Report from the
Fisheries Assessment Plenary, May 2012: stock assessments and yield estimates

Part 1: Introductory Sections to Jack Mackerel

Compiled by
Ministry for Primary Industries
Fisheries Science Group
May 2012

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## PREFACE

The May 2012 Fisheries Plenary Report summarises fishery, biological, stock assessment and stock status information for 82 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, a mid-year Plenary that is produced each November for species that operate on different management cycles includes Working Group and Plenary summaries for Highly Migratory Species (HMS), Antarctic toothfish, rock lobster, scallops and dredge oysters.

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

Fisheries plenary reports have represented a significant output of the Ministry for Primary Industries and its predecessors, the Ministry of Fisheries and the Ministry of Agriculture and Fisheries, for the last 28 years. Over this time, continual improvements have been made in data acquisition, stock assessment techniques, the development of reference points to guide fisheries management decisions, and the provision of increasingly comprehensive and meaningful information for a range of audiences. 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, for as many stocks as possible. The May 2012 Plenary now includes Status of the Stocks summary tables for 139 stocks or sub-stocks, spread over 45 species. These tables have several uses: they provide comprehensive summary information about current stock status and the prognosis for these stocks and their associated fisheries, and they are used to evaluate fisheries performance relative to the Harvest Strategy Standard for New Zealand Fisheries and other management measures. The number of cases where stock or fishery targets and limits have not yet been specified has been decreasing over time as the Harvest Strategy Standard continues to be implemented, and Fisheries Plans are further developed. We hope the enhanced presentation of information will assist fisheries managers, stakeholders and other interested parties in making informed decisions.

In 2012, for the first time, selected Status of the Stocks summary tables have incorporated a new science information quality ranking system, as specified in the Research and Science Information Standard for New Zealand Fisheries which was approved in April 2011.

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 am pleased to endorse this document as representing the best available scientific information relevant to stock and fishery status, as at 31 May 2012.

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## INTRODUCTION

This report summarises the conclusions and recommendations from the meetings of the Fisheries Assessment Working Groups 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 and Environment Working Group (AEWG) that has relevance to fishery management have been incorporated for selected species. Paragraph 11 (page 13) of the Terms of Reference for Fisheries Assessment Working Groups (FAWGs) includes "...information and advice on other management issues (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 20) 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."

During the Working Group meetings three sources of information were considered and discussed:

1. "Draft Reports" tabled at the meetings of the various Fisheries Assessment Working Groups held from May 2011 to May 2012;
2. Draft Fisheries Assessment Reports;
3. Additional data provided at the Working Group meetings by Ministry staff, science research providers, and representatives of stakeholder groups; and

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 2011-12.

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 noncommercial 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". The Guide is in the process of being updated by the Stock Assessment Methods Working Group through the Operational Guidelines for New Zealand's Harvest Strategy Standard.

## 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 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).

## Glossary of Common Technical Terms

Abundance Index: A quantitative measure of fish density or abundance, usually as a 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).

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 catch (or stock) of fish.
Age-structured stock assessment: An assessment of the status of a fish stock, that uses an assessment model to estimate how the numbers at age in the stock vary over time.
$\boldsymbol{A}_{M}$ : Age at maturity is the age at which fish, of a given sex, are considered to be reproductively mature. See $\mathrm{a}_{50}$.
$\mathbf{a}_{\mathbf{5 0}}$ : Either the age at which $50 \%$ of fish are mature ( $=A_{M}$ ) or $50 \%$ are recruited to the fishery $\left(=A_{R}\right)$
$\mathbf{a}_{\text {to95 }}$ : 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).

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
$\boldsymbol{A}_{\boldsymbol{R}}$ : 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 $a_{50}$.
$\boldsymbol{B}_{A V}$ : The average historic recruited biomass.
Bayesian analysis: 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.
$\boldsymbol{B}_{\boldsymbol{B E G}}$ : The estimated stock biomass at the beginning of the fishing year.
$\boldsymbol{B}_{\text {CURRENT }}$ : Current biomass (usually a mid-year biomass).
$\boldsymbol{B}_{\text {YEAR }}$ : Estimated or predicted biomass in the named year (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, recruited biomass, or vulnerable biomass, or recruited biomass the later two of which are essentially equivalent).
$\boldsymbol{B}_{M S Y}$ : 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.
$\boldsymbol{B}_{\boldsymbol{o}}$ : Virgin biomass. This is the theoretical carrying capacity of the recruited or vulnerable 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.

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.

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

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, $F_{\text {REF, }}$ to an estimate of the fishable biomass at the beginning of the fishing year (see page 27). Also see MAY.

CELR forms: Catch-Effort Landing Return.
CLR forms: Catch Landing Returns.
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.
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 an 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.

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.

EEZ: An Exclusive Economic Zone is a maritime zone 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 result 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 fraction of each age or size class of a stock that is vulnerable to fishing.

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

F: The fishing mortality rate is that part of the total mortality rate applying to a fish stock that is caused by fishing.
$F_{0.1}$ : A biological reference point. It is 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 $1 / 10$ th of the slope of the yield per recruit curve at its origin).

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, 2005 is shorthand for 2004-05.

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

$\boldsymbol{F}_{\text {MAX }}$ : A biological reference point. It is the fishing mortality rate that maximises equilibrium yield per recruit. $\boldsymbol{F}_{\text {MAX }}$ is the fishing mortality level that defines growth overfishing. In
general, $F_{M A X}$ is different from $F_{M S Y}$ (the fishing mortality that maximises sustainable yield), and is always greater than or equal to $F_{\text {MSY }}$, depending on the stock-recruitment relationship.
$\boldsymbol{F}_{\text {MEY }}$ : The fishing mortality corresponding the maximum (sustainable) economic yield.
$\boldsymbol{F}_{\text {MSY }}$ : A biological reference point. It is 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 $B_{\text {MSY }}$.
$\boldsymbol{F}_{\text {REF }}$ : 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.

Growth overfishing: Growth overfishing occurs when the fishing mortality rate is above $F_{M A X}$. This means that individual 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.

Index: Same as an abundance index.
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 often estimated based on a sample, and sometimes called a length composition.

Length-Structured Stock Assessment: An assessment of the status of a fish stock, which uses an assessment model to estimate how the numbers at length in the stock vary over time.

Limit: a biomass or fishing mortality reference point that should be avoided with high probability. The Harvest Strategy Standard defines both soft limits and hard limits.
$\boldsymbol{M}$ : The 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.

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

Model: A conceptual and simplified idea of how the 'real world’ works.
Monte Carlo Simulation: is an approach whereby the inputs that are used for a calculation are resampled many times assuming that the inputs follow known statistical distributions. The Monte Carlo method is used in many applications such as Bayesian analyses, parametric bootstraps and stochastic projections.

## MPD: Mode of the (joint) posterior distribution. See Bayesian analysis.

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. It is the maximum use that a renewable resource can sustain without impairing its renewability through natural growth and reproduction.

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

Otolith: One of the small bones or particles of calcareous substance in the internal ear of fish that can sometimes be used to age them.

Overexploitation: A situation where observed fishing mortality (or exploitation) rates exceed targets.

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 study of fish stock abundance and how and why it changes over time.

Posterior: a mathematical description of the uncertainty in some quantity (e.g., a biomass) estimated in a Bayesian stock assessment.

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 analysis. 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, longterm projections are more useful for evaluating overall management strategies than for making short-term decisions.

Proxy: A surrogate for $B_{M S Y}, F_{M S Y}$ 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 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.

RTWG: Marine Recreational Fisheries Technical Working Group, a sub group of the Marine Recreational Fisheries Working Group.
$\boldsymbol{S}_{\mathrm{AV}}$ : The average historic spawning biomass.
Selectivity ogive: Curve describing the relative vulnerability of fish of different ages or sizes to the fishing gear used.

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. Many types of analyses that address reproductive (spawning) potential should use a measure of production of viable eggs (e.g., fecundity). However, when such life-history information is lacking, SSB is used as a proxy. Same as mature biomass.

Spawning (biomass) per recruit (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:

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Stock: The term has different meanings. Under the Fisheries Act, it is defined with reference to units for the purpose of fisheries management. 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 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 benchmarks or reference points (e.g. $B_{M S Y}$ and/or $F_{M S Y}$ ).

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 stockrecruitment relationship is the Beverton and 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 and of the fishery. Stock status is often expressed relative to biological reference points such as $B_{M S Y}$ or $B_{0}$ or $F_{M S Y}$ or $F_{\% S P R}$. For example, the current biomass may be said to be above or below $B_{M S Y}$ or to be at some percentage of $B_{0}$. Similarly, fishing mortality may be above or below $F_{\text {MSY }}$ or $F_{\% S P R}$.

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 selfcontained 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 $F_{M S Y}$ could be achieved exactly each year, catches and stock biomass will oscillate around their average $M S Y$ and $B_{M S Y}$ 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 isthe total quantity of each fishstock that can be taken by commercial, customary moari interests, recreational fishery interests and other sources of fishing-related mortality, to ensure sustainability of that fishery in a given period, usually a year. A TAC must be set before a TACC can be set.

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 or fishing mortality 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 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 forms: Trawl Catch-Effort Processing Return.
TLCER forms: Tuna Longline Catch-Effort Return.
von Bertalanffy equation: An equation describing how fish increase in length as they grow older. The mean length ( $L$ ) at age $a$ is
$L=L_{\infty}\left(1-\mathrm{e}^{-\mathrm{k}(\mathrm{a}-\mathrm{t})}\right)$
where $L_{\infty}$ is the average length of the oldest fish, $k$ is the average growth rate 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 <br> (FAWGs) in 2012 

## 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 MSYcompatible 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 MAF 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), MAF fisheries scientists will produce a list of stocks 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, MAF fisheries managers will alert MAF 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 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. ${ }^{2}$
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 the 2010-11 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 existing data and analyses to draw conclusions about likely future trends in biomass

[^0]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, fisheries plan advisers, 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, fisheries plan advisers, 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, noncommercial 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 MSYcompatible 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 35-36 of the 2011 May Plenary document, following the associated instructions on pages $35-38 .{ }^{3}$
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 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

[^1]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 Fishery Assessment Plenary and those stocks that are not believed to warrant review by the Plenary. The general criterion for determining which stocks should be discussed by the Plenary is that 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
- 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 a MAF 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 ${ }^{4}$ (the Research Standard), and that research and science information is reviewed by the 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.
- striving for consensus while ensuring the transparency and integrity of research analyses, results, conclusions and final reports.

[^2]- reporting on Working Group recommendations, conclusions and action items; and ensuring follow-up and communication with the MAF Principal Advisor Fisheries Science, relevant MAF fisheries management staff, and other key stakeholders.


## Working Group members

18. Working Groups will consist of the following participants:

- MAF 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 MAF fisheries management teams
- Any interested party who agrees to the standards of participation below.

19. Working Group participants must commit to:

- participating 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
- 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 will 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.

## Information Quality Ranking:

22. 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). This information quality ranking must be documented in Working Group reports and, where appropriate, in Status of Stock summary tables.

- 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 must be included in Working Group reports. In particular, the quality shortcomings and concerns for moderate/mixed and low quality information must be documented.
- 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.


## Working Group papers:

23. Working group papers will be posted on the MAF-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 2 working days before a meeting, and near-final papers should be available at least 5 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.
24. 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.
25. Participants who use Working Group papers inappropriately, or who do not adhere to the standards of participation, may be requested by the Chair to leave a particular meeting or, in more serious instances, to refrain from attending one or more future meetings.
26. 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).
27. 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.
28. 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
- The status of the stocks, or the status/performance in relation to any relevant environmental standards or targets

29. The Chair is responsible for facilitating a consultative and collaborative discussion.
30. Working Group meetings will be run formally, with agendas pre-circulated, and formal records kept of recommendations, conclusions and action items.
31. A record of recommendations, conclusions and action items will be posted on the MAFFisheries website after each meeting has taken place.
32. Data upon which analyses presented to the Working Groups are based must be provided to MAF in the appropriate format and level of detail in a timely manner (i.e. the data must be available and accessible to MAF; however, data confidentiality concerns mean that such data are not necessarily available to Working Group members)
33. 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.
34. MAF fisheries scientists and science officers will provide administrative support to the Working Groups.

## Record-keeping

35. 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.
- 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 Fisheries Data Working Group

1. To identify the data used for stock assessment purposes for incorporation into the Ministry's data collection systems, for use in the fisheries stock assessment process, including,
a. Data from the commercial catch;
i. Commercial catch and effort data
ii. Commercial catch monitoring (Observers)
iii. Fishing Industry collected data (where appropriate)
b. Non-commercial data;
i. Scientific survey data
ii. Scientific experiment data
iii. Recreational catch data
iv. Customary catch data
v. Other data used for stock assessment purposes as may be deemed appropriate by the respective stock assessment working groups
c. Data from the Quota Management System;
i. TACCs and landed catches
ii. TACC overruns
iii. Bycatch trading
2. To review the systems for the collection of any new data used for stock assessment purposes that may be maintained as a part of the Ministry's data collection systems, and that may be used by any other Ministry working group as a part of the stock assessment process.
3. To report on any new information that may impact on the interpretation of data used for stock assessment purposes held in the Ministry's data collection systems.
4. To provide advice on methods, systems, and conditions of the release of data used for stock assessment purposes.
5. To report on changes to the Ministry's data collection and other systems that may impact on the interpretation of any data used for stock assessment purposes.

# Terms of Reference for the Aquatic Environment Working Group (AEWG) in 2012 

## 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
- 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 MAF fisheries managers and the Minister responsible for Fisheries).

MAF 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, MAF 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, MAF-Fisheries or standards managers will alert MAFFisheries science managers and the Principal Advisor Fisheries Science, at least 3 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 environment analogue of the Fisheries Assessment Plenary Report (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
- Consistent performance outside accepted reference points or Standards


## Fisheries Assessment Working Groups - Membership 2012

## Northern and Southern Inshore Working Group

Convenors: Marc Griffiths (Northern) and Stephen Brouwer (Southern)<br>Members: William Arlidge, Helena Armiger, Mark Baxter, Mike Beentjes, Nokome Bentley, Michelle Beritzhoff, Richard Bian, Andrew Bond, Anthony Brett, Tania Cameron, Glen Carbines, Bruce Chapman, Tom Clark, Patrick Cordue, Robert Davidson, Peter Dawson, Christopher Dick, Ian Doonan, Andy Doube, John Duncan, Chris Francis, Malcolm Francis, Dan Fu, Mark Geytenbeek, Eric Goodman, Vivian Haist, Steve Halley, Stewart Hanchet, Bruce Hartill, Ian Henderson, Michael Hill, Stephanie Hill, John Holdsworth, Arthur Hore, Peter Horn, Rosie Hurst, Weimin Jiang, Eric Jorgenson, Terese Kendrick, Ben Knight, Philippe Lallemand, Adam Langley, Laws Lawson, Greg Lydon, Warwick Lyon, Pamela Mace, Graeme McGregor, Jeremy McKenzie, Tania McPherson, David Middleton, Laura Mitchell, Leigh Mitchell, Clive Monds, Sophie Mormede, Steve Parker, Larry Paul, Andrew Penny, Marine Pomarede, Trish Rae, Nathan Reed, Eugene Rees, Pat Reid, Nicola Rush, Carol Scott, Hayden Smith, Tracey Smith, Mark Soboil, Paul Starr, Michael Stevenson, Kevin Stokes, Kevin Sullivan, John Taunton-Clarke, Paul Taylor, Geoff Tingley, Alison Undorf-Lay, Cameron Walsh, D’Arcy Webber.

Species: | Alfonsino | Porae |  |
| :--- | :--- | :--- |
|  | Anchovy | Red cod |
| Bluenose | Red gurnard |  |
| Blue cod | Red snapper |  |
| Blue mackerel | Rig |  |
| Blue moki | Rough Skate |  |
| Butterfish | Rubyfish |  |
| Elephant fish | School shark |  |
| Flatfish | Sea perch |  |
| Garfish | Smooth Skate |  |
| Grey mullet | Snapper |  |
| Groper | Spiny dogfish |  |
| Jack Mackerel (JMA 1) | Sprats |  |
| John dory | Stargazer |  |
| Kahawai | Tarakihi |  |
| Kingfish | Trevally |  |
| Leatherjacket | Trumpeter |  |
| Parore | Yellow-eyed mullet |  |
| Pilchard |  |  |

## Shellfish Working Group

## Convenor: Julie Hills

Members: Ed Abraham, Jason Baker, David Baker, Kate Bartrum, Michelle Beritzhoff, Erin Breen, Paul Breen, Stephen Brown, Jeremy Cooper, Patrick Cordue, Martin Cryer, Alistair Dunn, Ian Francis, Allen Frazer, Dan Fu, Vivian Haist, Bruce Hartill, Wiemin Jaing, Mark Janis, Pamela Mace, Andrew McKenzie, Keith Michael, David Middleton, Reyn Naylor, Tracey Osborne, Matthew Pawley, Marine Pomerade, Norman Ragg, Alan Riwaka, Storm Stanley, Paul Starr, Ian Tuck, Ellie Watts, James Williams, Graeme Wright.

Species: Cockles
Deepwater crab
Dredge oysters
Deepwater (king) clam (Geoduc)
Queen scallops
Deepwater tuatua
Giant spider crab
Trough shell
Green-lipped mussel Large trough shell
King crab
Frilled venus shell
Knobbled whelk
Sea cucumber
Kina
Paddle crab
Paua
Pipi
Red crab

Triangle shell
Ringed dosinia
Fine (Silky) dosinia
Scallop
Scampi
Surf clam
Toheroa
Tuatua
Horse mussel

## Middle Depth Working Group

Convenor: Kevin Sullivan
Members: William Arlidge, Michael Backhurst, Sira Ballara, Tiffany Bock, Paul Breen, Russell Cole, Patrick Cordue, Alistair Dunn, Matt Dunn, David Foster, Chris Francis, Dan Fu, Stuart Hanchet, Peter Horn, Charles Hufflet, Rosie Hurst, Aaron Irving, TP Katene, Andy McKenzie, David Middleton, Richard O’Driscoll, Johannes Oefner, Marine Pomarede, Vicky Reeve, Oliver Ross, Paul Starr, Rob Tilney, Geoff Tingley, D'Arcy Webber, Richard Wells.

Species: Arrow squid
Barracouta
Blue warehou
Frostfish
Gemfish
Dark ghost shark
Pale ghost shark
Hake
Jack Mackerel (JMA 3 and 7)

Ling
Lookdown dory
Ribaldo
Silver warehou
Southern blue whiting
White warehou

## Deepwater Working Group

Convenors: Kevin Sullivan, Pamela Mace
Members: Owen Anderson, William Arlidge, Neil Bagley, Milan Barbarich, Tom Birdsall, Tiffany Bock, Malcolm Clark, George Clement, Steve Collier, Patrick Cordue, Ian Doonan, Adam Dunford, Matt Dunn, Tyler Eddy, Jack Fenaughty, Chris Francis, Dan Fu, Ian Hampton, Alan Hart, Bill Healey, Jeremy Helson, Peter Horn, Rosie Hurst, Greg Johansson, Rudy Kloser, Aoife Martin, Andy McKenzie, Peter McMillan, David Middleton, Richard Nelson, Richard O’Driscoll, Johannes Oefner, Graham Patchell, Marine Pomarede, Jim Roberts, Oliver Ross, Andy Smith,

Paul Starr, Rob Tilney, Geoff Tingley, Grant Walker, D’Arcy Webber, Richard Wells.

Orange roughy
Smooth oreo

Black oreo
Black cardinalfish

## Hoki Working Group

| Convenor: | Kevin Sullivan |
| :--- | :--- |
| Members: | William Arlidge, Neil Bagley, Sira Ballara, Tiffany Bock, George Clement, |
|  | Patrick Cordue, Chris Francis, Vivian Haist, Jeremy Helson, Rosie Hurst, TP Katene, |
|  | Rudy Kloser, Adam Langley, Mary Livingston, Pamela Mace, Andy McKenzie, <br> David Middleton, Helen Neil, Richard O’Driscoll, Johannes Oefner, Graham |
|  | Patchell, Marine Pomarede, Vicky Reeve, Darryn Shaw, Paul Starr, Darren Stevens, <br> Kevin Stokes, Geoff Tingley, D'Arcy Webber, Richard Wells. |
| Species: | Hoki |

## Eel Working Group

Convenor: Marc Griffiths, Kevin Sullivan
Members: Jason Arnold, Mike Beentjes, Santiago Bermeo, Stephen Bishop, Jacques Boubee, Joan Burgman, Bill Chisholm, Shannan Crow, Sky Davies, Alistair Dunn, Jane Goodman, Marc Griffiths (Chair), Mike Holmes, Mandy Home, John Jameson, Don Jellyman, Greg Lydon, Mike Martin, David Middleton, Garry Pullan, Pauline Reid, Kim Russell-Reihana, Terrianna Smith, Clem Smith, Paul Starr, Vic Thompson, Phillip Walters, Hamiora Wehipeihana, Clare Williams.

Species: Freshwater eels

## Stock Assessment Methods Working Group

Convenor: Pamela Mace<br>Members: William Arlidge, Nokome Bentley, Paul Breen, Stephen Brouwer, Patrick Cordue, Martin Cryer, Ian Doonan, Alistair Dunn, Chris Francis, Dan Fu, Marc Griffiths, Vivian Haist, Jeremy Helson, Ray Hilborn, Rosie Hurst, Philippe Lallemand, Adam Langley, Andy McKenzie, Dave Middleton, Sophie Mormede, Andrew Penney, Mark Soboil, Paul Starr, Kevin Sullivan, D’Arcy Webber.

## Fisheries Data Working Group

Convenor: Kim George

Members: Edward Abrahams, Alexander Baider, Nokome Bentley, Alistair Dunn, David Fisher, Andrew France, Rosie Hurst, Bob Johnston, Te Puoho Katene, Craig Loveridge, Greg Lydon, Pamela Mace, Alan Martin, David Middleton, John Moriarty, Andrew Penney, Chantal Percy, Brian Sanders, Neville Smith, Paul Starr, Kevin Sullivan, Daryl Sykes, Finlay Thompson, Marianne Vignaux.

## Aquatic Environment Working Group

Convenors: Rich Ford, Martin Cryer and Rohan Wells.
Members: Blake Abernethy, Ed Abraham, Karen Baird, Suze Baird, Barry Baker, Michelle Beritzhoff, Katrin Berkenbusch, Santiago Bermeo-Alvear, Jenny Black, Tiffany Bock, Paul Breen, Steve Brouwer, Murray Bruges, Martin Cawthorn, Malcolm Clark, George Clement, Owen Cox, Rohan Currey, Igor Debski, Graeme Elliot, Jack Fenaughty, Chris Francis, Malcolm Francis, Christy Getzlaff, Marc Griffiths, Kevin Hackwell, Tim Haggit, Barb Hayden, Jeremy Helson, Stephanie Hill, Rosie Hurst, Aaron Irving, Mary Livingston, Greg Lydon, Warrick Lyon, Pamela Mace, Aoife Martin, Rob Mattlin, Jeremy McKenzie, David Middleton, Mark Morrison, Tracey Osborne, Milena Palka, Karen Palmigiano, Andrew Penney, Johanna Pierre, Irene Pohl, Kris Ramm, Vicky Reeve, Pat Reid, Yvan Richard, Carol Scott, Ben Sharp, Liz Slooten , Anna Smith, Paul Starr, Kevin Stokes, Katrina Subedar, Alex Thompson, Findlay Thompson, Geoff Tingley, Ian Tuck, Kath Walker, Cath Wallace, Dee Wallace, Susan Waugh, Barry Weeber, Richard Wells, Gunther Wild, Francene Wineti, Ray Wood, Bob Zuur.
QMS stocks and Ministry of Fisheries Management team with
responsibility for management



## 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, $\boldsymbol{M C Y}$ and $\boldsymbol{C A Y}$, 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 $\boldsymbol{C A Y}$ 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, $\boldsymbol{F}_{\boldsymbol{R E F}}$, to an estimate of the fishable biomass present during the next fishing year. $\boldsymbol{F}_{\text {REF }}$ 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 $\boldsymbol{M C Y}$ is dependent to a certain extent on the current state of the fish stock. If a stock is fished at the $\boldsymbol{M C Y}$ 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 $\boldsymbol{M C Y}$ remains unchanged (though our estimates of it may well be refined). If the current state of the stock is below this range the $\boldsymbol{M C Y}$ will be lower.

The strategy of applying a constant fishing mortality, $\boldsymbol{F}_{\boldsymbol{R E F}}$, from which the $\boldsymbol{C A Y}$ 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 $\boldsymbol{C A Y}$. 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 $\boldsymbol{F}_{\text {REF }}$ are discussed below.

What is meant by an "acceptable level of risk" for MCYs and CAYs 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 $\boldsymbol{M C Y}$ is generally less than MAY (see, e.g., Doubleday 1976, Sissenwine 1978, Mace 1988a). This is because $\boldsymbol{C A Y}$ will be larger than $\boldsymbol{M C Y}$ 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 $\boldsymbol{C A Y}$ and $\boldsymbol{M C Y}$ are exact. The following diagram shows the relationships between $\boldsymbol{C A Y}, \boldsymbol{M C Y}$ and $\boldsymbol{M A Y}$.


Figure 1: Relationship between CAY, MCY and MAY.
In this example $\boldsymbol{C A Y}$ represents a constant fraction of the fishable biomass, and so (if it is estimated and applied exactly) it will track the fish population exactly. $\boldsymbol{M A Y}$ is the average over time of $\boldsymbol{C A Y}$. The reason $\boldsymbol{M C Y}$ is less than $\boldsymbol{M A Y}$ is that $\boldsymbol{M C Y}$ 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. $\mathbf{M C Y}$ and $\boldsymbol{C A Y}$ 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 $\boldsymbol{M C Y}$ and $\boldsymbol{C A Y}$ are directly applicable only in idealised management regimes. The $\boldsymbol{M C Y}$ 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 $\boldsymbol{n}$ years a total mortality $\mathbf{Z}$ will reduce a population of size $\boldsymbol{B}$ to size $\boldsymbol{B} \boldsymbol{e}^{-n \boldsymbol{Z}}$, ignoring recruitment and growth). Units for mortalities are $1 /$ year.

## Natural mortality

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

$$
M=-\frac{\log _{e}(p)}{A}
$$

where $\boldsymbol{p}$ is the proportion of the population that reaches age $\boldsymbol{A}$ (or older) in an unexploited stock. $\boldsymbol{p}$ is often set to 0.01 , when $\boldsymbol{A}$ is the "maximum age" observed. Other values for $\boldsymbol{p}$ 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 $\boldsymbol{p}=0.05$, or higher. For a discussion of the method see Hoenig (1983).

## Reference Fishing Mortalities

Reference fishing mortalities in widespread use include $\boldsymbol{F}_{0.1}, \boldsymbol{F}_{\boldsymbol{M S Y}}, \boldsymbol{F}_{\boldsymbol{M A X}}, \boldsymbol{F}_{\boldsymbol{M E Y}}$, and $\boldsymbol{M}$.
The most common reference fishing mortality used in the calculation of CAY (and, in some cases, $\mathbf{M C Y}$ ) is $\boldsymbol{F}_{0.1}$ (pronounced ${ }^{\mathrm{F}} \mathrm{F}$ 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 $\boldsymbol{F}=0$. If an estimate of $\boldsymbol{F}_{0.1}$ is not available an estimate of $\boldsymbol{M}$ may be substituted.
$\boldsymbol{F}_{\text {MAX }}$, 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.
$\boldsymbol{F}_{\boldsymbol{M S Y}}$, the fishing mortality corresponding to the deterministic $\mathbf{M S Y}$, is another appropriate reference point. $\boldsymbol{F}_{\boldsymbol{M S Y}}$ 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 $\boldsymbol{F}_{\text {MEY }}$ 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 $\mathbf{M C Y}$ 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, $\boldsymbol{c}$, 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 $\boldsymbol{c}$. Values for $\boldsymbol{c}$ 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.


## Methods of Estimating MCY

It should be possible to estimate $\mathbf{M C Y}$ 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 $\mathbf{M C Y}$ 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 MCYs. For example, rather than saying "with the official catch statistics the MCY is $\boldsymbol{X}$ 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 $\boldsymbol{Y}$ 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

$$
M C Y=0.25 F_{0.1} B_{0}
$$

where $\boldsymbol{B}_{0}$ is an estimate of virgin recruited biomass. If there are insufficient data to conduct a yield per recruit analysis $\boldsymbol{F}_{0.1}$ should be replaced with an estimate of natural mortality ( $\boldsymbol{M}$ ). Tables 1-3 in Mace (1988b) show that $\boldsymbol{F}_{0.1}$ is usually similar to (or sometimes slightly greater than) $\boldsymbol{M}$.

It may appear that the estimate of $\boldsymbol{M C Y}$ for new fisheries is overly conservative, particularly when compared to the common approximation to MSY of $\mathbf{0 . 5 M B}_{0}$ (Gulland 1971). However various authors (including Beddington \& Cooke 1983; Getz et al. 1987; Mace 1988a) have shown that $\mathbf{0 . 5 M B} \mathbf{B}_{0}$ 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 $\boldsymbol{M C Y}$ from a stochastic population model (Method 5), if this is possible. The simulations of Mace (1988a) and Francis (1992) indicate that the appropriate factor to multiply $\boldsymbol{F}_{0.1} \boldsymbol{B}_{0}$ may be somewhat higher or somewhat lower than $\mathbf{0 . 2 5}$. 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 $\boldsymbol{F}$ has approximated or exceeded $\boldsymbol{M}$ for several successive years, depending on the lifespan of the species.

## 2. Developed fisheries with historic estimates of biomass

$$
M C Y=0.5 F_{0.1} B_{A V}
$$

where $\boldsymbol{B}_{A V}$ is the average historic 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 $\boldsymbol{F}_{0.1}$ approximates the average productivity of a stock.

As in the previous method an estimate of $\boldsymbol{M}$ can be substituted for $\boldsymbol{F}_{\mathbf{0 . 1}}$ if estimates of $\boldsymbol{F}_{\mathbf{0 . 1}}$ are not available.

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

$$
M C Y=2 / 3 M S Y
$$

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 $\boldsymbol{M S Y}$.

If it is possible to estimate $\boldsymbol{M S Y}$ then it is generally possible to estimate $\boldsymbol{M C Y}$ 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 $\boldsymbol{M S Y}$ varies between about $\mathbf{0 . 6}$ and $\mathbf{0 . 9}$. 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 $2 / 3 \mathbf{M S Y}$ then

$$
M C Y=2 / 3 C S P
$$

where $\boldsymbol{C S P}$ 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

$$
M C Y=c Y_{A V}
$$

where $\boldsymbol{c}$ is the natural variability factor (defined above) and $\boldsymbol{Y}_{\boldsymbol{A} V}$ 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, $\boldsymbol{Y}_{\boldsymbol{A V}}=\boldsymbol{M A Y}$. 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 $\boldsymbol{Y}_{\boldsymbol{A V}}$. The period chosen to perform the averaging will depend on the behaviour of the fishing mortality or fishing effort time series, the prevailing management regime, the behaviour of the catch time series, and the lifespan of the species.

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

The period chosen should also contain no systematic changes in catch. If the period shows a systematic upward (or downward) trend in catches then the $\boldsymbol{M C Y}$ 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 $\mathbf{M C Y}$ but it is the method requiring the most information. It is the only method that allows some specification of the risk associated with an $\mathbf{M C Y}$.

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

$$
C A Y=\frac{F_{r e f}}{F_{r e f}+M}\left(1-e^{-\left(F_{\text {ref }}+M\right)}\right) B_{b e g}
$$

Where $\boldsymbol{B}_{\text {BEG }}$ is the projected stock biomass at the beginning of the fishing year for which the $\boldsymbol{C A Y}$ is to be calculated and $\boldsymbol{F}_{\text {REF }}$ 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:

$$
\begin{gathered}
C A Y=\left(1-e^{-F_{\text {ref }}}\right) B_{b e g} \\
C A Y=\left(1-e^{-F_{r e f}}\right) e^{-\frac{M}{2}} B_{b e g} \\
C A Y=\left(1-e^{-F_{r e f}}\right) e^{-M} B_{b e g}
\end{gathered}
$$

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 $\boldsymbol{F}_{\text {REF }}$ 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 (1991), Shepherd (1984) and Pope (1983).

## FOR FURTHER INFORMATION

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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 previous sections, and were of variable utility to evaluations of stock status and fisheries management decisions.

In 2012 a number of changes were made to the format, primarily for the purpose of implementing the science information quality rankings called for in the Research and science Information Standard for New Zealand Fisheries that was approved in April 2011. However, these changes were only applied for Status of Stocks tables updated in 2012.

It is anticipated that the format of the Status of Stocks tables will be reviewed, standardised and possibly modified further for 2013. Any new format will be implemented each time stocks are reviewed and as time allows. The format will also be subjected to periodic revision so that it continues to remain relevant to fisheries management and other needs.

The table below provides a template for the Status of the Stocks summaries. The text following the table gives guidance on the contents of several 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 <br> Assessment | 2012 |
| Assessment Runs Presented | Base case model only |
| Reference Points ${ }^{4}$ | Target: $40 \% B_{0}$ <br> Soft Limit: $20 \% B_{0}$ <br> Hard Limit: $10 \% B_{0}$ |
| Status in relation to Target ${ }^{5,6}$ | $B_{2012}$ was estimated to be 50\% $B_{0} ;$; Very Likely (> 90\%) to be at or <br> above the target |
| Status in relation to Limits ${ }^{5,6}$ | $B_{2012}$ is Very Unlikely (< 10\%) to be below both the soft and hard <br> limits |
| Historical Stock Status Trajectory and Current Status |  |
| <insert relevant graphs> |  |


| Fishery and Stock Trends |  |
| :--- | :--- |
| Recent Trend in Biomass or <br> Proxy | Biomass reached its lowest point in 2001 and has since consistently <br> increased |
| Recent Trend in Fishing <br> Mortality or Proxy ${ }^{6} 7$ | Overfishing is Unlikely $(<40 \%)$ to be occurring |
| Other Abundance Indices ${ }^{8}$ | - |


| Trends in Other Relevant <br> Indicators or Variables ${ }^{9}$ | Recent recruitment (2005-2010) is estimated to be near the long- <br> term average |
| :--- | :--- |


| Projections and Prognosis | Biomass is expected to stay steady over the next 5 years assuming <br> current (2011-12) catch levels |
| :--- | :--- |
| Stock Projections or <br> Prognosis |  |
| Probability of Current Catch <br> or TACC causing decline <br> below Limits | Soft Limit: Very Unlikely $(<10 \%)$ <br> Hard Limit: Very Unlikely $(<10 \%)$ |


| Assessment Methodology |  |
| :--- | :--- |
| Assessment Type ${ }^{12}$ | Level 1 - Full quantitative stock assessment |
| Assessment Method | Age-structured CASAL model with Bayesian estimation of <br> posterior distributions |
| Main data inputs | - Research time series of abundance indices (trawl and acoustic <br> surveys) <br> - Proportions at age data from the commercial fisheries and trawl <br> surveys <br> - Estimates of biological parameters <br> - New information since the 2011 assessment included two trawl <br> surveys, an acoustic survey, and updated catch and catch-at-age <br> data |
| Period of Assessment | Latest assessment: 2012 $\quad$ Next assessment: 2014 |
| Changes to Model Structure <br> and Assumptions |  |
| Major Sources of Uncertainty | None since the 2009 assessment |
|  | The base case model deals with the lack of older fish in commercial <br> catches and surveys by estimating natural mortality at age which <br> results in older fish suffering high natural mortality. However, there <br> is no evidence to validate this outside the model estimates. <br> Aside from natural mortality, other major sources of uncertainty <br> include stock structure and migration patterns, stock-recruit <br> steepness and natal fidelity assumptions. Uncertainty about the size <br> of recent year classes affects the reliability of stock projections. |

## Qualifying Comments ${ }^{14}$

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

## Fishery Interactions ${ }^{15}$

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.

2012 revision to the Assessment Methodology section:

| Assessment Methodology and Evaluation |  |  |  |
| :--- | :--- | :--- | :---: |
| Assessment Type ${ }^{12}$ | Level 1- Full quantitative stock assessment |  |  |
| Assessment Method | Age-structured CASAL model with Bayesian estimation of <br> posterior distributions |  |  |
| Assessment Dates | Latest assessment: 2012 | Next assessment: 2014 |  |
| Overall assessment quality rank $^{16}$ | 1 - High Quality |  |  |
| Main data inputs (rank) ${ }^{16}$ | - Research time series of abundance indices <br> (trawl and acoustic surveys). | 1- High Quality |  |


|  | - Proportions at age data from the commercial <br> fisheries and trawl surveys. <br> - Estimates of biological parameters. <br> - New information since the 2011 assessment <br> included two trawl surveys, an acoustic <br> survey, and updated catch and catch-at-age <br> data | 1 - High Quality <br> 1 - High Quality |
| :--- | :--- | :--- | :--- |
| Data not used (rank) ${ }^{17}$ | Commercial CPUE | 3- Low Quality: does not track stock <br> biomass |
| Changes to Model Structure and <br> Assumptions ${ }^{13}$ | None since the 2009 assessment |  |
| Major Sources of Uncertainty | The base case model deals with the lack of older fish in <br> commercial catches and surveys by estimating natural mortality at <br> age which results in older fish suffering high natural mortality. <br> However, there is no evidence to validate this outside the model <br> estimates. <br> Aside from natural mortality, other major sources of uncertainty <br> include stock structure and migration patterns, stock-recruit <br> steepness and natal fidelity assumptions. Uncertainty about the <br> size of recent year classes affects the reliability of stock <br> projections. |  |

## Guidance on preparing the Status of the Stocks summary tables

1. Everything included in the Status of the Stocks summary tables should be derived from the Working Group and Plenary reports. No new data should be presented in the summary that was not encompassed in the main text of the Working Group or Plenary reports.

## Stock Structure Assumptions

2. The current assumptions regarding the stock structure and distribution of the stocks being reported on should be briefly summarised. Where a stock is not an administrative fishstock, an explanation must be provided of how the stock relates to the administrative fishstocks it includes.

## Stock Status

3. One Status of the Stocks summary table should be completed for each stock or stock complex.
4. Management targets for each stock will be established by fisheries managers or fisheries management advisory groups. Where management targets have not been established, it is suggested that an interim target of $40 \% B_{0}$, or a related $B_{M S Y}$-compatible target (or $F_{M S Y}$, or a related $F_{\text {MSY }}$-compatible 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). When agreed reference points have not been established, stock status may be reported against interim reference points.
5. Reporting the most 'likely’ stock status against reference points requires agreement on the most 'likely' 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 no agreement can be reached on a likely 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 or limit reference levels, the probability categories and associated verbal descriptions to be used (IPCC, 2007) are:

| 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) and below biomass limits.

## Recent Fishery and Stock Trends

7. Recent fishery or stock trends should be reported in terms of stock size and fishing intensity (or proxies for these), respectively. For quantitative assessments, median results should be used when reporting biomass, but it should be referred to as biomass (not median 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 or long term average. For the recent trend in fishing mortality, a statement about the likelihood that overfishing is occurring should be made, if possible, using the probability rankings in the IPCC (2007) table above.
8. Other Abundance Indices: Primarily intended for reporting of trends where only a Level 2 (semi-quantitative) evaluation has been conducted, but where appropriate abundance indices (such as standardised CPUE, or survey biomass) are available.
9. Other Relevant Indicators or Variables: 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 these trends. This section could also be used to report trends in useful fishery indicators for assessed or un-assessed stocks, where these indicators are agreed to provide some insight into the status of the stock.

## Projections and Prognosis

10. These sections should be used to report any available information on likely future trends in biomass or fishing pressure 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 needs to be stated.
11. 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 catch and TACC differ appreciably, resulting in differing conclusions for each. It may also be useful to specify the catch and TACC levels being referred to. If the stock is already below one or both of the limits, the text should be interpreted as 'causing the stock to remain below the limit(s)'. Again, the timeframe for the projections is approximately 3-5 years following the last year in the assessment unless a longer period of time is stated.

## Assessment Methodology

12. 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: Evaluation of agreed abundance indices (e.g., standardised CPUE) or other agreed appropriate fishery indicators (e.g., estimates of $F(Z)$ based on catch-at-age). Indices of abundance have not been used in a full quantitative
assessment to show where the stock or fishery is in relation to reference points. Age based estimates of F are usually compared with reference points such as $F_{40 \%}$.
3 - Qualitative Evaluation: Fishery characterization with evaluation of fishery trends (e.g., catch, effort and nominal CPUE, length-frequency information) - 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 Level 1 Status of the Stocks summary table.

Table content will vary for these different assessment levels.
13. The primary purpose of the section on changes in model assumptions and structure 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

14. 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

15. The 'Fishery Interactions' section should be used to simply list QMS by-catch species, nonQMS by-catch species and protected / endangered species interactions.

## Ranking of Science Information Quality

16. The Research and Science Information Standard for New Zealand Fisheries (2011) specifies (pages 21-23) that the Ministry will implement processes to rank the quality of research and science information that is 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.
17. In most cases, the 'data not used' row can be left blank; it is primarily useful for specifying particular datasets that the Working group considered but did not use in an assessment
because it was of low quality and should not be used to inform fisheries management decisions.

## 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. and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104pp.
New Zealand Ministry of Fisheries. 2008. Harvest Strategy Standard for New Zealand fisheries. 25 p. Available at http://fs.fish.govt.nz/Page.aspx?pk=61\&tk=208\&se=\&sd=Asc\&filSC=\&filAny=False\&filSrc=False\&filLoaded=False\&filDCG= 9\&filDC=0\&filST=\&filYr=0\&filAutoRun=1.
New Zealand Ministry of Fisheries. 2011. 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
New Zealand Ministry of Fisheries. 2011. Research and Science Information Standard for New Zealand Fisheries. 31 p. Available at http://www.fish.govt.nz/en-nz/Publications/Research+and+Science+Information+Standard.htm.

## ALFONSINO (BYX)

(Beryx splendens, B. decadactylus)


## 1. FISHERY SUMMARY

### 1.1 Commercial fisheries

The alfonsino fishery is essentially confined to BYX 2 \& 3. Alfonsino has supported a major midwater 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. Alfonsino was introduced into the Quota Management System (QMS) on 1 October 1986. The original gazetted TACs were based on the 198384 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 include 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 overcaught every year except one from the 2002-03 fishing year through 2008-09.

## ALFONSINO (BYX)

Table 1: Reported domestic landings ( $t$ ) of alfonsino by Fishstock from 1985-86 to 2010-11 and actual TACCs ( $t$ ) from 1986-87 to 2010-11. QMS data from 1986-present.

| Fishstock <br> FMA (s) | $\begin{array}{r} \text { BYX } 1 \\ 1 \& 9 \\ \hline \end{array}$ |  | $\begin{array}{r} \text { BYX } 2 \\ 2 \\ \hline \end{array}$ |  | $\begin{array}{r} \text { BYX } 3 \\ 3,4,5 \& 6 \end{array}$ |  | $\begin{array}{r} \text { BYX } 7 \\ 7 \end{array}$ |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  |  |  |  |
|  | Landings | TACC | Landings | TACC | Landings | TACC | Landings | TACC |
| 1985-86* | 11 | - | 1454 | - | 3 | - | 1 | - |
| 1986-87 | 3 | 10 | 1387 | 1510 | 75 | 220 | 4 | 30 |
| 1987-88 | 8 | 27 | 1252 | 1511 | 101 | 1000 | 2 | 30 |
| 1988-89 | 6 | 27 | 1588 | 1630 | 64 | 1000 | 4 | 30 |
| 1989-90 | 24 | 31 | 1496 | 1274 | 147 | 1007 | 21 | 80 |
| 1990-91 | 17 | 31 | 1459 | 1274 | 202 | 1007 | 26 | 81 |
| 1991-92 | 7 | 31 | 1368 | 1499 | 264 | 1007 | 2 | 81 |
| 1992-93 | 6 | 31 | 1649 | 1504 | 113 | 1007 | 12 | 81 |
| 1993-94 | 7 | 31 | 1688 | 1569 | 275 | 1007 | 31 | 81 |
| 1994-95 | 11 | 31 | 1670 | 1569 | 482 | 1010 | 59 | 81 |
| 1995-96 | 11 | 31 | 1868 | 1569 | 961 | 1010 | 66 | 81 |
| 1996-97 | 39 | 31 | 1854 | 1575 | 983 | 1010 | 77 | 81 |
| 1997-98 | 14 | 31 | 1652 | 1575 | 1164 | 1010 | 67 | 81 |
| 1998-99 | 37 | 31 | 1658 | 1575 | 912 | 1010 | 13 | 81 |
| 1999-00 | 25 | 31 | 1856 | 1575 | 743 | 1010 | 24 | 81 |
| 2000-01 | 25 | 31 | 1665 | 1575 | 890 | 1010 | 21 | 81 |
| 2001-02 | 123 | 300 | 1574 | 1575 | 1197 | 1010 | 10 | 81 |
| 2002-03 | 136 | 300 | 1665 | 1575 | 1118 | 1010 | 7 | 81 |
| 2003-04 | 219 | 300 | 1468 | 1575 | 884 | 1010 | 11 | 81 |
| 2004-05 | 300 | 300 | 1669 | 1575 | 1067 | 1010 | 14 | 81 |
| 2005-06 | 195 | 300 | 1633 | 1575 | 1068 | 1010 | 7 | 81 |
| 2006-07 | 66 | 300 | 1644 | 1575 | 945 | 1010 | 21 | 81 |
| 2007-08 | 154 | 300 | 1532 | 1575 | 1030 | 1010 | 32 | 81 |
| 2008-09 | 172 | 300 | 1589 | 1575 | 895 | 1010 | 18 | 81 |
| 2009-10 | 185 | 300 | 1643 | 1575 | 1016 | 1010 | 21 | 81 |
| 2010-11 | 48 | 300 | 1686 | 1575 | 1084 | 1010 | 17 | 81 |


| Fishstock <br> FMA (s) | BYX 10 |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
|  |  | 10 |  | Total |
|  | Landings | TACC | Landings | TACC |
| 1985-86* | 0 | - | 1469 | - |
| 1986-87 | 0 | 10 | 1470 | 1800 |
| 1987-88 | 0 | 10 | 1364 | 2598 |
| 1988-89 | 1 | 10 | 1663 | 2717 |
| 1989-90 | 0 | 10 | 1688 | 2422 |
| 1990-91 | 0 | 10 | 1664 | 2423 |
| 1991-92 | $<1$ | 10 | 1 641 $\ddagger$ | 2648 |
| 1992-93 | <1 | 10 | $1780 \ddagger$ | 2653 |
| 1993-94 | 0 | 10 | 2 001才 | 2718 |
| 1994-95 | 0 | 10 | $2223 \ddagger$ | 2721 |
| 1995-96 | 0 | 10 | 2 906 $\ddagger$ | 2721 |
| 1996-97 | 0 | 10 | $2953 \ddagger$ | 2727 |
| 1997-98 | 0 | 10 | $2898 \ddagger$ | 2727 |
| 1998-99 | 0 | 10 | $2624 \ddagger$ | 2727 |
| 1999-00 | 0 | 10 | $2648 \ddagger$ | 2727 |
| 2000-01 | 0 | 10 | 2 601才 | 2727 |
| 2001-02 | 0 | 10 | $2904 \ddagger$ | 2925 |
| 2002-03 | 0 | 10 | $2927 \ddagger$ | 2925 |
| 2003-04 | 0 | 10 | $2584 \ddagger$ | 2925 |
| 2004-05 | 0 | 10 | $3052 \ddagger$ | 2925 |
| 2005-06 | 0 | 10 | $2903 \ddagger$ | 2925 |
| 2006-07 | 0 | 10 | $2677 \ddagger$ | 2925 |
| 2007-08 | 0 | 10 | $2748 \ddagger$ | 3000 |
| 2008-09 | 0 | 10 | $2674 \ddagger$ | 3000 |
| 2009-10 | 0 | 10 | $2865 \ddagger$ | 3000 |
| 2010-11 | 0 | 10 | 2836 † | 2996 |

*FSU data.
$\ddagger$ Excludes catches taken outside the New Zealand EEZ.

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 1) 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 1999-00.


Figure 1: Historical landings and TACC for the four main BYX stocks. From top left to bottom right: BYX1 (Auckland), BYX2 (Central East), BYX3 (South East Coast, South East Chatham Rise, Sub Antarctic, Southland), and BYX7 (Challenger). Note that these figures do not show data prior to entry into the QMS.

## ALFONSINO (BYX)

### 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 worlds 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 this 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. Prespawning 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 $28-31 \mathrm{~cm} \mathrm{FL}$.

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 $M=\log _{\mathrm{e}} 100 /$ 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 2.
Table 2: Estimates of biological parameters for alfonsino.


## 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 targets species are alfonsino ( $81 \%$ ) and cardinalfish ( $12 \%$ ) for bottom trawl; alfonsino (55\%), blue nose ( $21 \%$ ) 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 2001-02. 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 (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 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).

## ALFONSINO (BYX)

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 $B_{M S Y}$, 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 $B_{\text {MSY, }}$ assuming that $B_{\text {MSY }}$ 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 $B_{\text {MSY }}$.
ii) BYX 2

A biomass index derived from a standardised CPUE (log linear, $\mathrm{kg} /$ day) analysis of the target trawl fishery represented by 7 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 has recently been investigated (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 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 $M C Y$ have not changed since the 1991 Plenary Report.
The level of risk to the stock by harvesting the population at the estimated $M C Y$ value cannot be determined.

## ii) Other areas

$M C Y$ cannot be determined.

### 4.4 Estimation of Current Annual Yield (CAY)

No estimates of current biomass are available for any stock and it is not possible to estimate CAY.

### 4.5 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 $8-9 \% B_{0}$.

## $4.6 \quad$ 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 availability of BNS 3 quota to cover likely bluenose bycatch.

Yield estimates are summarised in Table 3.

Table 3: Yield estimates (t).

| Parameter | Fishstock | Estimate |
| :--- | :--- | ---: |
| $M C Y$ | BYX 2 | $1110-1200$ |
| $F_{0.1}$ yield | BYX 2 | $1320-1800$ |
| $C A Y$ | 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 <br> Assessment | 2010 |
| Reference Points | Target(s): $B_{\text {MSY }}$ <br> Soft Limit: $20 \% B_{0}$ <br> Hard Limit: $10 \% B_{0}$ |
| Status in relation to Target | Likely ( $>60 \%)$ to be at or above $B_{\text {MSY, }}$ assuming that $B_{M S Y}$ is in the <br> range of 30-50\% $B_{0}$. |
| Status in relation to Limits | Soft Limit: Very Unlikely ( $<10 \%$ ) to be below. <br> Hard Limit: Very Unlikely ( $<10 \%$ ) to be below. |



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.

| Recent Trend in Fishing <br> Mortality or Proxy | Unknown |
| :--- | :--- |


| Projections and Prognosis |  |
| :--- | :--- |
| Stock Projections or Prognosis | Stock size is Likely (>60\%) to decline towards $B_{M S Y}$ under current <br> catches and TACCs. |
| Probability of Current Catch <br> or TACC causing decline <br> below Limits | Soft Limit: Unknown <br> 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. <br> Length frequency data summarised from logbooks compiled under <br> the industry Adaptive Management Programme. |  |  |
| Period of Assessment | Latest assessment: 2010 |  | Next assessment: 2013 |


| Changes to Model Structure <br> and Assumptions | Bottom/midwater trawl indices were not considered in 2010, and <br> the BLL indices were updated using the same models as used in <br> 2008. |
| :--- | :--- |
| Major Sources of Uncertainty | BLL is the least important method taking BYX 1 and there are <br> questions regarding how representative these indices are of the <br> 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

## 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 2008-09 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 4.
Table 4: Summary of yield estimates ( $t$ ), TACCs ( $t$ ) and reported landings ( $t$ ) for Alfonsino for the most recent fishing year.

| Fishstock |  | QMA | MCY | 2010-11 |  | 2010-11 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | $F_{0.1}$ yield | Actual TACC | Reported landings |
| BYX 1 | Auckland (East) (West) | 1 \& 9 | - | - | 300 | 48 |
| BYX 2 | Central (East) | 2 | $1110-1200$ | $1480-1610$ | 1575 | 1686 |
| BYX 3 | South-East (Coast) | 3, 4, 5, |  | - | 1010 | 1084 |
|  | Southland \& Sub-Antarctic | \& 6 |  |  |  |  |
| BYX 7 | Challenger | 7 | - | - | 81 | 17 |
| BYX 8 | Central (West) | 8 | - | - | 20 | <1 |
| BYX 10 | Kermadec | 10 | - | - | 10 | 0 |
| Total |  |  |  |  | 2996 | 2836 |

## 6. FOR FURTHER INFORMATION

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## ALFONSINO (BYX)

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## ANCHOVY (ANC)

## (Engraulis australis)

Kokowhaawhaa


## 1. FISHERY SUMMARY

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

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

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

## ANCHOVY (ANC)

Table 2: Reported catches or landings (t) of anchovy by fishstock from 1990-91 to 2010-11 (prior to 2002-03 reported by FMA). MHR data from 2001-02 - present.

| Fishstock FMA | ANC 1 | $\begin{array}{r} \text { ANC } 2 \\ 2 \\ \hline \end{array}$ | $\begin{array}{r} \text { ANC } 3 \\ 3,5 \& 6 \\ \hline \end{array}$ | $\begin{array}{r} \text { ANC } 4 \\ 4 \\ \hline \end{array}$ | $\begin{array}{r} \text { ANC } 7 \\ \hline \end{array}$ | $\begin{array}{r} \text { ANC } 8 \\ 8 \& 9 \\ \hline \end{array}$ | ANC 10 <br> 10 | Total |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1990-91 $\dagger$ | <1 | 0 | 0 | 0 | $<1$ | 0 | 0 | <1 |
| 1991-92† | 1 | 0 | 1 | 0 | <1 | 0 | 0 | 2 |
| 1992-93 $\dagger$ | 21 | 0 | 0 | 0 | 0 | 0 | 0 | 21 |
| 1993-94 $\dagger$ | $<1$ | 0 | 0 | 0 | 0 | 0 | 0 | <1 |
| 1994-95 $\dagger$ | <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 $\dagger$ | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 1998-99† | 4 | 0 | 2 | 0 | 0 | 0 | 0 | 6 |
| 1999-00 $\dagger$ | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| 2000-01 $\dagger$ | 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 |

### 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 $8-14 \mathrm{~cm}$, 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 Estimation of Maximum Constant Yield (MCY)

MCY cannot be determined.

### 4.4 Estimation of Current Annual Yield (CAY)

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

### 4.5 Other yield estimates and stock assessment results

No information is available.

### 4.6 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.

## ANCHOVY (ANC)

## 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 2010-11 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.

|  |  | $2010-11$ <br> Actual | $2010-11$ <br> Reported <br> landings |  |
| :--- | :--- | ---: | ---: | ---: |
| Fishstock |  | FMA | TACC | 1 |
| ANC 1 | Auckland (East) | 1 | 200 | 0 |
| ANC 2 | Central (East) | 2 | 100 | $<1$ |
| ANC 3 | South-east (Coast), Southland \& sub-Antarctic | $3,5 \& 6$ | 50 | 0 |
| ANC 4 | South-east (Chatham) | 4 | 10 | $<1$ |
| ANC 7 | Challenger | 7 | 100 | $<1$ |
| ANC 8 | Central (West), Auckland (West) | $8 \& 9$ | 100 | 0 |
| ANC 10 | Kermadec | 10 | 0 |  |
| Total |  |  | 560 | 1 |

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## ARROW SQUID (SQU)

(Nototodarus gouldi, N. sloanii)
Wheketere


## 1. FISHERY SUMMARY

### 1.1 Commercial fisheries

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

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

The New Zealand squid fishery began in the late 1970s and reached a peak in the early 1980s when over 200 squid jigging vessels came to fish in the New Zealand EEZ. The discovery and exploitation of the large squid stocks in the southwest Atlantic substantially increased the supply of squid to the Asian markets causing the price to fall. In the early 1980s, Japanese squid jiggers would fish in New Zealand for a short time before continuing on to the southwest Atlantic. In the late 1980s, the jiggers stopped transit fishing in New Zealand and the number of jiggers fishing declined from over 200 in 1983 to around 15 in 1994. The jig catch in SQU 1J declined from 53872 t in 1988-89 to 4865 t in 1992-93 but increased significantly to over 30000 t in 1994-95, before declining to just over 9000 t in 1997-98. The jig catch declined to low levels for the next 4 years but then increased back up to almost 9000 t in 2004-05, before declining again to 891 t in 2009-10.

From 1986 to 1998 the trawl catch fluctuated between about $30000-60000 t$, but in the last few years in SQU 6T the impact of management measures to protect the Hooker's sea lion (Phocarctos hookeri) restricted the total catch to much lower levels.

## ARROW SQUID (SQU)

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 28 (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 2010-11. Source - QMS.

| Fishstock | SQU1J* |  | SQU1T* |  | SQU6T $\dagger$ |  | SQU10T ${ }^{\text {+ }}$ |  | Total |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Landings | TACC | Landings | TACC | Landings | TACC | Landings | TACC | Landings | TACC |
| 1986-87 | 32394 | 57705 | 25621 | 30962 | 16025 | 32333 | 0 | 10 | 74040 | 121010 |
| 1987-88 | 40312 | 57705 | 21983 | 30962 | 7021 | 32333 | 0 | 10 | 69316 | 121010 |
| 1988-89 | 53872 | 62996 | 26825 | 36081 | 33462 | 35933 | 0 | 10 | 114160 | 135080 |
| 1989-90 | 13895 | 76136 | 13161 | 47986 | 19859 | 42118 | 0 | 10 | 46915 | 166250 |
| 1990-91 | 11562 | 46087 | 18680 | 42284 | 10658 | 30190 | 0 | 10 | 40900 | 118571 |
| 1991-92 | 12985 | 45766 | 36653 | 42284 | 10861 | 30190 | 0 | 10 | 60509 | 118571 |
| 1992-93 | 4865 | 49891 | 30862 | 42615 | 1551 | 30369 | 0 | 10 | 37278 | 122875 |
| 1993-94 | 6524 | 49891 | 33434 | 42615 | 34534 | 30369 | 0 | 10 | 74492 | 122875 |
| 1994-95 | 33615 | 49891 | 35017 | 42741 | 30683 | 30369 | 0 | 10 | 99315 | 123011 |
| 1995-96 | 30805 | 49891 | 17823 | 42741 | 14041 | 30369 | 0 | 10 | 62668 | 123011 |
| 1996-97 | 20792 | 50212 | 24769 | 42741 | 19843 | 30369 | 0 | 10 | 65403 | 123332 |
| 1997-98 | 9329 | 50212 | 28687 | 44741 | 7344 | 32369 | 0 | 10 | 45362 | 127332 |
| 1998-99 | 3240 | 50212 | 23362 | 44741 | 950 | 32369 | 0 | 10 | 27553 | 127332 |
| 1999-00 | 1457 | 50212 | 13049 | 44741 | 6241 | 32369 | 0 | 10 | 20747 | 127332 |
| 2000-01 | 521 | 50212 | 31297 | 44741 | 3254 | 32369 | <1 | 10 | 35071 | 127332 |
| 2001-02 | 799 | 50212 | 35872 | 44741 | 11502 | 32369 | 0 | 10 | 48173 | 127332 |
| 2002-03 | 2896 | 50212 | 33936 | 44741 | 6887 | 32369 | 0 | 10 | 43720 | 127332 |
| 2003-04 | 2267 | 50212 | 48060 | \#58 163 | 34635 | 32369 | 0 | 10 | 84962 | 127332 |
| 2004-05 | 8981 | 50212 | 49780 | 44741 | 27314 | 32369 | 0 | 10 | 86075 | 127332 |
| 2005-06 | 5844 | 50212 | 49149 | \#49 215 | 17425 | 32369 | 0 | 10 | 72418 | 127332 |
| 2006-07 | 2278 | 50212 | 49495 | 44741 | 18479 | 32369 | 0 | 10 | 70253 | 127332 |
| 2007-08 | 1371 | 50212 | 36171 | 44741 | 18493 | 32369 | 0 | 10 | 56035 | 127332 |
| 2008-09 | 1032 | 50212 | 16407 | 44741 | 28872 | 32369 | 0 | 10 | 46311 | 127332 |
| 2009-10 | 891 | 50212 | 16759 | 44741 | 14786 | 32369 | 0 | 10 | 32436 | 127332 |
| 2010-11 | 1414 | 50212 | 14957 | 44741 | 20934 | 32369 | 0 | 10 | 37304 | 127332 |
| All areas except Southern Islands and Kermadec. |  |  |  |  |  |  |  |  |  |  |
| $\dagger$ Southern Islands. |  |  |  |  |  |  |  |  |  |  |
| $\ddagger$ Kermadec. |  |  |  |  |  |  |  |  |  |  |
| \# In sea | increase | 30\% for | 03-04 and | \% for 2005 |  |  |  |  |  |  |

### 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.

## $1.4 \quad$ 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: Historical landings and TACC for the three main SQU stocks. Left to right: SQU1J (All Waters Except 10T and 6T, Jigging), SQU1T (All Waters Except 10T and 6T, All Other Methods) and SQU6T (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 1 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. All 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.

## ARROW SQUID (SQU)

Table 2: Estimates of biological parameters.

| Fishstock |  | Estimate |  | Source |
| :---: | :---: | :---: | :---: | :---: |
| 1. Weight | h in cm dorsal le |  |  |  |
|  |  | a | b |  |
| N. gouldi | $\leq 12 \mathrm{~cm}$ DML | 0.0738 | 2.63 | Mattlin et al. (1985) |
| N. sloanii | $\geq 12 \mathrm{~cm}$ 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 updated for the May 2012 Fishery Assessment Plenary after review by the Aquatic Environment Working Group. This summary is from the perspective of the squid fishery; a more detailed summary from an issue-by issue perspective is, or will shortly be, available in the Aquatic Environment \& Biodiversity Annual Review (http://fs.fish.govt.nz/Page.aspx?pk=113\&dk=22982) where the consequences are also discussed.

### 4.1 Role in the ecosystem

Arrow squid are short-lived and highly variable between years (see biology section). Hurst et al. (2012, In press) 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 (> $10 \%$ 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 albatrosses in Australia (Hedd \& Gales 2001) and Buller's albatross at the Snares and Solander Is. (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 16550 to 26730 t per year between 1999 and 2006 (compared with a landed squid catch of 19000 to 82000 t, Ballara \& Anderson 2008). About 82-90\% of this consisted of QMS species, especially barracouta, silver warehou, and spiny dogfish. Total annual discards varied from 2840 to 6740 t with spiny dogfish, rattails, silver warehou, javelin fish and crabs prominent. Discards averaged 0.2 kg per kilogram of squid caught.

### 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 or caught on a hook but not brought onboard the vessel, Middleton \& Abraham 2007, Brothers et al. 2010).

### 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, 2007 a\&b, Thompson \& Abraham 2010, Abraham \& Thompson 2011). The trend in observed and estimated captures is down. Until recently, captures occurred most frequently in the SQU6T 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 10 years, 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 for Primary Industries, 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 SQU6T fishery in 2001-02 and were in widespread use by 2004-05 (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. SLEDs have been subject to continuous design improvements over the last 10-15 years and, since 2007, a standard Mark 3/13 version has been used by all vessels in the SQU6T 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 $20 \%$ and was increased to $35 \%$ in 2007-08. Recent research indicates that a high proportion of sea lions encountering a SLED are likely to survive the encounter (Abraham 2011). There is some remaining uncertainty, including the unknown probability that a sea lion restrained in a net but not 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 Aquatic Environment and Biodiversity Annual Review (2012).

Smaller numbers of NZ sea lions are captured in the squid trawl fishery on the Stewart-Snares shelf (SQU1T, Table 5). Formal estimates of total captures in this fishery have not been calculated but

## ARROW SQUID (SQU)

captures across all trawl fisheries on the Stewart-Snares shelf were estimated by Thompson \& Abraham (2010) to vary from 3 to 9 sea lions each year.

Table 3: Fisheries-related mortality limit (FRML) from 1991 to 2011 ( $q=$ 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 <br> rate | Management actions |
| :--- | ---: | ---: | :--- |
| $1991-92$ | $16(q)$ |  |  |
| $1992-93$ | 63 |  |  |
| $1993-94$ | 63 |  |  |
| $1994-95$ | 69 |  | Fishery closed by MFish (4 May) |
| $1995-96$ | 73 |  | Fishery closed by MFish (28 Mar) |
| $1996-97$ | 79 |  | Fishery closed by MFish (27 Mar) |
| $1997-98$ | 63 |  | Voluntary withdrawal by industry |
| $1998-99$ | 64 |  | Fishery closed by MFish (13Apr) |
| $1999-00$ | 65 |  | Fishery closed by MFish (29 Mar), overturned by High Court |
| $2000-01$ | 75 |  | Voluntary withdrawal by industry on reaching the FRML |
| $2001-02$ | 79 |  |  |
| $2002-03$ | 70 |  |  |
| $2003-04$ | $62(124)$ | $20 \%$ | $20 \%$ |
| $2004-05$ | 115 | $20 \%$ | FRML increased in mid-March due to abundance of squid |
| $2005-06$ | $97(150)$ | $20 \%$ |  |
| $2006-07$ | 93 | 81 | $35 \%$ |

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 $\mathbf{9 5 \%}$ confidence intervals) for the squid trawl fisheries operating in SQU6T. Data up to 2009-10 from Thompson et al. (2011). Provisional data for 2010-11 from final MFish weekly monitoring report circulated 22 July 2011.

|  |  | Obs. captures |  |  | Est. captures |  | Est. interactions |  | Est. strike rate |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Year | Tow | \% obs. | No. | Rate | Mean | 95\% c.i. | Mean | 95\% c.i. | Mean | 95\% c.i. |
| 1995-96 | 4467 | 12 | 13 | 2.4 | 141 | 73-245 | 141 | 73-244 | 3.2 | 1.7-5.4 |
| 1996-97 | 3717 | 19 | 28 | 3.9 | 144 | 91-218 | 144 | 90-217 | 3.9 | 2.6-5.7 |
| 1997-98 | 1441 | 22 | 13 | 4.2 | 61 | 34-103 | 61 | 32-104 | 4.2 | 2.5-6.9 |
| 1998-99 | 402 | 38 | 5 | 3.2 | 15 | 7-27 | 15 | 5-29 | 3.7 | 2.2-5.9 |
| 1999-00 | 1206 | 36 | 25 | 5.7 | 68 | 44-104 | 67 | 41-106 | 5.6 | 3.9-8.3 |
| 2000-01 | 583 | 99 | 39 | 6.7 | 39 | 39-40 | 58 | 37-82 | 10.0 | 8.4-12.4 |
| 2001-02* | 1647 | 34 | 21 | 3.7 | 44 | 30-65 | 73 | 42-113 | 4.4 | 2.9-6.5 |
| 2002-03 | 1466 | 28 | 11 | 2.6 | 20 | 13-32 | 49 | 24-83 | 3.3 | 2.0-5.4 |
| 2003-04 | 2594 | 30 | 16 | 2.0 | 42 | 27-65 | 176 | 90-312 | 6.8 | 3.6-11.8 |
| 2004-05^ | 2693 | 30 | 9 | 1.1 | 34 | 18-56 | 147 | 69-274 | 5.4 | 2.6-9.9 |
| 2005-06 | 2459 | 28 | 9 | 1.3 | 30 | 17-51 | 135 | 62-249 | 5.5 | 2.6-10.0 |
| 2006-07 | 1317 | 41 | 7 | 1.3 | 17 | 10-28 | 77 | 33-144 | 5.8 | 2.7-10.7 |
| 2007-08 | 1265 | 46 | 5 | 0.9 | 12 | 6-21 | 82 | 28-183 | 6.5 | 2.4-14.3 |
| 2008-09 | 1925 | 40 | 2 | 0.3 | 9 | 3-18 | 77 | 19-175 | 4.0 | 1.1-9.0 |
| 2009-10 | 1188 | 26 | 3 | 0.1 | 13 | 5-27 | 85 | 28-191 | 7.2 | 2.5-15.8 |
| 2010-11 $\dagger$ | 1573 | 33 | 0 | 0.0 | - | - | - | - | - | - |

* SLEDs were introduced. ^ SLEDs were standardised and in widespread use. $\dagger$ 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.

Table 5: Number of tows by fishing year and observed NZ sea lion captures in squid trawl fisheries on the StewartSnares shelf, 2002-03 to 2009-10. No. obs, number of observed tows; \% obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Data from Thompson \& Abraham (2012), retrieved from http://bycatch.dragonfly.co.nz/v20120315/

|  | Tows | No. obs | \% obs | Captures | Rate |
| :--- | ---: | ---: | ---: | ---: | ---: |
| $2002-03$ | 3281 | 506 | 15.4 | 0 | 0.00 |
| $2003-04$ | 4534 | 957 | 21.1 | 1 | 0.10 |
| $2004-05$ | 5861 | 1580 | 27.0 | 3 | 0.19 |
| $2005-06$ | 4481 | 537 | 12.0 | 1 | 0.19 |
| $2006-07$ | 2924 | 706 | 24.1 | 1 | 0.14 |
| $2007-08$ | 2412 | 864 | 35.8 | 0 | 0.00 |
| $2008-09$ | 1808 | 530 | 29.3 | 0 | 0.00 |
| $2009-10$ | 2256 | 763 | 33.8 | 1 | 0.13 |

Vessels targeting arrow squid incidentally catch fur seals (Baird \& Smith 2007, Smith \& Baird 2009, Thompson \& Abraham 2010, Baird 2011), mostly off the east coast South Island, on the StewartSnares shelf, and close to the Auckland Islands. In the 2009-10 fishing year there were 8 observed captures of New Zealand fur seal in squid trawl fisheries. There were 35 ( $95 \%$ c.i.: 18-63) estimated captures, with the estimates made using a statistical model (Thompson \& Abraham 2012, Table 4). Total estimated captures in squid trawl fisheries varied from 22 to 152 between 2002-03 and 2009-10, 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). 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 fisheries.

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 2009-10. 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. Data from Thompson \& Abraham (2012), retrieved from http://bycatch.dragonfly.co.nz/v20120315/

|  | Tows | Observed |  |  |  | Estimated |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | No. obs | \% obs | Captures | Rate | Captures | 95\% c.i. | \% inc. |
| 2002-03 | 8410 | 1308 | 15.6 | 8 | 0.61 | 60 | 33-99 | 100.0 |
| 2003-04 | 8336 | 1770 | 21.2 | 17 | 0.96 | 82 | 50-130 | 100.0 |
| 2004-05 | 10489 | 2510 | 23.9 | 16 | 0.64 | 152 | 89-250 | 100.0 |
| 2005-06 | 8575 | 1103 | 12.9 | 4 | 0.36 | 96 | 50-167 | 100.0 |
| 2006-07 | 5908 | 1289 | 21.8 | 8 | 0.62 | 40 | 22-65 | 100.0 |
| 2007-08 | 4236 | 1457 | 34.4 | 6 | 0.41 | 31 | 16-52 | 100.0 |
| 2008-09 | 3866 | 1297 | 33.5 | 1 | 0.08 | 22 | 8-44 | 100.0 |
| 2009-10 | 3787 | 1069 | 28.2 | 8 | 0.75 | 35 | 18-63 | 100.0 |

### 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 (2007 and 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 2009-10 fishing year there were 92 observed captures of birds in squid trawl fisheries. There were 385 ( $95 \%$ c.i.: 299-494) estimated captures, with the estimates made using a statistical model. Total estimated seabird captures in squid trawl fisheries varied from 385 to 1525 between 2002-03 and 2009-10 at a rate of 8.6 to 20.0 captures per hundred tows without obvious trend (Thompson \& Abraham 2012, 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 eight years is about 13.3 birds per 100 tows, a high rate relative to trawl fisheries for scampi ( 3.53 birds per 100 tows) and hoki ( 2.2 birds per 100 tows) over the same years. The squid fishery accounted for about $25 \%$ of seabird captures in the trawl fisheries modelled by Thompson \& Abraham (2012).

