Ministry for Primary Industries
Manatū Ahu Matua

Fisheries Assessment Plenary November 2012

Stock Assessment and Yield Estimates

Compiled by the Fisheries Science Group

Growing and Protecting New Zealand

The New Zealand Government Ministry for Primary Industries
Fisheries Science Group

Fisheries Assessment Plenary **November 2012**
Stock Assessments and Yield Estimates

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Preface

The mid-year November 2012 Fisheries Plenary Report summarises fishery, biological, stock assessment and stock status information for 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. The November Plenary includes Working Group and Plenary summaries for species that operate on different management cycles to those summarised in the May Plenary Report. It includes Highly Migratory Species (HMS), rock lobster, scallops and dredge oysters, covering 17 species in total.

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 November 2012 Plenary now includes Status of the Stocks summary tables for 26 stocks or sub-stocks, spread over 16 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. A further addition to this year's Plenary is an environmental and ecosystems considerations section for all HMS sections. The HMS chapters have also been substantially overhauled, with considerable new stock assessment information and graphics included.

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 30 November 2012.

Pamela Mace

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Contents

Introduction

1. This report presents the status of the fish stocks for highly migratory species, rock lobster, dredge oysters, and scallops resulting from research and stock assessments up to and including 2012.

2. The reports from the Highly Migratory Species Working Group summarise the conclusions and recommendations of the meetings of the Working Group held during 2011, and the outcomes of the Western and Central Pacific Fisheries Commission (WCPFC) and the Commission for the Conservation of Southern Bluefin Tuna (CCSBT).

3. The report from the Rock Lobster Working Group summarises the conclusions and recommendations of the meetings of the Working Group up to 2012. The decision rules were evaluated and are reported for each stock in the report.

4. The reports from the Shellfish Working Group summarise the conclusions and recommendations of the meetings of the Working Group held during 2012.

5. The toothfish assessments, for the first year, have been shifted to the May Plenary as a summary of the most recent fishing year (ending in February) can be included and research planning for the upcoming year will be complete.

6. In all cases, consideration has been based on and limited to the best available information. The purpose has been to provide objective, independent assessments of the current state of the fish stocks.

7. Where possible, the statuses of the stocks relative to MSY-compatible targets and limits have been assessed. In many cases other management measures have also been discussed.

8. In considering Maori, traditional, recreational and other non-commercial interests, some difficulty was experienced both in terms of the data available and the intended scope of this requirement. In the absence of any more definitive guidelines, current interests and activities have been considered. In most cases, only very limited information is available on the nature and extent of non-commercial interests.

Sources of data

9. A major source of information for all assessments continues to be the fisheries statistics system. It is very important to maintain and develop that system to provide adequate and timely data for stock assessments.

10. There are issues with data reporting to the WCPFC that adds uncertainty to some of the regional highly migratory species assessments.

Other Information

11. Fisheries Assessment Reports more fully describing the data and the analyses have also been prepared. These documents will be distributed when final versions are available.

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.

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

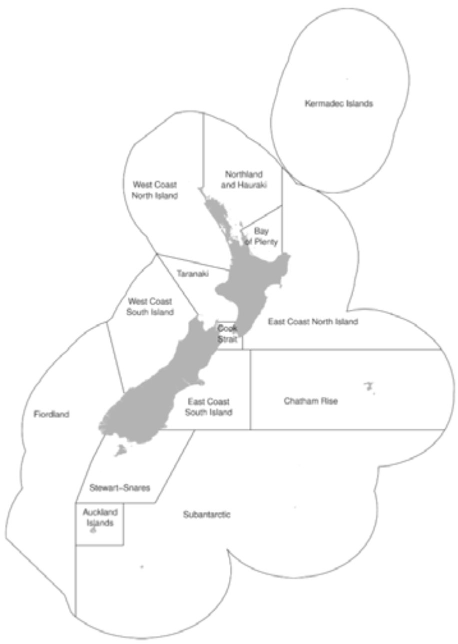
a_{50}: Either the age at which 50% of fish are mature (= A_M) or 50% are recruited to the fishery (=A_R)

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

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**

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

Areas used for summarising the fishing effort and protected species captures. For more information see: http://data.dragonfly.co.nz/psc/about/



B_{AV} **:** 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.

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

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

B_{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).

