-	$1\text{x}10^{-7}$	0.01
YCS	lognormal	1	0.9	0.01	10.0
Selectivity	uniform	-	-	0.1	80.0
Maturation	uniform	-	-	1.3	10.0
Difference in *M*	uniform	-	-	0	0.5
Process error CV.	uniform	-	-	$1e^{-3}$	2.0

Penalty functions were used to constrain the model so that any combination of parameters that did not allow the historical catch to be taken was strongly penalised.

MCMC chains were estimated using a burn-in length of 10^6 iterations, with every 10 000th sample taken from the next 10^7 iterations (i.e., a final sample of length 1000 was taken from the Bayesian posterior). Autocorrelations, and single chain convergence tests of Geweke (1992) and Heidelberger & Welch (1983) were applied to resulting chains to determine evidence of non-convergence (Smith 2001).

4.1.4 Results

Estimates of biomass were obtained using the biological parameters and model input described earlier. Three model runs were considered, as there were concerns that the recent SKI 2 catch-at-age samples could be biased due to possible 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 9 describes the three model runs.

Table 9: 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 yr^{-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 5. MCMC estimates of the posterior median and 95% percentile credible intervals for current and virgin biomass are reported in Table 10, and for year class strengths are shown in Figure 6.

No evidence of lack of convergence from the MCMC chains was found in the estimates of B_0, although some estimates of selectivity parameters showed evidence of lack of convergence.

The between-sex difference in natural mortality was estimated to have a median of 0.02, with a 95% credible interval between 0.01 and 0.03. The median natural mortality was estimated to be about 0.26 for males and 0.24 for female.

The spawning maturation ogives appeared to be poorly estimated; both male and female ogives had broad posterior density estimates. It appears that males were 50% mature at age 6, and females at 7–8 years.

The selectivity ogives for males and females taken by the SKI 2 commercial trawl fishery for the early period were very steep and the 3–4 year-olds had broad posterior density estimates, suggesting considerable uncertainty. The selectivity ogives for the recent period was also steep but had narrow bounds. There were marked differences in the ogives: about 80% and 65% of males were estimated to be fully selected relative to females for the early and recent fishery respectively. There is no information outside the model that allows the shape of the estimated ogives to be verified

Year class strengths were poorly estimated before 1990 when the only data available to determine year class strength were from older fish (see Figure 5). 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 $2006_{YCS2001}$, the 2001 year class strength was estimated to be weak. For run $2007_{YCS2003}$, 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. Since 1992, the stock declined to its lowest level due to increasing exploitation rates combined with a long period of low recruitment since the early 1990s (see Figure 4). 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 10).

Table 10: Bayesian median and 95% credible intervals of B_0, $B_{current}$, and $B_{current}$ as a percentage of B_0 for the three model runs. $B_{current}$ refers to B_{2006} for run $2006_{YCS2000}$ and $2006_{YCS2001}$, and B_{2007} for run $2007_{YCS2003}$;

Model run	B_0	$B_{current}$	$B_{current}$ (%B_0)
$2006_{YCS2000}$	12 672 (11 398–14 709)	4 007(2 759–5 766)	32(24–40)
$2006_{YCS2001}$	11 691 (10 636–13 283)	3 008(2 024–4 593)	26(19–35)
$2007_{YCS2003}$	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 $2007_{YCS2003}$: 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.

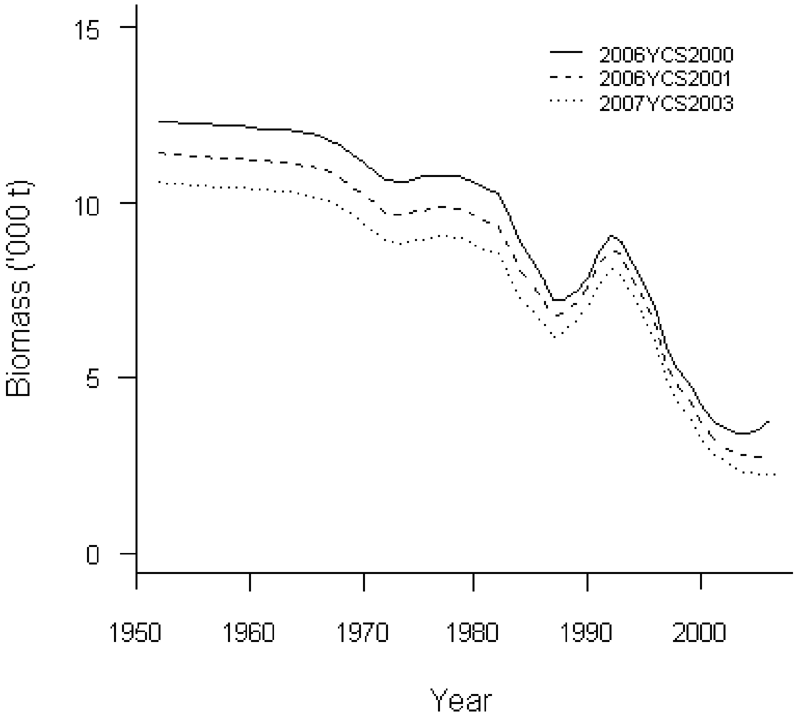


Figure 5: MPD biomass trajectories for the three model runs: *2006$_{YCS2000}$*, *2006$_{YCS2001}$*, and *2007$_{YCS2003}$*.

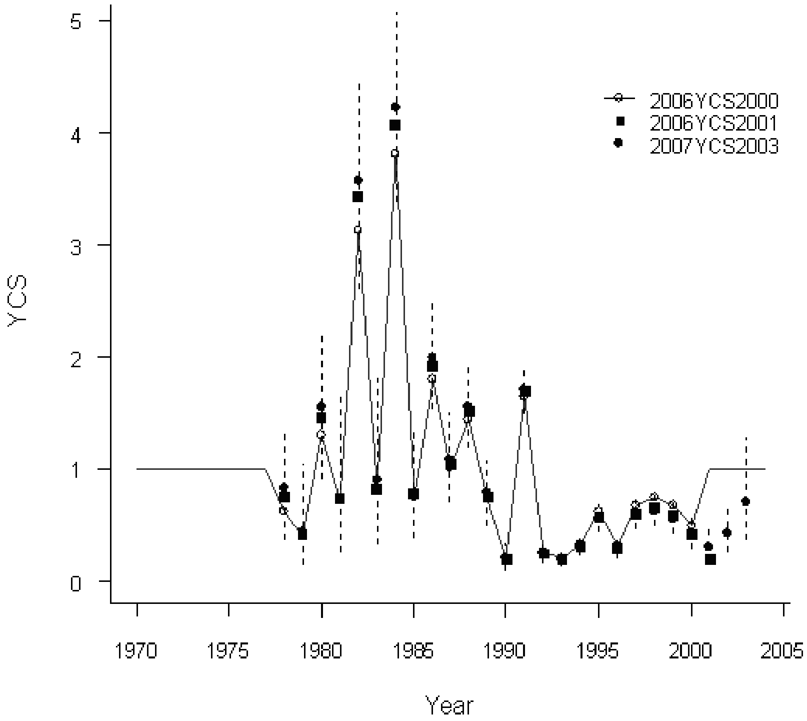


Figure 6: Bayesian median of year class strength for the three model runs *2006$_{YCS2000}$*, *2006$_{YCS2001}$*, and *2007$_{YCS2003}$*. Dotted lines are the 95% credible intervals for run *2007$_{YCS2003}$*.

4.1.5 Discussion of model results

This assessment updated the 2003 assessment using a similar model structure, revised catch history, revised CPUE indices, and addition of catch-at-age data. The model used sex-specific fishing selectivities and differential natural mortality to account for the sex ratio bias in the data, and the SKI 2 fishery was split into an early and a recent period to account for a possible change in selectivity.

Several model runs were carried out, in consideration of the uncertainty of the most recent recruitment, arising from the possible bias in the catch-at-age data in the last few years. Model estimates of the state of the northern gemfish stock show that the current biomass is about 32% of virgin level if recruitments since 2001 were assumed to be average, or 22% of virgin level if more recent recruitments were estimated using the additional catch-at-age data in 2007.

The CPUE indices were only used up to 2001, as the recent indices were considered to be unlikely to track abundance. The fits to the CPUE indices were reasonable, though the SKI 2 indices declined slightly more than those predicted by the model. There appears to be some inconsistency between SKI 1 and SKI 2 CPUE indices. Both show declining trends, but the SKI 2 indices decline faster for the first few years, and are relatively flat for the remainder of the time series.

The fits to the catch at age data were reasonable and diagnostics showed no great departure from the assumption of normality for all model runs. The models explained most of the between-sex difference for the early and recent SKI 2 catch at age. The main outliers were the SKI 2 female observations in 2005, and it is possible that a larger proportion of female fish have been selected by the trawl. There appear to be some structures in the residuals of the older age classes for the SKI 1 catch at age as there are very few observed 14 and 15+ year old fish from 1989 to 1994.

The additional year class strengths estimated for run $2007_{YCS2003}$ show improvement of recruitment since 2001, which appears to be corroborated by the increase in the abundance indices of the last five years. However, the representativeness of the more recent SKI 2 catch-at-age data needs to be further examined (few age 3 males were observed in 2005, but the 2002 year class was one of the dominant year classes at age five in the 2007 catch at age data). More reliable abundance indices for SKI 1 and 2 fisheries need to be developed in order to obtain better estimates of the recent recruitment.

4.1.6 Yield estimates and projections

MCY and *CAY* were determined using stochastic sample-based simulations. One simulation run is 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. For all model runs, the current stock status was at or below the estimated B_{MAY} (Table 10).

Table 11: Yield estimates (*MCY* and *CAY*) and associated parameters for the 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 Projections

The projections were estimated for five years under four scenarios (two alternative recruitment assumptions and two alternative catch levels). Recruitment was randomly resampled from the entire period in which the year class strengths were estimated, or only the recent period (e.g., 1992 to 2000 for run $2006_{YCS2000}$, 1992 to 2001 for run $2006_{YCS2001}$, and 1992 to 2003 for run $2007_{YCS2003}$). Future catches were set equal to the current TACC or the estimated *CAY* (see Table 11).

For all model runs, projections with recruitment resampled from the longer period suggest that the stock is likely to increase when future catches are assumed to be the current TAC, and is likely to decrease slightly when future catches are assumed to be the estimated *CAY*; projections with recruitment resampled from the recent period suggest that the future biomass is likely to decrease under the TAC, and is likely to decrease quickly under the estimated *CAY* (Table 12).

Table 12: Bayesian median and 95% credible intervals of projected biomass B_{PROJ}, B_{PROJ} as a percentage of B_0, and $B_{PROJ}/B_{CURRENT}$(%) for the three model runs where future catches were fixed at either TAC or estimated *CAY*, and future recruitments were randomly sampled from the long period or from the recent period. B_{PROJ} and $B_{CURRENT}$ refer to B_{2011} and B_{2006} for run $2006_{YCS2000}$ and $2006_{YCS2001}$, and B_{2012} and B_{2006} for run $2007_{YCS2003}$;

Model run	Catch (t)	Recruitment	B_{PROJ}	B_{PROJ} (%B_0)	$B_{PROJ}/B_{CURRENT}$ (%)
$2006_{YCS2000}$	450	1978–2000	6 060 (3 242–12 075)	47 (27–92)	151 (94–264)
	450	1992–2000	3 815 (2 128–6 071)	30 (18–44)	98 (74–122)
	1 305	1978–2000	3 472 (595–8 535)	27 (5–65)	85 (17–200)
	1 305	1992–2000	1 195 (135–3 414)	9 (1–24)	31 (5–66)
$2006_{YCS2001}$	450	1978–2001	4 263 (2 010–8 844)	36 (18–74)	140 (76–286)
	450	1992–2001	2 436 (1 257–4 136)	21 (11–32)	81 (57–107)
	1 305	1978–2001	2 809 (630–7 744)	23 (6–64)	91 (24–235)
	1 305	1992–2001	999 (100–2 863)	9 (1–22)	34 (5–68)
$2007_{YCS2003}$	450	1978–2003	3 580 (1 531–6 990)	33 (15–62)	139 (82–280)
	450	1992–2003	2 361 (1 019–4 509)	21 (10–38)	96 (62–137)
	755	1978–2003	2 497 (692–6 200)	23 (7–54)	99 (36–233)
	755	1992–2003	1 476 (199–3 481)	14 (2–29)	59 (13–105)

The projections suggest that unless recruitment improves and the catch remains at moderately low levels, the biomass is unlikely to increase in the short term.

4.2 South-East/Southland (SKI 3) and Challenger/Central (West) (SKI 7)

4.2.1 Estimation of fishery parameters and abundance

Estimates of relative abundance from two time series of trawl surveys used in the model for SKI 3 are presented in Table 13. Proportion-at-age data included in the model came from the *Tangaroa* trawl surveys. Model input parameters used in the assessment are given in Table 14.

Table 13: Biomass indices (t) and coefficients of variation (CV) from trawl surveys (assuming area availability, vertical availability and vulnerability = 1).

Fishstock	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

Table 14: MIAEL model input parameters used in the SKI 3 & 7 assessment.

Parameter	Estimate
Steepness	0.75
Recruitment variability	1.0
Proportion spawning	0.95
M	0.23
Maximum exploitation (r_{MAX}) pre-spawning, spawning	0.6, 0.8
Minimum exploitation with maximum catch (r_{MMX})	0.1
Maturity ogive (ages 2–5)	0.1, 0.4, 0.8 1.0

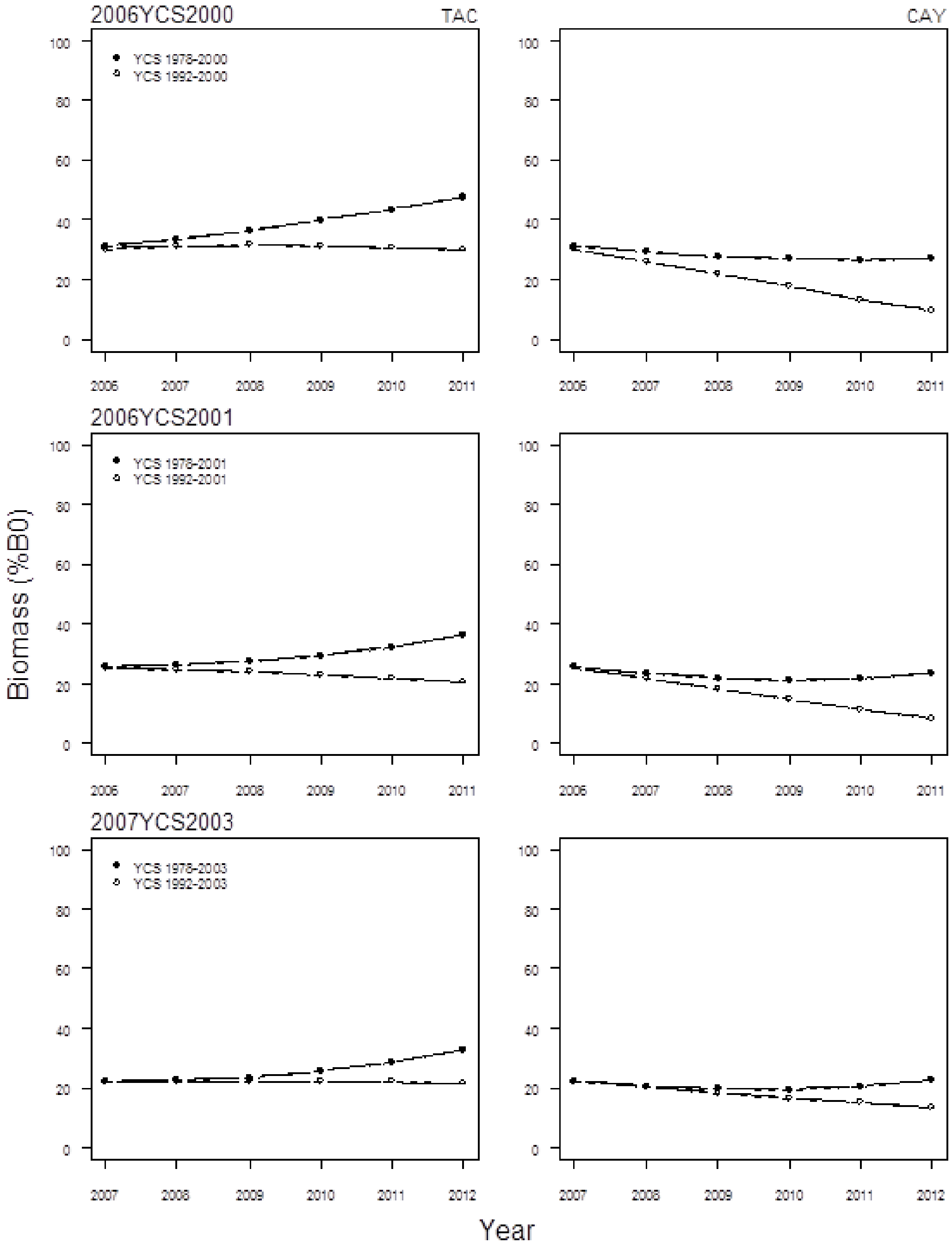


Figure 7: Bayesian median of projected biomass (% B_0) for the three model runs, with future catch fixed at TAC or estimated *CAY*, and future recruitment randomly resampled from the long period or the recent period.

Year class strength was estimated in the model. As some year classes were exceptionally weak or strong, constraints were set to give more realistic estimates of year class strengths. The estimated year class strengths are given in Table 15. These year class strengths were poorly estimated and should be considered as indicative of poor and strong year classes only.

Table 15: Estimated or assumed (*) year class strengths for the base case SKI 3 & 7 assessment.

Year class	Estimate	Year class	Estimate	Year class	Estimate
1979	3.310	1986	0.300	1993	0.010*
1980	1.940	1987	0.001	1994	0.010*
1981	0.001	1988	0.010		
1982	5.690	1989	0.240		
1983	0.070	1990	0.010		
1984	4.250	1991	0.001*		
1985	2.250	1992	0.001*		

4.2.2 Biomass estimates

There was concern over the MIAEL point estimates due to the low value of the performance indices and therefore only the upper and lower bounds using r_{MMX} and r_{MAX} were reported. B_0 ranged from 26 000 to 73 000 t, B_{MID97} from 0 to 63%, and B_{BEG98} from 200 to 51 400 t (see also figure 1 in the 1997 Plenary Report).

4.2.3 Yield estimates and projections

Details of the modelling procedure which produced the B_0 estimates from which *MCY* was estimated for SKI 3 & 7 are given above. The *MCY* ranges from 990 to 2770 t. MIAEL point estimates were not reported due to the low value of the performance indices.

Details of the modelling procedure which produced the B_{beg98} estimates from which *CAY* was estimated for SKI 3 & 7 are given above. The range of *CAY* for SKI 3 & 7 for 1998–99 was 20–5900 t. MIAEL point estimates were not reported due to the low value of the performance indices.

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 based on the east coast North Island, 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.

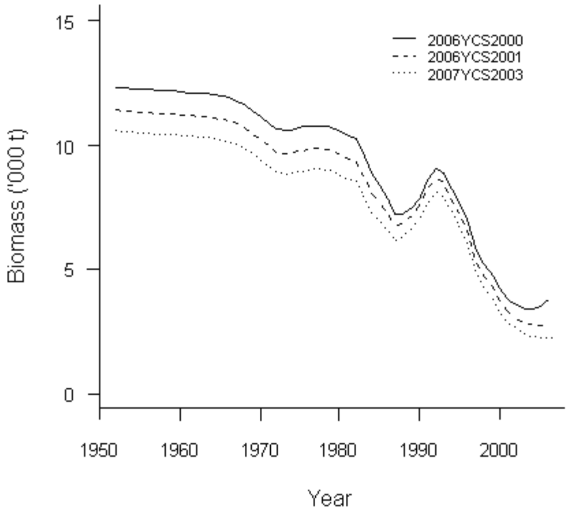
A new stock assessment was completed for SKI 1 & 2 in 2008.

SKI 1&2

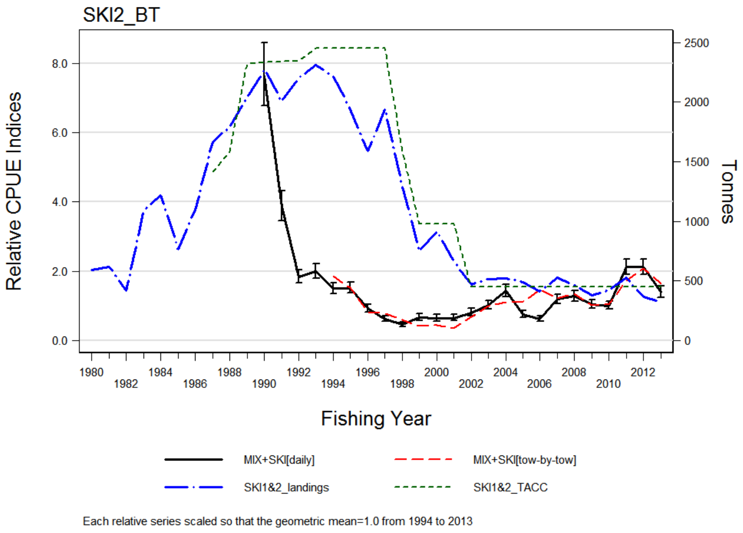
Stock Status	
Year of Most Recent Assessment	2008: Stock Assessment 2014: CPUE update
Assessment Runs Presented	Stock Assessment Three cases are presented. There was no single preferred model. CPUE Update Combined (lognormal + binomial) model based on mixed target species (including SKI) using daily effort data for statistical areas 11-19
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
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 2014 CPUE analysis indicates that relative abundance increased by 119% from the mean for 2005-2007 to the mean for 2011-13. Although biomass is increasing, it is not known whether the stock has

	reached the target
Status in relation to Limits	B_{2006} was estimated to be Unlikely (< 40%) to be below both the Soft Limit and the Hard Limit

Historical Stock Status Trajectory and Current Status



MPD biomass trajectories for the three model runs: $2006_{YCS2000}$, $2006_{YCS2001}$, and $2007_{YCS2003}$.



Historical CPUE Trajectory with combined SKI 1&2 landings and TACC (t)

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Standardised CPUE has increased steadily since the late 1990s.
Recent Trend in Fishing Mortality or Proxy	Fishing pressure has declined with the decrease in TACC since 1999–2000.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	One strong year class was estimated to have occurred in 1991. Recruitment in recent years appears lower than seen previously.

Projections and Prognosis		
Stock Projections or Prognosis	With catches at the current TACC the stock is projected to increase if recruitment returns to the 1978–2000 average level, but decline slightly if recent (1992–2000) recruitment continues.	
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Very Unlikely (< 10%) Hard Limit: Very Unlikely (< 10%)	
Assessment Methodology		
Assessment Type	Type 1 – Quantitative Stock Assessment (to 2006) Type 2 – Partial Quantitative Stock Assessment (2014)	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2007 CPUE update: 2014	Next assessment: Unknown next CPUE update: 2017
Main data inputs	Stock Assessment Updated from previous assessment: - Catch history - CPUE abundance indices - Proportions-at-age data (1 year SKI 1, 4 years SKI 2) CPUE Analysis MPI catch and effort data	
Changes to Model Structure and Assumptions	Incorporation of: - Age based selectivities - Differential natural mortality - Additional year of age data	
Major Sources of Uncertainty	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. CPUE Steep decline in first two years of series and sustained high catches suggest the first two data points may not reliably reflect abundance.	

Fishery Interactions
Gemfish are common bycatch in the hoki, tarakihi, scampi and squid target fisheries, although some gemfish target fisheries do exist. Bycatch is variable but includes hoki, tarakihi, silver warehou and bluenose. Bycatch of concern includes fur seals and seabirds.

SKI 3 & 7

The assessment of the southern gemfish stock has not been updated since 1997. Landings from SKI 7 increased from 2000 to be a level over twice the TACC in 2004–05, but have decreased since then.

Table 16: 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*	2013–14 Actual TACC	2013–14 Reported landings
SKI 1	Auckland (East) (West)	1 & 9 }			210	198
SKI 2	Central (East)	2 }	816	-	240	268
SKI 3	South-East (Coast) (Chatham), Southland, Sub-Antarctic	3, 4, 5, & 6 }			300	29
SKI 7	Challenger, Central (West)	7 & 8 }	990–2 770	-	300	268
SKI 10	Kermadec	10	-	-	10	0
Total					1 060	764

6. FOR FURTHER INFORMATION

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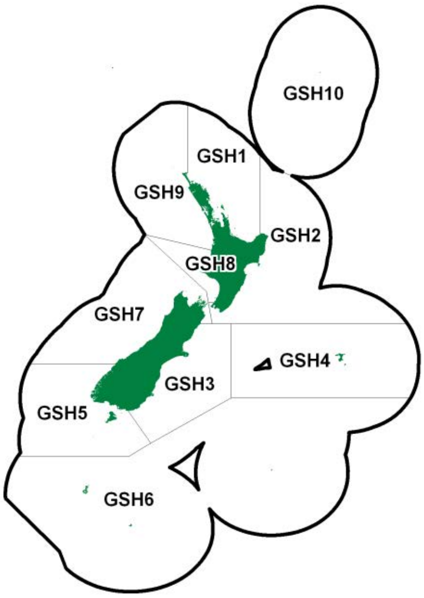
DARK GHOST SHARK (GSH)

(*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 Table 2, 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 are consistent from year to year and don’t 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 2013–14, based on reported landings of both ghost shark species combined, and actual TACCs set from 1998–99. No landings have been recorded from FMA 10, and no TACC has been set for this area. QMS data from 1986 to present.

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

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

* FSU data.

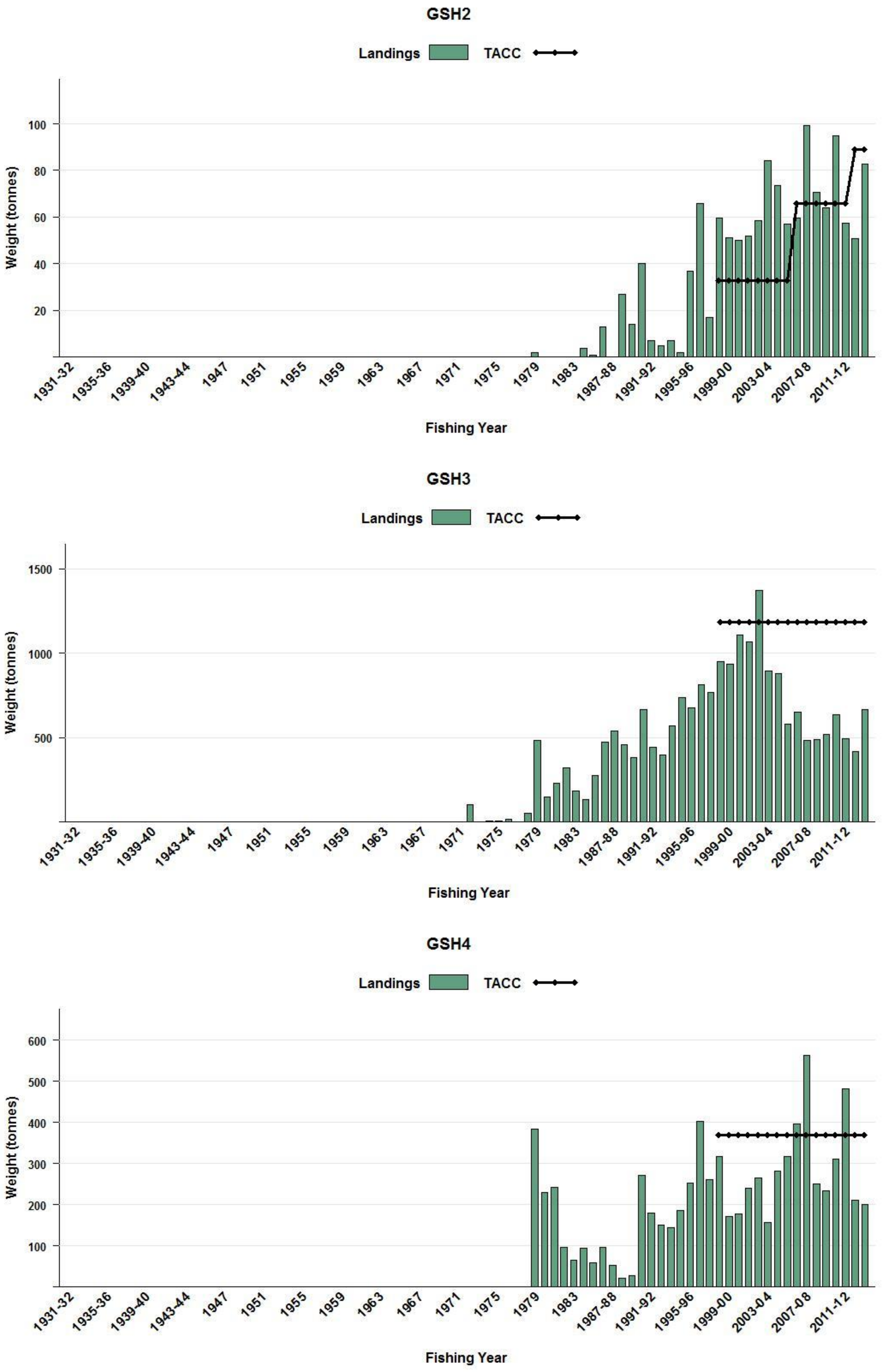
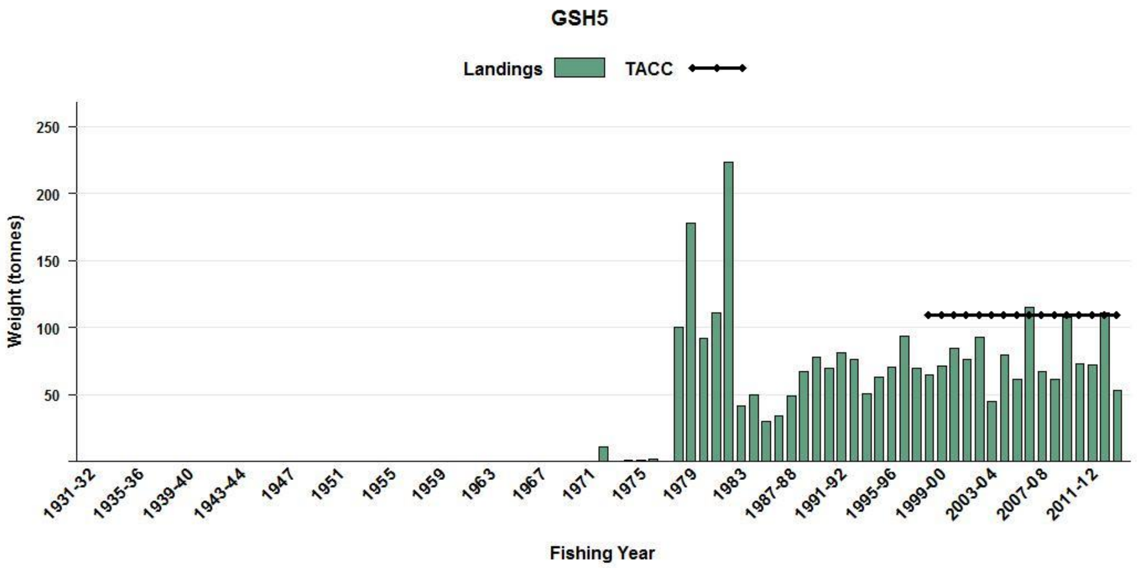


Figure 1: Reported commercial landings and TACC for GSH stocks. From top left: GSH2 (Central East), GSH3 (South East Coast), GSH4 (South East Chatham Rise) [Continued on the next page].



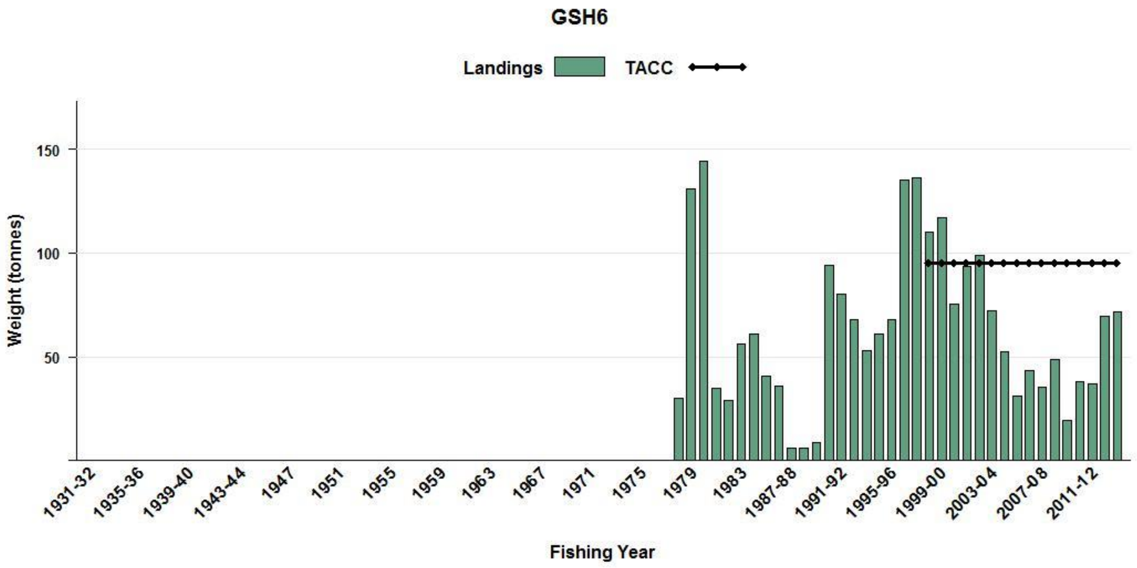


Figure 1 [Continued]: Reported commercial landings and TACC for GSH stocks. GSH5 (Southland). GSH6 (Sub-Antarctic).

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 were above the TACC for a number of years and the TACCs have been increased to the average of the previous 7 years plus an additional 10%. Landings exceeded the TACC slightly in GSH 3 in 2002–03, slightly in GSH 4 in 2006–07 and by 52% in 2007–08. Landings also exceeded the TACC slightly in GSH 5 in 2006–07, and GSH 6 in 1999–00 and 2002–03.

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 (< 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 (2000) 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 (2000).

		Von Bertalanffy growth parameters		
Region	Sex	L∞	K	t0
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	0.001853	3.299367	Bagley at al. (Submitted)

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 nto 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.

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).