Table 7: Number of tows by fishing year and observed and model-estimated total bird captures in squid trawl fisheries, 2002-03 to 2009-10. 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. Data from Thompson \& Abraham (2012), retrieved from http://bycatch.dragonfly.co.nz/v20120315/

|  |  | Observed |  |  |  | Estimated |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Tows | No. obs | \% obs | Captures | Rate | Captures | 95\% c.i. | \% inc. |
| 2002-03 | 8410 | 1308 | 15.6 | 158 | 12.08 | 962 | 755-1228 | 100.0 |
| 2003-04 | 8336 | 1770 | 21.2 | 204 | 11.53 | 862 | 715-1036 | 100.0 |
| 2004-05 | 10489 | 2510 | 23.9 | 384 | 15.30 | 1525 | 1304-1791 | 100.0 |
| 2005-06 | 8575 | 1103 | 12.9 | 200 | 18.13 | 1155 | 919-1461 | 100.0 |
| 2006-07 | 5908 | 1289 | 21.8 | 127 | 9.85 | 535 | 421-683 | 100.0 |
| 2007-08 | 4236 | 1457 | 34.4 | 162 | 11.12 | 463 | 368-585 | 100.0 |
| 2008-09 | 3866 | 1297 | 33.5 | 259 | 19.97 | 606 | 509-727 | 100.0 |
| 2009-10 | 3787 | 1069 | 28.2 | 92 | 8.61 | 385 | 299-494 | 100.0 |

Observed seabird captures since 2002-03 have been dominated by four species: white-capped and southern Buller's albatrosses make up $90 \%$ and $5 \%$ of the albatrosses captured, respectively; and sooty shearwaters and white-chinned petrels make up $56 \%$ and $41 \%$ of other birds, respectively (Table 8). Most captures occur on the Stewart-Snares shelf (55\%) or close to the Auckland Islands (42\%). 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 squid trawl fishery. Warp mitigation was voluntarily introduced from about 2004 and made mandatory in April 2006 (MFish 2006). The 2006 notice mandated that all trawlers $>28 \mathrm{~m}$ 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 birds warp strikes than for small birds. 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 (were mitigation is focused).

### 4.4 Benthic interactions

Between 1989-90 and 2004-05, 131973 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). The great majority of these tows were 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.

Table 8: Number of observed seabird captures in squid trawl fisheries, 2002-03 to 2009-10, 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. 2011 where full details of the risk assessment approach can be found). It is not an estimate of the risk posed by fishing for squid. Other data from Thompson \& Abraham (2012), retrieved from http://bycatch.dragonfly.co.nz/v20120315/

| Species | Risk <br> ratio | Auckland <br> Islands | East Coast <br> South Island | Fiordland | Stewart <br> Snares Shelf | Sub- <br> Antarctic | Total |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |

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 Aquatic Environment and Biodiversity Annual Review (2012).

### 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 Estimation of Maximum Constant Yield (MCY)

It is not possible to estimate MCY.

### 5.4 Estimation of Current Annual Yield (CAY)

It is not possible to estimate CAY.

### 5.5 Other yield estimates and stock assessment results

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

### 5.6 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 2010-11 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.

|  | $2010-11$ | $2010-11$ |
| :--- | ---: | ---: |
|  | Actual | Reported |
| Fishstock | TACC | landings |
| SQU 1J | 50212 | 1414 |
| SQU 1T | 44741 | 14957 |
| SQU 6T | 32369 | 20934 |
| SQU 10T | 10 | 0 |
| Total | 127332 | 37304 |

## 7. FOR FURTHER INFORMATION

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## BARRACOUTA (BAR)



## 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 increased significantly in the late 1960s and peaked at about 47000 t in 1977. Between 1983-84 and 2004-05, catches fluctuated between 18000 and 28000 t per annum (annual average about 24000 t ). Landings have increased from the lower level of the early 2000s to 26000 to 30000 t in the last 7 years (Table 2). 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 | 4697 | 0 | 34357 | 8109 | 0 | 47163 | - |
| 1978-79 | 5335 | 58 | 4781 | 2481 | 0 | 12655 |  |
| 1979-80 | 7748 | 6679 | 4339 | 3879 | 47 | 22922 |  |
| 1980-81 | 10058 | 4995 | 4227 | 15 | 60 | 19355 | - |
| 1981-82 | 12055 | 11077 | 2813 | 373 | 0 | 26328 | - |
| 1982-13 | 10814 | 7110 | 1746 | 1888 | 31 | 21589 | - |
| 1983-83* | 7763 | 2961 | 803 | 1115 | 0 | 12642 |  |
| 1983-84 | 12390 | 10226 | 1786 | 4355 | 0 | 28757 |  |
| 1984-85 | 7869 | 10425 | 1430 | 5252 | 0 | 24976 |  |
| 1985-86 | 8427 | 7865 | 1371 | 815 | 0 | 18478 | - |
| 1986-87 | 9829 | 13732 | 1575 | 742 | 0 | 25878 | 27 660† |
| 1987-88 | 9335 | 12077 | 896 | 609 | 0 | 22971 | 26 607† |
| * 6 month | ngeover in | hing years. |  |  |  |  |  |
| $\dagger$ The disc | cies betw | QMS and | andings | to und | orting to |  |  |

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

## BARRACOUTA (BAR)

in BAR 4 in the last 3 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 15000 t in 2006-07), but catch has decreased since to well below the TAC.

Table 2: Reported landings (t) of barracouta by Fishstock from 1983-84 to 2010-11 and actual TACCs (t) from 198687 to 2010-11. QMS data from 1986-present.

| Fishstock |  | BAR 1 |  | BAR 4 |
| :---: | :---: | :---: | :---: | :---: |
| FMAs |  | 1, 2, 3 |  | 4 |
|  | Landings | TACC | Landings | TACC |
| 1983-84* | 7805 | - | 1743 | - |
| 1984-85* | 5442 | - | 1909 | - |
| 1985-86* | 5395 | - | 1509 | - |
| 1986-87 | 8877 | 8510 | 3084 | 3010 |
| 1987-88 | 9256 | 8837 | 1775 | 3010 |
| 1988-89 | 5838 | 9426 | 946 | 3010 |
| 1989-90 | 9209 | 9841 | 1349 | 3016 |
| 1990-91 | 9401 | 9957 | 1399 | 3016 |
| 1991-92 | 6733 | 9957 | 1156 | 3016 |
| 1992-93 | 9032 | 9969 | 2251 | 3016 |
| 1993-94 | 7299 | 9969 | 606 | 3016 |
| 1994-95 | 10023 | 9969 | 331 | 3016 |
| 1995-96 | 11252 | 9969 | 2234 | 3016 |
| 1996-97 | 11873 | 11000 | 1081 | 3016 |
| 1997-98 | 11543 | 11000 | 1966 | 3016 |
| 1998-99 | 9229 | 11000 | 459 | 3016 |
| 1999-00 | 10032 | 11000 | 1911 | 3016 |
| 2000-01 | 7118 | 11000 | 2122 | 3016 |
| 2001-02 | 6900 | 11000 | 1160 | 3019 |
| 2002-03 | 7595 | 11000 | 573 | 3019 |
| 2003-04 | 5949 | 11000 | 477 | 3019 |
| 2004-05 | 6085 | 11000 | 98 | 3019 |
| 2005-06 | 7030 | 11000 | 687 | 3019 |
| 2006-07 | 5351 | 11000 | 3233 | 3019 |
| 2007-08 | 5987 | 11000 | 2975 | 3019 |
| 2008-09 | 8861 | 11000 | 968 | 3019 |
| 2009-10 | 10635 | 11000 | 1223 | 3019 |
| 2010-11 | 11420 | 11000 | 1190 | 3019 |
| Fishstock |  | BAR 10 |  |  |
| FMAs |  | 10 |  | Total |
|  | Landings | TACC | Landings | TACC |
| 1983-84* | 0 | - | 28061 | - |
| 1984-85* | 0 | - | 24263 | - |
| 1985-86* | 0 | - | 17820 | - |
| 1986-87 | 0 | 10 | 27660 | 31050 |
| 1987-88 | 0 | 10 | 26605 | 31471 |
| 1988-89 | 0 | 10 | 20178 | 32159 |
| 1989-90 | 0 | 10 | 23568 | 33073 |
| 1990-91 | 0 | 10 | 26755 | 33190 |
| 1991-92 | 0 | 10 | 22212 | 33190 |
| 1992-93 | 0 | 10 | 28443 | 33202 |
| 1993-94 | 0 | 10 | 19345 | 33202 |
| 1994-95 | 0 | 10 | 22345 | 33202 |
| 1995-96 | 0 | 10 | 26334 | 33202 |
| 1996-97 | 0 | 10 | 25996 | 34233 |
| 1997-98 | 0 | 10 | 28393 | 34233 |
| 1998-99 | 0 | 10 | 21417 | 32421 |
| 1999-00 | 0 | 10 | 21436 | 32421 |
| 2000-01 | 0 | 10 | 22231 | 32421 |
| 2001-02 | 0 | 10 | 21598 | 32672 |
| 2002-03 | 0 | 10 | 25036 | 32672 |
| 2003-04 | 0 | 10 | 22459 | 32672 |
| 2004-05 | 0 | 10 | 26919 | 32672 |
| 2005-06 | 0 | 10 | 27881 | 32672 |
| 2006-07 | 0 | 10 | 29617 | 32672 |
| 2007-08 | 0 | 10 | 27968 | 32672 |
| 2008-09 | 0 | 10 | 26443 | 32672 |
| 2009-10 | 0 | 10 | 28451 | 32672 |
| 2010-11 | 0 | 10 | 26937 | 32672 |


|  | BAR 5 <br> 5 \& 6 |  | $\begin{array}{r} \text { BAR } 7 \\ 7,8,9 \\ \hline \end{array}$ |
| :---: | :---: | :---: | :---: |
| Landings | TACC | Landings | TACC |
| 11291 | - | 7222 | - |
| 12487 | - | 4425 | - |
| 6380 | - | 4536 | - |
| 7653 | 9010 | 8046 | 10510 |
| 6457 | 9011 | 9117 | 10603 |
| 5323 | 9011 | 8071 | 10702 |
| 5960 | 9282 | 7050 | 10925 |
| 8817 | 9282 | 7138 | 10925 |
| 6897 | 9282 | 7326 | 10925 |
| 7019 | 9282 | 10141 | 10925 |
| 3410 | 9282 | 8030 | 10925 |
| 2645 | 9282 | 9345 | 10925 |
| 4255 | 9282 | 8593 | 10925 |
| 2839 | 9282 | 10203 | 10925 |
| 6167 | 9282 | 8717 | 10925 |
| 7302 | 7470 | 4427 | 10925 |
| 6205 | 7470 | 3288 | 10925 |
| 6101 | 7470 | 6890 | 10925 |
| 5883 | 7470 | 7655 | 11173 |
| 7843 | 7470 | 9025 | 11173 |
| 6919 | 7470 | 9114 | 11173 |
| 8593 | 7470 | 12156 | 11173 |
| 9479 | 7470 | 10685 | 11173 |
| 6334 | 7470 | 14699 | 11173 |
| 8561 | 7470 | 10451 | 11173 |
| 7659 | 7470 | 8955 | 11173 |
| 6951 | 7470 | 9642 | 11173 |
| 8199 | 7470 | 6128 | 11173 |

* FSU data.


Figure 1: Historical landings and TACC for the four main BAR stocks. From top left to bottom right: BAR1 (Auckland East), BAR4 (Chatham Rise), BAR5 (Southland), and BAR7 (Challenger). Note that these figures do not show data prior to entry into the QMS.

### 1.2 Recreational fisheries

Estimates of recreational catch from the Ministry of Fisheries recreational catch and effort surveys are shown in Table 3.

A key component of the 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 incorrect eligibility figures for the 1996 and previous surveys. Consequently the harvest estimates derived from these surveys are considered to be considerably underestimated and not reliable. 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 are nevertheless considered to be over-estimated, probably because of an unrepresentative diarist sample. The 1999-00 harvest estimates for each Fishstock should be evaluated with reference to the coefficient of variation.

### 1.3 Customary non-commercial fisheries

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

Table 3: Estimated number and weight of barracouta harvested by recreational fishers by Fishstock and survey*.

|  |  | Total |  |  |
| :--- | :--- | ---: | ---: | ---: |
| Fishstock | Survey | Number | CV | Survey harvest $(t)$ <br> $1991-92$ |
| BAR 1 | South | 27000 | $47 \%$ | $30-90$ |
| BAR 7 | South | 2100 | $44 \%$ | - |
| BAR 1 | Central |  |  | $17092-93$ |
| BAR 7 | Central | 15600 | $22 \%$ | $25-35$ |
|  |  |  | $24 \%$ | $25-35$ |
| BAR 1 | North |  | $*$ | $1993-94$ |
| BAR 7 | North |  |  | - |
|  |  |  |  | - |
| BAR 1 | National |  | 68000 | $8 \%$ |
| BAR 7 | National | 74000 | $15 \%$ | 1996 |
|  |  |  |  | $160-190$ |
| BAR 1 | National |  | 156000 | $35 \%$ |
| BAR 5 | National | 2000 | $51 \%$ | $1999-00$ |
| BAR 7 | National | 35000 | $28 \%$ | $182-377$ |
|  |  |  | $2-7$ |  |

* data not available
* Surveys were carried out in different years in the Ministry of Fisheries regions: South in 1991-92, Central in 1992-93, North in $1993-94$ (Teirney et al. 1997) and nationally in 1996 (Bradford 1998) and 1999/2000 (Boyd \& Reilly 2002). The estimated Fishstock harvest is indicative and made by combining estimates from the different years.


### 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 ( $<100 \mathrm{~m}$ ) 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 $M=\log _{\mathrm{e}} 100 /$ 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 4.

Table 4: Estimates of biological parameters.


## 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 new data which would alter the yield estimates given in the 1997 Plenary Report. The obsolete MCY estimates based on biomass estimates from trawl surveys have been removed and yield estimates are based on commercial landings data only. These estimates have not changed since 1992.

### 4.1 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.

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 5). 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.

### 4.2 Biomass estimates

Estimates of current and reference biomass are not available.

### 4.3 Estimation of Maximum Constant Yield (MCY)

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 availability of more preferred, higher value species. These, and other factors, also result in CPUE data being of limited use.

Table 5: Biomass indices (t) and coefficients of variation (CV) (Assumptions: areal availability, vertical availability and vulnerability =1).

| Area | Vessel | Trip code | Date | Biomass | \% CV |
| :--- | :--- | :--- | :--- | ---: | ---: |
| Southland |  | Tangaroa | TAN9301 | Feb-Mar 93 | 11587 |
|  |  | TAN9402 | Feb-Mar 94 | 6151 | 18 |
|  |  | TAN9502 | Feb-Mar 95 | 4539 | 17 |
| East coast |  | TAN9604 | Feb-Mar 96 | 7693 | 19 |
| Area |  |  |  |  |  |
|  |  | Trip code | Date | Biomass | \% CV |
| South Island | Kaharoa | KAH9105 | May-Jun 91 | 12936 | 29 |
|  |  | KAH9205 | May-Jun 92 | 11672 | 23 |
|  |  | KAH9306 | May-Jun 93 | 18197 | 22 |
|  |  | KAH9406 | May-Jun 94 | 7451 | 32 |
|  |  | KAH9618 | May-Jun 96 | 16845 | 19 |
| West coast |  |  |  |  |  |
| South Island | Kaharoa | KAH9203 | Mar-Apr 92 | 2478 | 14 |
|  |  | KAH9404 | Mar-Apr 94 | 5298 | 16 |
|  |  | KAH9504 | Mar-Apr 95 | 4480 | 13 |
|  |  | KAH9701 | Mar-Apr 95 | 2993 | 19 |
|  |  | KAH0004 | Mar-Apr 00 | 1787 | 11 |
|  |  | KAH0304 | Mar-Apr 03 | 4485 | 20 |
| East coast |  | KAH0503 | Mar-Apr 05 | 2763 | 13 |
| North Island | Kaharoa | KAH9304 | Mar-Apr 93 |  |  |
|  |  | KAH9402 | Feb-Mar 94 | 2673 | 15 |
|  |  | KAH9502 | Feb-Mar 95 | 8433 | 33 |
|  |  | KAH9602 | Feb-Mar 96 | 2103 | 29 |
|  |  |  |  | 2495 | 23 |

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

$M C Y$ was estimated using the equation $M C Y=c Y_{A V}$ (Method 4), where $Y_{A V}$ 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.

$$
M C Y=0.7 *(12000 t-500 t)=8050 t .
$$

The level of risk to the stock by harvesting the population at the estimated $M C Y$ 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.

### 4.4 Estimation of Current Annual Yield (CAY)

Estimates of current biomass are not available and $C A Y$ cannot be estimated.

### 4.5 Other yield estimates and stock assessment results

None available.

### 4.6 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 MCYs 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.

Table 6: Summary of yields ( $t$ ), TACCs ( $t$ ), and reported landings ( $t$ ) for Barracouta for the most recent fishing year.

|  |  | QMA | MCY | 2010-11 | 2010-11 |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | Actual TACC | Reported landings |
| Fishstock |  |  |  |  |  |
| BAR 1 | Auckland (East), Central (East), South-East (Coast) | $1,2, \& 3$ | 8050 | 11000 | 11420 |
| BAR 4 | South-East (Chatham) | 4 | - | 3019 | 1190 |
| BAR 5 | Southland, Sub-Antarctic | 5 \& 6 | - | 7470 | 8199 |
| BAR 7 | Challenger, Central (West), |  |  | 11173 | 6128 |
|  | Auckland (West) | 7, 8, \& 9 | - |  |  |
| BAR 10 | Kermadec | 10 | - | 10 | 0 |
| Total |  |  |  | 32672 | 26937 |

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## BLACK CARDINALFISH (CDL)

(Epigonus telescopus)
Akiwa


## 1. FISHERY SUMMARY

### 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 $300-1100 \mathrm{~m}$, 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 198990 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 1). 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

## BLACK CARDINALFISH (CDL)

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 1: Reported landings (t) of black cardinalfish by QMA and fishing year (1 October to 30 September) from 1982-83 to 2010-11. 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 T | 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 | - | 1738 | - | 72 | - | 2 | - | <1 | - | <1 | - |
| 1987-88 | 3 | - | 1556 | - | 28 | - | 1 | - | 3 | - | - | - |
| 1988-89 | 305 | - | 1434 | - | 57 | - | 4 | - | - | - | - | - |
| 1989-90 | 613 | - | 1718 | - | 20 | - | 18 | - | - | - | - | - |
| 1990-91 | 233 | - | 3473 | - | 598 | - | 1 | - | 4 | - | - | - |
| 1991-92 | 7 | - | 1652 | - | 146 | - | 3 | - | $<1$ | - | 2 | - |
| 1992-93 | 23 | - | 1550 | - | 519 | - | 2 | - | <1 | - | - | - |
| 1993-94 | 364 | - | 2310 | - | 277 | - | 10 | - | 5 | - | - | - |
| 1994-95 | 1162 | - | 2207 | - | 51 | - | 7 | - | 1 | - | $<1$ | - |
| 1995-96 | 1418 | - | 2621 | - | 57 | - | 4 | - | 10 | - | - |  |
| 1996-97 | 2001 | - | 1910 | - | 100 | - | 7 | - | - | - | - | - |
| 1997-98 | 995 | - | 1176 | - | 40 | - | 351 | - | - | - | - | - |
| 1998-99 | 24 | 1200 | 1268 | 2223 | 181 | 196 | 41 | 5 | - | 2 | <1 | 1 |
| 1999-00 | 980 | 1200 | 2158 | 2223 | 215 | 196 | 36 | 5 | < 1 | 2 | <1 | 1 |
| 2000-01 | 294 | 1200 | 1135 | 2223 | 99 | 196 | 35 | 5 | 74 | 2 | <1 | 1 |
| 2001-02 | 455 | 1200 | 1693 | 2223 | 146 | 196 | 29 | 5 | 18 | 2 | <1 | 1 |
| 2002-03 | 583 | 1200 | 1845 | 2223 | 172 | 196 | 80 | 5 | 9 | 2 | <1 | 1 |
| 2003-04 | 481 | 1200 | 966 | 2223 | 96 | 196 | 148 | 5 | 27 | 2 | <1 | 1 |
| 2004-05 | 267 | 1200 | 1102 | 2223 | 43 | 196 | 49 | 5 | 15 | 2 | <1 | 1 |
| 2005-06 | 643 | 1200 | 2153 | 2223 | 50 | 196 | 53 | 5 | <1 | 2 | <1 | 1 |
| 2006-07 | 415 | 1200 | 1692 | 2223 | 66 | 196 | 31 | 66 | 10 | 22 | <1 | 1 |
| 2007-08 | 202 | 1200 | 861 | 2223 | 7 | 196 | 23 | 66 | 20 | 22 | <1 | 1 |
| 2008-09 | 197 | 1200 | 1135 | 2223 | 52 | 196 | 58 | 66 | 11 | 22 | <1 | 1 |
| 2009-10 | 49 | 1200 | 1046 | 1620 | 45 | 196 | 15 | 66 | 3 | 22 | <1 | 1 |
| 2010-11 | 84 | 1200 | 736 | 1020 | 17 | 196 | 19 | 66 | 5 | 22 | <1 | 1 |
|  |  | QMA 7 |  | QMA 8 |  | QMA 9 |  |  | (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 | - | - | - | - | - | 1814 |  | - | - | 1814 |  |
| 1987-88 | 2 | - | <1 | - | $<1$ | - | 1638 |  | - | - | 1638 |  |
| 1988-89 | 2 | - | - | - | - | - | 1798 |  | - | 2 | 1800 |  |
| 1989-90 | 15 | - | - | - | - | - | 2385 |  | - | <1 | 2385 |  |
| 1990-91 | 1 | - | <1 | - | - | - | 4311 |  | - | - | 4311 |  |
| 1991-92 | 11 | - | - | - | - | - | 1821 |  | - | 17 | 1838 |  |
| 1992-93 | 2 | - | - | - | - | - | 2096 |  | - | 270 | 2366 |  |
| 1993-94 | 6 | - | - | - | - | - | 2972 |  | - | 829 | 3801 |  |
| 1994-95 | 51 | - | - | - | <1 | - | 3479 |  | - | 231 | 3710 |  |
| 1995-96 | 26 | - | - | - | - | - | 4150 |  | - | 340 | 4490 |  |
| 1996-97 | 27 | - | - | - | - | - | 4045 |  | - | 522 | 4567 |  |
| 1997-98 | 76 | - | - | - | 108 | - | 2338 |  | - | 405 | 2743 |  |
| 1998-99 | 16 | 39 | <1 | 0 | <1 | 4 | 1531 |  | 3670 | 390 | 1921 |  |
| 1999-00 | 27 | 39 | 0 | 0 | <1 | 4 | 3415 |  | 3670 | 962 | 4377 |  |
| 2000-01 | 2 | 39 | 0 | 0 | 3 | 4 | 1642 |  | 3670 | 571 | 2213 |  |
| 2001-02 | 3 | 39 | 0 | 0 | 5 | 4 | 2349 |  | 3670 | 490 | 2839 |  |
| 2002-03 | 27 | 39 | 0 | 0 | 5 | 4 | 2721 |  | 3670 | 275 | 2996 |  |
| 2003-04 | 2 | 39 | 0 | 0 | 6 | 4 | 1727 |  | 3670 | 58 | 1785 |  |
| 2004-05 | 2 | 39 | 0 | 0 | 1 | 4 | 1479 |  | 3670 | 204 | 1683 |  |
| 2005-06 | 1 | 39 | 0 | 0 | 2 | 4 | 2901 |  | 3670 | 44 | 2945 |  |
| 2006-07 | 1 | 39 | 0 | 0 | 1 | 4 | 2216 |  | 3751 | 2 | 2218 |  |
| 2007-08 | 2 | 39 | < 1 | 0 | 19 | 4 | 1134 |  | 3751 | 1 | 1135 |  |
| 2008-09 | 1 | 39 | 0 | 0 | 2 | 4 | 1456 |  | 3751 | 17 | 1474 |  |
| 2009-10 | <1 | 39 | 0 | 0 | 5 | 4 | 1163 |  | 3148 | - | - |  |
| 2010-11 | <1 | 39 | 0 | 0 | 1 | 4 | 863 |  | 2548 | - | - |  |

Black cardinalfish was introduced into the QMS on 1 October 1998 and quotas were set for QMAs 28. 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 8 years plus an additional $10 \%$. From 1 October 2009 the TACC was reduced in CDL 2 to 1620 t, further reduced to 1020 t in 2010-11. 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: Historical landings and TACC for the two main CDL stocks. Left to right: CDL1 (Auckland East) and CDL2 (Central East). Note that these figures do not show data prior to entry into the QMS.

### 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 2 (Dunn 2009). All yield estimates make an allowance for the current estimated level of overrun of $10 \%$.

Table 2: 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 $50-60 \mathrm{~cm}$ fork length (FL). Length frequency distributions from research surveys are unimodal with a peak at $55-65 \mathrm{~cm}$ 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 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 3.

Table 3: Life history parameters for black cardinalfish. All estimates are for CDL 2, except the length-weight parameters which are for CDL 2-4.

| Fishstock |  |  |  |  |  |  |  | Source |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1. Natural mortality ( $M$ ) |  |  |  |  |  |  | (Trace | 2000) |
| Age at recruitment ( $A_{r}$ ) |  |  |  |  |  |  |  |  |
| Gradual recruitment ( $A_{m}$ ) |  |  |  |  |  |  |  |  |
| Age at full recruitment |  |  |  |  |  | 45 | (Trace | 2000) |
| Age at maturity $\left(A_{s}\right)$ |  |  |  |  |  | 35 | (Field \& | 2001) |
| Gradual maturity ( $S_{m}$ ) |  |  |  |  |  | 3 | (Field \& | 2001) |
| 2. Weight $=\mathrm{a}(\text { length })^{\underline{\mathrm{b}}}(\text { weight in } \mathrm{g}, \text { fork length in } \mathrm{cm})^{\text {d }}$ |  |  |  |  |  |  |  |  |
| Both sexes |  |  |  |  |  |  |  |  |
|  |  |  |  | b |  |  |  |  |
|  |  |  |  | 528 |  |  |  | (2009) |
| 3. Von Bertalanffy growth parameters |  |  |  |  |  |  | (Trace | 2000) |
| Both sexes |  |  |  |  | Female |  |  | Male |
| $L_{\infty}$ | k | $t_{0}$ | $L_{\infty}$ | k | $t_{0}$ | $L_{\infty}$ | 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 ras 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 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 $\delta 13 \mathrm{C}$ 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 $800-1000 \mathrm{~m}$ (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 \& ECOSYSTEM CONSIDERATIONS

This section was updated with new tables for the May 2012 Fishery Assessment Plenary based on reviews of similar chapters by the Aquatic Environment Working Group. This summary is from the perspective of the deepwater trawl fisheries for orange roughy, oreos, and cardinalfish; a more detailed summary from an issue-by issue perspective is, or will shortly be, available in the Aquatic Environment \& Biodiversity Annual Review (http://fs.fish.govt.nz/Page.aspx?pk=113\&dk=22982).

### 4.1 Role in the ecosystem

Not yet considered.

### 4.2 Incidental catch (fish and invertebrates)

Anderson (2011) summarised the bycatch of orange roughy and oreo trawl fisheries from 1990-91 to 2008-09. For orange roughy trawls since 2005-06, orange roughy accounted for about $84 \%$ of the total observed catch and the remainder comprised mainly oreos ( $10 \%$ ), hoki ( $0.4 \%$ ), and cardinalfish (0.3\%). About 240 other species or species groups were recorded by observers, including various deepwater dogfishes (1.8\%), rattails (1.0\%), morid cods ( $0.8 \%$ ), and slickheads ( $0.3 \%$ ). For oreo trawl since 2002, oreos accounted for about $92 \%$ of the observed catch and the remainder was mainly orange roughy ( $3.5 \%$ ), hoki $(0.6 \%)$, and ling ( $0.3 \%$ ). About 240 other species or species groups were recorded, including deepwater dogfish (1.2\%), rattails (1.0\%), morid cods ( $0.1 \%$ ), and slickheads (0.1\%). No information is available for cardinalfish.

### 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 or caught on a hook but not brought onboard the vessel, Middleton \& Abraham 2007, Brothers et al. 2010).

### 4.3.1 Marine mammal interactions

Trawlers targeting orange roughy or oreos occasionally catch NZ fur seals (which were classified as "Not Threatened" under the NZ Threat Classification System in 2010, Baker et al. 2010). Between 2002-03 and 2009-10, there were 14 observed captures of NZ fur seals in orange roughy, oreo, and cardinalfish trawl fisheries. In the 2009-10 fishing year there were no observed captures (Table 4) but there were 4 ( $95 \%$ c.i.: $0-13$ ) estimated captures, with the estimates made using a statistical model (Thompson \& Abraham 2012). All observed fur seals captures occurred in the SubAntarctic region. The average rate of capture for these years was 0.10 per 100 tows (range 0 to 0.25 ). This is a low rate compared with that in the hoki fishery (1.5 to 5.6 per 100 tows).

### 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,c, 2005a, 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 5). In the 2009/10 fishing year there were 19 observed captures of birds in orange roughy, oreo, and cardinalfish trawl fisheries at a rate of 0.9 birds per 100 observed tows (Thompson \& Abraham 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 0.4 birds per 100 tows, a low rate relative to trawl fisheries for squid (13.3 birds per 100 tows), scampi (3.53 birds per 100 tows) and hoki (2.2 birds per 100 tows) over the same years

Table 4: 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 2009-10. 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. Data from Thompson \& Abraham (2012), retrieved from http://bycatch.dragonfly.co.nz/v20120315/

|  | Tows | Observed |  |  |  | Estimated |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | No.obs | \%obs | Captures | Rate | Captures | 95\%c.i. | \%inc. |
| 2002-03 | 8871 | 1378 | 15.5 | 0 | 0.00 | 4 | 0-11 | 99.9 |
| 2003-04 | 8005 | 1261 | 15.8 | 2 | 0.16 | 7 | 2-16 | 99.9 |
| 2004-05 | 8417 | 1617 | 19.2 | 4 | 0.25 | 17 | 5-53 | 99.8 |
| 2005-06 | 8305 | 1294 | 15.6 | 2 | 0.15 | 12 | 3-32 | 99.8 |
| 2006-07 | 7367 | 2323 | 31.5 | 2 | 0.09 | 3 | $2-6$ | 99.9 |
| 2007-08 | 6730 | 2811 | 41.8 | 4 | 0.14 | 8 | 4-20 | 100.0 |
| 2008-09 | 6131 | 2373 | 38.7 | 0 | 0.00 | 4 | 0-14 | 100.0 |
| 2009-10 | 6011 | 2133 | 35.5 | 0 | 0.00 | 4 | 0-13 | 99.9 |

Table 5: Number of tows by fishing year and observed seabird captures in orange roughy, oreo, and cardinalfish trawl fisheries, 2002-03 to 2009-10. No. obs, number of observed tows; \% obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Data from Thompson \& Abraham (2012), retrieved from http://bycatch.dragonfly.co.nz/v20120315/

|  | Tows | No. obs | \% obs | Captures | Rate |
| :--- | :--- | ---: | ---: | ---: | ---: |
| $2002-03$ | 8871 | 1378 | 15.5 | 0 | 0.00 |
| $2003-04$ | 8005 | 1261 | 15.8 | 3 | 0.24 |
| $2004-05$ | 8417 | 1617 | 19.2 | 20 | 1.24 |
| $2005-06$ | 8305 | 1294 | 15.6 | 7 | 0.54 |
| $2006-07$ | 7367 | 2323 | 31.5 | 1 | 0.04 |
| $2007-08$ | 6730 | 2811 | 41.8 | 5 | 0.18 |
| $2008-09$ | 6131 | 2373 | 38.7 | 8 | 0.34 |
| $2009-10$ | 6011 | 2133 | 35.5 | 19 | 0.89 |

Table 6: Number of observed seabird captures in orange roughy, oreo, and cardinalfish fisheries, 2002-03 to 200910, 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. 2011 where full details of the risk assessment approach can be found). It is not an estimate of the risk posed by fishing for orange roughy, oreo, and cardinalfish. Other data from Thompson \& Abraham (2012), retrieved from http://bycatch.dragonfly.co.nz/v20120315/

| Species | Risk ratio | Chatham Rise | East Coast South Island | Sub- <br> Antarctic | StewartSnares Shelf | Total |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Salvin's albatross | 2.49 | 11 | 2 | 3 | 0 | 16 |
| Chatham Island albatross | 2.71 | 7 | 0 | 0 | 0 | 7 |
| White capped albatross | 0.83 | 4 | 0 | 0 | 0 | 4 |
| Southern Buller's albatross | 1.28 | 3 | 0 | 0 | 0 | 3 |
| Gibson's albatross | 1.25 | 1 | 0 | 0 | 0 | 1 |
| Northern royal albatross | 2.21 | 1 | 0 | 0 | 0 | 1 |
| Shy albatross | - | 0 | 0 | 1 | 0 | 1 |
| Total albatrosses |  | 27 | 2 | 4 | 0 | 33 |
| Cape petrels | 0.76 | 9 | 10 | 0 | 0 | 19 |
| Grey petrel | 0.39 | 2 | 0 | 1 | 0 | 3 |
| Common diving petrel | 0.00 | 2 | 0 | 0 | 0 | 2 |
| Sooty shearwater | - | 0 | 1 | 0 | 1 | 2 |
| Northern giant petrel | 3.00 | 1 | 0 | 0 | 0 | 1 |
| Storm petrels | - | 1 | 0 | 0 | 0 | 1 |
| White chinned petrel | 0.79 | 0 | 1 | 0 | 0 | 1 |
| White-faced storm petrel | 0.00 | 1 | 0 | 0 | 0 | 1 |
| Total other birds |  | 16 | 12 | 1 | 1 | 30 |

Salvin's albatross were the most frequently captured albatross ( $48 \%$ of observed albatross captures) but seven different species have been observed captured since 2002-03. Cape petrels were the most frequently captured other bird ( $63 \%$, Table 6 ). Seabird captures in the orange roughy, oreo, and cardinalfish fisheries have been observed mostly around the Chatham Rise and off the east coast South Island. These numbers should be regarded as only a general guide on the distribution of captures because the observer coverage is not uniform across areas and may not be representative.

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 (MFish 2006). The 2006 notice mandated that all trawlers > 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

Orange roughy, oreo, and cardinalfish are taken using bottom trawls and 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).

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 2001, Hermsen et al. 2003, Hiddink et al. 2006, Reiss et al. (2009). These consequences are not considered in detail here but are discussed in the Aquatic Environment and Biodiversity Annual Review (2012).

### 4.4 Other considerations

None.

## 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 8), two CPUE indices (Table 7), 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 8 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.

## BLACK CARDINALFISH (CDL)

Table 7: 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 8: Estimated catches calculated by summing the CDL2-4 catches from Table 1 (column 2), and increasing them by the overrun values in Table 2 (column 3), with the combined TACC for CDL2-4 (column 4).

|  | Catch <br> Reported <br> catch |  |  |
| :--- | ---: | ---: | ---: |
| Year | including <br> overruns | TACC |  |
| $1982-83$ | 76 | 152 | - |
| $1983-84$ | 219 | 438 | - |
| $1984-85$ | 530 | 1060 | - |
| $1985-86$ | 291 | 582 | - |
| $1986-87$ | 1812 | 2718 | - |
| $1987-88$ | 1585 | 2378 | - |
| $1988-89$ | 1495 | 2243 | - |
| $1989-90$ | 1756 | 2634 | - |
| $19901-91$ | 4072 | 6108 | - |
| $1991-92$ | 1801 | 2341 | - |
| $1992-93$ | 2071 | 2692 | - |
| $1993-94$ | 2597 | 3376 | - |
| $1994-95$ | 2265 | 2718 | - |
| $1995-96$ | 2682 | 3218 | - |
| $1996-97$ | 2017 | 2420 | - |
| $1997-98$ | 1567 | 1880 | - |
| $1998-99$ | 1490 | 1639 | 2424 |
| $1999-00$ | 2409 | 2650 | 2424 |
| $2000-01$ | 1269 | 1396 | 2424 |
| $2001-02$ | 1868 | 2055 | 2424 |
| $2002-03$ | 2097 | 2307 | 2424 |
| $2003-04$ | 1210 | 1331 | 2424 |
| $2004-05$ | 1194 | 1313 | 2424 |
| $2005-06$ | 2256 | 2482 | 2424 |
| $2006-07$ | 1789 | 1968 | 2485 |
| $2007-08$ | 891 | 980 | 2485 |

### 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 are 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" for shorthand). 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 9).

Table 9: 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 $M 0.027$ run resulting in a larger and less productive stock, and the M0.06 run in a smaller and more productive stock (Table 10, 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 10: Biomass estimates (medians rounded to the nearest 100 t , with $95 \%$ confidence intervals in parentheses) for the four model runs. Bcurrent is the mid-year biomass in 2009. $p\left(B_{2009}<0.1 B_{0}\right)$ is the probability of the mature biomass in 2009 being less than $\mathbf{1 0 \%}$ of the virgin mature biomass ( $B_{0}$ ). $p\left(B_{2009}<0.2 B_{0}\right)$ is the probability of the mature biomass in 2009 being less than $20 \%$ of the virgin mature biomass $\left(B_{0}\right)$.

| Run | $B_{0}(\mathrm{t})$ | $B_{\text {current }}(\mathrm{t})$ |  | $\% B_{0}$ | $p\left(B_{2009}<0.1 B_{0}\right)$ |
| :--- | ---: | ---: | ---: | ---: | ---: |$\quad p\left(B_{2009}<0.2 B_{0}\right)$



Fishing Year
Figure 2: Estimated biomass trajectories (solid line) and 95\% confidence intervals (shaded area) for the model runs (a) Base, (b) mat\&sel, (c) M0.027, (d) M0.06. 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.

## $5.5 \quad$ 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 11). 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 11: 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 $\left(B_{0}\right) . P_{0.2}$ is the probability of the mature biomass in 2013 being less than $20 \%$ of the virgin mature biomass $\left(B_{0}\right) . P(n o$ catch $)$ is the probability that the catch could not be taken, which is assumed to occur if the exploitation rate exceeds $\mathbf{9 0 \%}$ ). 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) | $\begin{array}{r} 17.6 \\ (8.5-67.4) \end{array}$ | $\begin{array}{r} 16.5 \\ (7.01-66.0) \end{array}$ | $\begin{array}{r} 14.3 \\ (5.3-63.9) \end{array}$ | $\begin{array}{r} 12.6 \\ (3.6-62.7) \end{array}$ | $\begin{array}{r} 10.2 \\ (2.9-62.6) \end{array}$ | $\begin{array}{r} 5.2 \\ (2.7-56.2) \end{array}$ |
|  | $P_{0.1}$ | 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) | $\begin{array}{r} 24.5 \\ (14.0-68.8) \end{array}$ | $\begin{array}{r} 23.6 \\ (12.9-67.8) \end{array}$ | $\begin{array}{r} 20.4 \\ (10.2-65.5) \end{array}$ | $\begin{array}{r} 18.6 \\ (8.0-63.4) \end{array}$ | $\begin{array}{r} 16.2 \\ (6.5-61.7) \end{array}$ | $\begin{array}{r} 9.5 \\ (5.5-57.8) \end{array}$ |
|  | $P_{0.1}$ | 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) | $\begin{array}{r} 17.9 \\ (7.1-59.4) \end{array}$ | $\begin{array}{r} 16.7 \\ (6.2-59.1) \end{array}$ | $\begin{array}{r} 14.3 \\ (4.5-56.7) \end{array}$ | $\begin{array}{r} 12.0 \\ (2.9-56.5) \end{array}$ | $\begin{array}{r} 10.0 \\ (2.2-55.0) \end{array}$ | $\begin{array}{r} 4.3 \\ (2.0-50.1) \end{array}$ |
|  | $P_{0.1}$ | 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) | $\begin{array}{r} 33.6 \\ (13.0-80.2) \end{array}$ | $\begin{array}{r} 31.4 \\ (12.5-79.2) \end{array}$ | $\begin{array}{r} 29.8 \\ (10.6-77.5) \end{array}$ | $\begin{array}{r} 26.3 \\ (8.3-77.2) \end{array}$ | $\begin{array}{r} 24.6 \\ (6.7-75.7) \end{array}$ | $\begin{array}{r} 17.4 \\ (4.8-71.2) \end{array}$ |
|  | $P_{0.1}$ | 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 |

## 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


| Projections and Prognosis (2009) |  |
| :---: | :---: |
| 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 causing decline below Limits | Soft Limit: Likely (>60\%) Hard Limit: About as Likely as Not (40-60\%) |
| Probability of Current TACC causing decline below Limits | Soft Limit: Likely (>60\%) <br> Hard Limit: Likely (> 60\%) |


| Assessment Methodology |  |
| :--- | :--- |
| Assessment Type | Level 1 - Quantitative stock assessment |
| Assessment Method | Age-structured CASAL model with Bayesian estimation of <br> posterior distributions. |
| Main data inputs | -Two commercial catch-per-unit-effort (CPUE) series from the <br> trawl fishery. <br> -Estimates of biological parameters. <br> New information since the previous assessment included more years <br> of CPUE and updated catch information. |
| Period of Assessment | Latest assessment: 2009 Next assessment: undecided |
| Changes to Model Structure <br> and Assumptions | First accepted assessment for these stocks. |
| Major Sources of Uncertainty | Major sources of uncertainty include the representativeness of the <br> 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

- 


## 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 2010-11 fishing year are summarised in Table 11.
Table 11: Summary of TACCs $(t)$ and reported landings ( $t$ ) for black cardinalfish for the most recent (2010-11) fishing year.

|  |  | $2010-11$ | $2010-11$ |  |
| :--- | :--- | ---: | ---: | ---: |
| Fishstock |  | QMA | FMA | Actual TACC | Reported landings

## BLACK CARDINALFISH (CDL)

## 7. FOR FURTHER INFORMATION

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## BLUE COD (BCO)

(Parapercis colias)
Raawaru


## 1. FISHERY SUMMARY

### 1.1 Commercial fisheries

Blue cod is predominantly an inshore domestic fishery with very little deepwater catch. The major 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 may 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 1 and historical landings in Table 2, 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 200304). The total catch from this fishery remained relatively stable from 1982 to 1993 and subsequently

## BLUE COD (BCO)

increased to approach the level of the TACC in 1995-96. Catches have remained stable at this higher level in recent years.

Table 1: Reported landings ( $\mathbf{t}$ ) of blue cod by Fishstock from 1983 to 2010-11 and actual TACCs (t) from 1986-87 to 2010-11. QMS data from 1986-present. FSU data 1983-1986.

| Fishstock FMA (s) | $\begin{array}{r} \mathrm{BCO} 1 \\ 1 \& 9 \\ \hline \end{array}$ |  | $\begin{array}{r} \mathrm{BCO} 2 \\ 2 \\ \hline \end{array}$ |  | $\begin{array}{r} \mathrm{BCO} 3 \\ \\ \hline \end{array}$ |  | $\begin{array}{r} \mathrm{BCO} 4 \\ 4 \\ \hline \end{array}$ |  | $\begin{array}{r} \mathrm{BCO} 5 \\ 5 \& 6 \\ \hline \end{array}$ |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  |  |  |  |  |  |
|  | 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 | 1190 |
| 1987-88 | 9 | 40 | 1 | 10 | 148 | 140 | 204 | 647 | 938 | 1355 |
| 1988-89 | 8 | 42 | 1 | 10 | 136 | 142 | 279 | 647 | 776 | 1447 |
| 1989-90 | 10 | 45 | 1 | 10 | 121 | 151 | 358 | 749 | 928 | 1491 |
| 1990-91 | 12 | 45 | <1 | 10 | 144 | 154 | 409 | 757 | 1096 | 1491 |
| 1991-92 | 10 | 45 | 1 | 10 | 135 | 154 | 378 | 757 | 873 | 1536 |
| 1992-93 | 12 | 45 | 4 | 10 | 171 | 156 | 445 | 757 | 1029 | 1536 |
| 1993-94 | 14 | 45 | 2 | 10 | 142 | 162 | 474 | 757 | 1132 | 1536 |
| 1994-95 | 13 | 45 | 1 | 10 | 155 | 162 | 565 | 757 | 1218 | 1536 |
| 1995-96 | 11 | 45 | 2 | 10 | 158 | 162 | 464 | 757 | 1503 | 1536 |
| 1996-97 | 13 | 45 | 2 | 10 | 156 | 162 | 423 | 757 | 1326 | 1536 |
| 1997-98 | 16 | 45 | 4 | 10 | 163 | 162 | 575 | 757 | 1364 | 1536 |
| 1998-99 | 12 | 45 | 2 | 10 | 150 | 162 | 499 | 757 | 1470 | 1536 |
| 1999-00 | 14 | 45 | 2 | 10 | 168 | 162 | 490 | 757 | 1357 | 1536 |
| 2000-01 | 15 | 45 | 2 | 10 | 154 | 162 | 627 | 757 | 1470 | 1536 |
| 2001-02 | 12 | 46 | 2 | 10 | 138 | 163 | 648 | 759 | 1477 | 1548 |
| 2002-03 | 11 | 46 | 4 | 10 | 169 | 163 | 724 | 759 | 1497 | 1548 |
| 2003-04 | 9 | 46 | 4 | 10 | 167 | 163 | 710 | 759 | 1556 | 1548 |
| 2004-05 | 9 | 46 | 5 | 10 | 183 | 163 | 731 | 759 | 1473 | 1548 |
| 2005-06 | 7 | 46 | 1 | 10 | 183 | 163 | 580 | 759 | 1346 | 1548 |
| 2006-07 | 6 | 46 | 4 | 10 | 177 | 163 | 747 | 759 | 1382 | 1548 |
| 2007-08 | 6 | 46 | 3 | 10 | 167 | 163 | 779 | 759 | 1277 | 1548 |
| 2008-09 | 7 | 46 | 8 | 10 | 158 | 163 | 787 | 759 | 1391 | 1548 |
| 2009-10 | 8 | 46 | 7 | 10 | 171 | 163 | 691 | 759 | 1210 | 1548 |
| 2010-11 | 7 | 46 | 8 | 10 | 183 | 163 | 781 | 759 | 1296 | 1548 |

Table 1 [Continued]: Reported landings (t) of blue cod by Fishstock from 1983 to 2010-11 and actual TACCs (t) from 1986-87 to 2010-11. QMS data from 1986-present. FSU data 1983-1986.

| Fishstock <br> FMA (s) | BCO 7 |  | $\begin{array}{r} \mathrm{BCO} 8 \\ 8 \\ \hline \end{array}$ |  | BCO 10 |  | Total |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | 7 |  |  |  | 10 |  |  |
|  | Landings | TACC | Landings | TACC | Landings | TACC | Landings | TACC |
| 1983* | 91 | - | 53 | - | 0 | - | 1070 | - |
| 1984* | 129 | - | 56 | - | 0 | - | 1375 |  |
| 1985* | 169 | - | 70 | - | 0 | - | 1546 | - |
| 1986* | 83 | - | 42 | - | 0 |  | 1409 | - |
| 1986-87 | 79 | 110 | 22 | 60 | 0 | 10 | 1422 | 2130 |
| 1987-88 | 78 | 126 | 44 | 72 | 0 | 10 | 1420 | 2400 |
| 1988-89 | 66 | 131 | 32 | 72 | 0 | 10 | 1298 | 2501 |
| 1989-90 | 75 | 136 | 34 | 74 | 0 | 10 | 1527 | 2666 |
| 1990-91 | 63 | 136 | 28 | 74 | 0 | 10 | 1752 | 2677 |
| 1991-92 | 57 | 136 | 25 | 74 | 0 | 10 | 1480 | 2722 |
| 1992-93 | 85 | 136 | 32 | 74 | 0 | 10 | 1777 | 2724 |
| 1993-94 | 67 | 95 | 21 | 74 | 0 | 10 | 1852 | 2689 |
| 1994-95 | 113 | 95 | 24 | 74 | 0 | 10 | 2089 | 2689 |
| 1995-96 | 65 | 70 | 31 | 74 | 0 | 10 | 2234 | 2664 |
| 1996-97 | 71 | 70 | 38 | 74 | 0 | 10 | 2029 | 2664 |
| 1997-98 | 60 | 70 | 15 | 74 | 0 | 10 | 2197 | 2664 |
| 1998-99 | 52 | 70 | 35 | 74 | 0 | 10 | 2220 | 2664 |
| 1999-00 | 28 | 70 | 30 | 74 | 0 | 10 | 2089 | 2664 |
| 2000-01 | 26 | 70 | 22 | 74 | 0 | 10 | 2316 | 2664 |
| 2001-02 | 30 | 70 | 17 | 74 | 0 | 10 | 2319 | 2680 |
| 2002-03 | 39 | 70 | 13 | 74 | 0 | 10 | 2457 | 2680 |
| 2003-04 | 45 | 70 | 10 | 74 | 0 | 10 | 2501 | 2680 |
| 2004-05 | 44 | 50 | 7 | 74 | 0 | 10 | 2452 | 2680 |
| 2005-06 | 50 | 70 | 20 | 74 | 0 | 10 | 2184 | 2680 |
| 2006-07 | 69 | 70 | 34 | 74 | 0 | 10 | 2413 | 2680 |
| 2007-08 | 59 | 70 | 22 | 74 | 0 | 10 | 2313 | 2680 |
| 2008-09 | 58 | 70 | 18 | 74 | 0 | 10 | 2427 | 2680 |
| 2009-10 | 59 | 70 | 16 | 74 | 0 | 10 | 2162 | 2680 |
| 2010-11 | 51 | 70 | 16 | 74 | 0 | 10 | 2342 | 2681 |



Figure 1: Historical landings and TACC for the five main BCO stocks. From top left: BCO3 (South East Coast), BCO4 (South East Chatham Rise), BCO5 (Southland), BCO7 (Challenger), and BCO8 (Central Egmont).
Note that these figures do not show data prior to entry into the QMS.

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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 total New Zealand landings (t) of blue cod for the calendar years 1970 to 1983. Sources MAF and FSU data.

| Year | Landings |
| :--- | ---: |
| 1970 | 1022 |
| 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 | 1135 |

### 1.2 Recreational fisheries

Blue cod are generally the most important recreational finfish in Marlborough, Otago, Canterbury, Southland and the Chatham Islands. Recreational catches have been obtained from diary surveys in 1991-94, 1996 and December 1999 to November 2000 (Tables 3, 4 \& 5). Charter vessel catches have also been obtained separately in 1997-98 (Table 6).

Table 3: Estimated number of blue cod harvested by recreational fishers by Fishstock and survey.*

| Fishstock | Survey | Number <br> caught | CV (\%) | Estimate Harvest <br> range (t) |
| :--- | :--- | ---: | :---: | ---: |
| BCO 1 | North | 33000 | 14 | $15-30$ |
| BCO 1 | Central | 4000 | - | $0-5$ |
| BCO 2 | North | 1000 | - | $0-5$ |
| BCO 2 | Central | 117000 | 21 | $55-85$ |
| BCO 3 | South | 206000 | 16 | $205-285$ |
| BCO 5 | North | 1000 | - | $0-5$ |
| BCO 5 | South | 188000 | 22 | $150-230$ |
| BCO 7 | North | 2000 | - | $0-5$ |
| BCO 7 | Central | 311000 | 16 | $145-205$ |
| BCO 7 | South | 62000 | 21 | $20-40$ |
| BCO 8 | North | 2000 | - | $0-5$ |
| BCO 8 | Central | 124000 | 35 | $50-110$ |

* Surveys were carried out in different years in the Ministry of Fisheries regions: South in 1991-92, Central in 1992-93 and North in 1993-94 (Teirney et al. 1997).

Table 4: Results of a national diary survey of recreational fishers in 1996.*

| Fishstock | Number <br> caught | CV(\%) | Estimated <br> harvest range (t) | Point <br> Estimate (t) |
| :--- | ---: | ---: | ---: | ---: |
| BCO 1 | 34000 | 11 | $10-20$ | 17 |
| BCO 2 | 145000 | 13 | $70-90$ | 81 |
| BCO 3 | 217000 | 11 | $135-165$ | 151 |
| BCO 5 | 171000 | 12 | $120-155$ | 139 |
| BCO 7 | 356000 | 9 | $220-260$ | 239 |
| BCO 8 | 159000 | 12 | $70-90$ | 79 |

*Estimated number of blue cod 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. Harvest estimates ( t ) are also presented as a range to reflect the uncertainty in the estimates (from Bradford 1998).

Table 5: Results of the 1999/2000 national diary survey of recreational fishers (Dec 1999 - Nov 2000).*

| Fishstock | Number <br> caught | CV(\%) | Estimated <br> harvest range (t) | Point <br> Estimate (t) |
| :--- | ---: | ---: | ---: | ---: |
| BCO 1 | 37000 | 31 | $15-30$ | 23 |
| BCO 2 | 187000 | 25 | $121-201$ | 161 |
| BCO 3 | 1026000 | 29 | $530-973$ | 752 |
| BCO 5 | 326000 | 28 | $165-293$ | 229 |
| BCO 7 | 542000 | 20 | $230-347$ | 288 |
| BCO 8 | 232000 | 32 | $127-249$ | 188 |
| *The mean weights used to convert numbers to catch weight are considered the best available estimates. Harvest estimates (t) of blue cod are also |  |  |  |  |
| presented as a range to reflect the uncertainty in the estimates (from Boyd \& Reilly 2002). |  |  |  |  |

Table 6: Results of a national marine diary survey of recreational fishers from charter vessels, 1997-98 (November 1997 to October 1998).*

| Fishstock | Number <br> caught | CV(\%) | Estimated landings <br> (number of fish killed) | Point <br> Estimate (t) |
| :--- | ---: | ---: | ---: | ---: |
| BCO 1 | 430 | 18 | 2500 | 2.4 |
| BCO 2 | 34 | 50 | 300 | 0.2 |
| BCO 3 | 17272 | 29 | 72000 | 58 |
| BCO 5 | 16750 | 36 | 63000 | 51 |
| BCO 7 | 32026 | 13 | 110000 | 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 catch weight are considered the best available estimates (James \& Unwin 2000).

A key component of 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.

The recreational catches estimated for BCO 2, 3, 7 and 8 in the 1999-2000 fishing year far exceeded the current TACCs and commercial landings in those areas. The last nationwide recreational survey was undertaken in 2001, but the results are still under review and are not currently available.

Table 7: Changes to minimum legal size (MLS in cm ) and amateur maximum daily limits (MDL) of blue cod by Fishstock from 1986 to present.*

| FishstockQMA(s) | $\begin{array}{r} \text { BCO } 1 \\ 1 \& 9 \\ \hline \end{array}$ |  | BCO 2 |  |  | BCO 3 |  |  | BCO 4 |  |  | $\begin{array}{r} \text { BCO } 5 \\ 5 \& 6 \\ \hline \end{array}$ |  | Sub area provisions:$\qquad$ |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 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 |  |  | 07 | BCO 8 |  |  | BCO 10 |  |  |  |  |  |  |
| QMA(s) |  | 7 | Marlborough Sounds |  |  |  | 8 | 8 | 10 |  |  |  |  |  |  |
|  | MSL | MDL | MSL |  | MDL | MSL | MDL |  | MSL |  | 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 |  |  |  |  |  |  |  |  |  |  |
| 2010 |  |  |  |  | 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).

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 indicate that recreational catches from charter vessels (Table 6) follow

## BLUE COD (BCO)

the same pattern as overall recreational catch (Tables 3 and 4). The estimated recreational catches from charter vessels in BCO 7 exceeded the 1997-98 TACC and the commercial landings in QMA 7.

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. Recent changes to amateur size and bag limits are shown in Table 7.

### 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 $10-19 \mathrm{~cm}$ 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 $26-28 \mathrm{~cm}$ (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 $M=\log _{\mathrm{e}} 100 /$ 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 0.19 (Carbines et al. 2007).

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. 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 $156 \mathrm{~km}, 60 \%$ 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.


Sound
$\dagger$ Sub areas showed no significant difference from pooled area growth estimates.

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

3. Weight $=\mathrm{a}(\text { length })^{\mathrm{b}}$ - $($ Weight in g , length in cm fork length $)$.

| Area | Year | Sex | a | b | $\mathrm{R} \wedge 2$ |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| North |  |  |  |  |  |  |
| Canterbury | 2004 | Male | 0.00985 | 3.1394 | 0.97 | Carbines \& Beentjes (2006a) |
| (Kaikoura) | 2004 | Female | 0.00891 | 3.161 | 0.95 |  |
| Banks Peninsula | 2005 | Male | 0.006941 | 3.232 | 0.95 | Beentjes \& Carbines (2006) |
|  | 2005 | Female | 0.00895 | 3.1532 | 0.98 |  |
| North Otago | 2005 | Male | 0.00641 | 3.2743 | 0.95 | Carbines \& Beentjes (2006b) |
|  | 2005 | Female | 0.00421 | 3.4013 | 0.97 |  |
| Fiordland | 2002 | Male | 0.007825 | 3.1727 | 0.97 | Carbines \& Beentjes (2003) |
| (Dusky Sound) | 2002 | Female | 0.00506 | 3.2988 | 0.98 |  |
| Stewart Island | 2006 | Male | 0.00703 | 3.2208 | 0.99 | Carbines (2007) |
| (Paterson Inlet) | 2006 | Female | 0.00814 | 3.1824 | 0.98 |  |

The preliminary results of a mitochondrial DNA analysis (Smith \& Ritchie In prep.) 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

## South Island blue cod potting surveys

In 1995-96, a fishery independent survey using standardised cod pots at fixed stations provided catch rate estimates for recruited blue cod in Queen Charlotte Sound, Pelorus Sound and the east coast of D’Urville Island, and Marlborough Sounds (part of BCO 7) (Blackwell 1997 \& 1998). In September 2001, the survey was repeated (Blackwell 2002), and the weighted mean catch rate for recruited blue cod (total length greater than 28 cm ) was estimated to be $1.07 \mathrm{~kg} /$ pot hour ( $\mathrm{CV}=7 \%$ ). The stratum mean catch rates ranging from $0.09 \mathrm{~kg} /$ pot hour in the inner Pelorus Sounds to $4.54 \mathrm{~kg} / \mathrm{pot}$ hour at D'Urville Island. The estimated catch rates from the 2001 survey were lower (in all strata) than those estimated in 1995-96 (by 36 to 87\%). Catch rates were highest in the outer Marlborough Sounds areas in both surveys. A third potting survey was completed in 2004 (Blackwell 2005), in which the survey area was extended to include west D'Urville and Separation Point. In 2004 the potting catch rates by stratum for fish $>30 \mathrm{~cm}(\mathrm{MLS})$ had both further declined in Queen Charlotte Sound and D’Urville Island, and increased in the most outer Pelorus Sound Stratum, However, catch rates were generally similar to those obtained in 2001 and remained much lower than those obtained during the 1995 and 1996 surveys. The relative biomass of pre-recruit ( $<30 \mathrm{~cm}$ ) blue cod generally followed similar trends to recruited blue cod between 1995-96 and 2004. The relative biomass of juveniles $(17-27 \mathrm{~cm})$ followed a similar, but more variable pattern.

Blackwell (2009) reported that during the 1995 to 2001 period, the relative abundance of blue cod followed a generally declining trend, but between 2001 and 2004, relative abundance became more variable among strata. Relative abundance increased in the outer Sounds strata, but little change occurred in the inner and middle Sounds areas between 2001 and 2004. These trends have continued between 2004 and 2007, with a continued increase in relative abundance in the outer sounds strata, but little change in the inner and mid Sounds strata. The declining trend for the D'Urville Island stratum continued from 2001 to 2007, while relative abundance remained low for Separation Point.

The relative abundance for all blue cod and pre-recruits ( $<30 \mathrm{~cm}$ ) generally followed similar trends to the recruited blue cod between 1995 and 2007. Trends for small blue cod were variable among strata, with relative abundance increasing in the extreme outer Queen Charlotte Sound and extreme outer Pelorus Sound between 1996 and 2004, then declining to 2007, while a declining trend occurred in all other areas surveyed. From October 2008 to April 2011 the inner Sounds were closed to blue cod fishing. The 2010 potting survey showed that the areas that were open to fishing continued to decline while the area that was closed increased markedly (Figure 2).

Results from a fishery independent potting survey off Banks Peninsula (part of BCO 3) in 2002 estimated total mean catch rates for all blue cod of $2.13 \mathrm{~kg} / \mathrm{pot}$ hour ( $\mathrm{CV}=10.8 \%$ ). This ranged from $0.04 \mathrm{~kg} /$ pot hour near Akaroa Harbour entrance to $4.74 \mathrm{~kg} /$ pot hour for the offshore stratum located over Pompeys Rock (Beentjes \& Carbines 2003). The Banks Peninsula survey was repeated in 2005 and the estimated total mean catch rate for all blue cod was $4.43 \mathrm{~kg} /$ pot hour ( $\mathrm{CV}=5.7 \%$ ), strata ranging from 1.02 to $7.27 \mathrm{~kg} /$ pot hour (Beentjes \& Carbines 2004). The survey was repeated in 2008 (Beentjes \& Carbines 2009) and the mean catch rates of blue cod (all sizes) ranged from 0.07 kg per pot per hour in stratum 2 (Akaroa Harbour entrance), to 5.80 kg per pot per hour for offshore stratum 6 located over Le Bons Rock. 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 per hour) and lowest catch rates in stratum 2 ( 0.04 kg per pot per hour). Overall mean catch rate and CV for blue cod 30 cm and over were 2.30 kg per pot per 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 $1.5: 1$. Mortality is markedly greater for blue cod inshore compared to those offshore. Estimates are consistent with those from 2002 and 2005 surveys. Strong recruitment in 2002 occurred in both inshore and offshore strata, but was particularly strong inshore. Growth of these recruited fish resulted in much higher catch rates in 2005, an increase in the mean size and a change in the age distribution consistent with the growth characteristics of blue cod. By 2008 catch rates, size and age structure were similar to 2002, but there was no strong juvenile length mode.

A fishery independent 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 $2.45 \mathrm{~kg} / \mathrm{pot}(\mathrm{CV}=8.7 \%)$ for Kaikoura and $10.19 \mathrm{~kg} /$ pot ( $\mathrm{CV}=7.3 \%$ ) for Motunau. The catch rate of blue $\operatorname{cod} \geq 30 \mathrm{~cm}$ was $1.91 \mathrm{~kg} /$ pot hour (CV $=7.9 \%$ ) for Kaikoura and $5.97 \mathrm{~kg} /$ pot $(\mathrm{CV}=9.8 \%)$ for Motunau (Carbines \& Beentjes 2006a). Another potting survey of blue cod in North Otago (also part of BCO 3) in 2005 produced an overall mean catch rate for all blue cod of $10.14 \mathrm{~kg} / \mathrm{pot}(\mathrm{CV}=5.4 \%)$. The catch rate of blue $\operatorname{cod} \geq 30 \mathrm{~cm}$ was $8.22 \mathrm{~kg} /$ pot hour $(\mathrm{CV}=5.3 \%)$.


Figure 2: Scaled catch rate from the fixed site potting survey in the Marlborough Sounds Management Area (MSA) divided into the area that was subject to a fishery closure (Closed) and the area that remained open to fishing (Fished). The areas outside of the MSA (Outside) are the Cook Strait and D'Urville Island and have only been surveyed since 2007 (Beentjes et al. In press).

## BLUE COD (BCO)

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 from catch-curve analysis using the Chapman Robson estimator (CR). The combined estimates were between 0.31 and 0.37 , consistent with those from 2005 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.

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.

Table 9: Summary statistics from standardised blue cod potting surveys done in the Marlborough Sounds. CPUE catch per unit effort (kg/pot); CV - coefficient of variation; $\boldsymbol{Z}$ - Total mortality; $\boldsymbol{F}_{\%}{ }_{\% P R}$ estimated for for age-at-full recruitment $=6$ years and $M=0.14$. Mean length, mean age and $Z$ are from population scaled length and age (Beentjes et al. in press). CPUE taken from Beentjes (In press a).


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; $F_{\% S P R}$ 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 $F_{\% S P R}$ from Beentjes (In press a). CPUE taken from Carbines \& Beentjes (2006; 2009).

|  | Mean length |  | Mean age |  | Survey CPUE | CPUE range (CV) <br> CV is pot based or | Mean Z (CV) | $\mathrm{F}_{\%}$ SPR |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Area/Year | Female | Male | Female | Male |  |  |  |  |
| North Canterbury |  |  |  |  |  |  |  |  |
| Kaikoura |  |  |  |  |  |  |  |  |
| 2004 | 30.3 | 32.5 | 8.4 | 7.8 | 2.45 | $\begin{gathered} 0.60-7.97 \\ (8.7 \%) \end{gathered}$ | 0.30 (26\%) | 36.9\% |
| 2007 | 29.8 | 32.5 | 7.0 | 6.9 | 5.0 | $\begin{gathered} 1.91-20.45 \\ (8.2 \%) \end{gathered}$ | 0.35 (24\%) | 16.1\% |
| Motunau |  |  |  |  |  |  |  |  |
| 2005 | 25.7 | 29.6 | 5.7 | 6.3 | 10.2 | $\begin{gathered} 9.53-15.37 \\ (7.3 \%) \end{gathered}$ | 0.80 (42\%) | 13.6\% |
| 2008 | 25.2 | 29.3 | 5.1 | 6.2 | 5.5 | $\begin{aligned} & 4.1-8.9 \\ & (8.8 \%) \end{aligned}$ | 0.60 (18\%) | 30.3\% |

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 | $1.02-7.27$ <br> $(5.7 \%$ |
| 2008 | 32.5 | 35.5 | 9.2 | 8.0 | 2.6 | $0.07-5.80$ <br> $(7.7 \%)$ |

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 | $*$ | $0.07-2.3$ | $0.54(23 \%)$ | $18.0 \%$ |
| Offshore |  |  |  |  |  |  |  |  |
| 20.6 | 37.6 | 11.6 | 10.9 | $*$ | $5.04-4.74$ | $0.14(45 \%)$ | $100 \%$ |  |
| 2005 | 37.4 | 41.2 | 11.7 | 12.1 | $*$ | $3.13-5.80$ | $0.15(47 \%)$ | $90.8 \%$ |

[^4]
## BLUE COD (BCO)

A 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 $2.69 \mathrm{~kg} /$ pot $(\mathrm{CV}=6.7 \%)$. The catch rate of blue cod $\geq 30 \mathrm{~cm}$ was 2.23 $\mathrm{kg} /$ pot hour $(\mathrm{CV}=7.2 \%)$. Both the overall and catch rates for all blue cod and for fish $\geq 30 \mathrm{~cm}$ were highest on the open coast (i.e., at the entrance to the Sound), being 8.42 and 5.46 kg.pot.hour ${ }^{-1}$ respectively (Carbines \& Beentjes 2003).

Carbines et al. (2007) and Beentjes (in press a) 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.hour ${ }^{-1}$ ]) from potting surveys conducted in the Marlborough Sounds, Kaikoura, Motunau, Banks Peninsula, North Otago, Foveaux Strait, Paterson Inlet and Dusky Sound (Tables 9-13).

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 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; $\boldsymbol{F}_{\text {osPR }}$ estimated for age at full recruitment $=\mathbf{6}$ 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 $F_{\% S P R}$ from Beentjes (In press a), CPUE from Carbines \& Beentjes (2006; 2011). South Otago survey - all results from Beentjes \& Carbines (2011).

| Area/Year | Mean length |  | Mean age |  | Survey CPUE | CPUE range (CV) <br> CV is pot-based or set-based* | Mean Z (CV) | $F_{\%} /{ }_{\text {SPR }}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Female | Male | Female | Male |  |  |  |  |
| North Otago |  |  |  |  |  |  |  |  |
| 2005 (no stratum 6) | 27.8 | 32.8 | 6.2 | 7.5 | 10.1 | $\begin{gathered} 7.45-14.5 \\ (5.4 \%) \end{gathered}$ | 0.44 (19\%) | 18.7\% |
| 2009 (incl. stratum 6) | 27.4 | 32.3 | 7.0 | 8.3 | 11.5 | $\begin{gathered} 6.21-19.88 \\ (* 6.8 \%) \end{gathered}$ | 0.30 (23\%) | 31.7\% |
| South Otago |  |  |  |  |  |  |  |  |
| 2009** (fixed sites) | 29.4 | 33.6 | 8.7 | 9.7 | 9.7 | $\begin{aligned} & 3.3-16.9 \\ & (* 17.1 \%) \end{aligned}$ | 0.23 (23\%) | 50.3\% |
| 2009 (random sites) | 23.7 | 29.0 | 6.0 | 7.8 | 4.4 | $\begin{aligned} & 1.2-6.0 \\ & (* 17.8 \%) \end{aligned}$ | 0.28 (26\%) | 39.4\% |

[^5]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; $\boldsymbol{F}_{\text {SPR }}$ 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 $F_{\% S P R}$ from Beentjes (in press a), CPUE from Carbines \& Beentjes 2006, 2011. Foveaux Strait survey- all results from Carbines \& Beentjes in press; Paterson Inlet survey -all results from Carbines 2007, Carbines \& Haist in press; Dusky Sound survey - mean length, mean age, Z, and $F_{\% S P R}$ from Beentjes (in press) and CPUE from Carbines \& Beentjes (2003; 2011).
Mean length Mean age CPUE
CPUE range $(\mathrm{CV})$
CV is pot-based or $\quad$ Mean Z $(\mathrm{CV}) \quad F_{\% S P R}$
set-based*

| Area/Year | Female | Male | Female | Male |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  | Foveaux Strait |  |  |
| 2010 (random sites) | 27.8 | 30.5 | 6.9 | 7.1 | 4.8 | $1.17-14.14$ <br> $(* 11.3 \%)$ | $0.41(23 \%)$ |


| Paterson Inlet |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 2006 (fixed sites) (excl. marine reserve) | 26.9 | 32.8 | 6.4 | 7.9 | 4.8 | $\begin{gathered} 1.47-8.42 \\ (11.9 \%) \end{gathered}$ | Pending | Pending |
| 2010 (fixed sites) (excl. marine reserve) | 27.5 | 32.2 | 6.9 | 8.5 | 3.2 | $\begin{gathered} 1.43-3.29 \\ (11.3 \%) \end{gathered}$ | 0.29 | 48.5\% |
| 2010 (random sites) <br> (excl. marine reserve) | 25.9 | 29.0 | 6.2 | 7.1 | 0.4 | $\begin{gathered} 0.22-0.53 \\ (24.2 \%) \end{gathered}$ | 0.32 | 44.9\% |


|  |  |  |  | Dusky Sound |  |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 2002 (fixed sites) | 29.9 | 34.7 | 7.0 | 7.7 | 2.69 | $1.28-8.42$ <br> $(6.7 \%)$ | $0.32(17 \%)$ | $34.3 \%$ |

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 ( $F_{\text {SPR\% }}$ ). Fishing mortality ( $F$ ) is calculated from $F=Z-M$ where natural mortality $(M)$ is set at 0.14 . MR, marine reserve; ageR, age-atfull recruitment to the fishery; - , no estimate made. The original estimates of $Z$ in earlier Plenary reports are incorrect and should not be used in future. Beentjes (In press b).

| Survey area | Year | ageR | Z | lowCI | upCI | F | $F_{\text {\%SPR }}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 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 | $F_{30.0 \%}$ |
| North Otago | 2005 | 5 | 0.35 | 0.25 | 0.47 | 0.21 | $F_{\text {25.1\% }}$ |
|  |  | 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 | $F_{14.7 \%}$ |

Table 13 - Continued

| Survey area | Year | ageR | Z | lowCI | upCI | F | $\boldsymbol{F}_{\% S P R}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Banks Peninsula (all strata) | 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 |  | 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 | $F_{12.5 \%}$ |

offshore

|  |  | 5 | 0.14 | 0.11 | 0.18 | 0 | $F_{100 \%}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | 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 | $F_{49.4 \%}$ |
|  |  | 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 | $F_{22.2 \%}$ |
|  |  | 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 | $F_{100 \%}$ |
|  |  | 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 | $F_{64.6 \%}$ |

## BLUE COD (BCO)

Table 13 - Continued

| Survey area | Year | ageR | Z | lowCI | upCI | F | $F_{\% \text { \% }}{ }^{\text {PR }}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Banks Peninsula (all strata) | 2008 | 5 | 0.17 | 0.13 | 0.22 | 0.03 | $F_{76.1 \%}$ |
|  |  | 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 | $F_{\text {18.0\% }}$ |
|  |  | 6 | 0.54 | 0.35 | 0.80 | 0.40 | $F_{\text {18.0\% }}$ |
|  |  | 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 | $F_{12.1 \%}$ |
| offshore |  | 5 | 0.14 | 0.1 | 0.17 | 0 | $F_{100 \%}$ |
|  |  | 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 | $F_{\text {23.9\% }}$ |
|  |  | 8 | 0.47 | 0.32 | 0.63 | 0.33 | $F_{21.8 \%}$ |
|  |  | 9 | 0.41 | 0.27 | 0.57 | 0.27 | $F_{\text {25.2\% }}$ |
|  |  | 10 | 0.33 | 0.22 | 0.46 | 0.19 | $F_{32.5 \%}$ |

Table 13 - Continued

| Survey area | Year | ageR | $\boldsymbol{Z}$ | lowCI | upCI | $\boldsymbol{F}$ | $\boldsymbol{F}_{\% \text { SPR }}$ |
| :--- | :---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Motunau | 2005 | 5 | 0.53 | 0.33 | 0.77 | 0.39 | $F_{19.5 \%}$ |
|  |  | 6 | 0.80 | 0.47 | 1.23 | 0.66 | $F_{13.6 \%}$ |
|  |  | 7 | 0.74 | 0.41 | 1.17 | 0.6 | $F_{14.5 \%}$ |
| Motunau | 8 | 0.73 | 0.41 | 1.26 | 0.59 | $F_{14.6 \%}$ |  |
|  |  | 9 | 1.34 | 0.63 | 2.26 | 1.2 | $F_{9.0 \%}$ |
|  |  | 10 | 1.13 | 0.48 | 2.13 | 0.99 | $F_{10.8 \%}$ |
|  |  | 5 | 0.53 | 0.37 | 0.72 | 0.39 | $F_{18.2 \%}$ |
|  |  | 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 | $F_{9.8 \%}$ |

## BCO 3

Cod potting


Figure 3: Distribution of landings and number of potlifts for the cod potting method by grouped statistical area (Table 9) and fishing year from trips which landed BCO 3. Circles are proportional within each panel: [catches] largest circle $=92$ t in $05 / 06$ for 024; [number potlifts] largest circle $=7831$ pots in 90/91 for 024 (Starr \& Kendrick 2010).