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

B_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_{REF}, to an estimate of the fishable **biomass** at the beginning of the fishing year (see page 19). 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.

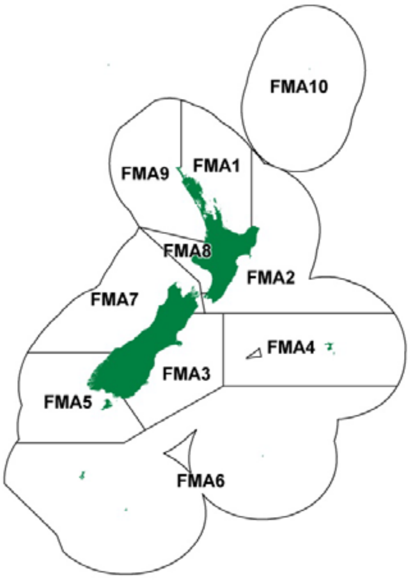
Exploitation rate: The proportion of the **recruited** or **vulnerable biomass** that is caught during a certain period, usually a fishing year.

***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 1/10th 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.



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

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

F_{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_{MSY}.

***F_{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_{MAX}. 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 limit**s and **hard limit**s.

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

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

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

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

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

S_{AV}: The average historic **spawning biomass**.

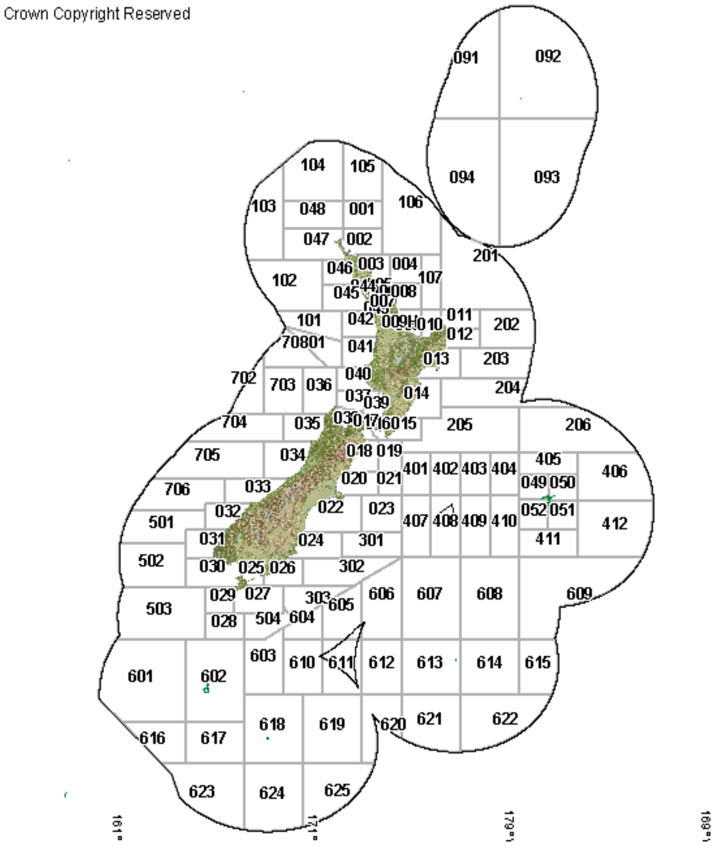
Selectivity ogive: Curve describing the relative vulnerability of fish of different ages or sizes to the fishing gear used.

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:



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_{MSY} and/or F_{MSY}).

Stock-recruitment relationship: An equation describing how the expected number of recruits to a stock varies as the **spawning biomass** changes. The most frequently used stock-recruitment relationship is the 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_{MSY} or B_0 or F_{MSY} or $F_{\%SPR}$. For example, the current biomass may be said to be above or below B_{MSY} or to be at some percentage of B_0. Similarly, fishing mortality may be above or below F_{MSY} or $F_{\%SPR}$.

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

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

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

TAC: Total Allowable Catch 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

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

where L_∞ 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 (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 MSY-compatible reference points and other relevant indicators of stock status; to conduct projections of stock size under alternative management scenarios; and to review results from relevant research projects.

Fisheries Assessment Working Groups (FAWGs) evaluate relevant research, determine the status of fisheries and fish stocks and evaluate the consequences of alternative future management scenarios. They do not make management recommendations or decisions (this responsibility lies with MPI fisheries managers and the Minister responsible for Fisheries).