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
5 & 6	Southland Sub-Antarctic	*Tangaroa* (summer)	TAN9105	Nov-Dec 1991	1 030	25.4
			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
5 & 6	Southland Sub-Antarctic	*Tangaroa* (summer)	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 (autumn)	TAN9204	Mar-Apr 1992	3 740	48.6
			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 North Island	*Kaharoa*	KAH9304	Mar-Apr 1993	450	61.5
			KAH9402	Feb-Mar 1994	40	41.3
			KAH9502	Feb-Mar 1995	10	48.6
			KAH9602	Feb-Mar 1996	80	33.5
3	ECSI winter surveys	*Kaharoa*	KAH9105	May-91	962	42
			KAH9205	May-92	934	44
			KAH9306	May-93	2 911	42
			KAH9406	May-94	2 702	25
			KAH9606	May-96	3 176	223
			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

Table 6 [continued]

FMA	Area	Vessel	Trip code	Date	Biomass	% CV
3	ECSI summer surveys	*Kaharoa*	KAH9618	Dec ’96 - Jan ’97	3 066	18
			KAH9704	Dec ’97 - Jan ’98	5 870	33
			KAH9809	Dec ’98 - Jan ’99	7 416	27
			KAH9917	Dec ’99 - Jan ’00	2512	19
			KAH0014	Dec ’00 - Jan ’01	2 950	18
7	West coast South Island	*Kaharoa*	KAH9204	Mar-Apr 1992	380	20
			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

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.

Total biomass in the east coast South Island winter surveys core strata (30–400 m) increased 14-fold between 1992 and 2014 (Table 6, Figure 2). Biomass increased markedly between 1992 and 1993, was stable to increasing up to 2009, increased more than 2-fold in 2012, and in 2014 increased again by nearly one-quarter. All surveys had a large component of pre-recruit biomass ranging from 30–61%— in 2014 the pre-recruit biomass was relatively high at 53% 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 2014 the juvenile biomass was 49% of total biomass. (Beentjes et al. 2015).

Distribution over the ECSI winters 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 2014 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 eight surveys (1993–2014) were similar and generally bimodal (Beentjes et al. 2015). The 2012 and 2014 length frequency were distinct from previous years with relatively large numbers of adults or mature fish. The distributions differ from those of the Chatham Rise and Southland/Sub-Antarctic surveys in that ECSI has a large component of juvenile fish, suggesting that this area may be an important nursery ground for dark ghost shark.

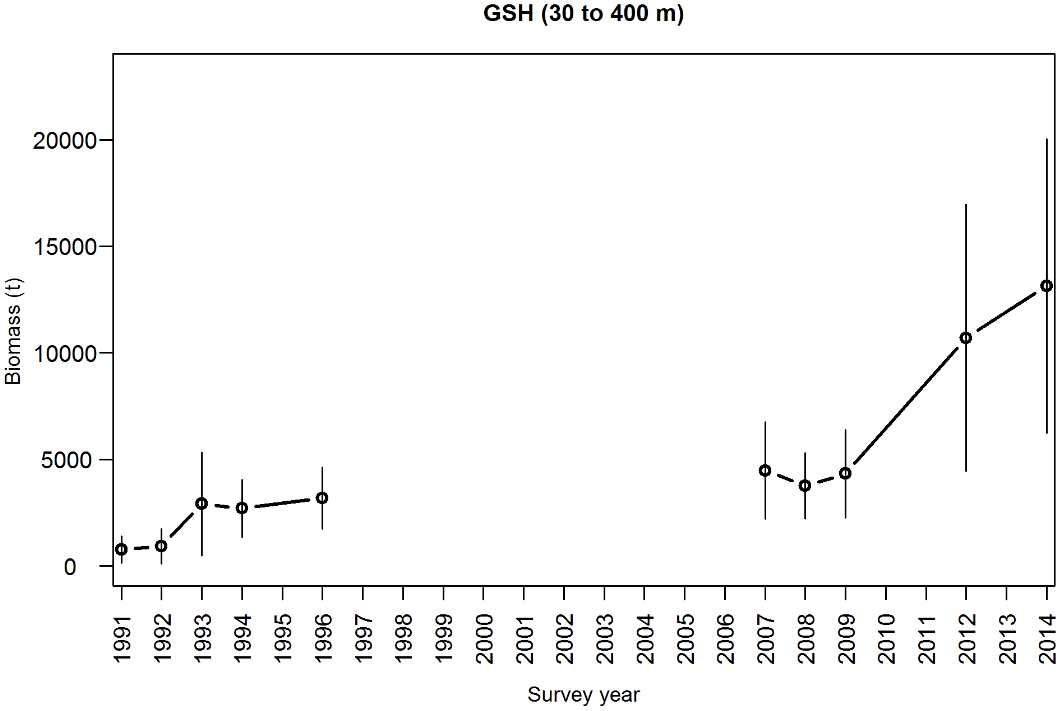


Figure 2: Biomass and 95% confidence intervals for dark ghost shark from the east coast South Island winter trawl surveys in core strata (30–400 m).

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.

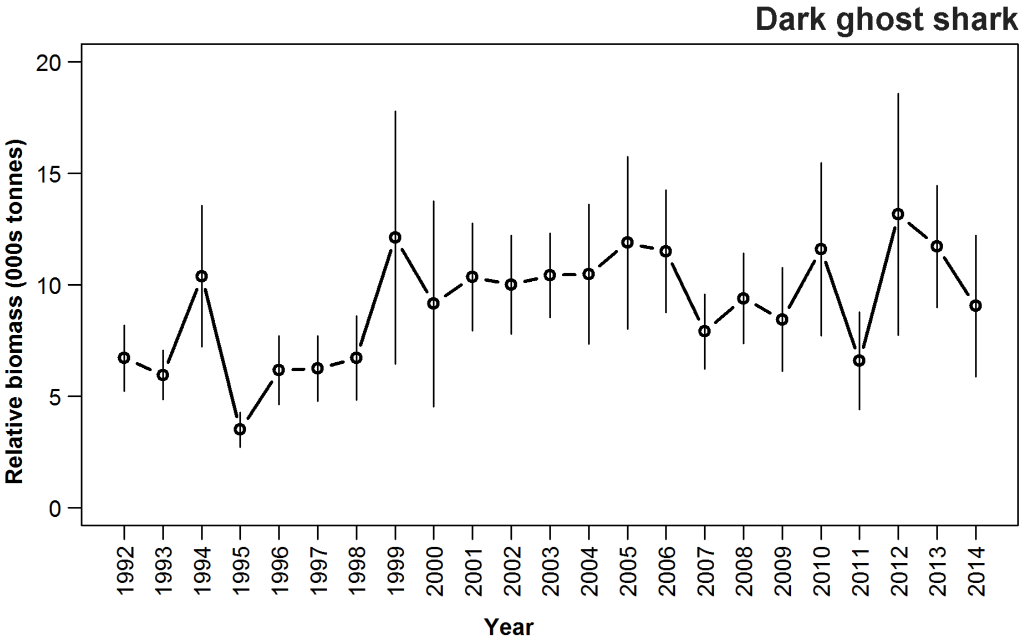


Figure 3: Biomass trends ±95% CI (estimated from survey CVs assuming a lognormal distribution) and the time series mean (dotted line) from the Chatham Rise trawl survey.

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.

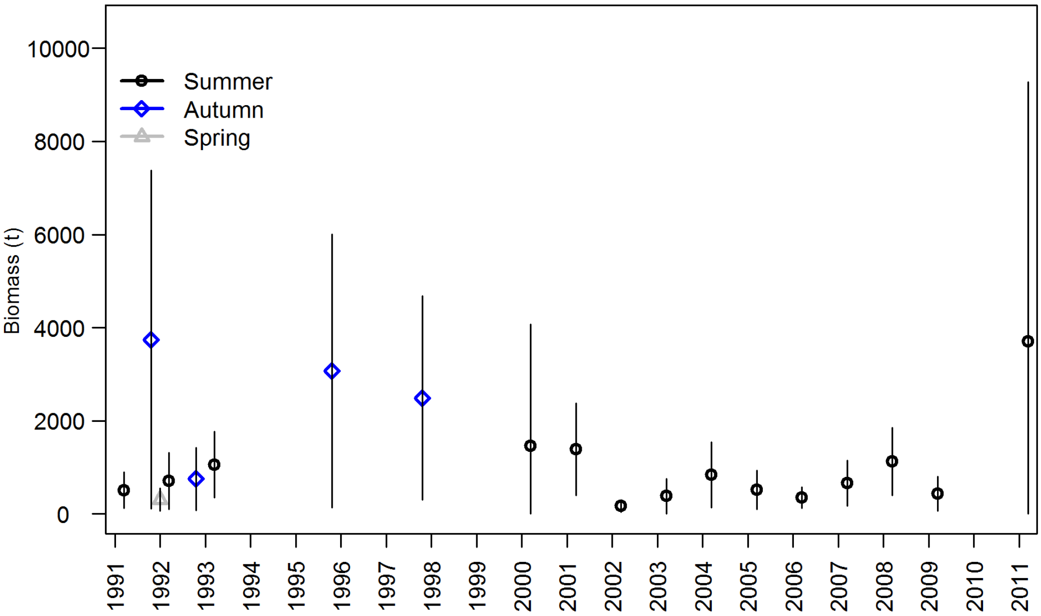


Figure 4: Biomass trends ±95% CI (estimated from survey CVs assuming a lognormal distribution) from the Sub-Antarctic trawl survey.

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).

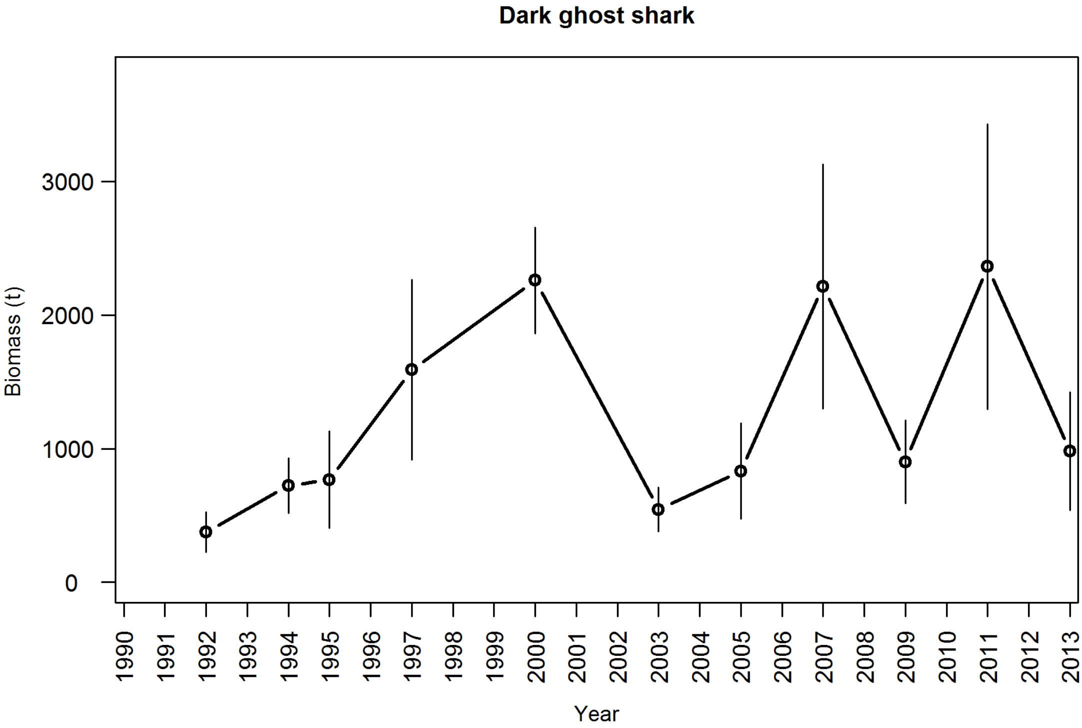


Figure 5: Biomass trends ±95% CI (estimated from survey CVs assuming a lognormal distribution) from the West Coast South Island trawl survey.

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.

5. STATUS OF THE STOCKS

Stock Structure Assumptions

Based on differences in length frequencies 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.

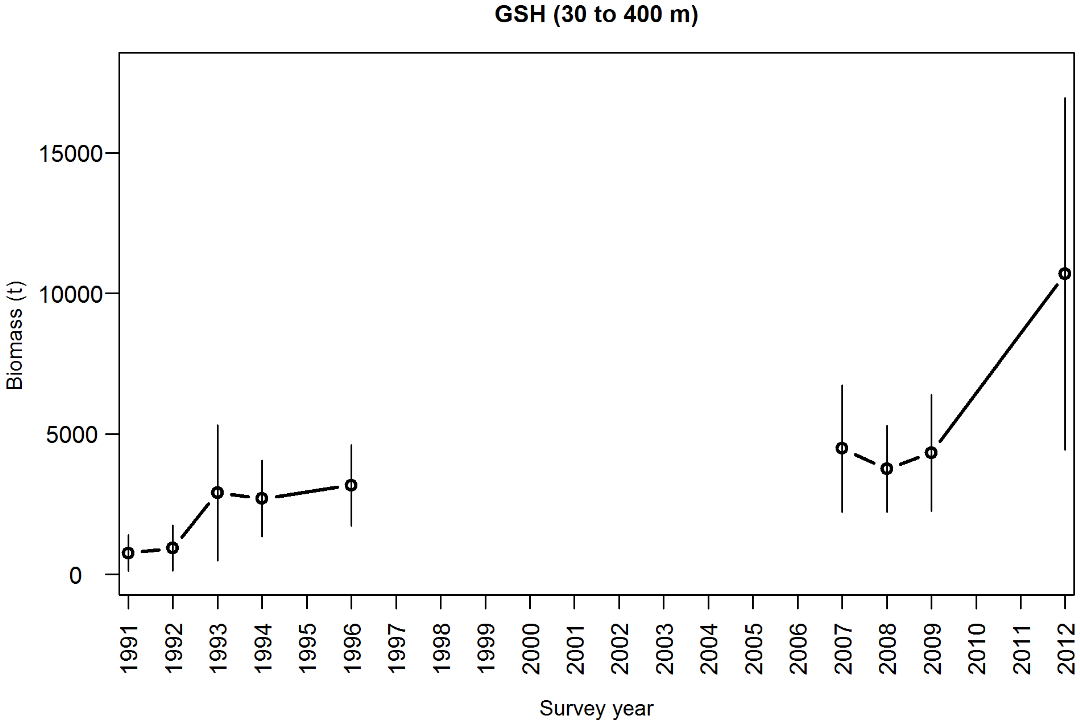
1. The eastern fishery; extending from the upper east coast of the South Island and out east across the Chatham Rise.
2. The southern fishery; extending from the lower east coast of the South Island, south around the Stewart/Snares Shelf, Campbell Plateau, and Puysegur trench.

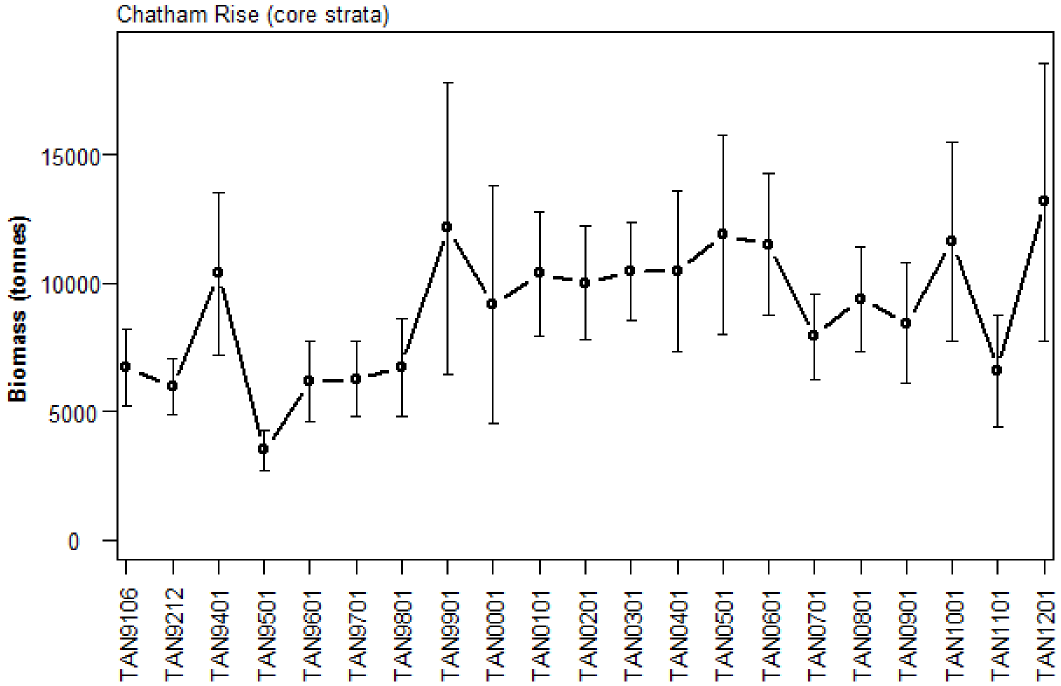
Further work needs to be done to investigate what if any relationship there is between dark ghost shark caught on the west coast of the South Island, around both coasts of the North Island, and the eastern and southern stocks.

Chatham Rise

Stock Status	
Year of Most Recent Assessment	-
Assessment Runs Presented	-
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
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





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 for the last few years. The 2012 estimate was particularly high, more than double 2009 estimate. 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	-

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.

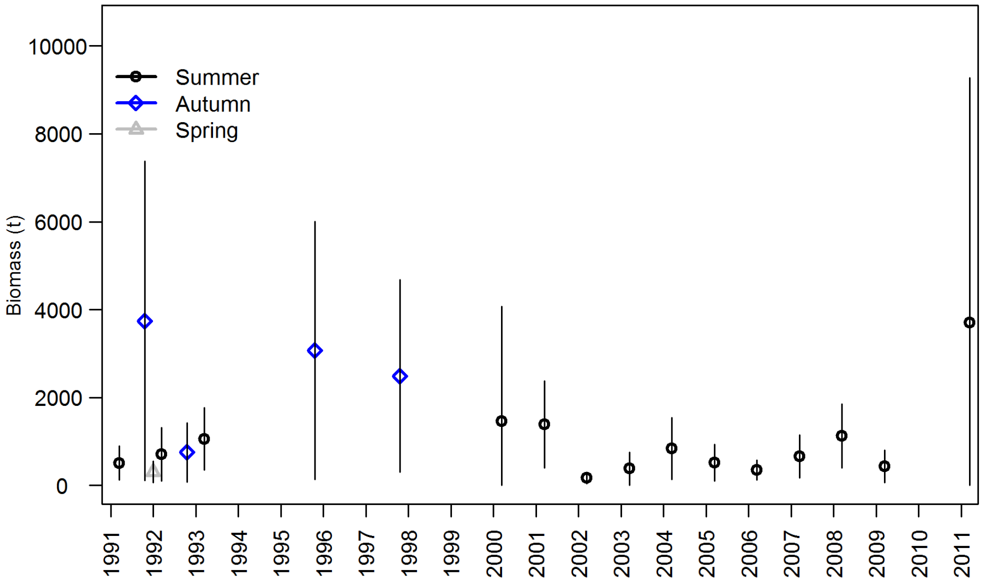
Qualifying Comments
-

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	-
Assessment Runs Presented	-
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
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



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	-

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.

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 are noted for New Zealand fur seals and seabirds, and low productivity species taken in the fisheries include basking sharks and deepsea skates.

Table 6: Summary of TACCs (t) and reported landings (t) for dark ghost shark for the most recent fishing year.

Fishstock		QMA	2013-14 Actual TACC	2013-14 Estimated Landings
GSH 1	Auckland (East)	1	22	15
GSH 2	Central (East)	2	89	83
GSH 3	South-east (Coast)	3	1 185	667
GSH 4	South-east (Chatham)	4	370	201
GSH 5	Southland	5	109	53
GSH 6	Sub-Antarctic	6	95	72
GSH 7	Challenger	7	1 121	690
GSH 8	Central (West)	8	34	27
GSH 9	Auckland (West)	9	22	9
GSH 10	Kermadec	10	0	0
Total			3 047	1 817

6. FOR FURTHER INFORMATION

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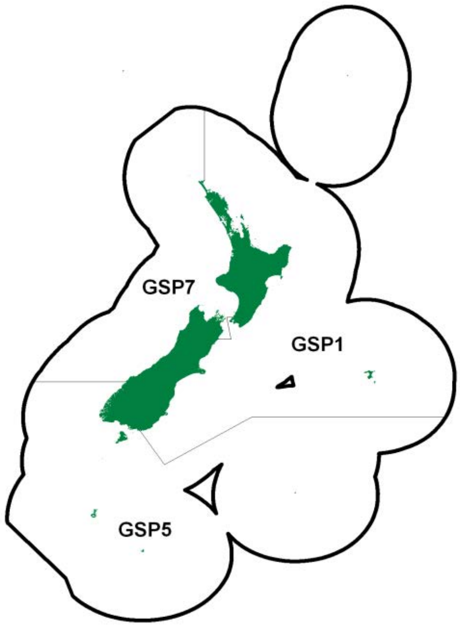
PALE GHOST SHARK (GSP)

(*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	
	B	C(M)	C(1)	D	E(B)	E(P)	E(C)	E(A)	F(E)	F(W)	G	H	Total
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 this was 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 pale ghost shark made up 30% of the total ghost shark catch in FMAs 5 and 6, and 25% in all other FMAs.

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, 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.

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

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.

Table 3: Estimated landings (t) of pale ghost shark by Fishstock for 1999–2000 to 2013–14 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

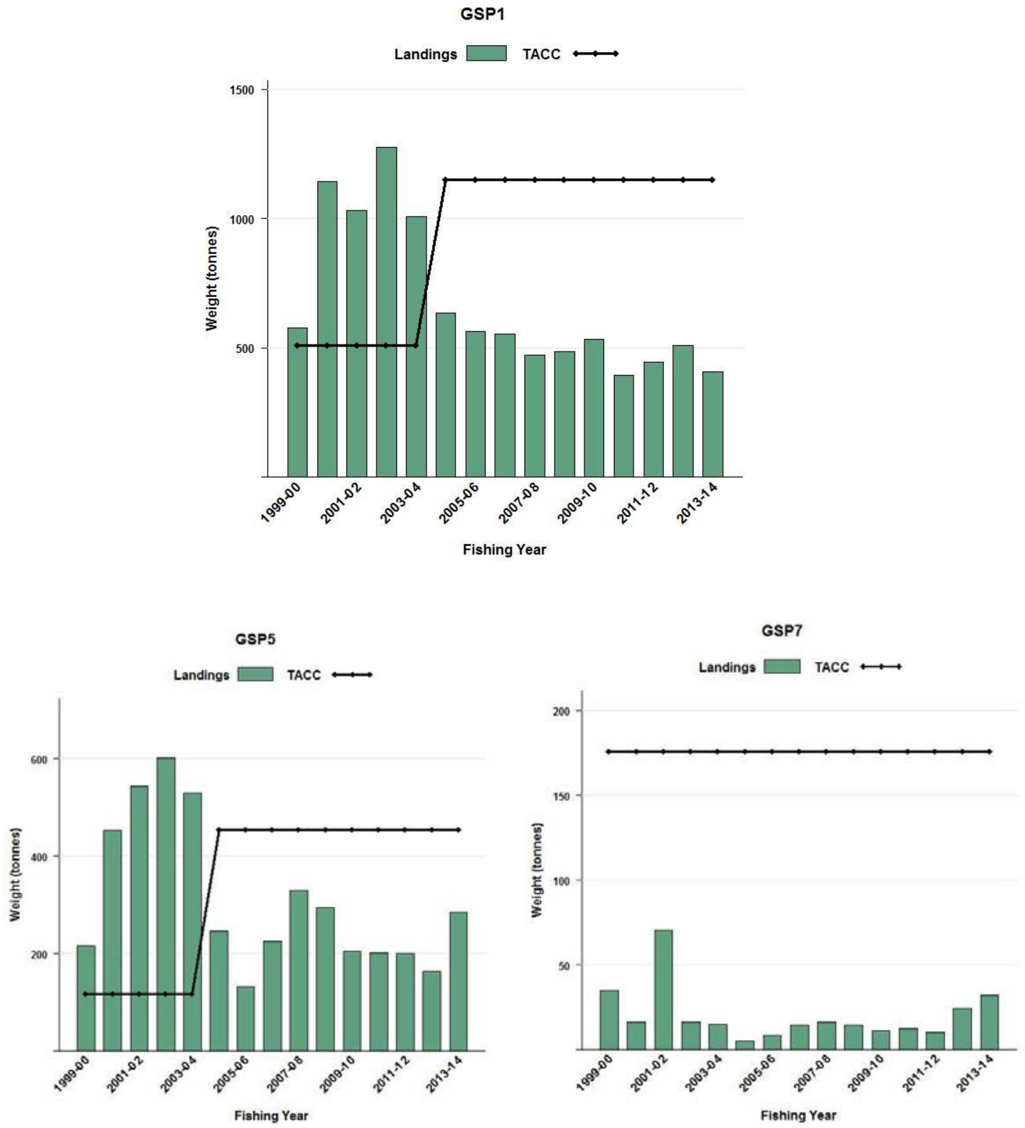


Figure 1: Reported commercial landings and TACC for the three main GSP stocks. From top: GSP 1 (Auckland East), GSP 5 (Southland), and GSP 7 (Challenger). Note that these figures do not show data prior to entry into the QMS.

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, ghost shark 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 = $a (\text{length})^b$ (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 Sub-Antarctic	*Tangaroa*	TAN9105	Nov–Dec 1991	11 210	6.1
			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 Sub-Antarctic	*Tangaroa*	TAN9204	Mar–Apr 1992	10 530	6.1
			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.

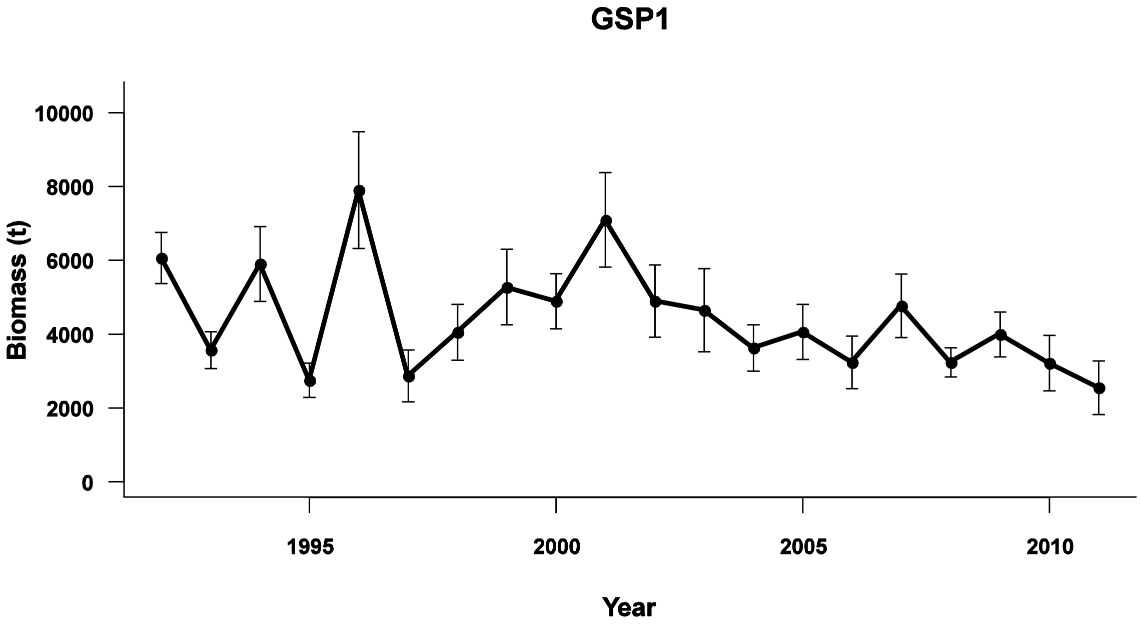
5. STATUS OF THE STOCKS

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
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

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 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

Assessment Methodology		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Evaluation of trawl survey indices on the Chatham Rise	
Main data inputs	- Research time series of abundance indices (trawl surveys)	
Period of Assessment	Latest assessment: 2011	Next assessment: 2012
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.

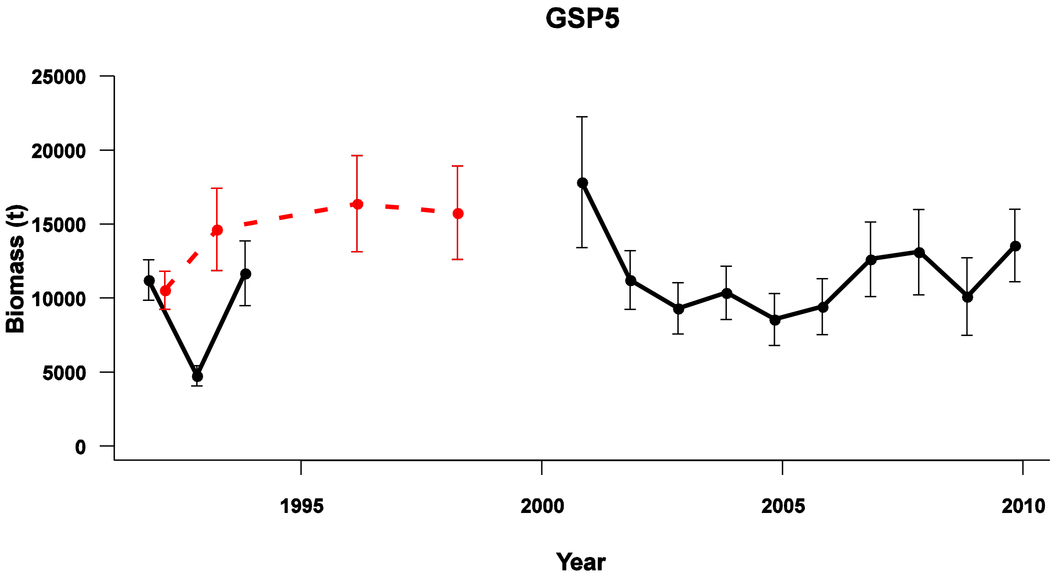
Qualifying Comments
The catch history for this species is likely to underestimate actual catches.

Fishery Interactions
The pale ghost shark in GSP 1 is mainly taken as bycatch of the hoki fishery.

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
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

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 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	
Assessment Methodology		
Assessment Type	Level 2 - Quantitative stock assessment	
Assessment Method	Evaluation of trawl survey indices on the Chatham Rise	
Main data inputs	- Research time series of abundance indices (trawl surveys)	
Period of Assessment	Latest assessment: 2011	Next assessment: 2012
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.

GSP 7

There are no accepted stock monitoring indices available for GSP 7.

TACCs and reported landings for the 2012–13 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	2013–14 Actual TACC	2013–14 Estimated landings
GSP 1	Auckland (East), Central (East) South-East (Coast) (Chatham), Kermadec	1, 2, 3, 4, 10	1 150	408
GSP 5	Southland, Sub-Antarctic	5, 6	454	286
GSP 7	Challenger, Central (West), Auckland (West)	7, 8, 9	176	33
Total			1 780	727

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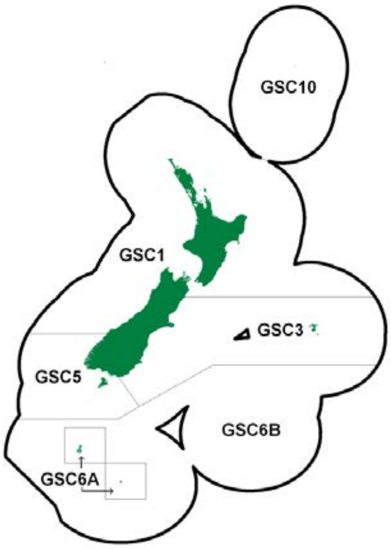
GIANT SPIDER CRAB (GSC)

(*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. 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. 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 70 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 and then little interest until, according to Ministry data, the 1999–2000 fishing year. Figure 1 shows the historical landings and TACC for the main GSC stocks.

Table 1: TACCs and reported landings (t) of giant spider crab by Fishstock from 2001–02 to 2013–14 from CELR and CLR data. (N/A = no TACC set). [Continued on next page].

	GSC 1		GSC 3		GSC 4		GSC 5		GSC 6	
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	-	< 1	-
1993–94	< 1	-	0	-	0	-	0	-	< 1	-
1994–95	0	-	0	-	0	-	0	-	0	-
1995–96	0	-	0	-	0	-	0	-	0	-
1996–97	< 1	-	0	-	0	-	< 1	-	0	-
1997–98	0	-	0	-	0	-	< 1	-	0	-
1998–99	< 1	-	0	-	0	-	0	-	0	-
1999–00	0	-	< 1	-	0	-	0	-	< 1	-
2000–01	0	-	< 1	-	0	-	0	-	< 1	-
2001–02	0	-	< 1	-	0	-	1	-	7	-
2002–03	0	-	< 1	-	0	-	< 1	-	3	-
2003–04	0	1	< 1	14	< 1	N/A	2	19	7	N/A
2004–05	0	1	< 1	14	N/A	N/A	5	19	N/A	N/A
2005–06	0	1	< 1	14	N/A	N/A	8	19	N/A	N/A
2006–07	0	1	< 1	14	N/A	N/A	5	19	N/A	N/A
2007–08	0	1	< 1	14	N/A	N/A	11	19	N/A	N/A
2008–09	< 1	1	13	14	N/A	N/A	10	19	N/A	N/A
2009–10	< 1	1	12	14	N/A	N/A	25	19	N/A	N/A
2010–11	0	1	1	14	N/A	N/A	19	19	N/A	N/A
2011–12	0	1	2	14	N/A	N/A	14	19	N/A	N/A
2012-13	<1	1	<1	14	N/A	N/A	54	19	N/A	N/A
2013-14	0	1	2	14	N/A	N/A	72	19	N/A	N/A

Table 1 [Continued].