A standardised CPUE analysis was conducted in 2010 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 20 years from 1989-90 to 2008-09 (see Table 10; Starr \& Kendrick 2010), 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 20 years (Figure 3 and see Table 12; Starr \& Kendrick 2010). There was a serious impediment to this analysis in that it was discovered that there was likely misreporting of RCO 3 landings as BCO 3, probably due to data entry errors. This problem was resolved prior to undertaking the CPUE analysis (Starr \& Kendrick 2010).

The effort data were matched with the landing data at the trip level and the daily stratification inherent in the CELR data was maintained. Each analysis was confined to a set of core vessels which had participated consistently in the fishery for a reasonably long period. The explanatory variables offered to the model included fishing year (forced), month, vessel, statistical area, and number of pots lifted in a day. 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 presented as there were too few unsuccessful fishing events to justify pursuing a binomial model.


Figure 4: Comparison of BCO 3 standardised series based on landed greenweight catch data and daily estimated catch (Starr \& Kendrick 2010).

The lognormal standardised model for BCO 3 (Figure 4) showed a declining trend in commercial CPUE since 2002-03 after a relatively long period of stability. While the Estimated Daily Catch model was thought to be more reliable, both models showed similar trends, with the exception of 2007-08 and 2008-09, where the estimated catch model showed a lesser decline. During the period 2002-03 to 2008-09, commercial catches in all of BCO 3 exceeded the TACC by $5 \%$. As the bulk of the total BCO 3 commercial catch ( $74 \%$ ) 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 4 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.

## 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 (Kendrick \& Bentley 2011). The analysis was based on a lognormal model of positive allocated landed catches from a core fleet of vessels.

The annual indices from the model increase steadily up to 2001-02 and has fluctuated without trend since then (Figure 5). The fishery shows considerable stability in the way that it has operated over time, although there have been some spatial shifts in catch. Catch rates aren't predicted to vary significantly among statistical areas and so the spatial shifts haven't influenced observed CPUE significantly.


Figure 5: Standardised CPUE analysis of BCO 4 based on records of positive BCO catch by core vessels standardised to the 1994-95 to 2009-10 geometric mean (Kendrick 2011).

## BCO 5

A Standardised CPUE analysis was were conducted on the target blue cod fishery operating in the three main statistical areas of BCO 5 (025, 027 and 030) for from the 1989-90 to 1999-00 period (Langley 2002), to and updated in 2005 2003-04 (SeaFIC 2005), to 2006-07 2009 (Starr \& Kendrick 2009) and again in 2011 for the 1994/95 most recently to 2009-10 fishing years (Starr \& Kendrick 2011). The Working Group accepted an index based on a reduced data set where 70 cod potting vessels were had been excluded because they accounted were responsible for over $90 \%$ of the apparent effort transposition data errors. When the effort for these vessels was transposed, it was determined that there was had a different trend in effort for these vessels compared to than the remaining vessels. This difference in trend was accepted by the WG as a basis for dropping the data for the 70 vessels. Two indices were presented prepared; the $\mathrm{CP}(\mathrm{BCO})-70$ which excluded the 70 vessels and $\mathrm{CP}(\mathrm{BCO})$-all which included all vessels, used as a sensitivity. The annual indices derived from both models indicated that catch rates gradually increased from 1994-95 to 2002-03, which may have be a resulted of better from increased recruitment following a mesh size increase implemented at the beginning of 1994-95. Catch rates then declined since after 2004-05 in all areas and have stabilised since 2006-07 at a level are currently about 10\% below the long-term (1994-95 to 2009-10) mean (Figure 6).

In $2007 M$ for blue cod was estimated at 0.14 , based on the age estimate of 32 years. The value of c was set equal to 0.9 based on the estimates of $M$. In all areas where blue cod catches were not reported (i.e., due to bait use, non-reporting and discarding), $M C Y$ is likely to be conservative.

## BCO5 cod-potting CPUE series



Figure 6: Standardised CPUE analysis of BCO 5 based on records of positive BCO catch by core vessels standardised to the 1994-95 to 2009-10 geometric mean (Starr \& Kendrick 2011). The series begins in 1994-95 coinciding with a mesh size regulation change.

### 4.2 Biomass estimates

No estimates of current or reference biomass are available.

### 4.3 Estimation of Maximum Constant Yield (MCY)

No estimates of MCY available.

### 4.4 Estimation of Current Annual Yield (CAY)

No estimate of $C A Y$ is available for blue cod stocks.

### 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. Both blue cod 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

Estimates of current and reference biomass are not available.

For BCO 1 and 8 recent commercial catch levels are considered sustainable. The remaining Fishstocks are described below.

## Fishstock name: 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.


| Fishery and Stock Trends |  |
| :--- | :--- |
| Recent Trend in Biomass or <br> Proxy | Biomass has declined from a reasonably stable level in the early <br> 2000s to the current level which is about 20\% below the long-term <br> mean and similar to the level at the beginning of the series. |
| Recent Trend in Fishing <br> Mortality or Proxy | Total mortality (catch curve analysis) from the North Otago potting <br> survey was lower in 2009 than 2005. |
| Other Abundance Indices |  |
| Trends in Other Relevant <br> Indicators or Variables |  |


| Projections and Prognosis |  |
| :--- | :--- |
| Stock Projections or Prognosis | For all of BCO 3, the commercial CPUE has declined since 2002/03 <br> and the catch has exceeded the TACC since 2002/03. As the bulk of <br> the commercial catch (74\%) is taken from Statistical Areas 024 and <br> 026, both CPUE and catch trends for BCO 3 are strongly influenced <br> by catches in these areas. <br> The estimate of $F$ from the North Otago survey reflects both the <br> commercial and recreational fisheries operating within the survey <br> area. The estimate of $F$ (0.15) from 2009 was larger than M (0.14). <br> Commercial catches during the period of the CPUE decline have <br> been on average 5\% greater than the TACC. Recent commercial <br> catches and commercial catch at the level of the TACC combined <br> with current recreational catch are Likely to cause the biomass in <br> Areas 024 and 026 to decline in the short- to medium-term. |
| Probability of Current Catch <br> or TACC causing decline <br> below Limits | Soft Limit: Unknown <br> Hard Limit: Unlikely (< 40\%) |
| Assessment Methodology | Assessment Type Level 2: Partial Quantitative Stock Assessment <br> Standardised CPUE analysis of a target cod-potting fishery, <br> estimation of $Z$ and survey abundance trends. <br> Assessment Method Catch and effort data derived from the Ministry of Fisheries catch <br> reporting and survey catch, length and age data. <br> Main data inputs Latest assessment: 2009 <br> (survey) 2010 (CPUE) <br> Period of Assessment: 2013 (survey)  <br> 2014 (CPUE)  |
| Changes to Model Structure <br> and Assumptions |  |
| Major Sources of Uncertainty | The relationship between CPUE and abundance of BCO 3 is <br> unknown. <br> The selective survey design may lead to a bias in the estimate of $Z$. |

## Qualifying Comments

A recent (June 2009) change in regulations governing commercial pots (change from 38 mm mesh to 48 mm square grids) will affect future CPUE indices, losing the comparability with the earlier series.

## Fishery Interactions

About $2 / 3$ 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 <br> Assessment | 2011 |
| Assessment Runs Presented | CPUE index based on landed catch |
| Reference Points | Target: Not established but $B_{M S Y}$ assumed <br> Soft Limit: $20 \% B_{0}$ <br> Hard Limit: $10 \% B_{0}$ |
| 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 <br> Hard Limit: Very Unlikely $(<10 \%)$ to be below |



Standardised CPUE analysis of BCO 4 based on records of positive BCO catch by core vessels standardised to the 1994-95 to 2009-10 geometric mean (Kendrick 2011).

| Fishery and Stock Trends |  |
| :--- | :--- |
| Recent Trend in Biomass or <br> Proxy | CPUE has increased from 1989-90 to a high in 2001-02, thereafter <br> the index has fluctuated without trend. |
| Recent Trend in Fishing <br> Mortality or Proxy | Increasing catch since 1987-88 coincide with increasing abundance <br> suggest that fishing mortality may have remained relatively <br> constant. |
| Other Abundance Indices |  |
| Trends in Other Relevant <br> Indicators or Variables | Projections and Prognosis The current catch and TACC are Unlikely (<40\%) to cause the <br> stock to decline <br> Stock Projections or Prognosis  |


| Probability of Current Catch <br> or TACC causing decline <br> below Limits | Soft Limit: Unlikely (<40\%) <br> Hard Limit: Very Unlikely (<10\%) |  |  |
| :--- | :--- | :---: | :---: |
| Assessment Methodology |  |  |  |
| Assessment Type | Fishery characterisation and CPUE analysis |  |  |
| Assessment Method | Potting catch and effort |  |  |
| Main data inputs | Latest assessment: 2011 |  |  |
| Period of Assessment | Next assessment: Unknown |  |  |
| Changes to Model Structure <br> and Assumptions | A relationship between CPUE and stock abundance is assumed. |  |  |
| 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 <br> species. |

## Fishstock name: 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 <br> Assessment | 2011 |
| Assessment Runs Presented | CPUE index based on landed catch |
| Reference Points | Target: Not determined but $B_{\text {MSY }}$ assumed <br> Soft Limit: $20 \% B_{0}$ <br> Hard Limit: $10 \% B_{0}$ |
| Status in relation to Target | Unknown |
| Status in relation to Limits | Soft Limit: Unknown <br> Hard Limit: Unlikely $(<40 \%)$ to be below |



Each series scaled so that the geometric mean=1 from $94 / 95$ to 09/10
Standardised CPUE analysis of BCO 5 based on records of positive BCO catch by core vessels standardised to the 1994-95 to 2009-10 geometric mean (Starr \& Kendrick 2011). The series begins in 1994-95 to coincide with a mesh size regulation change.

| Fishery and Stock Trends |  |
| :--- | :--- |
| Recent Trend in Biomass or <br> Proxy | CPUE increased gradually from the start of the series (1994-95) to <br> 2004-05 but has declined since then to just below the long-term <br> mean. |
| Recent Trend in Fishing <br> Mortality or Proxy |  |
| Other Abundance Indices | The TACC has only been achieved once, in 2003-04, and <br> commercial catch has been declining since then, coincident with the <br> decline in CPUE. |
| Trends in Other Relevant <br> Indicators or Variables |  |


| Projections and Prognosis |  |
| :--- | :--- |
| Stock Projections or Prognosis | Unknown |
| Probability of Current Catch <br> or TACC causing decline <br> below Limits | Soft Limit: Unknown <br> Hard Limit: Unlikely ( $<40 \%)$ |


| 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 Ministry of Fisheries catch <br> reporting |
| Period of Assessment | Latest assessment: 2011 $\quad$ Next assessment: 2013 |
| Changes to Model Structure <br> and Assumptions | The 2008 model was updated in 2011. <br> Vessels with reporting errors were removed. |

Major Sources of Uncertainty

The relationship between CPUE and abundance of BCO 5 is unknown
No historical biological information is available to corroborate/interpret the observed trends in CPUE

## Qualifying Comments

A random stratified potting survey is being developed in Foveaux Strait which should provide better information in the future. In addition, a fishery sampling programme was initiated at the beginning of 2010.

## Fishery Interactions

Ninety seven percent of BCO 5 commercial catches are taken in a target cod-potting fishery which has very little interaction with other species.

## Fishstock name: 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.


Scaled catch rate from the fixed site potting survey in the Marlborough Sounds Management Area (MSA) divided into the area that was subject to a fishery closure (Closed) and the area that remained open to fishing (Fished). The areas outside of the MSA (Outside) are the Cook Strait and D'Urville Island and have only been surveyed since 2007.

## Fishery and Stock Trends

| Recent Trend in Biomass or | The Marlborough Sounds fixed site potting survey index of |
| :--- | :--- |


| Proxy | abundance for the Marlborough Sounds Management area (MSA) <br> (fished) has declined from 1996 to 2010. The MSA (closed) index <br> declined from 1996 to 2007 but increased substantially in 2010. |
| :--- | :--- |
| Recent Trend in Fishing <br> Mortality or Proxy | Frequent regulatory changes to the recreational fishery (e.g. fishery <br> closures, changes to MLS and daily bag limits) are likely to have <br> resulted in a reduction in fishing mortality up to April 2011, after <br> which mortality increased with the re-opening of the fishery. |
| Other Abundance Indices | Age and size composition of catches from the 2010 blue cod potting <br> survey contained few fish greater than 37 cm or older than 10 years, <br> which is considerable smaller and younger than observed in <br> equivalent surveys elsewhere on the South Island. |
| Trends in Other Relevant <br> Indicators or Variables | None but in future sex ratio-at-size should be assessed. |


| Projections and Prognosis |  |
| :--- | :--- |
| Stock Projections or Prognosis | It is likely that, with the re-opening of this fishery, biomass will <br> deccline from the 2010 level. |
| Probability of Current Catch <br> or TACC causing decline <br> below Limits | Soft Limit: Unknown <br> Hard Limit: Unknown |


| Assessment Methodology and E | uati |  |  |
| :---: | :---: | :---: | :---: |
| Assessment Type | Fishery Independent Potting Survey |  |  |
| Assessment Method | Fixed site potting survey |  |  |
| Assessment Dates | Latest assessment: 2010 |  | Next assessment: 2014 |
| Overall assessment quality rank | 1 - High Quality |  |  |
| Main data inputs (rank) | Putting survey catch rates Age length |  | 1- High Quality <br> 1- High Quality <br> 1- High Quality |
| Data not used (rank) | $F_{\text {\%SSR }}$ | $F_{o S P R}$ was not used due to the frequent regulatory changes for this fishery resulting in inconsistent fishing mortality over the lifetime of the fish. |  |
| Changes to Model Structure and Assumptions | None |  |  |
| Major Sources of Uncertainty | The total removals from the recreational sector and the distribution of recreational effort are not well estimated. |  |  |

## Qualifying Comments

The survey is moving from a fixed site to a random 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.

## Fishery Interactions

Most of the catch is taken by recreational fishers, there is probably high catch of associated species 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.

## BLUE COD (BCO)

Table 13: Summary of yields ( $t$ ), TACCs ( $t$ ), and reported landings ( $t$ ) for blue cod from the most recent fishing year.

| Fishstocks | QMA | 2010-11 <br>  <br> BCO 1 |  | Actual TACC |
| :--- | :--- | ---: | ---: | ---: | Reported landings

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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 | 7630 | 7690 |
| EMA 2 | 5 | 2 | 180 | 187 |
| EMA 3 | 1 | 1 | 390 | 392 |
| EMA 7 | 1 | 1 | 350 | 3352 |
| EMA 10 | 0 | 0 | 0 | 0 |
| Total | 47 | 24 | 11550 | 11621 |

### 1.1 Commercial fisheries

Blue mackerel are taken by a variety of methods, including bottom longline, bottom pair trawl, beachseine, 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 $43^{\circ} \mathrm{S}$ (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. 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 2), 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 15000 t , of which $60-70 \%$ was taken by purse seine. More recently, commercial landings of over 12500 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 and 2009-10. The purse seine fishery accounted for $92 \%$ of the total EMA 1 landings in 2004-05.

Table 2: Reported landings (t) of blue mackerel by QMA, and where area was unspecified (Unsp.), from 1983-84 to 2010-11. 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 | 1028 |
| 1984-85* | 565 | 222 | 18 | 865 | 0 | 73 | 1743 |
| 1985-86* | 618 | 30 | 190 | 408 | 0 | 51 | 1296 |
| 1986-87 | 1431 | 7 | 424 | 489 | 0 | 49 | 2399 |
| 1987-88 | 2641 | 168 | 864 | 1896 | 0 | 58 | 5625 |
| 1988-89 | 1580 | < 1 | 1141 | 1021 | 0 | 469 | 4211 |
| 1989-90 | 2158 | 76 | 518 | 1492 | 0 | <1 | 4245 |
| 1990-91 | 5783 | 94 | 478 | 3004 | 0 | 0 | 9358 |
| 1991-92 | 10926 | 530 | 65 | 3607 | 0 | 0 | 15128 |
| 1992-93 | 10684 | 309 | 133 | 1880 | 0 | 0 | 13006 |
| 1993-94 | 4178 | 218 | 223 | 1402 | 5 | 0 | 6025 |
| 1994-95 | 6734 | 94 | 154 | 1804 | 10 | 149 | 8944 |
| 1995-96 | 4170 | 119 | 173 | 1218 | 0 | 1 | 5680 |
| 1996-97 | 6754 | 78 | 340 | 2537 | 0 | $<1$ | 9708 |
| 1997-98 | 4595 | 122 | 78 | 2310 | 0 | < 1 | 7104 |
| 1998-99 | 4505 | 186 | 62 | 8756 | 0 | 4 | 13519 |
| 1999-00 | 3602 | 73 | 3 | 3169 | 0 | 0 | 6847 |
| 2000-01 | 9738 | 113 | 6 | 3278 | 0 | < 1 | 13134 |
| 2001-02 | 6368 | 177 | 49 | 5101 | 0 | 0 | 11694 |
| 2002-03 | 7609 | 115 | 88 | 3563 | 0 | 0 | 11375 |
| 2003-04 | 6523 | 149 | 1 | 2701 | 0 | 0 | 9373 |
| 2004-05 | 7920 | 9 | <1 | 4817 | 0 | 0 | 12746 |
| 2005-06 | 6713 | 13 | 133 | 3784 | 0 | 0 | 10643 |
| 2006-07 | 7815 | 133 | 42 | 2698 | 0 | 0 | 10688 |
| 2007-08 | 5926 | 6 | 122 | 2929 | 0 | 0 | 8982 |
| 2008-09 | 3147 | 2 | 88 | 3503 | 0 | 0 | 6740 |
| 2009-10 | 8539 | 3 | 14 | 3260 | 0 | 0 | 11816 |
| 2010-11 | 6630 | 2 | 9 | 1996 | 0 | 0 | 8638 |
| * FSU data. |  |  |  |  |  |  |  |
| \# Landings | QM | ably | le to St | ea 010 | of Ple | MA 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 JulyAugust, runs through 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 where gear is not deployed between 2 a.m. and 4 a.m. It is unknown whether this affects total landing volumes.


EMA7


Figure 1: Historical landings and TACC for the three main EMA stocks. From top left: EMA1 (Auckland East), EMA2 (Central East), and EMA7 (Challenger to Auckland West). Note that these figures do not show data prior to entry into the QMS.

### 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 114000 fish by a diary survey in 1993-94 (Bradford 1996), 47000 fish in a national recreational survey in 1996 (Bradford 1998), 84 000 fish (CV 42\%) in the 2000 survey (Boyd \& Reilly 2002) and 58000 fish (CV 27\%) in the 2001 survey (Boyd et al. 2004). The surveys suggest a harvest of $35-90 \mathrm{t}$ 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.

## $1.4 \quad$ 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 to almost 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, thus 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 $15-23^{\circ} \mathrm{C}$. 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 accounts 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 3. 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 in 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 3: Von Bertalanffy growth parameters for Bay of Plenty (EMA 1) blue mackerel (Manning et al. 2006).

|  | Males | Females | Both sexes |
| :--- | ---: | ---: | ---: |
| $L_{\infty}$ | 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 through 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 199697 to 2004-05 using catch and effort by 7 core vessels.

For the early time series (Table 4), 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 1992-03, recovered in 1994-05, 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 4: 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 | Binomial | Vessels 1-12 1990 to 1998 <br> Lognormal <br> Combined | Binomial | Vessels 13-19 1997 to 2005 <br> Lognormal |  |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
|  |  |  |  |  |  |  |
| Combined |  |  |  |  |  |  |

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 5-15 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 10-11 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 Estimation of Maximum Constant Yield (MCY)

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.

### 4.4 Estimation of Current Annual Yield (CAY)

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

### 4.5 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 agelength 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 5: Summary of reported landings ( $t$ ) and TACCs by QMA for the most recent fishing year.

|  |  | $2010-11$ | $2010-11$ <br> Reported |
| :--- | ---: | ---: | ---: |
| Fishstock | FMA | TACC | Landings |
| EMA 1 | 1 | 7630 | 6630 |
| EMA 2 | 2 | 180 | 2 |
| EMA 3 | $3-6$ | 390 | 9 |
| EMA 7 | $7-9$ | 350 | 1996 |
| EMA 10 | 10 | 0 | 0 |
| TOTAL |  | 11550 | 8638 |

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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 | $1979 *$ | $1980 *$ | $1981 *$ | $1982 *$ | $1983 \dagger$ | $1983-84 \dagger$ | $1984-85 \dagger$ | $1985-86 \dagger$ |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Landings | 957 | 919 | 812 | 502 | 602 | 766 | 642 | 636 |
| *MAF data. |  |  |  |  |  |  |  |  |
| $\dagger$ 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 19992000 (Tables 3 and 4).

Table 2: Reported landings (t) and actual TACCs (t) of blue moki by Fishstock from 1986-87 to 2010-11. Source QMS data. MOK 10 is not tabulated; no landings have ever been reported from MOK 10.


Figure 1: Historical landings and TACC for the two main MOK stocks. Left to right: MOK1 (Auckland, Central, and Challenger) and MOK3 (South East Coast). Note: these figures do not show data prior to entry into the QMS.

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 Ministry of 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 | 6000 | - | $5-15$ |
| MOK 1 | Central | 38000 | 28 | $40-80$ |
| MOK 1 | South | 2000 | - | $0-5$ |
| MOK 3 | South | 31000 | 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 2002). 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 $(t)$ <br>  |
| :--- | ---: | ---: | ---: | ---: |
|  | 63000 | 14 | $80-110$ | 93 |
| MOK 1 | 16000 | 18 | $20-30$ | 24 |
| MOK 3 | 9000 | - | - | - |
| MOK 5 |  |  |  | $1999-2000$ |
|  | 81000 | 37 | $82-180$ | 131 |
|  | 36000 | 32 | $36-70$ | 53 |
| MOK 1 | 38000 | 89 | $7-115$ | 61 |

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 $=\mathrm{a}(\text { length })^{\mathrm{b}}$ (Weight in g, length in cm fork length $)$. <br> Both sexes |  |  |  |  |  |
|  | a |  | b |  |  |
| All areas | 0.055 |  | 2.713 |  | Francis (1979) |
| 3. von Bertalanffy growth parameters |  |  |  |  |  |
|  |  |  | Both sexes |  |  |
|  | $L_{\infty}$ | $k$ | $t_{0}$ |  |  |
| 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 $M=\log _{\mathrm{e}} 100$ /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.

## BLUE MOKI (MOK)

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 Estimation of Maximum Constant Yield (MCY)

$M C Y$ for all Fishstocks combined was estimated using the equation, $M C Y=c Y_{A V}$ (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 $M=0.14$.

$$
M C Y=0.9 * 705 \mathrm{t}=635 \mathrm{t}
$$

The level of risk to the stock by harvesting the population at the estimated $M C Y$ 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.

### 4.4 Estimation of Current Annual Yield (CAY)

No estimate of $C A Y$ is available for blue moki stocks.

### 4.5 Other yield estimates and stock assessment results

None available.

### 4.6 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 <br> Assessment | 2008 |
| Assessment Runs Presented |  |
| Reference Points | Target: Not established but $F=M$ assumed <br> Soft Limit: $20 \% B_{0}$ <br> 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 <br> Hard Limit: Unlikely $(<40 \%)$ to be below |
| Historical Stock Status <br> Trajectory and Current Status | None available |


| Fishery and Stock Trends |  |
| :--- | :--- |
| Recent Trend in Biomass or <br> Proxy | None |
| Recent Trend in Fishing <br> Mortality or Proxy | Low estimates of fishing mortality in 2005-06 and stable catches <br> over the previous 14 years, suggest that fishing mortality has been <br> low for more than two decades. |
| Other Abundance Indices |  |
| Trends in Other Relevant <br> Indicators or Variables |  |


| Projections and Prognosis | Stock Projections or Prognosis Catch curve analysis from recent catch sampling (2004-05 and <br> 2005-06) indicates that total mortality is low, with fishing mortality <br> well below natural mortality. The fishery is comprised of fish across <br> a broad range of ages across both sexes. Given that the MOK 1 <br> catch has been fairly stable since 1993-94, and that catches have <br> been near the TACC since 1995-96, stock size is Likely (> 60\%) to <br> remain above the limit reference points under current catches and <br> TACCs, in the short to medium term. <br> Probability of Current Catch <br> or TACC causing decline <br> below Limits Soft Limit: Unknown <br> 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: 2012 |
| Changes to Model Structure and Assumptions | None |  |
| 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 | $2010-11$ <br> Actual <br> TACC | $2010-11$ <br> Reported <br> landings |
| :--- | :--- | ---: | ---: | ---: |
| MOK 1 | Auckland (East) (West), |  |  |  |
| MOK 3 | Central (East) (West), Challenger 1, 2, 7, $8 \& 9$ | - | 403 | 421 |
| MOK 4 | South East (Coast) 3 (Chatham) 4 | - | 127 | 144 |
| MOK 5 | Southland, Sub-Antarctic 5 \& 6 | - | 25 | $<1$ |
| MOK 10 | Kermadec 10 | - | 44 | 10 |
| Total |  | - | 10 | 0 |
|  | 635 | 608 | 574 |  |

## 6. FOR FURTHER INFORMATION

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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.

This 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 a differential rates were also introduced. The differential rate applies 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 ( $\mathbf{t}$ ) of blue warehou by Fishstock 1983-84 to 2010-11 and actual TACCs ( $\mathbf{t}$ ) from 1986-87 to 2010-11. QMS data from 1986-present.


### 1.2 Recreational fisheries

Estimates of recreational catch in the Ministry of 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: Historical landings and TACC for the four main WAR stocks. From top left to bottom right: WAR2 (Central East), WAR3 (South East Coast), WAR7 (Challenger), and WAR8 (Central Egmont). Note that these figures do not show data prior to entry into the QMS.

Table 2: Estimated harvest ( $\mathbf{t}$ ) of blue warehou by recreational fishers. Surveys were carried out in the Ministry of Fisheries South 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.

### 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 $40-60 \mathrm{~cm}$ 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. 1997).

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 $(M)$ | 0.24 | Bagley et al. (1997) |
| WAR 3 |  |  |

2. Weight = a(length) (Weight in g, length in cm total length).


Bagley et al. (1997)

| 3. Von Bertalanffy growth parameters |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Females |  |  | Males |  |  |  |
|  | $L_{¥}$ | k | $t_{0}$ | $L_{¥}$ | k | $t_{0}$ |  |
| WAR 3 | 66.3 | 0.209 | -0.79 | 63.8 | 0.241 | -0.46 | Bagley et al. (1997) |
| 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. (1997), 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

There were no assessment results presented for blue warehou stocks in 2010. For the other blue warehou Fishstocks, a revised estimate of $M$ (from 0.30 to 0.24 ) resulted in a change in c (from 0.7 to 0.8 ) in the $M C Y$ formula, $M C Y=c Y_{A V}$ (Method 4). This 1998 analysis resulted in new (higher) yield estimates for all stocks although there was no new analysis of the catch data.

### 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 | 2100 | 43 |
|  |  |  | SHI8201 | Mar-May 82 | 800 | 62 |
|  |  |  | SHI8302 | Apr-83 | 4700 | 72 |
|  |  |  | SHI8601 | Jun-86 | 2000 | 59 |
| WAR 3 | Southland | Tangaroa | TAN9301 | Feb-Mar 93 | 2297 | 36 |
|  |  |  | TAN9402 | Feb-Mar 94 | 1629 | 38 |
|  |  |  | TAN9502 | Feb-Mar 95 | 1103 | 38 |
|  |  |  | TAN9604 | Feb-Mar 96 | 1615 | 40 |

### 4.2 Biomass estimates

Estimates of current and reference biomass are not available for any blue warehou Fishstocks.

### 4.3 Estimation of Maximum Constant Yield (MCY)

$M C Y$ was estimated using the equation $M C Y=c Y_{A V}$ (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 $30-40 \mathrm{t} . Y_{A V}$ for Central (East) (FMA 2) was estimated as 300-350 t.

$$
\begin{aligned}
M C Y & =0.8 *(300-350 \mathrm{t}) \\
& =240-280 \mathrm{t}
\end{aligned}
$$

## 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. $Y_{A V}=2040 \mathrm{t}$

$$
\begin{aligned}
M C Y & =0.8 * 2040 \mathrm{t} \\
& =1630 \mathrm{t}
\end{aligned}
$$

## Challenger (WAR 7)

The catches from 1983-84 to 1985-86 were considered to be a sustainable level of catch. $Y_{A V}=710 \mathrm{t}$.

$$
\begin{aligned}
M C Y & =0.8 * 710 \mathrm{t} \\
& =570 \mathrm{t}
\end{aligned}
$$

## 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.

$$
M C Y=80 \mathrm{t}
$$

The level of risk to the stock by harvesting the population at the estimated $M C Y$ value cannot be determined.

### 4.4 Estimation of Current Annual Yield (CAY)

CAY cannot be estimated because of the lack of current biomass estimates.

### 4.5 Other yield estimates and stock assessment results

No information available.

### 4.6 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 TACC's 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 2010-11 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.

|  |  |  |  |  |  |
| :--- | :--- | ---: | ---: | ---: | ---: |
|  |  |  |  | $2010-11$ <br> Actual | 2010-11 <br> Reported <br> landings |
| Fishstock |  | QMA | MCY | TACC |  |
| WAR 1 | Auckland (East) (West) | $1 \& 9$ | $240-280$ | 41 | 11 |
| WAR 2 | Central (East) | 2 |  | 578 | 102 |
| WAR 3 | South-east (Coast) (Chatham), | $3,4,5 \& 6$ | 1630 | 2531 | 2086 |
|  | Southland \& Sub-Antarctic |  |  |  |  |
| WAR 7 | Challenger | 7 | 570 | 1120 | 633 |
| WAR 8 | Central West) | 8 | 80 | 233 | 92 |
| WAR 10 | Kermadecs | 10 | 0 | 10 | 0 |
| Total |  |  |  | 4512 | 2924 |

## 6. FOR FURTHER INFORMATION

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## BLUENOSE (BNS)

## (Hyperoglyphe antarctica) Matiri



## 1. FISHERY SUMMARY

### 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 1988a). The largest domestic bluenose fisheries occur in BNS 1 and 2. Historically, catches in BNS 2 were predominately taken in the target alfonsino and bluenose trawl fisheries, but have been primarily taken by target bottom longline fishing in recent years. There is a substantial 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 fishery. 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 in a mid-water trawl fishery 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 occurs sporadically in 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.

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. Reported landings and TACCs since 1981 are given in Table 1, while the historical landings and TACC for the main BNS stocks are depicted in Figure 1.

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 . TACC’s 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). All AMP programmes were terminated on 30 September 2009.

Table 1: Reported landings (t) of bluenose by Fishstock from 1981 to 2010-11 and actual TACCs (t) from 1986-87 to 2010-11. QMS data from 1986-present.



Figure 1: Historical landings and TACC for the five main BNS stocks. BNS1 (Auckland East), BNS2 (Central East), BNS3 (South East Coast), BNS7 (Challenger) and BNS8 (Central Egmont). Note that these figures do not show data prior to entry into the QMS.

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 undercaught by an average $9 \%$ (average landings 1504 t / year) over 1987-88 to 1990-91, over-caught by an average $11 \%$ (average landings $2501 \mathrm{t} /$ 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

The annual recreational catch of BNS 1 was estimated from diary surveys to be 2000 fish in 1993-94 (Teirney et al. 1997), 5000 fish in 1996 (Bradford 1998) and 11000 fish in 1999-00 (Boyd \& Reilly 2005). The Recreational Working Group has concluded that the methodological framework used for telephone interviews produced incorrect eligibility figures for the 1996 and previous surveys. Consequently the harvest estimates derived from these surveys are considered to be unreliable. This group also indicated concerns with some of the harvest estimates from the 2000-01 survey. The group 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 harvest estimates are implausibly high for many important fisheries."

The recreational diary surveys indicated only small recreational catches of bluenose are landed in areas other than BNS 1.

### 1.3 Customary non-commercial fishing

No quantitative information on the level of customary non-commercial take is available.

### 1.4 Illegal catch

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

### 1.5 Other sources of mortality

There have been reports of depredation by Orca on bluenose caught by line fisheries.

## 2. BIOLOGY

## Depth distribution

The depth distribution of bluenose extends from near-surface waters to about 1200 m . Research trawl surveys record their main depth range as $250-750 \mathrm{~m}$, with a peak at $300-400 \mathrm{~m}$, 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 $<100 \mathrm{~m}$ to about 1000 m , depending on target species, but with a peak around 400 m for bluenose targeted fishing by any method.

The depth distribution of bluenose changes with size, with small juveniles known to occur at the surface under floating objects (Last et al. 1993, Duffy et al. 2000). Larger juveniles probably live in coastal and oceanic pelagic waters for one or two years. Fish 40-70 cm in length are caught between 200 m and 600 m , 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 ( $\delta^{18} \mathrm{O}$ ) 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 $700-1000 \mathrm{~m}$; i.e., deeper than most trawl or longline fishing for bluenose occurs. However, adult bluenose are also known to associate

## BLUENOSE (BNS)

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 1988a). Radiocarbon $\left({ }^{14} \mathrm{C}\right.$ ) 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 2.
Table 2: Estimates of biological parameters for bluenose.


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 since 2001-02. 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).

### 4.1 Methods

## Model structure

The model 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 3).

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.

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Table 3: The three alternative catch ( $\mathbf{t}$ ) 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 |
| 1949 | 0 | 95 | 189 | 1976 | 618 | 692 | 767 | 1976 | 0 | 112 | 211 |
| 1950 | 0 | 89 | 177 | 1977 | 821 | 913 | 1004 | 1977 | 0 | 385 | 1505 |
| 1951 | 0 | 74 | 147 | 1978 | 1 | 81 | 161 | 1978 | 0 | 0 | 0 |
| 1952 | 0 | 71 | 142 | 1979 | 9 | 92 | 176 | 1979 | 0 | 0 | 0 |
| 1953 | 0 | 70 | 141 | 1980 | 15 | 98 | 180 | 1980 | 0 | 0 | 0 |
| 1954 | 0 | 69 | 137 | 1981 | 235 | 300 | 365 | 1981 | 0 | 0 | 0 |
| 1955 | 0 | 66 | 132 | 1982 | 469 | 511 | 554 | 1982 | 0 | 0 | 0 |
| 1956 | 0 | 69 | 138 | 1983 | 730 | 755 | 780 | 1983 | 0 | 0 | 0 |
| 1957 | 0 | 69 | 138 | 1984 | 951 | 956 | 962 | 1984 | 324 | 324 | 324 |
| 1958 | 0 | 75 | 149 | 1985 | 1013 | 1013 | 1013 | 1985 | 372 | 372 | 372 |
| 1959 | 0 | 68 | 137 | 1986 | 982 | 982 | 982 | 1986 | 605 | 605 | 605 |
| 1960 | 0 | 62 | 124 | 1987 | 744 | 744 | 744 | 1987 | 667 | 667 | 667 |
| 1961 | 0 | 60 | 121 | 1988 | 752 | 752 | 752 | 1988 | 522 | 522 | 522 |
| 1962 | 0 | 59 | 118 | 1989 | 797 | 797 | 797 | 1989 | 623 | 623 | 623 |


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

Two CPUE indices were fitted as indices of abundance, one for line and one for trawl fisheries (Figure 3). CVs of $20 \%$ were assumed for each year. This assumption incorporates some process error 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 BNS model runs.

To construct the CPUE indices, candidate trips were identified by selecting all trips that landed bluenose in all statistical areas. Once a list of trips that satisfied this criterion was identified, all effort and landing records associated with those trips were extracted.


Figure 4: The NZ-wide line (left) and trawl (right) CPUE indices fitted in the BNS model runs, in comparison with the individual area indices (Starr \& Kendrick 2011b, c, d, e). Indices are scaled to a geometric mean of one over the period of temporal overlap of all indices in each panel.

Data grooming and scaling to trip landings were carried out using the methodology described by Starr (2007). For the line CPUE, effort and estimated catch data were summarised for every unique combination of trip, fishing method, statistical area, and target species ("trip stratum"). This reduced the CELR and the higher resolution catch effort records (from LTCER and LCER forms) to lower resolution data, giving fewer records per trip but retaining the original method, area, and target species recorded by the skipper. The trawl CPUE used the higher resolution tow by tow data (from TCEPR and TCER forms) at their original resolution.

The CPUE indices selected for the assessment were lognormal models of non-zero catch (Starr \& Kendrick 2011a). Fishing year, target, number of hooks and vessel were explanatory variables in the line CPUE while fishing year, vessel, and zone were accepted as explanatory variables in the trawl CPUE (zone represents statistical area, except all trawl records from BNS 1 were assigned to zone 1, and all trawl records from BNS 7 and 8 to zone 78). The New Zealand wide indices have broadly similar trajectories to the individual area indices (Figure 4; Starr \& Kendrick 2011b, c, d, e).

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 | 3.173 |
| b | 3.173 |  |  |
| von Bertalanffy growth |  |  |  |
| $t_{0}$ | -0.5 | -0.5 | Horn et al. 2010 |
| $L_{\infty}$ | 72.2 | 92.5 |  |
| $k$ | 0.125 | 0.071 | Horn \& Sutton 2010 |
| Maturity (logistic) |  |  | 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
- $\quad$ 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 $\mathrm{h}=0.75$ 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 5). 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 6). 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 7).


Figure 5: 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 6: The model fits to the line and trawl CPUE for the run with mid catch, mid $M$ and $\boldsymbol{h}=0.75$. The fits for the other runs were almost identical.


Figure 7: 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 $8 \& 9$ ) with estimates of $B_{0}$ ranging from just over 30000 t at an $M$ of 0.1 to around 60 000 t with an M of 0.06 .


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

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Figure 9: 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 9). 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 9, Table 4). 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 4: Estimates of $B_{0}, B_{2011}$ and stock status $\left(B_{2011} / B_{0}\right)$ 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).

| $\boldsymbol{M}$ | $\boldsymbol{B}_{0}(\mathbf{0 0 0} \boldsymbol{t})$ | $\left.\boldsymbol{B}_{\mathbf{2 0 1 1}} \mathbf{( 0 0 0} \boldsymbol{t}\right)$ | $\boldsymbol{B}_{201} / \boldsymbol{B}_{\boldsymbol{0}}$ |
| :--- | :--- | :--- | :--- |
| 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 10: MCMC posteriors for $B_{0}$ and $B_{2011} / B_{0}$ for the mid catch, $M=0.08$ and $\boldsymbol{h}=\mathbf{0 . 7 5}$.

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 10).

Assuming trawl and line catches remain in the same proportions as those used for 2010-11 in the model catch history, deterministic $B_{M S Y}$ 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 current 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 current TACC or the current catch (which is not much less than the TACC) are predicted to cause the stock to decline to very low abundance over the next 20 years (Figure 11). 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 $T_{\text {min }}$. 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 $T_{\text {min }}$. The estimates of $T_{\min }$ range from 10 to 13 years (Table 5) and the maximum catches that allow a rebuild to $40 \% B_{0}$ within twice $T_{\text {min }}$ (the maximum rebuilding time under the Harvest Strategy Standard) range from 570-840 t (Table 6).


Figure 11: 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 $2011+2 T_{\text {min }}$.

Table 5: 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 " $T_{\text {min }}$ " and is shown for the six runs with the mid catch and combinations of $M$ and $h$.

|  |  | $\mathbf{h}$ |
| ---: | ---: | ---: |
| $\boldsymbol{M}$ | $\mathbf{0 . 7 5}$ | $\mathbf{0 . 9 0}$ |
| $\mathbf{0 . 0 6}$ | 13 | 12 |
| $\mathbf{0 . 0 8}$ | 13 | 12 |
| $\mathbf{0 . 1 0}$ | 11 | 10 |

## BLUENOSE (BNS)

Table 6: The maximum catch ( $\mathbf{t}$ ) that allows SSB to rebuild to at least $40 \% B_{0}$ within twice $T_{\text {min }}$ for the six runs with mid catch.

|  |  | $\boldsymbol{h}$ |  |
| ---: | ---: | ---: | ---: |
| $\boldsymbol{M}$ |  | $\mathbf{0 . 7 5}$ | $\mathbf{0 . 9 0}$ |
| $\mathbf{0 . 0 6}$ |  | 600 | 720 |
| $\mathbf{0 . 0 8}$ |  | 570 | 770 |
| $\mathbf{0 . 1 0}$ |  | 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.

## 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 <br> Assessment | 2011 (Full quantitative stock assessment) |
| Assessment runs presented | Eighteen MPD runs exploring a plausible range of catch history, <br> natural mortality rate, and stock-recruitment steepness. |
| Reference Points | $B_{\text {MSY }}: 15-25 \% B_{0}$ <br> Target: Not formally established. Assumed to be $40 \% B_{0}$ (based on <br> draft Harvest Strategy Standard Operational Guidelines, low <br> productivity stock) |



Spawning stock biomass trajectories (proportion of $\boldsymbol{B}_{0}$ ) for the final set of 18 MPD runs.

| Fishery and Stock Trends | Recent Trend in Biomass or <br> Proxy |  |
| :--- | :--- | :---: |
| The MPD estimates of current stock size ranged from 14-27\% Bo. <br> Biomass is estimated to have declined continuously since the 1980s <br> and has been below the default target biomass since around 2000. |  |  |
| Recent Trend in Fishing | Exploitation rates are estimated to have increased from 1980 as the <br> stock has declined. Estimated exploitation rates in the trawl fishery <br> have declined since 2005, but remain high in the line fishery. |  |
|  |  |  |
| Other Abundance Indices | Standardised CPUE trends in the different QMAs show different <br> rates of decline, for example being steeper in BNS 2 and 3 and <br> flatter in BNS 7 and 8. (Figure 4) |  |
| Trends in Other Relevant <br> Indicator or Variables | - |  |


| Projections and Prognosis |  |
| :--- | :--- |
| Stock Projections or Prognosis | Deterministic projections with $M=0.08$ and $h=0.75$ predicted that <br> stock abundance will decline to below the hard limit within the next <br> 20 years under current levels of catch. The time to rebuild ( $T_{\text {min }}$ ) to <br> the assumed target (40\% $\left.B_{0}\right)$ under zero catches ranges from 10 to <br> 13 years, depending on model assumptions. Within the range of <br> model runs explored, the maximum catch (EEZ wide) that would <br> rebuild the stock to the target within twice $T_{\text {min }}$ is 570-600 t for $h=$ <br> 0.75 and 720-840 t for $h=0.9$. |
| Probability of Current Catch or <br> TACC causing decline below <br> LimitsSoft Limit: Very Likely ( $>60 \%$ ) <br> Hard Limit: Very Likely $(>60 \%)$ |  |


| Assessment Methodology |  |
| :--- | :--- |
| Assessment Type | Level 1: Full quantitative stock assessment |
| Assessment Method | Age-structured CASAL model with MPD estimation over a range of <br> plausible catch histories, natural mortality rates and steepness. |
| Main data inputs | - CPUE indices derived from statutory catch and effort reporting. <br> - Length frequency data from sampling conducted under the <br> Adaptive Management Programme, and from observer data. <br> - One age frequency distribution for each of the trawl and line <br> fisheries. |
| Period of Assessment | Latest assessment: 2011 $\quad$ Next assessment: Unknown |
| Changes to Model Structure <br> and Assumptions | This is the first full quantitative assessment of bluenose and <br> assumes a single NZ-wide stock. CPUE indices for longline and <br> trawl fisheries were assumed to index abundance. |
| Major Sources of Uncertainty | Stock structure and spatial dynamics are uncertain. <br> The assessment assumes that CPUE indexes abundance. <br> Natural mortality is uncertain; the plausible range considered affects <br> the estimate of current status, and is confounded with the estimated <br> fishery selectivities. <br> Method specific selectivities are considered constant across areas. <br> Deterministic recruitment is assumed, variation in year class <br> strengths are not estimated. <br> Catches are known and the catch history is complete. |

## Qualifying Comments

Alternative plausible stock hypotheses have not been explored.
Standardised CPUE trends in the different QMAs show different rates of decline; for example, BNS 1 tracks the combined index, BNS 2 and 3 have a steeper decline and BNS 7 and 8 show a more gradual decline (Figure 4).

## Fishery Interactions

Bluenose are 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 are 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.

Bluenose TACCs and landings by BNS stock for the most recent fishing year are summarised in Table 7.

Table 7: Summary of TACCs $(\mathbf{t})$ and reported landings ( $\mathbf{t}$ ) for bluenose for the most recent fishing year.

| Fish stock | QMA | 2010-11 | 2010-11 <br>  <br> BNS 1 |  |
| :--- | :--- | :--- | ---: | ---: |
| Auckland (East) (West) | $1 \& 9$ | TACC | Reported Landings |  |
| BNS 2 | Central (East) | 2 | 786 | 623 |
| BNS 3 | South-East (Coast) | $3,4,5,6$ | 902 | 560 |
|  | (Chatham), |  | 505 | 411 |
|  | Southland and Sub-Antarctic |  |  |  |
| BNS 7 | Challenger | 7 | 89 |  |
| BNS 8 | Central (West) | 8 | 43 | 75 |
| BNS 10 | Kermadec | 10 | 10 | 27 |
| Total |  |  | 233 | 0 |
|  |  |  |  | 1696 |

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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 | 225 |  |
| BUT 3 | 65 | 65 | 3 | 1 | 134 |
| BUT 4 | 4 | 4 | 10 | 0 | 18 |
| BUT 5 | 10 | 10 | 45 | 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 applies 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 of Fishing for reconsideration.

Table 2: Reported domestic landings ( $\mathbf{t}$ ) and TACCs of butterfish by Fishstock from 2001-02 to 2010-11.

| FMA | BUT 1 |  | BUT 2 |  | BUT 3 |  | BUT 4 |  | BUT 5 |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | 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 |
| 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 |  |  |



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

## BUTTERFISH (BUT)

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 \& 4).


Figure 2: Historical landings and TACC for the three main BUT stocks. BUT2 (Central East), BUT5 (Southland) and BUT 7 (Challenger). Note that these figures do not show data prior to entry into the QMS.

Table 3: Estimated recreational harvest of butterfish by QMA and survey.

| QMA | Survey | Number caught | Survey harvest (t) | Fishstock harvest (t) <br> $1991-92$ |
| :--- | :--- | ---: | ---: | ---: |
| QMA 7 | South | 6000 | 10 |  |
| QMA 7 | South | 4000 | 5 | 15 |
| QMA 3 | South | 36000 | 65 | 65 |
| QMA 5 | South | 8000 | 10 | 10 |
| QMA 2 | Central | 61000 | 80 | $1993-93$ |
| QMA 1 +9 | North | 9000 | 10 | 80 |
| TOTAL |  | 124000 |  | $1993-94$ |

*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 | 1000 | 71 | $<1-3$ |
| BUT 2 | National | 23000 | 39 | $16-36$ |
| BUT 3 | National | 45000 | 47 | $27-76$ |
| BUT 5 | National | 17000 | 42 | $11-27$ |
| BUT 7 | National | 18000 | 41 | $12-29$ |
| BUT 8 | National | 1000 | 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.

## $1.4 \quad$ 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 $0-20 \mathrm{~m}$. 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 .

## BUTTERFISH (BUT)

Adult butterfish average $45-55 \mathrm{~cm}$ (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 $\sim 75 \%$ of their life span. The maximum age ranged from 11 years in the north (Haukaki 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 $37-45 \mathrm{~cm}$ 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, inbetween 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 ( $<30 \mathrm{~cm}$ ) occur in the shallow weed beds ( $<15 \mathrm{~m}$ ) 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 $(\boldsymbol{M})$ |  |  |
| Cook Strait | $0.30-0.45$ | Paul et al. (2000) |


|  | Females |  | Males |  | Juvenile |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | a | b | a | b | a | b |  |
| Cook Strait | 67.699 | 1947.8 | 67.034 | 1885.9 | 21.205 | 362.28 | Ritchie (1969) |

Hauraki Gulf
Stewart Is.
Linear regression, $\mathrm{b}=$ constant. Weight is gutted weight.
3. von Bertalanffy growth parameters

|  | Both sexes |  |  |  |
| :--- | ---: | ---: | ---: | ---: |
| Cook Strait | $K$ | $t_{0}$ | $L_{\infty}$ | Paul et al. (2000) |
| Hauraki Gulf | 0.23 | -1.7 | 51.8 | 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, 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 in 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 Estimation of Maximum Constant Yield (MCY)

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. $M C Y$ for butterfish cannot be determined.

### 4.4 Estimation of Current Annual Yield (CAY) <br> CAY cannot be determined.

### 4.5 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 $B_{\text {MSY }}$.

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.


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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 noncommercial 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 COC3 (Figure 1). Landings from COC3 are relatively stable since 2002-03; by contrast landings from COC1A and COC7A 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 the New Zealand Food Safety Authority (NZFSA), in cooperation with the District

## COCKLES (COC)

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 NZFSA 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 also occurs for this 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 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 |
| :--- | :--- |
| COC1A | Whangarei Harbour |
| COC1B | East Northland |
| COC1C | Hauraki Gulf and Bay of Plenty |
| COC2 | Central |
| COC3 | Otago |
| COC3B | Part South East Coast |
| COC4 | South East (Chatham Rise) |
| COC5 | Southland and Sub-Antarctic |
| COC7A | Nelson Bays |
| COC7B | Marlborough |
| COC7C | Part Challenger |
| COC8 | Central (Egmont) |
| COC9 | Auckland (West) |


| TACC | Recreational <br> allowance | Customary <br> allowance | TAC |
| ---: | ---: | ---: | ---: |
| 346 | 25 | 25 | 396 |
| 0 | 22 | 22 | 44 |
| 5 | 32 | 32 | 69 |
| 0 | 2 | 2 | 4 |
| 1470 | 10 | 10 | 1490 |
| 1 | 27 | 27 | 55 |
| 0 | 1 | 1 | 2 |
| 2 | 2 | 2 | 6 |
| 1390 | 85 | 25 | 1500 |
| 0 | 5 | 5 | 10 |
| 0 | 3 | 3 | 6 |
| 0 | 1 | 1 | 2 |
| 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.

[^7]
## 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 1968, Spencer et al. 2002). Suspension feeders such as A. stutchburyi tend to be more abundant in sediments with a larger grain size. Cockles have been shown to be most abundant in sediments of below 12 percent mud in two separate studies (Thrush et al. 2003, Anderson 2008). They are also common in eelgrass (e.g., Zostera sp.), which often co-occurs with sand flats.

Cockles are found from the lowest high water neap tide mark to the lowest part of the shore. Larcombe (1971) suggested that the upper limit is found where submergence is only 3.5 hours per day. A. stutchburyi is often a dominant species and densities as high as $4500 / \mathrm{m}^{2}$ have been reported in some areas. In Pauatahanui Inlet the cockle biomass has been estimated at $80 \%$ ( 5000 t ) of the total intertidal biomass in 1976 (Richardson 1979). Calculations based on laboratory measurements of filtration rates suggested cockles $>35 \mathrm{~mm}$ shell length were capable of filtering $1.1 \times 10^{6} \mathrm{~m}^{3}$ 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 3 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 work 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 $1^{\text {st }}$ January, and a period of no growth occurs at the beginning of July (Tuck \& Williams In Press). 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 in press).

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 at all three QMA 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 ( $\sim 28 \mathrm{~mm} \mathrm{SL}$ ) in about 3 to 4 years, although these results showed great variability in growth rate (tabulated in Table 8, Tuck \& Williams In Press). At Pakawau beach (7A) $K$ has varied between 0.36 and 0.41 and $L_{\infty}$ between 47 and 49 mm (Osborne 1992, 1997). The work or Breen et al. (1999) in Papanui and Waitati Inlets, Purakanui and Otago Harbour shoed 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 > 25 mm shell length remain largely sessile, moving only in response to disturbance.

## COCKLES (COC)

Given that cockles recruit to the spawning biomass at $\sim 18 \mathrm{~mm}$ 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 $>30 \mathrm{~mm}$ in shell length (MFish 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. 2004, 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 $>30 \mathrm{~mm}$ 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 $>35 \mathrm{~mm}$ 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 In Press). 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. $\mathrm{SL}=$ shell length, within area 7A, $\mathbf{P}=$ Pakawau, FP = Ferry Point, TBR = Tapu Bay/Riwaka.

|  | 1A | 3 | 7A |
| :---: | :---: | :---: | :---: |
| 1. Natural mortality ( $M$ ) | 0.3 | 0.3 | 0.3 |
| 2. Weight (grams) | $=\mathrm{a}$ (shell length) ${ }^{\mathrm{b}}$ | $=\mathrm{a}($ shell length $)+\mathrm{b}$ | $=\mathrm{a}$ (shell length) ${ }^{\mathrm{b}}$ |
| a | 0.00014 | 0.7211 | $\mathrm{P}=0.000018, \mathrm{FP}=0.0002, \mathrm{TBR}=0.00015$ |
| b | 3.29 | 11.55 | $\mathrm{P}=3.78, \mathrm{FP}=3.153, \mathrm{TBR}=3.249$ |
| 3. von Bertalanffy growth parameters |  |  | used instead growth $=\mathrm{a}(\operatorname{Ln}($ age in years $)$ ) +b |
| K | 0.26 | 0.311 | $\mathrm{a}=11.452$ |
| $L_{\infty}(\mathrm{mm})$ | 35 | 40.95 | $\mathrm{b}=16.425$ |
| 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.

[^8]
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Tuck I., Williams J. In Press. Cockle growth at Snake Bank, Whangarei Harbour, 2001-10, Draft Fisheries Research Report, Ministry of Fisheries, 40p.
(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 noncommercial.

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 198889 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 156 t ), and landings in 2008-09 ( 88 t ) were the lowest ever recorded.

Table 1: Reported commercial landings and catch limits (t greenweight) of cockles from Snake Bank since 1986-87 (from QMR/MHR records)*. Before COC 1A entered the QMS, the fishery was restricted by daily catch limits which summed to 584 t in a 365 day year, but there was no explicit annual restriction. A TACC of 346 t was established in October 2002 when COC 1A entered the QMS.

| Fishing year | Landings (t) | Limit (t) | Fishing year | Landings (t) | Limit (t) |
| :--- | ---: | ---: | :--- | ---: | ---: |
| $1986-87$ | 114 | 584 | $1998-99$ | 472 | 584 |
| $1987-88$ | 128 | 584 | $1999-00$ | 505 | 584 |
| $1988-89$ | 255 | 584 | $2000-01$ | 423 | 584 |
| $1989-90$ | 426 | 584 | $2001-02$ | 405 | 584 |
| $1990-91$ | 396 | 584 | $2002-03$ | 237 | 346 |
| $1991-92$ | 537 | 584 | $2003-04$ | 218 | 346 |
| $1992-93$ | 316 | 584 | $2004-05$ | 151 | 346 |
| $1993-94$ | $* * 566$ | 584 | $2005-06$ | 137 | 346 |
| $1994-95$ | 501 | 584 | $2006-07$ | 111 | 346 |
| $1995-96$ | 495 | 584 | $2007-08$ | 151 | 346 |
| $1996-97$ | 457 | 584 | $2008-09$ | 88 | 346 |
| $1997-98$ | 439 | 584 | $2009-10$ | 93 | 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: Historical landings and TACC for COC 1A (Whangarei Harbour). Note that this figure does not show data prior to entry into the QMS.

### 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

[^9]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 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 200001 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.

|  | QMA 1 harvest <br> (number of cockles) | CV (\%) | QMA 1 harvest (t) |  |
| :--- | ---: | ---: | ---: | ---: |
| Year |  |  |  | Source |
| 1993-94 | 2140000 | 18 | 55 | Bradford (1997) |
| 1996 | 569000 | 18 | 14 | Bradford (1998) |
| $1999-00$ | 2357000 | 24 | 59 | Boyd \& Reilly (2002) |
| 2000-01 | 2327000 | 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 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 $C A Y$ and $M C Y$. 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 2009 was $11 \%$ and had generally trended down since 1991 (70\%) with the exception of a large peak around 2001 (93\%). Exploitation rate and 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.



Figure 2: Exploitation rate ( $\geq \mathbf{3 0} \mathbf{~ m m}$ 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).

Table 4: Estimates of biomass ( $t$ ) of cockles on Snake Bank for surveys ( $n$, number of stations) between 1982 and 2009. There was no survey in 2010. Biomass estimates for the $\geq 18 \mathrm{~mm}$ 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 others 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 "\% $B_{\text {recruited }}$ " compares the biomass in the $\geq 30 \mathrm{~mm}$ SL to the defined $B_{0}$ for that size (22340 t in 1982).

| Year | $n$ | Total |  | $\geq 18 \mathrm{~mm} \mathrm{SL}$ |  | $\geq 30 \mathrm{~mm} \mathrm{SL}$ |  | $\geq 35 \mathrm{~mm} \mathrm{SL}$ |  | $\% B_{\text {recruited }}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Biomass | c.v. | Biomass | c.v. | Biomass | c.v. | Biomass | c.v. |  |
| 1982 | 199 | 2556 | - | - | - | *2 340 | - | 1825 | $\sim 0.10$ | 100 |
| 1983 | 187 | 2509 | - | 2460 | 0.06 | *2 188 | - | 1700 | $\sim 0.10$ | 94 |
| 1985 | 136 | 2009 | 0.08 | 1360 | 0.07 | 1662 | 0.08 | 1174 | $\sim 0.10$ | 71 |
| 1988 a | 53 | - | - | - | - | 1140 | > 0.15 | - | - | - |
| 1988 b | 53 | - | - | - | - | 744 | > 0.15 | - | - | - |
| 1991 | 158 | 1447 | 0.09 | 1069 | 0.08 | 761 | 0.10 | 197 | 0.12 | 33 |
| 1992 | 191 | 1642 | 0.08 | 1355 | 0.07 | 780 | 0.08 | 172 | 0.11 | 33 |
| 1995 | 181 | 2480 | 0.07 | 2380 | 0.07 | 1478 | 0.07 | 317 | 0.12 | 63 |
| 1996 | 193 | 1755 | 0.07 | - | - | 796 | 0.08 | 157 | 0.11 | 34 |
| 1998 | 53 | 2401 | 0.18 | - | - | 880 | 0.17 | 114 | 0.20 | 38 |
| 1999 | 47 | 3486 | 0.12 | 2645 | 0.11 | 1321 | 0.14 | 194 | 0.32 | 56 |
| 2000 | 50 | 1906 | 0.23 | 2609 | 0.18 | 570 | 0.25 | 89 | 0.32 | 24 |
| 2001 | 51 | 1405 | 0.17 | 1382 | 0.17 | 435 | 0.17 | 40 | 0.29 | 19 |
| 2002 | 53 | 1618 | 0.14 |  |  | 466 | 0.19 | 44 | 0.29 | 20 |
| 2003 | 60 | 2597 | 0.11 | 2385 | 0.31 | 1030 | 0.12 | 121 | 0.14 | 44 |
| 2004 | 65 | 1910 | 0.15 | 1096 | 0.14 | 546 | 0.14 | 59 | 0.22 | 23 |
| 2005 | 57 | 2592 | 0.18 | 2035 | 0.15 | 967 | 0.20 | 111 | 0.20 | 41 |
| 2006 | 57 | 2412 | 0.13 | 2039 | 0.13 | 792 | 0.13 | 103 | 0.20 | 34 |
| 2007 | 73 | 2883 | 0.13 | 2681 | 0.13 | 1434 | 0.15 | 329 | 0.42 | 61 |
| 2008 | 70 | 2510 | 0.10 | - | - | 1165 | 0.11 | 193 | 0.43 | 50 |
| 2009 | 75 | 1686 | 0.15 | - | - | 815 | 0.13 | 88 | 0.19 | 35 |

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 $\geq 35 \mathrm{~mm}$ 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 ( $\geq 30 \mathrm{~mm}$ 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 in 2010.


Figure 3: Recruited biomass ( $\geq 30 \mathrm{~mm}$ 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 |  | $<30 \mathrm{~mm} \mathrm{SL}$ |  | $\geq 30 \mathrm{~mm} \mathrm{SL}$ |  | $\geq 35 \mathrm{~mm} \mathrm{SL}$ |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Biomass | CV | Biomass | CV | Biomass | CV | Biomass | CV |
| 1998 | 33 | 6939 | 0.19 | 5261 | 0.18 | 1678 | 0.31 | 128 | 0.41 |
| 2000 | 30 | 6037 | 0.28 | 4899 | 0.29 | 1137 | 0.30 | 34 | 0.37 |
| 2002 | 24 | 2548 | 0.12 | 2010 | 0.14 | 538 | 0.36 | 61 | 0.46 |

### 4.3 Estimation of Maximum Constant Yield (MCY)

A range of sizes are taken commercially, selectivity seems to vary between years and $M C Y$ 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 ( $L_{R E C R}$ ) for Snake Bank cockles

| $\begin{align*} & L_{\text {recr }}  \tag{t}\\ & (\mathrm{mm}) \tag{t} \end{align*}$ | Rationale | $B_{\text {av }}(1991-2009)$ | $B_{\text {curr }}(2009)$ | M | $F_{0.1}$ | MCY <br> (t) | CAY <br> (t) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 25 | Smallest in catch | 1877 | 1596 | 0.3 | 0.34 | 385 | 401 |
| 28 | Fisher selectivity | 1409 | 1265 | 0.3 | 0.38 | 289 | 349 |
| 30 | Historical assumption | 890 | 815 | 0.3 | 0.41 | 182 | 239 |
| 35 | Largest cockles | 145 | 88 | 0.3 | 1.00 | 30 | 49 |

### 4.4 Estimation of Current Annual Yield (CAY)

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.

### 4.5 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 $L_{\text {recr }}=25 \mathrm{~mm}$ ).

Table 7: MCY and CAY estimates ( $\mathbf{t}$ ) for different shell lengths at recruitment ( $L_{R E C R}$ ). 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 per Table 4.

| Year | $\underline{M C Y} \geq 28 \mathrm{~mm} \mathrm{SL}$ | $\underline{M C Y} \geq 30 \mathrm{~mm} \mathrm{SL}$ | $\underline{C A Y} \geq 28 \mathrm{~mm} \mathrm{SL}$ | $C A Y \geq 30 \mathrm{~mm} \mathrm{SL}$ |
| :---: | :---: | :---: | :---: | :---: |
| 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 |

### 4.6 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 > 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 3-5 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

| Stock Status |  |
| :---: | :---: |
| Year of Most Recent Assessment | 2009 |
| Assessment Runs Presented | Survey biomass estimate for $\geq 30 \mathrm{~mm}$ shell length |
| Reference Points | Target: Not defined, but $B_{M S Y}$ assumed. <br> Soft Limit: 20\% $B_{0}$ <br> Hard Limit: $10 \% B_{0}$ |
| Status in relation to Target | About as Likely as Not (40-60\%) to be at or above the target |
| Status in relation to Limits | Unlikely ( $<40 \%$ ) to be below both soft and hard limits |
| Historical Stock Status Trajectory and Current Status |  |
|  |  |


| 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 <br> Mortality or Proxy | Exploitation rate ( $\geq 30 \mathrm{~mm}$ shell length) generally trended downward from 1991 (70\%) until 2009 (11\%), with the exception of a a large peak in rate around 2001 (up to 93\%). It is Very Unlikely ( $<10 \%$ ) that overfishing is occurring. |
| Other Abundance Indices | None |
| Trends in Other Relevant Indicators or Variables | None |


| Projections and Prognosis |  |  |  |  |
| :--- | :--- | :---: | :---: | :---: |
| Stock Projections or Prognosis | None |  |  |  |
| Probability of Current Catch or | Fishing at present levels is Unlikely (<40\%) to cause declines |  |  |  |
| TACC causing decline below |  |  |  |  |
| Lelow soft or hard limits. |  |  |  |  |
| 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: 2009 |  |  |  |


| Changes to Model Structure <br> and Assumptions | None |
| :--- | :--- |
| Major Sources of Uncertainty | The estimate of $B_{0}$ was from 1982 and is not necessarily a good <br> estimate of average unfished biomass. <br> 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 $\% B_{\text {recruited }}$ 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.

## Fishery Interactions

None
Table 7: Summary of yields, catch limits, and reported landings (t) of Snake Bank cockles for the most recent fishing year.

| Fishstock |  |  |  |
| :--- | :--- | :--- | :--- |
| COC 1A | $\quad M C Y \geq 30 \mathrm{~mm} \mathrm{SL}$ |  |  |
| 174 | 182 | $\frac{C A Y \geq 30 \mathrm{~mm} \mathrm{SL}}{346}$ | $2010-11$ <br> Actual TACC |
| 346 | 2010-11 |  |  |
|  |  |  | 64 |

## 7. FOR FURTHER INFORMATION

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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 presently expires on the $31^{\text {st }}$ of August $2012^{1}$

In 1992, 35 mm shell length was the minimum size for commercial cockles. However, commercial fishers currently target $\geq 28 \mathrm{~mm}$ cockles, 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 $>30 \mathrm{~mm}$ ). 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

[^10]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 2010-11 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 | 1273 |
| 2000-01 | 90 | 427 | 606 | 746 | - | 696 | 1273 |
| 2001-02 | 49 | N/A | 591 | N/A | - | 640 | 1273 |
| 2002-03 | 52 | N/A | 717 | N/A | - | 767 | 1470 |
| 2003-04 | 73 | N/A | 689 | N/A | - | 762 | 1470 |
| 2004-05 | 91 | N/A | 709 | N/A | - | 800 | 1470 |
| 2005-06 | 68 | N/A | 870 | N/A | - | 943 | 1470 |
| 2006-07 | 0* | N/A | 907 | N/A | - | 907 | 1470 |
| 2007-08 | - | N/A | 760 | N/A | - | 760 | 1470 |
| 2008-09 | - | N/A | 751 | N/A | 25 | 774 | 1470 |
| 2009-10 | - | N/A | 379 | N/A | 441 | 820 | 1470 |
| 2010-11 | - | N/A | 240 | N/A | 596 | 836 | 1470 |



Figure 1: Historical landings and TACC for COC 3 (Otago). Note that this figure does not show data prior to entry into the QMS.

### 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 <br> $1993-94$ | Harvest ( $N$ ) | \% CV | Harvest (t) |
| :--- | :---: | :---: | :---: | :---: |
| FMA 3 | South <br> 1996 | 106000 | 51 | 2.7 |
| FMA 3 |  | 144000 | - | 3.6 |
| FMA3 | 2000 |  |  |  |
| FMA |  | 1476000 | 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 ${ }^{2}$. 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 in terms of 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 | 1109 |
| 2001 | 1090 |
| 2002 | 0 |
| 2003 | 2750 |
| 2004 | 4390 |
| 2005 | 5699 |

### 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 "quick-feeds" 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.

## 2. STOCKS AND AREAS

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

[^11]
## 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).

In 2004 and 2007 yield-per-recruit modelling was conducted for Papanui and Waitati inlets separately (Stewart 2005, 2008a). 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 both Waitati and Papanui Inlet (Figure 2) and is unable to be calculated for Otago harbour.

Table 4: Estimates of fishery parameters (recruitment to this fishery is at $\geq \mathbf{2 8 m m}$ )

| $\boldsymbol{M}$ | $\boldsymbol{F}_{0 . \mathbf{1}} \mathbf{2 0 0 4}$ | $\boldsymbol{F}_{0 . \mathbf{1} \mathbf{2 0 0 7}}$ |
| :--- | :--- | :--- |
| 0.2 | 0.2321 | 0.2899 |
| 0.3 | 0.3412 | 0.3863 |
| 0.4 | 0.4767 | 0.5537 |

Exploitation rate \% (for cockles $\leq \mathbf{3 0} \mathbf{~ m m}$ across each entire inlet)*

| Year | Papanui | Waitati |
| :--- | ---: | ---: |
| 1998 | 2 | 0 |
| 2002 | 1 | 5 |
| 2004 | 2 | 6 |
| 2007 | 0 | 7 |

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


Figure 2: Exploitation rate as calculated by landings divided by biomass ( $\geq 19 \mathrm{~mm}$ ) from whole inlets.

### 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 ${ }^{3}$ which means that comparison of biomass values between times of different calculation methodologies should be done cautiously.

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

The Spawning stock biomass ( $\geq 19 \mathrm{~mm}$ 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 ( $\geq 19 \mathrm{~mm}$ shell length) has shown a trend of gradual decline from 1984 until 2004, when it was at $78 \%$ of virgin biomass. The recruited biomass ( $\geq 30 \mathrm{~mm}$ shell length) in the sanitation areas (beds 1804 and 1805) in Otago Harbour decreased prior to the start of harvesting in 2008.

Table 5: Current ( $\mathbf{\pm 9 5 \%} \mathbf{C I}$ ) and previous biomass estimates from COC 3*.

*Wildish 1984; Stewart et al. 1992; Breen et al. 1999; Wing et al. 2002; Stewart, 2005; Stewart 2008a, Stewart 2008b. Area of current commercial beds, Papanui Inlet $=815,811 \mathrm{~m}^{2} .{ }^{* *}$ Area of current commercial beds, Waitati Inlet $=943,986 \mathrm{~m}^{2} .{ }^{* * *}=$ this value is only for $\geq 19 \mathrm{~mm}$ to $<30 \mathrm{~mm}$ cockles.