Preparatory tasks

1. Prior to the beginning of the main sessions of FAWG meetings (January to May and September to November), MPI fisheries scientists will produce a list of stocks for which new stock assessments or evaluations are likely to become available prior to the next scheduled sustainability rounds. FAWG Chairs will determine the final timetables and agendas.
2. At least six months prior to the main sessions of FAWG meetings, MPI fisheries managers will alert MPI science managers and the Principal Advisor Fisheries Science to unscheduled special cases for which assessments or evaluations are urgently needed.

Technical objectives

3. To review any new research information on stock structure, productivity, abundance and related topics for each fish stock 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 levels and/or fishing mortality (or exploitation) rates if current catches and/or

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

[2] Link to the Harvest Strategy Standard: http://fs.fish.govt.nz/Page.aspx?pk=61&tk=208&se=&sd=Asc&filSC=&filAny=False&filSrc=False&filLoaded=False&filDCG=9&filDC=0&filST=&filYr=0&filAutoRun=1

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, non-commercial and recreational interests in the stock; as well as all other mortality to that stock caused by fishing, which might need to be allowed for before setting a TAC or TACC.
11. To provide information and advice on other management considerations (e.g. area boundaries, by-catch issues, effects of fishing on habitat, other sources of mortality, and input controls such as mesh sizes and minimum legal sizes) required for specifying sustainability measures. Sections of the Working Group reports related to bycatch and other environmental effects of fishing will be reviewed by the Aquatic Environment Working Group although the relevant FAWG is encouraged to identify to the AEWG Chair any major discrepancies between these sections and their understanding of the operation of relevant fisheries.
12. To summarise the stock assessment methods and results, along with estimates of MSY-compatible references points and other metrics that may be used as benchmarks for assessing stock status.
13. To review, and update if necessary, the "Status of the Stocks" sections of the Fisheries Assessment Plenary report for all stocks under the purview of individual FAWGs (including those for which a full assessment has not been conducted in the current year) based on new data or analyses, or other relevant information.
14. For all important stocks, to complete (and/or update) the Status of Stocks template provided on pages 35-36 of the 2011 May Plenary document, following the associated instructions on pages 35-38. [3,4]
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

[3] Link to the 2011 May Plenary Report: http://fs.fish.govt.nz/Page.aspx?pk=61&tk=212

[4] The template was slightly modified in the May 2012 Plenary to incorporate new requirements from the Research and Science Information Standard for New Zealand Fisheries; some, but not all, of the reports in the 2012 November Plenary have used updated template. Link to the 2012 May Plenary Report: http://prod.maf.govt.nz/news-resources/publications.aspx

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 MPI fisheries scientist who is an active participant in the Working Group, providing technical input, rather than simply being a facilitator. Working Group Chairs will be responsible for:
    - ensuring that Working Group participants are aware of the Terms of Reference for the working group, and that the Terms of Reference are adhered to by all participants.
    - setting the rules of engagement, facilitating constructive questioning, and focussing on relevant issues.
    - ensuring that all peer review processes are conducted in accordance with the Research and Science Information Standard for New Zealand Fisheries[5] (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

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[5] Link to the Research Standard:

http://www.fish.govt.nz/en-nz/Publications/Research+and+Science+Information+Standard.htm 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.
- reporting on Working Group recommendations, conclusions and action items; and ensuring follow-up and communication with the MPI Principal Advisor Fisheries Science, relevant MPI fisheries management staff, and other key stakeholders.

Working Group members

18. Working Groups will consist of the following participants:
    - MPI fisheries science chair – required
    - Research providers – required (may be the primary researcher, or a designated substitute capable of presenting and discussing the agenda item)
    - Other scientists not conducting analytical assessments to act in a peer review capacity
    - Representatives of relevant MPI fisheries management teams
    - 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 MPI-Fisheries website prior to meetings if they are available. As a general guide, Powerpoint presentations and draft or discussion papers should be available at least 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 MPI-Fisheries website after each meeting has taken place.
32. Data upon which analyses presented to the Working Groups are based must be provided to MPI in the appropriate format and level of detail in a timely manner (i.e. the data must be available and accessible to MPI; however, data confidentiality concerns mean that such data are not necessarily available to Working Group members)
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. MPI 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.