	GSC 6A		GSC 6B		GSC 8		GSC 10		TOTAL	
Fishstock	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1990–91	0	-	0	-	0	-	0	-	< 1	-
1991–92	0	-	0	-	0	-	0	-	0	-
1992–93	0	-	0	-	0	-	0	-	0	-
1993–94	0	-	0	-	0	-	0	-	1	-
1994–95	0	-	0	-	0	-	0	-	0	-
1995–96	0	-	0	-	< 1	-	0	-	< 1	-
1996–97	0	-	0	-	0	-	0	-	< 1	-
1997–98	0	-	0	-	0	-	0	-	< 1	-
1998–99	0	-	0	-	0	-	0	-	0	-
1999–00	0	-	0	-	0	-	0	-	2	-
2000–01	0	-	0	-	0	-	0	-	< 1	-
2001–02	0	-	0	-	0	-	0	-	8	-
2002–03	0	-	0	-	0	-	0	-	4	-
2003–04	0	148	0	237	0	N/A	0	0	27	419
2004–05	24	148	2	237	N/A	N/A	0	0	35	419
2005–06	63	148	1	237	N/A	N/A	0	0	72	419
2006–07	23	148	< 1	237	N/A	N/A	0	0	30	419
2007–08	16	148	2	237	N/A	N/A	0	0	29	419
2008–09	13	148	< 1	237	N/A	N/A	0	0	36	419
2009–10	44	148	3	237	N/A	N/A	0	0	84	419
2010–11	23	148	< 1	237	N/A	N/A	0	0	43	419
2011–12	83	148	< 1	237	N/A	N/A	0	0	99	419
2012-13	80	148	5	237	N/A	N/A	0	0	140	419
2013-14	52	148	<1	237	N/A	N/A	0	0	127	419

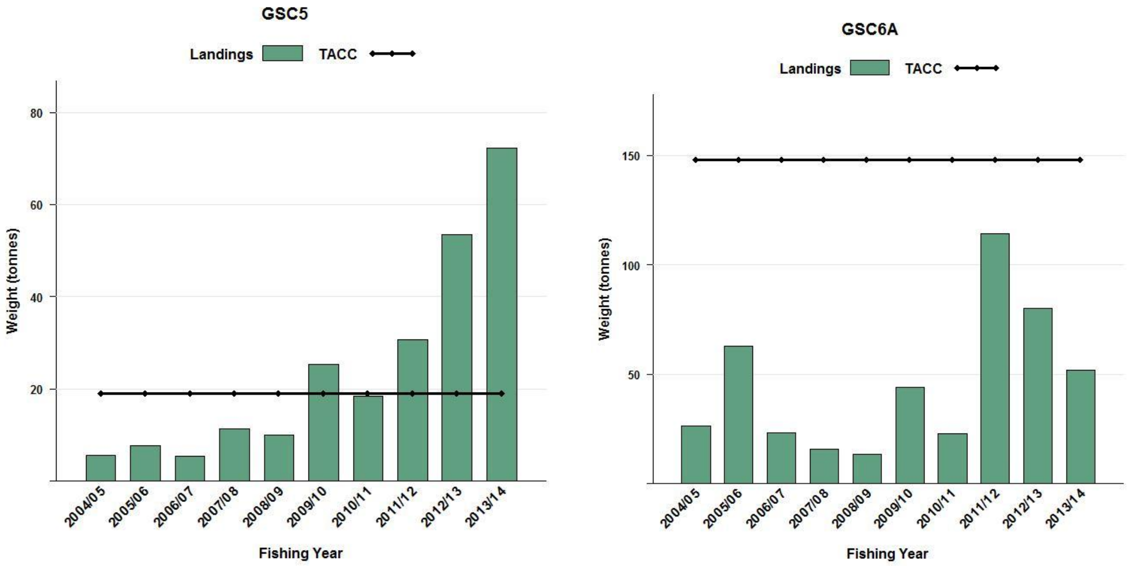


Figure 1: Reported commercial landings and TACC for GSC 5 (Southland), and GSC 6A (Southern Islands). Note that these figures do not show data prior to entry into the QMS.

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, although this crab is often taken as a bycatch in orange roughy fishing.

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, then decreasing quantities at the Campbell Islands, Bounty Islands, Stewart Island, Stewart Island 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.

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 while 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.

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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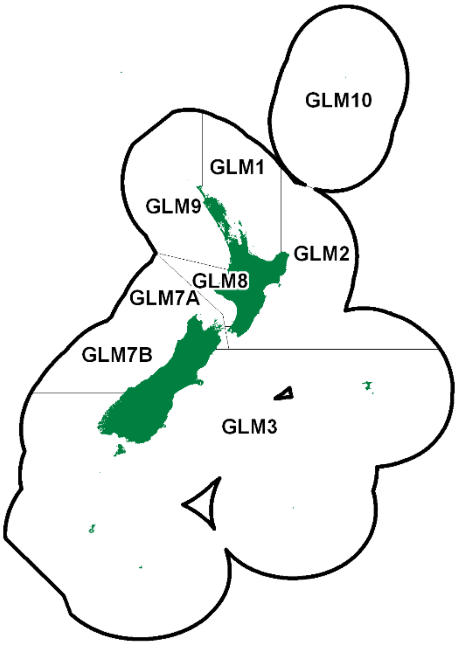
GREEN-LIPPED MUSSEL (GLM)

(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 2000 tonnes. 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. Since 2004 reported landings have been dominated by GLM 7A and GLM 9. Total landings have been low and declining compared to the total TACC. 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 (QMA)	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	0.19	10	410.9	1 500	121	180	539	1 720
2005–06	12.4	10	0.2	10	0.176	10	229.0	1 500	93	180	335	1 720
2006–07	7.8	10	0	10	0	10	84.3	1 500	137	180	229	1 720
2007–08	3.5	10	0	10	0.04	10	7.4	1 500	142	180	153	1 720
2008–09	6.7	10	0	10	0.04	10	0.07	1 500	68	180	75	1 720
2009–10	4.4	10	0	10	0.02	10	0.03	1 500	183	180	187	1 720
2010–11	1.0	10	0	10	0	10	1.4	1 500	78	180	80	1 720
2011–12	0.5	10	0	10	0	10	0.06	1 500	162	180	163	1 720
2012–13	0.6	10	0	10	0	10	0	1 500	129	180	130	1 720
2013-14	0.1	10	0	10	0	10	8.29	1 500	159	180	167	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.

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

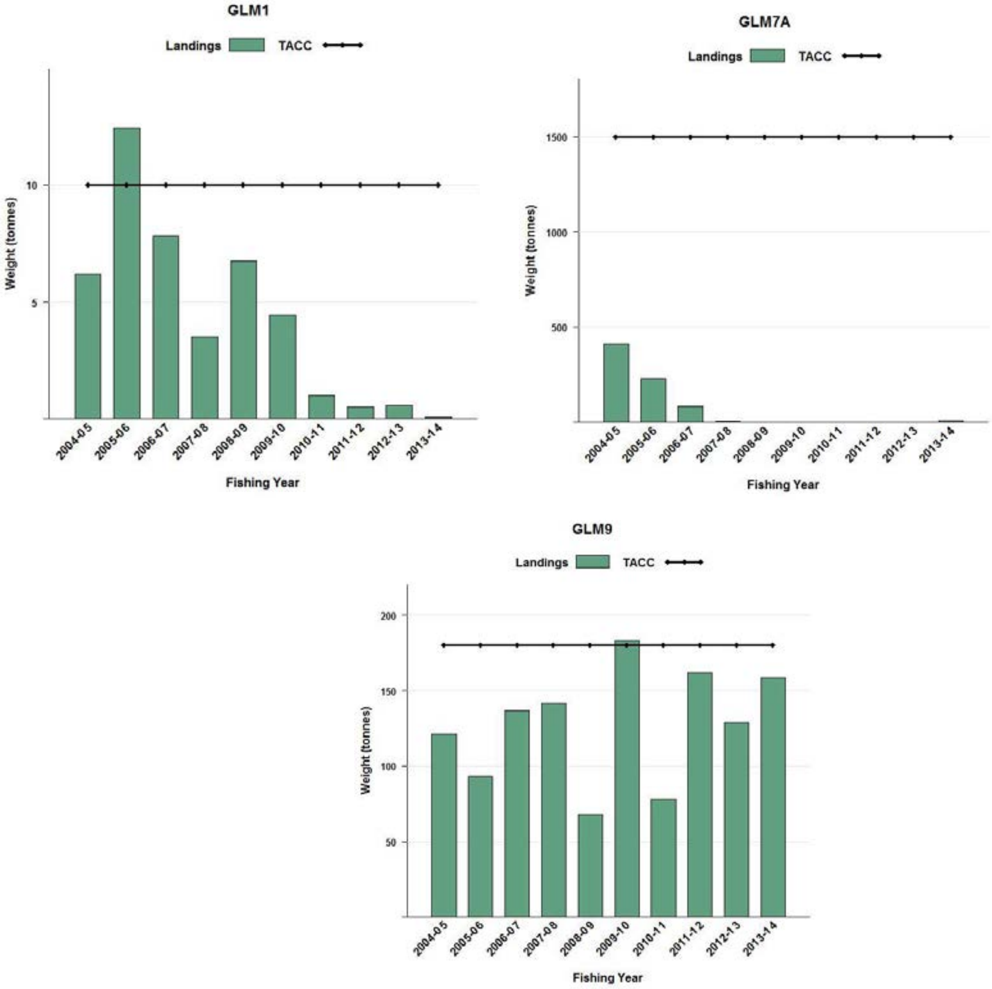


Figure 1: Reported commercial landings and TACC for the four main GLM stocks. From top left: GLM 1 (Auckland East), GLM 7A (Nelson Marlborough), and GLM 9 (Auckland West). Note that these figures do not show data prior to entry into the QMS.

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.

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).

FMA	1996 Harvest	2000 Harvest	2001 Harvest
1	818	1 308	949
2		8	22
3		402	187
5		1	36
7		3	363
8		242	-
9		25	148

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 no information is available, the green-lipped mussel remains an important element of customary fishing throughout many parts of New Zealand.

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. 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. 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

No estimates of reference or current biomass are available for any green-lipped mussel fishstock. It is not known whether green-lipped mussel stocks are at, above, or below a level that can produce *MSY*.

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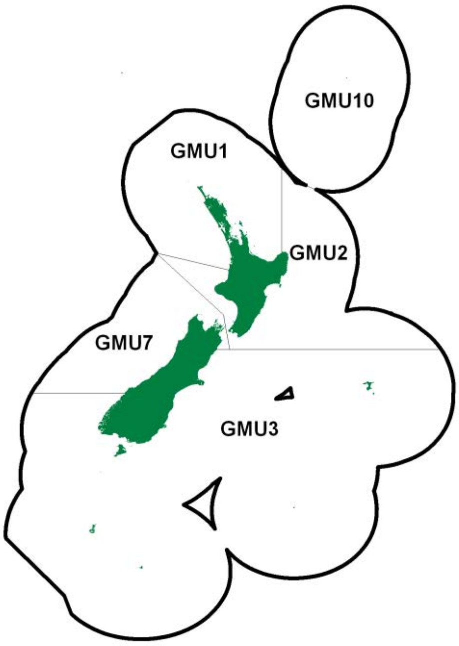
GREY MULLET (GMU)

(*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 1142 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 (1160 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 (Table 2).

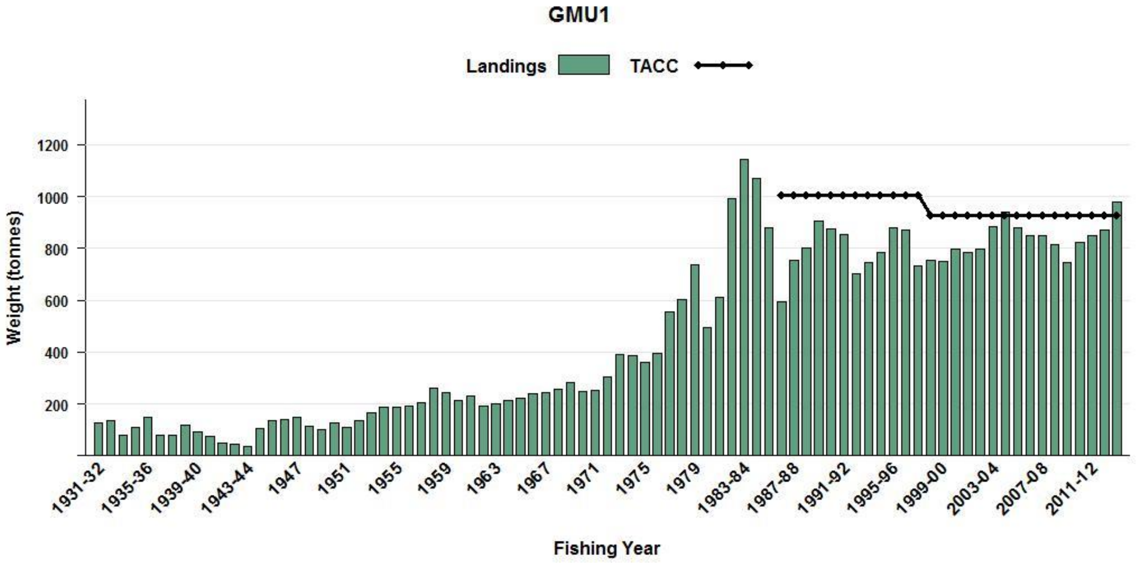


Figure 1: Reported commercial landings and TACC for the main GMU stock; GMU 1 (Auckland).

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 2013–14 and actual TACCs (t) for 1986–87 to 2013–14. 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	925	2	20	< 1	30	< 1	20	10	784	1 005
2002–03	797	925	1	20	< 1	30	0	20	10	798	1 005
2003–04	886	925	< 1	20	0	30	< 1	20	10	796	1 005
2004–05	941	925	< 1	20	0	30	0	20	10	941	1 005
2005–06	878	925	< 1	20	< 1	30	0	20	10	878	1 005
2006–07	847	925	1	20	0	30	< 1	20	10	845	1 005
2007–08	848	925	1	20	< 1	30	< 1	20	10	849	1 005
2008–09	814	925	1	20	0	30	0	20	10	815	1 005
2009–10	746	925	< 1	20	0	30	0	20	10	746	1 005
2010–11	825	925	< 1	20	< 1	30	< 1	20	10	826	1 006
2011–12	848	925	< 1	20	< 1	30	< 1	20	10	848	1 006
2012–13	871	925	< 1	20	< 1	30	< 1	20	10	871	1 006
2013-14	981	925	<1	20	0	30	0	20	10	981	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.

The 1993–94 North Region Recreational Fishing Survey (Teirney et al 1997) estimated the annual recreational catch from GMU 1 at 150 t (Table 3). This represents 17% of the total landings from GMU 1 in 1993–94. The 1996 National Recreational Fishing Survey (Bradford 1998) estimated the annual recreational catch from GMU 1 in the 1996 fishing year at 106 t (Table 3). The 2000 National Recreational Fishing Survey (Boyd et al 2004) fishing survey provided an estimate of 102 t (Table 3). Results from the three recreational surveys are relatively consistent; it is likely the annual level of recreational extraction from GMU 1 is in the order of 100–150 t. The Minister of Fisheries provided an allowance for customary harvest of 100 t beginning in 1998–99.

Table 3: Estimated number of grey mullet harvested by recreational fishers by Fishstock and survey year, the corresponding estimated survey harvest, and the estimated Fishstock harvest.

		Total			
Fishstock	Survey year	Number	CV	Estimated harvest range (t)	Point estimate (t)
GMU 1	1993–94	170 000	19%	90–210	150
GMU 1	1996	110 000	25%	80–130	106
GMU 1	2000	110 000	33%	68–136	102

It was recommended that the harvest estimates from the diary surveys 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. Relative comparisons may be possible between stocks within these surveys.

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 42° N and 42° 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 $M = \log_e 100$/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 (Ministry for Primary Industries 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*	2013–14 Actual TACC	2013–14 Reported landings
GMU 1	Auckland (East) (West) 1 & 9	825	925	981
GMU 2	Central (East) (West) 2 & 8	-	20	< 1
GMU 3	South-East (Coast) (Chatham) 3, 4, Southland and Sub-Antarctic 5 & 6	-	30	0
GMU 7	Challenger 7	-	20	0
GMU 10	Kermadec 10	_	10	0
Total		-	1 006	981

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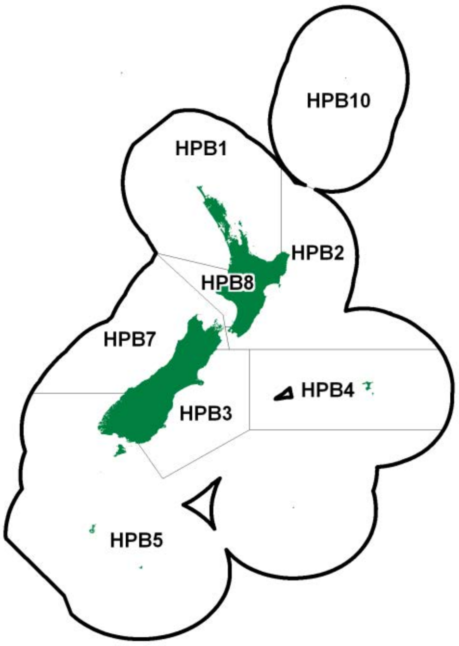
GROPER (HPB)

(*Polyprion oxygeneios*, *Polyprion americanus*)
Hapuku, Moeone



1. FISHERY SUMMARY

1.1 Commercial fisheries

Both groper species, *Polyprion oxygeneios* (hapuku) 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 catches 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 häpuku and bass. Historical estimated and recent reported grouper landings and TACCs are shown in Tables 2 and 3, while Figure 1 shows the historical and recent landings and TACC values for the main grouper 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: MPI 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 1500 t in 1936 were typical of the range of catches (1000–2000 t) from then until 1978. After a decrease during the war when effort was restricted, landings in the total fishery slowly declined from almost 2000 t in 1949 to about 1300 t in the mid 1970s. They then increased sharply to 2700 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 2. Total landings of groper were relatively stable throughout the mid 1990s, remaining below 1500 t until 1998–99. From 1999–2000 and onwards, catches have generally ranged between 1500 t and 1700 t. Although the TACC in HPB 3 has been exceeded in recent years, catches have generally remained within the quotas for individual Fishstocks. Despite recent increases in total landings, they have never exceeded the 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), this will result 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
1931-32	231	0	207	2
1932-33	201	276	242	0
1933-34	198	330	173	25
1934-35	204	304	212	57
1935-36	179	201	146	70
1936-37	129	445	115	12
1937-38	119	523	315	15
1938-39	90	621	479	8
1939-40	118	502	409	12
1940-41	120	444	286	9
1941-42	80	450	302	10
1942-43	69	287	315	9
1943-44	59	316	271	8
1944	55	332	286	9
1945	106	311	271	3
1946	154	326	409	7
1947	98	401	563	5
1948	111	450	526	11
1949	174	498	547	7
1950	141	423	555	9
1951	104	353	381	19
1952	112	368	373	35
1953	105	349	431	33
1954	156	355	397	32
1955	142	351	419	26
1956	106	404	439	32
1957	133	380	419	23
1958	115	473	458	30
1959	147	406	350	54
1960	122	394	331	48
1961	135	369	348	50
1962	163	355	298	40
1963	197	315	321	56
1964	224	397	365	41
1965	212	368	325	68
1966	213	415	315	4
1967	229	448	275	0
1968	139	357	264	0
1969	197	454	220	0
1970	259	670	239	2
1971	191	562	289	4
1972	401	370	188	0
1973	419	481	215	0
1974	356	457	208	2
1975	227	315	213	18
1976	183	220	350	107
1977	277	301	265	87
1978	348	470	194	10
1979	620	487	355	147
1980	956	376	414	40
1981	693	373	457	59
1982	957	336	402	26

Year	HPB 5	HPB 7	HPB 8
1931-32	130	13	13
1932-33	91	98	53
1933-34	99	127	53
1934-35	115	106	56
1935-36	33	109	33
1936-37	29	156	50
1937-38	29	148	52
1938-39	75	156	50
1939-40	59	155	43
1940-41	54	142	41
1941-42	46	150	44
1957	92	246	76
1958	96	250	109
1959	68	198	87
1960	100	150	77
1961	82	139	80
1962	101	142	75
1963	75	159	71
1964	76	193	74
1965	48	176	52
1966	49	163	62
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 2013–14 and actual TACCs (t) from 1986–87 to 2013–14. 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

	HPB 7		HPB 8		HPB 10			
	7		8		10		Total	
	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
1993–94	193	236	69	80	0	10	1 455	2 167
1994–95	192	236	68	80	0	10	1 437	2 179

Table 3 [Continued]

	HPB 7		HPB 8		HPB 10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
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

* FSU data.

# Values in HPB 10 included catches taken under exploratory permit.

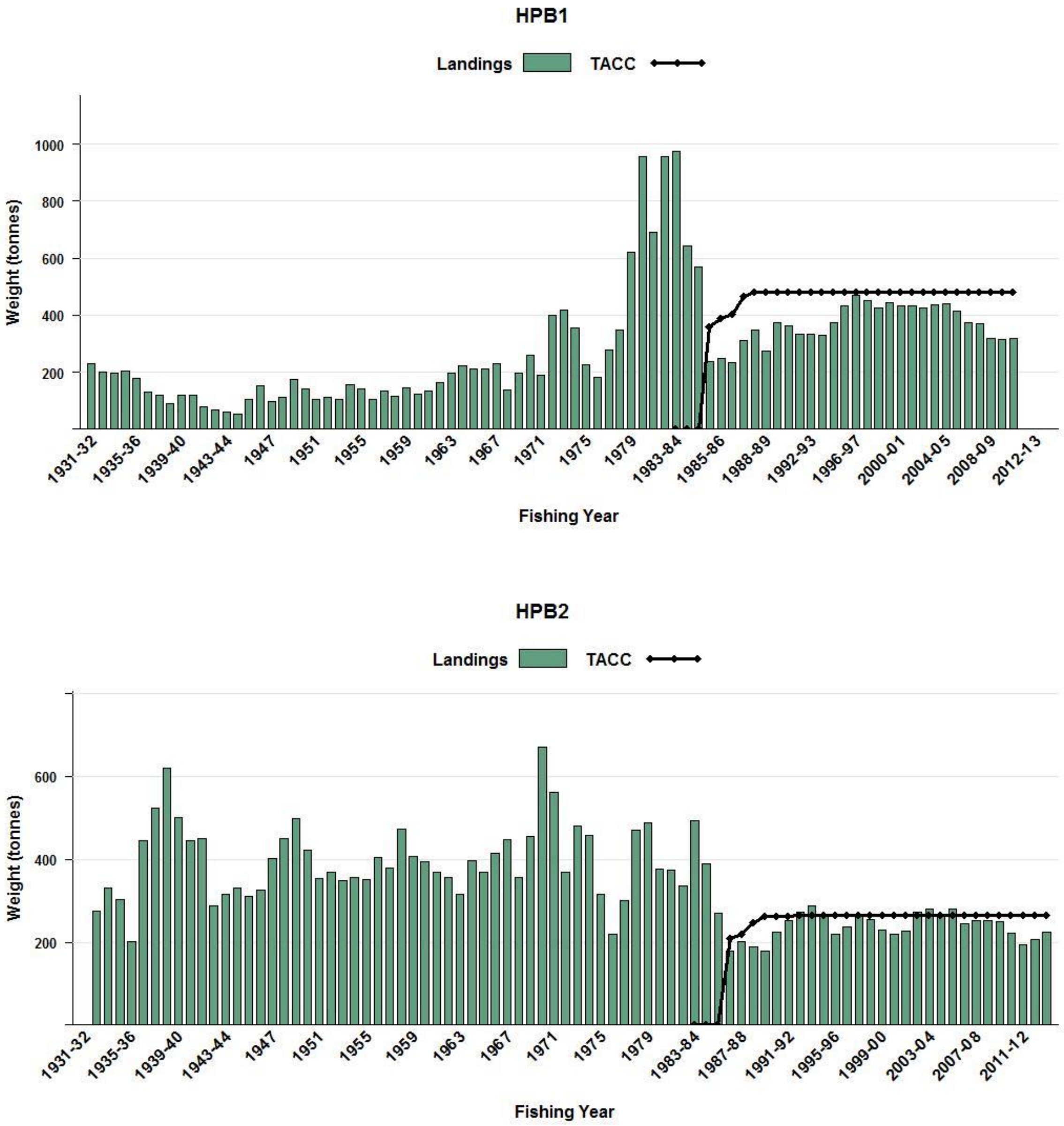


Figure 1: Total reported landings and TACC for the seven main HPB stocks. From top to bottom: HPB 1 (Auckland), and HPB 2 (Central East) [Continued on the next page].

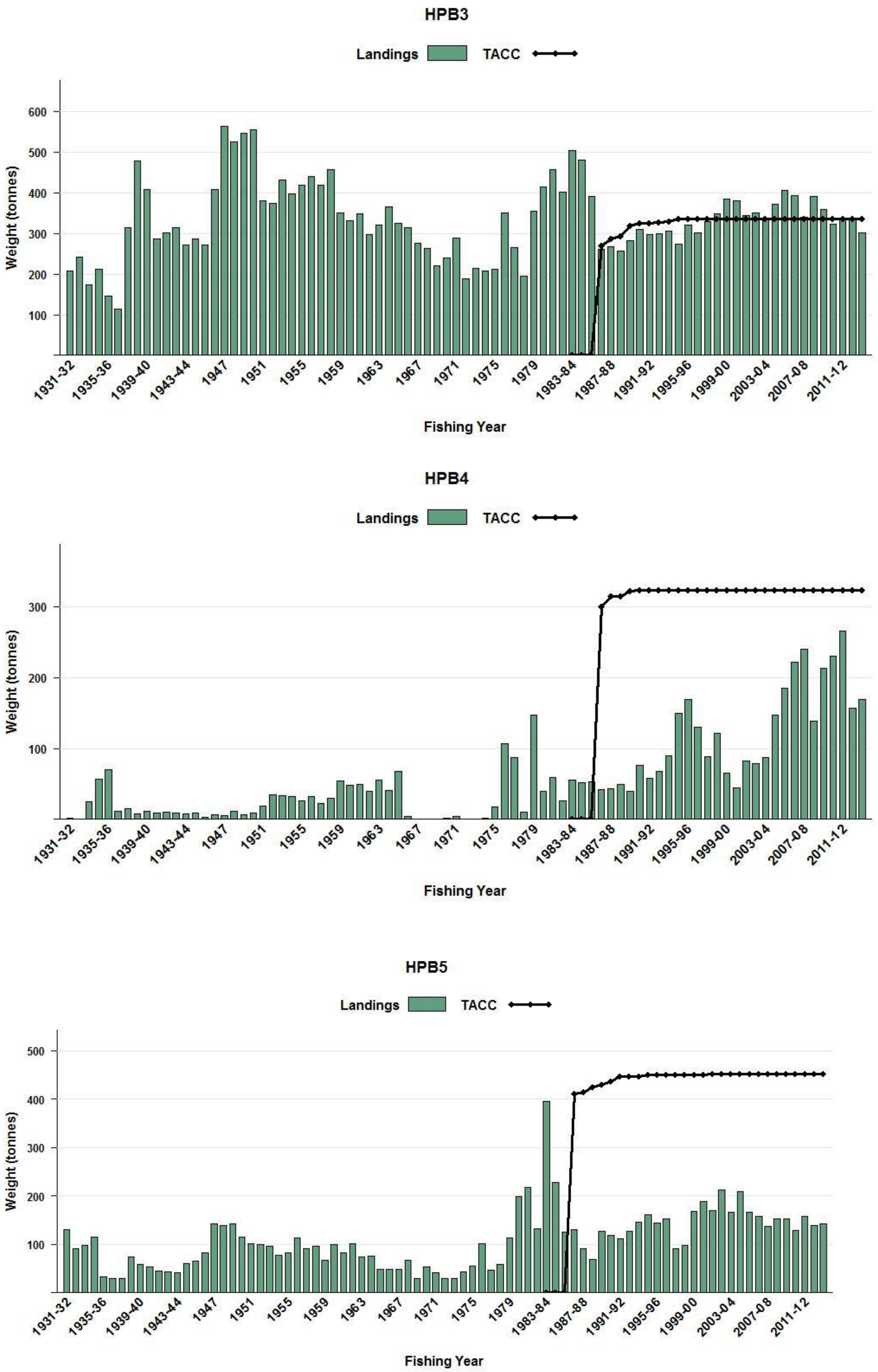
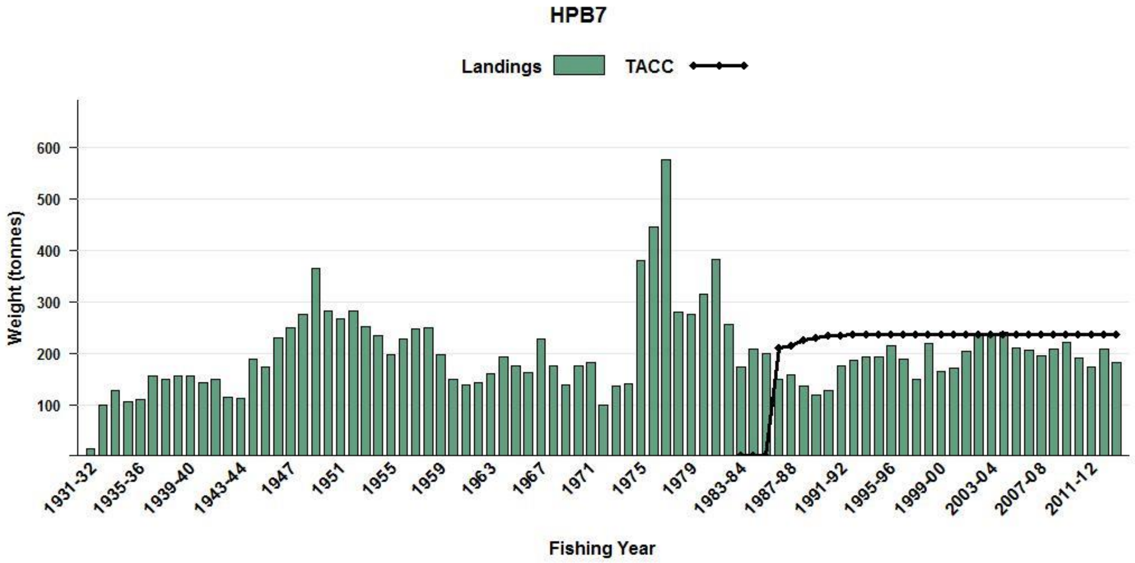


Figure 1 [Continued]: Total reported landings and TACC for the seven main HPB stocks. From top to bottom: HPB 3 (South East Coast), HPB 4 (Chatham Rise), and HPB 5 (Southland, Sub-Antarctic). [Continued on next page].



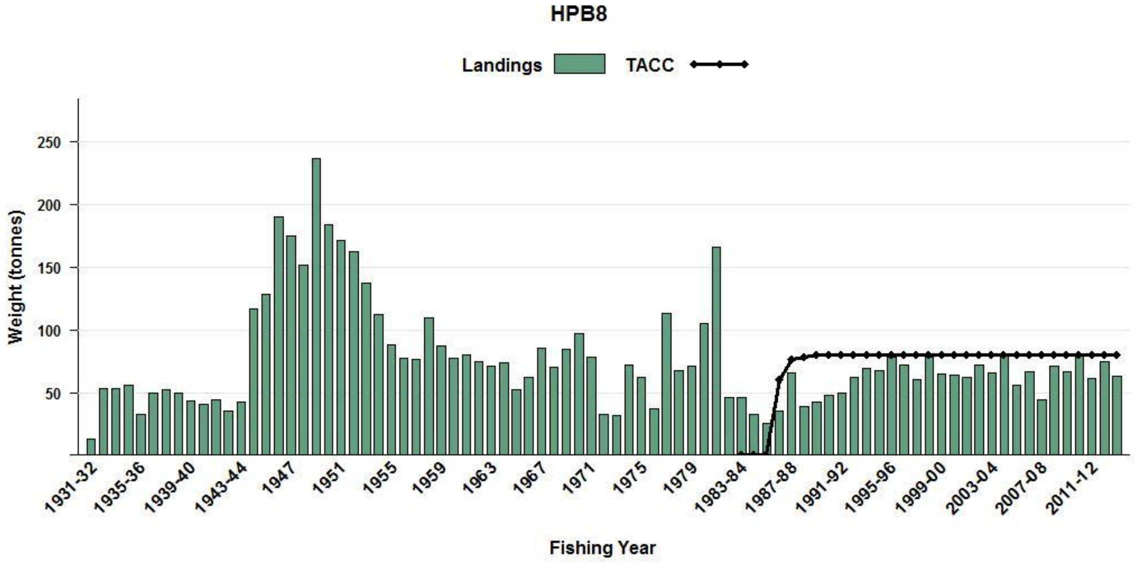


Figure 1 [Continued]: Total reported landings and TACC for the seven main HPB stocks. From top to bottom: HPB 7 (Challenger) and HPB 8 (Central).

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	Harvest CV (%)	Point range (t)	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

A key component of the estimating recreational harvest from diary surveys is determining the proportion of the population that fish. The Recreational Technical Working Group concluded that the harvest estimates from the diary surveys 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. The 1999–2000 harvest estimates for each Fishstock should be evaluated with reference to the coefficient of variation.

Recreational harvest appears to have exceeded the commercial catch in HPB 2. The last nationwide recreational survey was undertaken in 2001, but the results for QMA 2 were considered by the Recreational Technical Working Group to be unbelievably high.

1.3 Customary non-commercial fisheries

Groper (hapuku 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 hapuku 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 hapuku extends to at least 300 m and bass to 500 m.

Hapuku mature sexually between 10 and 13 years old and may live in excess of 60 years (Francis et al 1999). Cook Strait hapuku 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 hapuku 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 hapuku on the Stewart-Snares Shelf are mainly 50–80 cm, modal length 60 cm, and therefore juveniles. Trawl-caught hapuku 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.

Hapuku 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 7.

Table 7: 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 = hapuku, BAS = bass groper)

3. STOCKS AND AREAS

Tagging studies reveal considerable mixing of hapuku between Otago, South Canterbury and Cook Strait. Fishstock boundaries in Cook Strait separate Cook Strait hapuku 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 hapuku. Current stock boundaries are based on QMAs and do not reflect biological l stocks . Existing data cannot describe the stock structure of New Zealand groper (Paul 2002b). Electrophoretic studies suggest that separate stocks of hapuku could occur. However, the genetic heterogeneity of Cook Strait hapuku, seasonal movements of hapuku through this area, moderately long-distance movements of some tagged hapuku, 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 hapuku and bass either separately or in combination.

4.2 Biomass estimates

Estimates of current and reference biomass are not available. Data for hapuku 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).