Figure 3: Biomass as a proportion of $B_{0}$ for Waitati and Papanui Inlets, this is estimated from biomass $>19 \mathrm{~mm}$.
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, 2008). These data were then used to generate length to weight relationships

### 3.3 Estimates of Maximum Constant Yield (MCY)

Estimates of $M C Y$ are given in Table 6.
Table 6: Estimates of $M C Y(t)$ for COC 3 generated using Method 1 (Annala et al. 2003) an average biomass $\geq 30 \mathrm{~mm}$ as $B_{0}$ and the 2007 estimate of $F_{0.1}$. This calculation is likely to underestimate the true MCY.

| Location | M | 1998 | 2002 | 2004 | 2007 |
| :--- | ---: | ---: | ---: | ---: | ---: |
| Waitati Inlet | 0.2 | 1049 | 1045 | 1083 | 1070 |
| Waitati Inlet | 0.3 | 1397 | 1392 | 1443 | 1425 |
| Waitati Inlet | 0.4 | 2003 | 1996 | 2068 | 2043 |
| Waitati Inlet (commercial) | 0.2 |  |  | 813 | 749 |
| Waitati Inlet (commercial) | 0.3 |  |  | 1084 | 998 |
| Waitati Inlet (commercial) | 0.4 |  |  | 1554 | 1431 |
| Papanui Inlet | 0.2 | 289 | 280 | 266 |  |
| Papanui Inlet | 0.3 | 385 | 373 | 355 |  |
| Papanui Inlet | 0.4 | 552 | 534 | 509 |  |
| Papanui Inlet (commercial) | 0.2 |  |  | 175 |  |
| Papanui Inlet (commercial) | 0.3 |  |  | 234 |  |
| Papanui Inlet (commercial) | 0.4 |  |  | 335 |  |

### 3.4 Estimates of Current Annual Yield (CAY)

For Waitati Inlet, $C A Y$ was estimated (Table 7) using Method $1\left(C A Y=\left(F_{0.1} / Z\right)(1-\exp (-Z)) B_{B E G}\right)$ (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, $B_{\text {beg }}=$ Projected biomass at the beginning of the fishing year.

|  |  |  |  | WI |  | WIc |  | PI |  | PIc |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Year | M | $\boldsymbol{F}_{0.1}$ | $\geq$ SL (mm) | $\boldsymbol{B}_{\text {beg }}$ | CAY | $\boldsymbol{B}_{\text {beg }}$ | CAY | $\boldsymbol{B}_{\text {beg }}$ | CAY | $\boldsymbol{B}_{\text {beg }}$ | CAY | Reference |
| 2007 | 0.2 | 0.2899 | 28 | 8378 | 1920 | 5261 | 1206 |  |  |  |  | Stewart 2008a |
| 2007 | 0.3 | 0.3863 | 28 | 8378 | 2342 | 5261 | 1471 |  |  |  |  | Stewart 2008a |
| 2007 | 0.4 | 0.5537 | 28 | 8378 | 2990 | 5261 | 1878 |  |  |  |  | Stewart 2008a |
| 2007 | 0.2 | 0.2899 | 30 | 7106 | 1629 | 4725 | 1083 |  |  |  |  | Stewart 2008a |
| 2007 | 0.3 | 0.3863 | 30 | 7106 | 1986 | 4725 | 1321 |  |  |  |  | Stewart 2008a |
| 2007 | 0.4 | 0.5537 | 30 | 7106 | 2536 | 4725 | 1686 |  |  |  |  | Stewart 2008a |
| 2004 | 0.2 | 0.2321 | 30 | 9399 | 1771 | 6081 | 1146 | 4119 | 776 | 2454 | 462 | Stewart 2005 |
| 2004 | 0.3 | 0.3412 | 30 | 9399 | 2367 | 6081 | 1532 | 4119 | 1038 | 2454 | 618 | Stewart 2005 |
| 2004 | 0.4 | 0.4767 | 30 | 9399 | 2984 | 6081 | 1930 | 4119 | 1308 | 2454 | 779 | Stewart 2005 |
| 2002 | 0.2 | 0.2017 | 30 | 7183 | 1193 | 5364 | 891 | 3860 | 641 | 2322 | 386 | Wing et al. 2002 |
| 2002 | 0.3 | 0.3015 | 30 | 7183 | 1627 | 5364 | 1215 | 3860 | 874 | 2322 | 526 | Wing et al. 2002 |
| 2002 | 0.4 | 0.3956 | 30 | 7183 | 1960 | 5364 | 1464 | 3860 | 1053 | 2322 | 634 | Wing et al. 2002 |
| 1999 | 0.2 | 0.258 | 30 | 7235 | 1498 |  |  | 3990 | 826 |  |  | Breen et al. 1999 |
| 1999 | 0.3 | 0.357 | 30 | 7235 | 1848 |  |  | 3990 | 1019 |  |  | Breen et al. 1999 |
| 1999 | 0.4 | 0.457 | 30 | 7235 | 2221 |  |  | 3990 | 1225 |  |  | Breen et al. 1999 |

### 3.5 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 ( $>45 \mathrm{~mm}$ shell length and greater) whereas commercial fishers currently prefer cockles of around $28-34 \mathrm{~mm}$. Estimates of yields have been estimated for size of recruitment at $\geq 28 \mathrm{~mm}$; 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 impacts 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 <br> Assessment | 2007 |
| Assessment Runs Presented | Survey biomass estimate for $\geq 19 \mathrm{~mm}$ shell length |
| Reference Points | Target: Not defined, but $B_{\text {MSY }}$ assumed. <br> Soft Limit: $20 \% B_{0}$ <br> Hard Limit: $10 \% B_{0}$ |
| Status in relation to Target | Likely ( $>60 \%)$ to be at or above the target |
| Status in relation to Limits | Unlikely ( $<40 \%$ ) 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 > $\mathbf{1 9} \mathbf{~ m m}$.

| Fishery and Stock Trends |  |
| :---: | :---: |
| Recent Trend in Biomass or Proxy | Biomass at Waitati Inlet has been stable 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. |
| Recent Trend in Fishing Mortality or Proxy | Exploitation rate has never exceeded 2\% for Papanui Inlet and has increased in Waitati Inlet to just over 6\%. Exploitation rate is unable to be calculated for Otago Harbour. It is Very Unlikely ( $<10 \%$ ) that overfishing is occurring. <br> Exploitation rate as calculated by landings divided by biomass ( $\geq 19 \mathrm{~mm}$ ) from whole inlets. |
| Other Abundance Indices | Recruited biomass in the two currently harvested beds in Otago Harbour has declined between 1998 and 2008, prior to the start of harvesting. |
| Trends in Other Relevant Indicators or Variables | None |


| Projections and Prognosis |  |
| :--- | :--- |
| Stock Projections or Prognosis | None |
| Probability of Current Catch or <br> TACC causing decline below <br> Limits | Fishing at present levels is Very Unlikely (< 10\%) to cause declines <br> below soft or hard limits |
| Assessment Methodology |  |
| Assessment Type | Level 2: Partial quantitative stock assessment |
| Assessment Method | Absolute biomass estimates from quadrat surveys |

## COCKLES (COC 3)

| Main data inputs | Abundance and length frequency information |  |
| :--- | :--- | :--- |
| Period of Assessment | Latest assessment: 2007 | Next assessment: unknown |
| Changes to Model Structure <br> and Assumptions | N/A |  |
| Major Sources of Uncertainty | N/A |  |

## Qualifying Comments

Water quality issues have influenced the amount of time when cockles can be harvested from Papanui Inlet in recent years.

## Fishery Interactions <br> None

Table 8: Summary of yields, catch limits, and reported landings ( $t$ ) of COC 3 for the most recent fishing year.

|  |  |  | 2010-11 | 2010-11 |
| :---: | :---: | :---: | :---: | :---: |
| Fishstock | $\underline{M C Y} \geq 28 \mathrm{~mm} \mathrm{SL}$ | $\underline{C A Y} \geq 28 \mathrm{~mm} \mathrm{SL}$ | Actual TACC | Reported Landings |
| COC 3 | N/A | N/A | 1470 | 836 |

## 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 | 1130 |
| $1999-00$ | 752 | 1130 |
| $2000-01$ | 731 | 1134 |
| $2001-02$ | 556 | 1134 |
| $2002-03$ | 569 | 1390 |
| $2003-04$ | 553 | 1390 |
| $2004-05$ | 428 | 1390 |
| $2005-06$ | 460 | 1390 |
| $2006-07$ | 337 | 1390 |
| $2007-08$ | 237 | 1390 |
| $2008-09$ | 307 | 1390 |
| $2009-10$ | 301 | 1390 |
| $2010-11$ | 348 | 1390 |

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: Historical landings and TACC for COC7A (Nelson Bays). Note that this figure does not show data prior to entry into the QMS.

### 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 $>30 \mathrm{~mm}$ ) 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 under-estimate 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) |  |
| $1992-93$ | 166000 | 4 |
| 1996 | 325000 | 8 |
| 2000 | 499000 | 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 in the near future.

### 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 lengthfrequency 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 $=\mathrm{a}$ (shell length $)^{\underline{\mathrm{b}}}(\text { weight in } \mathrm{g} \text {, shell length in } \mathrm{mm})_{\text {( }}$ |  |  |  |  |
|  |  | a | b | Osborne (1992) |
| Pakawau Beach (1992) |  |  | 3.78 | Forrest \& Asher (1997) |
| Ferry Point (1996) |  |  | 3.153 | Stark \& Asher (1991) |
| Tapu Bay-Riwaka (1991) |  |  | 3.249 |  |
| 3. von Bertalanffy growth parameters |  |  |  |  |
|  | K | $t_{0}$ | $L_{\infty}$ |  |
| 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 $L_{\infty}$ 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 $\mathrm{y}=11.452 \operatorname{Ln}(\mathrm{x})+16.425$, where y is shell width and x is age in years, this equation is only applicable to individuals $23-55 \mathrm{~mm}$ 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 3 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). 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 $\mathbf{9 5 \%}$ confidence intervals (CI) where available, and mean density ( $\mathbf{k g} / \mathbf{m}^{2}$ ) for cockles on Pakawau Beach. Values are given for the total and recruited ( $\geq \mathbf{3 0} \mathbf{~ m m}$ ) 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 <br> (ha) | $n$ | Total biomass |  |  | Recruited biomass |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | $t$ | CI | $\mathrm{kg} / \mathrm{m}^{2}$ | $t$ | CI | $\mathrm{kg} / \mathrm{m}^{2}$ |
| 1984 | 326 | - | 4604 | 1562 | 1.41 | - | - | - |
| 1988 | 510 | - | 5640 | - | 1.11 | - | - | - |
| Nov 1992\# | 421 | 230 | 5540 | 824 | 1.32 | 5299 | 836 | 1.26 |
| May 1997\# | 421 | 224 | 7846 | 1588 | 1.86 | 7422 | 1665 | 1.76 |
| Jun 1998\# | 421 | 227 | 6838 | 1245 | 1.62 | 6285 | 1252 | 1.49 |
| Apr-99 | 421 | 228 | 6920 | 1154 | 1.64 | 6388 | 1091 | 1.52 |
| Mar-00 | 421 | 205 | 6357 | 1184 | 1.51 | 5966 | 1140 | 1.42 |
| Mar-01 | 421 | 190 | 8942 | 1570 | 2.12 | 8160 | 1460 | 1.94 |
| Feb-04 | 421 | 268 | 9432 | 1200 | 2.24 | 8803 | 1164 | 2.09 |
| Jan-08 | 407 | 180 | 8968 | 1662 | 2.2 | 8285 | 1599 | 2.04 |

\# Prior to 1999, recruited biomass was calculated for size of $\geq 35 \mathrm{~mm}$ shell length and has been adjusted to biomass $>30 \mathrm{~mm}$ using a length weight model.

Table 5: Estimates of biomass ( $t$ ) with $95 \%$ confidence intervals (CI) where available, and mean density $\left(\mathbf{k g m}^{2}\right)$ for cockles at various sites in Golden and Tasman Bays. Where possible, values are given for the total and recruited ( $\geq \mathbf{3 0} \mathbf{~ m m}$ ) populations. $n=$ number of samples in the survey.

| Site | Date | Area (ha) | $n$ | Total biomass |  |  | Recruited biomass |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | $t$ | CI | $\mathrm{kg} / \mathrm{m}^{2}$ | $t$ | CI | $\mathrm{kg} / \mathrm{m}^{2}$ |
| Tapu Bay-Riwaka | Mar-91 | 306 | 321 | ~3900 | - | 1.28 | - | - | - |
| Riwaka | Feb-04 | 122.7 | 144 | 1423 | 269 | 1.16 | 1076 | 235.6 | 0.88 |
| Riwaka | Mar-08 | 103 | 82 | 1475 | 257 | 1.44 | 939 | 178 | 0.9 |
| Riwaka (excl. Tapu Bay)* | Mar-91 | - | - | - | - | - | 1880 | 450 | - |
| Ferry Point | Dec-96 | 40 | 552 | 2617 | 190 | 5.99 | 2442 | 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 | 1850 | 671 | 0.55 | 796 | 395 | 0.24 |
| Rangihaeata Beach | Mar-93 | 197 | 75 | 473 | 345 | 0.24 | 438 | 320 | 0.22 |

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 $\mathrm{m}^{2}$, 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 $\geq 30 \mathrm{~mm}$ 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 ( $\geq \mathbf{3 0} \mathbf{~ m m}$ shell length) over time

The biomass that will support the maximum sustainable yield $\left(B_{M S Y}\right)$ is not known for any of the areas fished in COC 7A.

Estimates of MCY have been made for populations of cockles in various areas, and at various times, using the equation $M C Y=0.25 * F_{\text {ref }} * B_{0}$ (Method 1), where $F_{r e f}$ 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 $F_{r e f}$ is dependent on $M$, so owing to the uncertainty of $M$ a range of $M C Y$ 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 $=0.5 * F_{R E F} * B_{A V}$ (Method 2), using $F_{0.1}$, and with $B_{A V}$ being the average of the available recruited biomass from the previous comparable surveys). For a range of $M$ values, $M C Y$ is as follows:

| $M$ | 0.2 | 0.3 | 0.4 |
| :--- | ---: | ---: | ---: |
| $M C Y$ | 1182 | 2418 | 4658 |

Table 6: Estimates of MCY ( t , using $0.25 * F_{\text {REF }} * B_{0}$ ) for various cockle stocks in Tasman and Golden Bays, assuming a range of values for $M$.

| Site | Date | $F_{r e f}$ |  |  |  |  |
| :--- | ---: | :--- | ---: | ---: | ---: | ---: |
|  |  |  | 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 | $F_{M A X}$ | 1182 | 2418 | 4658 |  |
| 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 | $F_{M A X}$ | 264 | 453 | 789 | 1493 |
| 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 by harvesting the populations at the estimated $M C Y$ levels cannot be determined for any of the surveyed areas. However, yield estimates are substantially higher when based on $F_{M A X}$ rather than $F_{0.1}$, so risk would be greater at $M C Y$ s based on $F_{\text {MAX }}$.

### 4.4 Estimation of Current Annual Yield (CAY)

Estimates of CAY have been made in the past for cockle stocks at Pakawau Beach, Ferry Point and Riwaka, using $C A Y=F_{R E F} /\left(F_{R E F}+M\right) *\left(1-\mathrm{e}^{\left({ }^{(F R E F}+M\right)}\right) * B_{B E G}$ (Method 1), where beginning of season biomass $\left(B_{B E G}\right)$ is current recruited biomass available to the fishery, and $F_{R E F}$ 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 $C A Y$ available for all stocks are listed in Table 7.

### 4.5 Other yield estimates and stock assessment results

$F_{0.1}$ and $F_{M A X}$ 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 | $F_{R E F}$ |  |  |  |  |
| :--- | ---: | :--- | ---: | ---: | ---: | ---: |
|  |  |  | 0.2 | 0.3 | 0.4 | 0.5 |
| Pakawau Beach | 2001 | $F_{0.1}$ | 778 | 996 | 1210 | 1396 |
| Pakawau Beach \# | 2001 | $F_{0.1}$ | 1964 | 2514 | 3053 | 3522 |
| Pakawau Beach | 2001 | $F_{M A X}$ | 1599 | 2388 | 2975 | - |
| Pakawau Beach | 2004 | $F_{0.1}$ | 1202 | 1555 | 1910 |  |
| Pakawau Beach | 2008 | $F_{0.1}$ | 1161 | 1501 | 1845 |  |
| Ferry Point | 1996 | $F_{0.1}$ | 407 | 501 | 600 | 696 |
| Ferry Point | 1996 | $F_{M A X}$ | 748 | 1050 | 1369 | 1650 |
| 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 | Calculations using total recruited biomass, rather than available recruited biomass. |  |  |  |  |  |
| \# |  |  |  |  |  |  |

Table 8: Estimates of $F_{0.1}$ and $F_{M A X}$ using a range of $M$ values and two minimum harvest sizes (MHS).

| $F_{\text {REF }}$ | MHS |  |  | $M$ |  |
| :--- | ---: | ---: | ---: | ---: | ---: |
|  | $(\mathrm{~mm})$ | 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 |
| $F_{M A X}$ | 35 | 0.66 | 1.35 | 2.6 | - |
| $F_{\text {MAX }}$ | 30 | 0.53 | 0.91 | 1.59 | 3.01 |

### 4.6 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.

- COC7A

| Stock Status |  |
| :--- | :--- |
| Year of Most Recent <br> Assessment | 2008 |


| Assessment Runs Presented | Survey biomass estimates for $\geq 30 \mathrm{~mm}$ shell length |
| :---: | :---: |
| Reference Points | Target(s): Not defined, but $B_{\text {MSY }}$ 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 Tra <br>  | tory and Current Status |
| Recruited biomass ( $\geq \mathbf{3 0} \mathbf{~ m m}$ shel | gth) over time |


| Fishery and Stock Trends |  |
| :--- | :--- |
| Recent Trend in Biomass or <br> Proxy | The recruited biomass estimates of cockles from Pakawau beach <br> have shown a general trend of increase, with the lowest value in <br> 1992 (5299 t) and the highest value in 2004 $(8803 \mathrm{t})$. Ferry Point <br> recruited biomass estimates declined from 2442 t in 1996 to 443 t <br> and 470 t in 2004 and 2008, respectively. Riwaka total biomass <br> estimates decreased from 1991 (1880 t) to 2008 (939 t). |
| Recent Trend in Fishing <br> Mortality or Proxy | Landings since 2004-5 are intermediate compared to the history of <br> the fishery and have fluctuated without trend between 237 and 460 t |
| Other Abundance Indices | None |
| Trends in Other Relevant <br> Indicators or Variables | Nond |


| Projections and Prognosis |  |  |  |
| :--- | :--- | :---: | :---: |
| Stock Projections or Prognosis | None |  |  |
| Probability of Current Catch or <br> TACC causing decline below <br> Limits | Fishing at present levels is Very Unlikely (< 10\%) to cause declines <br> below the 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: 2008 |  |  |
| Changes to Model Structure <br> and Assumptions | None |  |  |
| Major Sources of Uncertainty | None |  |  |

## Qualifying Comments

Water quality issues have influenced the amount of time when cockles can be harvested from Ferry Point in recent years.

## Fishery Interactions

## None

Table 9: Summary of yields, catch limits, and reported landings ( $\mathbf{t}$ ) of COC7A for the most recent fishing year.

| Fishstock | $\frac{M C Y \geq 30 \mathrm{~mm} \mathrm{SL}}{\text { N/A* }}$ | $\frac{C A Y \geq 30 \mathrm{~mm} \mathrm{SL}}{\mathrm{N} / \mathrm{A}^{*}}$ | $\frac{2010-11}{\text { Actual TACC }}$ |
| :--- | ---: | ---: | ---: |
| COC7A | 1390 | 2010-11 | Reported Landings |
| * Osborne 2010 |  |  |  |

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## DEEPWATER (KING) CLAM (PZL)



## 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.

| QMA | TAC $(t)$ | TACC $(t)$ | Other sources of mortality |
| :--- | ---: | ---: | ---: |
| 1 | 1.5 | 1.2 | 0.3 |
| 2 | 1.5 | 1.2 | 0.3 |
| 3 | 1.5 | 1.2 | 0.3 |
| 4 | 1.5 | 1.2 | 0.3 |
| 5 | 1.5 | 1.2 | 0.3 |
| 7 | 30.0 | 23.1 | 6.9 |
| 8 | 1.5 | 1.2 | 0.3 |
| 9 | 1.5 | 1.2 | 0.3 |
| Total | $\mathbf{4 0 . 5}$ | $\mathbf{3 1 . 5}$ | $\mathbf{9 . 0}$ |

### 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 ( 5.116 t ) occurred in 2010-11 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 2010-11, 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 |  |

## $1.4 \quad$ 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 ( $5-25 \mathrm{~m}$ ) in sand and mud off sandy ocean beaches, while $P$. smithae lives mainly at greater depths ( $110-130 \mathrm{~m}$ ) 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 $15^{\circ} \mathrm{C}$ (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 $L_{\infty}$ 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 QMAs, 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 Estimation of Maximum Constant Yield (MCY)

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).

### 4.4 Estimation of Current Annual Yield (CAY)

$C A Y$ has not been estimated for any deepwater clam stocks.

## 5. STATUS OF THE STOCKS

- PZL 7 - Panopea zelandica

| Stock Status |  |
| :--- | :--- |
| Year of Most Recent <br> Assessment | No formal assessment done for any stock |
| Assessment Runs Presented | None |
| Reference Points | Target: Not defined, but $B_{\text {MSY }}$ assumed. <br> Soft Limit: $20 \% B_{0}$ <br> Hard Limit: $10 \% B_{0}$ |
| Status in relation to Target | Because of the relatively low levels of exploitation of P. zelandica, it <br> is likely that this stocks is still effectively in a virgin state, therefore it <br> is Very Likely (> 60\%) to be at or above the target. |
|  |  |
| Status in relation to Limits <br> Historical Stock Status Trajectory and Current |  |

[^12]| Fishery and Stock Trends |  |
| :--- | :--- |
| Recent Trend in Biomass or <br> Proxy | Unknown |
| Recent Trend in Fishing <br> Mortality or Proxy | In 1989- 92 the landings for PZL 7 averaged 52 t; however, since <br> that time fishing has been light in all QMAs with less than 5.2 t <br> having been taken per year |
| Other Abundance Indices | None |
| Trends in Other Relevant <br> Indicators or Variables | None |


| Projections and Prognosis |  |  |
| :--- | :--- | :--- |
| Stock Projections or Prognosis | None |  |
| Probability of Current Catch or <br> TACC causing decline below <br> Limits | Current catches are Unlikely (<40\%) to cause declines below soft <br> or hard limits |  |
| Assessment Methodology |  |  |
| Assessment Type | none |  |
| Assessment Method | N/A |  |
| Main data inputs | N/A | Next assessment: N/A |
|  | Latest assessment: N/A |  |
| Changes to Model Structure <br> and Assumptions | N/A |  |
| Major Sources of Uncertainty | N/A |  |

## Qualifying Comments

Early surveys show that density is generally low compared with North American species but that productivity is higher.

## Fishery Interactions <br> None known

## 7. FOR FURTHER INFORMATION

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## ELEPHANT FISH (ELE)

## (Callorhinchus milii) <br> Reperepe



## 1. FISHERY SUMMARY

### 1.1 Commercial fisheries

From the 1950s to the 1980s, landings of elephantfish of around 1000 t 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 $10-30 \mathrm{t}$ 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 1936 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 $5 \mathrm{t}, 5 \mathrm{t}$, and 50 t respectively, and ELE 5 has allowances $5 \mathrm{t}, 5 \mathrm{t}$, 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 | 1112 | 1976 | 705 |
| 1937 | 184 | 1947 | 188 | 1957 | 1069 | 1967 | 934 | 1977 | 704 |
| 1938 | 201 | 1948 | 230 | 1958 | 1238 | 1968 | 862 | 1978 | 596 |
| 1939 | 193 | 1949 | 310 | 1959 | 1148 | 1969 | 934 | 1979 | 719 |
| 1940 | 259 | 1950 | 550 | 1960 | 1163 | 1970 | 1128 | 1980 | 906 |
| 1941 | 222 | 1951 | 602 | 1961 | 983 | 1971 | 1401 | 1981 | 690 |
| 1942 | 171 | 1952 | 459 | 1962 | 1156 | 1972 | 1019 | 1982 | 661 |
| 1943 | 220 | 1953 | 530 | 1963 | 1095 | 1973 | 957 |  |  |
| 1944 | 270 | 1954 | 853 | 1964 | 1235 | 1974 | 848 |  |  |
| 1945 | 217 | 1955 | 802 | 1965 | 1111 | 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. ELE 3 fishing is seasonal, mostly
occurring in spring and summer in inshore waters. Most of the recent increase in catch from the ELE 3 fishery has been taken as a bycatch of the RCO 3 trawl fishery (Raj \& Voller 1999). During 1989-90 to 1997-98, the level of elephantfish bycatch from the RCO 3 fishery increased from around 50 t to 300 t (Raj \& Voller 1999). There was also a steady increase in the level of ELE 3 bycatch from the FLA 3 trawl fishery, with catches increasing from around 50 t in 1994-95 to 150 t in 1997-98. 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 been increased by $17 \%$ up from 120 t to 140 t . All AMP programmes ended on $30^{\text {th }}$ 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. As well, 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) of elephantfish by Fishstock from 1983-84 to 2010-11 and actual TACCs (t) from 1986-87 to 2010-11. QMR data from 1986 - present. No landings have been reported from ELE 10.

| Fishstock |  | $\begin{array}{r} \text { ELE } 1 \\ 1 \& \end{array}$ |  | ELE 2 |  | ELE 3 |  | ELE 5 |  | ELE 7 |  | Total |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| FMA (s) |  | $\underline{9}$ |  | 2 \& 8 |  | 3 \& 4 |  | 5 \& 6 |  | 7 |  |  |
|  | 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 | 1082 | 715 |
| 1998-99 | <1 | 10 | 9 | 22 | 842 | 500 | 129 | 71 | 117 | 102 | 1098 | 715 |
| 1999-00 | <1 | 10 | 6 | 22 | 950 | 500 | 105 | 71 | 87 | 102 | 1148 | 715 |
| 2000-01 | 2 | 10 | 7 | 22 | 956 | 825 | 153 | 71 | 90 | 102 | 1207 | 1040 |
| 2001-02 | <1 | 10 | 9 | 22 | 852 | 825 | 105 | 100 | 88 | 102 | 1053 | 1057 |
| 2002-03 | 1 | 10 | 9 | 22 | 950 | 950 | 106 | 100 | 59 | 102 | 1125 | 1194 |
| 2003-04 | $<1$ | 10 | 10 | 22 | 984 | 950 | 102 | 100 | 42 | 102 | 1139 | 1194 |
| 2004-05 | <1 | 10 | 13 | 22 | 972 | 950 | 125 | 120 | 74 | 102 | 1184 | 1214 |
| 2005-06 | <1 | 10 | 14 | 22 | 1023 | 950 | 147 | 120 | 76 | 102 | 1260 | 1214 |
| 2006-07 | <1 | 10 | 17 | 22 | 960 | 950 | 158 | 120 | 116 | 102 | 1251 | 1214 |
| 2007-08 | <1 | 10 | 16 | 22 | 1092 | 950 | 202 | 120 | 125 | 102 | 1435 | 1214 |
| 2008-09 | 1 | 10 | 21 | 22 | 1063 | 950 | 208 | 120 | 91 | 102 | 1384 | 1214 |
| 2009-10 | $<1$ | 10 | 21 | 22 | 1089 | 1000 | 176 | 140 | 86 | 102 | 1372 | 1274 |
| 2010-11 | <1 | 10 | 14 | 22 | 1123 | 1000 | 153 | 140 | 93 | 102 | 1384 | 1283 |



Figure 1: Historical 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). Note that these figures do not show data prior to entry into the QMS.

### 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 Ministry of 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 less than 500 fish in ELE 2, 1000 fish in ELE 3 and less 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 less than 500 in ELE 7 (Boyd \& Reilly 2002). Owing to biases inherent to telephone vs. 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 $M=$ loge 100 /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 3. 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 3: Estimates of biological parameters for elephant fish.

| Fishstock | Estimate |  |  |  | Source |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 1. Natural mortality ( $M$ ) |  |  |  |  |  |
| All | 0.35 |  |  |  | Francis (1997) |
| 2. Weight $=\mathrm{a}$ (length $)^{\mathrm{b}}$ ( Weight in g, length in cm fork length) |  |  |  |  |  |
|  |  |  |  |  |  |
|  | a | b |  |  |  |
| ELE 3 | 9.1-3 | 3.02 |  |  | Gorman (1963) |
| 3. von Bertalanffy Growth Function |  |  |  |  |  |
|  | Pegasus Bay 1966-68 |  | Canterbury Bight 1966-68 |  |  |
|  | Males | Females | Males | Females | Francis (1997) |
| $\mathrm{K}\left(\mathrm{yr}^{-1}\right)$ | $0.231 \pm 0.002$ | $0.096 \pm 0.001$ | $0.089 \pm 0.002$ | $0.060 \pm 0.001$ |  |
| $L_{\infty}(\mathrm{cm})$ | $74.7 \pm 0.12$ | $156.9 \pm 1.38$ | $141.5 \pm 2.28$ | $203.6 \pm 3.2$ |  |
| $t_{0}$ (yr) | $-0.78 \pm 0.008$ | $-0.87 \pm 0.006$ | $-0.96 \pm 0.008$ | $-1.06 \pm 0.009$ |  |
|  | Pegasus Bay 1983-84 |  | Canterbury Bight 1988 |  |  |
|  | Males | Females | Males | Females |  |
| $\mathrm{K}\left(\mathrm{yr}^{-1}\right)$ | $0.473 \pm 0.009$ | $0.195 \pm 0.008$ | $0.466 \pm 0.008$ | $0.224 \pm 0.001$ |  |
| $L_{\infty}(\mathrm{cm})$ | $66.9 \pm 0.52$ | $113.9 \pm 2.89$ | $62.7 \pm 0.23$ | $94.1 \pm 0.26$ |  |
| $t_{0}(\mathrm{yr})$ | $-0.24 \pm 0.017$ | $-0.53 \pm 0.023$ | $-0.38 \pm 0.015$ | $-0.69 \pm 0.006$ |  |

## 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

Indices of relative biomass are available from recent trawl surveys (Table 4, Figure 2). These have not been used to estimate absolute biomass or yields as historically, these trawl surveys have given variable abundance and high CV's for elephantfish, and probably have not monitored their biomass very well. A pilot survey off the east coast of the South Island was undertaken in the summer of 1996-97 and was repeated in 1997-98, 1998-99, 1999-2000 and 2000-01. This survey was initiated for several reasons, including a need to better survey elephantfish in ELE 3 in view of the recent TACC increase. In February 1999, the Inshore Fishery Assessment Working Group concluded that it was not clear whether the East Coast South Island (ECSI) trawl survey was adequately sampling elephantfish, as the commercial fishery for this species included depths < 10 m and the Kaharoa is unable to trawl in such areas. Subsequently, in 1999-2000 and 2000-01 the commercial vessel Compass Rose carried out surveys (concurrently) with the Kaharoa in which it fished areas inside 10 m . In 2001 the Inshore FAWG recommended that the east coast South Island trawl survey be discontinued due to the extreme variability in the catchability of the target species. A workshop (May 2006) to review the monitoring of inshore finfish concluded that the ECSI winter survey series should be reinstated, as based on simulations using existing data, it was predicted to provide useful relative biomass estimates for many species (excluding elephantfish). The workshop concluded that ELE 3 relative biomass should be estimated using industry run "hybrid" surveys.


Figure 2: Elephantfish biomass $\pm 95 \%$ CI (estimated from survey CVs assuming a lognormal distribution) and the time series mean (dotted line) estimated from the East Coast South Island trawl survey.

Table 4: 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*.
$\left.\begin{array}{llllrr}\text { Region } & & & \text { Trip } & \begin{array}{c}\text { Biomass } \\ \text { estimate }\end{array} & \text { CV (\%) } \\ \text { ECSI(winter) } & \text { FLE 3 } & \text { Year } & \text { number } & \text { KAH9105 } & 300\end{array}\right)$
*Assuming areal availability, vertical availability and vulnerability equal 1.0. Biomass is only estimated outside 10 m depth except for COM9901 and CMP0001. Note: because trawl survey biomass estimates are indices, comparisons between different seasons (e.g., summer and winter ECSI) are not strictly valid.

### 4.1.2 CPUE biomass indices

## ELE 3 and ELE 5

Three standardised CPUE series for ELE 3 were prepared for 2012, with each series based on the bycatch of 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.

Two standardised CPUE series for ELE 5 were prepared for 2012, again with each series based on the bycatch of elephantfish in the appropriate bottom trawl fisheries defined by target species combinations. One of these series [ELE 5 (MIX)] is analogous to the MIX series developed for ELE 3, with the series defined by 6 target species in all valid ELE 5 statistical areas. A series using the same suite of target species but confined to only Area 030 was dropped by the Working Group after it was determined that the Area 030 series showed a very similar trend to the total ELE 5 series, with much wider confidence intervals. The second ELE 5 analysis [ELE 5 (MIX)-trip] was a trip-based analysis using the same target species selection

## ELEPHANT FISH (ELE)

method as described for ELE 3(MIX)-trip.
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 appear to be an appropriate index of ELE abundance in either QMA.

These analyses were based on data which have been amalgamated into "trip-strata" (Starr 2007), defined as the sum of the catch and effort within a trip characterised by unique statistical areas, target species and method of capture. This approach loses much of the detailed information available in tow-by-tow records, but reduces all data to a common level of stratification, allowing the calculation of linked year coefficients. Unfortunately, the "trip-stratum" approach ignores problems associated with shifts in reporting behaviour associated with changes in form type requirements, while relying on the model parameterisation to adjust for potential biases. The Working Group was concerned in 2009 whether the shift to the new TCER forms in October 2007 may have affected the indices in the 2007-08 fishing year. As a further three years of catch/effort data have now been collected using the new, more detailed, TCER forms, further standardised analyses were run in both ELE 3 and ELE 5 on data which had been summarised to the level of a complete "trip" to test the sensitivity of the annual coefficients to the level of amalgamation. The presumption is that amalgamating the data to the level of a "trip" will minimise the effect of the change in form type, with the definition of a "trip" unaffected by form requirements.

Each series was modelled in the same manner, with $\log$ (catch) offered as the dependent variable and a range of explanatory variables offered, including duration and number of tows as continuous polynomials, and statistical area, target species, vessel and month as categorical explanatory variables. In every case, year was forced into the model as the first variable and was considered to be a proxy for relative annual abundance. Data were restricted to vessels which had participated for a specified number of years at a minimum level of participation (expressed as number of trips in a year). This filtering of the data was done to reduce the number of vessels in the data set without overly reducing the amount of catch represented in the model.

Trial models based on five alternative distributional assumptions were fit to a reduced set of explanatory variables, with the distribution giving the best log-likelihood fit selected for the final stepwise model fit. Table 5 lists the distribution giving the best fit for each model. A logit model which modelled the probability of success was also fit to the same data using a binomial distribution. This model was generated as a diagnostic but is not presented.

Table 5: Names and descriptions of the three elephantfish ELE 3 and two ELE 5 bottom trawl CPUE series accepted by the Working Group in 2012. Also shown is the error distribution that had the best fit to the distribution of standardised residuals for the fitted model.

| Name | Code |
| :--- | :--- |
| ELE 3 bottom trawl mixed | ELE3(MIX) |
| ELE 3 bottom trawl flatfish | ELE3(RCO) |
| ELE 3 bottom trawl trip-based | ELE3(MIX)-trip |
| ELE 5 bottom trawl mixed | ELE5(MIX) |
| ELE 5 bottom trawl trip-based | ELE5(MIX)-trip |


| Statistical areas | Target species | Best distribution |
| :--- | :--- | :--- |
| $018,020,022,024,026$ | RCO, STA, BAR, TAR, ELE | lognormal |
| $018,020,022,024,026$ | RCO | lognormal |
| $018,020,022,024,026$ | N/A | lognormal |
| ELE 5 (all statistical areas) | ELE, FLA, STA, BAR, SPD, RCO | lognormal |
| ELE 5 (all statistical areas) | N/A | lognormal |

ELE 3(RCO): This series showed a generally increasing trend from the beginning to the end of the series, with a possible levelling off of the series after 2007-08. There is a period in the middle of the series with four years of declining CPUE, reaching a nadir slightly below the long-term mean in 2004-05 (Figure 3).

ELE 3(MIX): This series has a trajectory similar to the ELE 3(RCO) series, showing an increasing trend which levels of around 2007-08 (Figure 3). Again there is a short period of decline in the early 2000s which reaches a low point in 2004-05 slightly below the long-term average.

ELE 3(MIX)-trip: This series was run as a diagnostic sensitivity to test whether the change in form type
in October 2007 introduced a bias into the analysis. This series (Figure 3) was similar to the ELE 3(MIX) series, leading to the conclusion that, for ELE 3, the form type change did not introduce strong bias.
$\boldsymbol{B}_{\text {MSY }}$ conceptual proxy: The Working Group proposed using the average of the ELE 3(MIX) series from 1998-99 to 2010-11 to represent a " $B_{M S Y}$ 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.

ELE 3: BT [lognormal]


Figure 3: Standardised CPUE indices for three ELE 3 bottom trawl fisheries [ELE 3(MIX), ELE 3 (MIX)-trip and ELE 3(RCO)] (Table 5). The horizontal grey line is the mean of ELE 3(MIX) from 98-99 to 10-11 (B MSY $^{\text {(M) }}$ conceptual proxy). All series have been normalised to a geometric mean $=1.0$. Error bars show $\pm 97.5 \%$ confidence intervals.

ELE 5(MIX): This series has a continually increasing trend (Figure 4).
ELE 5(MIX)-trip: This series was run as a diagnostic sensitivity to test whether the change in form type in October 2007 introduced a bias into the analysis. This series (Figure 4) was similar to the ELE 5(MIX) series, leading to the conclusion that, for ELE 5, the form type change did not introduce strong bias.
$\boldsymbol{B}_{M S Y}$ conceptual proxy: The Working Group was unable to agree on an appropriate " $B_{M S Y}$ conceptual proxy" for this Fishstock because of the continually increasing nature of the series. CPUE would need to stabilise or decline before a suitable target could be established.

### 4.2 Biomass Estimates

Estimates of current and reference absolute biomass are not available.

### 4.3 Other yield estimates and stock assessment results <br> No other yield estimates are available.



Figure 4: Standardised CPUE indices for a mixed target species ELE 5 bottom trawl fisheries [ELE 5- (MIX)] (Table 5), plotted along with the annual sum of catches from the series statistical areas plus target species listed in Table 5. Both series have been normalised to a geometric mean $=1.0$. Error bars show $\pm 97.5 \%$ confidence intervals.

## 5. STATUS OF THE STOCKS

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 $B_{M S Y}$ 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 <br> Assessment | 2012 |
| Reference Points | (Proposed) Target: $B_{\text {MSY-Compatible proxy based on CPUE }}^{\text {(average from 1998-99 to 2010-11 of the ELE3(MIX) model as }}$ <br> defined in Starr \& Kendrick 2012a) <br> Soft Limit: 50\% of target <br> Hard Limit: 25\% of target |
| Status in relation to Target | About as Likely as Not to be at or above the target |
| Status in relation to Limits | Soft Limit: Unlikely $(<40 \%$ ) to be below <br> Hard Limit: Very Unlikely $(<10 \%)$ to be below |



## ELEPHANT FISH (ELE)

| Assessment Methodology and Evaluation |  |  |
| :--- | :--- | :--- |
| Assessment Type | Level 2: Standardised CPUE abundance index and the winter ECSI <br> trawl survey index. |  |
| Assessment Method | Evaluation of agreed standardised CPUE indices which reflect <br> changes in abundance as well as the trawl survey biomass indices. |  |
| Assessment Dates | Latest assessment: 2012 | Next assessment: 2015 |
| Overall assessment quality rank | 1 - High Quality. The Southern Inshore Working Group agreed <br> that the ELE3(MIX) CPUE index was a credible measure of <br> abundance. |  |
| Main data inputs (rank) | - Catch and effort data derived <br> from the Ministry for <br> Primary Industries <br> compulsory catch reporting <br> system. <br> - Trawl survey biomass indices <br> and associated length <br> frequencies. | 1-High Quality <br> 1 - High Quality; however, the <br> survey does not cover the full <br> distribution range of elephantfish <br> in ELE 3 |
| Data not used (rank) | 3-Compass Rose trawl survey data - insufficient data <br> 3-Summer ECSI trawl survey data - variable catchability between <br> years |  |
| Changes to Model Structure and | The previously accepted target red cod CPUE series has been <br> expanded to include a range of mixed target species and updated <br> with data up to 2007-08. The winter east coast South Island trawl <br> Aurvey was resumed in 2007 and new biomass index values for |  |
| elephantfish applicable to 2007, 2008 and 2009 are available. |  |  |

## 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. This may allow the estimation of $B_{\text {MSY }}$ 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.
Incidental captures of seabirds occur and there is a risk of incidental capture of Hector's dolphins.

## 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 <br> Assessment | 2012 |
| Reference Points | Target: $B_{M S Y}$-compatible proxy based on CPUE (to be determined) <br> Soft Limit: $20 \% B_{0}$ <br> Hard Limit: $10 \% B_{0}$ |
| Status in relation to Target | Unknown |
| Status in relation to Limits | Soft Limit: Unlikely ( $<40 \%)$ to be below <br> Hard Limit: Unlikely ( $<40 \%)$ to be below |



Comparison of the mixed target species bottom trawl CPUE series (ELE5(MIX)) with the trajectories of catch (ELE5(QMR/MHR)) and TACCs from 1989-90 to 2010-11.

## Fishery and Stock Trends

| Recent trend in Biomass or <br> Proxy | The ELE 5 (MIX) CPUE series has a continually increasing trend. |
| :--- | :--- |
| Recent Trend in Fishing <br> Mortality or Proxy | Unknown. Catches and CPUE have both been steadily increasing <br> since the early 1990s. |
| Other Abundance Indices | None |
| Trends in Other Relevant <br> Indicator or Variables | None |

## Projections and Prognosis <br> Stock Projections or Prognosis

| Probability of Current Catch and TACC causing decline below Limits | Soft Limit: Unlikely (<40\%) <br> Hard Limit: Unlikely (<40\%) |  |
| :---: | :---: | :---: |
| Assessment Methodology and Evaluation |  |  |
| Assessment Type | Level 2: Standardised CPUE abundance index. |  |
| Assessment Method | Evaluation of agreed standardised CPUE indices which reflect changes in abundance. |  |
| Assessment Dates | Latest assessment: 2012 | Next assessment: 2014 |
| Overall assessment quality rank | 1 - High Quality |  |
| Main data inputs (rank) | -The Southern Inshore Working Group agreed that the ELE 5 (MIX) CPUE index was a credible measure of abundance. <br> -Catch and effort data derived from the Ministry for Primary Industries compulsory catch reporting system. | 1 - High Quality <br> 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 | Statistical Area 30 only model was dropped. |  |
| 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 <br> Assessment | 2009 |
| Assessment Runs Presented |  |
| Reference Points | Target: Not established but $B_{\text {MSY }}$ assumed |



## Fishery and Stock Trends

Recent Trend in Biomass or $\quad$ Biomass trends for this stock are unreliably estimated by the West Proxy

Recent Trend in Fishing Mortality or Proxy Coast South Island survey, particularly for the last year where the survey CV was 83\%.

Other Abundance Indices
Trends in Other Relevant
Indicators or Variables

| Projections and Prognosis |  |
| :--- | :--- |
| Stock Projections or Prognosis | Unknown |
| Probability of Current Catch or | Soft Limit: Unknown |
| TACC causing decline below | Hard Limit: Unknown |
| Limits |  |

Assessment Methodology

| Assessment Type | None |  |
| :--- | :--- | :--- |
| Assessment Method | None |  |
| Main data inputs |  | Next assessment: Unknown |
| Period of Assessment | Latest assessment: 2009 |  |


| Changes to Model Structure <br> and Assumptions |  |
| :--- | :--- |
| Major Sources of Uncertainty |  |
| Qualifying Comments |  |
| - |  |

## 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.
TACCs and reported landings are summarised in Table 6.

Table 6: Summary of yields ( $t$ ), TACCs ( $t$ ), and reported landings ( $t$ ) for elephant fish for the most recent fishing year.

|  |  |  | $2010-11$ <br> Actual <br> TACC | 2010-11 <br> Reported <br> Landings |
| :--- | :--- | ---: | ---: | ---: |
| Fishstock | QMA |  | R | 10 |

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## FLATFISH (FLA)

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


## 1. FISHERY SUMMARY

### 1.1 Commercial fisheries

Flatfish Individual Transferable Quota (ITQ) provides for the landing of eight species of flatfish. These are: the yellow-belly flounder, Rhombosolea leporina; sand flounder, Rhombosolea plebeia; black flounder, Rhombosolea retiaria; greenback flounder, Rhombosolea tapirina; lemon sole, Pelotretis flavilatus; New Zealand sole, Peltorhamphus novaezeelandiae; brill, Colistium guntheri; and turbot, Colistium nudipinnis. 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 Sand flounder Greenback flounder Black flounder Lemon sole
New Zealand sole
Brill and turbot

- Firth of Thames, Kaipara and Manukau harbours;
- Hauraki Gulf, Tasman/Golden Bay, Bay of Plenty, and Canterbury Bight;
- Canterbury Bight, Southland;
- Canterbury Bight;
- west coast South Island, Otago and Southland;
- west coast South Island, Otago and Canterbury Bight;
- 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 3417 t in 2008-09. Landings and TACCs are given in Table 1, 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, customary, recreational and other sources of mortality were allocated 5, 150 and 32 t respectively. 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. In 2008/09 the TAC for FLA 3 was increased in-season by 357 t . Of this, 7 t was allocated to other fishing related sources of mortality and, 350 t of newly generated Annual Catch Entitlement (ACE) was added to the Total Annual Commercial Catch (TACC) increasing this to 1780 t , however, as the increase was not available until July, this TACC was not reached. The annual catch was 1544 t of which 114 t was from the in-season increase.

The fishery is mainly confined to the inshore domestic trawl fleet except for small incidental bycatch of soles, brill and turbot by deepwater trawlers, and some localised setnetting, particularly in the north.

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) of flatfish by Fishstock from 1983-84 to 2010-11 and actual TACCs (t) from 1986-87 to 2010-11. QMS data from 1986-present

| Fishstock | $\begin{gathered} \text { FLA } 1 \\ 1 \& 9 \\ \hline \end{gathered}$ |  | $\begin{array}{r} \text { FLA } 2 \\ 2 \& 8 \\ \hline \end{array}$ |  | FLA 3 |  | FLA 7 |  | $\begin{array}{r} \text { FLA } 10 \\ 10 \\ \hline \end{array}$ |  | Total |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| FMA (s) |  |  |  | , 5 \& 6 |  |  |  |  |  |  |
|  | Landings | TACC |  |  | Landings | TACC | Landings | TACC | Landings | TACC | Landings | TACC | Landings | TACC |
| 1983-84* | 1215 | - | 378 | - | 1564 | - | 1486 | - | 0 | - | 5160 | - |
| 1984-85* | 1050 | - | 285 | - | 1803 |  | 951 | - | 0 | - | 4467 | - |
| 1985-86* | 722 | - | 261 | - | 1537 | - | 385 | - | 0 | - | $\ddagger 3215$ | - |
| 1986-87 | 629 | 1100 | 323 | 670 | 1235 | 2430 | 563 | 1840 | 0 | 10 | $\ddagger 2750$ | 6050 |
| 1987-88 | 688 | 1145 | 374 | 677 | 2010 | 2535 | 1000 | 1899 | 0 | 10 | $\ddagger 4072$ | 6266 |
| 1988-89 | 787 | 1153 | 297 | 717 | 2458 | 2552 | 757 | 2045 | 0 | 10 | 4299 | 6477 |
| 1989-90 | 791 | 1184 | 308 | 723 | 1637 | 2585 | 745 | 2066 | 0 | 10 | 3482 | 6568 |
| 1990-91 | 849 | 1187 | 292 | 726 | 1340 | 2681 | 502 | 2066 | 0 | 10 | 2983 | 6670 |
| 1991-92 | 940 | 1187 | 288 | 726 | 1229 | 2681 | 745 | 2066 | 0 | 10 | 3202 | 6670 |
| 1992-93 | 1106 | 1187 | 460 | 726 | 1954 | 2681 | 1566 | 2066 | 0 | 10 | 5086 | 6670 |
| 1993-94 | 1136 | 1187 | 435 | 726 | 1926 | 2681 | 1108 | 2066 | 0 | 10 | 4605 | 6670 |
| 1994-95 | 964 | 1187 | 543 | 726 | 1966 | 2681 | 1107 | 2066 | 0 | 10 | 4580 | 6670 |
| 1995-96 | 628 | 1187 | 481 | 726 | 2298 | 2681 | 1163 | 2066 | 1 | 10 | 4571 | 6670 |
| 1996-97 | 741 | 1187 | 363 | 726 | 2573 | 2681 | 1117 | 2066 | 0 | 10 | 4794 | 6670 |
| 1997-98 | 728 | 1187 | 559 | 726 | 2351 | 2681 | 1020 | 2066 | 0 | 10 | 4657 | 6670 |
| 1998-99 | 690 | 1187 | 274 | 726 | 1882 | 2681 | 868 | 2066 | 0 | 10 | 3714 | 6670 |
| 1999-00 | 751 | 1187 | 212 | 726 | 1583 | 2681 | 417 | 2066 | 0 | 10 | 2963 | 6670 |
| 2000-01 | 792 | 1187 | 186 | 726 | 1702 | 2681 | 447 | 2066 | 0 | 10 | 3127 | 6670 |
| 2001-02 | 596 | 1187 | 177 | 726 | 1693 | 2681 | 614 | 2066 | 0 | 10 | 3080 | 6670 |
| 2002-03 | 686 | 1187 | 144 | 726 | 1650 | 2681 | 819 | 2066 | 0 | 10 | 3299 | 6670 |
| 2003-04 | 784 | 1187 | 218 | 726 | 1286 | 2681 | 918 | 2066 | 0 | 10 | 3206 | 6670 |
| 2004-05 | 1038 | 1187 | 254 | 726 | 1353 | 2681 | 1231 | 2066 | 0 | 10 | 3876 | 6670 |
| 2005-06 | 964 | 1187 | 296 | 726 | 1177 | 2681 | 1283 | 2066 | 0 | 10 | 3720 | 6670 |
| 2006-07 | 922 | 1187 | 296 | 726 | 1429 | 2681 | 1419 | 2066 | 0 | 10 | 4066 | 6670 |
| 2007-08 | 703 | 1187 | 243 | 726 | 1365 | 1430 | 1313 | 2066 | 0 | 10 | 3624 | 5409 |
| 2008-09 | 639 | 1187 | 214 | 726 | **1544 | 1430 | 1020 | 2066 | 0 | 10 | 3417 | 5409 |
| 2009-10 | 652 | 1187 | 212 | 726 | 1525 | 1430 | 884 | 2066 | 0 | 10 | 3273 | 5409 |
| 2010-11 | 486 | 1187 | 296 | 726 | 1027 | 1430 | 659 | 2066 | 0 | 10 | 2467 | 5419 |

[^13]§ Includes landings from unknown areas before 1986-87.
** The TACC was increased in-season under Schedule 2 of the fisheries act.

Fishers and processors are required to use a generic flatfish (FLA) code in the monthly harvest returns to report landed catches of flatfish species. Although fishers are now instructed to use specific species codes when reporting estimated catches, they often use the generic FLA code. Beentjes

## FLATFISH (FLA)

(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 2). 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 3; codes provided in the caption to Table 2).

Table 2: Total estimated flatfish catch ( $\mathbf{t}$ ) by species and fishing year for all flatfish QMAs combined. Codes: black flounder (BFL), brill (BRI), New Zealand sole (ESO), flatfish not species (FLA, FLO, SOL), greenback flounder (GFL), lemon sole (LSO), sand flounder (SFL), Turbot (TUR), witch (WIT), yellow belly flounder (YBF) (Beentjes 2003).

| Year | BFL | BRI | ESO | FLA | FLO | GFL | LSO | SFL | SOL | TUR | WIT | YBF | Total (t) |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| 1989-90 | 0 | 0 | 0 | 2750 | 0 | 0 | 0 | $<1$ | 0 | 0 | $<1$ | $<1$ | 2750 |
| $1990-91$ | 114 | 44 | 238 | 1566 | 0 | 75 | 103 | 284 | 0 | 24 | 1 | 182 | 2629 |
| $1991-92$ | 23 | 45 | 384 | 1530 | 0 | 64 | 151 | 336 | $<1$ | 64 | 2 | 209 | 2809 |
| $1992-93$ | 40 | 74 | 904 | 1948 | 0 | 119 | 521 | 688 | 0 | 87 | 3 | 235 | 4619 |
| $1993-94$ | 24 | 54 | 836 | 1457 | 0 | 94 | 446 | 755 | 0 | 63 | 2 | 249 | 3980 |
| $1994-95$ | 66 | 54 | 742 | 1546 | $<1$ | 92 | 466 | 689 | 3 | 69 | 19 | 277 | 4024 |
| $1995-96$ | 95 | 48 | 730 | 1523 | 12 | 50 | 607 | 515 | 15 | 61 | 0 | 154 | 3810 |
| $1996-97$ | 39 | 43 | 731 | 1714 | 32 | 61 | 561 | 477 | 4 | 42 | 5 | 153 | 3863 |
| $1997-98$ | 14 | 33 | 550 | 1718 | 29 | 59 | 714 | 452 | 4 | 39 | 1 | 162 | 3775 |
| $1998-99$ | 24 | 41 | 418 | 1294 | 28 | 45 | 667 | 297 | 4 | 37 | 3 | 202 | 3060 |
| $1999-00$ | 61 | 44 | 355 | 1075 | 7 | 36 | 408 | 247 | 2 | 30 | 1 | 267 | 2534 |
| $2000-01$ | 42 | 42 | 479 | 1086 | 13 | 29 | 392 | 245 | 3 | 40 | 45 | 316 | 2733 |
| 2001-02 | 85 | 27 | 495 | 1098 | 9 | 35 | 271 | 199 | 1 | 41 | 28 | 210 | $* 2498$ |
| Total | 627 | 550 | 6864 | 20305 | 130 | 759 | 5306 | 5184 | 36 | 595 | 110 | 2617 | 43084 |
| Percent | 1.4 | 1.3 | 15.9 | 47.1 | 0.3 | 1.8 | 12.3 | 12.0 | 0.1 | 1.4 | 0.3 | 6.1 |  |
| * October 2001 to |  |  |  |  |  |  |  |  |  |  |  |  |  |

Table 3: Distribution (\%) of the total estimated catch of 13 flatfish species by QMA for the period 1989-90 and 200102 (Beentjes 2003). Species codes are provided in the caption to Table 1. Catches were allocated to specific QMAs based on the reported statistical area of catch.

| QMA | BFL | BLF | BRI | ESO | FLA | FLO | GFL | LSO | SFL | SOL | TUR | WIT | YBF | All species |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| FLA 1 | 6 |  | 3 | 2 | 27 | 1 | 26 | 2 | 23 | 8 | 2 | 0 | 83 | 22 |
| FLA 2 | 15 |  | 0 | 8 | 13 | 5 | 12 | 1 | 13 | 79 | 4 | 2 | 2 | 10 |
| FLA 3 | 74 | 99 | 62 | 64 | 41 | 94 | 28 | 92 | 29 | 12 | 26 | 87 | 11 | 48 |
| FLA 7 | 5 | 1 | 34 | 27 | 19 | 1 | 34 | 5 | 36 | 1 | 69 | 11 | 3 | 20 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |



Figure 1: Historical landings and TACC for the four main FLA stocks. Left to right: FLA1 (Auckland) and FLA2 (Central). [Continued on next page]...


Figure 1 [Continued]: Historical landings and TACC for the four main FLA stocks. FLA3 (South East Coast, South East Chatham Rise, Sub Antarctic, Southland), and FLA7 (Challenger). Note that these figures do not show data prior to entry into the QMS.

### 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 and spearing. 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). Harvest estimates from recreational surveys are given in Table 4. The flatfish MLS for recreational fishers is 25 cm (for all species).

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 Ministry of 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).

| Fishstock | Survey | Number | CV\% | Harvest range (t) | Point estimate (t) |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 1991-92 |  |  |  |  |  |
| FLA 1 | South | 3000 | - | - | - |
| FLA 3 | South | 15200 | 31 | 50-90 | - |
| FLA 7 | South | 3000 | - | - | - |
| 1992-93 |  |  |  |  |  |
| FLA 1 | Central | 6100 | - | - | - |
| FLA 2 | Central | 73000 | 26 | 20-40 | - |
| FLA 7 | Central | 37100 | 59 | 10-30 | - |
| 1993-94 |  |  |  |  |  |
| FLA 1 | North | 520000 | 19 | 225-275 | - |
| FLA 2 | North | 3000 | - | 0-5 | - |
| 1996 |  |  |  |  |  |
| FLA 1 | National | 308000 | 11 | 95-125 | 110 |
| FLA 2 | National | 67000 | 19 | 13-35 | 24 |
| FLA 3 | National | 113000 | 14 | 30-50 | 40 |
| FLA 7 | National | 44000 | 18 | 10-20 | 16 |
| 1999-00 |  |  |  |  |  |
| FLA 1 | National | 702000 | 25 | 203-336 | - |
| FLA 2 | National | 380000 | 49 | 82-238 | - |
| FLA 3 | National | 395000 | 33 | 128-252 | - |
| FLA 7 | National | 114000 | 53 | 23-73 | - |

## FLATFISH (FLA)

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

### 1.5 Other sources of mortality

Flatfish have always been subject to 'high-grading', and market preference has led to the establishment of 'processor' grading and size limits that are greater than the minimum legal size. Fishers often have no market for lower grade/size flatfish, and legal fish of small size may be discarded. The extent of this source 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 (Steven 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) 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 $1 \& 3$ 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 of flat fish.

Table 5 continued:
2. Weight $=\mathrm{a}(\text { length })^{\mathrm{b}}($ Weight in g , length in cm total length $)$.

|  | Females |  |  | Males |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | a |  | b | a | b |  |  |
| Brill (FLA 7) | 0.01443 |  |  | 0.02470 | 2.8080 |  | Hickman \& Tait (unpub.) |
| Turbot (FLA 7) | 0.00436 |  |  | 0.00571 | 3.1389 |  | Hickman \& Tait (unpub.) |
| Sand flounder (FLA 1) | 0.03846 |  |  | - | - |  | McGregor (unpub.) |
| Yellow-belly flounder (FLA 1) | 0.07189 |  |  | 0.00354 | 3.3268 |  | McGregor (unpub.) |
| New Zealand sole (FLA 3) | 0.03578 |  |  | 0.007608 | 3.0728 |  | McGregor (unpub.) |
| 3. von Bertalanffy growth parameters |  |  |  |  |  |  |  |
|  |  |  | Females |  |  | Males |  |
|  | $L_{\infty}$ | k | $t_{0}$ | $L_{\infty}$ | 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. (2006) |
| Greenback flounder (FLA 5) | 55.82 | 0.26 | -1.06 | 52.21 | 0.25 | -1.32 | Sutton et al. (in press) |

## 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 and in the Hauraki Gulf have been recaptured very far from their point of release.

Thus, though 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

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

## FLA 1

Standardised CPUE was investigated as a tool for monitoring FLA 1 (Coburn et al. 2005) and the accepted indices were updated with some modification in 2009 (Kendrick \& Bentley 2009) and 2012 (Kendrick \& Bentley In press.). The inshore FAWG 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

## FLATFISH (FLA)

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.


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


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 fluctuated without trend and is currently near the long-term mean (Figure 2). 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 remained at that level (Figure 3).

Coburn et al. (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 3

The Southern Inshore Working Group accepted a CPUE analysis intended to inform in-season adjustments to the FLA 3 TAC (Bentley In press.). This analysis estimated trends for three species (New Zealand sole, sand flounder and lemon sole) and the aggregated catch landed to FLA. 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 to the fishery. There are similarities in the fluctuations of the four standardised CPUE indices (Figure 4), 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 to the late 2000s. The TOT, ESO and SFL indices show the greatest similarity in their fluctuations. The LSO index had its peak in the 1990s later than the other indices and increased sooner than the other species in the mid-2000s (Figure 4).


Figure 4: Comparison of standardised CPUE indices in FLA 3 for TOT, (all flatfish species combined) LSO (lemon sole), ESO (New Zealand sole) and SFL (sand flounder). Note that only the TOT index is available for the 1989-90 fishing year because very little species composition data are available for that year (Bentley In press).

### 4.2 Biomass estimates

Estimates of current and reference biomass are not available for any flatfish species.

### 4.3 Estimation of Maximum Constant Yield (MCY)

The Working Group has agreed that $M C Y$ estimates are not appropriate for flatfish.

### 4.4 Estimation of Current Annual Yield (CAY)

No estimate of $C A Y$ is available for flatfish stocks.

## FLATFISH (FLA)

### 4.5 Other Factors

The flatfish complex is comprised of eight species though 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. In press) 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.

Flatfish TACCs were originally set at high levels so as to provide fishers with the flexibility to take advantage of the perceived variability associated with annual flatfish abundance. This approach has been modified with an in-season increase procedure for FLA 3.

## 5. STATUS OF THE STOCKS

Estimates of current and reference biomass are not available.

## 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.

| Stock Status |  |
| :--- | :--- |
| Year of Most Recent Assessment | 2012 |
| Assessment Runs Presented | CPUE in Manakau and Kaipara harbours, and the <br> Hauraki Gulf |
| Reference Points | Target(s): Not established but $B_{\text {MSY }}$ assumed <br> Soft Limit: $20 \% B_{0}$ <br> Hard Limit: $10 \% B_{0}$ |
| Status in relation to Target | Manukau: Unknown <br> Kaipara: Unknown <br> Hauraki Gulf: Unknown |
| Status in relation to Limits | Unknown |

## Historical Stock Status Trajectory and Current Status



Standardised CPUE indices for yellowbelly flounder (YBF or FLA) from models of catch rate in successful set net trips in Manukau Harbour, Kaipara Harbour and in the Hauraki Gulf (Kendrick \& Bentley In press).

| Fishery and Stock Trends |  |
| :--- | :--- |
| Recent Trend in Biomass or <br> Proxy | In spite of fluctuations, both the Manukau and Kaipara series show <br> a long-term declining trend. <br> The Hauraki Gulf yellowbelly CPUE index has fluctuated without <br> trend and is currently near the long-term mean. |
| Recent Trend in Fishing <br> Mortality or Proxy | None |
| Other Abundance Indices | None |
| Trends in Other Relevant <br> Indicators or Variables | None |


| Projections and Prognosis |  |
| :--- | :--- |
| Stock Projections or Prognosis | Unknown |
| Probability of Current Catch or | Soft Limit: Unknown |
| TACC causing decline below | Hard Limit: Unknown |
| Limits |  |

Assessment Methodology and Evaluation

| Assessment Type | Level 2 - Partial Quantitative stock assessment |  |
| :--- | :--- | :--- |
| Assessment Method | Standardised CPUE based on positive catches. |  |
| Assessment Dates | Latest assessment: 2012 |  |
| Overall assessment quality rank | 1-High Quality | Next assessment: 2015 |
| Main data inputs (rank) | -Catch and effort data | -1 High Quality |
| Data not used (rank) | N/A |  |
| Changes to Model Structure and <br> Assumptions | None |  |
| Major Sources of Uncertainty | Uncertainty in the stock structure and relationship between CPUE <br> and biomass. |  |
| Work by NIWA (McKenzie et al. in press) in the Manakau harbour has linked the decrease in local |  |  |

## FLATFISH (FLA)

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.

## 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 <br> Assessment | 2012 |
| Assessment Runs Presented | Standardised CPUE for Hauraki Gulf |
| Reference Points | Target(s): Not established but $B_{M S Y}$ assumed <br> Soft Limit: $20 \% B_{0}$ <br> Hard Limit: $10 \% B_{0}$ |
| Status in relation to Target | Unknown |
| Status in relation to Limits | Unknown |

Historical Stock Status Trajectory and Current Status


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

| Fishery and Stock Trends |  |
| :--- | :--- |
| Recent Trend in Biomass or <br> Proxy | The sand flounder index peaked from 1990-91 to 1993-94 and then <br> declined steeply to its lowest point in 2002-03, after which it has <br> remained at that level. |
| Recent Trend in Fishing <br> Mortality or Proxy | Unknown |


| Other Abundance Indices | None |
| :--- | :--- |
| Trends in Other Relevant <br> Indicators or Variables | None |


| Projections and Prognosis |  |  |
| :--- | :--- | :---: |
| Stock Projections or Prognosis | Unknown |  |
| Probability of Current Catch or | Soft Limit: Unknown |  |
| TACC causing decline below | Hard Limit: Unknown |  |
| Limits |  |  |


| Assessment Methodology |  |  |
| :--- | :--- | :--- |
| Assessment Type | Level 2 - Partial Quantitative stock assessment |  |
| Assessment Method | Standardised CPUE based on positive catches. |  |
| Assessment Dates | Latest assessment: 2012 | Next assessment: 2015 |
| Overall assessment quality rank | 1- High Quality <br> Main data inputs (rank) | Catch and effort data |
| Data not used (rank) | N/A | 1 - High Quality |
| Changes to Model Structure and <br> Assumptions | None |  |
| Major Sources of Uncertainty | Uncertainty in the stock structure and relationship between CPUE <br> and biomass. |  |

## Qualifying Comments

Coburn et al. (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 3 (Sand flounder, New Zealand sole and lemon sole)

## Stock Structure Assumptions

Sand flounder off the East Coast of South Island appear to be a single continuous population. The stock structure of New Zealand sole and lemon sole is unknown.

| Stock Status |  |
| :--- | :--- |
| Year of Most Recent <br> Assessment | 2010 |
| Assessment Runs Presented | Standardised CPUE for all flatfish combined in FLA 3 |
| Reference Points | Target(s): Not established but $B_{\text {MSY }}$ assumed <br> Soft Limit: $20 \% B_{0}$ <br> Hard Limit: $10 \% B_{0}$ |
| Status in relation to Target | Unknown |
| Status in relation to Limits | Soft Limit: Unknown <br> Hard Limit: Unlikely ( $<40 \%$ ) to be below |

## FLATFISH (FLA)

## Historical Stock Status Trajectory and Current Status



Standardised CPUE indices based on positive catches for TOT, (all flatfish species combined) LSO (lemon sole), ESO (New Zealand sole) and SFL (sand flounder) (Bentley in press).

| Fishery and Stock Trends |  |
| :--- | :--- |
| Recent Trend in Biomass or <br> Proxy $^{7}$ | The most recent index for lemon sole is well above the long-term <br> mean, while sand flounder is near the long-term mean and New <br> Zealand sole is below it. All four indices declined between the late <br> 1990s and the mid 2000s with increases in the last few years. |
| Recent Trend in Fishing <br> Mortality or Proxy | None |
| Other Abundance Indices | None |
| Trends in Other Relevant <br> Indicators or Variables | None |

## Projections and Prognosis

Stock Projections or Prognosis $\quad$ N/A stock managed with annual in-season adjustment procedure Probability of Current Catch or TACC causing decline Soft Limit: Unknown
Hard Limit: Unknown

| Assessment Methodology |  |  |
| :--- | :--- | :--- |
| Assessment Type | Level 2 - Partial Quantitative stock assessment |  |
| Assessment Method | Standardised CPUE based on positive catches. |  |
| Assessment Dates | Latest assessment: 2010 | Next assessment: 2013 |
| Main data inputs (rank) | Catch and effort data <br> Science quality rank <br> Information not used | -1 High Quality <br> - None |
| Changes to Model Structure <br> and Assumptions | None |  |
| Major Sources of Uncertainty | Uncertainty in stock structure assumptions and the relationship <br> between CPUE and biomass. |  |

## Qualifying Comments

The lack of species specific reporting for FLA stocks limits the ability to assess these stocks.

## 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.

TACCs and reported landings are summarised in Table 6.
Table 6: Summary of yields ( $t$ ), TACCs ( $\mathbf{t}$ ), and reported landings ( $\mathbf{t}$ ) of flatfish for the most recent fishing year.

|  |  | $2010-11$ | 2010-11 |
| :--- | :--- | ---: | ---: |
| Fishstock | QMA | Actual TACC | Reported Landings |
| FLA 1 | Auckland (East) (West) $1 \& 9$ | 1187 | 486 |
| FLA 2 | Central (East) (West) 2 \& 8 | 726 | 296 |
| FLA 3 | South-East (Coast) (Chatham), 3, 4, 5, \& 6 | 1430 | 1027 |
|  | Southland and Sub-Antarctic |  |  |
| FLA 7 | Challenger 7 | 2066 | 659 |
| FLA 10 | Kermadec 10 | 10 | 0 |
|  |  |  | 2467 |

## 6. FOR FURTHER INFORMATION

Beentjes M.P. 2003. Review of flatfish catch data and species composition. New Zealand Fisheries Assessment Report 2003/17. 22 p.
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# FRESHWATER EELS (SFE, LFE, ANG) <br> (Anguilla australis, Anguilla dieffenbachii, Anguilla reinhardtii) 



## 1. FISHERY SUMMARY

### 1.1 Commercial fisheries

The freshwater eel fishery is distributed throughout the 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 2023 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. The major North Island processors have agreed not to land eels < 300 g , and not to process migratory eels. In the late 1990s, the South Island eel industry agreed to voluntarily increase the diameter of escapement tubes in fyke nets, allowing larger juvenile eels to escape and effectively increasing the minimum size limit of both main species to 280 g . A recent initiative by the North Island eel industry seeks to implement similar escapement tube measures to bring them in line with South Island fishers by October 2010. 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).

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 198889 to 2010-11 for the whole of New Zealand.

Table 1: Eel catch data ( $\mathbf{t}$ ) from for calendar years 1965 to 1988 and fishing years 1988-89 to 2010-11 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 | 1977 | 906 | $1988-89$ | 1315 | $2000-01$ | 1071 |
| 1966 | 50 | 1978 | 1583 | $1989-90$ | 1356 | $2001-02$ | 978 |
| 1967 | 140 | 1979 | 1640 | $1990-91$ | 1590 | $2002-03$ | 808 |
| 1968 | 320 | 1980 | 1395 | $1991-92$ | 1585 | $2003-04$ | 729 |
| 1969 | 450 | 1981 | 1043 | $1992-93$ | 1466 | $2004-05$ | 708 |
| 1970 | 880 | 1982 | 872 | $1993-94$ | 1255 | $2005-06$ | 771 |
| 1971 | 1450 | 1983 | 1206 | $1994-95$ | 1438 | $2006-07$ | 718 |
| 1972 | 2077 | 1984 | 1401 | $1995-96$ | 1429 | $2007-08$ | 660 |
| 1973 | 1310 | 1985 | 1505 | $1996-97$ | 1342 | $2008-09$ | 518 |
| 1974 | 860 | 1986 | 1166 | $1997-98$ | 1210 | $2009-10$ | 560 |
| 1975 | 1185 | 1987 | 1114 | $1998-99$ | 1219 | $2010-11$ | 626 |
| 1976 | 1501 | 1988 | 1281 | $1999-00$ | 1133 |  |  |

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 2010-11, as well as separate shortfin and longfin landings from 1989-90 to 2010-11. 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 200708 have ranged between 487 and 642 tonnes. For the period 1991-92 to 2010-11, the North Island provided on average $63 \%$ 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 2010-11. Numbers in parentheses represent the percentage contribution from the North Island fishery.

| Fishing year | North Island | Total individual <br> processors | LFRR/QMR/MHR Total NZ <br> (excluding Chatham Islands) |  |
| :---: | ---: | ---: | ---: | ---: |
| $1991-92$ | 989 | 865 | 631 | $1621(61 \%)$ |

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 | 1069 (42\%) |
| 1990-91 | 808 | 616 | 1424 (43\%) |
| 1991-92 | 941 | 612 | 1553 (39\%) |
| 1992-93 | 872 | 741 | 1613 (46\%) |
| 1993-94 | 692 | 588 | 1279 (46\%) |
| 1994-95 | 909 | 588 | 1497 (39\%) |
| 1995-96 | 977 | 518 | 1495 (35\%) |
| 1996-97 | 841 | 465 | 1307 (36\%) |
| 1997-98 | 881 | 442 | 1323 (33\%) |
| 1998-99 | 824 | 434 | 1258 (34\%) |
| 1999-00 | 741 | 413 | 1154 (36\%) |
| 2000-01 | 698 | 388 | 1086 (36\%) |
| 2001-02 | 660 | 360 | 1020 (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\%) |

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. Since 1989-90 there has been a gradual decrease in the proportion of longfin eels in landings.