Fishery Assessment Working Groups – Membership 2012

Highly Migratory Species Working Group

Convenor: Stephen Brouwer

Members: Peter Ballantyne, Ian Doonan, Malcolm Francis, Marc Griffiths, Lynda Griggs, Bruce Hartill, Stephanie Hill, John Holdsworth, Arthur Hore, Charles Hufflet, Terese Kendrick, Adam Langley, Tania MacPherson, Jeremy McKenzie, David Middleton, Clive Monds, Marine Pomarede, Tim Sippel, Peter Smith.

Species: Albacore, Bigeye tuna, Blue shark, Mako shark, Pacific bluefin tuna, Porbeagle shark, Ray's bream, Skipjack tuna, Southern bluefin tuna, Striped marlin, Swordfish, Yellowfin tuna

Rock Lobster Working Group

Convenor: Kevin Sullivan, (Geoff Tingley)

Members: William Arlidge, Paul Breen, Charles Edwards, Jeff Forman, Chris Francis, Simon Gilmour, Vivian Haist, Malcolm Lawson, Andy McKenzie, Alicia McKinnon, John McKoy, Pamela Mace, David Middleton, Marine Pomarede, Paul Starr, Kevin Stokes, Daryl Sykes, D'Arcy Webber, Lance Wickman.

Species: Red rock lobster, packhorse rock lobster

Shellfish Working Group

Convenor: Julie Hills

Members: David Baker, Kate Bartrum, Jason Baker, Michelle Beritzhoff, Richard Bian, Erin Breen, Paul Breen, Stephen Brown, Willie Calder, Jeremy Cooper, Patrick Cordue, Martin Cryer, Alistair Dunn, Rich Ford, Allen Frazer, Russell Frew, Dan Fu, Bruce Hartill, Weimin Jiang, Jane Kuper, Pamela Mace, Andrew McKenzie, Keith Michael, David Middleton, Reyn Naylor, Tracey Osborne, Marine Pomarede, Alan Riwaka, Matthew Pawley, David Skeggs, Storm Stanley, Paul Starr, Ian Tuck, Ellie Watts, James Williams, Graeme Wright.

Species: Dredge oysters, scallops

QMS stocks and Ministry of Fisheries Management team with responsibility for management

INSHORE

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

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

DEEPWATER

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

HMS

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

** non-QMS species*

Guide to Biological Reference Points for Fisheries Assessment Meetings

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

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

Definitions of *MCY* and *CAY*

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

The definitions are:

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

and

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

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

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

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

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

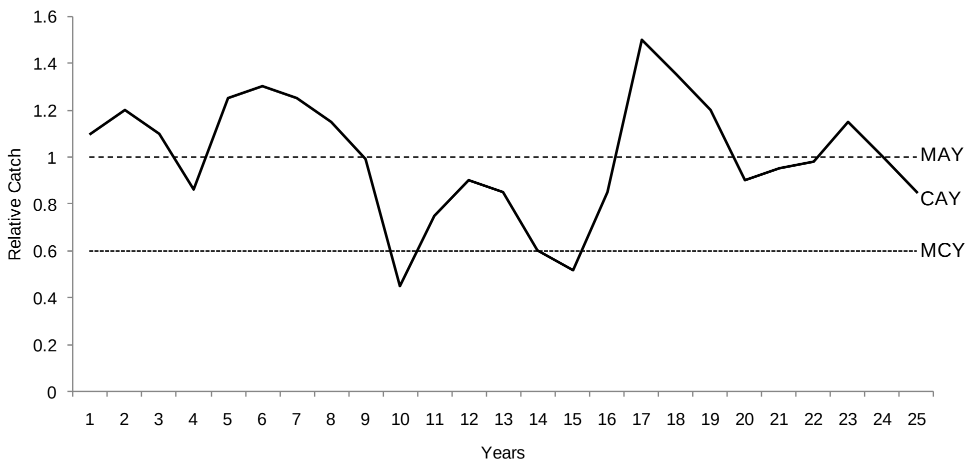

Figure 1: Relationship between *CAY*, *MCY* and *MAY*.

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

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

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

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

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

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

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

Natural and Fishing Mortality

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

Natural mortality

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

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

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

Reference Fishing Mortalities

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

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

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

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

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

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

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

Natural Variability Factor

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

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

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

Methods of Estimating *MCY*

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

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

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

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

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

New fisheries

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

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

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

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

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

2. Developed fisheries with historic estimates of biomass

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

where B_{AV} 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 $F_{0.1}$ approximates the average productivity of a stock.