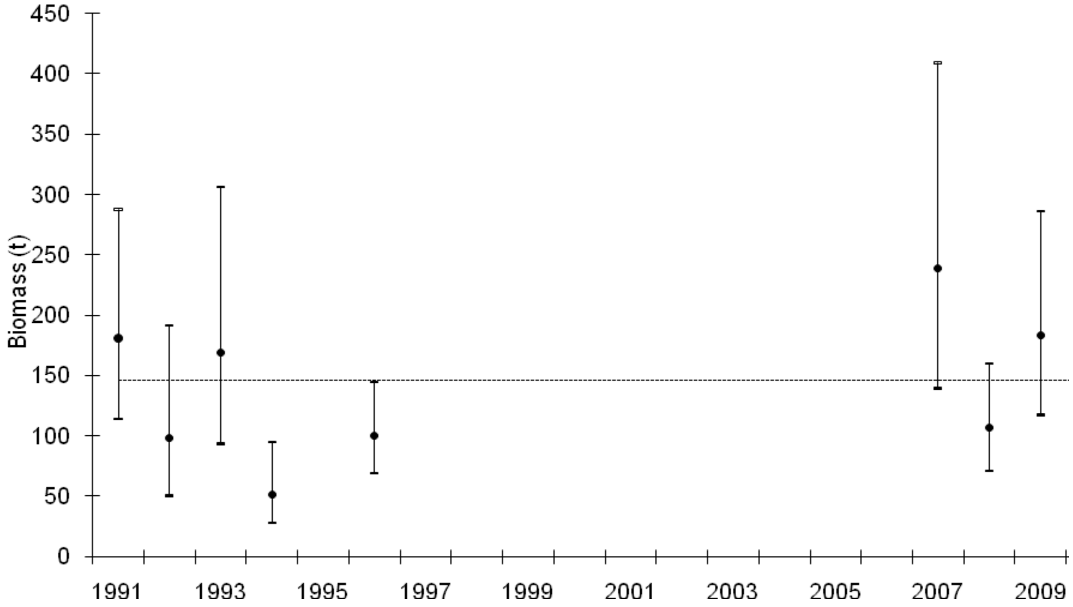


Figure 2: Biomass estimates ±95% CI (estimated from survey CV's assuming a lognormal distribution) and the time series mean (dotted line) from the East Coast South Island trawl survey.

4.4 Yield estimates and projections

Current biomass cannot be estimated, so *CAY* cannot be determined.
Yield estimates are summarised in Table 8.

Table 8: 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

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 9.

Table 9: Summary of TACCs (t) and reported landings (t) of groper for the most recent fishing year.

Fishstock	QMA	FMAs	2013–14 Actual TACC	2013–14 Reported Landings
HPB 1	Auckland (East, West)	1 & 9	481	319
HPB 2	Central (East)	2	266	224
HPB 3	South-east (Coast)	3	335	301
HPB 4	South-east (Chatham)	4	323	169
HPB 5	Southland, Sub-Antarctic	5 & 6	451	143
HPB 7	Challenger	7	236	182
HPB 8	Central (West)	8	80	63
HPB 10	Kermadec	10	10	0
Total			2 182	1 401

6. FOR FURTHER INFORMATION

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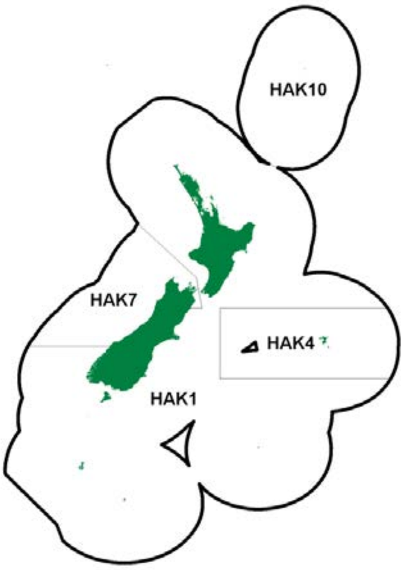
HAKE (HAK)

(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, while 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 7 700 t out of a total for the EEZ of 13 211 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 also 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 2 000 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 2012). From 1 October 2005 the TACC for HAK 7 was increased to 7 700 t within an overall TAC of 7 777 t. This new catch limit was set equal to average annual catches over the previous 12 years. However, HAK 7 landings have been relatively low since 2007–08.

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. 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 3 000 and 4 000 t) up to 2004–05, but have since been generally less than 3 000 t. 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 3 500 t to 1 800 t. Annual landings have been markedly lower than the new TACC since then.

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 2 000 t of hake were caught from that area. In previous years, catches from this area have typically been between 100–800 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 2013–14 and actual TACs (t) for 1986–87 to 2013–14. FSU data from 1984–1986; QMS data from 1986 to the present.

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

[1] FSU data

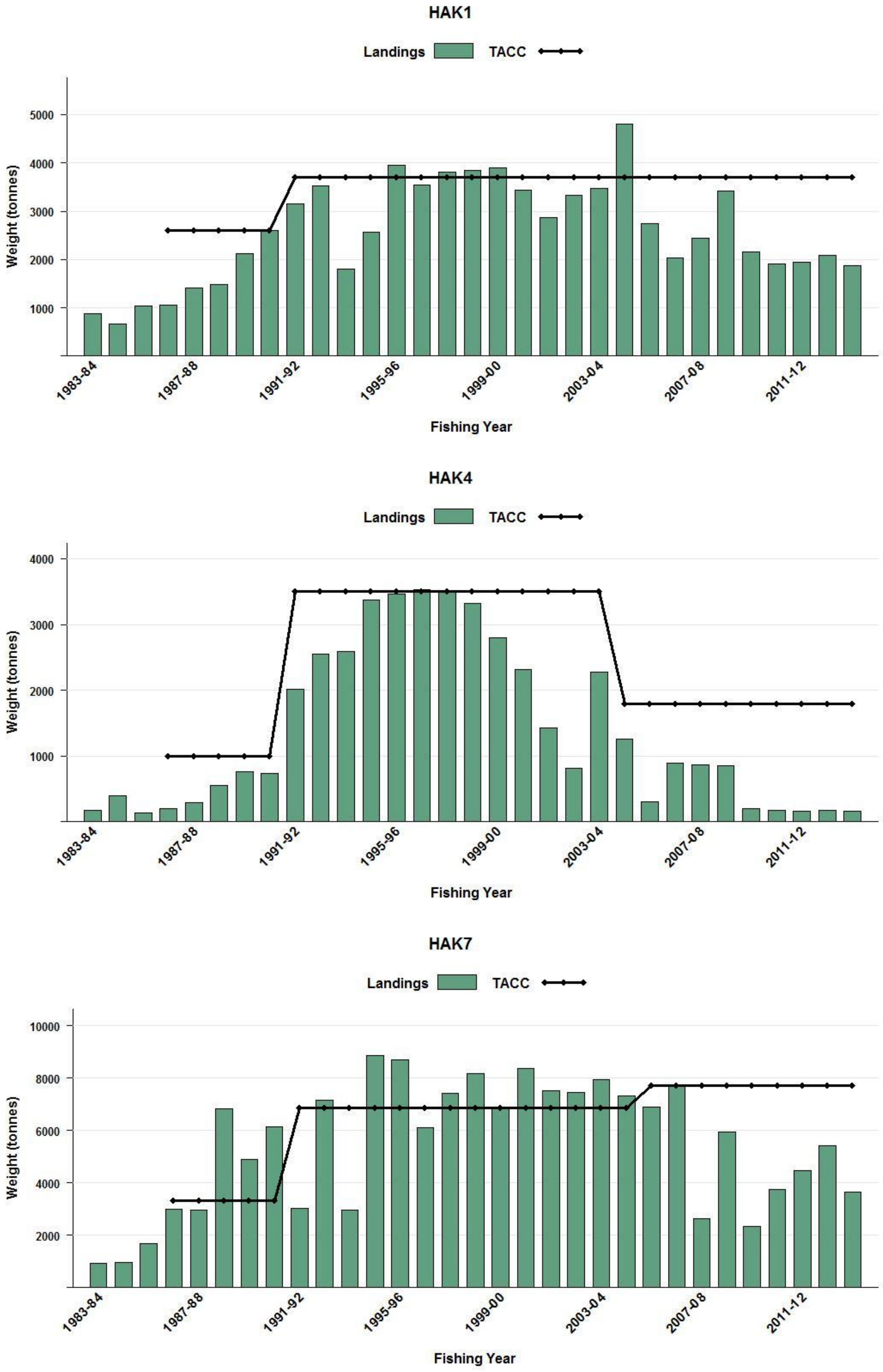


Figure 1: Reported commercial landings and TACC for the three main HAK stocks. From top left: HAK 1 (Sub-Antarctic and part of Chatham Rise), HAK 4 (eastern Chatham Rise), and HAK 7 (Challenger).

1.2 Recreational fisheries

The recreational fishery for hake is negligible.

1.3 Customary non-commercial fisheries

The amount of hake caught by Maori 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 stocks, estimating that the level of hake over-reporting on the Chatham Rise (and hence under-reporting on 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 6 835 t and 8 696 t; for 1989–90, 4 903 t reported and 8 741 t estimated; and for 1990–91, 6 189 t reported and 8 246 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 2012–13 are given in Table 3.

Table 3: Revised landings from fishing years 1974–75 to 2012–13 (t) for the west coast South Island, Sub-Antarctic, and Chatham Rise stocks. [Continued on next page].

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

Table 3 [Continued].

Fishing year	West coast S.I.	Sub-Antarctic	Chatham Rise
1997–98	7 674	2 606	4 074
1998–99	8 742	2 796	3 589
1999–00	7 031	3 020	3 174
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

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.

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 in 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* of 0.19 yr^{-1} for both sexes, 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 total length at one year old, and about 35 cm total length 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 javelinfish, *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	$a = 2.13 \text{ x}10^{-9}$	$b = 3.281$			(Horn 2013a)
	Females	$a = 1.83 \text{ x}10^{-9}$	$b = 3.314$			(Horn 2013a)
	Both sexes	$a = 1.95 \text{ x}10^{-9}$	$b = 3.301$			(Horn 2013a)
Chatham Rise	Males	$a = 2.56 \text{ x}10^{-9}$	$b = 3.228$			(Horn 2013a)
	Females	$a = 1.88 \text{ x}10^{-9}$	$b = 3.305$			(Horn 2013a)
	Both sexes	$a = 2.00 \text{ x}10^{-9}$	$b = 3.288$			(Horn 2013a)
WCSI	Males	$a = 2.85 \text{ x}10^{-9}$	$b = 3.209$			(Horn 2013a)
	Females	$a = 1.94 \text{ x}10^{-9}$	$b = 3.307$			(Horn 2013a)
	Both sexes	$a = 2.01 \text{ x}10^{-9}$	$b = 3.294$			(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 (τ_1 = 1 and τ_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 on 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 fish stock (with no recorded landings) exists for the Kermadec FMA (HAK 10).

4. STOCK ASSESSMENT

The stock assessments reported here were completed in 2014 for the Sub-Antarctic stock (Horn 2015), 2012 for the Chatham Rise stock (Horn 2013b), and 2012 for the west coast South Island stock (Horn 2013b). 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 2014 stock assessment was carried out with data up to the end of the 2012–13 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 2012), 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 base case model partitioned the Sub-Antarctic stock population into age groups 1–30 with the last age group considered a plus group. It had sex in the partition, but with unsexed observations, unsexed selectivity, and estimation of age-dependent M. 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 1974–2013. There were three double-normal selectivity-at-age ogives; commercial fishing selectivity, and survey selectivities 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 over all years in the fishery and the surveys, and hence there was no allowance for possible annual changes in selectivity.

Sensitivity models were also run to investigate the effects of down-weighting the catch-at-age data, fixing M, estimating M as a constant rather than an age-dependent ogive, and including a trawl fishery CPUE series.

Five-year biomass projections were made assuming future catches in the Sub-Antarctic to be 2 000 t annually (the mean annual catch from 2008 to 2013). For each projection scenario, estimated future recruitment variability was sampled from actual estimates between 1997 and 2009.

4.1.2 Fixed biological parameters and observations

Estimates and assumed values for biological parameters used in the assessments are given in Tables 4 and 5 respectively. Variability in the Schnute age-length relationship was assumed to be lognormal with a constant CV of 0.1.

Table 5: Fixed biological parameters assumed for the Sub-Antarctic, Chatham Rise and WCSI stock assessment models.

Parameter		Value
Steepness (Beverton & Holt stock- recruitment relationship)		0.80
Proportion spawning		1.0
Proportion of recruits that are male		0.5
Natural mortality (M)	Male, Female, Both	0.20 y^{-1}, 0.18 y^{-1}, 0.19 y^{-1}
Maximum exploitation rate (U_{max})		0.7
Ageing error		Normally distributed, with CV = 0.08

Catch-at-age observations were available for each trawl survey of the Sub-Antarctic, and for the commercial fisheries from observer data in some years. A plus group for all the catch-at-age data was set at 30 with the lowest age set at 3.

Research survey abundance indices are given in Table 6. The catch history assumed in all model runs (Table 7) includes the revised estimates of catch reported by Dunn (2003).

Table 6: Research survey indices (and associated CVs) for the Sub-Antarctic stock.

Fishing	Vessel	Nov–Dec series [1]		Apr–May series [2]		Sep series [2]	
Year		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	*Tangaroa*	1 943	0.25				
2015*	*Tangaroa*	1 477	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.

4.1.3 Model estimation

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.

Catch-at-age data were fitted to the model as proportions-at-age with a multinomial error structure, where estimates of the proportions-at-age and associated CVs by age were estimated using the NIWA catch-at-age software by bootstrap. Biomass indices were fitted with lognormal likelihoods with assumed CVs set equal to the sampling CV.

Table 7: 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 2014 assume catch similar to the previous year.

Model year	Total	Model year	Total
1975	120	1995	1 995
1976	281	1996	2 779
1977	372	1997	1 915
1978	762	1998	2 958
1979	364	1999	2 854
1980	350	2000	3 108
1981	272	2001	2 820
1982	179	2002	2 444
1983	448	2003	2 777
1984	722	2004	3 223
1985	525	2005	2 592
1986	818	2006	2 541
1987	713	2007	1 711
1988	1 095	2008	2 329
1989	1 237	2009	2 446
1990	1 897	2010	1 927
1991	2 381	2011	1 319
1992	2 810	2012	1 900
1993	3 941	2013	1 859
1994	1 596	2014	1 800

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 of Francis et al. (2001). For CPUE indices, process error CVs were estimated to be 0.15 following Francis (2011). For the proportions-at-age observations from the trawl survey and fishery, a multinomial error distribution was assumed. Process errors for the catch-at-age series were captured by the effective sample sizes per year, used in the multinomial likelihood, which were estimated iteratively using method TA1.8 described in 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. The values estimated for process error in the MPD runs were then fixed for the MCMC runs.

Year class strengths were assumed known (and equal to one) for years before 1974 and after 2013, 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 must average one. The Haist parameterisation for year class multipliers was used.

MCMCs were estimated using 2×10^7 iterations, a burn-in length of 1.75×10^7 iterations, and with every 2500th sample kept from the final 2.5×10^6 iterations (i.e., a final sample of length 1000 was taken from the Bayesian posterior).

4.1.4 Prior distributions and penalty functions

The assumed prior distributions used in the assessment are given in Table 8. Most priors were intended to be relatively uninformed, and were estimated with wide bounds. The exceptions were the choice of informative priors for the survey *q*s.

The priors for survey *q*s 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). 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 *q*s were estimated as free (not nuisance) parameters.

Penalty functions were 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, and to ensure that all estimated year class strengths averaged 1.

Table 8: 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	350 000
Year class strengths	Lognormal	1.0	1.1	0.01	100
Trawl survey q^1	Lognormal	0.16	0.79	0.01	0.4
CPUE q	Uniform-log	–	–	1e-8	1e-3
Selectivities	Uniform	–	–	0	20–200[2]
$M\ (x_0, y_0, y_1, y_2)^3$	Uniform	–	–	3, 0.01, 0.01, 0.01	15, 0.6, 1.0, 1.0

[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.
[3] x_0, age at minimum M; y_0, M at x_0; y_1, M at the minimum age in the partition; y_2, M at the maximum age in the partition.

4.1.5 Model estimates

Estimates of biomass were produced for an agreed base case run using the biological parameters and model input parameters described earlier. In addition, four sensitivities were investigated: (1) halving the effective sample sizes of the composition data (the half N_{eff} model), (2) the estimation of M as a sex-dependent constant (the estimate M model), (3) fixing M at the previously used default values of 0.20 for males and 0.18 for females (the fixed M model), and (4) including the trawl fishery CPUE series (the CPUE model). For all runs, MPD fits were obtained and qualitatively evaluated, and MCMC estimates of the median posterior and 95% percentile credible intervals were determined for current and virgin biomass, and projected states.

The estimated MCMC marginal posterior distributions from the base case model are shown for year class strength (Figure 2). Median and 95% CI are shown for biomass (Figure 3). Year class strength estimates suggested that the Sub-Antarctic stock is 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 2004. Estimates from 2005 to 2007 are just above average. Consequently, biomass estimates for the stock declined, particularly through the early 1990s, but are currently exhibiting an upturn. Biomass estimates for the stock appear relatively healthy, with estimated current biomass from the base model at 60% of B_0 (Figure 3, Table 9). Annual exploitation rates (catch over vulnerable biomass) were low (less than 0.1) in all years as a consequence of the high estimated stock size relative to the level of catches (Figure 4).

Resource survey and fishery selectivity ogives were essentially logistic (even though they were estimated using double-normal parameterisation). The summer survey ogive was tightly defined and suggested that hake were fully selected by the research gear at age 5. Fishing selectivity (also tightly defined) indicated that hake were fully selected by about age 9 years, as would be expected given the use of larger mesh size than in the trawl survey.

The assessment relied on biomass data from the two Sub-Antarctic trawl survey series (summer, and autumn), and both were reasonably well fitted. It was apparent, however, that there can be marked changes in catchability between adjacent pairs of surveys. Estimated trawl survey catchability constants were very low (in the base model about 4–7% based on doorspread swept area estimates), suggesting that the absolute catchability of the Sub-Antarctic trawl surveys is extremely low. It is not known if the catchability of the Sub-Antarctic trawl survey series is as low as estimated by the model, but 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.

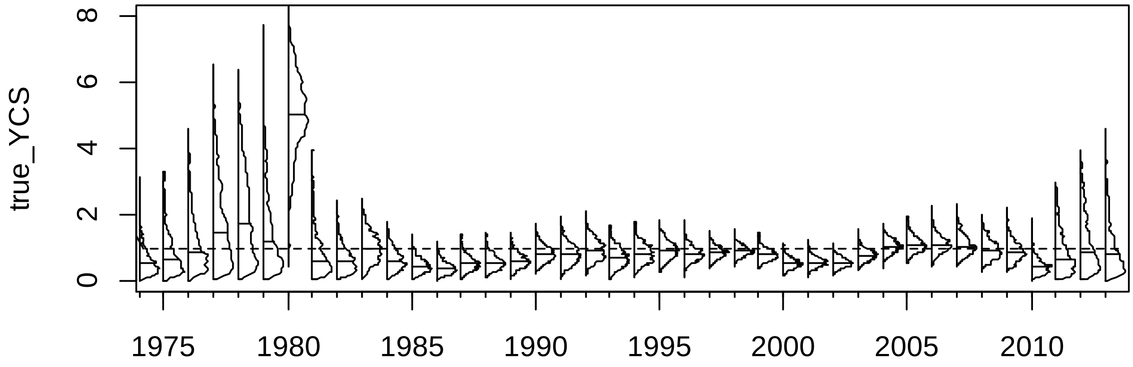


Figure 2: Estimated posterior distributions of year class strengths for the base case for the Sub-Antarctic stock. The dashed horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

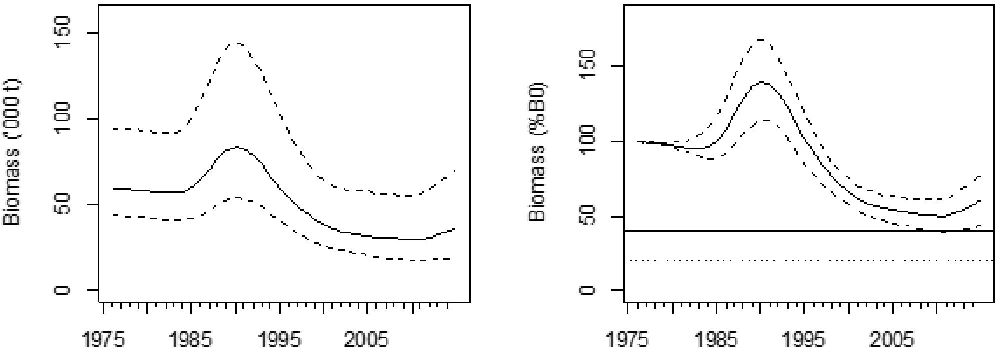


Figure 3: Estimated median trajectories (with 95% credible intervals shown as dashed lines) for the Sub-Antarctic stock base case model for absolute biomass and biomass as a percentage of B_0. The management target (40% B_0, solid horizontal line) and soft limit (20% B_0, dotted horizontal line) are shown on the right-hand panel.

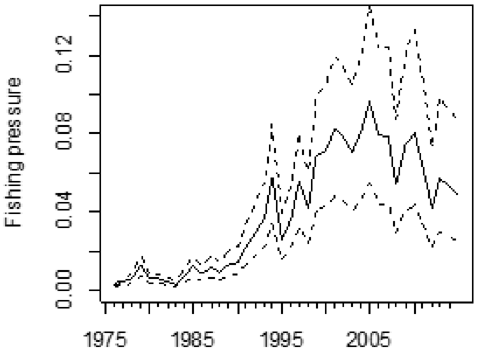


Figure 4: Exploitation rates (catch over vulnerable biomass) for the Sub-Antarctic stock base case model.

Estimates of the status of the Sub-Antarctic stock suggest that there has been a decline in the stock size since the late 1980s, but, owing to an apparent increase in stock size during the mid 1980s (driven by a series of above average year classes) current stock size is healthy relative to the estimated virgin biomass. Catches averaging about 2300 t annually since 1990–91 appear to have had a relatively slight effect on the biomass level, given the generally lower than average recruitment during that time. Consequently, future annual catches of 2000 t (the average since 2008), in tandem with some recent stronger than average year classes, are projected to allow stock size to be maintained or increase slightly by 2019 (Table 10). However, the lack of contrast in abundance indices since 1991 indicates that while the status of the Sub-Antarctic stock is probably similar to that in the mid 1990s, the absolute level of current biomass is very uncertain.

Table 9: Bayesian median (95% credible intervals) (MCMC) of B_0, B_{2014}, and B_{2014} as a percentage of B_0 for the Sub-Antarctic base model and sensitivity runs.

Model run	B_0	B_{2014}	B_{2014} (% B_0)
Base	59 290 (44 040–94 040)	37 990 (19 740–70 310)	60.4 (43.6–77.6)
Half N_{eff}	50 120 (39 340–77 510)	27 910 (14 890–55 840)	55.4 (37.2–77.5)
Estimate M	65 610 (47 940–105 840)	44 900 (25 500–84 370)	67.8 (49.9–89.1)
Fixed M	60 270 (46 210–99 970)	33 620 (19 170–67 160)	54.9 (39.8–72.5)
CPUE	79 580 (59 330–102 310)	60 980 (38 140–86 890)	76.2 (62.5–87.0)

Sensitivity runs including trawl CPUE and estimating M as a constant both give higher current stock status, while less weight on the ageing data and a fixed M at age give slightly lower current stock status. None of the tested sensitivity runs were considered to be better models than the base run, and some were clearly worse. Down-weighting the ageing data resulted in unrealistic survey selectivity ogives and estimates of M at younger ages. Estimating a constant M also produced unrealistic survey selectivity ogives. The inclusion of CPUE flattened the recent biomass trajectory, resulting in even lower estimates of survey catchability than in the base model.

Table 10: Bayesian median (95% credible intervals) projected biomass in 2019 (B_{2019}), B_{2019} as a percentage of B_0, and B_{2019}/B_{2014} (%) for the Sub-Antarctic base model and sensitivity models where future annual catches are assumed to be 2000 t.

Model run	Future catch (t)	B_{2019}	B_{2019} (% B_0)	B_{2019}/B_{2014} (%)
Base	2 000	39 560 (19 760–79 890)	65.5 (41.8–90.5)	107 (87–135)
Half N_{eff}	2 000	29 290 (14 130–62 070)	57.7 (34.3–87.4)	103 (80–133)
Estimate M	2 000	45 420 (23 550–89 220)	68.0 (46.0–102.6)	99 (79–139)
Fixed M	2 000	33 680 (16 950–75 050)	55.1 (34.5–83.8)	100 (77–140)
CPUE	2 000	66 350 (36 280–95 320)	81.8 (59.3–101.8)	107 (88–129)

4.1.6 Estimates of sustainable yields

Yield estimates were not reported.

4.2 HAK 4 (Chatham Rise stock)

The 2012 stock assessment was carried out with data up to the end of the 2010–11 fishing year. The assessment used research time series of abundance indices (trawl surveys of the Chatham Rise from 1992 to 2012), 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.

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 1975–2006. There were three double-normal selectivity-at-age ogives; east and west commercial fishing selectivities and a survey selectivity for the Chatham Rise January trawl survey series. Selectivities were assumed constant over 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.

Five-year biomass projections were made assuming future catches on the Chatham Rise equal to the HAK 4 TACC of 1800 t. For the projection, estimated future recruitment variability was sampled from actual estimates between 1984 and 2009, a period including the full range of recruitment successes.

4.2.2 Fixed biological parameters and observations

Estimates and assumed values for biological parameters used in the assessments are given in Tables 4 and 5 respectively. 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 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 v2.22 (Bull et al 2008). 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 0.2. 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.

Model year	West	East	Total	Model year	West	East	Total
1975	80	111	191	1994	368	2 912	3 280
1976	152	336	488	1995	597	2 903	3 500
1977	74	1 214	1 288	1996	1 353	2 483	3 836
1978	28	6	34	1997	1 475	1 820	3 295
1979	103	506	609	1998	1 424	1 124	2 547
1980	481	269	750	1999	1 169	3 339	4 509
1981	914	83	997	2000	1 155	2 130	3 285
1982	393	203	596	2001	1 208	1 700	2 908
1983	154	148	302	2002	454	1 058	1 512
1984	224	120	344	2003	497	718	1 215
1985	232	312	544	2004	687	1 983	2 671
1986	282	80	362	2005	2 585	1 434	4 019
1987	387	122	509	2006	184	255	440
1988	385	189	574	2007	270	683	953
1989	386	418	804	2008	259	901	1 159
1990	309	689	998	2009	1 069	832	1 902
1991	409	503	912	2010	231	159	390
1992	718	1 087	1 805	2011	822	118	940
1993	656	1 996	2 652	2012	800	150	950

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

* Not used in the reported assessment.

Year class strengths were assumed known (and equal to one) for years before 1975 and after 2009, 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 5×10^5 iterations, with every 2500th sample taken from the next 2.5×10^6 iterations (i.e., a final sample of 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 4.1.4 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.

Parameter description	Distribution	Parameters		Bounds	
B_0	Uniform-log	–	–	10 000	250 000
Year class strengths	Lognormal	1.0	1.1	0.01	100
Trawl survey q	Lognormal	0.16	0.79	0.01	0.4
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	50–200*

* A range of maximum values was used for the upper bound

4.2.5 Model estimates

Estimates of biomass were produced for an agreed base case run (research survey abundance series, constant M) using the biological parameters and model input parameters described earlier. Sensitivity models were run to investigate the effects of estimating M, including the CPUE series, and removing constraints on the survey selectivity ogive. Stock status from these three models was not markedly different to the base case, and the results are not presented here. For all runs, MPD fits were obtained and qualitatively evaluated. 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 5) and biomass (Figure 6). 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 (except for 2002). Consequently, biomass increased slightly during the late 1980s, then declined to about 2005. The growth of the strong 2002 year class has resulted in a recent slight upturn in biomass. Current stock biomass was estimated at about 47% of B_0 (see Figure 6 and Table 14). Annual exploitation rates (catch over vulnerable biomass) were low (less than 0.1) up to 1993 and since 2007, but moderate (although probably less than 0.25) in the intervening period (Figure 7).

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 6 years, compared to age 11 in the eastern fishery; this is logical given that the eastern fishery concentrates more on the spawning (i.e., older) biomass.

Base case model projections assuming a future annual catch of 1800 t suggest that biomass will decline to about 38% of B_0 by 2017 (Table 15). 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 1070 t in the last five years), but lower than what could be taken (if all the HAK 4 TACC plus some HAK 1 catch from the western Rise was taken).

Table 14: Bayesian median and 95% credible intervals of B_0, B_{2012}, and B_{2012} as a percentage of B_0 for the Chatham Rise model runs.

Model run	B_0	B_{2012}	B_{2012} (%B_0)
Base case	37 000 (30 110–67 000)	17 250 (11 010–41 550)	46.8 (35.3–63.4)

Table 15: Bayesian median and 95% credible intervals of projected B_{2017}, B_{2017} as a percentage of B_0, and B_{2017}/B_{2012} (%) for the Chatham Rise model runs.

Model run	Future catch (t)	B_{2017}	B_{2017} (%B_0)	B_{2017}/B_{2012} (%)
Base case	1 800	13 930 (6 990–35 800)	38.1 (22.0–57.2)	80 (56–109)

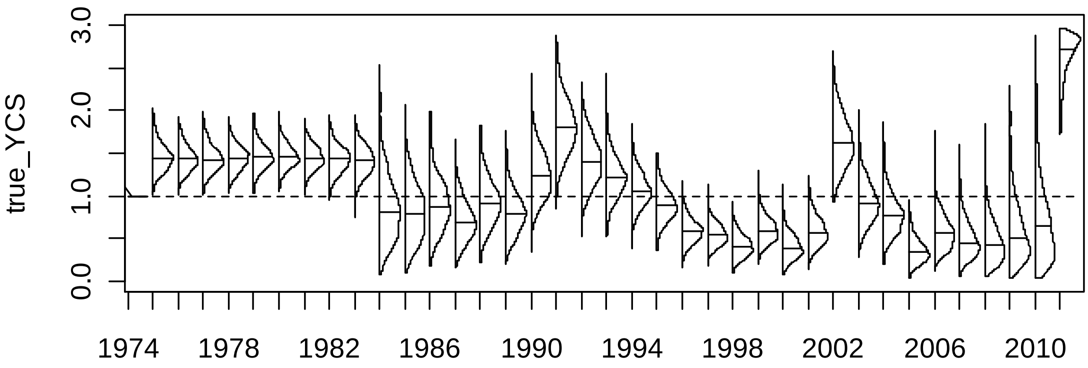


Figure 5: Estimated posterior distributions of year class strengths for the Chatham Rise (HAK 4) base case. The dashed horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

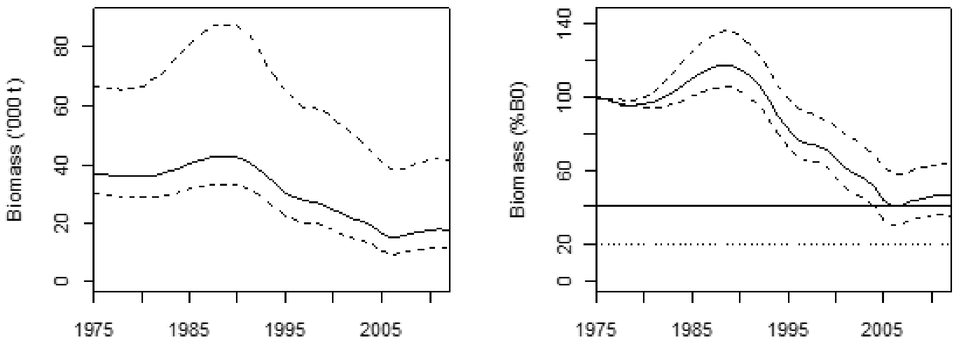


Figure 6: Estimated median trajectories (with 95% credible intervals shown as dashed lines) for the Chatham Rise (HAK 4) base case model for absolute biomass and stock status (biomass as a percentage of B_0).

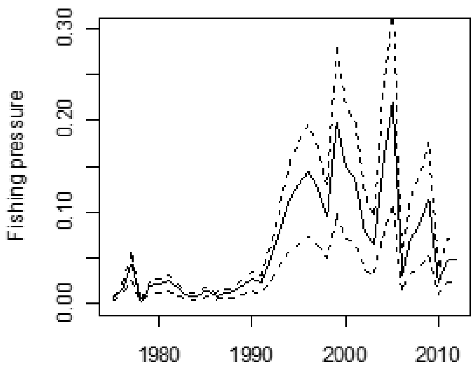


Figure 7: Exploitation rates (catch over vulnerable biomass) for the Chatham Rise stock base case model.

4.2.6 Estimates of sustainable yields

CAY yield estimates were not reported because of the uncertainty of the estimates of absolute biomass.

4.3 HAK 7 (West coast, South Island)

A new assessment for HAK 7 was carried out in 2012 using fisheries data up to the end of the 2010–11 fishing year. The assessment used catch-at-age from the commercial fishery since 1989–90, two comparable research surveys (in 2000 and 2012), a CPUE series from 2001 to 2011, and estimates of biological parameters. The selected CPUE series incorporated data since the change in 2001 to a new regulatory and reporting regime (involving ACE), and so was considered less likely to be biased by variations in fishing behaviour and catch reporting behaviour.

The stock assessment for HAK 7 had been last updated using data up to the end of the 2008–09 fishing year (Horn 2011). Commercial catch-at-age was the only input data series. No time series of biomass indices were incorporated in the model; no fishery-independent series were available and CPUE indices were considered unreliable.

4.3.1 Model structure

The base case model partitioned the WCSI stock population into unsexed age groups 1–30 with the last age group considered a plus group. The CPUE and survey biomass series were both included, and a constant *M* was used. The model was initialised assuming an equilibrium age structure at an unfished equilibrium biomass (B_0) in 1974, i.e., with constant recruitment set equal to the mean of the recruitments over the period 1973–2007. There were two double-normal selectivity-at-age ogives; commercial fishing selectivity, and survey selectivity. Selectivities were assumed constant over all years in the fishery and the surveys, and hence there was no allowance for possible annual changes in selectivity. Sensitivities to the base model investigated the effect of estimating *M* as an age-dependent function, and the effect of excluding the research survey data.

Five-year biomass projections were made assuming future WCSI catches of 4500 t annually (the mean annual catch since 2007–08) and 7700 t annually (the TACC). For each projection scenario, estimated future recruitment variability was sampled from actual estimates from 1995 to 2006, a period including both high and low recruitment success, but excluding the most recent estimated year class (2007).

4.3.2 Fixed biological parameters and observations

Estimates and assumed values for biological parameters used in the assessments are given in Tables 4 and 5, respectively. Variability in the Schnute age-length relationship was assumed to be lognormal with a constant CV of 0.1.

Commercial fishery catch-at-age observations were available for 1979 (fishing by RV *Wesermünde*) and 1989–90 to 2010–11 (observer data). Research survey biomass and proportions-at-age data (from 2000 and 2012) were also fitted in the model. The catch history assumed in the model runs is shown in Table 3. Resource survey abundance indices are given in Table 16, and CPUE indices in Table 17

Table 16: Research survey indices (and associated CVs) for the WCSI stock.

Year	Vessel	Biomass (t)	CV
2000	*Tangaroa*	803	0.13
2012	*Tangaroa*	583	0.12
2013*	*Tangaroa*	331	0.17

* Not used in the reported assessment.