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 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 |
| 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 |

*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 200304 to 2008-09 (based on ECLR data).

| Fishing Year | SFE1 |  | SFE2 |  | SFE4 |  | SFE8 |  | SFE9 |  | Total landings |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | TACC | Landings | TACC | Landings | TACC | Landings | TACC | Landings | TACC | Landings |  |
| 2001-02 | - | 279.2 | - | 81.8 | - | 27.7 | - | 60.9 | - | 20.8 | 470.4 |
| 2002-03 | - | 234.5 | - | 81.4 | - | 14.4 | - | 27.9 | - | 18.7 | 376.6 |
| 2003-04 | - | 251.3 | - | 52.5 | - | - | - | 11.8 | - | 14.0 | 330.0 |
| 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 |

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 2009-10. 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 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 200304 to 2010-11- (based on ECLR data).

| FishingYear | LFE1 |  | LFE2 |  | LFE4 |  | LFE8 |  | LFE9 |  | Total landings |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | TACC | Landings | TACC | Landings | TACC | Landings | TACC | Landings | TACC | Landings |  |
| 2001-02 | - | 92.3 | - | 43.5 | - | 13.6 | - | 45.0 | - | 11.3 | 470.4 |
| 2002-03 | - | 71.1 | - | 35.3 | - | 8.4 | - | 20.0 | - | 9.2 | 376.6 |
| 2003-04 | - | 79.2 | - | 12.0 | - | - | - | 13.5 | - | 7.9 | 330.0 |
| 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 |

### 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. 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 <br> Nelson/ | Nelson/ North Te Waihora Lake |  |  |  | ANG 16 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Marlborough | Canterbury | Ellesmere | South CanterburyO | Otago/Southland | 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. Data cover the periods from 2003-04 (Chatham) and 2004-05 (North Island) to 2008-09. 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 | $211(146)$ | $210(181)$ | $135(121)$ | $50(36)$ |
| Customary Non-Commercial Allowance | 3 | 30 | 24 | 14 | 6 |
| Recreational Allowance | 1 | 28 | 19 | 11 | 5 |
| Other fishing-related mortality | 1 | 2 | 4 | 2 | 2 |

Customary non-commercial fishers desire eels of a greater size, over 750 mm and 1 kg . Currently, there appears to be a substantially lower number of larger eels in the main stems of the major river catchments throughout New Zealand, which limits 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 noncommercial 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 authorization issued under fisheries regulations. Such authorizations 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. Data cover the periods from 2003-04 (Chatham) and 2004-05 (North Island) to 2008-09. 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 |  |

## $1.4 \quad$ 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. 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 in New Zealand. 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 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 world-wide, with the majority of species occurring in the IndoPacific 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 catadromous, living predominantly in freshwater and undertaking a spawning migration to an oceanic spawning ground. 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 south-west 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. Eels are presumed to spawn once and die after spawning.

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 muddy rivers, while longfins prefer fast flowing stony rivers and penetrate further inland to 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. 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 4048 cm , and for females $9-41$ years and $64-80 \mathrm{~cm}$. For longfinned eels the range in recorded age and length at migration is $11-34$ years and $48-74 \mathrm{~cm}$ for males, and 27-61 years and $75-158 \mathrm{~cm}$ for females. However because of the variable growth rates, eels of both sexes and species may migrate at younger or older ages.

## Recruitment

Glass eels enter rivers and streams around New Zealand between August and December. Regional differences in mean size and condition show 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. Differences in ages of glass eels between Australia and New Zealand indicate that glass eels arriving in New Zealand do not do so via the East Australian Current, but arrive more directly from the northwest. The recent discovery of the Antarctic Circumpolar Wave that effects how the ENSO cycles develop could also provide a further mechanism for the periodic alteration of glass eel recruitment. Rather than a fixed spawning ground, it has been suggested that the tropical spawning grounds may not be geographically fixed but associated with thermal fronts that might move.

Unlike the Northern Hemisphere, there are few glass eel data or long term data sets on elver migrations in New Zealand which could provide information on recruitment. Northern Hemisphere stocks have shown substantial declines in recruitment over recent decades. Available information on recent recruitment trends of New Zealand eels is equivocal and has focused on glass eel recruitment, elver migrations, age class structure of juvenile eels and length frequency data from commercial catch sampling. From the age composition of juvenile eels there is evidence that glass eel recruitment has declined in two North Island and three South Island waters. There is evidence from duration of runs and catch-effort data that glass eel runs are now smaller in the Waikato River than in the 1970s. 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. The density of shortfin glass eels exceeded that of longfins for any one year but the annual trends for both species were generally similar.

Table 10: Estimated numbers (1000s) of elvers trapped at elver recruitment monitoring sites by season (Dec-April) 1992-93 to 20010-11 Figures in brackets represent the \% of longfins present, whereas those in italics are incomplete records. (N/A) = sampling discontinued.

| Arnold |  |  |  |  |  |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: |
| Year | Karapiro Dam | Matahina Dam | Patea Dam Piripaua Dam | Waitaki Dam | Roxburgh Dam | - |
| River Dam |  |  |  |  |  |  |

Long-term data series on either glass eel or elver abundance is necessary to assess trends in recruitment. Therefore, current research on recruitment is aimed at establishing a time series of relative abundance of elvers at key locations in New Zealand where the upstream passage is restricted by hydro dams (Table 10 and Figure 2). The largest runs of elvers currently monitored occur at the Karapiro Dam on the Waikato River and the Matahina Dam on the Rangitaiki River. Results from the 2007-08 season showed a substantial increase in elver numbers at both sites, with total and longfin numbers exceeding all previous years of records (since 1992-93). Although the total number of elvers from the subsequent 2008-09 season was still among the highest recorded for these two sites, the number of longfin elvers decreased by approximately $50 \%$ relative to the previous year and has continued to decline.


Figure 2: Trends in total elver numbers for the Karapiro and Matahina dams, together with the number of longfin elvers, from 1992-93 to 2010-11.


Figure 2 [Continued].

## 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, south-west 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, adult eels 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. The broader provincial areas had previously been used since the 1980s to manage access under the non-QMS management framework (i.e., area conditions on fishing permits).

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 is 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.

For management purposes, this has been achieved in the Chatham Islands and North Island where separate stocks for shortfin and longfin eels were introduced into the QMS in 2003 and 2004 respectively. When eel stocks in the South Island were introduced into the QMS in 2000, there was insufficient information on the South Island species composition of the commercial catch to implement stock definitions and catch limits based on each species. However, there is sufficient science information now available to redefine the combined eel stock (ANG) into shortfin (SFE) and longfin (LFE) stocks for the quota management areas of the South Island.

## 4. STOCK ASSESSMENT

There is no formal stock assessment available for freshwater eels. Furthermore, the only data on population estimates apply to small areas and have limited application to the rest of New Zealand (Table 11). 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 ( 16000 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 WG 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.

Table 11: Estimates of fishery parameters.

| Total mortality (Z) | Estimate | Source |
| :--- | ---: | :--- |
| Lake Ellesmere shortfins | $0.1-0.3$ | Jellyman et al. (1995) |
| Lake Ellesmere longfins | 0.09 | Jellyman et al. (1995) |

### 4.1 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 from 1990-91 to 2006-07 for all North Island Eel Statistical Areas (ESAs) and to 2005-06 for all South Island ESAs (Tables 12 to 14 and Figures 3 and 4).

In the North Island, the ESAs with the largest longfin commercial catches (ESAs AA, AD, and AH) all showed declines of approximately $30-70 \%$ in CPUE indices in 2006-07 when compared to 199091, with the largest reduction occurring in ESA AH (Rangitikei-Wanganui). In ESAs AA and AD, the longfin CPUE index was relatively stable from 1990-91 to approximately 1998-99, thereafter
declining until 2001-02 and remaining stable until 2006-07, whereas the decline in ESA AH was generally more continuous over the 17 year period.

For shortfins, the North Island ESAs with the largest commercial catches (ESAs AA, AD, and AG) showed a generally increasing CPUE index for ESA AA (Auckland) over the same period, whereas those for ESA AD (Waikato) and AG (Hawke Bay) generally decreased until 2001-02 but increased thereafter. In 2006-07, the CPUE index for ESA AA was 1.5 times that estimated in 1990-91, whereas the indices for ESA AD and AG declined by $2 \%$ and $38 \%$, respectively.

Table 12: New Zealand Eel Statistical Areas (ESAs). Areas were given a numeric designation prior to Oct. 2001, at which point letter codes were assigned.


By contrast, although the main commercial longfin eel fisheries in the South Island (ESAs AX, AV, and AW) had either relatively stable or decreasing CPUE indices from 1990-91 to 2000-01 (the year eels were introduced into the QMS on the South Island), these generally increased from 2001-02 to 2005-06. Similar patterns were seen for the main shortfin eel fisheries (ESAs AX, AR, AV, AW, and AS), with the greatest increases in CPUE indices from 2000-01 to 2005-06 occurring in ESAs AX and AS.

### 4.2 Biomass estimates

Estimates of current and reference biomass for any eel fish stock are not available. Recent estimates of approximately 12000 t have been made for longfin eels (Graynoth et al. 2008, Graynoth \& Booker 2009), but these are based on limited data on density, growth and sex composition of longfin eel populations in various habitat types, including lakes and medium to large rivers.

### 4.3 Estimation of Maximum Constant Yield (MCY)

The Eel Working Group considered it inappropriate to include estimates of MCY in this report.

Table 13: CPUE indices for shortfin eels according to Eel Statistical Area (ESA). For the North Island, estimates are only available for the years prior to when the species was introduced into the QMS (2004-05). Fishing years are referred to by the second year (e.g., 1990-91 is referred to as 1991).

| ESA | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| North Island |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| AA | 0.80 | 0.75 | 0.78 | 0.72 | 0.91 | 0.97 | 0.93 | 1.13 | 1.23 | 1.27 | 1.28 | 1.02 | 1.03 | 1.07 | 1.03 | 1.14 | 1.22 |
| AB | 1.48 | 0.90 | 0.79 | 0.87 | 1.08 | 1.16 | 0.88 | 1.11 | 1.37 | 1.00 | 0.93 | 0.75 | 0.82 | 0.87 | 0.97 | 1.11 | 1.23 |
| AC | 0.99 | 0.96 | 1.14 | 1.07 | 1.11 | 1.17 | 0.83 | 0.76 | 0.79 | 0.91 | 0.87 | 1.19 | 1.01 | 1.16 | 1.07 | 1.10 | 1.02 |
| AD | 1.05 | 1.14 | 1.16 | 1.23 | 1.24 | 1.31 | 1.02 | 1.09 | 0.96 | 0.80 | 0.76 | 0.81 | 0.72 | 0.95 | 0.91 | 1.06 | 1.02 |
| AE/AF | 1.66 | 1.06 | 0.88 | 1.00 | 1.25 | 1.48 | 0.99 | 0.73 | 1.06 | 0.67 | 0.74 | 0.51 | 0.76 | 0.93 | 1.28 | 1.35 | 1.48 |
| AG | 1.53 | 1.60 | 1.51 | 1.42 | 1.47 | 1.13 | 0.89 | 0.70 | 0.97 | 0.82 | 1.10 | 0.53 | 0.59 | 0.78 | 0.83 | 1.13 | 0.95 |
| AH | 0.98 | 0.88 | 0.93 | 1.11 | 1.05 | 1.66 | 1.16 | 1.02 | 1.14 | 0.93 | 1.00 | 0.79 | 1.04 | 0.29 | 0.84 | 1.47 | 1.71 |
| AJ | 1.45 | 1.74 | 0.66 | 0.58 | 0.84 | 0.91 | 0.84 | 1.00 | 1.24 | 1.12 | 0.97 | 1.01 | 0.96 | 1.00 | 0.80 | 1.48 | 1.03 |
| AK | 3.08 | 5.13 | 2.06 | 0.68 | 0.65 | 0.51 | 0.48 | 0.69 | 0.92 | 0.69 | 0.74 | 0.87 | 0.48 | - | 1.02 | 1.30 | 1.62 |
| AL | 1.58 | - | 1.29 | 1.48 | 1.46 | 1.27 | 0.86 | 1.23 | 1.10 | 0.88 | 0.98 | 0.60 | 0.56 | 0.51 | 1.28 | 1.24 | 0.66 |
| South Island |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| AN | 0.40 | - | 1.27 | 0.31 | 0.70 | 0.58 | 0.78 | 0.60 | 0.83 | 2.42 | 2.02 | 2.86 | - | - | - | 2.84 |  |
| AP/AQ | 1.46 | 1.34 | 1.20 | 0.98 | 0.89 | 0.55 | 0.46 | 0.16 | 0.33 | 0.42 | 1.52 | 2.10 | 2.36 | 1.90 | 1.90 | 3.16 |  |
| AX | 0.84 | 0.63 | 1.03 | 0.78 | 0.83 | 0.44 | 0.44 | 1.11 | 1.37 | 1.17 | 1.12 | 1.41 | 1.15 | 1.54 | 1.69 | 1.74 |  |
| AR | 1.32 | 1.15 | 0.99 | 1.09 | 0.99 | 1.19 | 1.06 | 1.17 | 1.37 | 1.11 | - | 1.66 | 0.54 | 0.48 | 0.69 | 0.92 |  |
| AT | 1.64 | 0.91 | 0.73 | 0.77 | 0.71 | 0.99 | 0.91 | 1.40 | 0.66 | 0.94 | - | 1.31 | 1.23 | 1.32 | - | - |  |
| AU | 1.58 | 0.73 | 0.61 | 0.74 | 0.76 | 1.37 | 1.07 | 0.89 | 1.53 | 1.17 | - | - | - | 1.10 | - | - |  |
| AV | 1.54 | 1.16 | 0.88 | 0.83 | 0.87 | 0.84 | 0.87 | 0.95 | 0.60 | 1.06 | 1.23 | 0.96 | 0.99 | 1.01 | 1.28 | 1.29 |  |
| AW | 1.13 | 1.31 | 1.29 | 1.74 | 1.12 | 1.33 | 1.15 | 1.54 | 1.28 | 1.22 | 0.55 | 0.49 | 0.56 | 0.61 | 1.02 | 0.77 |  |
| AS1/ | 0.81 | 1.19 | 0.92 | 0.63 | 0.53 | 0.88 | 1.03 | 0.97 | 1.04 | 0.73 | 0.89 | 0.81 | 1.01 | 1.40 | 1.75 | 2.78 |  |

North Island

## South Island

Table 14: CPUE indices for longfin eels according to Eel Statistical Area (ESA). For the North Island, estimates are only available for the years prior to when the species was introduced into the QMS (2004-05). Fishing years are referred to by the second year (e.g., 1990-91 is referred to as 1991).

| ESA | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| North Island |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| AA | 1.30 | 1.19 | 1.25 | 1.21 | 1.21 | 1.36 | 1.05 | 1.35 | 1.50 | 1.04 | 1.04 | 0.78 | 0.67 | 0.82 | 0.65 | 0.58 | 0.71 |
| AB | 1.04 | 1.47 | 1.56 | 1.51 | 1.56 | 1.48 | 0.95 | 1.05 | 1.22 | 1.16 | 1.44 | 0.86 | 0.74 | 0.87 | 0.51 | 0.43 | 0.48 |
| AC | 2.55 | 2.31 | 2.04 | 1.04 | 1.23 | 1.15 | 1.31 | 0.93 | 0.72 | 0.94 | 0.62 | 0.80 | 0.69 | 0.60 | 0.78 | 0.72 | 0.59 |
| AD | 1.17 | 1.47 | 1.04 | 1.23 | 1.30 | 1.13 | 1.21 | 0.85 | 0.88 | 0.97 | 0.99 | 0.84 | 0.88 | 0.88 | 0.85 | 0.82 | 0.79 |
| AE/AF | 1.81 | 1.81 | 1.08 | 1.11 | 0.84 | 0.69 | 0.93 | 1.11 | 1.98 | 0.70 | 1.56 | 0.86 | 0.78 | 0.80 | 0.70 | 0.85 | 0.61 |
| AG | 1.83 | 1.76 | 1.92 | 1.86 | 1.53 | 1.44 | 0.76 | 0.91 | 1.26 | 1.13 | 1.00 | 0.58 | 0.69 | 0.46 | 0.57 | 0.60 | 0.63 |
| AH | 1.86 | 2.07 | 1.59 | 1.78 | 1.45 | 1.38 | 1.39 | 0.81 | 0.79 | 0.90 | 0.66 | 0.63 | 0.60 | 0.49 | 0.77 | 1.04 | 0.59 |
| AJ | 1.55 | 1.80 | 1.31 | 1.15 | 1.38 | 1.26 | 1.16 | 1.02 | 0.90 | 0.81 | 0.72 | 0.68 | 0.68 | 0.80 | 0.82 | 0.83 | 0.88 |
| AK | - | - | 1.44 | 1.2 | 0.99 | 0.68 | 1.08 | 1.17 | 3.32 | 0.64 | 0.93 | 0.58 | 0.42 | - | 0.33 | 0.52 | 0.64 |
| AL | 1.03 | - | 1.67 | 0.91 | 1.69 | 1.21 | 1.55 | 1.16 | 1.05 | 0.89 | 0.92 | 0.57 | 0.48 | 0.96 | 0.52 | 0.69 | 2.15 |
| South Island |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| AN | - | - | 1.46 | - | 0.94 | 0.77 | 1.0 | 0.79 | 1.02 | 0.94 | 0.60 | 1.91 | - | - | - | 1.10 | - |
| AP/AQ | 2.05 | 1.71 | 0.97 | 1.22 | 1.30 | 1.35 | 0.85 | 0.69 | 0.61 | 0.35 | 1.09 | 1.04 | 0.94 | 0.96 | 1.07 | - | - |
| AX | 1.04 | 1.07 | 0.78 | 0.84 | 1.07 | 1.04 | 0.99 | 0.99 | 1.10 | 1.36 | 1.06 | 0.86 | 0.90 | 0.91 | 1.03 | 1.10 | - |
| AR | 2.10 | 0.82 | 1.00 | 1.11 | 0.77 | 2.06 | 1.86 | 1.40 | 1.58 | 2.18 | 0.61 | 0.50 | 0.78 | 0.53 | 0.36 | 0.81 | - |
| AT | 1.97 | 0.59 | 0.80 | 1.19 | 1.00 | 0.98 | 1.14 | 0.91 | 0.94 | 1.84 | - | 0.70 | 0.72 | 1.02 | - | - | - |
| AU | 1.09 | 1.97 | 0.76 | 1.06 | 0.69 | 1.06 | 1.05 | 0.84 | 1.10 | 0.96 | - | - | - | 0.84 | - | - | - |
| AV | 1.37 | 1.19 | 1.09 | 1.28 | 0.88 | 0.81 | 0.85 | 0.92 | 0.79 | 0.86 | 0.87 | 0.94 | 0.96 | 1.01 | 1.27 | 1.14 | - |
| AW | 1.57 | 1.25 | 1.20 | 1.25 | 1.02 | 1.05 | 0.94 | 0.85 | 0.71 | 0.88 | 0.79 | 0.93 | 0.90 | 0.80 | 1.11 | 1.10 | - |
| AS1/ | 6.70 | 2.39 | 1.19 | 1.14 | 0.95 | 0.57 | 0.80 | 1.07 | 0.93 | 0.84 | 0.91 | 1.00 | 0.61 | 0.65 | 0.69 | 0.51 | - |

### 4.4 Estimation of Current Annual Yield (CAY)

In the absence of accurate current biomass estimates, this could not be estimated. Biological parameters relevant to stock assessment are given in Table 15.


Figure 3: Trends in North Island longfin (panel a) and shortfin (panel b) CPUE indices for ESAs Northland (AA), Waikato (AD), Hawke Bay (AG), and Rangitikei-Wanganui (AH) from 1990-91 to 2006-07.


Figure 4: Trends in South Island longfin (panel a) and shortfin (panel b) CPUE indices for ESAs Westland (AX), Otago (AV), Southland (AW), North Canterbury (AR) and Te Waihora (AS1 and AS2) from 1990-91 to 2005-06.

Table 15: 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 yield estimates and stock assessment results

No information is available.

### 4.6 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. Graynoth et al. (2008) estimated that, under catch levels prior to 2002, longfin spawning escapement was possibly sufficient to maintain existing depleted stocks but not sufficient for rebuilding stocks. However there is uncertainty in this assumption, even though catch limits have since been introduced and commercial catches reduced. 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 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 remaining.

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. 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/nonfished areas, with $\sim 49 \%$ of the national longfin stock estimate of $\sim 12000 \mathrm{t}$ being contained in these waterways (Graynoth et al. 2008). These estimates do not take into account habitat reductions caused by hydro development and habitat loss. If these factors are included, and based on biomass estimates from several South Island rivers, it is estimated that the biomass of longfin eels above the minimum weight at migration is less than $20 \%$ of historical values. However, the longevity and fecundities of large female eels, combined with a general lack of natural predators, means that it is possible that glass eel recruitment in the past exceeded what was needed to maintain stocks, and that eel recruitment might be maintained with only $10 \%$ of the virgin biomass (Graynoth et al. 2008). Some evidence also suggests that the survival of juvenile and adult eels is density dependent, and reductions in eel recruitment (resulting from lower spawner escapements) may consequently be compensated for by increased survival of juveniles and adults.

## 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 longfin fishery is based on immature male and female eels. A study on the Aparima River in Southland found that female longfins were rare in the catchment. Only five of 738 eels sexed were females. 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.

## 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 8) on their upriver migration. Nationally over 5 million elvers are 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. A capture and release programme has also been conducted from Lake Manapöuri to below the Mararoa Weir on the Wairau River, Southland by Waiau Mahika Kai Trust since 1998. 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.

Several projects have been undertaken to evaluate the enhancement of depleted customary fisheries through the transfer of juvenile eels. In 1997, over 2000 juvenile eels (100-200 g) were caught from Te Waihora (Lake Ellesmere), tagged and transferred to Cooper's Lagoon a few kilometres away. 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) eels weighing less than 220 g from Lake Waahi in the Waikato catchment to the Taharoa Lakes near Kawhia. No tagged eels were recovered when the lakes were surveyed in 2001. It is considered that a large number of eels migrated from the lake as males following the transfer. The conclusion from these two transfers is that transplanted 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 10000 juvenile eels were caught in the lower Clutha River, tagged and transferred to Lake Hawea. In 2001, 19.4\% of the tagged eels were recovered. An estimated $80 \%$ of transferred eels survived after three years. The transferred eels showed accelerated growth and the mean annual growth in length was almost double that of eels from the original transfer site.

## 5. STATUS OF THE STOCKS

The Eel Fishery Assessment Working Group has focused its attention in recent years on the stock status of longfin eels. This species is more susceptible to overexploitation than shortfins because of their limited geographical distribution (confined to New Zealand and offshore islands) and longevity.

## Longfin eel

The Working Group recognises that there are no stock assessments on which to base specific recommendations on longfin catch levels. Nevertheless, recruitment data, CPUE indices, and information on spawner escapement allow for a cautioned assessment to be made of longfin and shortfin stock status.

From the age composition of juvenile eels there is evidence that glass eel recruitment has declined in two North Island and three South Island waters, and there is evidence that glass eel runs are now smaller in the Waikato River than in the 1970s. Nevertheless, results from 2007-08 show that, with the exception of 1997-98, the number of longfin elvers at two of the main monitoring stations (Karapiro and Matahina dams) was the highest that has been recorded in the previous 16 years. However the total number of elvers captured in e subsequent seasons has declined

The only estimates of relative abundance are based on CPUE data. For the North Island, the ESAs with the largest longfin commercial catches (ESAs AA, AD, and AH) all showed declines of approximately $30-70 \%$ in CPUE indices from 1990-91 to 2006-07, with the largest reduction occurring in Rangitikei-Wanganui (ESA AH). By contrast, although the main commercial longfin fisheries in the South Island (ESAs AX, AV, and AW) had either relatively stable or decreasing CPUE indices from 1990-91 to 2000-01 (the year eels were introduced into the QMS on the South Island), these generally increased from 2001-02 to 2005-06.

A key component to ensuring the sustainability of eels is to maintain spawner escapement, and to that end approximately $30 \%$ of available longfin habitat in the North Island and $34 \%$ in the South Island
is either in reserves or in rarely/non-fished areas. If hydro development and habitat loss are added to these estimates, and based on biomass estimates from several South Island rivers, it is estimated that the biomass of longfin eels above the minimum weight at migration is less than $20 \%$ of historical values.

Following concerns that exploitation rates of longfin eels were unsustainable, in early 2005 three areas were closed to commercial fishing (the Mohaka, Motu and much of the Whanganui River catchments), and in 2007 management actions included reductions in TACCs and the introduction of an upper size limit for longfin (and shortfin) eels in the North Island and on Chatham Island.

## Shortfin eel

Based on available information, the Working Group does not consider that the same level of risk of unsustainable exploitation applies to shortfin eels. For example, shortfins have a wider geographic distribution than longfins, and their recruitment into New Zealand waters could be supplemented by juveniles which originate from other sources (e.g., South Australia, Tasmania, and New Caledonia stocks). Furthermore, the CPUE indices for the main commercial shortfin fisheries in the South Island (ESAs AX, AR, AV, AW, and AS) generally increased from 2001-02 to 2005-06, especially in ESAs AX (Westland) and AS (Te Waihora/Lake Ellesmere). By contrast, the North Island ESAs with the largest commercial catches (ESAs AA, AD, and AG) showed less consistent trends in CPUE indices, with ESA AA (Auckland) showing a general increase from 1990-91 to 2006-07 whereas those for ESA AD (Waikato) and AG (Hawke Bay) generally decreased until 2001-02 but increased thereafter. However, caution is required in managing shortfin stocks given the nature of their biology and the fact that they are harvested before they can spawn.

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## FROSTFISH (FRO)



## 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 are 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 2 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. Frostfish were introduced into the QMS from 1 October 1998.The TACCs for each QMA are given in Table 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 7 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 QMA 1, and rarely in QMA 2 and 9.

## FROSTFISH (FRO)

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 QMA 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 | 1283 | 226 | 1522 |
| $1979-80$ | 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 | 1545 | 1615 |
| $1983-83$ | 0 | 1 | 1 | 1 | 1 | 1 | 22 | 123 | 150 |

Table 2: Reported landings ( $t$ ) of frostfish by QMA and fishing year, 1983-84 to 2010-11. The data in this table has been updated from that published in previous Plenary Reports by using the data through 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.

| 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 |
| 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 | - | 1475 |  |
| 1984-85 | 0 | - | 214 | - | 455 | - | 129 | - | 901 |  |
| 1985-86 | 0 | - | 344 | - | 574 | - | 226 | - | 1415 |  |
| 1986-87 | 4 | - | 1089 | - | 898 | - | 190 | - | 2272 |  |
| 1987-88 | 0 | - | 3466 | - | 875 | - | 22 | - | 4391 |  |
| 1988-89 | 3 | - | 1950 | - | 413 | - | 455 | - | 2952 |  |
| 1989-90 | 29 | - | 1370 | - | 132 | - | 0 | - | 2132 |  |
| 1990-91 | 67 | - | 3029 | - | 539 | - | 0 | - | 4424 |  |
| 1991-92 | 7 | - | 2295 | - | 750 | - | 1 | - | 3582 |  |
| 1992-93 | 0 | - | 1360 | - | 1165 | - | 0 | - | 2665 |  |
| 1993-94 | 0 | - | 1998 | - | 696 | - | 12 | - | 2993 |  |
| 1994-95 | 0 | - | 3069 | - | 388 | - | 7 | - | 3740 |  |
| 1665-96 | 0 | - | 1536 | - | 22 | - | 9 | - | 1788 |  |
| 1996-97 | 0 | - | 2881 | - | 126 | - | 93 | - | 3328 |  |
| 1997-98 | 0 | - | 2590 | - | 143 | - | 205 | - | 3564 | - |
| 1998-99 | 0 | 11 | 2461 | 2623 | 156 | 649 | 33 | 138 | 2989 | 3858 |
| 1999-00 | <1 | 11 | 917 | 2623 | 28 | 649 | 48 | 138 | 1392 | 3858 |

Table 2 continued:

|  | FRO 6 |  | FRO 7 |  |
| :---: | :---: | :---: | :---: | :---: |
|  |  | 6 |  | 7 |
| 2000-01 | <1 | 11 | 1620 | 2623 |
| 2001-02 | <1 | 11 | 2303 | 2623 |
| 2002-03 | <1 | 11 | 1025 | 2623 |
| 2003-04 | <1 | 11 | 959 | 2623 |
| 2004-05 | $<1$ | 11 | 934 | 2623 |
| 2005-06 | <1 | 11 | 888 | 2623 |
| 2006-07 | $<1$ | 11 | 951 | 2623 |
| 2007-08 | <1 | 11 | 906 | 2623 |
| 2008-09 | <1 | 11 | 576 | 2623 |
| 2009-10 | <1 | 11 | 382 | 2623 |
| 2010-11 | <1 | 11 | 248 | 2623 |


|  | FRO 8 |
| ---: | ---: |
| 8 |  |
| 303 | 649 |
| 138 | 649 |
| 621 | 649 |
| 293 | 649 |
| 770 | 649 |
| 787 | 649 |
| 722 | 649 |
| 678 | 649 |
| 605 | 649 |
| 686 | 649 |
| 578 | 649 |


| FRO 9 |  |  |  |
| :---: | :---: | :---: | :---: |
|  | 9 |  | Total |
| 43 | 138 | 2424 | 3858 |
| 25 | 138 | 2913 | 3858 |
| 67 | 138 | 2252 | 3858 |
| 367 | 138 | 1809 | 3858 |
| 327 | 138 | 2661 | 3858 |
| 181 | 138 | 2119 | 3858 |
| 142 | 138 | 1972 | 4019 |
| 136 | 138 | 1837 | 4019 |
| 110 | 138 | 1369 | 4019 |
| 238 | 138 | 1389 | 4019 |
| 167 | 138 | 1106 | 4019 |






Figure 1: Historical landings and TACC for the eight main FRO stocks. From top left: FRO1 (Auckland East), FRO2 (Central East), FRO3 (South East Coast), and FRO4 (South East Chatham Rise). [Continued on next page]...


Figure 1 [Continued]: Historical landings and TACC for the eight main FRO stocks. From top left to bottom right: FRO5 (Southland), FRO7 (Challenger), FRO8 (Central West), and FRO9 (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 $34^{\circ} \mathrm{S}$ to $49^{\circ} \mathrm{S}$, but are most common between $36^{\circ} \mathrm{S}$ and $44^{\circ} \mathrm{S}$. 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 $10-16^{\circ} \mathrm{C}$.

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 was calculated to take place between noon and sunset at depths greater than 50 m where the surface waters have a temperature of 17.5 to $22.0^{\circ} \mathrm{C}$ (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 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, 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: (QMA 1 and 2); FRO 3: (QMA 3 and 4); FRO 5: (QMA 5 and 6) and FRO 7: (QMA 7, 8, and 9). There have been no reported landings from QMA 10. TACs were set for each QMA (1-9) in 1998 and are 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.

## FROSTFISH (FRO)

### 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 3). 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 3: Doorspread biomass indices (t) and CVs (\%) of frostfish from random stratified trawl surveys 1981-97.

| Vessel | Trip Code | Depth <br> Range (m) | Biomass index (t) | $\begin{gathered} \text { CV } \\ \text { (\%) } \end{gathered}$ | 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 | 1079 | 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 | 2173 | 22 | December 1980 - January 1981 |
| Shinkai Maru | SHI8102 | 20-300 | 6638 | 12 | October/November 1981 |
| Cordella | COR9001 | 25-300 | 2189 | 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 |
| WCSI south of $41^{0} 30$, |  |  |  |  |  |
| 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 Estimation of maximum constant yield (MCY)

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.

### 4.4 Estimation of Current Annual Yield (CAY)

There are no reliable data on current biomass; CAY was therefore not estimated.

### 4.5 Other yield estimates and stock assessment results

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 2010-11 fishing year are summarised in Table 4.

## Table 4: Summary of TACCs ( $t$ ), and reported landings ( $t$ ) of frostfish for the most recent fishing year.

|  |  | QMA | 2010-11 | Actual TACC |
| :--- | ---: | ---: | ---: | ---: |$\quad$| Reported landings |  |
| ---: | :--- |
| Fishstock | Auckland (East) |

## 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 (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 | 5 |
| GAR 8 | 8 | 4 | 5 | 23 |
| GAR 10 | 0 | 0 | 0 | 17 |

### 1.1 Commercial fisheries

Garfish landings were first recorded in 1933, and a minor fishery must have existed before this. 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.

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 2010-11*. Prior to 2001-02 the catches or landings ( $\mathbf{t}$ ) 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 $\dagger$ | 31 | - | <1 | - | 2 | - | - | - |
| 1991-92† | 22 | - | <1 | - | 1 | - | - | - |
| 1992-93 $\dagger$ | 14 | - | <1 | - | 1 | - | - | - |
| 1993-94 $\dagger$ | 23 | - | 0 | - | 2 | - | - | - |
| 1994-95 $\dagger$ | 17 | - | $<1$ | - | $<1$ | - | - | - |
| 1995-96 $\dagger$ | 15 | - | <1 | - | 1 | - | - | - |
| 1996-97† | 15 | - | $<1$ | - | 1 | - | - | - |
| 1997-98† | 21 | - | $<1$ | - | $<1$ | - | - | - |
| 1998-99 $\dagger$ | 19 | - | $<1$ | - | <1 | - | - | - |
| 1999-00† | 17 | - | <1 | - | <1 | - | - | - |
| 2000-01 $\dagger$ | 11 | - | 0 | - | $<1$ | - | - | - |
| 2001-02† | 8 | 25 | 0 | 5 | $<1$ | 5 | 0 | 2 |
| 2002-03 $\dagger$ | 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 $\dagger$ | 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 $\dagger$ | 10 | 25 | 0 | 5 | 0 | 5 | 0 | 2 |
| 2009-10† | 9 | 25 | 0 | 5 | 0 | 5 | 0 | 2 |
| 2010-11 $\dagger$ | 11 | 25 | 0 | 5 | <1 | 5 | 0 | 2 |
| Fishstock |  | GAR 7 |  | GAR 8 |  | GAR 10 |  |  |
| FMA (s) |  | 7 |  | 8\&9 |  | 10 |  | Total |
|  | Landings | TACC | Landings | TACC | Landings | TACC | Landings ${ }^{\text {\# }}$ | TACC |
| 1990-91 $\dagger$ | 4 | - | 1 | - | 0 | - | 38 |  |
| 1991-92 $\dagger$ | 6 | - | 0 | - | 0 | - | 29 | - |
| 1992-93 $\dagger$ | 2 | - | 2 | - | 0 | - | 18 | - |
| 1993-94 $\dagger$ | 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 $\dagger$ | 2 | - | 0 | - | 0 | - | 13 | - |
| 2001-02† | 3 | 8 | 0 | 5 | 0 | 0 | 11 | 50 |
| 2002-03 $\dagger$ | <1 | 8 | 0 | 5 | 0 | 0 | 6 | 50 |
| 2003-04 $\dagger$ | 1 | 8 | <1 | 5 | 0 | 0 | 12 | 50 |
| 2004-05† | 0 | 8 | <1 | 5 | 0 | 0 | 13 | 50 |
| 2005-06† $\dagger$ | 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 $\dagger$ | 1 | 8 | 0 | 5 | 0 | 0 | 11 | 50 |
| 2009-10† | 3 | 8 | 0 | 5 | 0 | 0 | 12 | 50 |
| 2010-11 $\dagger$ | 1 | 8 | 0 | 5 | 0 | 0 | 13 | 50 |

### 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-eye 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 $20-30 \mathrm{~cm}$.

Garfish feed on zooplankton. They form single-species schools, but occur in close proximity with other small pelagic fishes in shallow coastal waters, particularly yelloweye 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 where 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 ( $B_{0}, B_{\text {MSY }}$, or $B_{\text {current }}$ ) are available.

### 4.3 Estimation of Maximum Constant Yield (MCY)

$M C Y$ cannot be determined.

### 4.4 Estimation of Current Annual Yield (CAY)

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

### 4.5 Other yield estimates and stock assessment results <br> No information is available.

### 4.6 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.

|  |  |  | $2010-11$ <br> Actual | 2010-11 <br> Reported |  |
| :--- | :--- | :--- | ---: | ---: | ---: |
| Fishstock | FMA |  | estimates | TACC | landings |
| GAR 1 | Auckland (East) | 1 | - | 25 | 11 |
| GAR 2 | Central (East) | 2 | - | 5 | 0 |
| GAR 3 | South East (Coast), Southland, Sub-antarctic | $3,5,6$ | - | 5 | $<1$ |
| GAR 4 | South East (Chatham) | 4 | - | 2 | 0 |
| GAR 7 | Challenger | 7 | - | 8 | 1 |
| GAR 8 | Auckland (West), Central (West) | 8,9 | - | 5 | 0 |
| GAR 10 | Kermadec | 10 | - | 0 | 0 |
|  |  |  | - | 50 | 13 |

## GARFISH (GAR)

## 6. FOR FURTHER INFORMATION

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## GEMFISH (SKI)



## 1. FISHERY SUMMARY

### 1.1 Commercial fisheries

Gemfish are caught in coastal waters around mainland New Zealand down to about 550 m. 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 |  |
| :--- | ---: | ---: |
| Year | Domestic | Chartered |
| 1978-79* | 352 | 53 |
| $1979-80^{*}$ | 423 | 1174 |
| $1980-81^{*}$ | 1050 | N/A |
| $1981-82^{*}$ | 1223 | 1845 |
| $1982-83^{*}$ | 822 | 1368 |
| $1983-83^{\dagger}$ | 1617 | 1799 |
| $1983-84^{\ddagger}$ | 1982 | 3532 |
| $1984-85^{\ddagger}$ | 1360 | 2993 |
| $1985-86^{\ddagger}$ | 1696 | 4056 |
| $1986-87^{\ddagger}$ | 1603 | 2277 |
| $1987-88^{\ddagger}$ | 1016 | 2331 |

[^14]| Foreign Licensed |  |  |  |
| ---: | ---: | ---: | ---: |
| Japan | Korea | USSR | Total |
| 1509 | 1079 | 0 | 2993 |
| 1036 | 78 | 60 | 2771 |
| N/A | N/A | N/A | $>1050$ |
| 391 | 16 | 0 | 3475 |
| 274 | 567 | 0 | 3031 |
| 57 | 37 | 0 | 3510 |
| 819 | 305 | 0 | 6638 |
| 470 | 223 | 0 | 5046 |
| 2059 | 442 | 0 | 8253 |
| 269 | 76 | 0 | $4225 \S$ |
| 90 | 35 | 0 | $3472 \S$ |

[^15]
## GEMFISH (SKI)

Table 2: Reported landings ( $\mathbf{t}$ ) of gemfish by Fishstock from 1983-84 to 2010-11 and actual TACs from 1986-87.

| Fishstock QMA (s) | $\begin{aligned} & \text { SKI } 1 \\ & 1 \& 9 \\ & \hline \end{aligned}$ |  | $\begin{array}{r} \text { SKI } 2 \\ 2 \\ \hline \end{array}$ |  | SKI 3 |  | $\begin{aligned} & \text { SKI } 7 \\ & 7 \& 8 \\ & \hline \end{aligned}$ |  | $\begin{array}{r} \text { SKI } 10 \\ \quad 10 \\ \hline \end{array}$ | Total |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | 5, \& 6 |  |  |  |  |  |
|  | Landings | TAC |  |  | Landings | TAC | Landings | TAC | Landings | TAC | TAC | Landings | TAC |
| 1983-84* | 588 | - | 632 | - | 3481 | - | 1741 | - | $\dagger$ | 6442 § | - |
| 1984-85* | 388 | - | 381 | - | 2533 | - | 1491 | - | $\dagger$ | 4793 § | - |
| 1985-86* | 716 | - | 381 | - | 5446 | - | 1468 | - | $\dagger$ | 8011 § | - |
| 1986-87 | 773 | 550 | 896 | 860 | 2045 | 2840 | 1069 | 1490 | $\dagger 10$ | 4783 | 5750 |
| 1987-88 | 696 | 632 | 1095 | 954 | 1664 | 2852 | 1073 | 1543 | $\dagger 10$ | 4528 | 5991 |
| 1988-89 | 1023 | 1139 | 1011 | 1179 | 1126 | 2922 | 1083 | 1577 | $\dagger 10$ | 4243 | 6827 |
| 1989-90 | 1230 | 1152 | 1043 | 1188 | 1164 | 3259 | 932 | 1609 | $\dagger 10$ | 4369 | 7218 |
| 1990-91 | 1058 | 1152 | 949 | 1188 | 616 | 3339 | 325 | 1653 | $\dagger 10$ | 2948 | 7342 |
| 1991-92 | 1017 | 1152 | 1208 | 1197 | 287 | 3339 | 584 | 1653 | $\dagger 10$ | 3096 | 7350 |
| 1992-93 | 1292 | 1152 | 1020 | 1230 | 371 | 3345 | 469 | 1663 | †10 | 3152 | 7401 |
| 1993-94 | 1156 | 1152 | 1058 | 1300 | 75 | 3345 | 321 | 1663 | $\dagger 10$ | 2616 | 7470 |
| 1994-95 | 1032 | 1152 | 905 | 1300 | 160 | 3355 | 103 | 1663 | $\dagger 10$ | 2169 | 7480 |
| 1995-96 | 801 | 1152 | 789 | 1300 | 49 | 3355 | 81 | 1663 | $\dagger 10$ | 1720 | 7480 |
| 1996-97 | 965 | 1152 | 978 | 1300 | 58 | 1500 | 238 | 900 | $\dagger 10$ | 2240 | 4862 |
| 1997-98 | 627 | 752 | 671 | 849 | 27 | 300 | 44 | 300 | $\dagger 10$ | 1369 | 2211 |
| 1998-99 | 413 | 460 | 336 | 520 | 17 | 300 | 59 | 300 | $\dagger 10$ | 825 | 1590 |
| 1999-00 | 409 | 460 | 506 | 520 | 62 | 300 | 107 | 300 | $\dagger 10$ | 1083 | 1590 |
| 2000-01 | 335 | 460 | 330 | 520 | 47 | 300 | 87 | 300 | $\dagger 10$ | 799 | 1590 |
| 2001-02 | 201 | 210 | 268 | 240 | 72 | 300 | 123 | 300 | $\dagger 10$ | 664 | 1060 |
| 2002-03 | 206 | 210 | 313 | 240 | 115 | 300 | 268 | 300 | $\dagger 10$ | 902 | 1060 |
| 2003-04 | 221 | 210 | 301 | 240 | 78 | 300 | 542 | 300 | $\dagger 10$ | 1142 | 1060 |
| 2004-05 | 234 | 210 | 259 | 240 | 72 | 300 | 635 | 300 | $\dagger 10$ | 1199 | 1060 |
| 2005-06 | 230 | 210 | 182 | 240 | 27 | 300 | 248 | 300 | $\dagger 10$ | 687 | 1060 |
| 2006-07 | 215 | 210 | 317 | 240 | 26 | 300 | 209 | 300 | $\dagger 10$ | 767 | 1060 |
| 2007-08 | 216 | 210 | 249 | 240 | 18 | 300 | 179 | 300 | $\dagger 10$ | 662 | 1060 |
| 2008-09 | 191 | 210 | 191 | 240 | 11 | 300 | 213 | 300 | $\dagger 10$ | 606 | 1060 |
| 2009-10 | 247 | 210 | 176 | 240 | 20 | 300 | 144 | 300 | $\dagger 10$ | 587 | 1060 |
| 2010-11 | 226 | 210 | 300 | 240 | 33 | 300 | 301 | 300 | $\dagger 10$ | 860 | 1060 |

* 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).
$\dagger$ No recorded landings
Table 3: Catch history for gemfish stocks, divided into pre-spawning and spawning seasons (t). N/A - not available.

| Year | SKI 1 (spawn) |  |  | SKI 2 <br> (pre- | Total SKI 1 \& | Year | SKI 1 (spawn) |  |  | SKI 2 <br> (pre- | Total SKI 1 \& |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | SKI | SKI | Total |  |  |  | SKI | SKI | Total |  |  |
|  | 1E | 1W |  | spawn) | 2 |  | 1E | 1W |  | spawn) | 2 |
| 1952 | 5 | 0 | 5 | 50 | 55 | 1981 | 120 | 0 | 120 | 500 | 620 |
| 1953 | 5 | 0 | 5 | 25 | 30 | 1982 | 100 | 0 | 100 | 320 | 420 |
| 1954 | 5 | 0 | 5 | 60 | 65 | 1983 | 360 | 0 | 360 | 730 | 1090 |
| 1955 | 5 | 0 | 5 | 35 | 40 | 1984 | 588 | 0 | 588 | 632 | 1220 |
| 1956 | 5 | 0 | 5 | 35 | 40 | 1985 | 388 | 0 | 388 | 381 | 769 |
| 1957 | 5 | 0 | 5 | 55 | 60 | 1986 | 716 | 0 | 716 | 381 | 1097 |
| 1958 | 5 | 0 | 5 | 30 | 35 | 1987 | 773 | 0 | 773 | 896 | 1669 |
| 1959 | 5 | 0 | 5 | 45 | 50 | 1988 | 696 | 0 | 696 | 1095 | 1791 |
| 1960 | 5 | 0 | 5 | 85 | 90 | 1989 | 1023 | 0 | 1023 | 1011 | 2034 |
| 1961 | 5 | 0 | 5 | 70 | 75 | 1990 | 1230 | 0 | 1230 | 1043 | 2273 |
| 1962 | 5 | 0 | 5 | 60 | 65 | 1991 | 1048 | 10 | 1058 | 949 | 2007 |
| 1963 | 15 | 0 | 15 | 70 | 85 | 1992 | 940 | 77 | 1017 | 1208 | 2225 |
| 1964 | 15 | 0 | 15 | 65 | 80 | 1993 | 1137 | 155 | 1292 | 1020 | 2312 |
| 1965 | 20 | 0 | 20 | 130 | 150 | 1994 | 606 | 550 | 1156 | 1058 | 2214 |
| 1966 | 15 | 0 | 15 | 140 | 155 | 1995 | 438 | 594 | 1032 | 906 | 1938 |
| 1967 | 35 | 0 | 35 | 240 | 275 | 1996 | 485 | 316 | 801 | 789 | 1590 |
| 1968 | 40 | 0 | 40 | 250 | 290 | 1997 | 385 | 580 | 965 | 978 | 1943 |
| 1969 | 100 | 0 | 100 | 375 | 475 | 1998 | N/A | N/A | 627 | 671 | 1298 |
| 1970 | 95 | 0 | 95 | 400 | 495 | 1999 | N/A | N/A | 413 | 335 | 748 |
| 1971 | 100 | 0 | 100 | 420 | 520 | 2000 | N/A | N/A | 409 | 506 | 915 |
| 1972 | 130 | 0 | 130 | 400 | 530 | 2001 | N/A | N/A | 335 | 330 | 665 |
| 1973 | 45 | 0 | 45 | 300 | 345 | 2002 | N/A | N/A | 201 | 268 | 487 |
| 1974 | 35 | 0 | 35 | 230 | 265 | 2003 | N/A | N/A | 206 | 313 | 519 |
| 1975 | 10 | 0 | 10 | 170 | 180 | 2004 | N/A | N/A | 221 | 301 | 522 |
| 1976 | 30 | 0 | 30 | 190 | 220 | 2005 | N/A | N/A | 234 | 259 | 493 |
| 1978 | 90 | 0 | 90 | 240 | 330 | 2006 | N/A | N/A | 230 | 182 | 412 |
| 1979 | 120 | 0 | 120 | 200 | 320 | 2007 | N/A | N/A | 215 | 317 | 532 |
| 1980 | 140 | 0 | 140 | 450 | 590 |  |  |  |  |  |  |



Figure 1: Historical landings and TACC for the four main SKI stocks. From top left to bottom right: SKI1 (Auckland East), SKI2 (Central East), SKI3 (South East Coast), and SKI7 (Challenger). Note that these figures do not show data prior to entry into the QMS.

Most of the recorded catch is taken by trawlers. Target fisheries developed off the eastern and northern coasts of the North Island. From 1993 to 2000 there was a major shift in effort from east of North Cape to the west, and over $50 \%$ of the SKI 1 catch was taken from QMA 9 in some years. However, the distribution of fishing changed substantially after 2001 when the quota was last reduced and the west coast became less important. In the last 4 years there has been even more concentration in the Bay of Plenty area and no WCNI fishing at all. Catches off the west and southern coasts of the South Island are primarily bycatch of hoki and squid target fisheries. The reported landings in SKI 7 increased from 2000, with 2005 being more than double the level of the TACC in 2004-05, but decreased until 2007-08. Landings in SKI 3 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. Reported gemfish catch in the North region recreational survey December 1993 to November 1994 was negligible (i.e., 3 fish) and scaled up to about 1 t. Gemfish harvest estimates from the 1996 national recreational survey were 5000 fish

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from SKI $1 \& 2$ and less than 500 fish from SKI 7.

### 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.

## $1.4 \quad$ 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 probably undertake spawning migrations and pre-spawning runs form 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 was 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 4.
Table 4: Estimates of biological parameters for gemfish.

Fishstock Estimate Source

1. Natural mortality ( $M$ )

All stocks $\quad M=0.25 \mathrm{y}^{-1}$ considered best estimate for all areas for both sexes
2. Weight $=\mathrm{a}$ (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 |  |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | :---: |
|  | $L_{\infty}$ | $k$ | $t_{0}$ |  | $L_{\infty}$ | $k$ | $t_{0}$ |  |
| East Northland | 90.7 | 0.204 | -0.49 |  | 122.7 | 0.114 | -1.1 |  |
| East Northland | 88.4 | 0.235 | -0.54 |  | 108.5 | 0.167 | -0.71 |  |
| Wairarapa | 90.8 | 0.287 | 0.00 |  | 103.4 | 0.231 | -0.1 |  |
| West Northland | 86.3 | 0.295 | -0.11 |  | 103.4 | 0.209 | -0.37 |  |
| North combined | 87.4 | 0.266 | -0.35 |  | 105 | 0.194 | -0.55 |  |
| Southland | 88.5 | 0.242 | -0.66 |  | 104.2 | 0.178 | -0.88 |  |

## 3. STOCKS AND AREAS

In previous assessments, analysis of seasonal trends in gemfish fisheries indicated that there may be at least 2 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 and 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 3. This table also shows the split between east and west coast catches in SKI 1 from 1991 to 1997.

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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: (1) target catch only; (2) all gemfish catch; and (3) all gemfish catch on TCEPR forms (Figure 2 \& 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 5). 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 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 3 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 to use the CPUE indices from each fishery in the stock assessment based on TCEPR data including all SKI catch (Table 5).

Table 5: Standardised catch per unit effort indices and coefficient of variation (CV) for SKI 1 and SKI 2.

|  |  | SKI 1 |  | SKI 2 |
| :--- | ---: | ---: | ---: | ---: |
| Year | Index | CV | Index | CV |
| 1990 | 1.94 | 0.10 | - | - |
| 1991 | 1.71 | 0.12 | - | - |
| 1992 | 1.36 | 0.10 | - | - |
| 1993 | 1.48 | 0.07 | - | - |
| 1994 | 1.73 | 0.06 | 2.09 | 0.13 |
| 1995 | 1.65 | 0.07 | 1.68 | 0.09 |
| 1996 | 1.05 | 0.06 | 1.17 | 0.07 |
| 1997 | 1.20 | 0.06 | 0.91 | 0.06 |
| 1998 | 0.86 | 0.06 | 0.63 | 0.06 |
| 1999 | 0.68 | 0.07 | 0.92 | 0.09 |
| 2000 | 0.66 | 0.07 | 0.88 | 0.07 |
| 2001 | 0.56 | 0.08 | 0.70 | 0.07 |



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: Standardised CPUE indices for the three fishery subgroups in SKI 2: "target catch", black solid; "all catch", black dotted; "TCEPR all catch", gray solid. Vertical bars represent $\mathbf{9 5 \%}$ confidence interval.

### 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 6). 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.

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Table 6: 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 after the fishing mortality.

| Step | Period |  |  | Observations |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | 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. | rtion of na | tality that was assum | ve occ |  |  |
| 2. | centage of | al mortality within e | step | ave taken place at the time e | ch ob | 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 $0.25 \mathrm{y}^{-1}$ 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 $2006_{\text {YCS2000 }}$, see Table 8).

Year class strengths were assumed known (and equal to one) for years prior to 1978 and after 2000 (run $2006_{\text {YCS2000, }}$, see Table 8) 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 7. All priors were intended to be relatively uninformed, and were estimated with wide bounds.

Table 7: The assumed priors assumed for key distributions (when estimated). The parameters are mean (in natural space) and CV for lognormal.
Parameter description
$B_{0}$
SKI 1 CPUE $q$
SKI 2 CPUE $q$
YCS
Selectivity
Maturation
Difference in $M$
Process error CV .

| Distribution | Parameters |  |  | Bounds |
| :---: | ---: | ---: | ---: | ---: | ---: |
|  | Mean | CV | Lower | Upper |
| uniform-log | - | - | 2500 | 250000 |
| uniform-log | - | - | $1 \times 10^{-7}$ | 0.01 |
| uniform-log | - | - | $1 \times 10^{-7}$ | 0.01 |
| lognormal | 1 | 0.9 | 0.01 | 10.0 |
| uniform | - | - | 0.1 | 80.0 |
| uniform | - | - | 1.3 | 10.0 |
| uniform | - | - | 0 | 0.5 |
| uniform | - | - | $1 e^{-3}$ | 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 $10000^{\text {th }}$ 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 " $2006_{\text {YCS2000" }}$ used data up to 2006 and estimated year class strengths from 1978 to 2000; run " $2006_{\text {YCS2001 }}$ " used the same data but estimated the year class strengths from 1978 to 2001 ; run " $2007_{\text {YCS2003 }}$ " incorporated data up to 2007, with year class strengths estimated from 1978 to 2003. Table 8 describes the three model runs.

Table 8: Model run labels and descriptions for the base case and sensitivity model runs.

| Model run | Description |
| :--- | :--- |
| $2006_{\text {YCS2000 }}$ | Fitting to catch-at-age up to 2006, and CPUE indices based on TCEPR to 2001, and estimating YCSs 1978-00, <br> using an average natural mortality of $0.25 \mathrm{yr}^{-1}$ and separate age-based logistic fishing selectivities for SKI 2 fisheries |
|  | before and after 2001. |
| $2006{ }_{\text {YCS2001 }}$ | $2006_{\text {YCS2000, but estimated YCS from 1978-2001, }}$ <br> $2007_{\text {YCS2003 }}$ |
| $2006_{\text {YCS2000, but included 2007 SKI } 1 \text { and } 2 \text { catch and 2007 SKI } 2 \text { catch-at-age, and estimated YCSs 1978-2003. }}$ |  |

For each model run, MPD fits were obtained and qualitatively evaluated. MPD estimates of biomass trajectories are shown in Figure 3. MCMC estimates of the posterior median and $95 \%$ percentile credible intervals for current and virgin biomass are reported in Table 9, and for year class strengths are shown in Figure 4.

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

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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 $2006_{\text {ycs2001 }}$, the 2001 year class strength was estimated to be weak. For run $2007_{\text {YCS2003 }}$, 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 9).

The effect of using a lower and higher value of natural mortality was investigated for run $2007_{\text {YCS2003 }}$ : 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.

Table 9: Bayesian median and $95 \%$ credible intervals of $B_{0}, B_{\text {current }}$, and $B_{\text {current }}$ as a percentage of $B_{0}$ for the three model runs. $B_{\text {current }}$ refers to $B_{2006}$ for run $2006_{Y C S 2000}$ and $2006_{Y C S 2001}$, and $B_{2007}$ for run $2007{ }_{Y C S 2003}$;

| Model run | $B_{0}$ | $B_{\text {current }}$ | $B_{\text {current }}\left(\% B_{0}\right)$ |
| :--- | ---: | ---: | ---: |
| $2006_{\text {YCS2000 }}$ | $12672(11398-14709)$ | $4007(2759-5766)$ | $32(24-40)$ |
| $2006_{\text {YCS2001 }}$ | $11691(10636-13283)$ | $3008(2024-4593)$ | $26(19-35)$ |
| $2007_{\text {YCS2003 }}$ | $10900(9853-12403)$ | $2443(1448-3924)$ | $22(15-32)$ |



Figure 4: MPD biomass trajectories for the three model runs: $2006_{\text {YCS2000 }}, 2006_{Y C S 2001}$, and $2007_{Y C S 2003}$.


Figure 5: Bayesian median of year class strength for the three model runs $\mathbf{2 0 0 6}_{\text {YCS2000, }} \mathbf{2 0 0 6}_{\text {YCS2001 }}$, and 2007 $7_{\text {YCS2003 }}$. Dotted lines are the $\mathbf{9 5 \%}$ credible intervals for run $\mathbf{2 0 0 7}_{\text {YCS2003 }}$.

### 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.

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The additional year class strengths estimated for run $2007_{\text {YCS2003 }}$ 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 Estimation of Maximum Constant Yield (MCY) and Current Annual Yield (CAY)

$M C Y$ 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. 2005). 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 $B_{\text {MAY }}$ (Table 10).

Table 10: 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 | $B_{M C Y}(\mathrm{t})$ | $B_{M C Y}\left(\% B_{0}\right)$ | $M C Y(\mathrm{t})$ | $B_{M A Y}(\mathrm{t})$ | $B_{M A Y}\left(\% B_{0}\right)$ | $M A Y(\mathrm{t})$ | $C A Y(\mathrm{t})$ |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| $2006_{Y C S 2000}$ | 6698 | 53 | 995 | 4117 | 32 | 1404 | 1305 |
| $2006_{Y C S 2001}$ | 6304 | 54 | 865 | 3934 | 34 | 1270 | 925 |
| $2007_{Y C S 2003}$ | 5928 | 48 | 816 | 3676 | 34 | 1194 | 755 |

### 4.1.7 Projections

The projections were estimated for five years under four scenarios (two alternative recruitment assumptions ands 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 $2006_{\text {Ycs2000, }} 1992$ to 2001 for run $2006_{\text {YCS2001 }}$, and 1992 to 2003 for run $2007_{\text {YCS2003 }}$ ). Future catches were set equal to the current TACC or the estimated CAY (see Table 10).

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 11).

Table 11: Bayesian median and $95 \%$ credible intervals of projected biomass $B_{P R O J}, B_{P R O J}$ as a percentage of $B_{0}$, and $B_{\text {PROJ }} / B_{\text {CURRENT }}(\%)$ for the three model runs where future catches were fixed at either TAC or estimated $C A Y$, and future recruitments were randomly sampled from the long period or from the recent period. $B_{P R O J}$ and $B_{\text {CURRENT }}$ refer to $B_{2011}$ and $B_{2006}$ for run $2006_{Y C S 2000}$ and $2006_{Y C S 2001}$, and $B_{2012}$ and $B_{2006}$ for run $2007_{\text {YCS2003 }}$;

| Model run | Catch (t) | Recruitment | $B_{\text {PROJ }}$ | $B_{\text {PROJ }}\left(\% B_{0}\right)$ | $B_{\text {PROJ }} / B_{\text {CURRENT }}(\%)$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
| $2006{ }_{\text {YCS2000 }}$ | 450 | 1978-2000 | 6060 (3 242-12 075) | 47 (27-92) | 151 (94-264) |
|  | 450 | 1992-2000 | 3815 (2 128-6 071) | 30 (18-44) | 98 (74-122) |
|  | 1305 | 1978-2000 | 3472 (595-8 535) | 27 (5-65) | 85 (17-200) |
|  | 1305 | 1992-2000 | 1195 (135-3 414) | 9 (1-24) | 31 (5-66) |
| $2006{ }_{\text {YCS2001 }}$ | 450 | 1978-2001 | 4263 (2 010-8 844) | 36 (18-74) | 140 (76-286) |
|  | 450 | 1992-2001 | 2436 (1 257-4 136) | 21 (11-32) | 81 (57-107) |
|  | 1305 | 1978-2001 | 2809 (630-7 744) | 23 (6-64) | 91 (24-235) |
|  | 1305 | 1992-2001 | 999 (100-2 863) | 9 (1-22) | 34 (5-68) |
| $2007{ }_{\text {YCS2003 }}$ | 450 | 1978-2003 | 3580 (1 531-6 990) | 33 (15-62) | 139 (82-280) |
|  | 450 | 1992-2003 | 2361 ( 1 019-4 509) | 21 (10-38) | 96 (62-137) |
|  | 755 | 1978-2003 | 2497 (692-6 200) | 23 (7-54) | 99 (36-233) |
|  | 755 | 1992-2003 | 1476 (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 12. 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 13.


Figure 6: 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.

## GEMFISH (SKI)

Table 12: 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 | 3900 | 17 |
|  |  |  | SHI8201 | Mar-Apr 1982 | 3100 | 31 |
|  |  |  | SHI8303 | Apr 1983 | 5500 | 33 |
| SKI 3 | Southland |  |  |  |  |  |
|  |  |  | Tangaroa | TAN9301 | Feb-Mar 1993 | 1066 |
|  |  | Feb-Mar 1994 | 17 |  |  |  |
|  |  |  | TAN9502 | Feb-Mar 1995 | 406 | 18 |
|  |  |  | TAN9604 | Feb-Mar 1996 | 539 | 25 |
|  |  |  |  |  |  |  |

Table 13: 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 $\left(r_{M A X}\right)$ pre-spawning, | $0.6,0.8$ |
| spawning | 0.1 |
| Minimum exploitation with maximum catch $\left(r_{M M X}\right)$ | $0.1,0.4,0.81 .0$ |

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 14. These year class strengths were poorly estimated and should be considered as indicative of poor and strong year classes only.

Table 14: 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 $r_{M M X}$ and $r_{M A X}$ were reported. $B_{0}$ ranged from 26 000 to 73000 t, $B_{\text {MID97 }}$ from 0 to $63 \%$, and $B_{\text {BEG98 }}$ from 200 to 51400 t (see also Figure 1 in the 1997 Plenary Report).

### 4.2.3 Estimation of Maximum Constant Yield (MCY)

Details of the modelling procedure which produced the $\mathrm{B}_{0}$ estimates from which $M C Y$ was estimated for SKI 3 \& 7 are given above. The $M C Y$ ranges from 990 to 2770 t. MIAEL point estimates were not reported due to the low value of the performance indices.

### 4.2.4 Estimation of Current Annual Yield (CAY)

Details of the modelling procedure which produced the $B_{\text {beg98 }}$ 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


MPD biomass trajectories for the three model runs: $\mathbf{2 0 0 6}_{\text {YCS2000, }} \mathbf{2 0 0 6}_{\text {YCS2001 }}$, and $\mathbf{2 0 0 7}_{\text {YCS2003 }}$.

| Fishery and Stock Trends |  |
| :--- | :--- |
| Recent Trend in Biomass or <br> Proxy | Biomass is projected to have declined since the early 1990s; <br> however, some recovery may have occurred since 2004. |
| Recent Trend in Fishing | Fishing pressure has declined with the decrease in TACC since <br> 1999-2000. |
| Mortality or Proxy |  |
| Other Abundance Indices |  |

## GEMFISH (SKI)

| Trends in Other Relevant <br> Indicators or Variables | One strong year class was estimated to have occurred in 1991. <br> 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: Unlikely (<40\%) Hard Limit: Very Unlikely ( $<10 \%$ ) |
| Assessment Methodology |  |
| Assessment Type | Type 1- Quantitative stock assessment |
| Assessment Method | Age-structured CASAL model with Bayesian estimation of posterior distributions. |
| Assessment Dates | Latest assessment: 2008 Next assessment: Unknown |
| Main data inputs | Updated from previous assessment: <br> - Catch history <br> - CPUE abundance indices <br> - Proportions-at-age data (1 year SKI 1, 4 years SKI 2) |
| Changes to Model Structure and Assumptions | Incorporation of: <br> - Age based selectivities <br> - Differential natural mortality <br> - Additional year of age data |
| Major Sources of Uncertainty | - Recent CPUE indices (2001 onwards) are considered unlikely to track abundance effectively, and were dropped. CPUE indices are inconsistent between SKI1 and SKI2. <br> - 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. |

## Qualifying Comments

## Fishery Interactions

Gemfish are common bycatch in the hoki 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 15: Summary of yields ( $\mathbf{t}$ ) from base case assessments, TACCs ( $t$ ) and reported landings ( $\mathbf{t}$ ) for gemfish for the most recent fishing year.
$\left.\begin{array}{llrrrr}2010-11\end{array} \begin{array}{r}\text { 2010-11 } \\ \text { Actual } \\ \text { Reported } \\ \text { landings }\end{array}\right)$

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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 the 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 are likely to have resulted in under-reported total catches over the full period for which data are available.

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.

Table 1: Reported landings ( $\mathbf{t}$ ) 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 |  | Total |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | B | C(M) | C(1) | D | E(B) | E(P) | E(C) | E(A) | F(E) | F(W) | G | H |  |
| 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 3 | March | \# 1 April to 30 Sept. |  |  |  |  |  |  |  |  |  |  |  |

Table 2: Estimated landings (t) of dark ghost shark by Fishstock from 1982-83 to 2010-11, 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-present.

| Fishstock <br> FMA (s) | $\begin{array}{r} \text { GSH } 1 \\ 1 \end{array}$ |  | $\begin{array}{r} \text { GSH } 2 \\ 2 \\ \hline \end{array}$ |  | $\begin{array}{r} \text { GSH } 3 \\ 3 \\ \hline \end{array}$ |  | $\begin{array}{r} \text { GSH } 4 \\ 4 \\ \hline \end{array}$ |  | $\begin{array}{r} \text { GSH } 5 \\ 5 \\ \hline \end{array}$ |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  |  |  |  |  |  |
|  | 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 | 1187 | 318 | 373 | 64 | 109 |
| 1999-00 | 15 | 15 | 51 | 37 | 938 | 1187 | 173 | 373 | 71 | 109 |
| 2000-01 | 15 | 10 | 50 | 33 | 1111 | 1185 | 179 | 370 | 85 | 109 |
| 2001-02 | 22 | 10 | 52 | 33 | 1068 | 1185 | 241 | 370 | 76 | 109 |
| 2002-03 | 17 | 10 | 58 | 33 | 1371 | 1185 | 265 | 370 | 93 | 109 |
| 2003-04 | 21 | 10 | 84 | 33 | 894 | 1185 | 157 | 370 | 45 | 109 |
| 2004-05 | 14 | 10 | 74 | 33 | 880 | 1185 | 282 | 370 | 80 | 109 |
| 2005-06 | 20 | 10 | 57 | 33 | 583 | 1185 | 318 | 370 | 61 | 109 |
| 2006-07 | 20 | 22 | 60 | 66 | 654 | 1185 | 396 | 370 | 115 | 109 |
| 2007-08 | 19 | 22 | 100 | 66 | 484 | 1185 | 562 | 370 | 67 | 109 |
| 2008-09 | 14 | 22 | 71 | 66 | 490 | 1185 | 251 | 370 | 61 | 109 |
| 2009-10 | 13 | 22 | 64 | 66 | 520 | 1185 | 233 | 370 | 108 | 109 |
| 2010-11 | 17 | 22 | 95 | 66 | 640 | 1185 | 311 | 370 | 73 | 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 | - | 1361 |  |
| 1991-92 | 80 | - | 124 | - | 3 | - | 1 | - | 923 |  |
| 1992-93 | 68 | - | 221 | - | 11 | - | 0 | - | 938 |  |
| 1993-94 | 53 | - | 513 | - | 14 | - | 0 | - | 1357 |  |
| 1994-95 | 61 | - | 703 | - | 3 | - | 0 | - | 1778 |  |
| 1995-96 | 68 | - | 548 | - | 8 | - | 3 | - | 1679 |  |
| 1996-97 | 135 | - | 926 | - | 9 | - | 11 | - | 2477 |  |
| 1997-98 | 136 | - | 170 | - | 3 | - | 12 | - | 1454 |  |
| 1998-99 | 110 | 95 | 409 | 1121 | 7 | 12 | 22 | 14 | 1958 | 2963 |
| 1999-00 | 117 | 95 | 466 | 1121 | 19 | 12 | 25 | 14 | 1875 | 2963 |
| 2000-01 | 76 | 95 | 475 | 1121 | 22 | 12 | 31 | 8 | 2043 | 2943 |
| 2001-02 | 94 | 95 | 463 | 1121 | 22 | 12 | 25 | 8 | 2063 | 2943 |
| 2002-03 | 99 | 95 | 593 | 1121 | 15 | 12 | 20 | 8 | 2531 | 2943 |
| 2003-04 | 72 | 95 | 652 | 1121 | 27 | 12 | 12 | 8 | 1964 | 2943 |
| 2004-05 | 53 | 95 | 694 | 1121 | 31 | 12 | 10 | 8 | 2118 | 2943 |
| 2005-06 | 31 | 95 | 625 | 1121 | 22 | 12 | 8 | 8 | 1725 | 2943 |
| 2006-07 | 43 | 95 | 696 | 1121 | 16 | 22 | 6 | 22 | 2006 | 3012 |
| 2007-08 | 36 | 95 | 601 | 1121 | 29 | 22 | 13 | 22 | 1911 | 3012 |

Table 2 [Continued]:Estimated landings ( $t$ ) of dark ghost shark by Fishstock from 1982-83 to 2010-11, 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-present.



GSH4
Landings $\square$ TACC $\longleftrightarrow$


GSH3


GSH5
Landings $\square$ TACC $\longleftrightarrow$


Figure 1: Historical landings and TACC for the six main GSH stocks. From top left: GSH2 (Central East), GSH3 (South East Coast), GSH4 (South East Chatham Rise), and GSH5 (Southland). [Continued on the next page]...


Figure 1 [Continued]: Historical landings and TACC for the six main GSH stocks. GSH6 (Sub-Antarctic) and GSH7 (Challenger). Note that these figures do not show data prior to entry into the QMS.

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 in GSH 4 in 2007-08.

### 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.

### 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 $40^{\circ} \mathrm{S}$ and have not been recorded from the Bounty Platform. They are most abundant in waters $150-500 \mathrm{~m}$ deep on the west coast of the South Island and the Chatham Rise, and in depths of $150-700 \mathrm{~m}$ on the Stewart-Snares shelf and

Southland/sub-Antarctic. Smaller sharks (<40 cm CL) 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. Length-frequency histograms indicate that females grow to a larger size (and presumably have a faster growth rate) than males. Without population age structures or confident estimates of longevity, it is not possible to estimate natural or total mortalities. A research 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 dark ghost sharks is $52-53 \mathrm{~cm}$ for males and $62-63 \mathrm{~cm}$ 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 3.
Table 3: Estimates of biological parameters for dark ghost shark, from Horn (1997).

| FMA | Estimate |
| :--- | :---: | :---: |
| 1. Weight $=\mathrm{a}$ (length) $)^{\mathrm{b}}$ (Weight in g, length in cm chimaera length)  <br> a b  <br> Dark ghost shark   <br> $3 \& 4$ 0.00202 3.274 <br> $5 \& 6$ 0.00192 3.297 |  |

## 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 $3-4 \mathrm{~cm}$ greater than those in Southland/sub-Antarctic waters.