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

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

$$MCY = 2/3MSY$$

where MSY is the deterministic maximum equilibrium yield.

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

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

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

$$MCY = 2/3CSP$$

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

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

$$MCY = cY_{AV}$$

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

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

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

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

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

5. Sufficient information for a stochastic population model

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

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

Methods of Estimating *CAY*

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

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

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

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

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

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

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

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

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

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

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

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

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

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Guidelines for Status of the Stocks Summary Tables

A new format for Status of the Stocks summaries was developed by the Stock Assessment Methods Working Group over the period February-April 2009. The purpose of this project was to provide more comprehensive and meaningful information for fisheries managers, stakeholders and other interested parties. Previously, Status of the Stocks summary sections had not reflected the full range of information of relevance to fisheries management contained in the 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 Assessment	2012
Assessment Runs Presented	Base case model only
Reference Points[4]	Target: 40% B_0 Soft Limit: 20% B_0 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 above the target
Status in relation to Limits[5,6]	B_{2012} is Very Unlikely (< 10%) to be below both the soft and hard limits
Historical Stock Status Trajectory and Current Status <insert relevant graphs>	

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy[7]	Biomass reached its lowest point in 2001 and has since consistently increased
Recent Trend in Fishing Mortality or Proxy[6,7]	Overfishing is Unlikely (< 40%) to be occurring
Other Abundance Indices[8]	-
Trends in Other Relevant Indicators or Variables[9]	Recent recruitment (2005-2010) is estimated to be near the long-term average

Projections and Prognosis	
Stock Projections or Prognosis[10]	Biomass is expected to stay steady over the next 5 years assuming current (2011-12) catch levels
Probability of Current Catch or TACC causing decline below Limits[6,11]	Soft Limit: Very Unlikely (< 10%) 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 posterior distributions	
Main data inputs	- Research time series of abundance indices (trawl and acoustic surveys) - Proportions at age data from the commercial fisheries and trawl surveys - Estimates of biological parameters - New information since the 2011 assessment included two trawl surveys, an acoustic survey, and updated catch and catch-at-age data	
Period of Assessment	Latest assessment: 2012	Next assessment: 2014
Changes to Model Structure and Assumptions[13]	None since the 2009 assessment	
Major Sources of Uncertainty	The base case model deals with the lack of older fish in commercial catches and surveys by estimating natural mortality at age which results in older fish suffering high natural mortality. However, there is no evidence to validate this outside the model estimates. Aside from natural mortality, other major sources of uncertainty include stock structure and migration patterns, stock-recruit steepness and natal fidelity assumptions. Uncertainty about the size of recent year classes affects the reliability of stock projections.	

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

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_{MSY}-compatible target (or F_{MSY}, or a related F_{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, non-QMS 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.

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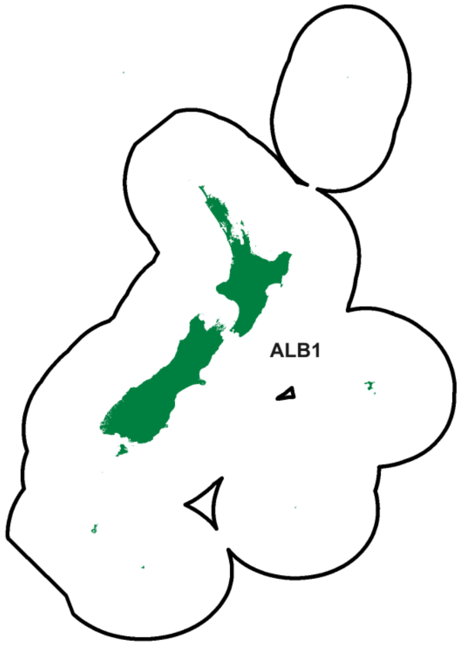
ALBACORE (ALB)

(*Thunnus alalunga*)
Ahipataha



1. FISHERY SUMMARY

Albacore is currently outside the Quota Management System.

Management of albacore stock throughout the South Pacific is the responsibility of the Western and Central Pacific Fisheries Commission (WCPFC). Under this regional convention New Zealand is responsible for ensuring that the management measures applied within New Zealand fisheries waters are compatible with those of the Commission.