Table 17: Trawl fishery CPUE indices (and associated CVs) for the WCSI stock.

Year	Index	CV
2000–01	1.17	0.04
2001–02	1.55	0.04
2002–03	1.11	0.04
2003–04	0.95	0.04
2004–05	0.85	0.04
2005–06	0.79	0.04
2006–07	0.64	0.04
2007–08	0.44	0.04
2008–09	0.61	0.04
2009–10	0.68	0.05
2010–11	0.88	0.05

4.3.3 Model estimation

Model parameters were derived using Bayesian estimation implemented using the general-purpose stock assessment program CASAL v2.22 (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.

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. A process error CV of 0.16 for the CPUE series was estimated following 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 discrete normally distributed error with a CV of 0.08.

Year class strengths were assumed known (and equal to one) for years before 1973 and after 2007, 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 one.

MCMCs were estimated using 3×10^6 iterations, a burn-in length of 5×10^5 iterations, and with every 2500th sample kept from the final 2.5×10^6 iterations (i.e., a final sample of length 1000 was taken from the Bayesian posterior).

4.3.4 Prior distributions and penalty functions

The assumed prior distributions used in the assessment are given in Table 18. 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 priors as a starting point (see Section 4.1.4) 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 in strata 0004 A–C and 0012 A–C 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. So because biomass from only 54% of the WCSI hake habitat was included in the indices, the Chatham Rise prior on μ 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]. Priors for all selectivity parameters were assumed to be uniform.

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 18: The assumed priors for key distributions (when estimated) for the WCSI stock assessment. The parameters are mean (in natural space) and CV for lognormal.

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*
M (x_0, y_0, y_1, y_2)	Uniform	–	–	3, 0.01, 0.01, 0.01	15, 0.6, 1.0, 1.0

* A range of maximum values was used for the upper bound

4.3.5 Model estimates

Estimates of biomass were produced for an agreed base case run (CPUE and survey abundance series, constant *M*) using the biological parameters and model input parameters described earlier. In addition, two sensitivities were investigated: (1) estimating *M* as a double exponential function thus allowing *M* to vary with age, and (2) excluding the research survey biomass series. For all runs, MPD fits were obtained and qualitatively evaluated, and MCMC estimates of the median posterior and 95% percentile credible intervals were determined for current and virgin biomass, and projected states. However, only the estimates from the base case run and the sensitivity estimating M are reported in detail here. The other sensitivity produced estimates of stock status that were little different to those from the base case.

The estimated MCMC marginal posterior distributions from the base case model are shown for year class strength (Figure 8) and biomass (Figure 9). WCSI year class strength estimates exhibit a relatively low level of between-year variation, although there was a period of generally less than average recruitment from 1993 to 2003, followed by four years of relatively strong year classes. Estimated biomass declined throughout the late 1970s owing to relatively high catch levels, then increased through the mid 1980s concurrent with a marked decline in catch. Biomass then steadily declined from 1988 to 2007 owing to higher levels of exploitation and the recruitment of year classes that were generally of below-average strength. The increase since 2006 is a consequence of the recruitment of the above-average year classes since 2004. Estimated current biomass from the base model was 58% B_0 (Figure 9, Table 19). Annual exploitation rates (catch over vulnerable biomass) were low to moderate (less than 0.2) up to about 1999, but increased to 0.2 to 0.4 in 1977 and throughout the 2000s, and have subsequently declined (Figure 10). The exploitation rate that produced a biomass equal to 40% B_0 was 0.34 (Figure 10); it was determined by running the base MPD model for 1000 years, assuming constant average recruitment.

The median selectivity ogives for both the survey and the fishery were approximately logistic shaped, and their bounds were relatively wide. The ogives suggested that hake were fully selected by the fishery by about age 9, and slightly older in the survey.

The assessment relied on CPUE data since 2001 and biomass data from two trawl surveys. Both abundance series were well fitted. Likelihood profiling indicated that the fishery catch-at-age data dominated, but the abundance indices were consistent with a B_0 in the relatively narrow range of 80 000–100 000 t.

4.3.5.1 Deterministic B_{MSY}

Deterministic B_{MSY} was calculated in the 2013 assessment as 26% B_0. There are several reasons why B_{MSY}, as calculated in this way, is not a suitable target for management of the HAK 7 fishery. First, it assumes a harvest strategy that is unrealistic in that it involves perfect knowledge including perfect catch and biological information and perfect stock assessments (because current biomass must be known exactly in order to calculate target catch), a constant-exploitation management strategy with annual changes in TACC (which are unlikely to happen in New Zealand and not desirable for most stakeholders), and perfect management implementation of the TACC and catch splits with no under- or overruns. Second, it assumes perfect knowledge of the stock-recruit relationship, which is actually very poorly known. Third, it would be very difficult with such a low biomass target to avoid the biomass occasionally falling below 20% B_0, the default soft limit according to the Harvest Strategy Standard. Thus, the actual target needs to be above this theoretical optimum; but the extent to which it needs to be above has not been determined.

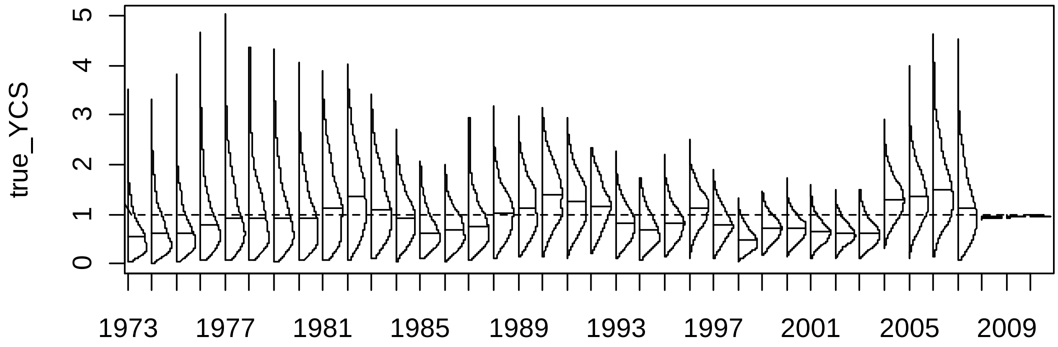


Figure 8: Estimated posterior distributions of year class strengths for the base case for the WCSI stock. The dashed horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

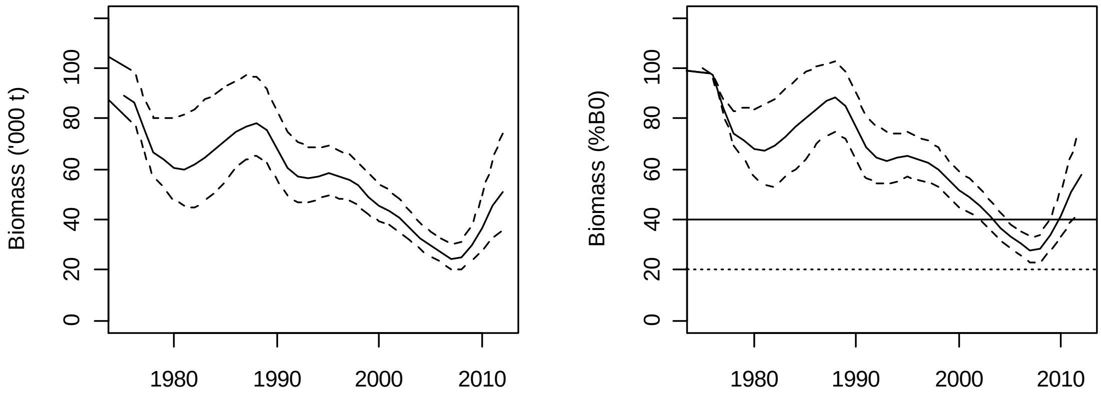


Figure 9: Estimated median trajectories (with 95% credible intervals shown as dashed lines) for the WCSI stock base case model for absolute biomass and biomass as a percentage of B_0. The management target (40% B_0, solid horizontal line) and soft limit (20% B_0, dotted horizontal line) are shown on the right-hand panel.

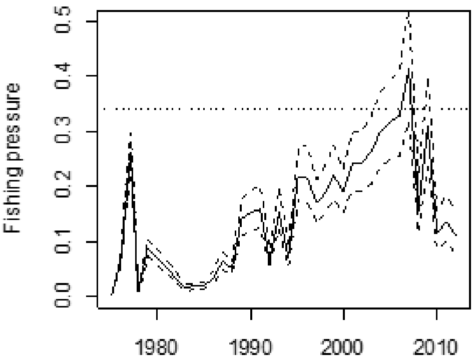


Figure 10: Exploitation rates (catch over vulnerable biomass) for the WCSI stock base case model. The dashed horizontal line shows the exploitation rate (*U*, 0.34) that produces a biomass of 40% B_0 (at equilibrium, and with deterministic recruitment).

Estimates of the status of the WCSI stock suggest that there has been a steady increase in stock size since 2007, when it was about 30% B_0.

4.3.6 Yield estimates and projections

Projections assuming future catches similar to recent levels (i.e., 4500 t annually) will probably allow the stock to grow slightly in the next five years, while catches at the level of the TACC (7700 t) will probably cause the stock to decline slightly but still be above the management target (40% B_0) in 2017 (Table 20).

Table 19: Bayesian median (95% credible intervals) (MCMC) of B_0, B_{2012}, and B_{2012} as a percentage of B_0 for the WCSI base case and the sensitivity.

Model run	B_0	B_{2012}	B_{2012} (%B_0)
Base case	88 920 (80 660–101 210)	51 190 (35 850–74 790)	57.7 (43.1–77.4)
Estimate *M*	88 360 (78 790–114 920)	48 190 (29 260–90 800)	54.2 (35.8–86.4)

Table 20: Bayesian median and 95% credible intervals of projected B_{2017}, B_{2017} as a percentage of B_0, and B_{2017}/B_{2012} (%) for the base run and the sensitivity, under two future annual catch scenarios.

Model run	Future catch (t)	B_{2017}	B_{2017} (%B_0)	B_{2017}/B_{2012} (%)
Base case	4 500	54 320 (33 010–92 820)	61.2 (39.2–97.7)	107 (78–146)
	7 700	41 990 (22 740–79 420)	47.4 (27.4–83.9)	83 (56–122)
Estimate *M*	4 500	54 810 (30 520–104 150)	61.1 (36.2–101.4)	114 (81–158)
	7 700	43 310 (17 390–93 410)	48.1 (20.8–89.1)	88 (55–130)

5. STATUS OF THE STOCKS

Stock Structure Assumptions

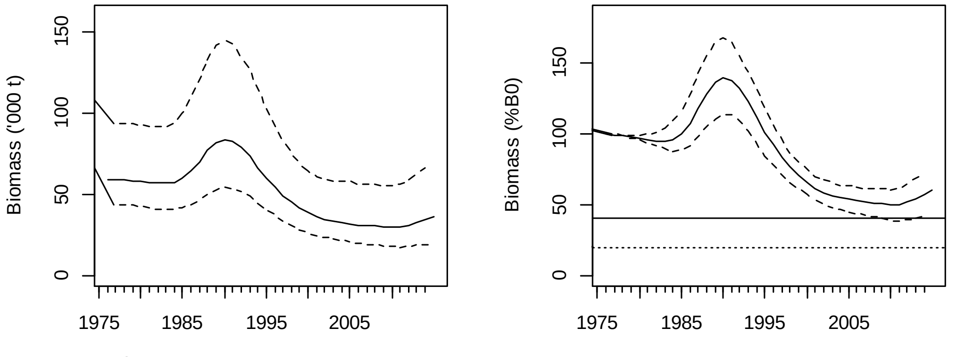
Hake are assessed as three independent biological stocks, based on the presence of three main spawning areas (eastern Chatham Rise, south of Stewart-Snares shelf, and WCSI), and some differences in biological parameters between these areas.

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	2014
Assessment Runs Presented	One 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_{2014} was estimated at 60% B_0; Very Likely (> 90%) to be at or above the target
Status in relation to Limits	B_{2014} is Exceptionally Unlikely (< 1%) to be below both 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



Trajectory over time of spawning biomass (absolute, and %B_0, with 95% credible intervals shown as broken lines) for the Sub-Antarctic hake stock from the start of the assessment period in 1975 to 2014 (the final assessment year). 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. Years on the x-axis indicate fishing year with "1995" representing the 1994–95 fishing year. Biomass estimates are based on MCMC results from the base model.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass is estimated to have been increasing since 2010.
Recent Trend in Fishing Mortality or Proxy	Fishing pressure is estimated to have been relatively low throughout the duration of the fishery.
Other Abundance Indices	–
Trends in Other Relevant Indicators or Variables	–

Projections and Prognosis (2019)	
Stock Projections or Prognosis	The biomass of the Sub-Antarctic stock was expected to increase at a catch level equivalent to the mean since 2008 (i.e., 2000 t annually).
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Exceptionally Unlikely (< 1%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or 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: 2014	Next assessment: 2017
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 New information since the 2011 assessment included two trawl surveys, and updated catch and catch-at-age data	1 – High Quality
Data not used (rank)	Commercial CPUE (used in sensitivity run only)	3 – Low Quality: potentially biased owing to changes in fishing practice and catch reporting
Changes to Model Structure and Assumptions	Previous assessments excluded sex from the partition. The model runs reported include sex in the partition, but have unsexed observation data and selectivities.	
Major Sources of Uncertainty	- The summer trawl survey series has shown a slight overall 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. - 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.

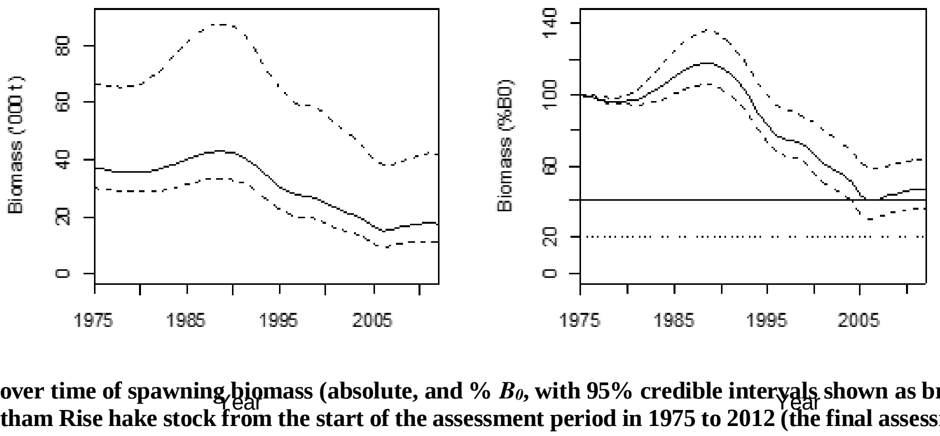
Qualifying Comments
–

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. Incidental interactions and associated mortality are noted for 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	2012
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: $F_{40\%B_0}$
Status in relation to Target	B_{2012} was estimated to be about 47% B_0; Likely (> 60%) to be at or above target
Status in relation to Limits	B_{2012} 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 (absolute, and % 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 2012 (the final assessment year). 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. Years on the x-axis indicate fishing year with "2005" representing the 2004-05 fishing year. Biomass estimates are based on MCMC results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Median estimates of biomass are unlikely to have been below 40% B_0. Biomass has been slowly increasing since 2006.
Recent Trend in Fishing Intensity or Proxy	Fishing pressure is estimated to have been low since 2006 (relative to estimated pressure in most years from 1994 to 2005).
Other Abundance Indices	–
Trends in Other Relevant Indicators or Variables	Recruitment (1995–2009, but excluding 2001) is estimated to be lower than the long-term average for this stock.

Projections and Prognosis	
Stock Projections or Prognosis	The biomass of the Chatham Rise stock is expected to decrease slightly over the next 5 years at catch levels equivalent to those from recent years (i.e., about 1100 t annually), but is projected to decline markedly if future catches are close to the high catch scenario (i.e. annual catch levels equivalent to the HAK 4 TACC of 1800 t).
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Assuming future catches at the HAK 4 TACC: Soft Limit: About as Likely as Not (40–60%) Hard Limit: Unlikely (< 40%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Assuming future catches at 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: 2013	Next assessment: 2015
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Research time series of abundance indices (trawl survey)	1 – High Quality
	- Proportions-at-age data from the commercial fisheries and trawl surveys	1 – High Quality
	- Estimates of biological parameters - New information since the 2009 assessment included three trawl surveys, and updated catch and catch-at-age data.	1 – High Quality
Data not used (rank)	Commercial CPUE	3 – Low Quality: does not track stock biomass
Changes to Model Structure and Assumptions	The model structure is unchanged from the previous assessment, but the assumed error structure on the at-age data was changed from lognormal to multinomial.	
Major Sources of Uncertainty	- The assumption of a single Chatham Rise stock independent of hake in all other areas is the most parsimonious interpretation of available information. - Uncertainty about the size of recent year classes affects the reliability of stock projections. - 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. The use of dome-shaped selectivity ogives will compensate for some variation in mortality rate with age.	

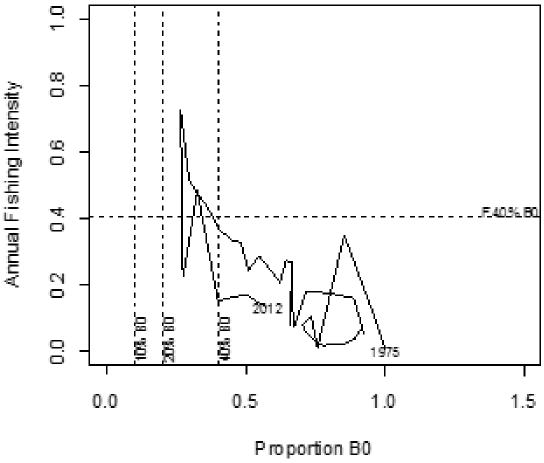
Qualifying Comments
The increase in relative abundance seen since 2006 is the result of good recruitment in 2002. In October 2004, large catches were taken in the western deep fishery (i.e. near the Mernoo Bank). This has been repeated to a lesser extent in 2008 and 2010. There is no information indicating 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.

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. Incidental interactions and associated mortality are seen 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	2012
Assessment Runs Presented	A base case, with sensitivity run estimating an age-dependent *M*
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B_0} = 0.41$
Status in relation to Target	B_{2012} was estimated to be 58% B_0; Very Likely (> 90%) to be at or above the target
Status in relation to Limits	B_{2012} 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	The fishing intensity in 2012 was Very Unlikely (< 10%) to be above the overfishing threshold

Historical Stock Status Trajectory and Current Status



Trajectory over time of fishing intensity and spawning biomass (Proportion *B₀*), for WCSI hake from the start of the assessment period in 1975, to 2012. The vertical lines represent the hard limit (10% *B₀*), the soft limit (20% *B₀*), and the target (40% *B₀*). The horizontal line represents the long-term level of fishing mortality that will produce a biomass of 40% *B₀*. Biomass estimates and fishing intensity are based on MPD results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Median estimates of biomass are unlikely to have been below 28% B_0. Biomass is estimated to have been decreasing from the late 1980s to 2007, but has been increasing since then.
Recent Trend in Fishing Intensity or Proxy	Fishing pressure is estimated to have been declining since 2007, and is currently lower than in all years since 1995.
Other Abundance Indices	-

Trends in Other Relevant Indicators or Variables	Recent recruitment (2004–2007) is estimated to be higher than the long-term average for this stock.

Projections and Prognosis	
Stock Projections or Prognosis	The biomass of the WCSI stock is expected to increase slightly at a catch level equivalent to the mean since 2007 (i.e., 4 500 t annually), or decline slightly at a catch level equivalent to the TACC (i.e., 7 700 t annually).
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	For either current catches or the TACC: Soft Limit: Very Unlikely (< 10%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unlikely (< 40%)

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: 2012	Next assessment: 2015
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Trawl fishery CPUE since 2001	1 – High Quality
	- Two comparable research trawl surveys (2000 and 2012)	1 – High Quality
	- Proportions-at-age data from the commercial fishery and two research surveys	1 – High Quality
	- Estimates of fixed biological parameters	1 – High Quality
Data not used (rank)	- Trawl fishery CPUE prior to 2001	3 – Low Quality: may not track stock biomass
Changes to Model Structure and Assumptions	- The model structure is unchanged from the previous assessment, but the assumed error structure on the at-age data was changed from lognormal to multinomial.	
Major Sources of Uncertainty	- The assumption of a single WCSI stock independent of hake in all other areas is the most parsimonious interpretation of available information. - Uncertainty about the size of recent year classes affects the reliability of stock projections. - 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. The use of dome-shaped selectivity ogives will compensate for some variation in mortality rate with age.	
Qualifying Comments		
The fishery-independent abundance series is sparse (i.e., two comparable trawl surveys). CPUE from this stock has previously been considered too unreliable to be used as an abundance index, but a truncated series from 2001 has been used here under the assumption that any biases owing to changes in fishing or reporting behaviour are small.		
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. Incidental interactions and associated mortality are seen for some protected species, notably New Zealand fur seals and seabirds.		

Table 21: Summary of TACCs (t) and reported landings for the most recent fishing year.

Fishstock	QMA	2013–14 actual TACC	2013–14 reported landings
HAK 1	Auckland, Central Southeast, Southland, Sub-Antarctic (FMAs 1, 2, 3, 5, 6, 8, 9)	3 701	1 883
HAK 4	Chatham Rise (FMA 4)	1 800	168
HAK 7	Challenger (FMA 7)	7 700	3 642
HAK 10	Kermadec	10	–
Total		13 211	5 693

6. FOR FURTHER INFORMATION

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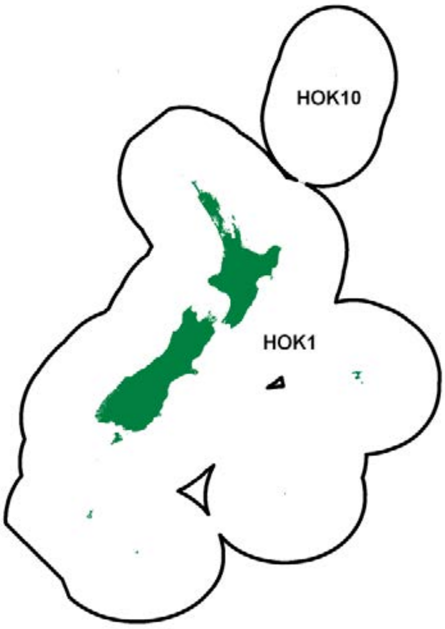
HOKI (HOK)

(*Macruronus novaezelandiae*)
Hoki



1. FISHERY SUMMARY

1.1 Commercial fisheries

Historically, the main fishery for hoki operated from mid-July to late August on the west coast of the South Island (WCSI) where hoki aggregate to spawn. The spawning aggregations begin to concentrate in depths of 300–700 m around the Hokitika Canyon from late June, and further north off Westport later in the season. Fishing in these areas continues into September in some years. Starting in 1988, another major fishery developed in Cook Strait, where separate spawning aggregations of hoki occur. The spawning season in Cook Strait runs from late June to mid September, peaking in July and August. Small catches of spawning hoki are taken from other spawning grounds off the east coast South Island (ECSI) and late in the season at Puysegur Bank.

Outside the spawning season, when hoki disperse to their feeding grounds, substantial fisheries have developed since the early 1990s on the Chatham Rise and on the Southern Plateau. These fisheries usually operate in depths of 400–800 m. The Chatham Rise fishery generally has similar catches over all months except in July-September, when catches are lower due to the fishery moving to the spawning grounds. On the Southern Plateau, catches have typically peaked in April-June. Out-of-season catches are also taken from Cook Strait and the east coast of the North Island, but these are small by comparison.

The hoki fishery was developed by Japanese and Soviet vessels in the early 1970s. Catches peaked at 100 000 t in 1977, but dropped to less than 20 000 t in 1978 when the EEZ was declared and quota limits were introduced (Table 1). From 1979 on, the hoki catch increased to about 50 000 t until an increase in the TACC from 1986 to 1990 saw the fishery expand to a maximum catch in 1987–88 of about 255 000 t (Table 2).

From 1986 to 1990, surimi vessels dominated the catches and took about 60% of the annual WCSI catch. However, since 1991, the surimi component of catches has decreased and processing to head and gut, or to fillet product has increased, as has “fresher” catch for shore processing. The hoki fishery now operates throughout the year, producing high quality fillet product from both spawning and non-spawning fisheries. Since 1998 twin-trawl rigs have operated in some hoki fisheries.

Table 1: Reported trawl catches (t) from 1969 to 1987–88, 1969–83 by calendar year, 1983–84 to 1987–88 by fishing year (Oct-Sept). Source - FSU data.

				New Zealand		
Year	USSR	Japan	South Korea	Domestic	Chartered	Total
1969	-	95	-	-	-	95
1970	-	414	-	-	-	414
1971	-	411	-	-	-	411
1972	7 300	1 636	-	-	-	8 936
1973	3 900	4 758	-	-	-	8 658
1974	13 700	2 160	-	125	-	15 985
1975	36 300	4 748	-	62	-	41 110
1976	41 800	24 830	-	142	-	66 772
1977	33 500	54 168	9 865	217	-	97 750
1978*	†2 028	1 296	4 580	678	-	8 581
1979	4 007	8 550	1 178	2 395	7 970	24 100
1980	2 516	6 554	-	2 658	16 042	27 770
1981	2 718	9 141	2	5 284	15 657	32 802
1982	2 251	7 591	-	6 982	15 192	32 018
1983	3 853	7 748	137	7 706	20 697	40 141
1983–84	4 520	7 897	93	9 229	28 668	50 407
1984–85	1 547	6 807	35	7 213	28 068	43 670
1985–86	4 056	6 413	499	8 280	80 375	99 623
1986–87	1 845	4 107	6	8 091	153 222	167 271
1987–88	2 412	4 159	10	7 078	216 680	230 339

* Catches for foreign licensed and New Zealand chartered vessels from 1978 to 1984 are based on estimated catches from vessel logbooks. Few data are available for the first 3 months of 1978 because these vessels did not begin completing these logbooks until 1 April 1978.

† Soviet hoki catches are taken from the estimated catch records and differ from official MAF statistics. Estimated catches are used because of the large amount of hoki converted to meal and not recorded as processed fish.

Table 2: Reported catch (t) from QMS, estimated catch (t) data, and TACC (t) for HOK 1 from 1986–97 to 2013–14. Reported catches are from the QMR and MHR systems. Estimated catches include TCEPR and CELF data (from 1989–90), LCER data (from 2003–04), NCELR data (from 2006–07), and TCER and LTCER data (from 2007–08). Catches are rounded to the nearest 500 t.

Year	Reported catch	Estimated catch	TACC
1986–1987	158 000	175 000	250 000
1987–1988	216 000	255 000	250 000
1988–1989	208 500	210 000	250 000
1989–1990	210 000	210 000	251 884
1990–1991	215 000	215 000	201 897
1991–1992	215 000	215 000	201 897
1992–1993	195 000	195 000	202 155
1993–1994	191 000	190 000	202 155
1994–1995	174 000	168 000	220 350
1995–1996	210 000	194 000	240 000
1996–1997	246 000	230 000	250 000
1997–1998	269 000	261 000	250 000
1998–1999	244 500	234 000	250 000
1999–2000	242 500	237 000	250 000
2000–2001	230 000	224 500	250 000
2001–2002	195 500	195 500	200 000
2002–2003	184 500	180 000	200 000
2003–2004	136 000	133 000	180 000
2004–2005	104 500	102 000	100 000
2005–2006	104 500	100 500	100 000
2006–2007	101 000	97 500	100 000
2007–2008	89 500	87 500	90 000
2008–2009	89 000	87 500	90 000
2009–2010	107 000	105 000	110 000
2010–2011	118 500	116 000	120 000
2011–2012	130 000	126 000	130 000
2012–2013	131 500	128 000	130 000
2013–2014	146 500	144 000	150 000

Note: Discrepancies between QMS data and actual catches from 1986 to 1990 arose from incorrect surimi conversion factors. The estimated catch in those years has been corrected from conversion factors measured each year by Scientific Observers on the WCSI fishery. Since 1990 the new conversion factor of 5.8 has been used, and the total catch reported to the QMS is considered to be more representative of the true level of catch.

Annual catches ranged between 175 000 and 215 000 t from 1988–89 to 1995–96, increasing to 246 000 t in 1996–97, and peaking at 269 000 t in 1997–98, when the TACC was over-caught by 19 000 t. Catches declined, tracking the TACC as it was reduced to address poor stock status, reaching a low of 89 000 t in 2008–09, and increasing again following increases in the TACC over the past four years as stock status has improved (Table 2). The reported catch in 2013–14 of 146 500 t was about 3500 t less than the TACC of 150 000 t (Table 2).

The pattern of fishing has changed markedly since 1988–89 when over 90% of the total catch was taken in the WCSI spawning fishery (Tables 3 and 4). This has been due to a combination of TACC changes and re-distribution of fishing effort. The catch from the WCSI declined steadily from 1988–89 to 1995–96, increased again to between 90 000 and 107 000 t from 1996–97 until 2001–02, then dropped sharply over seven years, to 20 600 t in 2008–09. The WCSI catch has increased again over the past five years to 69 400 t in 2013–14. This was about 47% of the total catch, making the WCSI the largest hoki fishery for the fourth consecutive year. In Cook Strait, catches peaked at 67 000 t in 1995–96, declined to 14 900 in 2010–11, but have increased over the past two years to 19 400 t in 2002–13 and 18 400 t in 2013–14. Non-spawning catches on the Chatham Rise peaked at about 75 000 t in 1997–98 and 1998–99, decreased to a low of 30 700 t in 2004–05, before increasing again to about 39 000 t from 2008–09 to 2011–12, decreasing to 36 500 t in 2012–13 and 33 800 t in 2013–14. The Chatham Rise was the largest hoki fishery from 2006–07 to 2009–10, but contributed only about 23% of the total catch in 2013–14. Catches from the Sub-Antarctic peaked at over 30 000 t in 1999–00 to 2001–02, declined to a low of 6200 t in 2004–05 before increasing slowly to 19 900 t in 2013–14 (Table 3).

Table 3: Estimated total catch (t) (scaled to reported QMR or MHR) of hoki by area 1988–89 to 2013–14 and based on data reported on TCEPR and CELR forms from 1988–89, but also include data reported on LCER (from 2003–04), NCELR (from 2006–07) and TCER and LTCER data (both from 2007–08). Catches from 1988–89 to 1997–98 are rounded to the nearest 500 t and catches from 1998–99 to 2013–14 are rounded to the nearest 100 t. Catches less than 100 t are shown by a dash.

	Spawning fisheries				Non-spawning fisheries				
Fishing Year	WCSI	Puysegur	Cook Strait	ECSI	Southern Plateau	Chatham Rise and ECSI	ECNI	Unrep.	Total Catch
1988–1989	188 000	3 500	7 000	–	5 000	5 000	–	–	208 500
1989–1990	165 000	8 000	14 000	–	10 000	13 000	–	–	210 000
1990–1991	154 000	4 000	26 500	1 000	18 000	11 500	–	–	215 000
1991–1992	105 000	5 000	25 000	500	34 000	45 500	–	–	215 000
1992–1993	98 000	2 000	21 000	–	26 000	43 000	2 000	3 000	195 000
1993–1994	113 000	2 000	37 000	–	12 000	24 000	2 000	1 000	191 000
1994–1995	80 000	1 000	40 000	–	13 000	39 000	1 000	–	174 000
1995–1996	73 000	3 000	67 000	1 000	12 000	49 000	3 000	2 000	210 000
1996–1997	91 000	5 000	61 000	1 500	25 000	56 500	5 000	1 000	246 000
1997–1998	107 000	2 000	53 000	1 000	24 000	75 000	4 000	3 000	269 000
1998–1999	90 100	3 000	46 500	2 100	24 300	75 600	2 600	–	244 500
1999–2000	101 100	2 900	43 200	2 400	34 200	56 500	1 400	500	242 400
2000–2001	100 600	6 900	36 600	2 400	30 400	50 500	2 100	100	229 900
2001–2002	91 200	5 400	24 200	2 900	30 500	39 600	1 200	-	195 500
2002–2003	73 900	6 000	36 700	7 100	20 100	39 200	900	-	184 700
2003–2004	45 200	1 200	40 900	2 100	11 700	33 600	900	-	135 800
2004–2005	33 100	5 500	24 800	3 300	6 200	30 700	500	100	104 400
2005–2006	38 900	1 500	21 800	700	6 700	34 100	700	-	104 400
2006–2007	33 100	400	20 100	1 000	7 700	37 900	700	-	101 000
2007–2008	21 000	300	18 400	2 300	8 700	38 000	600	-	89 300
2008–2009	20 600	200	17 500	1 100	9 800	39 000	600	-	88 800
2009–2010	36 300	300	17 900	700	12 300	39 100	600	-	107 200
2010–2011	48 300	1 200	14 900	1 600	12 600	38 400	1 600	-	118 700
2011–2012	54 000	1 300	15 900	2 500	15 700	39 000	900	-	130 100
2012–2013	56 200	1 000	19 400	3 300	14 100	36 500	1 100	-	131 600
2013–2014	69 400	800	18 400	2 800	19 900	33 800	1 300	-	146 300

From 1999–00 to 2001–02, there was a redistribution in catch from eastern stock areas (Chatham Rise, ECSI, ECNI, and Cook Strait) to western stock areas (WCSI, Puysegur, and Southern Plateau) (Table 4). This was initially due to industry initiatives to reduce the catch of small fish in the area of the Mernoo Bank, but from 1 October 2001 was part of an informal agreement with the Minister responsible for fisheries that 65% of the catch should be taken from the western fisheries to reduce pressure on the eastern stock. This agreement was removed following the 2003 hoki assessment in

2002–03, which indicated that the eastern hoki stock was less depleted than the western stock and effort was shifted back into eastern areas, particularly Cook Strait. From 2004–05 to 2006–07 there was an agreement with the Minister that only 40% of the catch should be taken from western fisheries and from 1 October 2007 the target catch from the western fishing grounds was further reduced to 25 000 t within the overall TACC of 90 000 t. This target was exceeded in both 2007–08 and 2008–09, with about 30 000 t taken from western areas (Table 3). In 2009–10, the target catch from the western fishing grounds was increased to 50 000 t within the overall TACC of 110 000 t, and catches were at about the industry-agreed catch split. The target catch from the western fishing grounds was further increased to 60 000 t in 2010–11 (within the overall TACC of 120 000 t), 70 000 t in 2011–12 and 2012–13 (overall TACC of 130 000 t), and 90 000 t in 2013–14 (overall TACC of 150 000 t). The split between eastern and western catches has been within 2000 t of the management targets since 2010–11. Figure 1 shows the reported landings and TACC for HOK1, and also the eastern and western catch components of this stock since 1988–89.