Horn (1997) proposed that dark 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.

## 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 4, Figure 2), but wide fluctuations between years suggest the need for caution in using these as indicators of relative abundance. Longer time series may ultimately prove useful, as a recent (2008) study suggest that the West Coast South Island trawl survey is probably monitoring adult abundance.


| FMA | Area | Vessel | Trip code | Date | Biomass | \% CV |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 3 \& 4 | Chatham Rise | Tangaroa | TAN9106 | Jan-Feb 1992 | 6700 | 11.1 |
|  |  |  | TAN9212 | Jan-Feb 1993 | 5950 | 9.2 |
|  |  |  | TAN9401 | Jan-94 | 10360 | 15.3 |
|  |  |  | TAN9501 | Jan-95 | 3490 | 11.2 |
|  |  |  | TAN9601 | Jan-96 | 6170 | 12.4 |
|  |  |  | TAN9701 | Jan-97 | 6240 | 11.7 |
|  |  |  | TAN9801 | Jan-98 | 6720 | 14.1 |
|  |  |  | TAN9901 | Jan-99 | 12125 | 23.4 |
|  |  |  | TAN0001 | Jan-00 | 9154 | 25.2 |
|  |  |  | TAN0101 | Jan-01 | 10356 | 12 |
|  |  |  | TAN0201 | Jan-02 | 9997 | 11.1 |
|  |  |  | TAN0301 | Jan-03 | 10341 | 9.1 |
| FMA | Area | Vessel | Trip code | Date | Biomass | \% CV |
|  |  |  | TAN0401 | Jan-04 | 10471 | 15 |
|  |  |  | TAN0501 | Jan-05 | 11885 | 16.3 |
|  |  |  | TAN0601 | Jan-06 | 11502 | 12 |
|  |  |  | TAN0701 | Jan-07 | 7852 | 11 |
|  |  |  | TAN0801 | Jan-08 | 9391 | 10.9 |
|  |  |  | TAN0901 | Jan-09 | 8445 | 13.7 |
|  |  |  | TAN1001 | Jan-10 | 11596 | 16.8 |
|  |  |  | TAN1101 | Jan-11 | 6588 | 17 |
|  |  |  | TAN1201 | Jan-12 | 13162 | 20.6 |
| 5 \& 6 | Southland | Tangaroa | TAN9105 | Nov-Dec 1991 | 1030 | 25.4 |
|  | Sub-Antarctic | (summer) | TAN9211 | Nov-Dec 1992 | 710 | 43.2 |
|  |  |  | TAN9310 | Nov-Dec 1993 | 1060 | 33.6 |
|  |  |  | TAN0012 | Nov-Dec 2000 | 1459 | 89.6 |
|  |  |  | TAN0118 | Nov-Dec 2001 | 1391 | 35.7 |
|  |  |  | TAN0219 | Nov-Dec 2002 | 175 | 37.7 |
|  |  |  | TAN0317 | Nov-Dec 2003 | 382 | 48.9 |
|  |  |  | TAN0414 | Nov-Dec 2004 | 843 | 41.7 |
|  |  |  | TAN0515 | Nov-Dec 2005 | 517 | 40 |
|  |  |  | TAN0617 | Nov-Dec 2006 | 354 | 32 |
|  |  | Tangaroa | TAN9204 | Mar-Apr 1992 | 3740 | 48.6 |
|  |  | (autumn) | TAN9304 | Apr-May 1993 | 750 | 44.7 |
|  |  |  | TAN9605 | Mar-Apr 1996 | 3080 | 47.6 |
|  |  |  | TAN9805 | Apr-May 1998 | 2490 | 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 | 1870 | 63 |
| 2 | East coast | Kaharoa | KAH9304 | Mar-Apr 1993 | 450 | 61.5 |
|  | North Island |  | KAH9402 | Feb-Mar 1994 | 40 | 41.3 |
|  |  |  | KAH9502 | Feb-Mar 1995 | 10 | 48.6 |
|  |  |  | KAH9602 | Feb-Mar 1996 | 80 | 33.5 |
| 3 | East coast | Kaharoa | KAH9105 | May-91 | 770 | 41.5 |
|  | South Island |  | KAH9205 | May-92 | 930 | 43.6 |
|  |  |  | KAH9306 | May-93 | 2910 | 41.5 |
|  |  |  | KAH9406 | May-94 | 2700 | 25.1 |
|  |  |  | KAH9606 | May-96 | 3180 | 22.7 |
|  |  |  | KAH0705 | May-07 | 4480 | 25 |
|  |  |  | KAH0806 | May-June-08 | 3760 | 20.5 |
|  |  |  | KAH0905 | May-Jun-09 | 4330 | 29 |
| 3 | East coast | Kaharoa | KAH9618 | Dec '96-Jan '97 | 3070 | 18 |
|  | South Island |  | KAH9704 | Dec '97-Jan '98 | 5870 | 33 |
|  |  |  | KAH9809 | Dec '98-Jan '99 | 7420 | 27 |

## DARK GHOST SHARK (GSH)

Table 4 continued:

| West coast | Kaharoa | KAH9204 | Mar-Apr 1992 | 380 | 20 |
| :--- | :--- | :--- | :--- | ---: | ---: |
| South Island |  | KAH9404 | Mar-Apr 1994 | 720 | 14.3 |
|  | KAH9504 | Mar-Apr 1995 | 770 | 23.7 |  |
|  | KAH9701 | Mar-Apr 1997 | 1590 | 21.2 |  |
|  | KAH0004 | Mar-Apr 2000 | 2260 | 9 |  |
|  |  | KAH0304 | Mar-Apr 2003 | 540 | 15 |
|  | KAH0503 | Mar-Apr 2005 | 830 | 22 |  |
|  | KAH0704 | Mar-Apr 2007 | 2215 | 21 |  |
|  | KAH0904 | Mar-Apr 2009 | 900 | 17 |  |
|  |  | KAH1004 | Mar-Apr 2010 | 2363 | 23 |

### 4.2 Biomass estimates

No biomass estimates are available for dark ghost shark.

### 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 $M C Y=c Y_{A V}$ (Method 4). However, it was decided that no estimates of $M C Y$ would be presented because:
i. $\quad M$ (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 $Y_{A V}$ 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

No estimates of current and reference biomass are available for dark ghost shark.
Reported landings from the two major fisheries (GSH 3 and 7) have been well below the TACCs in recent years. However for all stocks, it is not known if recent catch levels or current TACCs are sustainable in the long term or whether they will allow the stocks to move towards a size that will support the maximum sustainable yield.

TACCs and reported landings are summarised in Table 5.


Figure 2: Biomass trends $\pm 95 \%$ CI (estimated from survey CVs assuming a lognormal distribution) and the time series mean (dotted line) from the Chatham Rise (top), West (middle) and East (bottom) Coast South Island trawl surveys.

## DARK GHOST SHARK (GSH)



Figure 3: Scaled length frequency distributions for dark ghost shark, for Chatham Rise surveys. M, males and F, females, (CV) (Stevens et al. 2011).


Figure 3 [Continued].

## DARK GHOST SHARK (GSH)



Figure 3 [Continued].


Figure 3 [Continued].

## DARK GHOST SHARK (GSH)

Table 5: Summary of TACCs (t) and reported landings (t) for dark ghost shark for the most recent fishing year.

|  |  | $2010-11$ | $2010-11$ <br> Estimated |  |
| :--- | :--- | ---: | ---: | ---: |
| Fishstock |  | QMA | TACC | Landings |
| GSH 1 | Auckland (East) | 1 | 22 | 17 |
| GSH 2 | Central (East) | 2 | 66 | 95 |
| GSH 3 | South-east (Coast) | 3 | 1185 | 639 |
| GSH 4 | South-east (Chatham) | 4 | 370 | 311 |
| GSH 5 | Southland | 5 | 109 | 73 |
| GSH 6 | Sub-Antarctic | 6 | 95 | 38 |
| GSH 7 | Challenger | 7 | 1121 | 1129 |
| GSH 8 | Central (West) | 8 | 22 | 33 |
| GSH 9 | Auckland (West) | 9 | 22 | 6 |
| GSH 10 | Kermadec | 10 | 0 | 0 |
| Total |  |  | 3012 | 2341 |

## 6. FOR FURTHER INFORMATION

Francis M.P., Francis R.I.C.C. 1992. Growth, mortality, and yield estimates for rig (Mustelus lenticulatus). New Zealand Fisheries Assessment Research Document 1992/5. 32 p.
Francis M.P., Ó Maolagáin C.O. 2001. Development of ageing techniques for dark ghost shark (Hydrolagus novaezelandiae). Final Research Report for Ministry of Fisheries Research Project MOF2000/03C. 10 p.
Francis M.P., McMillan P., Lasenby R., Didier D. 1998. How to tell dark and pale ghost sharks apart. Seafood New Zealand 6 (11): 29-30. (December 1998.)
Horn P.L. 1997. A summary of biology and commercial landings, and a stock assessment of ghost sharks (Hydrolagus spp.) in New Zealand waters. New Zealand Fisheries Assessment Research Document 97/3. 36 p.
Stevens D., Livingston M., Bagley N. 2001. Trawl survey of hoki and middle depth species on the Chatham Rise, January 2001 (TAN0101). Final Research Report for Ministry of Fisheries Research Project HOK2000/02 Objectives 1 and 2.13 p.
Stevens D.W., O’Driscoll R.L., Ballara S.L., Bagley N., Horn P.L. 2011. Chatham Rise Trawl Survey, 2 Jan - 28 Jan 2011 (TAN1011). WG-HOK-2011/X. X p. (Unpublished report held by Ministry of Fisheries, Wellington.)

## 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 199900 fishing year as 3 Fishstocks: GSP 1 - QMAs 1 to 4, and 10; GSP 5 - QMAs 5 and 6 and GSP 7 QMAs 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 QMA boundaries is used to assign catches to QMAs. No data are available for the $\mathbf{1 9 8 0 - 8 1}$ 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 |  |
| 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 |

In the early to mid 1980s, about half of the reported ghost shark landings were from QMA 3. Virtually all the additional catch was spread over QMAs 4-7. In 1988-89, landings from west coast South Island (QMA 7) began to increase - this is almost certainly associated with the development of
the hoki fishery. In 1990-91, significant landings increases 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 QMAs 5 and 6 , and $25 \%$ in all other QMAs.

From 1 Oct 1999 TACCs were set for pale ghost shark fishstocks as follows: GSP 1-509t, 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 GSP1 and GSP5 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 were only 25-30\% of the QMR totals.

Table 2: Estimated landings (t) of pale ghost shark by fishery 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 $\mathbf{3 0 \%}$ of the total ghost shark catch in QMAs 5 and 6, and $\mathbf{2 5 \%}$ in all other QMAs.

1982-83
1983-84
1984-85
1985-86
1986-87
1987-88
1988-89
1989-90
1990-91
1991-92
1992-93
1993-94
1994-95
1995-96
1996-97
1997-98
1998-99

| QMA |  |  |  |  |  |  |  |  |  | Total |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |  |
| 1 | 1 | 74 | 35 | 21 | 13 | 2 | 1 | 0 | 0 | 148 |
| 0 | 1 | 63 | 24 | 11 | 15 | 7 | 1 | 0 | 0 | 122 |
| 1 | 1 | 60 | 49 | 16 | 19 | 12 | 0 | 0 | 0 | 158 |
| 1 | 1 | 96 | 23 | 10 | 14 | 7 | 1 | 0 | 0 | 153 |
| 1 | 2 | 110 | 27 | 11 | 12 | 13 | 1 | 0 | 0 | 177 |
| 1 | 1 | 138 | 21 | 13 | 2 | 15 | 1 | 0 | 0 | 192 |
| 2 | 7 | 124 | 9 | 19 | 2 | 34 | 1 | 0 | 0 | 198 |
| 1 | 3 | 86 | 8 | 41 | 5 | 33 | 5 | 0 | 0 | 182 |
| 1 | 7 | 148 | 63 | 61 | 82 | 39 | 1 | 0 | 0 | 402 |
| 1 | 2 | 218 | 95 | 64 | 54 | 35 | 2 | 1 | 0 | 472 |
| 2 | 1 | 227 | 99 | 77 | 55 | 53 | 7 | 0 | 0 | 521 |
| 1 | 2 | 173 | 42 | 36 | 32 | 99 | 4 | 0 | 0 | 389 |
| 1 | 1 | 246 | 62 | 27 | 26 | 234 | 1 | 0 | 0 | 598 |
| 4 | 12 | 226 | 84 | 30 | 29 | 183 | 3 | 1 | 0 | 572 |
| 6 | 22 | 272 | 134 | 40 | 58 | 309 | 3 | 3 | 0 | 847 |
| 6 | 6 | 256 | 87 | 30 | 58 | 57 | 1 | 4 | 0 | 505 |
| 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.

### 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.

Table 3: Estimated landings (t) of pale ghost shark by Fishstock for 1999-2000 to 2010-11 and actual TACCs set from 1999-2000 (QMR data).

| Fishstock | GSP 1 |  |  | GSP 5 | GSP 7 |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| QMA (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 | 1142 | 509 | 454 | 118 | 16 | 176 | 1613 | 803 |
| 2001-02 | 1033 | 509 | 545 | 118 | 71 | 176 | 1649 | 803 |
| 2002-03 | 1277 | 509 | 602 | 118 | 16 | 176 | 1895 | 803 |
| 2003-04 | 1009 | 509 | 529 | 118 | 15 | 176 | 1553 | 803 |
| 2004-05 | 635 | 1150 | 247 | 454 | 5 | 176 | 887 | 1780 |
| 2005-06 | 565 | 1150 | 134 | 454 | 9 | 176 | 708 | 1780 |
| 2006-07 | 553 | 1150 | 226 | 454 | 15 | 176 | 794 | 1780 |
| 2007-08 | 473 | 1150 | 329 | 454 | 16 | 176 | 818 | 1780 |
| 2008-09 | 486 | 1150 | 294 | 454 | 15 | 176 | 795 | 1780 |
| 2009-10 | 534 | 1150 | 206 | 454 | 11 | 176 | 751 | 1780 |
| 2010-11 | 395 | 1150 | 203 | 454 | 13 | 176 | 611 | 1780 |




GSP7
Landings $\square$ TACC $\longleftrightarrow$


Figure 1: Historical landings and TACC for the three main GSP stocks. From top left: GSP1 (Auckland East), GSP5 (Southland), and GSP7 (Challenger). Note that these figures do not show data prior to entry into the QMS.

### 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

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 $400-1000 \mathrm{~m}$ on the Chatham Rise and Southland/subAntarctic, but are uncommon north of $40^{\circ} \mathrm{S}$ 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 $59-60 \mathrm{~cm}$ for males and $69-70 \mathrm{~cm}$ 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 (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 (QMAs 1-4), Stewart-Snares shelf and Campbell Plateau (QMAs 5 and 6), and west coast New Zealand (QMAs 7, 8, and 9). Areas of narrow continental shelf separate these QMA 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 | 6060 | 5.7 |
|  |  |  | TAN9212 | Jan-Feb 1993 | 3570 | 7 |
|  |  |  | TAN9401 | Jan-94 | 5900 | 8.6 |
|  |  |  | TAN9501 | Jan-95 | 2750 | 8.4 |
|  |  |  | TAN9601 | Jan-96 | 7900 | 10 |
|  |  |  | TAN9701 | Jan-97 | 2870 | 12.2 |
|  |  |  | TAN9801 | Jan-98 | 4052 | 9.3 |
|  |  |  | TAN9901 | Jan-99 | 5272 | 9.7 |
|  |  |  | TAN0001 | Jan-00 | 4892 | 7.6 |
|  |  |  | TAN0101 | Jan-01 | 7094 | 9 |
|  |  |  | TAN0201 | Jan-02 | 4896 | 10 |
|  |  |  | TAN0301 | Jan-03 | 4653 | 12.1 |
|  |  |  | TAN0401 | Jan-04 | 3627 | 8.6 |
|  |  |  | TAN0501 | Jan-05 | 4061 | 9.2 |
|  |  |  | TAN0601 | Jan-06 | 3237 | 11 |
|  |  |  | TAN0701 | Jan-07 | 4766 | 9.0 |
|  |  |  | TAN0801 | Jan-08 | 3235 | 6.1 |
|  |  |  | TAN0901 | Jan-09 | 3995 | 7.6 |
|  |  |  | TAN1001 | Jan-10 | 3216 | 11.7 |
|  |  |  | TAN1101 | Jan-11 | 2550 | 14.2 |
|  |  |  | TAN1201 | Jan-12 | 4327 | 8.5 |
| 5 | Southland | Tangaroa | TAN9105 | Nov-Dec 1991 | 11210 | 6.1 |
|  | Sub-Antarctic |  | TAN9211 | Nov-Dec 1992 | 4750 | 7.2 |
|  |  |  | TAN9310 | Nov-Dec 1993 | 11670 | 9.4 |
|  |  |  | TAN0012 | Nov-Dec 2000 | 17823 | 12.4 |
|  |  |  | TAN0118 | Nov-Dec 2001 | 11219 | 8.8 |
|  |  |  | TAN0219 | Nov-Dec 2002 | 9297 | 9.3 |
|  |  |  | TAN0317 | Nov-Dec 2003 | 10360 | 8.7 |
|  |  |  | TAN0414 | Nov-Dec 2004 | 8549 | 10.3 |
|  |  |  | TAN0515 | Nov-Dec 2005 | 9416 | 10 |
|  |  |  | TAN0617 | Nov-Dec 2006 | 12619 | 10 |
|  |  |  | TAN0714 | Nov-Dec 2007 | 13107 | 11 |
|  |  |  | TAN0813 | Nov-Dec 2008 | 10098 | 13 |
|  |  |  | TAN0911 | Nov-Dec 2009 | 13553 | 9 |
|  |  |  | TAN1117 | Nov-Dec 2011 | 11677 | 9.6 |
| 5 | Southland | Tangaroa | TAN9204 | Mar-Apr 1992 | 10530 | 6.1 |
|  | Sub-Antarctic |  | TAN9304 | Apr-May 1993 | 14640 | 9.5 |
|  |  |  | TAN9605 | Mar-Apr 1996 | 16380 | 9.9 |
|  |  |  | TAN9805 | Apr-May 1998 | 15758 | 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 Estimation of Maximum Constant Yield (MCY)

As no estimate of biomass or harvest rate are available, the only possible method of calculating maximum constant yield is $M C Y=c Y_{A V}($ Method 4).

## PALE GHOST SHARK (GSP)

However, it was decided that no estimates of $M C Y$ would be presented because:
i. $\quad M$ (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 $Y_{A V}$ 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, $C A Y$ 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 $M C Y$ 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 7

There are no accepted stock monitoring indices available for GSP 7.
GSP 1

| Stock Status |  |
| :--- | :--- |
| Year of Most Recent Assessment | 2011 |
| Assessment Runs Presented |  |
| Reference Points | Target: $40 \% B_{0}$ <br> Soft Limit: $20 \% B_{0}$ <br> Hard Limit: $10 \% B_{0}$ |
| Status in relation to Target | Unknown |
| Status in relation to Limits | Unlikely $(<40 \%)$ to be below soft limit. <br> Very Unlikely ( $<10 \%)$ to be below hard limit. |

Historical Stock Status Trajectory and Current Status

## GSP1



Doorspread biomass estimates of pale ghost shark (error bars are $\pm$ two standard deviations) from the Chatham Rise, from Tangaroa surveys from 1992 to 2011.

$\left.$| Fishery and Stock Trends |  |  |
| :--- | :--- | :---: |
| Recent Trend in Biomass or |  |  |
| Proxy |  |  |$\quad$| 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. | \right\rvert\,

## 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 | Level 2 - Quantitative stock assessment |
| :--- | :--- |
| Assessment Type | Evaluation of trawl survey indices on the Chatham Rise |
| Assessment Method | - Research time series of abundance indices (trawl surveys). |
| Main data inputs | Latest assessment: 2011 |
| Period of Assessment | Next assessment: 2012 |
| Changes to Model Structure and <br> Assumptions | The core strata in the trawl survey do not cover the full depth <br> distribution of pale ghost shark. |
| Major Sources of Uncertainty |  |
| Qualifying Comments |  |
| The catch history for this species is likely to underestimate actual catches |  |

## Fishery Interactions

The pale ghost shark in GSP1 is mainly taken as bycatch of the hoki fishery.

GSP 5


Doorspread biomass estimates of pale ghost shark (error bars are $\pm$ two standard deviations) from the SubAntarctic, 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 <br> Proxy | Biomass estimates from trawl surveys on the Sub-Antarctic have <br> increased in recent years. Precision is generally good in this time <br> series (about 10\%). The Working Group considered this index to <br> be suitable to monitor major trends in this stock. |
| Recent Trend in Fishing <br> Mortality or Proxy | Unknown |
| Other Abundance Indices | - |
| Trends in Other Relevant <br> 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 <br> levels in FMA 5\&6. |
| Probability of Current Catch or <br> TACC causing decline below | Soft Limit: Unlikely ( $<40 \%$ ) at recent catch levels; unknown at <br> the TACC |


| Limits | Hard Limit: Very Unlikely (<10\%) at recent catch levels; <br> 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 |
| 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.
TACCs and reported landings for the 2010-11 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.

|  |  | $2010-11$ <br> Actual | $2010-11$ <br> Estimated <br> Fishstock |
| :--- | :--- | ---: | ---: |
| GSP 1 | Auckland (East), Central (East) | QMA | 1150 |

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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 2011-12 from CELR and CLR data. ( $\mathrm{N} / \mathbf{A}=$ no TACC set).

|  | 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 | 12 | N/A | N/A | 14 | 19 | N/A | N/A |


|  | 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 |



Figure 1: Historical landings and TACC for GSC5 (Southland), and GSC6A (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 Island. 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 37500 eggs; a female of 126 mm CL about 71200 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 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 QMAs, 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 Estimation of Maximum Constant Yield (MCY)

There are no estimates of $M C Y$ for any giant spider crab fishstock.

### 4.4 Estimation of Current Annual Yield (CAY)

There are no estimates of $C A Y$ 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.

## 6. FOR FURTHER INFORMATION

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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 19th 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 2010-11.

| 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 | 1500 | 121 | 180 | 539 | 1720 |
| 2005-06 | 12.4 | 10 | 0.2 | 10 | 0.176 | 10 | 229.0 | 1500 | 93 | 180 | 335 | 1720 |
| 2006-07 | 7.8 | 10 | 0 | 10 | 0 | 10 | 84.3 | 1500 | 137 | 180 | 229 | 1720 |
| 2007-08 | 3.5 | 10 | 0 | 10 | 0.04 | 10 | 7.4 | 1500 | 142 | 180 | 153 | 1720 |
| 2008-09 | 6.7 | 10 | 0 | 10 | 0.04 | 10 | 0.07 | 1500 | 68 | 180 | 75 | 1720 |
| 2009-10 | 4.4 | 10 | 0 | 10 | 0.02 | 10 | 0.03 | 1500 | 183 | 180 | 187 | 1720 |
| 2010-11 | 1.0 | 10 | 0 | 10 | 0 | 10 | 1.4 | 1500 | 78 | 180 | 80 | 1720 |

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 the following TAC and TACCs in Table 2.

Table 2: Recreational and Customary non-commercial allowances, TACCs and TACs for green-lipped mussel.



Figure 1: Historical landings and TACC for the four main GLM stocks. From top left: GLM1 (Auckland East), GLM7A (Nelson Marlborough), and GLM9 (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 QMA (Bradford 1998, Boyd et al. 2004).

| FMA | 1996 Harvest | 2000 Harvest | 2001 Harvest |
| :--- | ---: | ---: | ---: |
| 1 | 818 | 1308 | 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 $100 \mathrm{~m}^{2}$. 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 $11^{\circ} \mathrm{C}$ 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 $\mu \mathrm{m}$ 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 $111-115 \mathrm{~mm}$ 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 $20-70 \mathrm{~mm}$ 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 southernnorthern 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)



## 1. FISHERY SUMMARY

### 1.1 Commercial fisheries

Commercial fishing for grey mullet occurs predominantly in the GMU 1, where annual landings increased from approximately 420 t in 1974 to a maximum of 1142 t in 1983-84. 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 1).


Figure 1: Historical landings and TACC for the main GMU stock; GMU 1 (Auckland). Note that this figure does not show data prior to entry into the QMS.

Table 1: Reported landings ( $t$ ) of grey mullet by Fishstock from 1983-84 to 2010-11 and actual TACCs (t) for 198687 to 2010-11. QMS data from 1986-present. There have been no report landings for GMU 10.

| Fishstock QMA (s) | $\begin{gathered} \text { GMU } 1 \\ 1 \& 9 \\ \hline \end{gathered}$ |  | $\begin{array}{r} \text { GMU } 2 \\ 2 \& 8 \\ \hline \end{array}$ |  | $\begin{array}{r} \text { GMU } 3 \\ 3,4,5 \& 6 \end{array}$ |  | $\begin{array}{r} \text { GMU } 7 \\ 7 \\ \hline \end{array}$ |  | GMU 10 $\qquad$ <br> TACC | Total |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  |  |  |  |  |  |  |
|  | Landings | TACC | Landings | TACC | Landings | TACC | Landings | TACC |  | Landings | TACC |
| 1983-84* | 1142 | - | 6 | - | 5 | - | 7 | - | - | 1160 | - |
| 1984-85* | 1069 | - | 5 | - | 0 | - | 15 | - | - | 1089 | - |
| 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 | 1021 |
| 1988-89 | 792 | 963 | 3 | 20 | 0 | 30 | 0 | 20 | 10 | 795 | 1043 |
| 1989-90 | 907 | 990 | 2 | 20 | 0 | 30 | 4 | 20 | 10 | 913 | 1070 |
| 1990-91 | 875 | 994 | 2 | 20 | 1 | 30 | <1 | 20 | 10 | 879 | 1073 |
| 1991-92 | 848 | 1006 | 1 | 20 | 2 | 30 | 1 | 20 | 10 | 852 | 1086 |
| 1992-93 | 711 | 1006 | $<1$ | 20 | < 1 | 30 | 0 | 20 | 10 | 712 | 1086 |
| 1993-94 | 743 | 1006 | <1 | 20 | <1 | 30 | 0 | 20 | 10 | 706 | 1086 |
| 1994-95 | 776 | 1006 | 0 | 20 | <1 | 30 | 10 | 20 | 10 | 787 | 1086 |
| 1995-96 | 866 | 1006 | 0 | 20 | <1 | 30 | < 1 | 20 | 10 | 866 | 1086 |
| 1996-97 | 870 | 1006 | <1 | 20 | 1 | 30 | < 1 | 20 | 10 | 872 | 1086 |
| 1997-98 | 730 | 1006 | <1 | 20 | <1 | 30 | <1 | 20 | 10 | 730 | 1086 |
| 1998-99 | 750 | 925 | $<1$ | 20 | <1 | 30 | <1 | 20 | 10 | 750 | 1005 |
| 1999-00 | 749 | 925 | <1 | 20 | 0 | 30 | $<1$ | 20 | 10 | 750 | 1005 |
| 2000-01 | 797 | 925 | 1 | 20 | 0 | 30 | <1 | 20 | 10 | 798 | 1005 |
| 2001-02 | 782 | 925 | 2 | 20 | < 1 | 30 | < 1 | 20 | 10 | 784 | 1005 |
| 2002-03 | 797 | 925 | 1 | 20 | < 1 | 30 | 0 | 20 | 10 | 798 | 1005 |
| 2003-04 | 886 | 925 | $<1$ | 20 | 0 | 30 | < 1 | 20 | 10 | 796 | 1005 |
| 2004-05 | 941 | 925 | <1 | 20 | 0 | 30 | 0 | 20 | 10 | 941 | 1005 |
| 2005-06 | 878 | 925 | <1 | 20 | < 1 | 30 | 0 | 20 | 10 | 878 | 1005 |
| 2006-07 | 847 | 925 | 1 | 20 | 0 | 30 | < 1 | 20 | 10 | 845 | 1005 |
| 2007-08 | 848 | 925 | 1 | 20 | < 1 | 30 | < 1 | 20 | 10 | 849 | 1005 |
| 2008-09 | 814 | 925 | 1 | 20 | 0 | 30 | 0 | 20 | 10 | 815 | 1005 |
| 2009-10 | 746 | 925 | $<1$ | 20 | 0 | 30 | 0 | 20 | 10 | 746 | 1005 |
| 2010-11 | 825 | 926 | <1 | 20 | < 1 | 30 | < 1 | 20 | 10 | 826 | 1006 |
| *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 2). 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 2). The 2000 National Recreational Fishing Survey (Boyd et al. 2000) fishing survey provided an estimate of 102 t (Table 2). 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 $100-150 \mathrm{t}$. The Minister of Fisheries provided an allowance for customary harvest of 100 t beginning in 1998-99.

Table 2: 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 | $1993-94$ | 170000 | $19 \%$ | $90-210$ | 150 |
| GMU 1 | 1996 | 110 | 000 | $25 \%$ | $80-130$ |

The RTWORKING GROUP recommends 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.

## GREY MULLET (GMU)

### 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 world wide distribution, occurring commonly along coasts, in estuaries, and in lower river systems between latitudes of $42^{\circ} \mathrm{N}$ and $42^{\circ} \mathrm{S}$. 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 $4-8$ comprises the bulk of the commercial fishery.

Natural mortality was estimated from the equation $M=\log _{\mathrm{e}} 100 /$ 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 through 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 3.
Table 3: Estimates of biological parameters of grey mullet.


## 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 level of net movement cannot be ascertained. There is evidence in the CPUE data that GMU 1 may be comprised of 6 populations with low to moderate mixing between them (McKenzie 1997).

GMU 1 has been divided into two substocks for the purposes of fisheries stock assessment: east cost substock; west coast substock. 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 agestructured 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 Estimation of Maximum Constant Yield (MCY)

There is insufficient information with which to revise the yield estimates of either the West or East coast GMU 1 substocks. The $M C Y$ estimate derived in 1986 using the equation $M C Y=c Y_{A V}$ (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 $Y_{A V}$. 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 $M C Y$ derived for grey mullet is uncertain. The estimate of MCY for GMU 1 is shown in Table 4. MCY cannot be estimated for the other fish stocks.

Table 4: Estimate of MCY (t) rounded to the nearest 5 t .

| Fishstock | QMA | $Y_{A V}$ | $M C Y$ |
| :--- | ---: | ---: | ---: |
| GMU 1 | Auckland $1 \& 9$ | 1030 | 825 |

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

### 4.4 Estimation of Current Annual Yield (CAY)

No estimates of current biomass, fishing mortality, or other information are available which would permit the estimation of CAY.

## GREY MULLET (GMU)

### 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 (MFish 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: $L_{\infty}$ will be biased low, $K$ biased high.

Grey mullet have been exploited by customary, commercial, and recreational fishers for over 100 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 carry-capacity and productivity are not understood and this potentially has impacts on the yields for 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

Grey mullet have been exploited by customary, commercial, and recreational fishers for over 100 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 for GMU.

Given the misreporting of method and its consequences, 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.

Yields, TACCs and reported landings are summarised in Table 5.

Table 5: Summary of yields ( $t$ ), TACCs ( $t$ ), and reported landings ( $t$ ) of grey mullet for the most recent fishing year.

|  |  | 2010-11 | 2010-11 |  |
| :--- | :--- | ---: | ---: | ---: |
| Fishstock | QMA | MCY | Actual TACC | Reported landings |
| GMU 1 | Auckland (East) (West) 1 \& 9 | 825 | 926 | 825 |
| GMU 2 | Central (East) (West) 2 \& 8 | - | 20 | $<1$ |
| GMU 3 | South-East (Coast) (Chatham) 3, 4, |  |  |  |
|  | Southland and Sub-Antarctic 5 \& 6 | - | 30 | $<1$ |
| GMU 7 | Challenger 7 | - | 20 | $<1$ |
| GMU 10 | Kermadec 10 | - | 10 | 0 |
| Total |  | - | 1006 | 826 |

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GROPER (HPB)

## (Polyprion oxygeneios, Polyprion americanus) <br> 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.

Table 1: Reported total New Zealand landings (t) of groper from 1948 to 1983.

| Year | Landings | Year | Landings | Year | Landings | Year | Landings |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1948 | 1665 | 1957 | 1368 | 1966 | 1222 | 1975 | 1422 |
| 1949 | 1969 | 1958 | 1532 | 1967 | 1314 | 1976 | 1512 |
| 1950 | 1709 | 1959 | 1310 | 1968 | 1073 | 1977 | 1942 |
| 1951 | 1396 | 1960 | 1223 | 1969 | 1122 | 1978 | 1488 |
| 1952 | 1430 | 1961 | 1203 | 1970 | 1499 | 1979 | 2078 |
| 1953 | 1403 | 1962 | 1173 | 1971 | 1346 | 1980 | 2435 |
| 1954 | 1364 | 1963 | 1194 | 1972 | 1120 | 1981 | 2379 |
| 1955 | 1305 | 1964 | 1370 | 1973 | 1312 | 1982 | 2218 |
| 1956 | 1399 | 1965 | 1249 | 1974 | 1393 | 1983 | 2511 |
| Reported foreign catches are included from 1974. Source: MAF 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) of groper by Fishstock from 1983-84 to 2010-11 and actual TACCs (t) from 1986-87 to 2010-11. QMS data from 1986-present.

| Fishstock | HPB 1189 |  | HPB 2 |  | HPB 3 |  | HPB 4 |  | HPB 5 |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| QMA (s) |  |  |  | 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 |
|  | HPB 7 |  |  | HPB 8 | HPB 10 |  |  |  |  |  |
|  |  | 7 |  | 8 |  | 10 |  | Total |  |  |
|  | Landings | TACC | Landings | TACC | Landings | TACC | Landings | TACC |  |  |
| 1983-84* | 174 | - | 46 | - | 0 | - | 2698 | - |  |  |
| 1984-85* | 207 | - | 33 | - | 0 | - | 2039 | - |  |  |
| 1985-86* | 199 | - | 25 | - | 0 | - | 1697 | - |  |  |
| 1986-87 | 149 | 210 | 35 | 60 | 0 | 10 | 1036 | 1830 |  |  |
| 1987-88 | 158 | 215 | 66 | 76 | 0 | 10 | 1076 | 1923 |  |  |
| 1988-89 | 132 | 226 | 39 | 78 | 1 | 10 | 968 | 2001 |  |  |
| 1989-90 | 119 | 229 | 43 | 80 | 0 | 10 | 1098 | 2117 |  |  |
| 1990-91 | 128 | 235 | 48 | 80 | \# 23 | 10 | 1282 | 2153 |  |  |
| 1991-92 | 175 | 235 | 50 | 80 | \# 83 | 10 | 1319 | 2163 |  |  |
| 1992-93 | 186 | 236 | 62 | 80 | \# 22 | 10 | 1405 | 2165 |  |  |
| 1993-94 | 193 | 236 | 69 | 80 | 0 | 10 | 1455 | 2167 |  |  |
| 1994-95 | 192 | 236 | 68 | 80 | 0 | 10 | 1437 | 2179 |  |  |
| 1995-96 | 214 | 236 | 78 | 80 | 0 | 10 | 1479 | 2179 |  |  |

## GROPER (HPB)

Table 2 continued:

|  | $\bigcirc$ HPB 7 |  | HPB 8 |  | HPB 10 |  | Total |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Landings | TAC | Landings | TAC | Landings | TAC | Landings | TAC |
| 1996-97 | 186 | 236 | 71 | 80 | 15 | 10 | 1418 | 2179 |
| 1997-98 | 147 | 236 | 60 | 80 | \# 33 | 10 | 1406 | 2181 |
| 1998-99 | 218 | 236 | 78 | 80 | \# 3 | 10 | 1562 | 2181 |
| 1999-00 | 165 | 236 | 65 | 80 | \# 0 | 10 | 1561 | 2181 |
| 2000-01 | 171 | 236 | 64 | 80 | \# 0 | 10 | 1519 | 2181 |
| 2001-02 | 204 | 236 | 62 | 80 | < 1 | 10 | 1514 | 2181 |
| 2002-03 | 233 | 236 | 72 | 80 | 0 | 10 | 1661 | 2181 |
| 2003-04 | 239 | 236 | 66 | 80 | 0 | 10 | 1607 | 2181 |
| 2004-05 | 240 | 236 | 80 | 80 | 0 | 10 | 1742 | 2181 |
| 2005-06 | 207 | 236 | 56 | 80 | 0 | 10 | 1728 | 2181 |
| 2006-07 | 206 | 236 | 66 | 80 | 0 | 10 | 1773 | 2181 |
| 2007-08 | 195 | 236 | 44 | 80 | 0 | 10 | 1651 | 2181 |
| 2008-09 | 207 | 236 | 71 | 80 | 0 | 10 | 1628 | 2181 |
| 2009-10 | 221 | 236 | 66 | 80 | 0 | 10 | 1633 | 2181 |
| 2010-11 | 191 | 236 | 80 | 80 | 0 | 10 | 1543 | 2181 |
| * FSU data. |  |  |  |  |  |  |  |  |



HPB1

HPB2

Figure 1: Historical landings and TACC for the seven main HPB stocks. From top left: HPB1 (Auckland) and HPB2 (Central East) [Continued on the next page]...


Figure 1: Historical landings and TACC for the seven main HPB stocks. From top left: HPB3 (South East Coast), HPB4 (Chatham Rise) and HPB5 (Southland, Sub-Antarctic). [Continued on the next page]...


Figure 1 [Continued]: Historical landings and TACC for the seven main HPB stocks. HPB7 (Challenger) and HPB8 (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 3-5.

Table 3: 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 Ministry of Fisheries regions: South in 1991-92, Central in 1992-93 and North in 1993-94 (Teirney et al. 1997).

|  |  | Total |  |  |
| :--- | :--- | ---: | ---: | ---: |
|  | Fishstock | Survey | 22000 | CV (\%) |$\quad$ Survey harvest (t)

Table 4: 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).

| Number | Harvest | Point |  |  |
| :--- | ---: | ---: | ---: | ---: |
| Fishstock | caught | CV (\%) | range (t) | estimate (t) |
| HPB 1 | 11000 | 17 | $40-60)$ | 49 |
| HPB 2 | 23000 | 22 | $75-125 J$ | 100 |
| HPB 3 | 4000 | - | - | - |
| HPB 5 | 2000 | - | $-J$ | - |
| HPB 7 | 9000 | - | - | - |
| HPB 8 | $<500$ | - | $-J$ | - |

Table 5: 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).

|  | Number <br> Fishstock | Caught | CV (\%) | Harvest |
| :--- | ---: | ---: | ---: | ---: |
| range $(t)$ | Point |  |  |  |
| HPB 1 | 60000 | 39 | $209-476$ | estimate $(t)$ |
| HPB 2 | 5600 | 33 | $307-608$ | 342 |
| HPB 3 | 52000 | 50 | $97-293$ | 457 |
| HPB 5 | 6000 | 70 | $14-80$ | 195 |
| HPB 7 | 17000 | 37 | $79-172$ | 47 |
| HPB 8 | 2000 | 67 | $6-32$ | 125 |
|  |  |  |  | 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 illdefined, but hapuku extends to at least 300 m and bass to 500 m .

## GROPER (HPB)

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. Trawlcaught 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 $60-75 \mathrm{~cm}$; 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 aging 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 aging. Parker et al. (In press) compared regional difference in the catch composition form observer collected data. This report noted that the proportion of age 10+ fish in the catch in Kermadec and Northeastern regions (FMA2) 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 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 6.
Table 6: Estimates of biological parameters of groper.

| Fishstock | Estimate |  | Source |
| :---: | :---: | :---: | :---: |
| 1. Natural mortality ( $M$ ) |  |  |  |
| All | $M=0.1$ |  | Francis (1999) |
| 2. Weight $=\mathrm{a}\left(\right.$ length ${ }^{\mathrm{b}}$ ( Weight in g , length in cm fork length) |  |  |  |
| Both sexes combined |  |  |  |
| BAS 1 | $\mathrm{a}=0.2734$ | $\mathrm{b}=2.382$ | Johnston (1993) |
| HAP 1 | $\mathrm{a}=0.0142$ | $\mathrm{b}=3.003$ | Johnston (1993) |
| HAP 2 | $\mathrm{a}=0.0242$ | $\mathrm{b}=2.867$ | Johnston (1993) |
| $\begin{aligned} & \text { HAP 7, } 8 \\ & \text { (HAP = ha } \end{aligned}$ | $\mathrm{a}=0.0142$ ku, BAS = ba | $\mathrm{b}=2.998$ <br> groper) | Johnston (1983) |

## 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 natural stock boundaries. 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: Biomass estimates $\pm 95 \%$ 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 Estimation of Current Annual Yield (CAY)

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

## GROPER (HPB)

Yield estimates are summarised in Table 7.

Table 7: Yield estimates ( $\mathbf{t}$ ).

| 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 yield estimates and stock assessment results

No information is available.

### 4.6 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 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 $B_{A V}$ 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 8.

Table 8: Summary of yield estimates ( $\mathbf{t}$ ), TACCs ( $\mathbf{t}$ ), and reported landings ( $\mathbf{t}$ ) of groper for the most recent fishing year.

|  |  | 2010-11 <br> Fishstock | QMA | $2010-11$ <br> HPB 1 Auckland (East, West) |
| :--- | :--- | :--- | ---: | ---: |
| HPB 2 | Central (East) | 2 | 481 | Reported Landings |
| HPB 3 | South-east (Coast) | 3 | 266 | 371 |
| HPB 4 | South-east (Chatham) | 4 | 335 | 222 |
| HPB 5 | Southland, Sub-Antarctic | $5 \& 6$ | 323 | 322 |
| HPB 7 | Challenger | 7 | 451 | 231 |
| HPB 8 | Central (West) | 8 | 236 | 128 |
| HPB 10 | Kermadec | 10 | 80 | 191 |
| Total |  |  | 10 | 80 |

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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 $40^{\circ} \mathrm{S}$. Adults are mainly distributed from $250-800 \mathrm{~m}$, 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 ( 17000 t ) recorded in 1977, immediately before the establishment of the EEZ. The TACC for HAK 7 is the largest, at 7700 t out of a total for the EEZ of 13211 t . The WCSI hake fishery has generally consisted of bycatch in the much larger hoki fishery, but it has undergone a number of changes during the last decade (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, notably in 1992, 1993, and 2006 there has been a hake target fishery in September after the peak of the hoki fishery is over; more than 2000 t of hake were taken in this target fishery during September 1993. Bycatch levels of hake early in the fishing season in 1995, 1996, 1999, 2001, 2004 and 2005 were relatively high. From 1 October 2005 the TACC for HAK 7 was increased to 7700 t within an overall TAC of 7777 t . This new catch limit was set equal to average annual catches over the previous 12 years. 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 occurs 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 3000 and 4000 t ) up to 2004-05, but have since been generally less than 3000 t . Landings from HAK 4 declined erratically from 1998-99 to a low of 208 t in 2009-10. From 200405 , the TACC for HAK 4 was reduced from 3500 t to 1800 t . Annual landings have been markedly lower than the new TACC since then.

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, approximately 2000 t of hake were caught from that area. In previous years, catches from this area have typically been between $100-800 \mathrm{t}$. 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 (> 3700 t ) associated with the Chatham Rise. The reasons for the presence of the large aggregation are not known, although periodic and minor aggregations of premature and mature hake have been found in that area in previous years.

Reported catches from 1975 to 1987-88 are shown in Table 1. Reported landings for each Fishstock since 1983-84 and TAC's 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 | 5474 | 0 | 300 | 5774 | 5774 |
| $1977{ }^{\text { }}$ | 0 | 0 | 0 | 12482 | 5784 | 1200 | 19466 | 19466 |
| 1978-79 ${ }^{2}$ | 0 | 3 | 3 | 398 | 308 | 585 | 1291 | 1294 |
| 1979-80 ${ }^{2}$ | 0 | 5283 | 5283 | 293 | 0 | 134 | 427 | 5710 |
| 1980-81 ${ }^{2}$ | No data available |  |  |  |  |  |  |  |
| 1981-82 ${ }^{2}$ | 0 | 3513 | 3513 | 268 | 9 | 44 | 321 | 3834 |
| 1982-83 ${ }^{2}$ | 38 | 2107 | 2145 | 203 | 53 | 0 | 255 | 2400 |
| $1983{ }^{3}$ | 2 | 1006 | 1008 | 382 | 67 | 2 | 451 | 1459 |
| 1983-84 ${ }^{4}$ | 196 | 1212 | 1408 | 522 | 76 | 5 | 603 | 2011 |
| 1984-85 ${ }^{4}$ | 265 | 1318 | 1583 | 400 | 35 | 16 | 451 | 2034 |
| 1985-86 ${ }^{4}$ | 241 | 2104 | 2345 | 465 | 52 | 13 | 530 | 2875 |
| 1986-87 ${ }^{4}$ | 229 | 3666 | 3895 | 234 | 1 | 1 | 236 | 4131 |
| 1987-88 ${ }^{4}$ | 122 | 4334 | 4456 | 231 | 1 | 1 | 233 | 4689 |
| 1. Calendar year. |  |  |  |  |  |  |  |  |
| 2. April 1 to March 31. |  |  |  |  |  |  |  |  |
| 3. April 1 to September 30. |  |  |  |  |  |  |  |  |
| 4. October | ptember 30 |  |  |  |  |  |  |  |

Table 2: Reported landings ( $t$ ) of hake by Fishstock from 1983-84 to 2010-11 and actual TAC's (t) for 1986-87 to 2010-11. QMS data are from 1986 to the present.



Figure 1: Historical landings and TACC for the three main HAK stocks. From top left: HAK1 (Sub-Antarctic and part of Chatham Rise), HAK4 (eastern Chatham Rise), and HAK7 (Challenger). Note that these figures do not show data prior to entry into the QMS.

### 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.

## $1.4 \quad$ 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 overreporting on the Chatham Rise (and hence under-reporting on the west coast South Island) was between 16 and $23 \%$ ( $700-1000 \mathrm{t}$ 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).

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 199091, suggested that actual catches were probably considerably higher than reported catches. For these years, the ratio of hake to hoki in the catch of vessels carrying observers was significantly higher than in the catch of vessels not carrying observers (Colman \& Vignaux 1992). The actual hake catch in HAK 7 for these years was estimated by multiplying the total hoki catch (which was assumed to be correctly reported by vessels both with and without observers) by the ratio of hake to hoki in the catch of vessels carrying observers. Reported and estimated catches for 1988-89 were respectively 6835 t and 8696 t ; for 1989-90, 4903 t reported and 8741 t estimated; and for 1990-91, 6189 t reported and 8246 t estimated. More recently, the level of such misreporting has not been estimated and is not known. No such corrections have been applied to either the HAK 1 or HAK 4 fishery.

For the purposes of stock assessment, the Chatham Rise stock was considered to include the whole of the Chatham Rise (including the western end currently forming part of the HAK 1 management area). Therefore, catches from this area were subtracted from the Sub-Antarctic stock and added to the Chatham Rise stock. The revised landings for $1974-75$ to 2009-10 are given in Table 3.

Table 3: Revised landings from fishing years 1974-75 to 2009-10 (t) for the west coast South Island, Sub-Antarctic, and Chatham Rise stocks.

| Fishing year | West coast S.I. | Sub-Antarctic | Chatham Rise |
| :---: | :---: | :---: | :---: |
| 1974-75 | 71 | 120 | 191 |
| 1975-76 | 5005 | 281 | 488 |
| 1976-77 | 17806 | 372 | 1288 |
| 1977-78 | 498 | 762 | 34 |
| 1978-79 | 4737 | 364 | 609 |
| 1979-80 | 3600 | 350 | 750 |
| 1980-81 | 2565 | 272 | 997 |
| 1981-82 | 1625 | 179 | 596 |
| 1982-83 | 745 | 448 | 302 |
| 1983-84 | 945 | 722 | 344 |
| 1984-85 | 965 | 525 | 544 |
| 1985-86 | 1918 | 818 | 362 |
| 1986-87 | 3755 | 713 | 509 |
| 1987-88 | 3009 | 1095 | 574 |
| 1988-89 | 8696 | 1237 | 804 |
| $1989-90^{1}$ | 8741 | 1917 | 957 |
| 1990-91 ${ }^{1}$ | 8246 | 2370 | 905 |
| 1991-92 | 3001 | 2743 | 2414 |
| 1992-93 | 7014 | 3254 | 2808 |
| 1993-94 | 2952 | 1450 | 2933 |
| 1994-95 | 9499 | 1852 | 3386 |
| 1995-96 | 9248 | 2870 | 3913 |
| 1996-97 | 6960 | 2271 | 3661 |
| 1997-98 | 7889 | 2628 | 3983 |
| 1998-99 | 8936 | 2802 | 3372 |
| 1999-00 | 7423 | 3030 | 2943 |
| 2000-01 | 8623 | 2849 | 2504 |
| 2001-02 | 7404 | 2512 | 1769 |
| 2002-03 | 7360 | 2729 | 1414 |
| 2003-04 | 8550 | 3252 | 2492 |
| 2004-05 | 7280 | 2528 | 3753 |
| 2005-06 | 6423 | 2554 | 359 |
| 2006-07 | 7656 | 1815 | 1081 |
| 2007-08 | 2618 | 2204 | 1098 |
| 2008-09 | 5922 | 2432 | 1825 |
| 2009-10 | 2316 | 1958 | 391 |

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.

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## 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. Both sexes reach sexual maturity between about 6 and 10 years of age, at lengths of about 67-75 cm TL (males) and 75-85 cm TL (females). Hake in HAK 1 and HAK 4 reach $50 \%$ maturity at about 6 years for males, and $7-8$ years for females (Horn \& Francis 2010).

Estimates of natural mortality ( $M$ ) and the associated methodology are given in Dunn et al. (2000); $M$ is estimated as $0.18 \mathrm{y}^{-1}$ for females and $0.20 \mathrm{y}^{-1}$ for males. Colman et al. (1991) previously estimated $M$ as $0.20 \mathrm{y}^{-1}$ for females and $0.22 \mathrm{y}^{-1}$ 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).

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).

Table 4: Estimates of biological parameters.


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 $15-20 \mathrm{~cm}$ total length at one year old, and about 35 cm total length at 2 years (Colman 1998). The biological parameters relevant to the stock assessments are given in Table 4.

## 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 QMA (HAK 7), (b) the Chatham Rise QMA (HAK 4) and (c), the remainder of the EEZ comprising the Auckland, Central, Southeast (Coast), Southland and Sub-Antarctic QMAs (HAK 1). An administrative fish stock (with no recorded landings) exists for the Kermadec QMA (HAK 10).

## 4. STOCK ASSESSMENT

The stock assessments reported here were completed in 2009 for the Chatham Rise stock (Horn \& Francis 2010), 2010 for the west coast South Island stock (Horn 2011), and 2011 for the SubAntarctic stock (Horn In prep.). 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 2011 stock assessment was carried out with data up to the end of the 2009-10 fishing year, implemented as a Bayesian model using the general-purpose stock assessment program CASAL v2.22 (Bull et al. 2008). The assessment used research time series of abundance indices (trawl surveys of the Sub-Antarctic from 1991 to 2009), catch-at-length and catch-at-age from the commercial fishery since 1990-91, and estimates of biological parameters.

### 4.1.1 Model structure

The base case model ('Single sex') partitioned the Sub-Antarctic stock population into unsexed age groups $1-30$ with the last age group considered a plus group. 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 1974-2007. The model used three doublenormal 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.

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Sensitivity models were also run to investigate the effects of including sex in the partition, including a trawl fishery CPUE series, estimating $M$ varying with age, and fitting the summer trawl survey series with two $q$ values separated between the 2006 and 2007 surveys.

Five-year biomass projections were made assuming future catches in the Sub-Antarctic to be 2300 t annually (the mean annual catch from 2005 to 2010). For each projection scenario, estimated future recruitment variability was sampled from actual estimates between 1974 and 2007.

### 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.

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 .

The catch history assumed in all model runs (Table 7) includes the revised estimates of catch reported by Dunn (2003). Resource survey abundance indices are given in Table 6.

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) | 0.90 |
| Proportion spawning | 1.0 |
| Proportion of recruits that are male $\quad$ Male, Female, Both | 0.5 |
| Natural mortality $(M) \quad 0.20 \mathrm{y}^{-1}, 0.18 \mathrm{y}^{-1}, 0.19 \mathrm{y}^{-1}$ |  |
| Maximum exploitation rate $\left(U_{\max }\right)$ | 0.7 |
| Ageing error | Normally distributed, with $\mathrm{CV}=0.08$ |

Table 6: Research survey indices (and associated CVs) for the Sub-Antarctic stock.

| Fishing Year | Vessel | Nov-Dec series ${ }^{1}$ |  | Apr-May series ${ }^{2}$ |  | Sep series ${ }^{2}$ |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Biomass (t) | CV | Biomass (t) | CV | Biomass (t) | CV |
| 1989 | Amaltal Explorer | 2660 | 0.21 |  |  |  |  |
| 1992 | Tangaroa | 5686 | 0.43 | 5028 | 0.15 | 3760 | 0.15 |
| 1993 | Tangaroa | 1944 | 0.12 | 3221 | 0.14 |  |  |
| 1994 | Tangaroa | 2567 | 0.12 |  |  |  |  |
| 1996 | Tangaroa |  |  | 2026 | 0.12 |  |  |
| 1998 | Tangaroa |  |  | 2554 | 0.18 |  |  |
| 2001 | Tangaroa | 2657 | 0.16 |  |  |  |  |
| 2002 | Tangaroa | 2170 | 0.20 |  |  |  |  |
| 2003 | Tangaroa | 1777 | 0.16 |  |  |  |  |
| 2004 | Tangaroa | 1672 | 0.23 |  |  |  |  |
| 2005 | Tangaroa | 1694 | 0.21 |  |  |  |  |
| 2006 | Tangaroa | 1459 | 0.17 |  |  |  |  |
| 2007 | Tangaroa | 1530 | 0.17 |  |  |  |  |
| 2008 | Tangaroa | 2470 | 0.15 |  |  |  |  |
| 2009 | Tangaroa | 2162 | 0.17 |  |  |  |  |
| 2010 | Tangaroa | 1442 | 0.20 |  |  |  |  |
| 2012* | Tangaroa | 2004 | 0.23 |  |  |  |  |

* Not used in the reported assessment.

Notes: (1) Series based on indices from $300-800 \mathrm{~m}$ core strata, including the $800-1000 \mathrm{~m}$ strata in Puysegur, but excluding Bounty Platform, (2) Series based on the biomass indices from 300-800 m core strata, excluding the $800-1000 \mathrm{~m}$ strata in Puysegur and the Bounty Platform.

Table 7: Commercial catch history ( $t$ ) for the Sub-Antarctic stock. Note that from 1990 totals by model year differ to 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 2011 are estimated assuming catch patterns similar to the previous year.

| Model year | Total | Model year | Total |
| :--- | ---: | :--- | ---: |
| 1975 | 120 | 1994 | 1596 |
| 1976 | 281 | 1995 | 1995 |
| 1977 | 372 | 1996 | 2779 |
| 1978 | 762 | 1997 | 1915 |
| 1979 | 364 | 1998 | 2958 |
| 1980 | 350 | 1999 | 2854 |
| 1981 | 272 | 2000 | 3108 |
| 1982 | 179 | 2001 | 2820 |
| 1983 | 448 | 2002 | 2444 |
| 1984 | 722 | 2003 | 2777 |
| 1985 | 525 | 2004 | 3223 |
| 1986 | 818 | 2005 | 2592 |
| 1987 | 713 | 2006 | 2541 |
| 1988 | 1095 | 2007 | 1711 |
| 1989 | 1237 | 2008 | 2329 |
| 1990 | 1897 | 2009 | 2446 |
| 1991 | 2381 | 2010 | 1927 |
| 1992 | 2810 | 2011 | 2000 |
| 1993 | 3941 |  |  |

### 4.1.3 Model estimation

Model parameters were estimated using Bayesian estimation implemented using the CASAL software (Bull et al. 2008). 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 lognormal likelihood, 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.

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 the survey biomass indices and proportion-at-age data in all model runs. The additional variance, termed process error, was estimated from MPD runs of the each model. The values for process error were then fixed for the MCMC runs.

Year class strengths were assumed known (and equal to one) for years prior to 1974 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 $3 \times 10^{6}$ iterations, a burn-in length of $5 \times 10^{5}$ iterations, and with every $2500^{\text {th }}$ sample kept from the final $2.5 \times 10^{6}$ 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 qs were estimated by assuming that $q$ was the product of areal availability, vertical availability, and vulnerability. A simple simulation was conducted that estimated a distribution of possible values for the relativity constant by assuming that each of these factors was uniformly distributed. A prior was then determined by assuming that the resulting, sampled, distribution was lognormally distributed. Values assumed for the parameters were; areal availability

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( $0.50-1.00$ ), 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 $q$.

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 1974 to 1979.

Table 8: The assumed priors for key distributions (when estimated). The parameters are mean (in natural space) and c.v. for lognormal.

| Parameter description | Distribution | Parameters |  |  | Bounds |
| :--- | :--- | ---: | ---: | ---: | ---: |
|  |  |  |  |  |  |
| $B_{0}$ | Uniform-log | - | - | 000 | 350000 |
| Year class strengths | Lognormal | 1.0 | 1.1 | 0.01 | 100 |
| Trawl survey $q$ | Lognormal | 0.16 | 0.79 | 0.01 | 0.4 |
| CPUE $q$ | Uniform-log | - | - | $1 \mathrm{e}-8$ | 0 |
| Selectivities | Uniform | - | - | 0 | $20-200^{*}$ |
| $M\left(x_{0}, y_{0}, y_{1}, y_{2}\right)$ | 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


### 4.1.5 Model estimates

Estimates of biomass were produced for an agreed base case run (the Single sex model using the biological parameters and model input parameters described earlier. In addition, four sensitivities were investigated: (1) splitting the summer survey series into early (1992-2006) and recent (2007-09) series with independent $q \mathrm{~s}$, (2) including sex in the partition, (3) including the trawl CPUE series, and (4) estimating $M$ as a double-exponential function, thus allowing $M$ to vary with age. 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 and estimate $M$ runs are reported in detail here. The other three sensitivities produced estimates of stock status that were little different to those from the reported models.

The estimated MCMC marginal posterior distributions from the base case model are shown for year class strength (Figure 2) and biomass (Figure 3). Year class strength estimates suggested that the SubAntarctic stock is characterised by a group of relatively strong relative 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 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 two reported models at about $50 \%$ 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 in relationship to the level of relative catches.

Resource survey and fishery selectivity ogives were relatively tightly defined and strongly domed. The survey ogive suggested that hake were not fully selected by the research gear until about age 14. Fishing selectivities indicated that hake were fully selected by about age 9 years. Fish younger than about 7 years were more selected by the trawl surveys, as would be expected given the use of smaller mesh size than in the commercial fishery.

The assessment relied on biomass data from the Sub-Antarctic trawl survey series. The summer survey series was not well fitted and had clear patterns in the residuals. It was also apparent that there can be marked changes in catchability between adjacent pairs of surveys. Estimated trawl survey catchability constants were very low (about $2-6 \%$ 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 the 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 $\left(20 \% B_{0}\right.$, dotted horizontal line) are shown on the right-hand panel.

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 catch-at-age data) current stock size is healthy relative to the estimated virgin biomass. Catches averaging about 2400 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 2300 t , in tandem with some recent stronger than average year classes, are projected to allow stock size to increase by about $50 \%$ by 2016 (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 early 1990s, the absolute level of current biomass is very uncertain.

Table 9: Bayesian median ( $95 \%$ credible intervals) (MCMC) of $B_{0}, B_{2011}$, and $B_{2011}$ as a percentage of $B_{0}$ for the Sub-Antarctic base case.

| Model run | $B_{0}$ |  | $B_{2011}$ |  | $B_{2011}\left(\% B_{0}\right)$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Base case (Single sex) | 94150 | (59 220-156 350) | 49590 | (23 860-95 220) | 52.3 (39.0-64.5) |
| Estimate M | 78240 | (51 810-135 590) | 36170 | (17 820-77 080) | 46.2 (32.3-58.6) |

Table 10: Bayesian median ( $95 \%$ credible intervals) projected biomass in $2016\left(B_{2016}\right), B_{2016}$ as a percentage of $\boldsymbol{B}_{0}$, and $B_{2016} / B_{2011}(\%)$ for the Sub-Antarctic base case where future catches are assumed to be 2300 t .

| Future catch | Model run | B $_{2016}$ |  | $\mathrm{B}_{2016}\left(\% \mathrm{~B}_{0}\right.$ ) |  | $\underline{B}_{2016}$ | (B2011 (\%) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 2300 t | Base case (Single sex) | 74630 | (35 390-147 810) | 78.4 | (53.5-110.9) | 150 | (119-200) |
|  | Estimate M | 62080 | (27 760-136 220) | 78.8 | (51.2-111.6) |  | (132-229) |

### 4.1.6 Estimates of sustainable yields

$C A Y$ yield estimates were not reported because of the high uncertainty of the estimates of absolute biomass.

### 4.2 HAK 4 (Chatham Rise stock)

The 2009 stock assessment was carried out with data up to the end of the 2008-09 fishing year, implemented as a Bayesian model using the general-purpose stock assessment program CASAL v2.21 (Bull et al. 2008). The assessment used research time series of abundance indices (trawl surveys of the Chatham Rise from 1992 to 2009), catch-at-age from the trawl survey series and the commercial fishery since 1990-91, and estimates of biological parameters.

### 4.2.1 Model structure

Two stock assessment models were run. The base case model ('Single sex') partitioned the Chatham Rise stock population into unsexed age groups 1-30 with the last age group considered a plus group. A sensitivity model ('Two sex') was the same as the base case except that sex was included in the partition. The models were initialised assuming an equilibrium age structure at an unfished equilibrium biomass $\left(B_{0}\right)$, i.e., with constant recruitment set equal to the mean of the recruitments over the period 1975-2006.

The Single sex model used three selectivity-at-age ogives; east and west commercial fishing selectivities and a survey selectivity for the Chatham Rise January trawl survey series. All selectivity ogives were fitted using the double-normal parameterisation. 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. In the Two sex model, ogives were estimated by sex, i.e., there were six ogives.

Five-year biomass projections were made assuming future catches on the Chatham Rise to be either the HAK 4 TACC of 1800 t plus average estimated HAK 1 Chatham catch from 1991-92 to 2004-05 of 1000 t (i.e., 2800 t , "high catch scenario"), or the approximate catch level from recent years of 1150 t ("low catch scenario"). For each projection scenario, estimated future recruitment variability was sampled from actual estimates between 1997 and 2006 (i.e., a period of recruitment lower than the long term average).

### 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 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 .

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 estimated using Bayesian estimation implemented using the CASAL software (Bull et al. 2008). Only the mode of the joint posterior distribution (MPD) was estimated in preliminary runs. For final 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 lognormal likelihood, 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 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 | 1993 | 656 | 1996 | 2652 |
| 1976 | 152 | 336 | 488 | 1994 | 368 | 2912 | 3280 |
| 1977 | 74 | 1214 | 1288 | 1995 | 597 | 2903 | 3500 |
| 1978 | 28 | 6 | 34 | 1996 | 1353 | 2483 | 3836 |
| 1979 | 103 | 506 | 609 | 1997 | 1475 | 1820 | 3295 |
| 1980 | 481 | 269 | 750 | 1998 | 1424 | 1124 | 2547 |
| 1981 | 914 | 83 | 997 | 1999 | 1169 | 3339 | 4509 |
| 1982 | 393 | 203 | 596 | 2000 | 1155 | 2130 | 3285 |
| 1983 | 154 | 148 | 302 | 2001 | 1208 | 1700 | 2908 |
| 1984 | 224 | 120 | 344 | 2002 | 454 | 1058 | 1512 |
| 1985 | 232 | 312 | 544 | 2003 | 497 | 718 | 1215 |
| 1986 | 282 | 80 | 362 | 2004 | 687 | 1983 | 2671 |
| 1987 | 387 | 122 | 509 | 2005 | 2585 | 1434 | 4019 |
| 1988 | 385 | 189 | 574 | 2006 | 184 | 255 | 440 |
| 1989 | 386 | 418 | 804 | 2007 | 270 | 683 | 953 |
| 1990 | 309 | 689 | 998 | 2008 | 259 | 901 | 1159 |
| 1991 | 409 | 503 | 912 | 2009 | 250 | 890 | 1140 |
| 1992 | 718 | 1087 | 1805 |  |  |  |  |

Table 12: Research survey indices (and associated CVs) for the Chatham Rise stock.

| Year | Vessel | Biomass (t) | CV |
| :--- | :--- | ---: | ---: |
| 1989 | Amaltal Explorer | 3576 | 0.19 |
| 1992 | Tangaroa | 4180 | 0.15 |
| 1993 | Tangaroa | 2950 | 0.17 |
| 1994 | Tangaroa | 3353 | 0.10 |
| 1995 | Tangaroa | 3303 | 0.23 |
| 1996 | Tangaroa | 2457 | 0.13 |
| 1997 | Tangaroa | 2811 | 0.17 |
| 1998 | Tangaroa | 2873 | 0.18 |
| 1999 | Tangaroa | 2302 | 0.12 |
| 2000 | Tangaroa | 2090 | 0.09 |
| 2001 | Tangaroa | 1589 | 0.13 |
| 2002 | Tangaroa | 1567 | 0.15 |
| 2003 | Tangaroa | 890 | 0.16 |
| 2004 | Tangaroa | 1547 | 0.17 |
| 2005 | Tangaroa | 1049 | 0.18 |
| 2006 | Tangaroa | 1384 | 0.19 |
| 2007 | Tangaroa | 1820 | 0.12 |
| 2008 | Tangaroa | 1257 | 0.13 |
| 2009 | Tangaroa | 2419 | 0.21 |
| $2010 *$ | Tangaroa | 1700 | 0.25 |
| $2011^{*}$ | Tangaroa | 1099 | 0.15 |
| $2012^{*}$ | Tangaroa | 1292 | 0.15 |
| * | Not used in the reported assessment. |  |  |

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 the proportion-at-age data in all model runs. The additional variance, termed process error, was estimated from MPD runs of the each model. The values for process error were then fixed for the MCMC runs. No process error was added to the trawl survey biomass estimates, hence encouraging the model to fit this series well.

Year class strengths before 1975 were assumed known (and equal to one), as 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.

## HAKE (HAK)

MCMCs were estimated using a burn-in length of $5 \times 10^{5}$ iterations, with every $2500^{\text {th }}$ sample taken from the next $2.5 \times 10^{6}$ 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. 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 qs which were estimated using a simple simulation as described in section 4.1.4 above. Note that the values of survey catchability 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 $q$.

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 1974 to 1983.

Table 13: The assumed priors assumed for key distributions (when estimated). The parameters are mean (in natural space) and CV for lognormal; and mean and s.d. for normal.

| Stock | Parameter | Distribution | Parameters |  | Bounds |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Chatham Rise | $B_{0}$ | Uniform-log | - | - | 10000 | 250000 |
|  | Survey $q$ | Lognormal | 0.16 | 0.79 | 0.01 | 0.40 |
|  | YCS | Lognormal | 1.0 | 1.1 | 0.01 | 100 |

### 4.2.5 Model estimates

Estimates of biomass were produced for the two model runs using the biological parameters and model input parameters described earlier (Table 14). For all runs, MPD fits were obtained and qualitatively evaluated. In addition, MCMC estimates of the median posterior and $95 \%$ percentile credible intervals are reported for current and virgin biomass, and projected states based on either the high or low catch scenarios.

Table 14: Model run labels and descriptions for the base case and sensitivity model runs.

Model run
Single sex (Base case)
Two sex

## Description

Two fisheries, survey biomass series, unsexed catch-at-age data, sex excluded from the partition
Same as the base case, but including sexed catch-at-age data, and sex in the partition

Estimated MCMC marginal posterior distributions from the Base case model are shown for year class strengths (Figures 4) and biomass (Figure 5). 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 biomass estimates for the stock were estimated at about $47 \%$ of $B_{0}(95 \%$ credible intervals $39-55 \%$ ) (see Figure 5 and Table 15). 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.

Resource survey and fishery selectivity ogives were relatively tightly defined. The survey ogive suggested that hake were not fully selected by the research gear until about age 16. Fishing selectivities indicated that hake were fully selected in the western fisheries by about age 7 years, compared to age 12 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 under two assumed future catch scenarios ( 1150 t or 2800 t annually from 2010 to 2014) suggested that biomass will decline slightly to about $44 \%$ of $B_{0}$ (lower catch) or $31 \%$ of $B_{0}$ (higher) by 2014 (Table 16). There is little risk that the stock will fall below $20 \% B_{0}$ in the next five years under either catch scenario.

Table 15: Bayesian median and $95 \%$ credible intervals of $\boldsymbol{B}_{0}, \boldsymbol{B}_{2009}$, and $\boldsymbol{B}_{2009}$ as a percentage of $\boldsymbol{B}_{0}$ for the Chatham Rise base and sensitivity case.

Model run
Base case (Single sex)
Two sex

## - $\boldsymbol{B}$ <br> 41030 (34 910-52 070)

 67600 (52 420-98 560)$\boldsymbol{B}_{200}$
$19160(14160-27810)$
$37870(25870-62 ~ 260)$
37870 (25 870-62 260)
$\boldsymbol{B}_{2009}\left({ }^{\left(\% B_{0}\right)}\right.$
46.7 (39.4-54.5)
56.4 (48.6-64.9)

Table 16: Bayesian median and $95 \%$ credible intervals of projected $B_{2014}, B_{2014}$ as a percentage of $B_{0}$, and $B_{2014} / B_{2009}$ (\%) for the Chatham Rise base and sensitivity case where future catches are assumed to be 2800 t or 1150 t .

| Model run | Future catch (t) | $\boldsymbol{B}_{2014}$ | $\boldsymbol{B}_{2014}\left(\% \boldsymbol{B}_{\boldsymbol{o}}\right)$ | $\boldsymbol{B}_{2014} / \boldsymbol{B}_{2009}(\%)$ |
| :--- | ---: | ---: | ---: | ---: |
| Base case (Single sex) | 1150 | $18080(12740-27300)$ | $44.1(35.0-54.9)$ | $94(83-107)$ |
|  | 2800 | $12850(7370-22450)$ | $31.1(20.4-43.9)$ | $67(51-82)$ |
| Two sex | 1150 | $35910(22960-60250)$ | $52.8(42.4-68.8)$ | $93(83-113)$ |
|  | 2800 | $30760(18010-55870)$ | $45.0(33.2-62.0)$ | $79(66-101)$ |



Figure 4: Estimated posterior distributions of year class strengths for the base case. The dashed horizontal line indicates the year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.


Figure 5: Estimated median trajectories (with $95 \%$ credible intervals shown as dashed lines) for the base case model for absolute biomass and biomass as a percentage of $\boldsymbol{B}_{0}$.

Estimated MCMC marginal posterior distributions from the Two sex model for year class strengths were virtually identical to those from the base case. Absolute biomass was estimated to be greater, and stock status estimated to be better, than for the base case, i.e., current biomass at about $56 \%$ of $B_{0}$ (Figure 6, Table 15). Annual exploitation rates have been generally low (i.e., unlikely to have been greater than 0.2 in the years of peak exploitation). Selectivity ogives were relatively tightly defined. The survey ogive suggested that hake of both sexes were not fully selected until about age 14. Fishing selectivities indicated full selection in the western and eastern fisheries by about ages 7 and 12, respectively.

Two sex model projections under two assumed future catch scenarios (1150 t or 2800 t annually from 2010 to 2014) suggested that biomass will decline slightly to about $53 \%$ of $B_{0}$ (lower catch) or $45 \%$ of $B_{0}$ (higher) by 2014 (Table 16). There is negligible risk that the stock will fall below $20 \% B_{0}$ in the next five years under either catch scenario.