Table 4: Proportions of total catch for different fisheries.

	Spawning fisheries		Non-spawning fisheries	
Fishing	West	East	West	East
1988–1989	92%	3%	2%	3%
1989–1990	82%	7%	5%	6%
1990–1991	74%	13%	8%	5%
1991–1992	51%	12%	16%	21%
1992–1993	51%	11%	14%	24%
1993–1994	60%	19%	7%	14%
1994–1995	47%	23%	7%	23%
1995–1996	36%	33%	6%	25%
1996–1997	39%	26%	10%	25%
1997–1998	41%	20%	9%	30%
1998–1999	38%	20%	10%	32%
1999–2000	43%	19%	14%	24%
2000–2001	47%	17%	13%	23%
2001–2002	49%	14%	16%	21%
2002–2003	43%	24%	11%	22%
2003–2004	34%	32%	9%	25%
2004–2005	37%	27%	6%	30%
2005–2006	39%	21%	7%	33%
2006–2007	33%	21%	8%	38%
2007–2008	24%	23%	10%	43%
2008–2009	23%	21%	11%	45%
2009–2010	34%	17%	12%	37%
2010–2011	42%	14%	11%	34%
2011–2012	43%	14%	12%	31%
2012–2013	43%	17%	11%	29%
2013–2014	48%	12%	14%	27%

Total Allowable Commercial Catch (TACC) and area restrictions

In the 2013–14 fishing year, the TACC for HOK1 was 150 000 t. This TACC applied to all areas of the EEZ (except the Kermadec FMA which had a TACC of 10 t). There was an agreement with the Minister responsible for fisheries that only 90 000 t of the TACC should be taken from western stock areas. With the allowance for other mortality at 1 300 t and 20 t allowances for customary and recreational catch, the 2013–14 TAC was 151 340 t. The TACC was increased to 160 000 t from 1 October 2014, with an agreement that 100 000 t should be taken from western areas

Chartered vessels may not fish inside the 12-mile Territorial Sea and there are various vessel size restrictions around some parts of the coast. On the WCSI, a 25-mile line closes much of the hoki spawning area in the Hokitika Canyon and most of the area south to the Cook Canyon to vessels larger than 46 m overall length. In Cook Strait, the whole spawning area is closed to vessels over 46 m overall length. In November 2007 the Government closed 17 large areas, Benthic Protection Areas (BPAs) to bottom trawling and dredging.

The fishing industry introduced a Code of Practice (COP) for hoki target trawling in 2001 with the aim of protecting small fish (less than 60 cm). The main components of this COP were: 1) a restriction on fishing in waters shallower than 450 m; 2) a rule requiring vessels to 'move on' if there are more than 10% small hoki in the catch; and 3) seasonal and area closures in spawning fisheries. The COP was superseded by Operational Procedures for Hoki Fisheries, also introduced by the fishing industry from 1 October 2009. The Operational Procedures aim to manage and monitor fishing effort within four industry Hoki Management areas, where there are thought to be high abundances of juvenile hoki (Narrows Basin of Cook Strait, Canterbury Banks, Mernoo, and Puysegur). These areas are closed to trawlers over 28 m targeting hoki, with increased monitoring when targeting species other than hoki. There is also a general recommendation that vessels move from areas where catches of juvenile hoki (now defined as less than 55 cm total length) comprise more than 20% of the hoki catch by number.

2013–14 Hoki fishery

The overall estimated total catch in 2013–14 of 146 500 t was 20 000 t higher than that in 2012–13 and about 3500 t lower than the TACC (Table 3). Relative to 2012–13, catches from the main western areas (WCSI and Sub-Antarctic) increased in 2013–14, while those from the main eastern areas (Cook Strait and the Chatham Rise) decreased slightly.

The WCSI catch increased by 13 000 t to 69 400 t in 2013–14. Catches from inside the 25 n. mile line made up 13% of the total WCSI catch in 2013–14, an increase in proportion from 2012–13, but still down from a peak of 41% of the catch in 2003–04. The WCSI fishing is season now longer – with fishing in May (although most pre-June catch is from inside the 25 n. mile line), and the 2014 season had higher catches through mid-August compared to the previous four seasons. Unstandardised catch rates on the WCSI in 2013–14 decreased slightly from 2012–13, but were the fourth highest in the series, with a median catch rate in all midwater tows targeting hoki of 5.9 t per hour. The WCSI catch in 2014 was dominated by fish from 60 to 100 cm from the 2005–09 year-classes (ages 5–9), with a smaller length mode from the 2011 year class (age 3). The percentage of hoki aged 7 and older in the catch declined steeply from 68% in 2003–04 to 16% in 2005–06, but has increased again to 49% in 2013–14. Conversely, the percentage of small fish (under 65 cm) by number in the catch decreased from 31% in 2008–09 to 8% in 2012–13, but increased to 14% in 2013–14. From 1999–00 to 2003–04, the sex ratio of the WCSI catch was highly skewed, with many more females caught than males. In 2004–05 to 2010–11, as the catch of younger fish increased, the sex ratio reversed with more males than females caught. The sex ratio of the WCSI catch has been about even since 2011–12, with 53% females in 2012–13 and 2013–14. The mean length-at-age for hoki aged from 3–10 on the WCSI has increased since the start of the fishery, but there are signs that this has been decreasing recently.

The Chatham Rise fishery took 33 800 t in 2013–14. Over 97% of the Chatham Rise catch was taken in bottom trawls, with the median unstandardised catch rate in bottom trawls targeting hoki of 1.1 t per hour in 2013–14. The catch was bimodal and dominated by hoki of 50–90 cm, with the left hand mode from the 2011 year-class (age 2), with the right hand mode from the 2007–09 year-classes (ages 4–6), and few larger, older fish. The 2010 year-class was poorly represented at age 3+. The modal age was 2+. The Chatham Rise fishery caught more young fish than the WCSI fishery, with only 23% of hoki aged 7 years and older. About 45% of the catch by number was less than 65 cm in 2013–14, due to the high numbers of 2+ hoki caught. The sex ratio was even.

The catch from Cook Strait in 2013–14 (18 000 t) decreased by about 1000 t from that in 2012–13. Peak catches were from mid-July to mid-September, with about 3800 t caught outside the spawning season. Unstandardised catch rates in Cook Strait continued to be high, but the median catch rate in midwater tows targeting hoki decreased from 17.5 t per hour in 2012–13 to 12.3 t per hour in 2013–14. There was a broad age distribution of females from ages 3 to 14, while most males were ages 3–10. The modal age was 5 (2009 year-class), with another mode at age 3 (2011 year class). Only 16% of the catch was fish less than 65 cm. The sex ratio of the Cook Strait catch has fluctuated over time, but was female-dominated from 2001–05, and has been generally male-dominated since, with 63% males in the catch in 2013–14. Apparent changes in sex ratio in the last four years may be related to biases in sampling. As on the WCSI, the mean length at age showed a period of increase in the Cook Strait fishery, but appears to have decreased recently.

The catch from the Southern Plateau of 19 900 t in 2013–14 was about 5800 t higher than that in 2012–13. The percentage of the catch from hoki target tows in 2013–14 was 87%, having fallen as low as 70% in 2006–07. Unstandardised catch rates in bottom trawls targeting hoki were 1.6 t per hour in 2013–14. The length distribution of hoki from the Sub-Antarctic in 2013–14 was bimodal with the smaller mode consisting of fish from the 2011 year-class (age 2), and the larger mode from the 2007–09 year-classes (ages 4–6). The modal age of females and males was 2+ (2011 year-class). The percentage of fish in the catch less than 65 cm was 42% in 2013–14, and about 54% of the fish caught in the Sub-Antarctic in 2013–14 were females.

Catches from ECNI increased by 280 t to 1300 t, whereas catches from Puysegur and ECSI decreased by 170 t to 780 t, and by 560 t to 2 800 t, respectively.

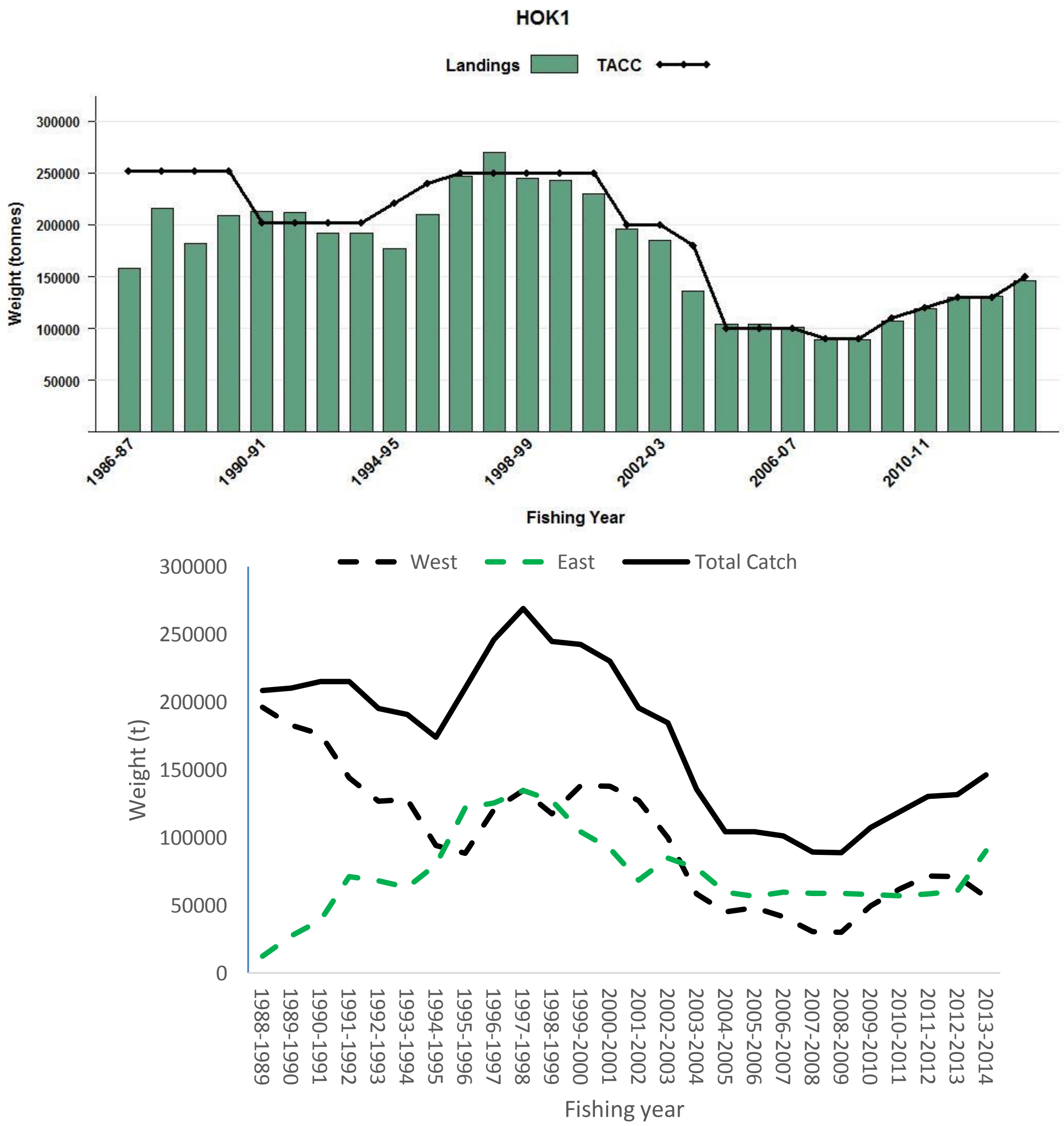


Figure 1: Upper: Reported commercial landings and TACCs for HOK 1 since 1986–87. Lower: The eastern and western components of the total HOK 1 landings since 1988–89. Note that these figures do not show data prior to entry into the QMS.

1.2 Recreational fisheries

Recreational fishing for hoki 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.

1.5 Other sources of fishing mortality

There are a number of potential sources of additional fishing mortality in the hoki fishery:
In the years just prior to the introduction of the EEZ, when large catches were first reported, and following the increases of the TACC in the mid-1980s, it is likely that high catch rates on the west coast, South Island spawning fishery resulted in burst bags, loss of catch and some mortality. Although burst bags were recorded by some scientific observers, the extent of fish loss has not been estimated, however, the occurrence was at a sufficient level to result in the introduction of a code of practice to minimise losses in this way. Based on observer records from the period 2000–01 to 2006–07, Ballara et al. (2010) noted that fish lost from the net during landing accounted for only a small fraction (0–14.5%) of the total fish discards each year in the hoki, hake and ling fishery.

- The use of escape panels or windows part way along the net that was developed to avoid burst bags may also in itself result in some mortality of fish that pass through the window. The extent of these occurrences and the historical and current use of such panels/windows have not been quantified.
- The development of the fishery on younger hoki (2 years and over) on the Chatham Rise from the mid-1990s and the prevalence of small hoki in catches on the WCSI in recent years may have resulted in some discarding of small fish.
- Overseas studies indicate that large proportions of small fish can escape through trawl meshes during commercial fishing and that the mortality of escapees can be high, particularly among species with deciduous scales (i.e., that shed easily) such as hoki. Selectivity experiments in the 1970s indicated that the 50% selection length for hoki for a 100 mm mesh codend is about 57–65 cm total length (Fisher 1978, as reported by Massey & Hore 1987). More recent research, using a twin-rig trawler in June 2007, estimated that the 50% selection length was somewhat lower at 41.5 cm with a selection range (length range between 25% and 75% retention) of 14.3 cm (Haist et al 2007). Applying the estimated retention curve to scaled length frequency data for the Chatham Rise fishery, suggested that annually between 47 t (in 1997–98) and 4287 t (in 1995–96) of hoki may have escaped commercial fishing gear. Net damaged adult hoki have been recorded in the WCSI fishery in some years indicating that there may be some survival of escapees. The extent of damage and resulting mortality of fish passing through the net is unknown.

These sources of additional fishing mortality are not incorporated in the current stock assessment.

2. BIOLOGY

Hoki are widely distributed throughout New Zealand waters from 34° S to 54° S, from depths of 10 m to over 900 m, with greatest abundance between 200 and 600 m. Large adult hoki are generally found deeper than 400 m, while juveniles are more abundant in shallower water. In the January 2003 Chatham Rise trawl survey, exploratory tows with mid-water gear over a hill complex east of the survey area found low density concentrations of hoki in mid-water at 650 m over depths of 900 m or greater (Livingston et al 2004). The proportion of larger hoki outside the survey grounds is unknown. Commercial data also indicate that larger hoki have been targeted over other hill complexes outside the survey areas of both the Chatham Rise and Southern Plateau (Dunn & Livingston 2004), and have also been caught as a bycatch by tuna fishers over very deep water (Bull & Livingston 2000).

The two main spawning grounds on the WCSI and in Cook Strait are considered to comprise fish from separate stocks, based on the geographical separation of these spawning grounds and a number of other factors (see Section 3 “Stocks and areas” below).

Hoki migrate to spawning grounds in Cook Strait, WCSI, Puysegur, and ECSI areas in the winter months. Throughout the rest of the year the adults are dispersed around the edge of the Stewart and

Snares shelf, over large areas of the Southern Plateau and Chatham Rise, and to a lesser extent around the North Island. Juvenile fish (2–4 yrs) are found on the Chatham Rise throughout the year.

Hoki spawn from late June to mid-September, releasing multiple batches of eggs. They have moderately high fecundity with a female of 90 cm TL spawning over 1 million eggs in a season (Schofield & Livingston 1998). Not all hoki within the adult size range spawn in a given year. Winter surveys of both the Chatham Rise and Southern Plateau have found significant numbers of large hoki with no gonad development, at times when spawning is occurring in other areas. Histological studies of female hoki on the Southern Plateau in May 1992 and 1993 estimated that 67% of hoki age 7 years and older on the Southern Plateau would spawn in winter 1992, and 82% in winter 1993 (Livingston et al 1997). A similar study repeated in April 1998 found that a much lower proportion (40%) of fish age 7 and older was developing to spawn (Livingston & Bull 2000). Reanalysis of the 1998 data has shown that there is a correlation between stratum and oocyte development (Francis 2009). A new method, developed to estimate proportion spawning from summer samples of post-spawner hoki on the Southern Plateau, indicated that approximately 85% of the hoki aged 4 years and older from 2003–2004 had spawned (Grimes & O'Driscoll 2006, Parker et al 2009).

The main spawning grounds are centred on the Hokitika Canyon off the WCSI and in Cook Strait Canyon. The planktonic eggs and larvae move inshore by advection or upwelling (Murdoch 1990; Murdoch 1992) and are widely dispersed north and south with the result that 0+ and 1-year-old fish can be found in most coastal areas of the South Island and parts of the North Island. The major nursery ground for juvenile hoki aged 2–4 years is along the Chatham Rise, in depths of 200 to 600 m. The older fish disperse to deeper water and are widely distributed on both the Southern Plateau and Chatham Rise. Analyses of trawl survey (1991–02) and commercial data suggests that a significant proportion of hoki move from the Chatham Rise to the Southern Plateau as they approach maturity, with most movement between ages 3 and 7 years (Bull & Livingston 2000, Livingston et al 2002). Based on a comparison of RV *Tangaroa* trawl survey data, on a proportional basis (assuming equal catchability between areas), 80% or more of hoki aged 1–2 years occur on the Chatham Rise. Between ages 3 and 7, this drops to 60–80%. By age 8, 35% or fewer fish are found on the Chatham Rise compared with 65% or more in the Southern Plateau. A study of the observed sex ratios of hoki in the two spawning and two non-spawning fisheries found that in all areas, the proportion of male hoki declines with age (Livingston et al 2000). There is little information at present to determine the season of movement, the exact route followed, or the length of time required, for fish to move from the Chatham Rise to the Southern Plateau. Bycatch of hoki from tuna vessels following tuna migrations from the Southern Plateau showed a northward shift in the incidence of hoki towards the WCSI in May-June (Bull & Livingston 2000). The capture of net-damaged fish on Pukaki Rise following the WCSI spawning season where there had been intense fishing effort in 1989 also provides circumstantial evidence that hoki migrate from the WCSI back to the Southern Plateau post-spawning (Jones 1993).

Growth is fairly rapid with juveniles reaching about 27–35 cm TL at the end of the first year. In the past, hoki reached about 45, 55 and 60–65 cm TL at ages 2, 3, and 4 respectively. More recently, length modes have been centred at 45–50, 60–65, and 70–75 cm TL for ages 2, 3, and 4. Although smaller spawning fish are taken on the spawning grounds, males appear to mature mainly from 60–65 cm TL at 3–5 years, while females mature at 65–70 cm TL. From the age of maturity the growth of males and females differs. Males grow up to about 115 cm TL, while females grow to a maximum of 130 cm TL and up to 7 kg weight. Horn & Sullivan (1996) estimated growth parameters for the two stocks separately (Table 5). Fish from the eastern stock sampled in Cook Strait are smaller on average at all ages than fish from the WCSI. Maximum age is from 20–25 years, and the instantaneous rate of natural mortality in adults is about 0.25 to 0.30 per year.

There is evidence that ageing error causes problems in the estimation of year class strength. For example, the 1989 year class appeared as an important component in the catch at age data at older ages, yet this year class is believed to have been extremely weak in comparison to the preceding 1988 and 1987 year classes. An improved ageing protocol was developed to increase the consistency of hoki age estimation and this has been applied to the survey data from 2000 onwards and to catch samples from 2001 (Francis 2001). Data from earlier samples, however, are still based on the original methodology and otolith readings.

Estimates of biological parameters relevant to stock assessment are shown in Table 5 (but note that natural mortality was estimated in the model in the assessment).

Table 5: Estimates of fixed biological parameters.

Fishstock						**Estimate**	**Source**
1. Natural mortality (*M*)							
					Females	Males	
HOK 1					0.25	0.30	Sullivan & Coombs (1989)
2. Weight = a (length)^b (Weight in g, length in cm total length)							
						Both stocks	
					a	b	
HOK1					0.00479	2.89	Francis (2003)
3. von Bertalanffy growth parameters							
			Females			Males	
	K	t_0	L_∞	*K*	t_0	L_∞	
HOK 1 (Western Stock)	0.213	-0.60	104.0	0.261	-0.50	92.6	
HOK 1 (Eastern Stock)	0.161	-2.18	101.8	0.232	-1.23	89.5	

3. STOCKS AND AREAS

Morphometric and ageing studies have found consistent differences between adult hoki taken from the two main dispersed areas (Chatham Rise and Southern Plateau), and from the two main spawning grounds in Cook Strait and WCSI (Livingston et al 1992, Livingston & Schofield 1996b, Horn & Sullivan 1996). These differences clearly demonstrate that there are two sub-populations of hoki. Whether or not they reflect genetic differences between the two sub-populations, or they are just the result of environmental differences between the Chatham Rise and Southern Plateau, is not known. No genetic differences have been detected with selectively neutral markers (Smith et al 1981, 1996) but a low exchange rate between stocks could reduce genetic differentiation.

Two pilot studies appeared to provide support for the hypothesis of spawning stock fidelity for the Cook Strait and WCSI spawning areas. Smith et al (2001) found significant differences in gill raker counts, and Hicks & Gilbert (2002) found significant differences in measurements of otolith rings, between samples of 3 year-old hoki from the 1997 year-class caught on the WCSI and in Cook Strait. However, when additional year-classes were sampled, differences were not always detected (Hicks et al 2003). It appears that there are differences in the mean number of gill rakers and otolith measurements between stocks, but, due to high variation, large sample sizes would be needed to detect these (Hicks et al 2003). Francis et al (2011) carried out a pilot study to determine whether analyses of stable isotopes and trace elements in otoliths could be useful in testing stock structure hypotheses and the question of natal fidelity. However, none of the six trace elements or two stable isotopes considered unambiguously differentiated the two stocks.

The Hoki Working Group has assessed the two spawning groups as separate stock units. The west coast of the North and South Islands and the area south of New Zealand including Puysegur, Snares and the Southern Plateau has been taken as one stock unit (the "western stock"). The area of the ECSI, Mernoo Bank, Chatham Rise, Cook Strait and the ECNI up to North Cape has been taken as the other stock unit (the "eastern stock").

4. CLIMATE AND RECRUITMENT

Annual variations in hoki recruitment have considerable impact on this fishery and a better understanding of the influence of climate on recruitment patterns would be very useful for the future projection of stock size. However, any link between climate, oceanographic conditions and recruitment is still unknown. Recent analyses (Francis et al 2006) do not support the conclusions of Bull & Livingston (2001) that model estimates of recruitment to the western stock are strongly correlated with the southern oscillation index (SOI). Francis et al (2006) noted that there is a correlation of -0.70 between the autumn SOI and annual estimates of recruitment (1+ and 2+ fish) from the Chatham Rise trawl survey but found this hard to interpret because the survey is an index of the combined recruitment to both the eastern and western stocks. A more recent analysis supports some climate effect on hoki recruitment but remains equivocal about its strength or form (Dunn et al 2009b). Bradford-Grieve & Livingston (2011) collated and reviewed information on the ocean environment on the WCSI in relation to hoki and other spawning fisheries. Hypotheses about which variables drive hoki recruitment were presented, but the authors noted that understanding of the underlying mechanisms and causal links between the WCSI marine environment and hoki year class survival remain elusive.

A baseline report summarising trends in climatic and oceanographic conditions in New Zealand that are of potential relevance for fisheries and marine ecosystem resource management in the New Zealand region has been completed (Hurst et al 2012).

5. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was last reviewed by the Aquatic Environment Working Group for the May 2012 Fishery Assessment Plenary. The tables have been updated and minor corrections made for this report by the DWFAWG. This summary is from the perspective of the hoki fishery; a more comprehensive review from an issue-by-issue perspective is available in the Aquatic Environment and Biodiversity Annual Review 2103 (MPI 2013).

5.1 Role in the ecosystem

Hoki is the species with the highest biomass in the bottom fish community of the upper slope (200–800 m), particularly around the South Island (Francis et al 2002), and is considered to be a key biological component of the upper slope ecosystem. Understanding the predator-prey relationships between hoki and other species in the slope community is important, particularly since substantial changes in the biomass of hoki have taken place since the fishery began. Other metrics including ecosystem indicators can also provide insight into fishery interactions with target and non-target fish populations. For example, changes in growth rate can be indicative of density-dependent compensatory mechanisms in response to changes in population density.

5.1.1 Trophic interactions

On the Chatham Rise, hoki is a benthopelagic and mesopelagic forager, preying primarily on lantern fishes and other mid-water fishes and natant decapods with little seasonal variation (Clark 1985a, b, Dunn et al 2009a, Connell et al 2010, Stevens et al 2011). Hoki show ontogenetic shifts in their feeding preferences, and larger hoki (over 80 cm) consume proportionately more fish and squid than do smaller hoki (Dunn et al 2009a, Connell et al 2010). The diet of hoki overlaps with those of alfonsino, arrow squid, hake, javelinfish, Ray’s bream, and shovelnose dogfish (Dunn et al 2009a). Hoki are prey to several piscivores, particularly hake but also stargazers, smooth skates, several deep water shark species, and ling; (Dunn et al 2009a). The proportion of hoki in the diet of hake averages 38% by weight, and has declined since 1992 (Dunn & Horn 2010), possibly because of a decline in the relative abundance of hoki on the Chatham Rise between 1991 and 2007. There is little information about the size of hoki eaten by predators (i.e. specifically whether the hoki are large enough to have recruited to the fishery or not), but this could be an important factor in understanding the interaction with the fishery and the potential for competition.

5.1.2 Ecosystem Indicators

Tuck et al (2009) used data from the Sub-Antarctic and Chatham Rise trawl survey series to derive fish-based ecosystem indicators using diversity, fish size, and trophic level. Species-based indicators appeared the most useful in identifying changes correlated with fishing intensity; Pielou’s evenness appears the most consistent but the Shannon-Wiener index, species richness, and Hill’s N1 and N2 also showed some promise (Tuck et al 2009). Trends in diversity in relation to fishing are not necessarily downward, and depend on the nature of the community. Size-based indicators did not appear as useful for New Zealand trawl survey series as they have been overseas, and this may be related to the requirement to consider only measured species. In New Zealand, routine measurement of all fish species in trawl surveys was implemented in 2008 and this may increase the utility of size-based indicators in the future.

Between 1992 and 1999 the growth rates of all year classes of hoki increased by 10% in all four fishery areas but it is unclear whether this was a result of reduced competition for food within and among cohorts or some other factor (Bull & Livingston 2000). The abundance of mesopelagic fish, a major prey item for hoki, has the potential to be an indicator of food availability. Recent research using acoustic backscatter data collected during trawl surveys has shown no clear temporal trend in mesopelagic fish biomass on the Chatham Rise between 2001 and 2009, but a decline for the Sub-Antarctic area from 2001 to 2007, followed by an increase in 2008 and 2009. The abundance of mesopelagic fish is consistently much higher on the Chatham Rise than in the Sub-Antarctic, with highest densities observed on the western Chatham Rise and lowest densities on the eastern Campbell Plateau (O'Driscoll et al 2011a). Spatial patterns in mesopelagic fish abundance closely matched the distribution of hoki. O'Driscoll et al (2011a) hypothesise that prey availability influences hoki distribution, but that hoki abundance is being driven by other factors such as recruitment variability and fishing. There was no evidence for a link between hoki condition and mesopelagic prey abundance and there were no obvious correlations between mesopelagic fish abundance and environmental indices.

5.2 Incidental catch (fish and invertebrates)

The main commercial bycatch species in hoki target fisheries off the west coast South Island, Chatham Rise and Sub-Antarctic are hake, ling, silver warehou, jack mackerel and spiny dogfish. In Cook Strait, the main commercial bycatch species are ling and spiny dogfish. Between 2000–01 and 2006–07, hoki, hake, and ling accounted for 87% (77%, 6%, and 4%, respectively) of the total observed catch from trawls targeting these species. These three species made up 90%, 1%, and 2%, respectively, of the catch in target hoki trawls between 2008–09 and 2012–13 (Table 6). The hoki-hake-ling fishery is complex, and changes in fishing practice are likely to have contributed to variability between years (Ballara et al 2010a).

Table 6: Raw catch weight and percentage by weight of species taken in hoki trawls with an observed catch of > 20 t by fishing year. Data from the Central Observer Database.

Species	2008–09		2009–10		2010–11		2011–12		2012–13	
	Catch (t)	%	Catch (t)	%	Catch (t)	%	Catch (t)	%	Catch (t)	%
Hoki	19 522	87.2	24 696	87.	20 600	86.5	32 360	89.1	27 309	94.5
Ling	548	2.5	624	2.2	555	2.3	975	2.7	348	1.2
Javelinfish	494	2.2	734	2.6	469	2.0	425	1.2	93	0.3
Rattails	334	1.5	572	2.0	403	1.7	441	1.2	91	0.3
Silver warehou	191	0.9	337	1.2	380	1.6	352	1.0	139	0.5
Hake	227	1.0	235	0.8	319	1.3	396	1.1	379	1.3
Spiny dogfish	187	0.8	233	0.8	226	0.9	439	1.2	137	0.5
White warehou	58	0.3	64	0.2	89	0.4	65	0.2	5	0.02
Pale ghost shark	81	0.4	101	0.4	82	0.3	95	0.3	4	0.01
Sea perch	16	0.1	55	0.2	81	0.3	56	0.2	11	0.04
Barracouta	6	0.0	4	0.0	44	0.2	4	0.01	<1	<0.01
Southern blue whiting	37	0.2	7	0.0	40	0.2	12	0.03	2	0.01
Shovelnose dogfish	35	0.2	29	0.1	38	0.2	26	0.1	2	0.01
Lookdown dory	24	0.1	33	0.1	40	0.2	49	0.1	19	0.1
Ribaldo	27	0.1	39	0.1	33	0.1	26	0.1	8	0.03
Arrow squid	16	0.1	26	0.1	31	0.1	35	0.1	24	0.1
Gemfish	9	0.0	6	0.0	27	0.1	6	0.02	10	0.03
Smooth skate	11	0.1	22	0.1	26	0.1	21	0.1	18	0.1
Stargazer	14	0.1	23	0.1	25	0.1	15	0.04	5	0.02
Others	555	2.5	485	1.7	305	1.3	510	1.4	285	1.0

5.3 Incidental catch (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).

New Zealand fur seal interactions

The New Zealand fur seal was classified in 2008 as “Least Concern” by the International Union for Conservation of Nature (IUCN) and in 2010 as “Not Threatened” under the NZ Threat Classification System (Baker et al 2010).

Vessels targeting hoki incidentally catch fur seals (Baird 2005b, Smith & Baird 2009, Thompson & Abraham 2010a, Baird 2011). The numbers captured have been declining since 1998–99 and the capture rate has also been declining, with the lowest capture rates over the last four years (Table 7). Captures occur mostly in Cook Strait (54%), off the west coast South Island (24%), and east coast South Island, including the western Chatham Rise (15%) (Table 8). Estimated captures of New Zealand fur seals in the hoki fishery have accounted for about half of all fur seals estimated to have been caught by trawling in the EEZ between 2002–03 and 2011–12 for those fisheries modelled. This figure should be interpreted with caution because a large proportion of inshore trawl effort targeting species other than hoki could not be included in the models.

Table 7: Number of tows by fishing year and observed and model-estimated total NZ fur seal captures in hoki trawl fisheries, 1998–99 to 2012–13. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows, % inc, percentage of total effort included in the statistical model. * Estimates 1998–99 to 2001–02 from Smith & Baird (2009) who estimated captures by area and confidence intervals have not been estimated at this level of aggregation. Estimates are based on methods described in Thompson et al (2013) and available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Data for 2002–03 to 2011–12 are based on data version 20130304 and preliminary data for 2012–13 are based on data version 20140131.

		Observed				Estimated		
	Tows	No. obs	% obs	Captures	Rate	Mean	95% c.i.	% inc.
1998–99	32 242	3 558	11.0	84	2.36	919	*	95.6
1999–00	33 061	3 273	9.9	102	3.12	764	*	95.8
2000–01	32 018	3 549	11.1	66	1.86	804	*	97.6
2001–02	27 224	3 274	12.0	110	3.36	844	*	96.3
2002–03	27 786	2 593	9.3	45	1.74	636	352–1 142	100.0
2003–04	22 523	2 346	10.4	49	2.09	750	398–1 376	100.0
2004–05	14 545	2 131	14.7	120	5.63	797	422–1 504	100.0
2005–06	11 590	1 775	15.3	62	3.49	452	217–938	100.0
2006–07	10 602	1 758	16.6	29	1.65	269	121–567	100.0
2007–08	8 788	1 879	21.4	58	3.09	323	163–677	100.0
2008–09	8 174	1 660	20.3	37	2.23	217	99–470	100.0
2009–10	9 965	2 066	20.7	30	1.45	179	88–366	100.0
2010–11	10 404	1 724	16.6	24	1.39	180	84–375	100.0
2011–12	11 333	2 579	22.8	33	1.28	213	101–448	100.0
2012–13	11 682	4 515	38.7	58	1.28	242	114-534	100.0

Table 8: Model estimates (means) of the number of NZ fur seal captures in hoki trawl fisheries by area, 2002–03 to 2011–12. Data version 20130304. Model estimates for 2012–13 were not available at the time of publication.

	Cook	WCSI	ECSI	Fiordland	Stewart-Snares	Chatham Rise	Sub-Antarctic	Total
2002–03	263	162	91	23	19	12	27	597
2003–04	354	191	109	10	17	11	8	700
2004–05	384	203	94	30	26	11	8	756
2005–06	230	108	55	10	12	5	0	420
2006–07	155	33	42	1	17	3	0	251
2007–08	190	45	58	0	7	3	2	305
2008–09	139	24	27	0	9	1	0	200
2009–10	103	29	28	0	11	2	1	174
2010–11	95	43	23	1	6	1	1	170
2011–12	114	52	25	1	5	2	0	199

NZ sea lion interactions

The New Zealand (or Hooker's) sea lion was classified in 2008 as "Vulnerable" by IUCN and in 2010 as "Nationally Critical" under the NZ Threat Classification System. Pup production at the main rookeries has shown a steady decline since the late 1990s.

NZ sea lions are captured only rarely by vessels trawling for hoki, the highest recorded rate in the last 15 years being 0.05 sea lions per 100 tows and with a total of only five animals observed captured since 1998–99 (Table 9, MPI 2103). All observed captures have been close to the Auckland Islands or nearby on the Stewart-Snares shelf.

Table 9: Number of tows by fishing year and observed NZ sea lion captures in hoki trawl fisheries, 1998–99 to 2012–13. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows. No estimates of total captures are presented here because the data are so sparse. Estimates are based on methods described in Thompson et al (2013) and available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Data for 2002–03 to 2011–12 are based on data version 20130304 and preliminary data for 2012–13 are based on data version 20140131.