Figure 6: Estimated median trajectories (with 95\% credible intervals shown as dashed lines) for the Two sex model for absolute biomass and biomass as a percentage of $\boldsymbol{B}_{0}$.

The Single sex model was considered to be better than the Two sex model (and was chosen as the base case) because it fitted the research biomass series and the observer catch-at-age data best, and it does not have to try and account for the apparent changes in population sex ratios over time.

### 4.2.6 Estimates of sustainable yields

$C A Y$ yield estimates were not reported because of the uncertainty of the estimates of absolute biomass.

### 4.3 HAK 7 (West coast, South Island)

The 2010 stock assessment was carried out with data up to the end of the 2009-10 fishing year, implemented as a Bayesian model using the general-purpose stock assessment program CASAL v2.21 (Bull et al. 2008). The assessment used catch-at-age from the commercial fishery since 1989-90 and from a single research survey in 1979, and estimates of biological parameters. CPUE series were available, but were considered unreliable as abundance indices as fishing (particularly target fishing) and reporting practices for hake off WCSI have varied markedly over time.

The stock assessment for HAK 7 had been last updated using data up to the end of the 2003-04 fishing year (Dunn 2004). 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 stock assessment model partitioned the population into unsexed age groups $1-30$, with the last age class considered a plus group. The model was initialised assuming an equilibrium age structure at an unfished equilibrium biomass $\left(B_{0}\right)$, i.e., with constant recruitment set equal to the mean of the recruitments over the period 1973-2004. A single sex model was considered to be better than a two sex model because it fitted the observer catch-at-age data best, and it does not have to try and account for the apparent changes in population sex ratios over time.

The model used a single selectivity ogive for the trawl fishery and trawl survey, fitted using the double normal parameterisation. Selectivity was assumed constant over all years, and hence there was no allowance for possible annual changes in selectivity. A base model was run, as well as two sensitivity models testing the effect of changing $M$ to 0.15 or 0.24 (instead of the base value of 0.19 ).

Five-year biomass projections were made assuming future annual catches off WCSI to be either 6000 t or 7700 t . The low catch scenario ( 6000 t ) approximates the catch level from recent years. The high catch scenario ( 7700 t ) is the highest likely level of catch as it equates to the HAK 7 TACC. For each projection scenario, estimated future recruitment variability was sampled from actual recent estimates between 1995 and 2004.

### 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.

Catch-at-age observations were available for commercial observer data from 1989-90 to 2008-09. These data, along with the proportions-at-age data from the Wesermünde in 1979, were fitted to the model as proportions-at-age. The catch history assumed in the model runs (Table 3) included the revised estimates of catch reported by Dunn (2003).

### 4.3.3 Model estimation

Model parameters were estimated using Bayesian estimation implemented using CASAL (Bull et al. 2008). Catch-at-age data were fitted to the model as proportions-at-age with a lognormal likelihood, where estimates of the proportions-at-age and associated CVs by age were estimated using the NIWA catch-at-age software by bootstrap. The CVs 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 the proportion-at-age data in all model runs. The additional variance, termed process error, was estimated from initial MPD runs to be 0.45 .

Year class strengths before 1973 were assumed known (and equal to one), as 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.

### 4.3.4 Prior distributions and penalty functions

The assumed prior distributions used in the assessment are given in Table 17. The priors were intended to be relatively uninformed, and were estimated with wide bounds.

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, and b) to ensure that all estimated year class strengths averaged 1.

Table 17: The assumed priors assumed for key distributions (when estimated). The parameters are mean (in natural space) and CV for lognormal.

| Stock | Parameter | Distribution | Parameters |  | Bounds |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| West coast S.I. | $B_{0}$ | Uniform-log | - | - | 10000 | 350000 |
|  | YCS | Lognormal | 1.0 | 1.1 | 0.01 | 100 |

### 4.3.5 Model estimates

Estimates of biomass were produced for the three model runs using the biological parameters and model input parameters described earlier. For all runs, MPD fits were obtained and qualitatively evaluated, and MCMC estimates of the median posterior and $95 \%$ percentile credible intervals were produced for current and virgin biomass, and projected states. However, the Working Group concluded that none of the models provided results that were sufficiently reliable to be reported here.

### 4.3.6 Investigation of mortality rates

Rates of total instantaneous mortality (Z) were estimated from each of the available commercial trawl catch-at-age distributions using the Chapman-Robson method. The point estimates were very variable, ranging from 0.24 to 0.56 (Figure 7). There appeared to be two distinct groups of samples: 1990-98 (with a mean $Z$ of 0.31 ), and 1999-2009 (with a mean of 0.43 ). Assuming that 0.19 is a reasonably accurate estimate of $M$, then instantaneous fishing mortality $(F)$ in the peak exploitation years of the fishery has averaged about 0.24 annually.


Figure 7: Maximum likelihood Chapman-Robson estimates of instantaneous total mortality ( $Z$ ), by year, from the commercial trawl fishery proportion-at-age distributions. $Z$ has been derived in each year using three values of age at full selectivity $(R)$.

An examination of the most recent trawl fishery catch-at-age distributions indicated successful recruitment in recent years and relatively abundant fish in year classes older than the age at full recruitment out to about 19 years (Figure 8).


Figure 8: Estimated proportions-at-age (sexes combined) in the commercial trawl fishery in 2008 and 2009.

### 4.3.6 Estimates of sustainable yields

$M C Y$ or $C A Y$ yield estimates were not reported because there are no reliable estimates of absolute biomass.

## 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 | 2011 |  |  |  |  |
| Assessment Runs Presented | A base case and one sensitivity run. |  |  |  |  |
| Reference Points | Management Target: $40 \% B_{0}$ <br> Soft Limit: $20 \% B_{0}$ <br> Hard Limit: $10 \% B_{0}$ |  |  |  |  |
| Status in relation to Target | $B_{2011}$ was estimated to be about $50 \% B_{0}$; Very Likely (> 90\%) to be at or above the target. |  |  |  |  |
| Status in relation to Limits | $B_{2011}$ is Exceptionally Unlikely ( $<1 \%$ ) to be below both the Soft and Hard Limits. |  |  |  |  |
|  |  |  |  |  |  |

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 2011 (the final assessment year). The management target $\left(40 \% B_{0}\right.$, solid horizontal line) and soft limit $\left(20 \% B_{0}\right.$, 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.

| Fishery and Stock Trends |  |
| :--- | :--- |
| Recent Trend in Biomass or <br> Proxy | Median estimates of biomass are unlikely to have been below <br> $51 \% B_{0}$. Biomass is estimated to have been decreasing from the <br> late 1980s to 2009, but is now increasing. |
| Recent Trend in Fishing <br> Mortality or Proxy | Fishing pressure is estimated to have been relatively low <br> throughout the duration of the fishery. |
| Other Abundance Indices | - |
| Trends in Other Relevant <br> Indicators or Variables | Recent recruitment (2005-2007) is estimated to be higher than the <br> long-term average for this stock. |

## Projections and Prognosis (2016)

Stock Projections or Prognosis $\quad$ The biomass of the Sub-Antarctic stock was expected to increase at a catch level equivalent to the mean since 2005 (i.e., 2300 t annually).
Probability of Current Catch or TACC causing decline below

Soft Limit: Very Unlikely (< 10\%)
Hard Limit: Exceptionally Unlikely (< 1\%)

Median estimates of biomass are unlikely to have been below $51 \% B_{0}$. Biomass is estimated to have been decreasing from the late 1980s to 2009, but is now increasing.
Fishing pressure is estimated to have been relatively low throughout the duration of the fishery.

Recent recruitment (2005-2007) is estimated to be higher than the long-term average for this stock.

Assessment Methodology

| Assessment Type | Level 1-Quantitative stock assessment |
| :--- | :--- |
| Assessment Method | Age-structured CASAL model with Bayesian estimation of <br> posterior distributions. |
| Main data inputs | - Two research time series of abundance indices (trawl surveys). <br> - Proportions-at-age data from the commercial fisheries and trawl <br> surveys. |


|  | -Estimates of biological parameters. |
| :--- | :--- |
| Period of Assessment | Latest assessment: $2011 \quad$ Next assessment: 2014 |
| Changes to Model Structure and <br> Assumptions | Previous assessments included sex in the partition. The two model <br> runs reported above exclude sex from the partition. |
| Major Sources of Uncertainty | The summer trawl survey series has shown a slight overall decline <br> over time, but individual survey estimates are variable and <br> catchability clearly varies between surveys. The general lack of <br> contrast in this series (the main relative abundance series) makes it <br> difficult to accurately estimate past and current biomass. <br> The assumption of a single Sub-Antarctic stock (including the <br> Puysegur Bank), independent of hake in all other areas, is the most <br> parsimonious interpretation of available information. However, <br> this assumption may not be correct. |
|  | Uncertainty about the size of recent year classes affects the <br> reliability of stock projections. <br> Although the catch history used in the assessment has been <br> corrected for some misreported catch (see section 1.4), it is <br> possible that additional misreporting exists. |

## Qualifying Comments

Four sensitivity model runs reported in a FAR but not in the Plenary Report all produced similar estimates of stock status to the base case (i.e., $B_{2011}=45-67 \% B_{0}$ ).

## 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 | 2009 |
| Assessment Runs Presented | Two alternative model runs: the "Single sex" (base case) model <br> was considered more plausible than the "Two sex" model. |
| Reference Points | Management Target: $40 \% B_{0}$ <br> Soft Limit: $20 \% B_{0}$ <br> Hard Limit: $10 \% B_{0}$ |
| Status in relation to Target | $B_{2009}$ was estimated to be about 47\% $B_{0 ;}$; Likely (> 60\%) to be at or <br> above target. |
| Status in relation to Limits | $B_{2009}$ is Very Unlikely $(<10 \%)$ to be below the Soft Limit and <br> Exceptionally Unlikely (<1\%) to be below the Hard Limit. |

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 2009 (the final assessment year). 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 | Median estimates of biomass are unlikely to have been below <br> $41 \% \boldsymbol{B}_{0}$. Biomass has subsequently been increasing. |
| :--- | :--- |
| Recent Trend in Biomass or |  |
| Proxy |  |$\quad$| Fishing pressure is estimated to have been low since 2006 (relative |
| :--- |
| to estimated pressure in most years from 1994 to 2005). |


| Projections and Prognosis (2009) |  |
| :--- | :--- |
| Stock Projections or Prognosis | The biomass of the Chatham Rise stock is expected to decrease <br> slightly over the next 5 years at catch levels equivalent to those <br> from recent years (i.e., about 1150 t annually), but is projected to <br> decline markedly if future catches are close to the high catch <br> scenario (i.e. annual catch levels equivalent to the HAK 4 TACC <br> of 1800 t plus the average HAK 1 Chatham Rise catch from 1991- <br> 92 to 2004-05 of 1000 t per year). |
| Probability of Current Catch or <br> TACC causing decline below <br> Limits | Soft Limit: Unlikely ( $<10 \%$ ) <br> Hard Limit: Very Unlikely ( < 1\%) |


| Assessment Methodology | Level 1 - Quantitative stock assessment |
| :--- | :--- |
| Assessment Type | Age-structured CASAL model with Bayesian estimation of <br> posterior distributions. |
| Assessment Method | - Research time series of abundance indices (trawl survey). <br> - Proportions-at-age data from the commercial fisheries and trawl <br> surveys. <br> -Estimates of biological parameters. <br> New information since the 2006 assessment included three trawl <br> surveys, and updated catch and catch-at-age data. |
| Main data inputs | Latest assessment: 2009 Next assessment: 2012 <br> Period of Assessment <br> (Single sex) model reported above excludes sex from the partition. |
| Changes to Model Structure and <br> Assumptions | Sever |


| Major Sources of Uncertainty | While the Single sex model is considered more credible than the <br> Two sex model, it is not clear why the addition of sex in the <br> partition results in a 66\% increase in $B_{0}$. It is possible that a larger <br> stock allows the model to better fit the variable catch-at-age by sex <br> data when biomasses are higher. However, the Two sex model <br> should not be considered completely unreliable. <br> The assumption of a single Chatham Rise stock independent of <br> hake in all other areas is the most parsimonious interpretation of <br> available information. <br> Uncertainty about the size of recent year classes affects the <br> reliability of stock projections. <br> Although the catch history used in the assessment has been <br> corrected for some misreported catch (see section 1.4), it is <br> possible that additional misreporting exists. <br> It is assumed in the assessment models that natural mortality is <br> constant over all ages. The use of dome-shaped selectivity ogives <br> will compensate for some variation in mortality rate with age. |
| :--- | :--- |

## Qualifying Comments

The increase in relative abundance seen since 2005 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 not been repeated in subsequent years, nor did it occur in previous years. There is no information indicating whether the 2004 aggregation fished on the western Chatham Rise was spawning; if it was 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 noted for New Zealand fur seals and seabirds.

## - West coast South Island Stock (HAK 7)

| Stock Status | 2010 |
| :--- | :--- |
| Year of Most Recent Assessment | A base case, with sensitivity runs investigating the effects of <br> varying $M$. However, none of the models was believed to provide <br> reliable results. |
| Assessment Runs Presented | Management Target: $40 \% B_{0}$ <br> Soft Limit: $20 \% B_{0}$ <br> Hard Limit: $10 \% B_{0}$ |
| Reference Points | Unknown |
| Status in relation to Target | Unknown |
| Status in relation to Limits | Historical Stock Status Trajectory and Current Status <br> Unknown |

## Fishery and Stock Trends

| Recent Trend in Biomass or <br> Proxy | Unknown |
| :--- | :--- |


| Recent Trend in Fishing Mortality or Proxy |  <br> Maximum likelihood Chapman-Robson estimates of instantaneous total mortality ( $Z$ ), by year, from the commercial trawl fishery proportion-at-age distributions. $Z$ has been derived in each year using three values of age at full selectivity ( $R$ ). <br> Fishing pressure is estimated to have about the level of, or slightly higher than $M$ since the mid 1990s. |
| :---: | :---: |
| Other Abundance Indices | - |
| Trends in Other Relevant Indicators or Variables | Recruitment appears to have varied little over time, and has continued to be successful in recent years. |


| Projections and Prognosis (2010) |  |
| :--- | :--- |
| Stock Projections or Prognosis | The relatively constant catch history since 1989 and the relative <br> constancy of the trawl catch-at-age distributions since 1990 <br> suggest that future catches at the TACC can probably be <br> maintained without causing the stock size to decline markedly. |
| Probability of Current Catch or <br> TACC causing decline below <br> Limits | Soft Limit: Unknown <br> Hard Limit: Unknown |


| Assessment Methodology | Level 1 - Quantitative stock assessment |
| :--- | :--- |
| Assessment Type | Age-structured CASAL model with Bayesian estimation of <br> posterior distributions. |
| Assessment Method | - Proportions-at-age data from the commercial fishery and one <br> research voyage. <br> - Estimates of biological parameters. |
| Main data inputs | Latest assessment: 2010 Next assessment: 2012 |
| Period of Assessment | The previous assessment had used a two-sex model. |
| Assumptions |  |$\quad$| There are no reliable indices of abundance. Although CPUE series |
| :--- |
| are available they are believed to be driven by fisher behaviour |
| rather than hake abundance, so are considered unreliable. |
| The assumption of a single WCSI stock independent of hake in all |
| other areas is the most parsimonious interpretation of the available |
| information. |
| 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 (although the effects of varying $M$ have been |

## Qualifying Comments

Owing to the lack of a reliable abundance series this assessment is considered too uncertain to be reported.

## 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.

## Table 18: Summary of TACCs ( $\mathbf{t}$ ) and reported landings for the most recent fishing year.

| Fishstock | QMA | $\mathbf{2 0 1 0 - 1 1}$ <br> actual TACC | $\mathbf{2 0 1 0 - 1 1}$ <br> reported landings |
| :--- | :--- | ---: | ---: |
| HAK 1 | Auckland, Central Southeast, Southland, | 3701 | 1904 |
|  | Sub-Antarctic (QMA 1, 2, 3, 5, 6, 8, 9) | 1800 | 179 |
| HAK 4 | Chatham Rise (QMA 4) | 7700 | 3754 |
| HAK 7 | Challenger (QMA 7) | 10 | - |
| HAK 10 |  | 13211 | 5838 |
| Total |  |  |  |

## 6. FOR FURTHER INFORMATION

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Colman J.A. 1988. Hake. New Zealand Fisheries Assessment Research Document 1988/31. 23 p.
Colman J.A. 1998. Spawning areas and size and age at maturity of hake (Merluccius australis) in the New Zealand Exclusive Economic Zone. New Zealand Fisheries Assessment Research Document 1998/2. 17 p.
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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 $300-700 \mathrm{~m}$ 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 $400-800 \mathrm{~m}$. 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-ofseason 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 100000 t in 1977, but dropped to less than 20000 t in 1978 when the EEZ was declared and quota limits were introduced (Table 1). From 1979 on, the hoki catch increased to about 50000 t until an increase in the TACC from 1986 to 1990 saw the fishery expand to a maximum catch in 1987-88 of about 255000 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 nonspawning fisheries. Since 1998 twin-trawl rigs have operated in some hoki fisheries.
Annual catches ranged between 175000 and 215000 t from 1988-89 to 1995-96, increasing to 246000 t in 1996-97, and peaking at 269000 t in 1997-98, when the TACC was over-caught by 19000 t . Catches

## HOKI (HOK)

declined as the TACC was reduced, to a low of 89000 t in 2008-09, but increased to 118500 t in 2010-11 following increases in TACC to 120000 t (Table 2). From 1 October 2011 the TACC was further increased to 130000 t as well as the allowance for other mortality to 1200 t . With the 20 t allowance for customary and recreational catch, implemented in 1 October 2007, the TAC increased to 131240 t .

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 | 7300 | 1636 | - | - | - | 8936 |
| 1973 | 3900 | 4758 | - | - | - | 8658 |
| 1974 | 13700 | 2160 | - | 125 | - | 15985 |
| 1975 | 36300 | 4748 | - | 62 | - | 41110 |
| 1976 | 41800 | 24830 | - | 142 | - | 66772 |
| 1977 | 33500 | 54168 | 9865 | 217 | - | 97750 |
| $1978^{*}$ | $\dagger 2028$ | 1296 | 4580 | 678 | - | 8581 |
| 1979 | 4007 | 8550 | 1178 | 2395 | 7970 | 24100 |
| 1980 | 2516 | 6554 | - | 2658 | 16042 | 27770 |
| 1981 | 2718 | 9141 | 2 | 5284 | 15657 | 32802 |
| 1982 | 2251 | 7591 | - | 6982 | 15192 | 32018 |
| 1983 | 3853 | 7748 | 137 | 7706 | 20697 | 40141 |
| $1983-84$ | 4520 | 7897 | 93 | 9229 | 28668 | 50407 |
| $1984-85$ | 1547 | 6807 | 35 | 7213 | 28068 | 43670 |
| $1985-86$ | 4056 | 6413 | 499 | 8280 | 80375 | 99623 |
| $1986-87$ | 1845 | 4107 | 6 | 8091 | 153222 | 167271 |
| $1987-88$ | 2412 | 4159 | 10 | 7078 | 216680 | 230339 |

* 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.
$\dagger$
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.

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 TAC changes and re-distribution of fishing effort. The catch from the WCSI declined steadily from 1988-89 to 1995-96, increased again to between 90000 and 107000 t from 1996-97 until 2001-02, then dropped sharply over seven years, to 20600 t in 2008-09. The WCSI catch increased to 48300 t in 2010-11, which was about $41 \%$ of the total hoki catch, making this the largest fishery. In Cook Strait, catches peaked at 67000 t in 1995-96, but have been decreasing for the last seven years. The catch from Cook Strait in 2010-11 of 14900 t was the lowest since 1989-90. Non-spawning catches on the Chatham Rise peaked at about 75000 t in 1997-98 and 1998-99, then decreased to a low of 30700 t in 2004-05, before increasing again to 39000 t in 2008-09 and 2009-10. The Chatham Rise was the largest fishery from 2006-07 to 2009-10. Catches from the Chatham Rise dropped slightly to 38400 t in 2010-11, contributing about $32 \%$ of the total catch. Catches from the Southern Plateau peaked at over 30000 t in 1999-00 to 2001-02, declined to a low of 6200 t in 2004-05 before increasing slowly to 12600 t in 2010-11. Catches from other areas have remained at relatively low levels (Table 3).

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 of 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 a further agreement with the Minister that only $40 \%$ of the catch should be taken from western fisheries. From 1 October 2007 the target catch from the western fishing grounds was further reduced to 25000 t within the overall TACC of 90000 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 344
grounds was increased to 50000 t within the overall TACC of 110000 t , and catches were at about the industry-agreed catch split. In 2010-11, the target catch from the western fishing grounds was increased to 60000 t within the overall TACC of 120000 t and a catch of 62000 t was taken. In the current fishing year (2011-12), the target catch from the western fishing grounds has been increased further to 70000 t within the overall TACC of 130000 t . 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 2: Reported catch (t) from QMS, estimated catch (t) data, and TACC (t) for HOK 1 from 1986-97 to 2010-11.
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 |
| :--- | ---: | ---: | ---: |
| $1986-1987$ | 158000 | 175000 | 250000 |
| $1987-1988$ | 216000 | 255000 | 250000 |
| $1988-1989$ | 208500 | 210000 | 250000 |
| $1989-1990$ | 210000 | 210000 | 251884 |
| $1990-1991$ | 215000 | 215000 | 201897 |
| $1991-1992$ | 215000 | 215000 | 201897 |
| $1992-1993$ | 195000 | 195000 | 202155 |
| $1993-1994$ | 191000 | 190000 | 202155 |
| $1994-1995$ | 174000 | 168000 | 220350 |
| $1995-1996$ | 210000 | 194000 | 240000 |
| $1996-1997$ | 246000 | 230000 | 250000 |
| $1997-1998$ | 269000 | 261000 | 250000 |
| $1998-1999$ | 244500 | 234000 | 250000 |
| $1999-2000$ | 242500 | 237000 | 250000 |
| $2000-2001$ | 230000 | 224500 | 250000 |
| $2001-2002$ | 195500 | 195500 | 200000 |
| $2002-2003$ | 184500 | 180000 | 200000 |
| $2003-2004$ | 136000 | 133000 | 180000 |
| $2004-2005$ | 104500 | 102000 | 100000 |
| $2005-2006$ | 104500 | 100500 | 100000 |
| $2006-2007$ | 101000 | 97500 | 100000 |
| $2007-2008$ | 89500 | 87500 | 90000 |
| $2008-2009$ | 107000 | 87500 | 90000 |
| $2009-2010$ | 118500 | 105000 | 110000 |
| $2010-2011$ | 116000 | 120000 |  |

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.

## Total Allowable Commercial Catch (TACC) and area restrictions

In the 2010-11 fishing year, the TACC for HOK1 was 120000 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 of Fisheries that only 60000 t of the TACC should be taken from western stock 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 former Hoki Fishery Management Company introduced a Code of Practice for hoki target trawling in 2001 with the aim of protecting small fish (less than 60 cm ). The main components of this Code of Practice were: 1) a restriction on fishing in waters shallower than $450 \mathrm{~m} ; 2$ ) 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 Code of Practice was superseded by Operational Procedures for Hoki Fisheries, introduced by the Deepwater Group 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 abundance of juvenile hoki (Narrows Basin of Cook Strait, Canterbury Banks, Mernoo, and Puysegur). These areas are closed to hoki target trawling by vessels greater than 28 m ,
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.

Table 3: Estimated* total catch (t) of hoki by area 1988-89 to 2010-11. Estimated catches were 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 2009-10 are rounded to the nearest 100 t.

* Estimated catches were scaled to reported (QMR or MHR) catch totals.

| Fishing | Spawning fisheries |  |  |  |  |  | Non-spawning fisheries |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | Cook |  | Southern | Chatham Rise |  |  | Total |
| Year | WCSI | Puysegur | Strait | ECSI | Plateau | and ECSI | ECNI | Unrep. | Catch |
| 1988-1989 | 188000 | 3500 | 7000 | - | 5000 | 5000 | - | - | 208500 |
| 1989-1990 | 165000 | 8000 | 14000 | - | 10000 | 13000 | - | - | 210000 |
| 1990-1991 | 154000 | 4000 | 26500 | 1000 | 18000 | 11500 | - | - | 215000 |
| 1991-1992 | 105000 | 5000 | 25000 | 500 | 34000 | 45500 | - | - | 215000 |
| 1992-1993 | 98000 | 2000 | 21000 | - | 26000 | 43000 | 2000 | 3000 | 195000 |
| 1993-1994 | 113000 | 2000 | 37000 | - | 12000 | 24000 | 2000 | 1000 | 191000 |
| 1994-1995 | 80000 | 1000 | 40000 | - | 13000 | 39000 | 1000 | - | 174000 |
| 1995-1996 | 73000 | 3000 | 67000 | 1000 | 12000 | 49000 | 3000 | 2000 | 210000 |
| 1996-1997 | 91000 | 5000 | 61000 | 1500 | 25000 | 56500 | 5000 | 1000 | 246000 |
| 1997-1998 | 107000 | 2000 | 53000 | 1000 | 24000 | 75000 | 4000 | 3000 | 269000 |
| 1998-1999 | 90100 | 3000 | 46500 | 2100 | 24300 | 75600 | 2600 | - | 244500 |
| 1999-2000 | 101100 | 2900 | 43200 | 2400 | 34200 | 56500 | 1400 | 500 | 242400 |
| 2000-2001 | 100600 | 6900 | 36600 | 2400 | 30400 | 50500 | 2100 | 100 | 229900 |
| 2001-2002 | 91200 | 5400 | 24200 | 2900 | 30500 | 39600 | 1200 | - | 195500 |
| 2002-2003 | 73900 | 6000 | 36700 | 7100 | 20100 | 39200 | 900 | - | 184700 |
| 2003-2004 | 45200 | 1200 | 40900 | 2100 | 11700 | 33600 | 900 | - | 135800 |
| 2004-2005 | 33100 | 5500 | 24800 | 3300 | 6200 | 30700 | 500 | 100 | 104400 |
| 2005-2006 | 38900 | 1500 | 21800 | 700 | 6700 | 34100 | 700 | - | 104400 |
| 2006-2007 | 33100 | 400 | 20100 | 1000 | 7700 | 37900 | 700 | - | 101000 |
| 2007-2008 | 21000 | 300 | 18400 | 2300 | 8700 | 38000 | 600 | - | 89300 |
| 2008-2009 | 20600 | 200 | 17500 | 1100 | 9800 | 39000 | 600 | - | 88800 |
| 2009-2010 | 36300 | 300 | 17900 | 700 | 12300 | 39100 | 600 | - | 107200 |
| 2010-2011 | 48300 | 1200 | 14900 | 1600 | 12600 | 38400 | 1600 | - | 118700 |

- Catch less than 100 t .


## 2010-11 Hoki fishery

The overall catch of 118700 t was 11500 t higher than the catch in 2009-10 and 1300 t lower than the TACC. Catches in 2010-11 increased from the western spawning area (WCSI), decreased from the eastern spawning area (Cook Strait), remained at similar levels for the non-spawning areas (Chatham Rise and Southern Plateau), and increased slightly for other areas (Table 3). The increase in the western spawning catch was expected, given the increase in the target catch from western areas from 50000 t in 2009-10 to 60000 t in 2010-11.

For the first time in 5 years, the WCSI was the largest hoki fishery, with the catch increasing by nearly 12000 t to 48300 t in $2010-11$. Catches from inside the 25 n . mile line made up $15 \%$ of the total WCSI catch in 2010-11, up from $8 \%$ in $2009-10$, but down from a peak of $41 \%$ of the catch in 200304. Unstandardised catch rates on the WCSI in 2010-11 were the highest in the time series going back to 1990 , with a median catch from all midwater tows targeting hoki of 8.9 t per hour. Most of the hoki caught on the WCSI were fish from the 2003-08 year classes (ages 3-8). 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 to $32 \%$ in 2010-11. Conversely, the percentage of small fish (less than 65 cm ) by number in the catch decreased from $31 \%$ in 2008-09 to $17 \%$ in 2010-11. From 1999-00 to 2003-04, the sex ratio of the WCSI catch was highly skewed, with many more females caught than males. This sex bias has reversed in the last seven years as the catch of younger fish has increased, and in 2010-11, only 43\% of fish in the catch by numbers were females. The mean length at age for hoki aged from 3-10 on the WCSI has increased since the start of the fishery.

Table 4: Proportions of total catch.

|  | Spawning fisheries |  | Non-spawning fisheries |  |
| :--- | ---: | ---: | ---: | ---: |
| Fishing | West | East | West | East |
| $1988-1989$ | $92 \%$ | $3 \%$ | $2 \%$ | $3 \%$ |
| $1989-1990$ | $82 \%$ | $7 \%$ | $5 \%$ | $6 \%$ |
| $1990-1991$ | $74 \%$ | $13 \%$ | $8 \%$ | $5 \%$ |
| $1991-1992$ | $51 \%$ | $12 \%$ | $16 \%$ | $21 \%$ |
| $1992-1993$ | $51 \%$ | $11 \%$ | $14 \%$ | $24 \%$ |
| $1993-1994$ | $60 \%$ | $19 \%$ | $7 \%$ | $14 \%$ |
| $1994-1995$ | $47 \%$ | $23 \%$ | $7 \%$ | $23 \%$ |
| $1995-1996$ | $36 \%$ | $33 \%$ | $6 \%$ | $25 \%$ |
| $1996-1997$ | $39 \%$ | $26 \%$ | $10 \%$ | $25 \%$ |
| $1997-1998$ | $41 \%$ | $20 \%$ | $9 \%$ | $30 \%$ |
| $1998-1999$ | $38 \%$ | $20 \%$ | $10 \%$ | $32 \%$ |
| $1999-2000$ | $43 \%$ | $19 \%$ | $14 \%$ | $24 \%$ |
| $2000-2001$ | $47 \%$ | $17 \%$ | $13 \%$ | $23 \%$ |
| $2001-2002$ | $49 \%$ | $14 \%$ | $16 \%$ | $21 \%$ |
| $2002-2003$ | $43 \%$ | $24 \%$ | $11 \%$ | $22 \%$ |
| $2003-2004$ | $34 \%$ | $32 \%$ | $9 \%$ | $25 \%$ |
| $2004-2005$ | $37 \%$ | $27 \%$ | $6 \%$ | $30 \%$ |
| $2005-2006$ | $39 \%$ | $21 \%$ | $7 \%$ | $33 \%$ |
| $2006-2007$ | $33 \%$ | $21 \%$ | $8 \%$ | $38 \%$ |
| $2007-2008$ | $24 \%$ | $23 \%$ | $10 \%$ | $43 \%$ |
| $2008-2009$ | $23 \%$ | $21 \%$ | $11 \%$ | $45 \%$ |
| $2009-2010$ | $34 \%$ | $17 \%$ | $12 \%$ | $37 \%$ |
| $2010-2011$ | $42 \%$ | $14 \%$ | $11 \%$ | $34 \%$ |

The Chatham Rise was the second largest hoki fishery, with 38400 t taken from this area in 2010-11. Over $99 \%$ of the Chatham Rise catch was taken in bottom trawls, with the median unstandardised catch in bottom trawls targeting hoki in 2010-11 of 1.5 t per hour. The Chatham Rise catch was dominated by small hoki from the 2006-09 year-classes and $53 \%$ of the catch by number was fish less than 65 cm . Female hoki made up a higher percentage of the Chatham Rise catch than males $(53 \%$ female).

The catch from Cook Strait of 14900 t was down about 3000 t from that in 2009-10, and the lowest catch in this fishery since 1989-90. Unstandardised catch rates in Cook Strait continue to be high, with a median catch rate of 24.9 t per hour in midwater tows targeting hoki. There was a broad age distribution of females from ages 3-13, while most males were ages 3-9. The sex ratio in the observed Cook Strait catch was skewed towards females ( $61 \%$ female) and only $3 \%$ of the fish were less than 65 cm . As on the WCSI, the mean length at age has increased in the Cook Strait fishery.

The catch from the Southern Plateau of 12600 t in 2010-11 was at a similar level to 2009-10, and the percentage of the catch from hoki target tows increased to $86 \%$, having fallen as low as $70 \%$ in 200607. Unstandardised catch rates in bottom trawls targeting hoki have remained between 1.2 and 1.3 t per hour for the past three seasons with a median of 1.2 t per hour in 2010-11. Catch-at-age estimates showed the Southern Plateau catch, like that from the other areas, consisted mainly of fish from the 2001-09 year classes. The percentage of fish less than 65 cm in the catch decreased from $42 \%$ in 200910 to $28 \%$ in 2010-11. As on the WCSI, fewer females were caught than males ( $45 \%$ female).

Catches from both Puysegur and ECSI in 2010-11 were higher than in 2009-10, with 1600 t taken from the ECSI and 1200 t from Puysegur.

### 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.


Figure 1: Left: Reported landings and TACCs for HOK 1. Right: 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.

### 1.4 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 and Anderson (2008) 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 $57-65 \mathrm{~cm}$ 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 $34^{\circ} \mathrm{S}$ to $54^{\circ} \mathrm{S}$, 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 small catches of older hoki are targeted over other hill complexes outside the survey areas of both the Chatham Rise and Southern Plateau (Dunn \& Livingston 2004), and are also 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 ( $2-4 \mathrm{yrs}$ ) 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 In prep.) A new method to estimate proportion spawning from summer samples of post-spawner hoki is under development (Parker 2007, Grimes \& O'Driscoll 2006).

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 less 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 $27-35 \mathrm{~cm}$ TL at the end of the first year. In the past, hoki reached about 45,55 and $60-65 \mathrm{~cm} \mathrm{TL}$ at ages 2,3 , and 4 respectively. More recently, length modes have been centred at $45-50,60-65$, and $70-75 \mathrm{~cm} \mathrm{TL}$ for ages 2,3 , and 4 . Although smaller spawning fish are taken on the spawning grounds, males appear to mature mainly from 6065 cm TL at 3-5 years, while females mature at $65-70 \mathrm{~cm}$ 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 biological parameters.

Fishstock

1. Natural mortality ( $M$ )

HOK 1
2. Weight $=\mathrm{a}$ (length $) \underline{\mathrm{b}}($ Weight in g , length in cm total length $)$


## 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. 2009). 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. 2009).

## 5. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the May 2012 Fishery Assessment Plenary after review by the Aquatic Environment Working Group. This summary is from the perspective of the hoki fishery; a more detailed summary from an issue-by issue perspective is, or will shortly be, available in the Aquatic Environment \& Biodiversity Annual Review (http://fs.fish.govt.nz/Page.aspx?pk=113\&dk=22982).

### 5.1 Role in the ecosystem

Hoki is the species with the highest biomass in the bottom fish community of the upper slope (200800 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. 2009, Connell 2010, Stevens et al. 2011). Hoki show ontogenetic shifts in their feeding preferences, and larger hoki ( $>80 \mathrm{~cm}$ ) consume proportionately more fish and squid than do smaller hoki (Dunn et al. 2009, Connell 2010). The diet of hoki overlaps with those of alfonsino, arrow squid,
hake, javelinfish, Ray's bream, and shovelnose dogfish (Dunn et al. 2009). Hoki are prey to several piscivores, particularly hake but also stargazers, smooth skates, several deep water shark species, and ling; (Dunn et al. 2009). 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 sizebased 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 SubAntarctic 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)

Based on models using observer and fisher-reported data, total bycatch in the combined hoki, hake and ling trawl fisheries between 2000-01 and 2006-07 ranged from about 36000 to 58000 t per year compared with the combined total landed catch of hoki, hake, and ling of 130000 to 238000 t ) (Ballara et al. 2010a; see also Anderson et al. 2001, Livingston et al. 2003, Anderson \& Smith 2005 for previous estimates). The main commercial bycatch species in hoki target fisheries off the west coast S.I., 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 $87 \%, 1 \%$, and $2 \%$, respectively, of the catch in target hoki trawls between 2008-09 and 20010-11 (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).

Total annual discard estimates ranged from about 5500 to 29000 t per year between 2000-01 and 2006-07, with the main species being spiny dogfish, rattails, javelinfish, hoki, and shovelnose dogfish (although up to 470 species have been observed in the incidental catch). Discard ratios of commercial species were highest in Cook Strait and Sub-Antarctic and lowest in Cook Strait. Spiny dogfish was the
main QMS species discarded, but hoki, hake, and ling made up $9.7 \%$ of total observed discards. About 0.03 kg was discarded per kilogram of hoki, hake, and ling caught (Ballara et al. 2010a).

Table 6: Raw catch weight and percentage by weight of species taken in hoki trawls with an observed catch of $\mathbf{>} \mathbf{2 0} \mathbf{t}$ in the 2010-11 fishing year. Data from the central observer database.

| Species |  | $\mathbf{2 0 0 8}-\mathbf{0 9}$ |  | $\mathbf{2 0 0 9 - 1 0}$ | $\mathbf{2 0 1 0 - 1 1}$ |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: |
|  | Catch (t) | $\mathbf{\%}$ | Catch (t) | $\mathbf{\%}$ | Catch (t) | $\mathbf{\%}$ |
| Hoki | 19522 | 87.2 | 24696 | 87.2 | 19151 | 86.3 |
| Ling | 548 | 2.5 | 624 | 2.2 | 527 | 2.4 |
| Javelinfish | 494 | 2.2 | 734 | 2.6 | 436 | 2.0 |
| Rattails | 334 | 1.5 | 572 | 2.0 | 381 | 1.7 |
| Silver warehou | 191 | 0.9 | 337 | 1.2 | 376 | 1.7 |
| Hake | 227 | 1.0 | 235 | 0.8 | 307 | 1.4 |
| Spiny dogfish | 187 | 0.8 | 233 | 0.8 | 217 | 1.0 |
| White warehou | 58 | 0.3 | 64 | 0.2 | 79 | 0.4 |
| Pale ghost shark | 81 | 0.4 | 101 | 0.4 | 72 | 0.3 |
| Sea perch | 16 | 0.1 | 55 | 0.2 | 68 | 0.3 |
| Barracouta | 6 | 0.0 | 4 | 0.0 | 44 | 0.2 |
| Southern blue whiting | 37 | 0.2 | 7 | 0.0 | 40 | 0.2 |
| Shovelnose dogfish | 35 | 0.2 | 29 | 0.1 | 35 | 0.2 |
| Lookdown dory | 24 | 0.1 | 33 | 0.1 | 34 | 0.2 |
| Ribaldo | 27 | 0.1 | 39 | 0.1 | 28 | 0.1 |
| Arrow squid | 16 | 0.1 | 26 | 0.1 | 29 | 0.1 |
| Gemfish | 9 | 0.0 | 6 | 0.0 | 27 | 0.1 |
| Smooth skate | 11 | 0.1 | 22 | 0.1 | 25 | 0.1 |
| Stargazer | 14 | 0.1 | 23 | 0.1 | 23 | 0.1 |
| Others | 555 | 2.5 | 485 | 1.7 | 284 | 1.3 |

### 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 or caught on a hook but not brought onboard the vessel, Middleton \& Abraham 2007, Brothers et al. 2010).

## NZ 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 \& Smith 2007, Smith \& Baird 2009, Thompson \& Abraham 2010, Baird 2011). Although the numbers captured have been declining over the past 12 years (Table 7), the rate of capture has no obvious trend. Captures occur mostly in Cook Strait ( $44 \%$ ), off the west coast South Island ( $27 \%$ ), and east coast South Island, including the western Chatham Rise ( $18 \%$ ) (Table 8). Captures of NZ fur seals in the hoki fishery account for an average of $53 \%$ of all trawl caught fur seals since 2002-03 for the fisheries modelled. This figure should be interpreted with caution because a large proportion of inshore trawl effort not targeting hoki could not be included in the models.

## 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 shows a steady decline since the late 1990s.

NZ sea lions are captured only rarely by vessels trawling for hoki (Smith \& Baird 2005, 2007 a , b, Thompson \& Abraham 2010, Abraham \& Thompson 2011), the highest recorded rate in the last 12 years being 0.05 sea lions per 100 tows (Table 9). All observed captures have been close to the Auckland Islands or nearby on the Stewart-Snares shelf.

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 2009-10. 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. Other estimates and data are from Thompson \& Abraham (2012), retrieved from http://bycatch.dragonfly.co.nz/v20120315/


Table 8: Model estimates (means) of the number of NZ fur seal captures in hoki trawl fisheries by area, 2002-03 to 2009-10. Data from Thompson \& Abraham (2012), retrieved from http://bycatch.dragonfly.co.nz/v20120315/

| Cook | WCSI | ECSI | Fiordland | Stewart- <br> Snares | Chatham | Sub- <br> Antarctic | Total |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| $2002-03$ | 181 | 184 | 91 | 32 | 21 | 12 | 22 | 548 |
| $2003-04$ | 260 | 195 | 108 | 9 | 27 | 11 | 12 | 628 |
| $2004-05$ | 278 | 201 | 90 | 34 | 23 | 10 | 5 | 653 |
| $2005-06$ | 167 | 114 | 56 | 24 | 18 | 6 | 0 | 391 |
| $2006-07$ | 129 | 36 | 34 | 1 | 18 | 3 | 0 | 222 |
| $2007-08$ | 151 | 54 | 70 | 1 | 12 | 3 | 3 | 297 |
| $2008-09$ | 114 | 25 | 34 | 0 | 10 | 1 | 0 | 186 |
| $2009-10$ | 93 | 32 | 35 | 0 | 14 | 2 | 1 | 177 |

## Seabird interactions

Table 9: Number of tows by fishing year and observed NZ sea lion captures in hoki trawl fisheries, 2002-03 to 200910. 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. Data from Thompson \& Abraham (2012), retrieved from http://bycatch.dragonfly.co.nz/v20120315/

|  | Tows | No. obs | \% obs | Captures | Rate |
| :--- | ---: | ---: | ---: | ---: | ---: |
| $1998-99$ | 32242 | 3558 | 11.0 | 0 | 0.00 |
| $1999-00$ | 33061 | 3273 | 9.9 | 1 | 0.03 |
| $2000-01$ | 32018 | 3549 | 11.1 | 1 | 0.03 |
| $2001-02$ | 27224 | 3274 | 12.0 | 0 | 0.00 |
| $2002-03$ | 27784 | 2594 | 9.3 | 1 | 0.04 |
| $2003-04$ | 22535 | 2344 | 10.4 | 0 | 0.00 |
| $2004-05$ | 14540 | 2131 | 14.7 | 0 | 0.00 |
| $2005-06$ | 11590 | 10610 | 1775 | 1758 | 0 |
| $2006-07$ | 8786 | 1876 | 16.6 | 0 | 0.00 |
| $2007-08$ | 8177 | 1963 | 21.4 | 1 | 0.00 |
| $2008-09$ | 2066 | 20.3 | 0 | 0.05 |  |
| $2009-10$ |  | 20.7 | 0 | 0.00 |  |

Vessels targeting hoki incidentally catch seabirds. Baird (2005a) summarised observed seabird captures 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 (2007, 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 2009-2010 fishing year there were 53 observed captures of birds in hoki trawl fisheries. It was estimated by a statistical model that there were a total of 228 ( $95 \%$ c.i.: $178-290$ ) captures in hoki trawl fisheries (Thompson \& Abraham 2012, Table 10). Annual observed seabird capture rates have ranged from 1.31 to 8.34 per 100 tows in the hoki fishery between 1998-99 and 2009-10, without obvious trend. These estimates include all bird species and should be interpreted with caution. The average capture rate in hoki trawl fisheries over the last eight years is about 2.2 birds per 100 tows, a low rate relative to trawl fisheries for scampi ( 3.53 birds per 100 tows) and squid ( 13.33 birds per 100 tows) over the same years. The hoki fishery accounted for about $9 \%$ of seabird captures in the trawl fisheries modelled by Thompson \& Abraham (2012).

Table 10: Number of tows by fishing year and observed and model-estimated total seabird captures in hoki trawl fisheries, 1998-99 to 2009-10. 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). Other estimates and data are from Thompson \& Abraham (2012), retrieved from http://bycatch.dragonfly.co.nz/v20120315/

|  | Observed |  |  |  |  | Estimated |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Tows | No. obs | \% obs | Captures | Rate | Captures | 95\% c.i. | \% inc. |
| 1998-99 | 32242 | 3558 | 11.0 | 133 | 3.74 | 1144 * | 950-1374 | 100.0 |
| 1999-00 | 33061 | 3273 | 9.9 | 91 | 2.78 | 993 * | 821-1199 | 100.0 |
| 2000-01 | 32018 | 3549 | 11.1 | 296 | 8.34 | 2055 * | 1803-2348 | 100.0 |
| 2001-02 | 27224 | 3274 | 12.0 | 50 | 1.53 | 1133 * | 941-1358 | 100.0 |
| 2002-03 | 27784 | 2594 | 9.3 | 85 | 3.28 | 578 | 459-731 | 100.0 |
| 2003-04 | 22535 | 2344 | 10.4 | 33 | 1.41 | 354 | 272-456 | 100.0 |
| 2004-05 | 14540 | 2131 | 14.7 | 46 | 2.16 | 385 | 295-494 | 100.0 |
| 2005-06 | 11590 | 1775 | 15.3 | 54 | 3.04 | 274 | 208-359 | 100.0 |
| 2006-07 | 10610 | 1758 | 16.6 | 23 | 1.31 | 165 | 122-220 | 100.0 |
| 2007-08 | 8786 | 1876 | 21.4 | 28 | 1.49 | 148 | 107-196 | 100.0 |
| 2008-09 | 8177 | 1662 | 20.3 | 37 | 2.23 | 205 | 155-266 | 100.0 |
| 2009-10 | 9963 | 2066 | 20.7 | 53 | 2.57 | 228 | 178-290 | 100.0 |

Observed seabird captures since 2002-03 have been dominated by six species: Salvin's, white-capped, and southern Buller's albatrosses make up $44 \%, 27 \%$, and $20 \%$ of the albatrosses captured, respectively; and sooty shearwaters, white-chinned petrels, and cape petrels make up $61 \%, 13 \%$, and $13 \%$ of other birds, respectively (Table 11). A high proportion of captures were observed off the east coast of the South Island, including the Chatham Rise ( $60 \%$ ), off the west coast of the South Island $(17 \%)$ or on the Stewart-Snares shelf (13\%). 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 (MFish 2006). The 2006 notice mandated that all trawlers $>28 \mathrm{~m}$ 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 2009-10, 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. 2011 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 from Thompson \& Abraham (2012), retrieved from http://bycatch.dragonfly.co.nz/v20120315/

| Species | Risk ratio | ECSI | WCSI | Chatham | Stewart Snares | Cook | Other | Total |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Salvin's albatross | 2.49 | 27 | 0 | 30 | 0 | 6 | 1 | 64 |
| White capped | 0.83 | 6 | 14 | 4 | 13 | 2 | 0 | 39 |
| Southern Buller's | 1.28 | 4 | 17 | 4 | 3 | 0 | 1 | 29 |
| Albatrosses | - | 4 | 0 | 0 | 0 | 1 | 1 | 6 |
| Campbell albatross | 1.84 | 0 | 4 | 0 | 0 | 0 | 0 | 4 |
| Smaller albatrosses | - | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| Sthn black-browed | - | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Total albatrosses |  | 42 | 35 | 39 | 16 | 9 | 3 | 144 |
| Sooty shearwater | - | 108 | 0 | 2 | 15 | 1 | 6 | 132 |
| White chinned petrel | 0.79 | 13 | 0 | 2 | 6 | 3 | 4 | 28 |
| Cape petrels | 0.76 | 2 | 11 | 3 | 2 | 8 | 2 | 28 |
| Westland petrel | 3.31 | 0 | 8 | 0 | 0 | 1 | 0 | 9 |
| Common diving petrel | 0.00 | 0 | 0 | 0 | 0 | 0 | 3 | 3 |
| Fairy prion | 0.00 | 1 | 2 | 0 | 0 | 0 | 0 | 3 |
| Northern giant petrel | 3.00 | 1 | 2 | 0 | 0 | 0 | 0 | 3 |
| Black-bellied st-petrel | 0.01 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| Flesh footed shearwater | 2.51 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Grey petrel | 0.39 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| Grey-backed st-petrel | - | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| Snares Cape petrel | - | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Seabirds (generic codes) | - | 1 | 3 | 0 | 0 | 0 | 0 | 4 |
| Total other birds |  | 127 | 27 | 7 | 26 | 13 | 15 | 215 |

## 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 the highest rates and catches occurred in 1989 off the west coast of the South Island, and in 1987-92 off the east coast of the South Island. 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). Further research is currently in progress to improve the understanding the interactions between basking sharks and fisheries (DOC projects POP2011/04 and 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 trawl for hoki accounted for $20-40 \%$ of all tows on or near the sea floor reported on TCEPR forms up to 2005-06. In the early years of the hoki fishery, vessels predominantly used midwater trawl as most of the catch was taken during the spawning season off the WCSI from spawning aggregations. Outside of the spawning season, bottom trawling is used almost exclusively on the Chatham Rise and Sub-Antarctic fishing grounds (Table 8). As the incidence of year round fishing increased, vessels increased fishing effort on the Chatham Rise and in the SubAntarctic, and the overall bottom trawl effort increased to a peak between 1997-98 and 2003-04. Bottom trawling effort has declined substantially in all areas since 2005-06, largely as a result of hoki TACC reductions. 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 $\sim 90 \%$ since the peak in 1997 and bottom trawling by $\sim 70 \%$ since the peak in 2000 (Table 13).

Table 12: Number of tows (retrieved from http://bycatch.dragonfly.co.nz/v20120315/, Thompson \& Abraham 2012), and number of captures (from Francis \& Smith 2010) of basking shark in hoki trawls. *, awaiting data for recent years.

| Year | Tows* | No. observed | \% observed | No. Captures |
| :--- | ---: | ---: | ---: | ---: |
| $1994-05$ | 21583 | - | - | 2 |
| $1995-06$ | 24610 | - | - | 0 |
| $1996-07$ | 28756 | - | - | 5 |
| $1997-08$ | 30354 | - | - | 14 |
| $1998-09$ | 32242 | 3558 | 11.0 | 8 |
| $1999-00$ | 33061 | 3273 | 9.9 | 2 |
| $2000-01$ | 32018 | 3549 | 11.1 | 3 |
| $2001-02$ | 27224 | 3274 | 12.0 | 0 |
| $2002-03$ | 27785 | 2594 | 9.3 | 5 |
| $2004-04$ | 22536 | 2344 | 10.4 | 2 |
| $2004-05$ | 14543 | 2132 | 14.7 | 8 |
| $2005-06$ | 11592 | 1775 | 16.6 | 0 |
| $2006-07$ | 10613 | 1758 | 21.3 | 0 |
| $2007-08$ | 8785 | 1875 | 20.3 | 1 |
| $2008-09$ | 8176 | 1662 | 20.7 | $*$ |
| $2009-10$ | 9964 | 2066 |  | $*$ |

Bottom trawling for hoki, 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 Aquatic Environment and Biodiversity Annual Review (2012).

### 5.5 Other considerations

Table 13: Summary of number of hoki target trawl tows (TCEPR only) in the hoki fishery from fishing years (FY) 1989-90 to 2010-11. (MW, mid-water trawl; BT, bottom trawl). Twin trawls were used to catch almost half of the TACC in some years and this gear is substantially wider than single trawl gear. NB, numbers in this table differ significantly from 2010 and 2011 versions because of problems with the data extract.

| FisherySeason | WCSI/Puys Spawning |  | Cook Strait/ECSI$\qquad$ |  | Sub-Antarctic Non-spawn |  | Chatham Rise/ECSI$\qquad$ |  | All areas combined |  | \% |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  |  |  |  |  |  |  |
| Method | MW | BT | MW | BT | MW | BT | MW | BT | MW | BT | BT |
| FY |  |  |  |  |  |  |  |  |  |  |  |
| 1990 | 7849 | 1188 | 1087 | 21 | 36 | 2111 | 30 | 2027 | 9002 | 5347 | 37 |
| 1991 | 7354 | 1679 | 2229 | 21 | 81 | 3927 | 954 | 3490 | 10618 | 9117 | 46 |
| 1992 | 5628 | 1579 | 1776 | 14 | 115 | 5441 | 441 | 5556 | 7960 | 12590 | 61 |
| 1993 | 5490 | 1861 | 1583 | 22 | 442 | 4913 | 1057 | 5269 | 8572 | 12065 | 58 |
| 1994 | 8012 | 1638 | 1867 | 153 | 562 | 2039 | 1338 | 3449 | 11779 | 7279 | 38 |
| 1995 | 7225 | 1505 | 2030 | 255 | 419 | 2328 | 2175 | 6262 | 11849 | 10350 | 47 |
| 1996 | 5715 | 2017 | 3198 | 1368 | 415 | 2504 | 2302 | 7920 | 11630 | 13809 | 54 |
| 1997 | 7563 | 1890 | 3561 | 1335 | 334 | 3421 | 2342 | 9303 | 13800 | 15949 | 54 |
| 1998 | 6968 | 1541 | 2402 | 666 | 165 | 4372 | 3782 | 11448 | 13317 | 18027 | 58 |
| 1999 | 5477 | 2118 | 2033 | 635 | 419 | 3659 | 2424 | 11439 | 10353 | 17851 | 63 |
| 2000 | 5470 | 2275 | 1944 | 380 | 511 | 5944 | 2696 | 9493 | 10621 | 18092 | 63 |
| 2001 | 6228 | 2577 | 1968 | 170 | 667 | 5448 | 912 | 9862 | 9775 | 18057 | 65 |
| 2002 | 4988 | 3095 | 1136 | 138 | 132 | 6449 | 858 | 7820 | 7114 | 17502 | 71 |
| 2003 | 4615 | 2977 | 2117 | 167 | 96 | 4407 | 496 | 9278 | 7324 | 16829 | 70 |
| 2004 | 4274 | 1887 | 1812 | 267 | 78 | 3023 | 385 | 7225 | 6549 | 12402 | 65 |
| 2005 | 2534 | 1308 | 1457 | 74 | 68 | 1428 | 340 | 4996 | 4399 | 7806 | 64 |
| 2006 | 1783 | 1508 | 1020 | 88 | 74 | 721 | 140 | 4822 | 3017 | 7139 | 70 |
| 2007 | 1147 | 752 | 919 | 35 | 25 | 1194 | 57 | 4769 | 2148 | 6750 | 76 |
| 2008 | 813 | 492 | 393 | 281 | 36 | 925 | 75 | 4203 | 1317 | 5901 | 82 |
| 2009 | 689 | 354 | 747 | 267 | 38 | 927 | 11 | 3914 | 1485 | 5462 | 79 |
| 2010 | 1182 | 612 | 797 | 70 | 56 | 1251 | 116 | 4361 | 2151 | 6294 | 75 |
| 2011 | 1581 | 912 | 489 | 63 | 62 | 1245 | 52 | 4075 | 2184 | 6295 | 74 |

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.

### 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 off the WCSI 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 2009).

## 6. STOCK ASSESSMENT

A new stock assessment was carried out in 2012 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 two trawl surveys, an acoustic 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 2011 assessment (McKenzie 2011).

### 6.1 Methods

## Model structure

The model partitions the population into two sexes, 17 age groups ( 1 to 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)]. The adult fish of the two stocks do not mix: those from the W stock spawn in 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). A sensitivity model run is 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 we have no direct observations of maturity to put in the model but we do have information about spawners (there are two April/May observations on SA of proportions of females that will spawn that year).

The model's annual cycle divides the fishing year into five time steps and includes four types of migration (Table 14). The first type 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.

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 occur 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 is treated as being of age 2.25 in that time step. etc. The last column ("Propn. mort.") shows the proportion of that time step's total mortality that is assumed to have taken place when each observation is made.

|  |  |  |  |  | Observations |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Step | Approx. months | Processes | fraction |  | Label | Propn. 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 on the Chatham Rise in January 2012 (Stevens et al. 2012b), a trawl survey on the Southern Plateau in December 2011 (Bagley \& O'Driscoll 2012b), and an acoustic survey of spawning hoki in Cook Strait in winter 2011 (O’Driscoll 2012).

The error distributions assumed were multinomial (Bull et al. 2008) 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 2012a, 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, CSacous biomasses were recalculated using a different method). 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 | 340 | - | - | - | $191 *$ |
| 1992 | 345 | 80 | 68 | 120 | - |
| 1993 | 550 | 87 | - | 186 | $613{ }^{*}$ |
| 1994 | - | 100 | - | 146 | $597 *$ |
| 1995 | - | - | - | 120 | 411* |
| 1996 | - | - | 89 | 153 | 196* |
| 1997 | 654 | - | - | 158 | $302 *$ |
| 1998 | - | - | 68 | 87 | 170* |
| 1999 | - | - | - | 109 | $245 *$ |
| 2000 | 396 | - | - | 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 | $218 *$ |
| 2008 | - | 46 | - | 77 | 179** |
| 2009 | - | 47 | - | 144 | $334 *$ |
| 2010 | - | 65 | - | 98 | - |
| 2011 | - | - | - | 94 | $269 *$ |
| 2012 | - | $46^{*}$ | - | 88* | - |

The age data used in the assessment (Table 16) are similar to those used in 2011, but with an additional years' data (and two more years for Enspage).

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 initial 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 add as squares: $\mathrm{CV}_{\text {total }}{ }^{2}=\mathrm{CV}_{\text {process }}{ }^{2}+\mathrm{CV}_{\text {observation }}{ }^{2}$ ). 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 include only the uncertainty associated with between-transect (and within-stratum) variation in total backscatter. In some model runs (including all final runs) it was decided to use the observation-error rather than the total CVs for all trawl survey biomass indices as a way of giving more weight to these data.

Table 16: Age data used in the assessment (* data new to this assessment). Data are from otoliths or from the lengthfrequency analysis program OLF (Hicks et al. 2002). Years are fishing years (1990=1989-90).

| Area | Label | Data type | Years | Source of age data |
| :--- | :--- | :--- | :--- | :--- |
| WC | Wspage | Catch at age | $1988-11^{*}$ | otoliths |
| SA | WnspOLF | Catch at age | $1992-94,96,99-00$ | OLF |
|  | Wnspage | Catch at age | $2001-04,06-11^{*}$ | otoliths |
|  | SAsumage | Trawl survey | $1992-94,2001-10,12^{*}$ | otoliths |
|  | SAautage | Trawl survey | $1992,96,98$ | otoliths |
|  | pspawn | Proportion spawning | $1992,93,98$ | otoliths |
| CS | Espage | Catch at age | $1988-11^{*}$ | otoliths |
| CR | EnspOLF | Catch at age | $1992,94,96,98$ | OLF |
|  | Enspage | Catch at age | $1999-10^{*}, 11^{*}$ | otoliths |
|  | CRsumage | Trawl survey | $1992-12^{*}$ | otoliths |

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 |  |
|  | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |  |  |  |  |  |  |
| Total | 0.23 | 0.23 | 0.22 | 0.23 | 0.23 | 0.25 | 0.24 | 0.22 |  |  |  |  |  |  |
| Observation | 0.12 | 0.11 | 0.08 | 0.11 | 0.11 | 0.15 | 0.14 | 0.10 |  |  |  |  |  |  |
| SAsumbio | 1992 | 1993 | 1994 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2012 |
| 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 | 0.25 |
| 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 | 0.15 |
| 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 |  |
|  | 2007 | 2008 | 2009 | 2011 |  |  |  |  |  |  |  |  |  |  |
| Total | 0.46 | 0.30 | 0.39 | 0.39 |  |  |  |  |  |  |  |  |  |  |
| Observation | 0.26 | 0.06 | 0.15 | 0.18 |  |  |  |  |  |  |  |  |  |  |
| WCacous | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1997 | 2000 |  |  |  |  |  |  |
| Total | 0.60 | 0.38 | 0.40 | 0.73 | 0.49 | 0.38 | 0.60 | 0.60 |  |  |  |  |  |  |
| Observation |  |  | 0.22 | 0.14 | 0.14 | 0.07 | 0.10 | 0.14 |  |  |  |  |  |  |

The observation CVs for the otolith-based at-age data were calculated by a bootstrap procedure, which includes 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 some, which were forced to be higher than those from the spawning fisheries (Francis 2004).

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.

The catch for each year was divided into the six fisheries of Table 19 according to area and month. 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) is the same as that used in the 2011 assessment, so the catches used in the model (Table 20) are unchanged, except for minor revisions to years 2001 to 2011 (including removing catches taken outside the New Zealand EEZ).

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 |

For 2011-12 year, the TACC is 130000 t with a catch limit arrangement for 60000 t to be taken from the eastern fisheries and 70000 t from the western fisheries. For the western stock the catch was split: 15000 t (non-spawning), 55000 t (spawning). In the stock assessment model the non-spawning fishery is split into two parts, separated by the migration of fish from the Chatham Rise to the Southern Plateau. The same proportions as in 2011 were used to split the western non-spawning catch into two parts. For the eastern stock the catch was split 41000 (non-spawning), 19000 t (spawning) based on advice from industry representatives. As with the western stock, the non-spawning catch was split into two parts, using the same proportions as in 2011.

Table 19: Method of dividing annual catches into the six fisheries of Table 6. The small amount of catch reported in the areas west coast North Island and Challenger (typically 100 t per year) was ignored (which means that this catch is pro-rated across all fisheries).

Area
West coast South Island; Puysegur
Southern Plateau
Cook Strait; Pegasus
Chatham Rise; east coasts of South Island \& North Island; null ${ }^{1}$
${ }^{1}$ no area stated

| Oct-Mar | Apr-May | Jun-Sep |
| ---: | ---: | ---: |
| Wsp | Wsp | Wsp |
| Wnsp1 | Wnsp2 | Wnsp2 |
| Ensp1 | Ensp2 | Esp |
| Ensp1 | Ensp2 | Ensp2 |

## 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). (The YCS for 1970, say, is for fish which were spawned in the winter of 1970, and which first arrive in the model, in area CR, at age 1.6 y , in about December 1971, which is in model year 1972). Associated with $B_{0}$ is an estimated mean recruitment, $R_{0}$, which is used, together with a Beverton-Holt stock-recruit relationship and the YCSs, to calculate the recruitment in each year. The first five YCSs (for years 1970 to 1974) are set equal to 1 (because of the lack of at-age data for the early years), but all the remaining YCSs (for 1975 to 2010) are estimated. The model corrects for bias in estimated YCSs arising from ageing error. YCSs are constrained to average 1 over the years 1975 to 2007, so that $R_{0}$ may be thought of as the average recruitment over that period. $R_{0}$ and a set of YCSs are estimated separately for each stock. The $B_{0}$ for each stock is calculated as the spawning biomass that
would occur given no fishing and constant recruitment, $R_{0}$, and the initial biomass before fishing ( $B_{I N I T}$ ) is set equal to $B_{0}$.

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 | 1500 | 2500 | 0 | 0 | 0 | 5000 | 9000 |
| 1973 | 1500 | 2500 | 0 | 0 | 0 | 5000 | 9000 |
| 1974 | 2200 | 3800 | 0 | 0 | 0 | 5000 | 11000 |
| 1975 | 13100 | 22900 | 0 | 0 | 0 | 10000 | 46000 |
| 1976 | 13500 | 23500 | 0 | 0 | 0 | 30000 | 67000 |
| 1977 | 13900 | 24100 | 0 | 0 | 0 | 60000 | 98000 |
| 1978 | 1100 | 1900 | 0 | 0 | 0 | 5000 | 8000 |
| 1979 | 2200 | 3800 | 0 | 0 | 0 | 18000 | 24000 |
| 1980 | 2900 | 5100 | 0 | 0 | 0 | 20000 | 28000 |
| 1981 | 2900 | 5100 | 0 | 0 | 0 | 25000 | 33000 |
| 1982 | 2600 | 4400 | 0 | 0 | 0 | 25000 | 32000 |
| 1983 | 1500 | 8500 | 3200 | 3500 | 0 | 23300 | 40000 |
| 1984 | 3200 | 6800 | 6700 | 5400 | 0 | 27900 | 50000 |
| 1985 | 6200 | 3800 | 3000 | 6100 | 0 | 24900 | 44000 |
| 1986 | 3700 | 13300 | 7200 | 3300 | 0 | 71500 | 99000 |
| 1987 | 8800 | 8200 | 5900 | 5400 | 0 | 146700 | 175000 |
| 1988 | 9000 | 6000 | 5400 | 7600 | 600 | 227000 | 255600 |
| 1989 | 2300 | 2700 | 700 | 4900 | 7000 | 185900 | 203500 |
| 1990 | 3300 | 9700 | 900 | 9100 | 14000 | 173000 | 210000 |
| 1991 | 17400 | 14900 | 4400 | 12700 | 29700 | 135900 | 215000 |
| 1992 | 33400 | 17500 | 14000 | 17400 | 25600 | 107200 | 215100 |
| 1993 | 27400 | 19700 | 14700 | 10900 | 22200 | 100100 | 195000 |
| 1994 | 16000 | 10600 | 5800 | 5500 | 35900 | 117200 | 191000 |
| 1995 | 29600 | 16500 | 5900 | 7500 | 34400 | 80100 | 174000 |
| 1996 | 37900 | 23900 | 5700 | 6800 | 59700 | 75900 | 209900 |
| 1997 | 42400 | 28200 | 6900 | 15100 | 56500 | 96900 | 246000 |
| 1998 | 55600 | 34200 | 10900 | 14600 | 46700 | 107100 | 269100 |
| 1999 | 59200 | 23600 | 8800 | 14900 | 40500 | 97500 | 244500 |
| 2000 | 43100 | 20500 | 14300 | 19500 | 39000 | 105600 | 242000 |
| 2001 | 36200 | 19700 | 13200 | 16900 | 34800 | 109000 | 229800 |
| 2002 | 24600 | 18100 | 16800 | 13400 | 24600 | 98000 | 195500 |
| 2003 | 24200 | 18700 | 12400 | 7800 | 41700 | 79800 | 184600 |
| 2004 | 17900 | 19000 | 6300 | 5300 | 41000 | 46300 | 135800 |
| 2005 | 19300 | 13800 | 4300 | 2000 | 26300 | 38700 | 104400 |
| 2006 | 22000 | 14700 | 2000 | 4700 | 20500 | 40400 | 104300 |
| 2007 | 22400 | 18400 | 4200 | 3500 | 18800 | 33700 | 101000 |
| 2008 | 22100 | 19400 | 6500 | 2200 | 17900 | 21200 | 89300 |
| 2009 | 29300 | 13100 | 6000 | 3800 | 15900 | 20800 | 88900 |
| 2010 | 28500 | 13500 | 6700 | 5600 | 16400 | 36600 | 107300 |
| 2011 | 30500 | 12800 | 7500 | 5200 | 13300 | 49500 | 118800 |
| 2012 | 28900 | 12100 | 8900 | 6100 | 19000 | 55000 | 130000 |

The steepness of the stock-recruitment relationship is set at 0.75 (Francis 2009).
Two alternative approaches are used in modelling natural mortality. In some model runs it is assumed to vary with age (following a double-exponential curve), separately for each sex; in others (where sex is ignored) it is assumed to be independent of age.

The model uses six selectivity ogives (one each for the four fisheries and one each for the trawl surveys in areas CR and SA) and three migration ogives (Whome, Espmg, and Wspmg - see Table 20).

Assumed maximum exploitation rates are as agreed to by the Working Group in 2004: 0.5 and 0.67 for the non-spawning and spawning fisheries, respectively. Because the non-spawning fisheries are split into two approximately equal halves a maximum exploitation rate of 0.3 is assumed for each half. This is approximately equivalent to 0.5 for the two halves combined. Penalty functions are used to discourage model fits which exceeded these maxima.

Prior distributions are assumed for all parameters. The main priors used are given in Table 21. In addition, bounds are imposed for parameters with non-uniform distributions. For the catchability parameters these are those calculated by O'Driscoll et al. (2002) (who called them overall bounds); for other parameters they are set at the 0.001 and 0.999 quantiles of their distributions. Prior distributions for all other parameters are 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 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 |
| :---: | :---: | :---: | :---: | :---: | :---: |
| $\log _{\text {_ }}$ Bmean_total | $\log \left(B_{0, \mathrm{E}}+B_{0, \mathrm{~W}}\right)$ | uniform | 11.6 | 16.2 |  |
| $\mathrm{pE}(=$ Bmean_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 |  |
| recruitment[W].YCS | year-class strengths (W) | lognormal | 1 | 0.95 |  |
| 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 ${ }^{3}$ | $M_{\text {male }} \& M_{\text {female }}$, ages 5-9 only | lognormal | 0.182 | 0.509 | Cordue (2006) |
| 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 |  |  |  |  |  |

## Calculation of fishing intensity and $B_{M S Y}$

The fishing intensity for a given stock and model run was calculated as an annual exploitation rate, $\mathrm{U}_{y}=$ $\max _{a s}\left(\sum_{f} C_{a s f y} / N_{a s y}\right)$, 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 nonspawning fisheries, and thus represents the total fishing intensity for each stock.

For a given stock and run, the reference fishing intensities, $U_{35 \%}$ and $U_{50 \%}$, 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 $m U_{f, \text { current }}$, where $U_{f, \text { current }}$ 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, $U_{x \%}$ was set equal to $m_{x \%} U_{\text {current }}$, 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 $B_{M S Y}$ for each stock for the base case model. This 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 $B_{M S Y}$ estimates

There are several reasons why $B_{M S Y}$, 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, it makes no allowance for extended periods of low recruitment, such as was observed in 1995-2001 for the W stock. 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 were carried out after the new data became available (McKenzie 2012b). In the 2008 assessment the model was unable to fit the threefold increase in estimated biomass between the 2007 and 2008 surveys in the summer Southern Plateau series (see SAsumbio in Table 14). This biomass increase was sustained in the three subsequent surveys ( 2009,2010 and 2012), and as in the previous assessment, it was decided that all series of trawl survey biomass observations should be upweighted in order to improve the fit to the SAsumbio series.

However, no upweighted runs fitted well to the SAsumbio series. Furthermore, the SAsumbio 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. To improve the fit to the SAsumbio series, an alternative approach to upweighting is to assume that the catchability has changed over time. This alternative approach was explored in runs in which two catchabilities were fitted for the SAsumbio series, instead of just one, and were found to improve the fit substantially.

In a final alternative model run natal fidelity was not assumed, in contrast to the other model runs.

## Five final runs

Five final runs were chosen by the Working Group: one base run, and four sensitivities to the base run.
In the base run adopted by the Working Group (1.3), the problem of the lack of old fish in both fishery-based and survey-based observations is dealt with by allowing $M$ (natural mortality) to be dependent on age (Table 18). This problem is dealt with in sensitivity run 1.4 by allowing the spawning fishery selectivities (Espsl, Wspsl) to be domed. In past assessments when domed selectivities were used, it was found that it was better to combine sexes in the model and make the selectivities age-based (Francis 2005). As in the previous assessment, the trawl biomass indices were upweighted to improve the fit to them, for both runs 1.3 and 1.4.

Two other sensitivities to run 1.3 were chosen by the Working Group as final runs. They differ from run 1.3 in that two catchabilities are fitted for the SAsumbio series instead of one (Table 22). In run 1.8, the catchability for 2008-2011 and 2012 inclusive is estimated separately from the other years in the series, whereas for run 1.9 the catchability from 2004 to 2007 inclusive is estimated separately.

Table 22: Distinguishing characteristics for the five final model runs. The base case model is run 1.3, the other four model runs are sensitivities.

|  | Trawl surveys up- | Two catchabilities for | Response to lack of old <br> fish in the observations | Sex in model and <br> Label | Natal <br> seighted? |
| :--- | :--- | :--- | :--- | ---: | ---: |
| 1.3 | Y | SAsumbio? | $M$ dependent on age | Fidelity? |  |

Bayesian posterior distributions were estimated for each of these runs using a Markov Chain Monte Carlo (MCMC) approach. For each run, three chains of length 2 million were completed, the initial
quarter of each chain was discarded, and the remaining samples were concatenated and thinned to produce a posterior sample of size 1000 .