	Fishing effort			Observed captures		Estimated captures		
	Tows	No. obs	% obs	Captures	Rate	Mean	95% c.i.	% included
1998–99	32 242	3 558	11.0	0	0.00	-	-	-
1999–00	33 061	3 273	9.9	1	0.03	-	-	-
2000–01	32 018	3 549	11.1	1	0.03	-	-	-
2001–02	27 224	3 274	12.0	0	0.00	-	-	-
2002–03	27 786	2 593	9.3	1	0.04	2	0–6	100.0
2003–04	22 521	2 346	10.4	0	0.00	2	0–5	100.0
2004–05	14 540	2 131	14.7	0	0.00	1	0–4	100.0
2005–06	11 590	1 775	15.3	0	0.00	0	0–2	100.0
2006–07	10 607	1 758	16.6	0	0.00	0	0–2	100.0
2007–08	8 787	1 877	21.4	1	0.05	1	1–2	100.0
2008–09	8 176	1 662	20.3	0	0.00	0	0–2	100.0
2009–10	9 967	2 066	20.7	0	0.00	0	0–2	100.0
2010–11	10 402	1 724	16.6	0	0.00	0	0–2	100.0
2011–12	11 332	2 579	22.8	0	0.00	0	0–2	100.0
2012–13†	11 678	4 515	38.7	1	0.02	1	1–3	100.0

† Model estimates were not available for the most recent year at the time of publication.

Seabird interactions

Vessels targeting hoki incidentally catch seabirds, with information on observed captures summarised for 1998–99 to 2002–03 by Baird (2005a), for 2003–04 to 2005–06 by Baird & Smith (2007, 2008) and for 1989–90 to 2008–09 by Abraham & Thompson (2011).

In the 2011–12 fishing year there were 61 observed captures of birds in hoki trawl fisheries. In the same year it was estimated by a statistical model that there were a total of 265 (95% c.i. 207–347) captures in hoki trawl fisheries (Table 10). Annual observed seabird capture rates have ranged between 1.31 and 8.34 per 100 tows in the hoki fishery over the time period 1998–99 and 2012–13, with a slight downward trend over time. These estimates include all bird species and should be interpreted with caution. The average capture rate in hoki trawl fisheries over the last ten years is about 2.16 birds per 100 tows, a low rate relative to other New Zealand trawl fisheries, e.g. for scampi (5.57 birds per 100 tows) and squid (13.78 birds per 100 tows) over the same years. The hoki fishery accounted for about 13% of seabird captures in the trawl fisheries modelled by Abraham et al (2013) from v20130304.

Table 10: Number of tows by fishing year and observed and model-estimated total seabird captures in hoki trawl fisheries, 1998–99 to 2012–13. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows, % inc, percentage of total effort included in the statistical model. * Estimates 1998–99 to 2001–02 from McKenzie & Fletcher (2006). Estimates are based on methods described in Abraham et al (2013) and are available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Estimates from 2002–03 to 2011–12 are based on data version 20130304 and preliminary estimates for 2012–13 are based on data version 20140131.

		Observed				Estimated	
	Tows	No. obs	% obs	Captures	Rate	95% c.i.	% inc.
1998–99	32 242	3 558	11.0	133	3.74	950–1374	100.0
1999–00	33 061	3 273	9.9	91	2.78	821–1199	100.0
2000–01	32 018	3 549	11.1	296	8.34	1803–2348	100.0
2001–02	27 224	3 274	12.0	50	1.53	941–1358	100.0
2002–03	27 786	2 593	9.3	85	3.28	478–892	100.0
2003–04	22 523	2 346	10.4	33	1.41	254–433	100.0
2004–05	14 545	2 131	14.7	46	2.16	282–505	100.0
2005–06	11 590	1 775	15.3	54	3.04	232–580	100.0
2006–07	10 602	1 758	16.6	23	1.31	120–238	100.0
2007–08	8 788	1 879	21.4	28	1.49	105–191	100.0
2008–09	8 174	1 660	20.3	37	2.23	140–247	100.0
2009–10	9 965	2 066	20.7	53	2.57	158–247	100.0
2010–11	10 404	1 724	16.6	54	2.90	207-371	100.0
2011–12	11 333	2 579	22.8	61	2.29	194-307	100.0
2012–13†	11 682	4 515	38.6	96	2.13	215-333	100.0

† Provisional data, model estimates for the most recent year were not available at the time of publication.

Observed seabird captures since 2002–03 have been dominated by six species: Salvin's, southern Buller's, and NZ white-capped albatrosses make up 39%, 28%, and 25% of the albatrosses captured, respectively; and sooty shearwaters, white-chinned petrels, and cape petrels make up 58%, 16%, and 12% of other birds, respectively (Table 11). The highest proportions of captures have been observed off the east coast of the South Island (39%), off the west coast of the South Island (19%), on the Chatham Rise (16%), and on the Stewart-Snares shelf (15%). 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.

Mitigation methods such as streamer (tori) lines, Brady bird bafflers, warp deflectors, and offal management are used in the hoki trawl fishery. 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). In the four complete fishing years after mitigation was made mandatory, the average rates of capture for Salvin's and white-capped albatross (71% of albatross captures in this fishery) were 0.20 and 0.21 birds per 100 tows, respectively, compared with 0.61 and 0.26 per 100 tows in the three complete years before mitigation was made mandatory. This trend is masked in Table 10 by continued captures of smaller birds, especially sooty shearwater, in trawl nets (as opposed to on trawl warps where mitigation is applied).

Table 11: Number of observed seabird captures in hoki trawl fisheries, 2002–03 to 2012–13, by species and area. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Potential Biological Removals, PBR (from Richard et al 2013 where full details of the risk assessment approach can be found). It is not an estimate of the risk posed by fishing for hoki. Other data, version 20140131.

Albatrosses	Risk Ratio	Auckland Islands	Chatham Rise	Cook Strait	ECSI	Fiordland	Stewart Snares Shelf	Sub-Antarctic	WCSI	Total
Salvin's	V. high	0	50	8	40	0	3	1	0	102
Southern Buller's	V. high	0	5	0	7	9	14	0	38	73
NZ white capped	V. high	0	4	3	6	4	22	1	25	65
Southern royal	Medium	0	0	0	1	0	0	0	0	1
Campbell black-browed	Medium	0	0	0	2	0	0	0	7	9
Unidentified	N/A	0	1	1	6	0	2	1	0	11
Total albatrosses	**N/A**	**0**	**60**	**12**	**62**	**13**	**41**	**3**	**70**	**261**
Other birds										
Flesh footed shearwater	V. high	0	0	0	1	0	0	0	0	1
Cape petrel	High	0	3	8	4	6	3	0	15	39
Westland petrel	Medium	0	2	1	0	0	0	0	12	15
Northern giant petrel	Medium	0	0	0	1	0	0	0	2	3
White-chinned petrel	Medium	1	13	3	17	2	12	1	0	49
Grey petrel	Medium	0	0	0	0	0	1	1	0	2
Sooty shearwater	V. low	0	8	1	133	6	27	0	0	175
Black-bellied storm petrel	-	0	0	0	0	0	1	0	0	1
Common diving petrel	-	0	0	0	0	3	1	0	0	4
Fairy prion	-	0	0	0	1	0	0	0	3	4
Grey-backed storm petrel	-	0	0	0	0	0	1	0	0	1
Unidentified seabird	N/A	0	2	0	1	0	0	0	6	9
Total other birds	**N/A**	**1**	**28**	**13**	**158**	**17**	**46**	**2**	**38**	**303**
All birds total	**N/A**	**1**	**88**	**25**	**220**	**30**	**87**	**5**	**108**	**564**

Basking shark interactions

The basking shark was classified in 2005 as "Vulnerable" by IUCN and as in "Gradual Decline" under the NZ Threat Classification System, and are listed in CITES (Appendix II). Basking shark has been a protected species in New Zealand since 2010

Basking sharks are caught occasionally in hoki trawls (Francis & Duffy 2002, Francis & Smith 2010, Ballara et al 2010a). Standardised capture rates from observer data showed that the highest rates and catches occurred in 1989 off the WCSI, and in 1987–92 off the ECSI. Smaller peaks in both areas were observed in the late 1990s and early 2000s, but captures have been few since (Table 12). Most basking sharks have been captured in spring and summer and nearly all came from FMAs 3, 5, 6 and 7. Much of the recent decline in basking shark captures is probably attributable to a decline in fishing effort (Francis & Smith 2010). 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 is in progress to improve the understanding of the interactions between basking sharks and fisheries (DOC project PRO2011/03).

5.4 Benthic interactions

The only target method of capture in the hoki fishery is trawling using either bottom (demersal) or midwater gear. Baird & Wood (2010) estimated that trawling for hoki accounted for 20–40% of all tows on or near the sea floor reported on TCEPR forms up to 2005–06, and Black et al (2013) estimated that hoki has accounted for 30% of all tows reported on TCEPR forms since 1989–90. Between 2006–07 and 2010–11, 93% of hoki catch was reported on TCEPR forms. In the early years of the hoki fishery, vessels predominantly used midwater trawls as most of the catch was taken from spawning aggregations off the WCSI. Outside of the spawning season, bottom trawling is used on the Chatham Rise and Sub-Antarctic fishing grounds (Table 13). Twin trawls were used to catch almost half of the TACC in some years. This gear is substantially wider than single trawl gear and catches more fish per tow than single trawl gear. The relationship between total catch and bottom impact of twin trawls has, however, not been analysed. As the incidence of year round fishing increased, vessels increased fishing effort on the Chatham Rise and in the Sub-Antarctic, and the bottom trawl effort increased to a peak between 1997–98 and 2003–04. Effort has declined substantially in all areas since 2005–06, largely as a result of TACC reductions but is now likely to increase again with increases in TACCs in recent years. Midwater trawling peaked in 1995–96 to 1996–97 in Cook Strait and on the Chatham Rise 1996–97 to 1997–98, but declined in all areas from 1997–98. Overall, midwater trawling has declined by about 90% since the peak in 1997 and bottom trawling by about 70% since the peak in 2000 (Table 13).

Table 12: Number of tows (data version 20140131), and number of captures (1994–95 to 2007–08 from Francis & Smith 2010; 2008–09 to 2011–12 from the Central Observer Database) of basking shark in hoki trawls. Data for 2012–13 is provisional and is from v20140131.

Year	Tows*	No. observed	% observed	No. Captures
1994–05	21 583	–	–	2
1995–06	24 610	–	–	0
1996–07	28 756	–	–	5
1997–08	30 354	–	–	14
1998–09	32 242	3 558	11.0	8
1999–00	33 061	3 273	9.9	2
2000–01	32 018	3 549	11.1	3
2001–02	27 224	3 274	12.0	0
2002–03	27 785	2 593	9.3	5
2004–04	22 535	2 346	10.4	2
2004–05	14 543	2 131	14.7	8
2005–06	11 590	1 775	15.3	0
2006–07	10 607	1 758	16.6	0
2007–08	8 786	1 877	21.3	1
2008–09	8 176	1 662	20.3	0
2009–10	9 966	2 066	20.7	0
2010–11	10 405	1 724	16.6	0
2011–12	11 332	2 579	22.8	1
2012–13	11 680	4 517	38.7	3

Table 13: Summary of number of hoki target trawl tows (TCEPR only) in the hoki fishery from fishing years (FY) 1989–90 to 2011–12. (MW, mid-water trawl; BT, bottom trawl).

Fishery	**WCSI/Puysegur**		**Cook Strait/ECSI**		**Sub-Antarctic**		**Chatham Rise/ECSI**				
Season	Spawning		Spawning		Non-spawn		Non-spawn		all areas combined		%
Method	MW	BT	MW	BT	MW	BT	MW	BT	MW	BT	BT
FY											
1989–90	7 849	1 188	1 087	21	36	2 111	30	2 027	9 002	5 347	37
1990–91	7 354	1 679	2 229	21	81	3 927	954	3 490	10 618	9 117	46
1991–92	5 628	1 579	1 776	14	115	5 441	441	5 556	7 960	12 590	61
1992–93	5 490	1 861	1 583	22	442	4 913	1 057	5 269	8 572	12 065	58
1993–94	8 012	1 638	1 867	153	562	2 039	1 338	3 449	11 779	7 279	38
1994–95	7 225	1 505	2 030	255	419	2 328	2 175	6 262	11 849	10 350	47
1995–96	5 715	2 017	3 198	1 368	415	2 504	2 302	7 920	11 630	13 809	54
1996–97	7 563	1 890	3 561	1 335	334	3 421	2 342	9 303	13 800	15 949	54
1997–98	6 968	1 541	2 402	666	165	4 372	3 782	11 448	13 317	18 027	58
1998–99	5 477	2 118	2 033	635	419	3 659	2 424	11 439	10 353	17 851	63
1999–00	5 470	2 275	1 944	380	511	5 944	2 696	9 493	10 621	18 092	63
2000–01	6 228	2 577	1 968	170	667	5 448	912	9 862	9 775	18 057	65
2001–02	4 988	3 095	1 136	138	132	6 449	858	7 820	7 114	17 502	71
2002–03	4 615	2 977	2 117	167	96	4 407	496	9 278	7 324	16 829	70
2003–04	4 274	1 887	1 812	267	78	3 023	385	7 225	6 549	12 402	65
2004–05	2 534	1 308	1 457	74	68	1 428	340	4 996	4 399	7 806	64
2005–06	1 783	1 508	1 020	88	74	721	140	4 822	3 017	7 139	70
2006–07	1 147	752	919	35	25	1 194	57	4 769	2 148	6 750	76
2007–08	813	492	393	281	36	925	75	4 203	1 317	5 901	82
2008–09	689	354	747	267	38	927	11	3 914	1 485	5 462	79
2009–10	1 182	612	797	70	56	1 251	116	4 361	2 151	6 294	75
2010–11	1 581	912	489	63	62	1 245	52	4 075	2 184	6 295	74
2011–12	1 660	1 188	836	81	70	1 202	74	4 397	2 640	6 868	72
2012–13	2 662	1 032	1 045	71	6	1 373	169	4 175	3 882	6 651	60
2013–14	2 327	1 110	1 029	40	12	1 872	133	4 016	3 501	7 038	67

Note: Spawning fisheries include WCSI (Jul–Sep), Cook Strait (Jul–Sep), Puysegur (Jul–Dec), ECSI (Jul–Sep). Non-spawning fisheries include ECSI (Aug–Jun), Chatham Rise (Aug–Jun), Sub-Antarctic (Aug–Jun). TCER, CELR and North Island tows are excluded.

Bottom trawling for hoki, 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 are not considered in detail here but are discussed in the Aquatic Environment and Biodiversity Annual Review 2013 (MPI 2013).

5.5 Other factors

5.5.1 Spawning disruption

Fishing during spawning may disrupt spawning activity or success. Although there has been no research on the disruption of spawning hoki by fishing in New Zealand, the hoki quota owners voluntarily closed ceased fishing some defined spawning grounds for certain periods on the WCSI, Pegasus Canyon (ECSI) and Cook Strait as a precautionary measure from 2004 to 2009 with the intention of assisting stock rebuilding. This closure was lifted in 2010 because the biomass of the western stock was estimated to have rebuilt to within the management target range.

5.5.2 Habitat of particular significance to fisheries management

Habitats of particular significance to fisheries management have not been defined for hoki or any other New Zealand fish. Studies of potential relevance have identified areas of importance for spawning and juveniles (O'Driscoll et al 2003). Areas on Puysegur Bank, Canterbury Bight, Mernoo Bank, and Cook Strait have been subject to non-regulatory measures to reduce fishing mortality on juvenile hoki (Deepwater Group 2011).

6. STOCK ASSESSMENT

A new stock assessment was carried out in 2015 using research time series of abundance indices (trawl and acoustic surveys), proportions at age data from the commercial fisheries and trawl surveys, and estimates of biological parameters. New information included a trawl survey, and updated catch at age data. The general-purpose stock assessment program, CASAL (Bull et al 2012), was used and the approach, which used Bayesian estimation, was similar to that in the 2014 assessment (McKenzie 2015b).

6.1 Methods

Model structure

The model partitioned the population into two sexes, 17 age groups (1 to 16 and a plus group, 17+), two stocks [east (E) and west (W)], and four areas [Chatham Rise (CR), West Coast South Island (WC), Sub-Antarctic (SA), and Cook Strait (CS)]. It is assumed that the adult fish of the two stocks do not mix: those from the W stock spawn off the WC and spend the rest of the year in SA; the E fish move between their spawning ground, CS, and their home ground, CR. Juvenile fish from both stocks live in CR, but natal fidelity is assumed for most model runs (i.e., all fish spawn in the area in which they were spawned). Sensitivity model runs were done in which natal fidelity is not assumed (but all fish once they have spawned in a given area return there for future spawnings, i.e., adult fidelity). There is little direct evidence of natal fidelity for hoki, though its life history characteristics would indicate that 100% natal fidelity is unlikely (Horn 2011).

The model does not distinguish between mature and immature fish; rather than having a maturity ogive and a single proportion spawning (assumed to be the same for all ages) there is simply a spawning ogive. The reason for this is that there are no direct observations of maturity to use in the model but information about proportion spawning is available (there are two April/May observations on SA of proportions of females that will spawn that year).

The model's annual cycle divided the fishing year into five time steps and includes four types of migration (Table 14). The first type of migration involves only newly spawned fish, all of which are assumed to move from the spawning grounds (CS and WC) to arrive at CR at time step 2 and approximate age 1.6 y. The second affects only young W fish, some of which are assumed to migrate, at time step 3, from CR to SA. The last two types of migrations relate to spawning. Each year some fish migrate from their home ground (CR for E fish, SA for W fish) to their spawning ground (CS for E fish, WC for W fish) at time step 4. At time step 1 in the following year all spawners return to their home grounds. Both non-spawning fisheries (on CR and SA) were split into two halves to allow some of the catch to be taken before the Whome migration, and some after (and given the labels in the model of Ensp1, Ensp2, Wnsp1, Wnsp2).

Table 14: Annual cycle of the assessment model, showing the processes taking place at each time step, their sequence within each time step, and the available observations (excluding catch-at-age). Any fishing and natural mortality within a time step occurred after all other processes, with half of the natural mortality occurring before and after the fishing mortality. An age fraction of, say, 0.25 for a time step means that a 2+ fish was treated as being of age 2.25 in that time step. etc. The last column ("Prop. mort.") shows the proportion of that time step's total mortality that was assumed to have taken place when each observation is made.

					Observations	
Step	Approx. months	Processes	*M* fraction	Age fraction	Label	Prop. Mort.
1	Oct–Nov	migrations Wreturn: WC->SA, Ereturn: CS->CR	0.17	0.25	-	
2	Dec–Mar	recruitment at age 1+ to CR (for both stocks)	0.33	0.6	SAsumbio	0.5
		part1, non-spawning fisheries (Ensp1, Wnsp1)			CRsumbio	0.6
3	Apr–Jun	migration Whome: CR->SA	0.25	0.9	SAautbio	0.1
		part2, non-spawning fisheries (Ensp2, Wnsp2)			pspawn	
4	End Jun	migrations Wspmg: SA->WC, Espmg: CR->CS	0	0.9	-	
5	Jul–Sep	increment ages	0.25	0	CSacous	0.5
		spawning fisheries (Esp, Wsp)			WCacous	0.5

Data and error assumptions

Five series of abundance indices were used in the assessment (Table 15). New data were available from a trawl survey on the Southern Plateau in December 2014 (Bagley et al 2015). The age data used in the assessment (Table 16) are similar to those used in 2014, but with an additional year's data.

The error distributions assumed were multinomial (Bull et al 2012) for the at-age data, and lognormal for all other data. The weight assigned to each data set was controlled by the effective sample size for each observation, calculated from the observation error, and a reweighting procedure for the data sets (McKenzie 2015a, Francis 2011). An arbitrary CV of 0.25 (as used by Cordue 2001) was assumed for the proportion spawning observations.

Table 15: Abundance indices ('000 t) used in the stock assessment (* data new to this assessment). Years are fishing years (1990 = 1989–90). - no data.

Year	Acoustic survey WCSI winter WCacous	Trawl survey Southern Plateau December SAsumbio	Trawl survey Southern Plateau April SAautbio	Trawl survey Chatham Rise January CRsumbio	Acoustic survey Cook Strait winter CSacous
1988	417	-	-	-	-
1989	249	-	-	-	-
1990	255	-	-	-	-
1991	341	-	-	-	191
1992	345	80	68	120	-
1993	549	87	-	186	613
1994	-	100	-	146	597
1995	-	-	-	120	411
1996	-	-	89	153	196
1997	655	-	-	158	302
1998	-	-	68	87	170
1999	-	-	-	109	245
2000	397	-	-	72	-
2001	-	56	-	60	217
2002	-	38	-	74	307
2003	-	40	-	53	222
2004	-	14	-	53	-
2005	-	18	-	85	124
2006	-	21	-	99	128
2007	-	14	-	70	225
2008	-	46	-	77	179
2009	-	47	-	144	359
2010	-	65	-	98	-
2011	-	-	-	94	298
2012	412	46	-	88	-
2013	357	56	-	124	353
2014	-	-	-	102	-
2015	-	31*	-	-	-

Table 16: Age data used in the assessment (* data new to this assessment). Data are from otoliths or from the length-frequency analysis program OLF (Hicks et al 2002). Years are fishing years (1990 = 1989–90). Espage for 2011, 2012, 2013 were omitted for model runs.

Area	Label	Data type	Years	Source of age data
WC	Wspage	Catch at age	1988–14*	Otoliths
SA	WnspOLF	Catch at age	1992–94, 96, 99–00	OLF
	Wnspage	Catch at age	2001–04, 06–14*	Otoliths
	SAsumage	Trawl survey	1992–94, 2001–10, 2012–13, 15*	Otoliths
	SAautage	Trawl survey	1992, 96, 98	Otoliths
	pspawn	Proportion spawning	1992, 93, 98	Otoliths
CS	Espage	Catch at age	1988–14*	Otoliths
CR	EnspOLF	Catch at age	1992, 94, 96, 98	OLF
	Enspage	Catch at age	1999–14*	Otoliths
	CRsumage	Trawl survey	1992–14	Otoliths

Two alternative sets of CVs were used for the biomass indices (Table 17). The "total" CVs represent the best estimates of the uncertainty associated with these data, and were used in final model runs. For the trawl-survey indices, these were calculated as the sum of an observation-error CV (which was calculated using the standard formulae for stratified random surveys, e.g., Livingston & Stevens (2002) and a process-error CV, which was set at 0.2, following Francis et al (2001) (note that CVs added as squares: $CV_{total}^2 = CV_{process}^2 + CV_{observation}^2$). For the acoustic indices, the total CVs were calculated using a simulation procedure intended to include all sources of uncertainty (O'Driscoll 2002). The observation-error CVs were calculated using standard formulae for stratified random acoustic surveys (e.g., Coombs & Cordue (1995)) and included only the uncertainty associated with between-transect (and within-stratum) variation in total backscatter. In some model runs only the observation-error rather than the total CVs for all trawl survey biomass indices was used as a way of giving more weight to these data.

Table 17: Coefficients of variation (CVs) used with biomass indices in the assessment. Observation-error CVs were used when it was desired to up-weight a series of indices. Years are fishing years (1990 = 1989–90).

CRsumbio	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Total	0.21	0.22	0.22	0.21	0.22	0.22	0.23	0.23	0.23	0.22	0.23	0.22	0.24
Observation	0.08	0.10	0.10	0.08	0.10	0.08	0.11	0.12	0.12	0.10	0.11	0.09	0.13

CRsumbio	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total	0.23	0.23	0.22	0.23	0.23	0.25	0.24	0.22	0.25	0.22
Observation	0.12	0.11	0.08	0.11	0.11	0.15	0.14	0.10	0.15	0.10

SAsumbio	1992	1993	1994	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Total	0.21	0.21	0.22	0.24	0.26	0.24	0.24	0.23	0.24	0.23	0.26	0.24	0.26
Observation	0.07	0.06	0.09	0.13	0.16	0.14	0.13	0.12	0.13	0.11	0.16	0.14	0.16

SAsumbio	2012	2013	2015
Total	0.25	0.25	0.24
Observation	0.15	0.15	0.13

SAautbio	1992	1996	1998
Total	0.22	0.22	0.23
Observation	0.08	0.09	0.11

CSacous	1991	1993	1994	1995	1996	1997	1998	1999	2001	2002	2003	2005	2006
Total	0.41	0.52	0.91	0.61	0.57	0.40	0.44	0.36	0.30	0.34	0.34	0.32	0.34
Observation	0.13	0.15	0.06	0.12	0.09	0.12	0.10	0.10	0.12	0.13	0.17	0.11	0.17

CSacous	2007	2008	2009	2011	2013
Total	0.46	0.30	0.39	0.35	0.30
Observation	0.26	0.06	0.13	0.14	0.15

WCacous	1988	1989	1990	1991	1992	1993	1997	2000	2012	2013
Total	0.60	0.38	0.40	0.73	0.49	0.38	0.60	0.28	0.34	0.35
Observation	0.22	0.15	0.06	0.14	0.14	0.07	0.10	0.14	0.15	0.13

The observation CVs for the otolith-based, at-age data were calculated by a bootstrap procedure, which included an explicit allowance for age estimation error. No observation-error CVs were available for the OLF-based data from the non-spawning fisheries, so an ad hoc procedure was used to derive observation-errors, which were forced to be higher than those from the spawning fisheries (Francis 2004b).

The age ranges used in the model varied amongst data sets (Table 18). In all cases, the last age for these data sets was treated as a plus group.

Table 18: Age ranges used for at-age data sets.

	Age range	
Data set	Lower	Upper
Espage, Wspage, SAsumage, SAautage	2	15+
Wnspage	2	13+
CRsumage, Enspage	1	13+
WnspOLF	2	6+
EnspOLF	1	6+
pspawn	3	9+

The catch for each year was divided into the six fisheries in the model according to area and month (Table 19). This division was done using TCEPR, TCER, CELR, NCELR, LTCER LCER and TLCER data, and the resulting values were then scaled up to sum to the HOK 1 MHR total. The method of dividing the catches (Table 19) was the same as that used in the 2014 assessment, so the catches used in the model (Table 20) are unchanged, except for minor revisions to years 2001 to 2014 (including removing catches taken outside the New Zealand EEZ).

Table 19: The division of annual catches by area and months into the six model fisheries (Esp, Wsp, Ensp1, Ensp2, Wnsp1, and Wnsp1). The small amount of catch reported in the areas west coast North Island and Challenger, typically about 100 t per year, has been distributed pro-rata across all fisheries).

Fishery	Model fishery	Areas	Months
Western spawning fishery	Wsp	West Coast South Island & Puysegur	October–September
Western non-spawning fishery 1	Wnsp 1	Southern Plateau	October–March
Western non-spawning fishery 2	Wnsp 2	Southern Plateau	April–September
Eastern spawning fishery	Esp	Cook Strait & Pegasus Canyon	June–September
Eastern non-spawning fishery 1	Ensp 1	Cook Strait & Pegasus Canyon Chatham Rise, East Coast South Island, East Coast North Island & null[1]	October–March
Eastern non-spawning fishery 2	Ensp 2	Cook Strait & Pegasus Canyon Chatham Rise East Coast South Island East Coast North Island null[1]	April–May April–September

[1] catch reported to no area.

For the 2013–14 year, the TACC was 150 000 t with a catch limit arrangement for 60 000 t to be taken from the eastern fisheries and 90 000 t from the western fisheries (this limit was not met by 3 800 t for the eastern fisheries, and exceeded by 100 t for the western fisheries). For 2014–15 year, the TACC was 160 000 t with a catch limit arrangement for 60 000 t to be taken from the eastern fisheries and 100 000 t from the western fisheries. It was estimated by industry representatives that the 100 000 t catch limit for the 2014–2015 western fishery would be split: 22 000 t (non-spawning), 78 000 t (spawning). In the stock assessment model the non-spawning fishery was split into two parts, separated by the migration of fish from the Chatham Rise to the Southern Plateau. The same proportions as in 2014 were used to split the western non-spawning catch into two parts. For the eastern stock, the catch split for 2014–15 was estimated as 41 500 t (non-spawning), 18 500 t (spawning). As with the western stock, the non-spawning catch was split into two parts, using the same proportions as in 2014.

Further assumptions

Two key outputs from the assessment are B_0 - the average spawning stock biomass that would have occurred, over the period of the fishery, had there been no fishing - and year-class strengths (YCSs). For example, the YCS for 1970, was for fish spawned in the winter of 1970, that first arrived in the model in area CR, at age 1.6 y, in about December 1971, which was in model year 1972. Associated with B_0 was an estimated mean recruitment, R_0, which was used, together with a Beverton-Holt stock-recruit function and the YCSs, to calculate the recruitment in each year. The first five YCSs (for years 1970 to 1974) were set equal to 1 (because of the lack of at-age data for the early years), but all remaining YCSs (for 1975 to 2013) were estimated. The model corrects for bias in estimated YCSs arising from ageing error. YCSs were constrained to average to 1 over the years 1975 to 2010, so that R_0 may be thought of as the average recruitment over that period. R_0 and a set of YCSs were estimated separately for each stock. The B_0 for each stock was calculated as the spawning biomass that would occur given no fishing and constant recruitment, R_0, and the initial biomass before fishing (B_{INIT}) was set equal to B_0. The steepness of the stock-recruitment relationship was assumed fixed at 0.75 (Francis 2009).

Two alternative approaches were used in modelling natural mortality. In some model runs it was assumed to vary with age (following a double-exponential curve) and separately for each sex; in others (where sex is ignored) it was assumed to be independent of age.

The model used six selectivity ogives (four for the eastern and western spawning and non-spawning fisheries and one each for the trawl surveys in areas CR and SA) and three migration ogives (Whome, Espmg, and Wspmg).

Assumed maximum exploitation rates were as agreed by the Working Group in 2004: 0.5 and 0.67 for the non-spawning and spawning fisheries, respectively. Because the non-spawning fisheries were split into two approximately equal halves, a maximum exploitation rate of 0.3 was assumed for each half. This was approximately equivalent to 0.5 for the two halves combined. Penalty functions were used to discourage model fits which exceeded these maxima.

Prior distributions were assumed for all parameters. The main priors used are shown in Table 21. In addition, bounds were imposed for parameters with non-uniform distributions. For the catchability parameters, these were calculated by O'Driscoll et al (2002) (who called them overall bounds); for other parameters, they were set at the 0.001 and 0.999 quantiles of their distributions. Prior distributions for all other parameters were assumed to be uniform, with bounds that were either natural (e.g., 0,1 for proportion migrating at age), wide enough so as not to affect point estimation, or, for some ogive parameters, deliberately set to constrain the ogive to a plausible shape.

Table 20: Catches (t) by fishery and fishing year (1972 means fishing year 1971–72), as used in this assessment. Years are fishing years (1990 = 1989–90).

	Fishery						
Year	Ensp1	Ensp2	Wnsp1	Wnsp2	Esp	Wsp	Total
1972	1 500	2 500	0	0	0	5 000	9 000
1973	1 500	2 500	0	0	0	5 000	9 000
1974	2 200	3 800	0	0	0	5 000	11 000
1975	13 100	22 900	0	0	0	10 000	46 000
1976	13 500	23 500	0	0	0	30 000	67 000
1977	13 900	24 100	0	0	0	60 000	98 000
1978	1 100	1 900	0	0	0	5 000	8 000
1979	2 200	3 800	0	0	0	18 000	24 000
1980	2 900	5 100	0	0	0	20 000	28 000
1981	2 900	5 100	0	0	0	25 000	33 000
1982	2 600	4 400	0	0	0	25 000	32 000
1983	1 500	8 500	3 200	3 500	0	23 300	40 000
1984	3 200	6 800	6 700	5 400	0	27 900	50 000
1985	6 200	3 800	3 000	6 100	0	24 900	44 000
1986	3 700	13 300	7 200	3 300	0	71 500	99 000
1988	9 000	6 000	5 400	7 600	600	227 000	255 600
1989	2 300	2 700	700	4 900	7 000	185 900	203 500
1990	3 300	9 700	900	9 100	14 000	173 000	210 000
1991	17 400	14 900	4 400	12 700	29 700	135 900	215 000
1992	33 400	17 500	14 000	17 400	25 600	107 200	215 100
1993	27 400	19 700	14 700	10 900	22 200	100 100	195 000
1994	16 000	10 600	5 800	5 500	35 900	117 200	191 000
1995	29 600	16 500	5 900	7 500	34 400	80 100	174 000
1996	37 900	23 900	5 700	6 800	59 700	75 900	209 900
1997	42 400	28 200	6 900	15 100	56 500	96 900	246 000
1998	55 600	34 200	10 900	14 600	46 700	107 100	269 100
1999	59 200	23 600	8 800	14 900	40 500	97 500	244 500
2000	43 100	20 500	14 300	19 500	39 000	105 600	242 000
2001	36 200	19 700	13 200	16 900	34 800	109 000	229 800
2002	24 600	18 100	16 800	13 400	24 600	98 000	195 500
2003	24 200	18 700	12 400	7 800	41 700	79 800	184 600
2004	17 900	19 000	6 300	5 300	41 000	46 300	135 800
2005	19 000	13 800	4 200	2 100	27 000	38 100	104 200

Table 20 [continued]

	Fishery						
Year	Enspl	Ensp2	Wnspl	Wnsp2	Esp	Wsp	Total
2006	23 100	14 400	2 300	4 700	20 100	39 700	104 300
2007	22 400	18 400	4 200	3 500	18 800	33 700	101 000
2008	22 100	19 400	6 500	2 200	17 900	21 200	89 300
2009	29 300	13 100	6 000	3 800	15 900	20 800	88 900
2010	28 500	13 500	6 700	5 600	16 400	36 600	107 300
2011	30 500	12 800	7 500	5 200	13 300	49 500	118 800
2012	28 400	14 700	9 100	6 600	15 400	55 800	130 000
2013	29 900	11 800	6 500	7 600	18 600	57 200	131 600
2014	27 200	11 700	10 600	9 300	17 300	70 200	146 300
2015	29 000	12 500	10 000	12 000	18 500	78 000	160 000

Calculation of fishing intensity and B_{MSY}

The fishing intensity for a given stock and model run was calculated as an annual exploitation rate, $U_y = \max_{as}\left(\sum_f C_{asfy}/N_{asy}\right)$, where the subscripts *a*, *s*, *f*, and *y* index age, sex, fishery, and year, respectively, *C* is the catch in numbers, and *N* is the number of fish in the population immediately before the first fishery of the year. This measure is deemed to be more useful than the spawning fisheries exploitation rates that have been presented in previous assessments, because it does not ignore the effect of the non-spawning fisheries, and thus represents the total fishing intensity for each stock.

Table 21: Assumed prior distributions for key parameters. Parameters are bounds for uniform; mean (in natural space) and CV for lognormal; and mean and SD for normal and beta.