The model estimates are summarised in Table 23 (estimates of spawning biomass), Figures 3-4 (biomass trajectories and year-class strengths), and Figures 5-6 (current biomass distributions). The status of the W stock is lower than that of the E stock for the base run and 1.8, but not for the other model runs. All model runs show that the biomasses of both stocks were at their lowest points in about 2005 and are now increasing, and that the W stock experienced seven consecutive years of poor recruitment from 1995 to 2001 inclusive. However, recruitment for the W stock is estimated to have been near or above average in the last four years, except for in 2010 where it is below average (Figures 3-4). There is good agreement on estimates of year-class strengths, except that run 1.4 tends to estimate relatively stronger year classes in the early years, and run 1.9 estimates stronger years classes in more recent years for the W stock.

The current status of the W stock is similar to that in the 2011 assessment. In that assessment, for the base case model corresponding to Run 1.1, there was a 0.91 probability that the stock was above $35 \%$ $B_{0}$, whereas the probability for 2012 is 0.92 . According to the Harvest Strategy Standard this means that the western stock is now considered to be fully rebuilt (at least a $70 \%$ probability that the target has been achieved).


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 model (Run 1.3 ) and the two catchability sensitivity runs (Runs $1.8,1.9$ ). Plotted values are medians of marginal posterior distributions. Years are fishing years $(1990=1989-90)$.

In all sensitivity runs, the current biomass estimates $\left(\% B_{0}\right)$ for the E stock are at least as high as the associated base run, but with greater uncertainty (Table 23, Figures 5-6). For the W stock, current biomass for the sensitivity runs is higher with greater uncertainty than the base, except for run 1.8 where the biomass estimate is about the same but with greater uncertainty.

Fishing intensity on both stocks was estimated to be at or near all-time highs in 2003 and is now substantially lower (Figure 7). The values for run 1.4 tend to be lower as this run assumes domed selectivity in the spawning fisheries. The peak fishing intensity on the W stock is estimated to have been higher than that on the E stock for the base run and 1.4, but not for the runs 1.8 and 1.9 where two catchabilities are allowed for SAsumbio.

Table 23: Estimates of spawning biomass for the final runs (median of marginal posteriors, with $95 \%$ confidence intervals in parentheses). $B_{\text {current }}$ is the spawning biomass in mid-season 2011-12.

| Run | $B_{0}(, 0000 \mathrm{t})$ |  | $B_{\text {current }}(0,000 \mathrm{t})$ |  |  | $B_{\text {current }}\left(\% \mathrm{O}_{0}\right)$ |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | W | E | W |  | E | W | $\mathrm{E}+\mathrm{W}$ |
| 1.3 | 532(427,659) | 831(727,966) | 250(170,352) | $342(252,478)$ | 47(35,59) | 41(32,52) |  | $44(38,50)$ |
| 1.8 | 530(424,682) | 905(756,1166) | 280(186,420) | 377(211,691) | 52(39,70) | 41(26,62) |  | 46(35,59) |
| 1.9 | $549(445,691)$ | 1094(847,1485) | 282(186,439) | 659(398,1073) | 52(37,70) | $60(44,79)$ |  | 57(46,72) |
| 1.11 | 745(578,981) | 932(774,1099) | 354(226,532) | 516(348,746) | 48(35,61) | 55(43,73) |  | 52(45,62) |
| 1.4 | 616(447,893) | 886(755,1070) | $325(208,501)$ | 486(331,700) | 52(40,68) | 55(41,71) |  | 54(43,65) |

Estimates of $B_{M S Y}$ for the base case model (Run 1.1) were $25 \%$ for both the E and W stocks.


Figure 3: 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 model (Run 1.1) and the two sensitivity runs (Runs 1.4 and 1.11). Plotted values are medians of marginal posterior distributions. Years are fishing years $(1990=1989-90)$.

### 6.3 Projections

Five-year projections were carried out, for each of the five final runs (1.3, 1.4, 1.8, 1.9, 1.11), under each of two alternative assumptions about future recruitment: „long-term' (in which future recruitments were selected at random from those estimated for 1975-10) and ,recent' (future recruitments selected from 1995-10). The recent recruitment option was considered because of the recent period of below-average recruitment for the western stock, which may persist in the short-term. The eastern stock does not show such poor recruitment in recent years. In all projections, future catches in each fishery were assumed to be the same as for 2012 (i.e., as in the last line of Table 24). The projections indicate that with these assumed catches, the E \& W biomasses are unlikely to change much in the next 5 years (Figures 8 and 9).


Figure 4: Estimated posterior distributions of current (spawning) biomass ( $B_{2011-12}$ ), expressed as \% $B_{0}$, for the $E$ (left panel), $W$ (middle panel) and $E+W$ stocks (right panel) from the base case model (Run 1.3) and the two catchability sensitivities (Runs 1.8, 1.9).




Figure 5: Estimated posterior distributions of current (spawning) biomass ( $B_{2011-12}$ ), expressed as \% $B_{0}$, for the $E$ (left panel), $W$ (middle panel) and $E+W$ stocks (right panel) from the base case model (Run 1.3) and two sensitivity runs (Runs 1.4 and 1.11).


Figure 6: Fishing intensity, U (from MPDs), plotted by run and stock. Also shown (as broken lines) are the reference levels $\boldsymbol{U}_{35 \%}$ (upper line) and $\boldsymbol{U}_{50 \%}$ (lower line), which are the fishing intensities that would cause the spawning biomass to tend to $35 \% \boldsymbol{B}_{0}$ and $50 \% \boldsymbol{B}_{0}$, respectively. The $y$-axes are scaled so that the $\boldsymbol{U}_{35 \%}$ reference lines align horizontally (within and across the stocks).

The probabilities of the current (2011) 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 20 for the case where future catches remain at 2012 levels. The probability of either stock being less than either the soft or the hard limit over the five year projection period is negligible. Both stocks are projected to be within or above the $35-50 \% B_{0}$ target range by the end of the projection period.


Figure 7: Projected spawning biomass ( $\mathbf{a s} \% \boldsymbol{B}_{0}$ ) assuming long-term (thin lines) or recent (thick lines) recruitment: median (solid lines) and 95\% confidence intervals (broken lines) for the base case model (Run 1.3) and the two catchability sensitivities runs (Runs 1.8 and 1.9).


Figure 8: Projected spawning biomass (as $\% B_{0}$ ) assuming long-term (thin lines) or recent (thick lines) recruitment: median (solid lines) and $95 \%$ confidence intervals (broken lines) for the base case model (Run 1.3) and two sensitivities runs (Runs 1.4 and 1.11).

Table 24: Probabilities (rounded to two decimal places) associated with projections for SSB (\% $\boldsymbol{\%}_{\boldsymbol{o}}$ ) in Figures 7-8.

|  | 2012 |  |  |  |  |  | 2017: Recent recruitment |  |  |  | 2017: Long-term recruitment |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1.3 | 1.8 | 1.9 | 1.11 | 1.4 | 1.3 | 1.8 | 1.9 | 1.11 | 1.4 | 1.3 | 1.8 | 1.9 | 1.11 | 1.4 |
| EAST |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| $\mathrm{P}\left(\mathrm{SSB}<10 \% B_{0}\right)$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $\mathrm{P}\left(\mathrm{SSB}<20 \% B_{0}\right)$ | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0.02 | 0 | 0 | 0 | 0 | 0.01 | 0 |
| $\mathrm{P}\left(\mathrm{SSB}<35 \% B_{0}\right)$ | 0.02 | 0 | 0.01 | 0.03 | 0 | 0.21 | 0.08 | 0.1 | 0.22 | 0.17 | 0.14 | 0.04 | 0.05 | 0.13 | 0.06 |
| $\mathrm{P}\left(\mathrm{SSB}<50 \% B_{0}\right)$ | 0.68 | 0.38 | 0.42 | 0.63 | 0.36 | 0.7 | 0.42 | 0.44 | 0.65 | 0.67 | 0.58 | 0.32 | 0.34 | 0.45 | 0.41 |
| WEST |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| $\mathrm{P}\left(\mathrm{SSB}<10 \% B_{0}\right)$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $\mathrm{P}\left(\mathrm{SSB}<20 \% B_{0}\right)$ | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.05 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0 |
| $\mathrm{P}\left(\mathrm{SSB}<35 \% B_{0}\right)$ | 0.08 | 0.22 | 0 | 0 | 0 | 0.19 | 0.3 | 0.02 | 0.09 | 0.09 | 0.1 | 0.16 | 0.01 | 0.04 | 0.03 |
| $\mathrm{P}\left(\mathrm{SSB}<50 \% B_{0}\right)$ | 0.95 | 0.81 | 0.13 | 0.24 | 0.3 | 0.68 | 0.66 | 0.16 | 0.47 | 0.49 | 0.5 | 0.47 | 0.08 | 0.29 | 0.24 |

## 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 spawning takes place simultaneously (Cook Strait and 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 | 2012 |
| :--- | :--- |
| Year of Most Recent <br> Assessment | One base case model was used to evaluate hoki stock status in this <br> assessment: Run 1.3 <br> Four sensitivity runs are also presented. |
| Assessment Runs Presented | $B_{M S Y}: 25 \% B_{0}$ <br> Management Target: $35-50 \% B_{0}$ <br> Soft Limit: $20 \% B_{0}$ <br> Hard Limit: $10 \% B_{0}$ |
| Reference Points | $B_{2012}$ was estimated to be $47 \% B_{0} ;$ Very Likely $(>90 \%)$ to be <br> above the lower end of the Management Target |
| Status in relation to Target | $B_{2012}$ is Exceptionally Unlikely $(<1 \%)$ to be below both the Soft <br> and Hard Limits |
| Status in relation to Limits |  |

## Historical Stock Status Trajectory and Current Status



Trajectory over time of fishing intensity $(U)$ and spawning biomass $\left(\% B_{0}\right)$, for the eastern hoki stock from the start of the assessment period in 1972 (represented by a red square), to 2012 . The vertical line at $10 \% B_{0}$ represents the hard limit, that at $20 \% B_{0}$ is the soft limit, and the shaded area represents the interim 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 <br> Proxy | The minimum estimate of biomass was 27\% $B_{0}$ (in 2006). <br> Biomass has subsequently been increasing. |
| :--- | :--- |
| Recent Trend in Fishing <br> Mortality or Proxy | Fishing intensity is estimated to have been continuously <br> decreasing since 2004, with a slight increase in 2012. |
| Other Abundance Indices | - |
| Trends in Other Relevant <br> Indicators or Variables | Recent recruitment (2003-2009) is estimated to be near the long- <br> term average for this stock, but for 2010 is well below average. |


| Projections and Prognosis |  |
| :--- | :--- |
| Stock Projections or Prognosis | The biomass of the eastern hoki stock is expected to stay steady <br> over the next 5 years at assumed 2011-12 eastern fishery catch <br> levels. |
| Probability of Current Catch or <br> TACC causing decline below <br> Limits | Soft Limit: Exceptionally Unlikely $(<1 \%)$ <br> Hard Limit: 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 <br> posterior distributions. |  |
| Assessment Dates | Latest assessment: 2012 | Next assessment: 2013 |
| Overall assessment quality rank | 1- High Quality |  |
| Main data inputs (rank) | - Research time series of <br> abundance indices (trawl and <br> acoustic surveys). <br> - Proportions at age data from | 1- High Quality |


|  | the commercial fisheries and <br> trawl surveys. <br> - Estimates of biological <br> parameters. <br> - New information since the <br> 2011 assessment included <br> two trawl surveys, an <br> acoustic survey, and updated <br> catch and catch-at-age data | 1 - High Quality |
| :--- | :--- | :--- |
| Commercial CPUE | 3- High Quality <br> track stock biomass |  |
| Data not used (rank) | Reweighting of the at-age data and multinomial error <br> assumption |  |
| Changes to Model Structure and <br> Assumptions | - Model structure <br> - Target strength <br> -Stock structure and migration patterns |  |
| Major Sources of Uncertainty |  |  |

## Qualifying Comments

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

## 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 ghostsharks, 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 hoki fisheries include basking sharks, deepsea skates and some other elasmobranchs.

## Western Hoki Stock

| Stock Status |  |
| :--- | :--- |
| Year of Most Recent <br> Assessment | 2012 |
| Assessment Runs Presented | One base case model was used to evaluate hoki stock status in <br> this assessment: Run 1.3 <br> Four sensitivity runs are also presented. |
| Reference Points | $B_{\text {MSY: }} 25 \% B_{0}$ <br> Management Target: $35-50 \% B_{0}$ <br> Soft Limit: $20 \% B_{0}$ <br> Hard Limit: $10 \% B_{0}$ |
| Status in relation to Target | $B_{2012}$ was estimated to be 41\% $B_{0} ;$ Very Likely $(>90 \%)$ to be <br> above the lower end of the Management Target |
| Status in relation to Limits | $B_{2012}$ Exceptionally Unlikely $(<1 \%)$ to be below both the Soft <br> and Hard Limits |



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 2012 . The vertical line at $\mathbf{1 0 \%} \boldsymbol{B}_{0}$ represents the hard limit, that at $\mathbf{2 0 \%} \boldsymbol{B}_{0}$ is the soft limit, and the shaded area represents the interim 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 is estimated to have nearly tripled from a historical low <br> of 14\% $B_{0}$ that occurred in 2004. The stock was below the soft <br> limit from 2003-07 and has now rebuilt to the target zone (in the <br> last 2 years). According to the Harvest Strategy Standard the <br> western stock is now considered to be fully rebuilt (at least a <br> $70 \%$ probability that the target has been achieved). |
| :--- | :--- |
| Recent Trend in Fishing <br> Mortality or Proxy | Fishing intensity is estimated to have been decreasing since <br> 2003, and to have increased in the last three years. |
| Other Abundance Indices | - |
| Trends in Other Relevant <br> Indicators or Variables | This stock experienced an extended period of poor recruitment <br> from 1995 to 2001. Year-classes after 2001 are estimated to be <br> stronger, with four years in which recruitment is estimated to be <br> near or above the long-term average, but the 2010 recruitment is <br> well below average. |
| Projections and Prognosis | The biomass of the western hoki stock is expected to remain <br> stable over the next 5 years at assumed 2011-12 western fishery <br> catch levels. |
| Stock Projections or Prognosis |  |
| Probability of Current Catch or <br> TACC causing decline below <br> Limits | Soft Limit: Exceptionally Unlikely (< 1\%) <br> Hard Limit: 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 <br> posterior distributions. |


| Assessment Dates | Latest assessment: 2012 | Next assessment: 2013 |
| :---: | :---: | :---: |
| Overall assessment quality rank | 1-High Quality |  |
| Main data inputs (rank) | - Research time series of abundance indices (trawl and acoustic surveys). <br> - Proportions at age data from the commercial fisheries and trawl surveys. <br> - Estimates of biological parameters. <br> - New information since the 2011 assessment included two trawl surveys, an acoustic survey, and updated catch and catch-at-age data | 1 - High Quality <br> 1 - High Quality <br> 1 - High Quality <br> 1 - High Quality |
| Data not used (rank) | Commercial CPUE | 3 - Low Quality: does not track stock biomass |
| Changes to Model Structure and Assumptions | Reweighting of the at-age data and multinomial error assumption |  |
| Major Sources of Uncertainty | - Model structure <br> - Target strength <br> - Stock structure and migration patterns <br> - Possible catchability changes in Southern Plateau trawl surveys |  |

## Qualifying Comments

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

## Fishery Interactions

On the westcoast, South Island and in the Southern Plateau fisheries the main bycatch species are hake, ling, silver warehou, jack mackerel and spiny dogfish.. Incidental interactions and associated mortalities are noted for New Zealand fur seals and seabirds. Low productivity species taken in the hoki fisheries include basking sharks, deepsea skates and some other elasmobranchs.

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## HORSE MUSSEL (HOR)



## 1. FISHERY SUMMARY

### 1.1 Commercial fisheries

Horse mussels (Atrina zelandica) were introduced into the Quota Management System on 1 April 2004, with a combined TAC of 103 t and TACC of 29. Customary non-commercial and recreational allowances are 9 t each, and 56 t was allowed for other sources of mortality. The fishing year is from 1 April to 31 March and commercial catches are measured in greenweight. TACCs have been allocated in HOR 1-HOR 9. Most reported landings have been from HOR 1, and apart from 1994-95 and 2002-03, when catches of about 5 and 7 t respectively were reported, reported landings have all been small (Table 1). About $90 \%$ of the catch is taken as a bycatch during bottom trawling and the remainder is taken as a bycatch of dredge and Danish seine. It is likely that there is a reasonably high level of unreported discarded horse mussel catch.

### 1.2 Recreational fisheries

A. zelandica do not appear in records from recreational fishing surveys (Bradford 1998, Bradford et al. 1998), but are nevertheless taken from time to time by recreational fishers. There are no estimates of recreational take for this species.

### 1.3 Customary non-commercial fisheries

A traditional food of Maori, although probably underrepresented in midden shell counts because of the fragile and short-lived nature of the shell. There are no estimates of current customary noncommercial use of this species.

## $1.4 \quad$ Illegal catch

There is no known illegal catch of this mussel.

### 1.5 Other sources of mortality

There is no quantitative information on other sources of mortality, although widespread die-offs appear to be characteristic of this species. Storm scour, shell damage and subsequent predation, and exceeding carrying capacity have been suggested as possible reasons for this.

Table 1: TACCs and reported landings (t) of Horse mussel by Fishstock from 1990-91 to 2011-12 from CELR and CLR data. There have never been any reported landings in HOR 4, 5, 6 or 8 . These fishstocks each have a TACC of $1 \mathbf{t}$ and are not reported in Table 1 below.

|  | HOR 1 |  | HOR 2 |  | HOR 3 |  | HOR 7 |  | HOR 9 |  | Total |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Fishstock | Landings | TACC | andings | TACC | Landings | TACC | Landings | TACC | Landings | TACC | Landings | TACC |
| 1990-91 | 0.834 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0.834 | - |
| 1991-92 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - |
| 1992-93 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - |
| 1993-94 | 0.003 | - | 0 | - | 0.016 | - | 0 | - | 0 | - | 0.019 | - |
| 1994-95 | 5.525 | - | 0 | - | 0 | - | 0 | - | 0 | - | 5.525 | - |
| 1995-96 | 0 | - | 0.019 | - | 0 | - | 0 | - | 0 | - | 0.019 | - |
| 1996-97 | 0.024 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0.024 | - |
| 1997-98 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0.128 | - |
| 1998-99 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - |
| 1999-00 | 0 | - | 0 | - | 0 | - | 0.81 | - | 0 | - | 0.1 | - |
| 2000-01 | 0 | - | 0 | - | 0 | - | 0.128 | - | 0 | - | 0.128 | - |
| 2001-02 | 0 | - | 0.002 | - | 0 | - | 0 | - | 0 | - | 0 | - |
| 2002-03 | 7.153 | - | 0 | - | 0 | - | 0 | - | 0 | - | 7.155 | - |
| 2003-04 | 0.026 | 4 | 0 | 2 | 0 | 2 | 0 | 16 | 0 | 1 | 0.026 | 29 |
| 2004-05 | 0.217 | 4 | 0 | 2 | 0 | 2 | 1.017 | 16 | 0.065 | 1 | 1.299 | 29 |
| 2005-06 | 0.026 | 4 | 0 | 2 | 0 | 2 | 0 | 16 | 0.942 | 1 | 0.968 | 29 |
| 2006-07 | 0 | 4 | 0 | 2 | 0 | 2 | 0.06 | 16 | 0.261 | 1 | 0.321 | 29 |
| 2007-08 | 0 | 4 | 0 | 2 | 0 | 2 | 0.451 | 16 | 0 | 1 | 0.451 | 29 |
| 2008-09 | 0.068 | 4 | 0 | 2 | 0 | 2 | 0 | 16 | 0 | 1 | 0.068 | 29 |
| 2009-10 | 0.289 | 4 | 0 | 2 | 0 | 2 | 0.112 | 16 | 0 | 1 | 0.401 | 29 |
| 2010-11 | 0 | 4 | 0 | 2 | 0 | 2 | 857 | 16 | 0 | 1 | 1 | 29 |
| 2011-12 | 0 | 4 | 0 | 2 | 0 | 2 | 0.605 | 16 | 0 | 1 | 0.605 | 29 |

## 2. BIOLOGY

The horse (or fan) mussel, Atrina zelandica, is a widespread endemic bivalve that lives mainly on muddy-sand substrates in the lowest inter-tidal and sub-tidal shallows of mainly sheltered waters. Horse mussels are also found in deeper waters (to 50 m ) off open coasts. The horse mussel is a flattened, emergent, filter-feeding mollusc, particularly conspicuous because of its size and abundance. Although more usually $260-300 \mathrm{~mm}$ long ( $110-120 \mathrm{~mm}$ wide) it can reach 400 mm in length and is New Zealands largest bivalve. Horse mussels often live in groups, forming patches of up to $10 \mathrm{~m}^{2}$ or more. The shell remains firmly embedded in the substrate by its pointed anterior end, the animal anchored to particles in the sediment by its byssus. The crenellated posterior edge projects a few centimetres above the substrate, keeping the water intake clear of surface deposits and providing attachment for an array of algae and invertebrates such as sponges and sea squirts.

Horse mussels are dioecious broadcast spawners. Although spawning may take place throughout much of the year it is probably mainly during summer. There is no information on the size or age at which breeding begins. A pelagic larva is free swimming for several days or weeks but nothing is known of its primary settlement locations, which may not necessarily be within the adult beds (some bivalves including soft sediment ones such as pipi settle in one area but later migrate to another where adult beds develop). Recruitment events can be sporadic and short-lived.

There is little published information on age, growth and mortality for horse mussels. It appears that Atrina grows rapidly for at least the first $2-4$ years: shells about 120 mm long in a northern bed increased about 40 mm per year until 166 mm , after which growth slowed dramatically (Hayward 1999, Hay C. pers. comm. in Hayward et al. 1999). Large shells are at least 5 y and possibly up to 15 y old. Widespread die-offs seem to be a feature of this species (Allan \& Walshe 1984, Grant-Mackie 1987, Hayward et al. 1999, my pers. obs.). For example, in the Rangitoto Channel, densities of 200300 per $\mathrm{m}^{2}$ reduced to $1-35$ per $\mathrm{m}^{2}$ over $2-3 \mathrm{y}$, with storm scour, shell damage and subsequent predation, and exceeding carrying capacity being possible reasons (Hayward et al. 1999).

Horse mussels have widespread effects on ecosystem structure and function. They provide shelter and refuge for invertebrates and fish, and act as substrata for the settlement of epifauna such as sponges and soft corals. They also affect boundary layer dynamics, and facilitate productivity and biodiversity by depositing pseudofaeces. The horse mussel community in most northern harbours is almost entirely
subtidal, in medium to fine muddy, but fairly stable, sand with moderate current velocities and no wave action. Similar communities have been observed in the Hauraki Gulf and Marlborough Sounds. Scallops, dredge oysters, and green lipped mussels are the main commercial shellfish species whose beds sometimes broadly overlap with the horse mussel.

## 3. STOCKS AND AREAS

For management purposes stock boundaries are based on QMAs, however, there is no biological information on stock structure, recruitment patterns, or other biological characteristics which might indicate stock boundaries.

## 4. STOCK ASSESSMENT

### 4.1 Estimates of fishery parameters and abundance

There are no estimates of fishery parameters or abundance for any horse mussel fishstock.

### 4.2 Biomass estimates

There are no biomass estimates for any horse mussel fishstock.

### 4.3 Estimation of Maximum Constant Yield (MCY)

There are no estimates of MCY for any horse mussel fishstock.

### 4.4 Estimation of Current Annual Yield (CAY)

There are no estimates of $C A Y$ for any horse mussel fishstock.

## 5. STATUS OF THE STOCKS

There are no estimates of reference or current biomass for any horse mussel fishstock. It is not known whether horse mussel stocks are at, above, or below a level that can produce MSY.

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## JACK MACKERELS (JMA)

## (Trachurus declivis, Trachurus novaezelandiae, Trachurus murphyi)

Hauture


## 1. FISHERY SUMMARY

The jack mackerel fisheries catch three species; two New Zealand species, Trachurus declivis and T. novaezelandiae, and T. murphyi which appeared in New Zealand in the 1980s.

Jack mackerels have been included in the QMS since 1 October 1996, with four QMAs. Previously jack mackerels were considered part of the QMS, although ITQs were issued only in JMA 7. In JMA 1 and JMA 3, quota for the fishery was fully allocated as IQs by regulation with the exception of the $20 \%$ allocated to customary non-commercial. Before the 1995 jack mackerel regulations were issued, catch in JMA 1 taken in the Muriwhenua area north of $36^{\circ} \mathrm{S}$ to the limit of the Territorial Sea was not covered by the JMA 1 regulations. Allowances for customary non-commercial fishers, recreational fishers and an allowance for other sources of mortality have not yet been set.

### 1.1 Commercial fisheries

In JMA 1, the jack mackerel catch is largely (about $96 \%$ of annual landings) taken by the purse seine fishery operating in the Bay of Plenty and on the east Northland coast, which was, prior to 1992, dominated by T. novaezelandiae, but included a small component of $T$. declivis. Between 1991-92 and 1995-96 the proportion of T. murphyi in the catch increased considerably, and markets were developed for large jack mackerels, but, by 1996-97, their low value resulted in less targeting of large fish. In recent years the proportion of $T$. novaezelandiae has been variable with an initial return to more than $95 \%$ in 1999-2000 and 2000-01, a decline to $46 \%$ in 2003-04, and an increase to $81 \%$ in 2004-05. Some trawl bycatch of jack mackerel has been recorded in JMA 1 .

Since 1991-92, jack mackerel targeted landings in JMA 1 have represented more than $80 \%$ of total catch. The highest rates of bycatch are from kahawai and blue mackerel targeted operations which each accounting for about $7 \%$ of the total jack mackerel catch. The majority of JMA 1 catch over these years has been taken from statistical areas 008 and 009 (Bay of Plenty) between June and November; considerably less has been taken in statistical areas 002 and 003 , although high catches were recorded from these areas in 1993-94 and 1994-95.

Jack mackerel catch in JMA 3 is almost exclusively T. murphyi and little targeting occurred before 1992-93. During the 1990s targeting increased and accounted for the majority of catch (about $50 \%$

## JACK MACKERELS (JMA)

between 1991-92 and 1996-97), but, after a peak of more than $80 \%$ in 1997-98 and 1998-99, has decreased again to about $50-60 \%$ in recent years. The balance of the catch in this area comes from trawl bycatch (squid $15-30 \%$; barracouta $15-20 \%$ ) on the Chatham Rise and in the Southland/SubAntarctic region. A purse seine fishery has operated between the Clarence River mouth and the Kaikoura Peninsula, which peaked at 4400 t in 1992-93 and averaged more than 3000 t between 1989-90 and 1993-94. Purse seine catches have shown a steady decline since, dropping from 1000 t in 1994-95, to 100 t in 2001-02 and 2002-03; no catch was recorded for 2003-04.

Increased availability of jack mackerels caused by the influx of T. murphyi resulted in increased quotas in JMA 1 and JMA 3, to 8000 t and 9000 t respectively for the 1993-94 fishing year, and a further increase to 10000 t and 18000 t respectively for the 1994-95 year. The latter increases were made under the proviso that they be accounted for by increased catches of T. murphyi only; combined landings of $T$. declivis and $T$. novaezelandiae in JMA 1 and JMA 3 must not exceed the original quotas of 5970 t and 2700 t respectively. Industry agreed to these limits and voluntarily introduced monitoring programmes to provide the information necessary for them to be met.

The three species occur in each of the Fishstocks, but are not individually identified in catch records. Landings and TACCs for 1983-84 to 2010-11 are shown for all Fishstocks in Table 1, while Figure 1 shows the historical landings and TACC values for the main JMA stocks.Total annual landings have ranged between 21059 t and 47855 t since 1986-87.

Table 1: Reported landings ( $t$ ) of jack mackerel by Fishstock from 1983-84 to 2010-11 and actual TACCs (t) for 198687 to 2010-11. QMS data from 1986-present.


Landings in JMA 1 before 1989-90 were generally well below the quota of 5970 t (Table 1), with the maximum in 1986-87 only slightly above 4000 t . Landings increased to 7529 t in 1992-93, followed
by a substantial increase to the highest recorded value of 14256 t in 1993-94, which was more than twice the original quota and exceeded the quota of 8000 t set for that year. In 1994-95 reported landings ( 7832 t ) were half those of 1993-94. Landings from 1994-95 to 1997-98 were around 7000 t . Since 1997-98 landings have fluctuated with no real pattern between a low of 2864 t in 1999-00 to the high of 11167 t in 2007-08. JMA 1 landings in 2010-11 were 8262 t .

Total landings in JMA 3 over the period 1984-85 to 1988-89 were relatively constant, at a level below the quota of 2700 t . Landings increased over subsequent years to peak in 1992-93 at almost three times that of the preceding year and more than five times the quota. Under the first of two consecutive annual increases to the JMA 3 TACC in 1993-94, landings were slightly above the limit set, but dropped almost to the higher TACC level in 1994-95. The lower 1994-95 catch relative to that in 1992-93 has been attributed to the delayed implementation of the quota, less targeting of jack mackerel, and low bycatch in the squid trawl fishery. The reduced effort is thought to be a result of marketing difficulties for the relatively lower valued T. murphyi. Landings in JMA 3 increased markedly in 1995-96 (19 803 t) to a value exceeding the quota, with catches remaining stable around 15500 t over three subsequent years. More recently, landings have decreased to levels well below the TACC, fluctuating between 705 t and 5000 t since 2000-01. Declines in landings are attributed to declining abundance of $T$. murphyi, which historically comprised the bulk of JMA 3 landings. JMA 3 landings in 2010-11 were 3592 t .

Landings in JMA 7 represent the greatest proportion of total landings and are mainly taken by chartered trawlers. Landings fluctuated between 17403 t and 25880 t from the mid 1980s through the mid 1990s. The marked decrease to 12270 t in 1995-96 is attributed to changes in fishing strategies (mid-water trawling between 2 a.m. and 4 a.m. is banned under a code of practice to eliminate dolphin bycatch in JMA 7 that has been operational since 1995-96), the withdrawal of a major company from the fishery for much of the season, and difficulty marketing the relatively low valued T. murphyi. From 1995-96 to 1998-99, landings were in the range 12 056-14 293 t . Subsequently, landings increased steadily from 15703 t in 2000-01 to 28888 t in 2003-04 and to 36507 t in 2004-05. The 2004-05 landings were 3971 t in excess of the TACC. This increase in JMA 7 landings has been attributed to market demand and a lack of availability of preferred species quota as a result of cuts in quotas for other species and taking the lower-cost option of targeting jack mackerel instead of hoki. The 2007-08 landings were 34059 t , about 1500 t larger than the TACC. In 2008-09 catches decreased below the TACC by nearly 4000 t but increased again in 2009-10 to 31152 t , which is within 1500 t of the quota.

A number of factors have been identified that can influence landing volumes in the jack mackerel fisheries. In the purse seine fishery, jack mackerel is often mixed with kahawai. Fishing companies will avoid these mixed schools to conserve kahawai quota, particularly at the beginning of the fishing year. When mixing of the two species is prevalent, low kahawai TACC can result in the targeting of jack mackerel being inhibited. Both skipjack tuna and blue mackerel have been fished in preference to jack mackerel in the purse seine fishery with the jack mackerel season being influenced by the availability of these species. However, global increases in the market price for jack mackerel have increased its importance in the purse seine fishery to a level similar to blue mackerel. This has provided fishers with a cost effective alternative to traditional purse seine targets, particularly skipjack tuna, which incurs higher costs related to on-board storage and handling.

A number of bycatch issues exist in the JMA 7 fishery. A large bycatch fishery for blue mackerel operates for many months of the year and other bycatch species taken in this fishery include barracouta, gurnard, John dory, kingfish, and snapper. Although non-availability of ACE is unlikely to be constraining in the first three of these additional species, the same is not true of kingfish, blue mackerel, and snapper. Fishing company spokespersons have stated that known hotspots of snapper are avoided.


Figure 1: Historical landings and TACC for the three main JMA stocks. From top left: JMA1 (Auckland East, Central East), JMA3 (South East coast, South East Chatham Rise, Sub Antarctic, Southland), and JMA7 (Challenger, Central Egmont, Auckland West). Note that these figures do not show data prior to entry into the QMS.

### 1.2 Recreational fisheries

Jack mackerels do not rate highly as a recreational target species although they are popular as bait.
There is some uncertainty with all recreational harvest estimates for jack mackerels 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 (JMA 1) was estimated at 333,000 fish (CV 0.13) by a diary survey in 1993-94 (Bradford 1996), 79000 fish (CV 0.16) in a national recreational survey in 1996 (Bradford 1998), 349000 fish (CV 39\%) in the 2000 survey (Boyd \& Reilly 2002) and 295000 fish (CV 0.2\%) in the 2001 survey (Boyd et al. 2004). The surveys suggest a harvest of $80-110 \mathrm{t}$ per year for JMA 1, insignificant in the context of the commercial catch. Estimates from other areas are very low (between 500 and 47000 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 Maori customary non-commercial catch is not available.

## $1.4 \quad$ Illegal catch

There is no information on illegal activity or catch but it is considered to be insignificant.

### 1.5 Other sources of mortality

There is no information on other sources of mortality.

## 2. BIOLOGY

The three species of jack mackerel in New Zealand have different geographical distributions, but their ranges partially overlap. T. novaezelandiae predominates in waters shallower than 150 m and warmer than $13^{\circ} \mathrm{C}$; it is uncommon south of latitude $42^{\circ} \mathrm{S}$. T. declivis generally occurs in deeper ( $<$ 300 m ) waters less than $16^{\circ} \mathrm{C}$, north of latitude $45^{\circ} \mathrm{S}$. T. murphyi occurs to depths of least 500 m and has a wide latitudinal range ( $0^{\circ} \mathrm{S}$ at the Galapagos Islands and coastal Ecuador, to south of $40^{\circ} \mathrm{S}$ off the Chilean coast).
T. murphyi was first described in New Zealand waters in 1987. Its presence was recorded off the south and east coasts of the South Island in the mid 1980s. It expanded onto the west coast of the South Island and the North and South Taranaki Bights by the late 1980s, reaching the Bay of Plenty in appreciable quantities by 1992 and becoming common on the east coast of Northland by June 1994. However, this extensive distribution has decreased in more recent years and, since the late 1990s, its presence north of Cook Strait has been sporadic with occasional landings in the JMA 1 purse seine fishery north of East Cape and from the JMA 1 inshore trawl fishery south of East Cape. The total range of $T$. murphyi now extends along the west coast of South America, across the South Pacific, through much of the New Zealand EEZ, and into waters off southeastern Australia.

All species can be caught by bottom trawl, mid-water trawl, or by purse seine targeting surface schools.

The vertical and horizontal movement patterns are poorly understood. Jack mackerels are presumed to be generally off the bottom at night, and surface schools can be quite common during the day.

Jack mackerels have a protracted spring-summer spawning season. T. novaezelandiae probably matures at about $26-30 \mathrm{~cm}$ fork length (FL) at an age of 3-4 years, and T. declivis matures when about $26-30 \mathrm{~cm}$ FL at an age of 2-4 years. Spawning occurs in the North and South Taranaki Bights, and probably in other areas as well.

The reproductive biology of T. murphyi in New Zealand waters is not well understood. Pre- and postspawning fish have been recorded from the Chatham Rise, Stewart-Snares shelf, Northland east coast and off Kaikoura in summer, but it is unknown whether there has been any resulting recruitment in New Zealand waters. A recent study showed that older size/age groups become increasingly dominant in catches as one moves westward from the South American coast, suggesting that an eastward migration of oceanic spawned larvae and juveniles occurs in the South Pacific.

Initial ageing of $T$. murphyi taken in New Zealand waters has been recently completed, but the estimates are yet to be validated. Initial growth is rapid, slowing at 6-7 years, and T. murphyi is a moderately long-lived species with a maximum observed age of 32 years. T. novaezelandiae and T. declivis have moderate initial growth rates that slow after about 6 years. Both species reach a maximum age of $25+$ years.

The best available estimate of $M$ for T. novaezelandiae and $T$. declivis is 0.18 based on the age-frequency distributions of lightly exploited populations in the Bay of Plenty. Assuming $M=0.18$,
estimates of $Z$ made in 1989 suggest that $F$ is less than 0.05 for both endemic species off the central west coast (the main jack mackerel fishing ground). Biological parameters relevant to the stock assessment are shown in Table 2.

Table 2: Estimates of biological parameters.

| Fishstock |  | Estimate |  | Source |
| :---: | :---: | :---: | :---: | :---: |
| 1. Natural mortality ( $M$ ) |  |  |  |  |
| All |  |  | 0.18 |  |
|  | Considered best estimate for both endemic species from all areas. |  |  | Horn (1991a) |
| 2. Weight $=\mathrm{a}(\text { length })^{\underline{\mathrm{b}}}{ }^{( }$Weight in g, length in cm fork length $)$ |  |  |  |  |
|  |  | a | All |  |
| T. declivis |  | 0.023 | 2.84 | Horn (1991a) |
| T. novaezelandiae |  | 0.028 | 2.84 | Horn (1991a) |
| 3. von Bertalanffy growth parameters |  |  |  |  |
|  |  |  | All |  |
|  | $L_{\infty}$ | $k$ | $t_{0}$ |  |
| T. declivis | 46 cm | 0.28 | -0.40 | Horn (1991a) |
| T. novaezelandiae | 36 cm | 0.30 | -0.65 | Horn (1991a) |
| T. s. murphyi | 51.2 cm | 0.155 | -1.4 | Taylor et al. (2002) |

## 3. STOCKS AND AREAS

There are no new data that would alter the stock boundaries given in previous assessment documents. For assessment purposes the three jack mackerel species are treated separately where possible.

There are two possible hypotheses on the stock structure of T. murphyi in New Zealand waters: it is either a separate stock established by fish migrating from South America, or part of a single, extensive trans-Pacific stock. While successful recruitment in New Zealand waters would indicate the establishment of a separate stock, current evidence favours the latter hypothesis with an extensive stock between latitudes $35-50^{\circ} \mathrm{S}$, linking the coasts of Chile and New Zealand across what has been described as 'the jack mackerel belt'. Few detailed data are available to document the process of range expansion by $T$. murphyi or indicate the relative abundance of the three species in particular areas. Data from jack mackerel catch monitoring, which is a requirement of the increased TACCs introduced in 1994-95, will be useful in quantifying species composition and the relative abundance in JMA 1 and JMA 3.

## 4. ENVIRONMENTAL \& ECOSYSTEM CONSIDERATIONS

This section was updated with new tables for the May 2012 Fishery Assessment Plenary based on reviews of similar chapters by the Aquatic Environment Working Group. This summary is from the perspective of the jack mackerel trawl fishery; a more detailed summary from an issue-by issue perspective is, or will shortly be, available in the Aquatic Environment \& Biodiversity Annual Review (http://fs.fish.govt.nz/Page.aspx?pk=113\&dk=22982).

### 4.1 Role in the ecosystem

Not discussed by the AEWG.

### 4.2 Incidental catch (fish and invertebrates)

Not discussed by the AEWG.

### 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 or caught on a hook but not brought onboard the vessel, Middleton \& Abraham 2007, Brothers et al. 2010).

### 4.3.1 Marine mammal interactions

Jack mackerel trawlers occasionally catch marine mammals, primarily common dolphin, long-finned pilot whales, and NZ fur seals (which were all classified as "Not Threatened" under the NZ Threat Classification System in 2010, Baker et al. 2010).

Between 2002-03 and 2009-10, there were 116 observed captures of whales and dolphins in Jack mackerel trawl fisheries. Observed captures were common dolphin (105), long-finned pilot whale (8), "porpoise" (1), dusky dolphin (1), and bottlenose dolphin (1) In the 2009-10 fishing year there were four observed captures of common dolphins in Jack mackerel trawl fisheries (Table 3). There were 30 ( $95 \%$ c.i.: $7-69$ ) estimated captures, with the estimates made using a statistical model. Common dolphins were observed captured off the Taranaki coast or off the west coast of the North Island (Thompson \& Abraham 2012). The rate of capture varied in these years from 0.3 to 11.2 per 100 tows with some tendency for lower rates of capture in recent years.

In the 2009-10 fishing year there were 2 observed captures of NZ fur seal in Jack mackerel trawl fisheries (Table 4). No estimates of total captures have been made for this fishery, but the low capture rate suggests only a small fraction of the total captures of NZ fur seals in trawl fisheries have been taken when targeting Jack mackerel. Fur seal captures in the Jack mackerel trawl fishery have been off the Taranaki coast, off the west coast of the North Island, or off the east coast of the South Island. The rate of capture for NZ fur seals has averaged 0.7 captures per 100 tows (range 0.2 to 1.3) and has fluctuated without obvious trend.

Table 3: Number of tows by fishing year and observed and model-estimated total common dolphin captures in Jack mackerel trawl fisheries, 2002-03 to 2009-10. 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. Data from Thompson \& Abraham (2012), retrieved from http://bycatch.dragonfly.co.nz/v20120315/

|  | Tows | Observed |  |  |  | Estimated |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | No.obs | \%obs | Captures | Rate | Captures | 95\%c.i. | \%inc. |
| 2002-03 | 3067 | 346 | 11.3 | 20 | 5.78 | 157 | 62-306 | 73.3 |
| 2003-04 | 2383 | 152 | 6.4 | 17 | 11.18 | 117 | 51-219 | 93.5 |
| 2004-05 | 2509 | 558 | 22.2 | 20 | 3.58 | 84 | 45-140 | 92.2 |
| 2005-06 | 2807 | 709 | 25.3 | 2 | 0.28 | 13 | 2-35 | 74.2 |
| 2006-07 | 2712 | 800 | 29.5 | 11 | 1.38 | 58 | 23-111 | 78.0 |
| 2007-08 | 2647 | 818 | 30.9 | 20 | 2.44 | 45 | 25-77 | 79.0 |
| 2008-09 | 2169 | 813 | 37.5 | 11 | 1.35 | 29 | 13-55 | 81.6 |
| 2009-10 | 2407 | 785 | 32.6 | 4 | 0.51 | 30 | 7-69 | 89.2 |

Table 4: Number of tows by fishing year and observed and model-estimated total NZ fur seal captures in Jack mackerel trawl fisheries, 2002-03 to 2009-10. No. obs, number of observed tows; \% obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Data from Thompson \& Abraham (2012), retrieved from http://bycatch.dragonfly.co.nz/v20120315/

|  | Tows | No. obs | \% obs | Captures | Rate |
| :--- | ---: | ---: | ---: | ---: | ---: |
| $2002-03$ | 3067 | 346 | 11.3 | 1 | 0.29 |
| $2003-04$ | 2383 | 152 | 6.4 | 2 | 1.32 |
| $2004-05$ | 2509 | 558 | 22.2 | 5 | 0.90 |
| $2005-06$ | 2807 | 709 | 25.3 | 6 | 0.85 |
| $2006-07$ | 2712 | 800 | 29.5 | 2 | 0.25 |
| $2007-08$ | 2647 | 818 | 30.9 | 7 | 0.86 |
| $2008-09$ | 2169 | 813 | 37.5 | 8 | 0.98 |
| $2009-10$ | 2407 | 785 | 32.6 | 2 | 0.25 |

### 4.3.2 Seabird interactions

Annual observed seabird capture rates ranged from 0 to 2.56 per 100 tows in jack mackerel fisheries between 1998-99 and 2007-08 (Baird 2001, 2004 a,b,c, 2005a, 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 5). In the 2009-10 fishing year there were three observed captures of birds in the Jack mackerel trawl fishery at a rate of 0.4 birds per 100 observed tows (Thompson \& Abraham 2012). No estimates of total captures were made. The average capture rate in Jack mackerel trawl fisheries over the last eight years is only 0.5 birds per 100 tows, a low rate relative to trawl fisheries for squid (13.3 birds per 100 tows), scampi ( 3.53 birds per 100 tows) and hoki ( 2.2 birds per 100 tows) over the same years.

Table 5: Number of tows by fishing year and observed seabird captures in jack mackerel trawl fisheries, 2002-03 to 2009-10. No. obs, number of observed tows; \% obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Data from Thompson \& Abraham (2012), retrieved from http://bycatch.dragonfly.co.nz/v20120315/

|  | Tows | No. obs | \% obs | Captures | Rate |
| :--- | ---: | ---: | ---: | ---: | ---: |
| $2002-03$ | 3067 | 346 | 11.3 | 4 | 1.16 |
| $2003-04$ | 2383 | 152 | 6.4 | 0 | 0.00 |
| $2004-05$ | 2509 | 558 | 22.2 | 7 | 1.25 |
| $2005-06$ | 2807 | 709 | 25.3 | 0 | 0.00 |
| $2006-07$ | 2712 | 800 | 29.5 | 1 | 0.12 |
| $2007-08$ | 2647 | 818 | 30.9 | 1 | 0.12 |
| $2008-09$ | 2169 | 813 | 37.5 | 6 | 0.74 |
| $2009-10$ | 2407 | 785 | 32.6 | 3 | 0.38 |

Observed seabird captures since 2002-03 have been mostly prions, shearwaters, and petrels (20 of the 22 observed seabird captures), and only one albatross capture has been observed (Table 6). Seabird captures in the jack mackerel fishery have been observed mostly off Taranaki and on the Stewart-Snares shelf. These numbers should be regarded as only a general guide on the distribution of captures because the numbers are small, and the observer coverage is not uniform across areas and may not be representative.

Table 6: Number of observed seabird captures in jack mackerel trawl fisheries, 2002-03 to 2009-10, 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. 2011 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 from Thompson \& Abraham (2012), retrieved from http://bycatch.dragonfly.co.nz/v20120315/

| Species | $\begin{aligned} & \text { Risk } \\ & \text { ratio } \end{aligned}$ | Taranaki | Stewart Snares Shelf | West Coast South Island | East Coast South Island | Total |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Southern Buller's | 1.28 | 0 | 0 | 0 | 1 | 1 |
| "Large seabird" | - | 1 | 0 | 0 | 0 | 1 |
| Total albatrosses |  | 1 | 0 | 0 | 1 | 2 |
| Fairy prion | 0.00 | 5 | 0 | 0 | 0 | 5 |
| Sooty shearwater | - | 1 | 3 | 0 | 0 | 4 |
| White chinned petrel | 0.79 | 0 | 4 | 0 | 0 | 4 |
| Fulmar prion | - | 3 | 0 | 0 | 0 | 3 |
| Cape petrels | 0.76 | 1 | 0 | 1 | 0 | 2 |
| Common diving petrel | 0.00 | 0 | 0 | 1 | 0 | 1 |
| Westland petrel | 3.31 | 0 | 0 | 1 | 0 | 1 |
| Total other birds |  | 10 | 7 | 3 | 0 | 20 |

Mitigation methods such as streamer (tori) lines, Brady bird bafflers, warp deflectors, and offal management are used in the Jack mackerel trawl fishery. Warp mitigation was voluntarily introduced from about 2004 and made mandatory in April 2006 (MFish 2006). The 2006 notice mandated that all trawlers $>28 \mathrm{~m}$ 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

Jack mackerel are taken using trawls that are sometimes fished on or near the seabed. Target Jack mackerel tows accounted for about $3.5 \%$ 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 C, E (shelf), H (upper slope), and J (mid-slope) (Baird \& Wood 2012), and 91\% were in water shallower than 200 m (Baird et al. 2011).

Trawling for Jack mackerel with some or all of the gear contacting the bottom, 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 2001, Hermsen et al. 2003, Hiddink et al. 2006, Reiss et al. 2009). These consequences are not considered in detail here but are discussed in the Aquatic Environment and Biodiversity Annual Review (2012).

### 4.5 Other considerations

None considered by the AEWG.

## 5. STOCK ASSESSMENT

Stock assessments for jack mackerel are complicated by the reporting and management of three species under a single code. Preliminary stock assessments for T. declivis and T. novaezealandiae in JMA 7 were undertaken in 2007 based on data from a new Bayesian analysis for splitting the recorded commercial catch into T. declivis, T. novaezealandiae, and T. murphyi components. This analysis was used to derive a catch history and CPUE indices for the T. declivis fishery in JMA 7, which were incorporated along with a proportions-at-age series into the assessments.

The assessment for $T$. declivis is described below, but the assessment for $T$. novaezealandiae is not included because of convergence problems with the assessment model which led to its rejection by the working group.

Otherwise, there are no new data that would alter the yield estimates given in the 1996 Plenary Report. Estimates of MCY for JMA 1 and JMA 3 have not changed since the 1993 Plenary Report. Other yield estimates have not changed since the 1991 Plenary Report. The yield estimates are based on biomass estimates from a stock reduction analysis and aerial sightings data.

### 5.1 T. declivis in Challenger, Central West and Auckland West (JMA 7)

## Species Proportion Estimates

A Bayesian species proportions model was used to estimate the proportion of T. declivis in the reported (TCEPR) catch for the JMA 7 fishery from 1989-09 through to 2004-05. Six spatialtemporal strata were used in the model: three spatial strata in combination with two temporal strata. The three spatial strata consisted of three regions with differing patterns in the relative proportions of the three jack mackerel species. The two temporal strata are a summer fishery (October-March) and a winter fishery (April-September). In the model the species proportions are estimated for each year (1989-90 to 2004-05), and the six strata for that year.

## CPUE

The Bayesian species proportions model was used to estimate the T. declivis catch for each TCEPR tow, and the derived catch-effort data used in a standardised CPUE analysis. Based on changes in jack mackerel fishery practice, and changes in vessel composition over time, the CPUE analysis was split into two time periods: into an early period covering the years 1989-90 to 1995-96, and a late period covering 1996-97 to 2004-05 (Table 7).

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Table 7: Standardised CPUE indices (relative year effects) with number of tows from 1989-90 to 2004-05.

|  | Year | CPUE index | CV | Number of tows |
| :--- | :--- | ---: | ---: | ---: |
| $1989-90$ | 1990 | 2.07 | 0.1 | 716 |
| $1990-91$ | 1991 | 2.05 | 0.1 | 688 |
| $1991-92$ | 1992 | 1.9 | 0.1 | 947 |
| $1992-93$ | 1993 | 1.56 | 0.09 | 1088 |
| $1993-94$ | 1994 | 1.37 | 0.09 | 1444 |
| $1994-95$ | 1995 | 1.28 | 0.09 | 597 |
| $1995-96$ | 1996 | 0.89 | 0.1 | 502 |
| $1996-97$ | 1997 | 1.69 | 0.13 | 160 |
| $1997-98$ | 1998 | 0.92 | 0.11 | 252 |
| $1998-99$ | 1999 | 2.7 | 0.08 | 712 |
| $1999-00$ | 2000 | 2.15 | 0.08 | 717 |
| $2000-01$ | 2001 | 2.67 | 0.07 | 1240 |
| $2001-02$ | 2002 | 2.85 | 0.07 | 1760 |
| $2002-03$ | 2003 | 2.38 | 0.06 | 2272 |
| $2003-04$ | 2004 | 2.59 | 0.07 | 2055 |
| $2004-05$ | 2005 | 3.23 | 0.07 | 2002 |

## Catch History

Catch records for jack mackerel extend back to 1946, though landings are small until the mid 1960s. The Bayesian model annual species proportions were used to estimate the T. declivis landings from 1991-92 to 2004-05, while previous species proportions were used to estimate landings for the earlier years (Table 7).

Recreational catch, illegal catch, and customary non-commercial catch are not well known, though are thought to be small relative to the commercial catch, so no components are included for these in the catch history.

## Catch at Age

Catch-at-age data were used from the commercial fishery in the years 1989-90, 1990-91, 1995-96, and 2004-05.

Table 8: Catch history ( $t$ ) for T. declivis in the JMA 7 fishery. The year denotes the year at the end of the fishing year.

| Year | Estimated catch | Year | Estimated catch | Year | Estimated catch |
| :--- | ---: | :--- | ---: | :--- | ---: |
| 1946 | 3 | 1967 | 3326 | 1988 | 10340 |
| 1947 | 1 | 1968 | 3326 | 1989 | 10963 |
| 1948 | 2 | 1969 | 3326 | 1990 | 6315 |
| 1949 | 8 | 1970 | 2787 | 1991 | 6759 |
| 1950 | 0 | 1971 | 4634 | 1992 | 12422 |
| 1951 | 0 | 1972 | 6405 | 1993 | 7925 |
| 1952 | 3 | 1973 | 5284 | 1994 | 10741 |
| 1953 | 4 | 1974 | 6423 | 1995 | 6809 |
| 1954 | 0 | 1975 | 4591 | 1996 | 5276 |
| 1955 | 5 | 1976 | 5518 | 1997 | 4702 |
| 1956 | 1 | 1977 | 6151 | 1998 | 5002 |
| 1957 | 3 | 1978 | 2197 | 1999 | 10045 |
| 1958 | 4 | 1979 | 2524 | 2000 | 4339 |
| 1959 | 0 | 1980 | 1522 | 2001 | 6595 |
| 1960 | 2 | 1981 | 3547 | 2002 | 13403 |
| 1961 | 2 | 1982 | 3372 | 2003 | 12781 |
| 1962 | 2 | 1983 | 5540 | 2004 | 16752 |
| 1963 | 5 | 1984 | 6980 | 2005 | 17154 |
| 1964 | 4 | 1985 | 8967 | 2006 | - |
| 1965 | 3 | 1986 | 6801 | 2007 | - |
| 1966 | 23 | 1987 | 11493 | 2008 | - |

## Model Structure

In 2007, the observational data were incorporated into an age-based Bayesian stock assessment to estimate stock size. The stock was considered to reside in a single area, with no partition by sex or
maturity. In the model age groups were 1-25 years, with a plus group of $25+$. The model covered the period 1965-2005 (estimated catch was insignificant before 1965).

There was a single time step in the model, in which the order of processes is ageing, recruitment, and mortality (natural and fishing). Recruitment numbers followed a Beverton-Holt relationship with steepness of 0.924 derived from a mean value over a number of species similar to jack mackerel. Maturation was not explicitly modeled; instead a maturity-at-age logistic ogive was used with an $a_{50}$ of 3 and an $a_{\text {to95 }}$ of 9 years. Growth was assumed to follows a von Bertalanffy curve.

The model was fitted to: (a) an early CPUE series covering the years 1990 to 1996, (b) a late CPUE series covering the years 1997 through to 2005, (c) and a commercial proportions-at-age series for 1990, 1991, 1996, and 2005. A research trawl proportions-at-age for 1981 was not entered into the model, but the fit to it was evaluated outside the model assuming that the research trawl selectivity is the same as the commercial trawl selectivity. A double half normal curve was used to model the commercial trawl selectivity.

The relative influence of the different data series in the model were evaluated by dropping the early CPUE series, dropping the late CPUE series, and putting more weight on the proportions-at-age data by increasing their effective sample size.

## Results

For the base model in this preliminary assessment it was estimated that current biomass is at $53 \%$ of virgin biomass $\left(B_{0}\right)$. The biomass trajectory indicates a decline in biomass until the mid 1990s, followed by an increase in biomass until 2002, subsequently followed by a slight decline (Figure 2).

Dropping the early CPUE series estimated the current biomass to be at $76 \% B_{0}$, in contrast dropping the late CPUE series put the current biomass at only $30 \% B_{0}$. Doubling the effective sample sizes for all the proportions-at-age data estimated the current biomass at $66 \% B_{0}$.


Figure 2: Biomass trajectories for the base case. The left-hand graph shows the fit of the CPUE indices to the vulnerable biomass; the right-hand graph the mature biomass trajectory. The year denotes the year at the end of the fishing year.

### 5.2 Estimates of fishery parameters and abundance

Estimates of fishery parameters are given in Table 9.
Table 9: Estimates of fishery parameters.

| Parameter | Fishstock | Estimate | Comments | Source |
| :--- | :--- | ---: | ---: | ---: |
| F0.1 | JMA 7 | 0.23 | T. declivis | Horn (1991a) |
|  |  | 0.33 | T. novaezelandiae | Horn (1991a) |

### 5.3 Biomass estimates

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

### 5.4 Estimation of Maximum Constant Yield (MCY)

The 2007 assessment for T. declivis did not include yield estimates so there is no information to update the historical estimates described below.
(i) Challenger, Central (West) and part of Auckland (West) (QMAs 7, 8, and part of 9)

MCY was estimated in the early 1990s for the two endemic jack mackerel species separately using the equation MCY = $2 / 3$ MSY (Method 3). The deterministic MSY values ( $8.8 \%$ and $14.7 \%$ of $B_{0}$ for T. declivis and $T$. novaezelandiae respectively) were calculated using a yield per recruit analysis and a Beverton and Holt stock-recruitment relationship with an assumed steepness of $0.95 . B_{0}$ was estimated using a backward projection of a stock reduction analysis that produced biomass trajectories over the period 1970-90.

For Trachurus declivis, $B_{o}=200000 \mathrm{t}$,
$M C Y=2 / 3 *(0.088 * 200000 \mathrm{t})=11800 \mathrm{t}$
For Trachurus novaezelandiae, $B_{0}=100000 \mathrm{t}$,
$M C Y=2 / 3 *(0.147 * 100000 \mathrm{t})=9800 \mathrm{t}$
Because these yield estimates are based on an assumed stock-recruitment relationship, they are highly uncertain.
(ii) Northland, Bay of Plenty, east coast North Island (QMAs 1 and 2)

Annual landings before 1990-91 ranged from 1173 t to less than 5000 t . Since then, landings have increased markedly as a result of the increased availability of $T$. murphyi to a maximum in excess of 14000 t in 1993-94. Concerns about the assumptions used to produce the original yield estimate and the production of time series abundance indices from aerial sightings data resulted in a revised yield estimate in the mid 1990s. The aerial sightings indices showed little change in jack mackerel abundance estimates in JMA 1 between 1976 and 1990.
$M C Y$ was estimated in 1993 using the equation $M C Y=c Y_{A V}(\operatorname{method} 4)$ incorporating the mean of removals from 1983-84 to 1989-90, before the T. murphyi invasion influenced total catches. It is assumed that this represents a period when fishing effort was relatively stable, thus satisfying the criterion for the use of method 4 . The calculated $M C Y$ applies only to $T$. declivis and $T$. novaezelandiae.

Using $M=0.18$ and therefore $c=0.8, M C Y=0.8 * 3013=2410 \mathrm{t}$ (rounded to 2400 t ).

## (iii) Rest of the EEZ (QMAs 3-6)

Trawl surveys in QMAs 3-6 are not considered to be a suitable means to estimate biomass of jack mackerels, due primarily to the slow towing speed. Landings from JMA 3 have fluctuated widely since 1983-84, and were relatively high in the 1990s due probably to an increased abundance of $T$. murphyi. In the two most recent years, catches were equivalent to the lowest on record, which was last experienced in 1984-85.

For JMA 3 there are no available estimates of biomass and no series of catch data from a period of relatively constant fishing mortality. Therefore, it is not possible to estimate MCY for this Fishstock.

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

### 5.5 Estimation of Current Annual Yield (CAY)

Estimates of current biomass are not available for any jack mackerel stock, so CAY cannot be estimated.

Yield estimates for T. declivis and T. novaezelandiae are shown in Table 10.
Table 10: Yield estimates for T. declivis and T. novaezelandiae (t).

| Parameter | Fishstock | Estimate |
| :--- | :--- | ---: |
| MCY | JMA 1 | 2400 |
|  | JMA 3 | Cannot be determined |
|  | JMA 7 | 21600 |
| CAY | All | Cannot be determined |

### 5.6 Other yield estimates and stock assessment results

For T. declivis and T. novaezelandiae catch-at-age proportions are available for the years 2006-07 through to 2008-09 in JMA 7. These were used to estimate instantaneous total mortality $Z$ values by the Chapman-Robson maximum likelihood method (Chapman \& Robson 1960). As a sensitivity analysis the assumed age of recruitment was varied from three to six years (Smith 2011).

For $T$. declivis estimates of $Z$ vary between $0.17 \mathrm{y}^{-1}$ and $0.23 \mathrm{y}^{-1}$. For $T$. novaezelandiae, $Z$ varied between $0.23 \mathrm{y}^{-1}$ and $0.43 \mathrm{y}^{-1}$. Estimates were lowest in the 2008-09 year for both species. The accepted value of natural mortality for both species is $0.18 \mathrm{y}^{-1}$, indicating that estimates of average instantaneous fishing mortality $(F)$ were well below M for JMD and about M for JMN.


Figure 3: Estimates of instantaneous total mortality $(Z)$ by year for T. declivis and T. novaezelandiae in JMA 7.

### 5.7 Other factors

The estimates of $M C Y$ given above are likely to be conservative as they do not take into account the presence of the third species, T. murphyi, which has been known at times to comprise a substantial proportion of the purse seine catches in the area between Cook Strait and Kaikoura, in the Bay of Plenty and on the east Northland coast, although the proportion of this component seems to have declined considerably since the late 1990s. It is also the main trawl-caught mackerel on the Chatham Rise and the Stewart Island-Snares shelf region and has been a major proportion of jack mackerel catches on the west coast South Island. T. murphyi has also been an important component of the west coast North Island jack mackerel trawl fishery, but its presence appears to have declined in recent years. Thus, there has been a contraction in the range of this species in New Zealand waters, although
it is unknown yet whether this represents a decrease in its overall abundance here. The effect of in $T$. murphyi on the range and abundance of the other two species is unknown.

Aerial sightings data were used to produce a time series of relative abundance indices for jack mackerel. The time series covered the period from the beginning of the purse seine fishery in 1976, to 1993. They indicated increases in abundance in JMA 1 from the early 1990s, and, although the result is not as clear, similar trends in JMA 3 and JMA 7. These increases were attributed to the invasion of T. murphyi.

The validity of this early aerial sightings abundance index is uncertain. Further analysis of these data have been the focus of considerable effort in recent years and the Northern Inshore Working Group had not yet accepted revised abundance indices due to data and model concerns. Research into developing abundance indices from aerial sightings data is continuing.

The stipulation that catches in JMA 1 and JMA 3 above the original TACs ( 5970 t and 2700 t , respectively) be accounted for by increases in T. murphyi only, is a method of managing this species independently of the other two. This approach was introduced as a means of maintaining stocks of the endemic species while allowing exploitation of increased stocks of $T$. murphyi resulting from its invasion.

## 6. STATUS OF THE STOCKS

Assessment of the status of JMA is complicated by the reporting and management of three species under a single code. This is further complicated by the uncertain 'status' of T. murphyi. The effect of the T. murphyi invasion on stocks of the New Zealand jack mackerels is unknown.

## Stock Structure Assumptions

The three species have different levels of mobility and different spatial distributions within New Zealand. T. murphyi has been extremely mobile, with a widespread distribution throughout New Zealand during the 1990s, but is now rarely seen in areas where once it was common. The degree to which its biomass has actually declined is difficult to determine and there are no recent reliable estimates of its current spatial distribution. There are reports from hoki surveys in Cook Strait of aggregations of T. murphyi lying in deeper water.
T. declivis is also believed to be highly mobile within New Zealand. Because of this, a single biological stock is assumed, but this has not been reliably investigated. The mobility of $T$. novaezelandiae is assumed to be lower, given that it is a smaller animal with a more northerly and inshore distribution than T. declivis. Consequently, there is a higher probability of multiple independent breeding populations for T. novaezelandiae.

JMA 1

| Stock Status |  |
| :--- | :--- |
| Year of Most Recent <br> Assessment | 1993: $M C Y=c Y_{A V}$ |
| Reference Points | Target(s): Not established but $B_{\text {MSY }}$ assumed <br> Soft Limit: $20 \% B_{0}$ <br> Hard Limit: $10 \% B_{0}$ |
| Status in relation to Target | Unknown |
| Status in relation to Limits | Unknown |
| Historical Stock Status <br> Trajectory and Current Status | Unknown |

## Fishery and Stock Trends

Recent Trend in Biomass or Proxy

An index for JMA 1 is not available at this time. Recent work and

|  | relative abundance indices concluded that the inter-annual variation <br> was too great for these data to provide a reliable index. |
| :--- | :--- |
| Recent Trend in Fishing <br> Mortality or Proxy | - |
| Trends in other Relevant <br> Indicators or Variables | - |


| Projections and Prognosis |  |
| :--- | :--- |
| Stock Projections or Prognosis | It is not known whether catches at the level of the current TACCs or <br> recent catch levels are sustainable in the long-term. |
| Probability of Current Catch <br> or TACC causing decline <br> below Limits | Soft Limit: Unknown <br> Hard Limit: Unknown |


| Assessment Methodology |  |
| :--- | :--- |
| Assessment Type | Level 3 — Qualitative Evaluation: Fishery characterisation with <br> evaluation of fishery trends (e.g., catch, effort and nominal CPUE, <br> length-frequency information) - there is no agreed index of <br> abundance. |
| Assessment Method | None |
| Main data inputs | Species proportions estimates |
| Period of Assessment | Latest assessment: 1993 | Next assessment: Unknown $\quad$| Changes to Model Structure <br> and Assumptions | - |
| :--- | :--- |
| Major Sources of Uncertainty | - |

## Qualifying Comments

## Fishery Interactions

JMA 1 catches are primarily taken by targeted purse seine. Because jack mackerel often occur in mixed schools with kahawai, particularly towards the end of the fishing year, this can inhibit jack mackerel targeting in this fishery at this time.

## JMA 3

## Stock Status

| Year of Most Recent <br> Assessment | - |
| :--- | :--- |
| Reference Points | Management Target: $40 \% B_{0}$ <br> Soft Limit: $20 \% B_{0}$ <br> Hard Limit: $10 \% B_{0}$ |
| Status in relation to Target | Unknown |
| Status in relation to Limits | Unknown |
| Historical Stock Status <br> Trajectory and Current Status | Unknown |

## Fishery and Stock Trends

| Recent Trend in Biomass or <br> Proxy | - |
| :--- | :--- |
| Recent Trend in Fishing <br> Mortality or Proxy | - |

## Projections and Prognosis

Stock Projections or Prognosis

Probability of Current Catch or TACC causing decline below Limits

Soft Limit: Unknown
Hard Limit: Unknown

| Assessment Methodology |  |
| :--- | :--- |
| Assessment Type | Level 4: Low information evaluation - there are only data on catch <br> and TACC, with no other fishery indicators. Catch is qualified with <br> species proportions estimates from MFish observer data. Some <br> length-frequency information is available. |
| Assessment Method | None |
| Main data inputs | Species proportions estimates |
| Period of Assessment | Latest assessment: |
| Changes to Model Structure <br> and Assumptions | - |
| Major Sources of Uncertainty | - |

## Qualifying Comments

## Fishery Interactions

JMA 3 catches are primarily taken by midwater trawl and comprise a very high percentage of $T$. murphyi.

JMA 7

| Stock Status |  |
| :--- | :--- |
| Year of Most Recent <br> Assessment | 2011 |
| Reference Points | Management Target: $40 \% B_{0}$ <br> Soft Limit: 20\% $B_{0}$ <br> Hard Limit: $10 \% B_{0}$ |
| Status in relation to Target | Unknown |
| Status in relation to Limits | Unknown |
| Historical Stock Status Trajectory and Current Status |  |


| Fishery and Stock Trends |  |
| :--- | :--- |
| Recent Trend in Biomass or <br> Proxy | - |
| Recent Trend in Fishing <br> Mortality or Proxy | Estimates of total mortality for T. declivis (JMD) and T. <br> novaezelandiae (JMN) from catch curve analyses in 2011 suggest <br> that fishing mortality was well below M for JMD and about M for <br> JMN; i.e. it is Unlikely (<40\%) that overfishing is occurring. |
| Other Abundance Indices | - |
| Trends in Other Relevant <br> Indicators or Variables | - |


| Projections and Prognosis |  |
| :--- | :--- |
| Stock Projections or Prognosis | Unknown |
| Probability of Current Catch <br> or TACC causing decline <br> below Limits | Soft Limit: Unknown <br> Hard Limit: Unknown |


| Assessment Methodology |  |
| :--- | :--- |
| Assessment Type | Level 2 - Partial quantitative stock assessment |
| Assessment Method | Catch curve analysis |


| Main data inputs | - | Next assessment: 2014 |
| :--- | :--- | :--- |
| Period of Assessment | Latest assessment: 2011 |  |
| Changes to Model Structure <br> and Assumptions | - |  |
| Major Sources of Uncertainty | No abundance indices are available. The analyses (catch curves) <br> may not provide accurate values of average fishing mortality. |  |

## Qualifying Comments

## Fishery Interactions

JMA 7 catches are primarily taken by targeted midwater trawl. A number of bycatch issues exist with blue mackerel an important component of this fishery and non-availability of ACE for kingfish, blue mackerel, and snapper potentially influencing targeting in some sub-areas. Incidental interactions and associated mortality of common dolphins occurs in this fishery.

Yield estimates, TACCs and reported landings for the 2010-11 fishing year are summarised in Table 11.

Table 11: Summary of TACCs ( $t$ ) and reported landings ( $t$ ) for all three species in the most recent fishing year.

| Fishstock |  | QMA | 2010-11 <br> Actual TAC | 2010-11 <br> Reported landings |
| ---: | :--- | :--- | ---: | :--- |
| JMA 1 | Auckland (East)/ Central (East) | 1,2 | 10000 | 8262 |
| JMA 3 | South-East/Southland/Sub-Antarctic | $3,4,5,6$ | 18000 | 3592 |
| JMA 7 | Challenger/Central (West)/Auckland | $7,8,9$ | 32537 | 28177 |
| (West) | 10 | 10 | 0 |  |
| JMA 10 | Kermadec |  | 60547 | 40031 |

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[^0]:    ${ }^{1}$ MSY-compatible reference points include those related to stock biomass (i.e. $\mathrm{B}_{\mathrm{MSY}}$ ), fishing mortality (i.e. $\mathrm{F}_{\mathrm{MSY}}$ ) 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=61\&tk=208\&se=\&sd=Asc\&filSC=\&filAny=False\&filSrc=False\&filLoaded=False\&filDCG=9\&filDC= 0\&filST=\&filYr=0\&filAutoRun=1

[^1]:    ${ }^{3}$ Link to the 2011 May Plenary Report: http://fs.fish.govt.nz/Page.aspx?pk=61\&tk=212

[^2]:    ${ }^{4}$ Link to the Research Standard:
    http://www.fish.govt.nz/en-nz/Publications/Research+and+Science+Information+Standard.htm

[^3]:    Abraham E.R. 2011. Probability of Mild Traumatic Brain Injury for sea lions interacting with SLEDs. Final Research Report for project SRP2011-03 (Unpublished report held by the Ministry of Fisheries, Wellington). 21 p.
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[^4]:    * 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).

[^5]:    ** 2009 south Otago survey only covered half the survey strata. Results are shown for fixed and random sites from all pot placements.

[^6]:    Anderson O.F., Bagley N.W., Hurst R.J., Francis M.P., Clark M.R., McMillan P.J. 1998. Atlas of New Zealand fish and squid distributions from research bottom trawls. NIWA Technical Report 42. 303 p.
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[^7]:    ${ }^{1}$. 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

[^8]:    ${ }^{2} \mathrm{http}: / / \mathrm{www}$. biosecurity.govt.nz/media/21-08-09/cockle-death-whangateau-estuary 164

[^9]:    ${ }^{1}$ Statistics supplied by New Zealand Food Safety Authority in Whangarei.

[^10]:    ${ }^{1}$ This permit is able to be extended or revoked before this date. 176

[^11]:    ${ }^{2}$ 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 Runanaga and various recreational, environmental, commercial, community and scientific groups, was appointed in 2001.

[^12]:    ${ }^{1}$ No confidence intervals were available for these estimates. 196

[^13]:    * FSU data.
    $\ddagger$ Includes 11 t Turbot, area unknown but allocated to QMA 7.

[^14]:    * 1 April-31 March.
    $\ddagger 1$ October-30 September.
    $\dagger 1$ April-30 September.

[^15]:    § These totals do not match those in Table 2 due to under-reporting to the FSU.
    N/A Unknown.