Parameter	Description	Distribution	Parameters		Reference
log_B$_0$_total	log($B_{0,\mathrm{E}}$ + $B_{0,\mathrm{W}}$)	uniform	11.6	16.2	
pE (= B$_0$_prop_stock1)	proportion unfished stock in E	beta(0.1,0.6)[1]	0.344	0.072	Smith (2004)
recruitment[E].YCS	year-class strengths (E)	lognormal	1	0.95	Francis (2004a)
recruitment[W].YCS	year-class strengths (W)	lognormal	1	0.95	Francis (2004a)
q[CSacous].q	catchability, CSacous	lognormal	0.77	0.77	WG Minutes of 24-2-04
q[WCacous].q	catchability, WCacous	lognormal	0.57	0.68	O'Driscoll et al (2002)
q[CRsum].q	catchability, CRsumbio	lognormal	0.15	0.65	O'Driscoll et al (2002)
q[SAsum].q	catchability, SAsumbio	lognormal	0.17	0.61	O'Driscoll et al (2002)
q[SAaut].q	catchability, SAautbio	lognormal	0.17	0.61	O'Driscoll et al (2002)
selectivity[Wspsl].shift_a	allows annual shifting of Wspsl	normal	0	0.25	Francis (2006)
natural_mortality.all[2]	*M*	lognormal	0.298	0.153	Smith (2004)
natural_mortality[3]	M_{male} & M_{female}, ages 5–9 only	lognormal	0.182	0.509	Cordue (2006)

[1] This is a beta distribution, transformed to have its range from 0.1 to 0.6, rather than the usual 0 to 1.

[2] Used only in runs where *M* was independent of age and sex

[3] Used only in runs where *M* varied with age and sex

For a given stock and run, the reference fishing intensities, $U_{35\%B_0}$ and $U_{50\%B_0}$, are defined as the levels of *U* that would cause the spawning biomass for that stock to tend to 35%B_0 or 50%B_0, respectively, assuming deterministic recruitment and individual fishery exploitation rates that are multiples of those in the current year. These reference fishing intensities were calculated by simulating fishing using a harvest strategy in which the exploitation rate for fishery *f* was $mU_{f,\mathrm{current}}$, where $U_{f,\mathrm{current}}$ is the estimated exploitation rate for that fishery in the current year, and *m* is some multiplier (the same for all fisheries). For each of a series of values of *m*, simulations were carried out with this harvest strategy and deterministic recruitment, with each simulation continuing until the population reached equilibrium. For a given stock, $U_{x\%B_0}$ was set equal to $m_{x\%}U_{\mathrm{current}}$, where the multiplier, $m_{x\%}$ (calculated by interpolation) was that which caused the equilibrium biomass of that stock to be $x\%B_0$.

The same sets of simulations were used to calculate B_{MSY} for each stock for the final model runs. B_{MSY} was defined as the equilibrium biomass (expressed as %B_0) for the value of *m* which maximised the equilibrium catch from that stock.

Caution about the interpretation of B_{MSY} estimates

There are several reasons why B_{MSY}, as calculated in this way, is not a suitable target for management of the hoki fishery. First, it assumes a harvest strategy that is unrealistic in that it involves perfect knowledge (current biomass must be known exactly in order to calculate the target catch) and annual changes in TACC (which are unlikely to happen in New Zealand and not desirable for most stakeholders). Second, it assumes perfect knowledge of the stock-recruit relationship, which is actually very poorly known (Francis 2009). Third, the closeness of B_{MSY} to the soft limit permits the limit to be breached too easily and too frequently, given, for example, a limited period of low recruitment. Fourth, it would be very difficult with such a low biomass target to avoid the biomass occasionally falling below 20% B_0, the default soft limit according to the Harvest Strategy Standard.

6.2 Results

The assessment was conducted in two steps. First, a set of initial exploratory model runs was carried out generating point estimates (so-called MPD runs, which estimate the mode of the posterior distribution). Their purpose was to provide information to make the decision as to which sets of assumptions should be carried forward and used in the final runs. The final runs were fully Bayesian, producing posterior distributions for all quantities of interest.

Initial runs

An initial set of analyses was carried out after the new data became available (McKenzie 2015c). In the 2008 assessment, the model was unable to fit the threefold increase in estimated biomass between the 2007 and 2008 trawl surveys in the summer Southern Plateau series (see SAsumbio in Table 15). This biomass increase was sustained in the four subsequent surveys (2009, 2010, 2012 and 2013), but the biomass declined substantially in 2015. Furthermore, the SAsumbio survey data shows large annual changes in numbers-at-age which cannot be explained by changes in abundance, and are suggestive of a change in catchability for the survey. Because of this, and to improve the fit to the SAsumbio series, two model runs were conducted in which it was assumed that the catchability has changed over time.

In an alternative approach to try to improve the fit to the SAsumbio series, the trawl survey data was upweighted in a sensitivity run.

Final runs

The DWFAWG chose four model runs to investigate, which were similar to the three final runs of 2014 assessment. The four runs consisted of a constant catchability (single q) model for the SAsumbio series (1.1), a variation on this with the trawl surveys upweighted (1.2), and two runs with qs that varied over different periods: a 2004–07 variable-q model (1.3) and a 2008–15 variable-q model (1.4). The models where the trawl surveys were not upweighted (1.1, 1.3, and 1.4) showed acceptably good fits to the data and broadly similar trends in biomass and stock status. Compared to the other models, the model with the trawl surveys upweighted gave a much reduced estimate of current western biomass.

Following exploration of these four models, the DWFAWG selected the single-q model (1.1) as the base case. This choice was based largely on the fit to the data, and the expectation that a run of four low biomass estimates from a survey time-series is not unexpected statistically (Cordue 2014). Results of both of the variable-q models are presented as sensitivities to the base case, as is the upweighted trawl survey model. Results from other sensitivities to the base case are described and presented below.

For the 2014 base model run, the problem of the lack of old fish in both fishery-based and survey-based observations was dealt with by allowing M (natural mortality) to be dependent on age. Also, natal fidelity was assumed, and the trawl survey data were not upweighted. In the base model of the 2015 assessment, these model features were kept, and the model updated with the new data. There are some differences between the 2014 and 2015 assessments in the way the Bayesian runs are conducted. For the 2014 assessment, the migration and selectivity parameters that hit bounds in the MPD fits were set at these bounds for the Bayesian runs; whereas for the 2015 assessment they are not set at the bounds. In the 2014 assessment catchability parameters were estimated as nuisance parameters, but are estimated as free parameters for the 2015 assessment.

Other sensitivity model runs were carried out to the base model run (Table 22). These tested the sensitivity of model 1.1 to assumptions about natal fidelity but still assuming adult fidelity (1.5), and domed spawning selectivity (1.6).

Table 22: Distinguishing characteristics for all model runs, including all sensitivities to the base run 1.1.

Run	Main assumptions
1.1 - base case	natal fidelity *M* is age-dependent single q for Southern Plateau trawl series trawl surveys are not upweighted
1.2	as 1.1 but the trawl surveys are upweighted
1.3 - 2004–07 two-*q*	as 1.1 but with a different q for 2004-07
1.4 - 2008–15 two-*q*	as 1.1 but with a different q for 2008-15
1.5	as 1.1 but natal fidelity is not assumed
1.6	as 1.1 but domed spawning selectivity (instead of *M* age-dependent)

Bayesian posterior distributions were estimated for each of these runs using a Markov Chain Monte Carlo (MCMC) approach (McKenzie 2015d & e). For each run, three chains of length four million were completed, the initial 500 000 samples of each chain was discarded, and the remaining samples were concatenated and thinned to produce a posterior sample of size 2000.

Model estimates are presented for the spawning stock biomass (Table 23), biomass trajectories and year-class strengths (Figure 2), and current biomass distributions (Figure 3). Compared to the base case (1.1), upweighting the trawl surveys results in the same current biomass for the E stock (%B_0), whereas for the W stock the %B_0 is much lower. Allowing two catchabilities results in the same current status of the E stock (%B_0), whereas for the W stock, the %B_0 is either higher (1.3) or lower (1.4). The other sensitivities give higher %B_0 for the stock estimates, except for the E stock when natal fidelity is not assumed (1.5).

Table 23: Estimates of spawning biomass for the base case* and sensitivities (median of marginal posteriors, with 95% confidence intervals in parentheses). $B_{current}$ is the spawning biomass in mid-season 2014–15. The base case 1.1 estimates a single catchability for SAsumbio, runs 1.3 and 1.4 estimate two catchabilities. All other sensitivities are conducted against the base case 1.1– see table 22.

	B_0(‘000 t)		$B_{current}$(‘000 t)		$B_{current}$(%B_0)		
Run	E	W	E	W	E	W	E+W
1.1*	540(446,674)	897(758,1126)	322(213,476)	459(286,735)	59(43,78)	51(36,69)	55(43,67)
1.2	517(425,636)	773(686,887)	313(221,426)	230(150,337)	60(48,74)	30(20,40)	42(35,50)
1.3	563(461,707)	978(804,1258)	343(225,519)	537(319,838)	60(45,80)	55(38,71)	57(45,70)
1.4	556(450,693)	890(746,1133)	336(226,515)	372(197,646)	61(45,81)	42(25,61)	49(38,63)
1.5	711(539,943)	1011(844,1268)	364(207,599)	584(360,956)	51(33,71)	58(40,82)	55(44,71)
1.6	629(443,882)	976(767,1293)	383(239,607)	618(393,963)	61(45,82)	63(47,81)	63(51,76)

In the base case model (Run1.1), where constant catchability is assumed for all years, the observation of low biomass in the November 2014 Southern Plateau trawl survey was interpreted as observation error (i.e. the survey underestimated the biomass by chance). If the low biomass is real, the implication is that the western stock status is much lower (30%). In run 1.2 the trawl survey indices are upweighted relative to other data by removing the process error of 20%. The lower stock status also resulted in more pessimistic projections shown in Table 24, with the probability of the western stock going below 20% B_0 reaching 0.34 in 2020. The WG noted that the next scheduled Southern Plateau trawl survey is in November 2016, although the hoki stock assessment will be updated with other sources of data in 2016.

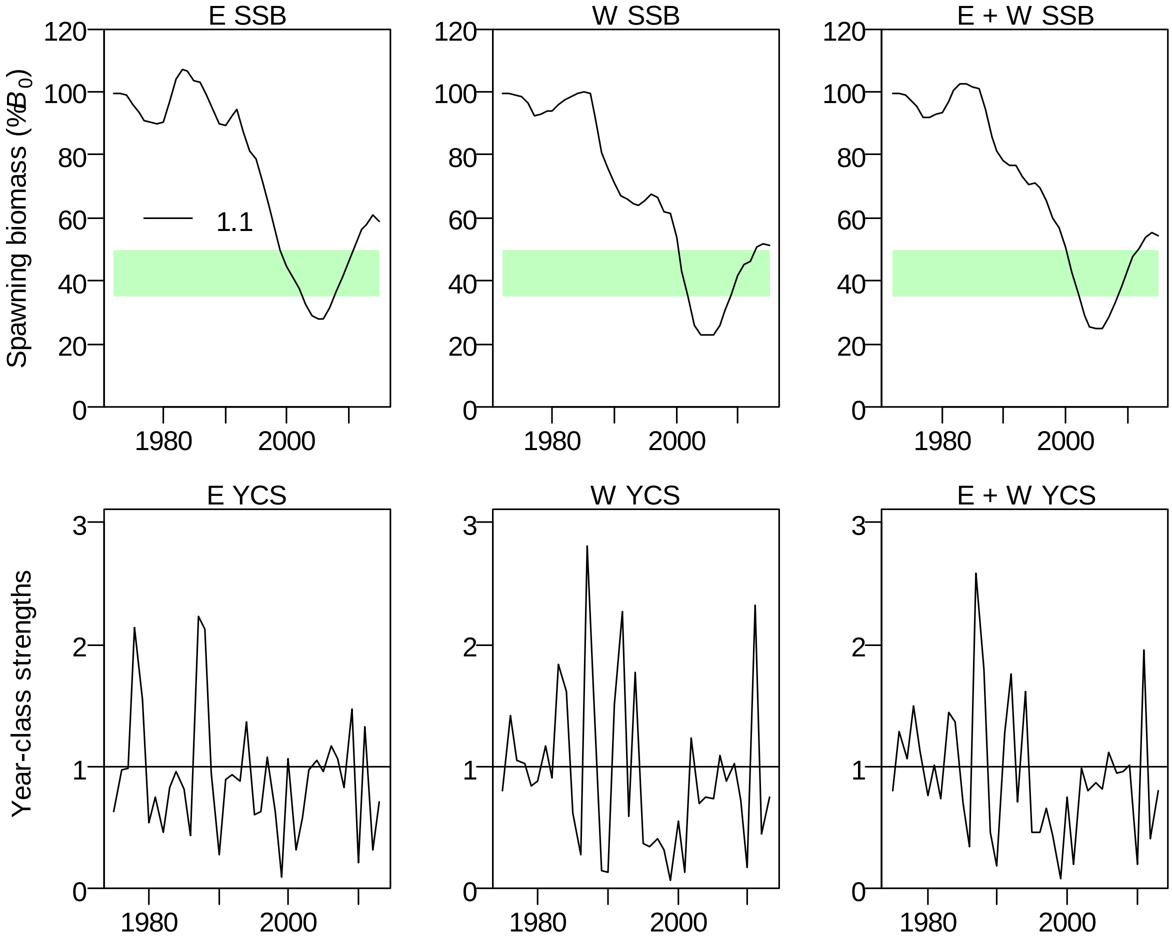


Figure 2: **Estimated spawning biomass trajectories (SSB, upper panels) and year-class strengths (YCS, lower panels) for the E (left panels), W (middle panels) and E + W stocks (right panels) from the base case run 1.1. Plotted values are medians of marginal posterior distributions. Years are fishing years (1990 = 1989–90). The shaded green region represents the target zone of 35–50% B_0.**

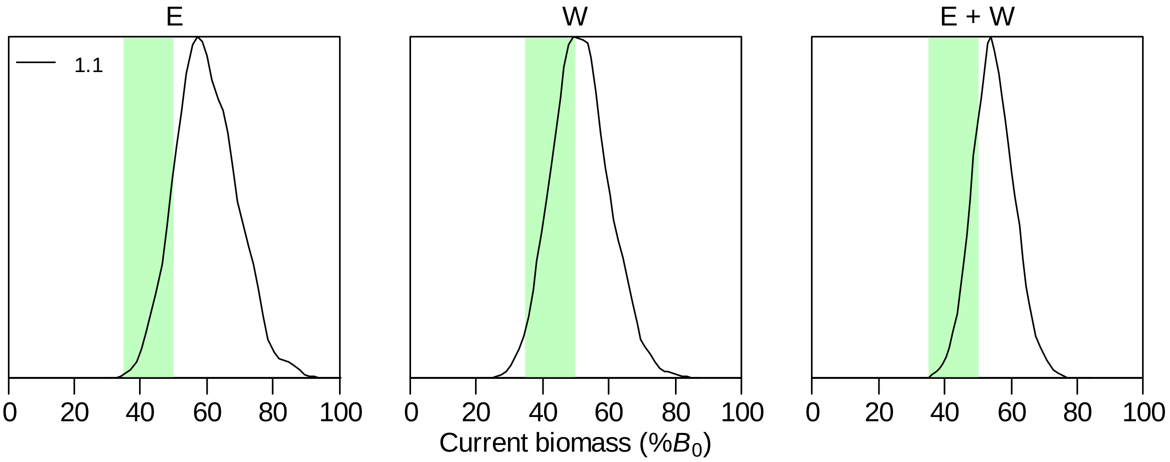


Figure 3: **Estimated posterior distributions of current (spawning) biomass ($B_{2013\text{-}14}$) expressed as %B_0 for the E (left panel), W (middle panel), and E + W (right panel) from the base case run 1.1. The shaded green region represents the target zone of 35–50% B_0.**

The base run (1.1) shows that the biomasses of both stocks were at their lowest points in about 2004–06 (at about 30% B_0 for the E stock and 25% B_0 for the W stock), are continuing to increase, and that the W stock experienced seven consecutive years of poor recruitment from 1995 to 2001 inclusive (Figure 2). During the period of poor recruitment to the W stock, the E stock showed below average recruitment but not as poor as that seen for the W stock (Figure 2). Recruitment to the W stock following the 1995–2001 period of poor recruitment was estimated to have been just below average for 2002–2009, below average in 2010 and 2012 and 2013, and well above average in 2011.

In the 2014 assessment base case there was a 1.00 probability that the stock was above 35% B_0, whereas the probability for 2015 is 0.98 for the base case (1.1). Based on the 2015 assessment, the Harvest Strategy Standard defines that the western stock has been fully rebuilt (i.e. at least a 70% probability of being above the lower bound of the management target of 35% B_0) for at least three years.

Fishing intensity on both stocks was estimated to be at or near all-time highs in about 2003 and is now substantially lower (Figure 4). For the base run (1.1) estimates of deterministic B_{MSY} were 25% for the E stock and 26% for the W stock.

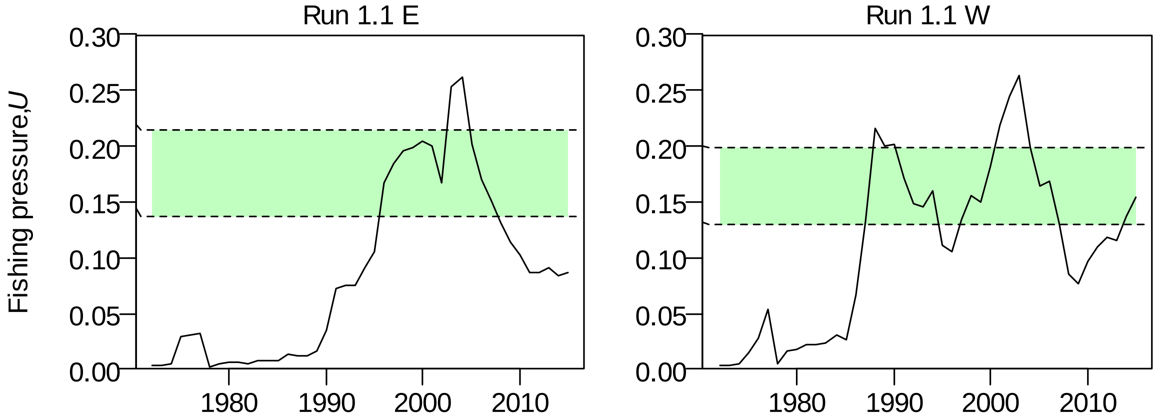


Figure 4: Base case fishing intensity, U (from MPDs), plotted by stock. Also shown (as broken lines) are the reference levels $U_{35\%B_0}$ (upper line) and $U_{50\%B_0}$ (lower line), which are the fishing intensities that would cause the spawning biomass to tend to 35% B_0 and 50% B_0, respectively (with the associated management range shaded in green).

6.3 Projections

Five-year projections were carried out for two models: the base model with a single catchability for the SAsumbio series (1.1), and the model where the trawl surveys are upweighted (1.2).

In all projections, future recruitments were selected at random from those estimated for 2004–2013, and the future catches in each fishery were assumed to be the same as for 2015 (i.e. as in the last line of Table 20). The projections indicate that with these assumed catches, the E and W biomasses are likely to remain flat or decline slightly over the next 5 years (Figure 5).

The probabilities of the current (2015) and projected spawning stock biomass being below the hard limit of 10% B_0, the soft limit of 20% B_0, and the lower and upper ends of the interim management target range of 35–50% B_0 are presented in Table 24 for the case where future catches remain at 2015 levels. The probability of either stock being less than either the soft or the hard limit over the five year projection period is negligible for the E stock, but 0.34 or less for the W stock when trawl surveys are upweighted (run 1.2). Both stocks are projected to be within or above the 35–50% B_0 target range at the end of the projection period, except for the W stock when trawl surveys are upweighted.

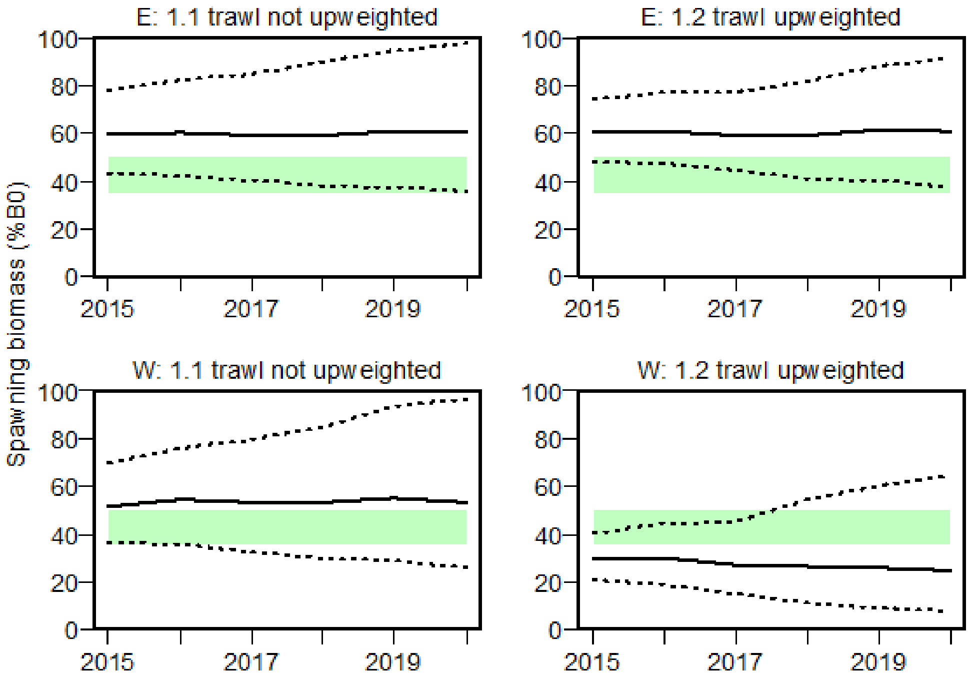


Figure 5: Projected spawning biomass (as %B_0): median (solid lines) and 95% confidence intervals (broken lines) for the base case (1.1) and a sensitivity with the trawl surveys upweighted (1.2). The shaded green region represents the target management range of 35–50% B_0.

Table 24: Probabilities (to two decimal places) associated with projections for SSB (%B_0) for the base case (1.1) and a sensitivity with the trawl surveys upweighted (1.2) for 2015 through to 2020.

	2015	2016	2017	2018	2019	2020
EAST 1.1						
P (SSB<10%B_0)	0	0	0	0	0	0
P (SSB<20%B_0)	0	0	0	0	0	0
P (SSB<35%B_0)	0	0	0.01	0.01	0.01	0.02
P (SSB<50%B_0)	0.13	0.15	0.20	0.23	0.22	0.24
EAST 1.2						
P (SSB<10%B_0)	0	0	0	0	0	0
P (SSB<20%B_0)	0	0	0	0	0	0
P (SSB<35%B_0)	0	0	0	0	0	0.01
P (SSB<50%B_0)	0.04	0.06	0.12	0.18	0.16	0.20
WEST 1.1						
P (SSB<10%B_0)	0	0	0	0	0	0
P (SSB<20%B_0)	0	0	0	0	0	0
P (SSB<35%B_0)	0.02	0.02	0.04	0.06	0.07	0.11
P (SSB<50%B_0)	0.44	0.34	0.39	0.41	0.38	0.43
WEST 1.2						
P (SSB<10%B_0)	0	0	0	0.01	0.04	0.07
P (SSB<20%B_0)	0.02	0.05	0.15	0.24	0.29	0.34
P (SSB<35%B_0)	0.84	0.78	0.83	0.8	0.77	0.77
P (SSB<50%B_0)	1.00	1.00	0.99	0.96	0.94	0.92

7. STATUS OF THE STOCKS

Stock Structure Assumptions

Hoki are assessed as two intermixing biological stocks, based on the presence of two main areas where simultaneously spawning takes place (Cook Strait and the WCSI), and observed and inferred migration patterns of adults and juveniles:

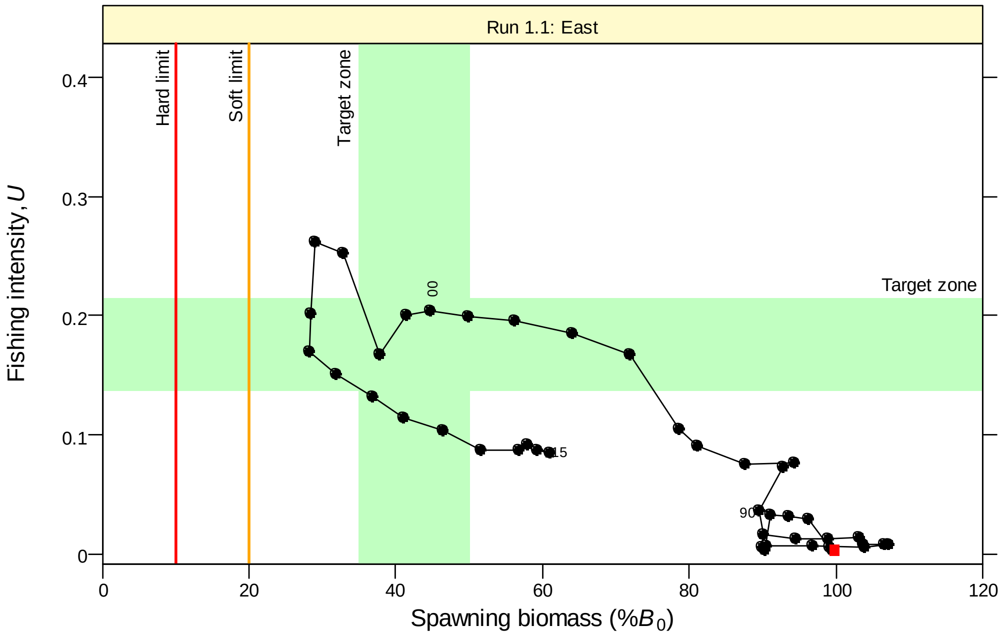
- Adults of the western stock occur on the west coast of the North and South Islands and the area south of New Zealand including Puysegur, Snares and the Southern Plateau;
- Adults of the eastern stock occur on the east coast of the South Island, Cook Strait and the ECNI up to North Cape;
- Juveniles of both biological stocks occur on the Chatham Rise including Mernoo Bank.

Both of these biological stocks lie within the HOK 1 Fishstock boundaries.

Eastern Hoki Stock

Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	A base run used to evaluate hoki stock status: run 1.1
Reference Points	Target: 35–50% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{35\%B0}$
Status in relation to Target	B_{2015} was estimated to be 59% B_0; Virtually Certain (> 99%) to be at or above the lower end of the target range and Likely (> 60%) to be at or above the upper end of the target range
Status in relation to Limits	B_{2015} is Exceptionally Unlikely (< 1%) to be below either the Soft or Hard Limit
Status in relation to Overfishing	Overfishing is Exceptionally Unlikely (< 1%) to be occurring

Historical Stock Status Trajectory and Current Status



Trajectory over time of fishing intensity (*U*) and spawning biomass (% B_0), for the eastern hoki stock from the start of the assessment period in 1972 (represented by a red square), to 2015 (15). The red vertical line at 10% B_0 represents the hard limit, the yellow line at 20% B_0 is the soft limit, and the shaded area represents the management target ranges in biomass and fishing intensity. Biomass estimates are based on MCMC results, while fishing intensity is based on corresponding MPD results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass has been stable for the last 4 years.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has been flat for the last 5 years.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Recent recruitment (2003–2009) is estimated by the model to be near the long-term average for this stock, but 2010 was well below average, 2011 about average and 2012 below average. The actual split of recruitment between the eastern and western stocks for these three year classes is uncertain.

Projections and Prognosis	
Stock Projections or Prognosis	If the year classes recruit to the eastern stock as estimated by the model, the biomass of the eastern hoki stock is expected to remain more or less constant over the next five years at assumed 2014–15 eastern fishery catch levels.
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	Exceptionally Unlikely (< 1%)

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: 2015	Next assessment: 2016
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 fixed 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	Catchabilities estimated as free instead of nuisance, MPD parameters not set at bounds (when they hit them) for Bayesian runs	
Major Sources of Uncertainty	- Stock structure and migration patterns - Split of 2011 year class between eastern and western stocks with respect to projections	

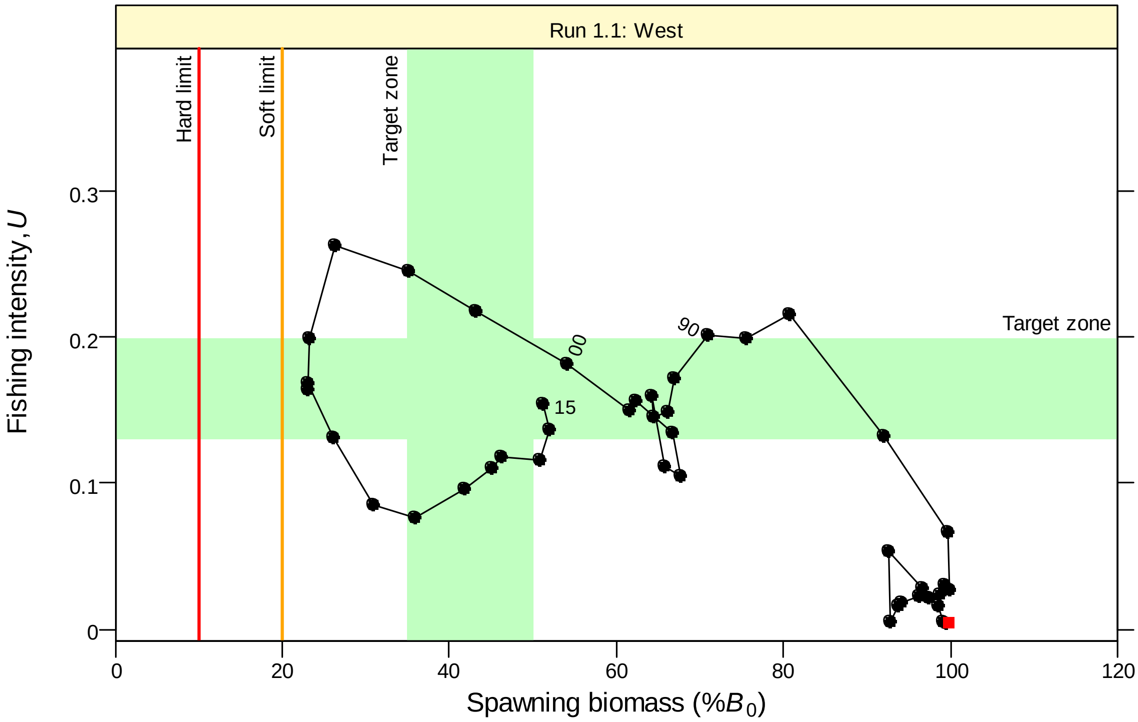
Qualifying Comments
-

Fishery Interactions
In Cook Strait, the main bycatch species are ling and spiny dogfish while on the Chatham Rise the main bycatch species are hake, ling, silver warehou, javelinfish, rattails and spiny dogfish, with lesser bycatches of ghost sharks, white warehou, sea perch and stargazers. Low productivity species taken in the hoki fisheries include basking sharks, deepsea skates and some other elasmobranchs. Incidental captures or protected species are noted for New Zealand fur seals and seabirds.

Western Hoki Stock

Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	A base run used to evaluate hoki stock status: run 1.1
Reference Points	Target: 35–50% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{35\%B0}$
Status in relation to Target	B_{2015} was estimated to be 51% B_0; Very Likely (> 90%) to be at or above the lower end of the target range and About as Likely as Not (40–60%) to be at or above the upper end of the target range
Status in relation to Limits	B_{2015} is Exceptionally Unlikely (< 1%) to be below the Hard Limit and Very Unlikely (< 10%) to be below the Soft Limit
Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring

Historical Stock Status Trajectory and Current Status



Trajectory over time of fishing intensity (U) and spawning biomass (% B_0), for the western hoki stock from the start of the assessment period in 1972 (represented by a red square), to 2015 (15). The red vertical line at 10% B_0 represents the hard limit, that the yellow line at 20% B_0 is the soft limit, and the shaded area represents the management target ranges in biomass and fishing intensity. Biomass estimates are based on MCMC results, while fishing intensity is based on corresponding MPD results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass has been stable at about 50% B_0 for the last 3 years.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity is estimated to have decreased from 2003 to 2009, and to have increased since.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	This stock experienced an extended period of poor recruitment from 1995 to 2001. Year-classes after 2001 are estimated by the model to be stronger, with five to six years in which recruitment is estimated to be near or above the long-term average, but the

	2010 recruitment was well below average, 2011 was well above average, and 2012 below average The actual split of recruitment between the eastern and western stocks for these three year classes is uncertain.

Projections and Prognosis	
Stock Projections or Prognosis	If the year classes recruit to the western stock as estimated by the model, the biomass of the western hoki stock is expected to to remain more or less constant over the next five years at assumed 2014–15 western fishery 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: Exceptionally Unlikely (< 1%)
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: 2015	Next assessment: 2016
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Research time series of abundance indices (trawl and acoustic surveys) - Proportions at age data from the commercial fisheries and trawl surveys - Estimates of fixed biological parameters	1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	- Commercial CPUE - WCSI trawl survey biomass estimate	3 – Low Quality: does not track stock biomass 3 – Low Quality: currently not included in the assessment pending an evaluation of their reliability for hoki
Changes to Model Structure and Assumptions	- Catchabilities estimated as free instead of nuisance, MPD parameters not set at bounds (when they hit them) for Bayesian runs	
Major Sources of Uncertainty	- Stock structure and migration patterns - Split of 2011 year class between eastern and western stocks with respect to projections - Possible catchability changes in Southern Plateau trawl surveys	

Qualifying Comments
The low abundance index from the 2014 southern trawl survey is interpreted by the model as observation error. Run 1.2 shows the implications (low stock status) if the trawl survey index is reflecting an actual change in biomass.

Fishery Interactions
In the west coast South Island and Southern Plateau fisheries, the main bycatch species are hake, ling, silver warehou, jack mackerel and spiny dogfish. Low productivity species taken in the hoki fisheries include basking sharks, deepsea skates and some other elasmobranchs. Incidental captures of protected species are noted for New Zealand fur seals and seabirds.

8. FOR FURTHER INFORMATION

Abraham, E R; Thompson, F N (2011) Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002–03 to 2008–09. *New Zealand Aquatic Environment and Biodiversity Report* No. 79. 74 p.

Abraham, E R; Thompson, F N; Berkenbusch, K (2013) Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002–03 to 2010–11. Final Research Report for Ministry for Primary Industries project PRO2010-01 (Unpublished report held by Ministry for Primary Industries, Wellington).

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