At its seventh annual meeting the WCPFC passed a Conservation and Management Measure (CMM) (this is a binding measure that all parties must abide by) CMM2010-05 relating to conservation and management measures for South Pacific albacore tuna. Key aspects of this CMM are repeated below:

1. "Commission Members, Cooperating Non-Members, and participating Territories (CCMs) shall not increase the number of their fishing vessels actively fishing for South Pacific albacore in the Convention Area south of 20°S above current (2005) levels or recent historical (2000-2004) levels".

2. The provisions of paragraph 1 shall not prejudice the legitimate rights and obligations under international law of small island developing State and Territory CCMs in the Convention Area for whom South Pacific albacore is an important component of the domestic tuna fishery in waters under their national jurisdiction, and who may wish to pursue a responsible level of development of their fisheries for South Pacific albacore.

3. CCMs that actively fish for South Pacific albacore in the Convention Area south of the equator shall cooperate to ensure the long-term sustainability and economic viability of

the fishery for South Pacific albacore, including cooperation and collaboration on research to reduce uncertainty with regard to the status of this stock.

4. This measure will be reviewed annually on the basis of advice from the Scientific Committee on South Pacific albacore.”

1.1 Commercial fisheries

In New Zealand, albacore form the basis of a summer troll fishery, primarily on the west coasts of the North and South Islands. This fishery accounts for a large proportion of the domestic albacore landings. Albacore are also caught throughout the year by longline (1000-2500 t per year). Total annual landings between 2000 and 2009 have averaged 4047 t (largest landing 6744 t in 2003) (Table 1). Figure 1 shows the historical landings and fishing effort for albacore stocks.

The earliest known commercial catch of tuna (species unknown but probably skipjack tuna) was by trolling and was landed in Auckland in the year ending March 1943. Regular commercial catches of tuna, however, were not reported until 1961. These catches are summarised in Table 1 (species unknown but primarily albacore and skipjack and possibly included southern bluefin and yellowfin tuna). Prior to 1973 the albacore troll fishery was centred off the North Island (Bay of Plenty to Napier and New Plymouth) with the first commercial catches off Greymouth and Westport (54% of the total catch) in 1973. The expansion of albacore trolling to the west coast of the South Island immediately followed experimental fishing by the *W. J. Scott*, which showed substantial quantities of albacore off the Hokitika Canyon and albacore as far south as Doubtful Sound. Tuna longlining was not established as a fishing method in the domestic industry until the early 1990s.

While albacore trolling occurs in most FMAs during summer months and accounts for the bulk of the domestic albacore catch, they are also a longline target and are caught incidentally during longline sets for bigeye and southern bluefin tuna. Longline albacore has been important in some years since 1999 and currently represents 10% of annual domestic albacore landings. In addition to troll and longline, some albacore are reported caught by pole-and-line and hand line.

Table 1: Reported total New Zealand landings (t) and landings (t) from the South Pacific Ocean (SPO) of albacore tuna from 1972 to present.

Year	NZ fisheries waters	SPO	Year	NZ fisheries waters	SPO	Year	NZ fisheries waters	SPO
1972	240	39 521	1987	1 236	25 052	2002	5 566	73 153
1973	432	47 330	1988	672	37 867	2003	6 744	62 105
1974	898	34 049	1989	4 884	49 076	2004	4 459	61 788
1975	646	23 600	1990	3 011	36 062	2005	3 459	63 514
1976	25	29 082	1991	2 450	35 600	2006	2 542	62 443
1977	621	38 740	1992	3 481	38 668	2007	2 092	58 585
1978	1 686	34 676	1993	3 327	35 438	2008	3 720	62 767
1979	814	27 076	1994	5 255	42 318	2009	2 115	82 943
1980	1 468	32 541	1995	6 159	38 467	2010	2 290	89 021
1981	2 085	34 784	1996	6 320	34 328	2011	3 212	72 654
1982	2 434	30 788	1997	3 628	39 490			
1983	720	25 092	1998	6 525	50 371			
1984	2 534	24 704	1999	3 903	39 586			
1985	2 941	32 328	2000	4 428	47 152			
1986	2 044	36 590	2001	5 349	58 233			

Source: LFRR and MHR WCPFC Yearbook 2012 Anon (2012).

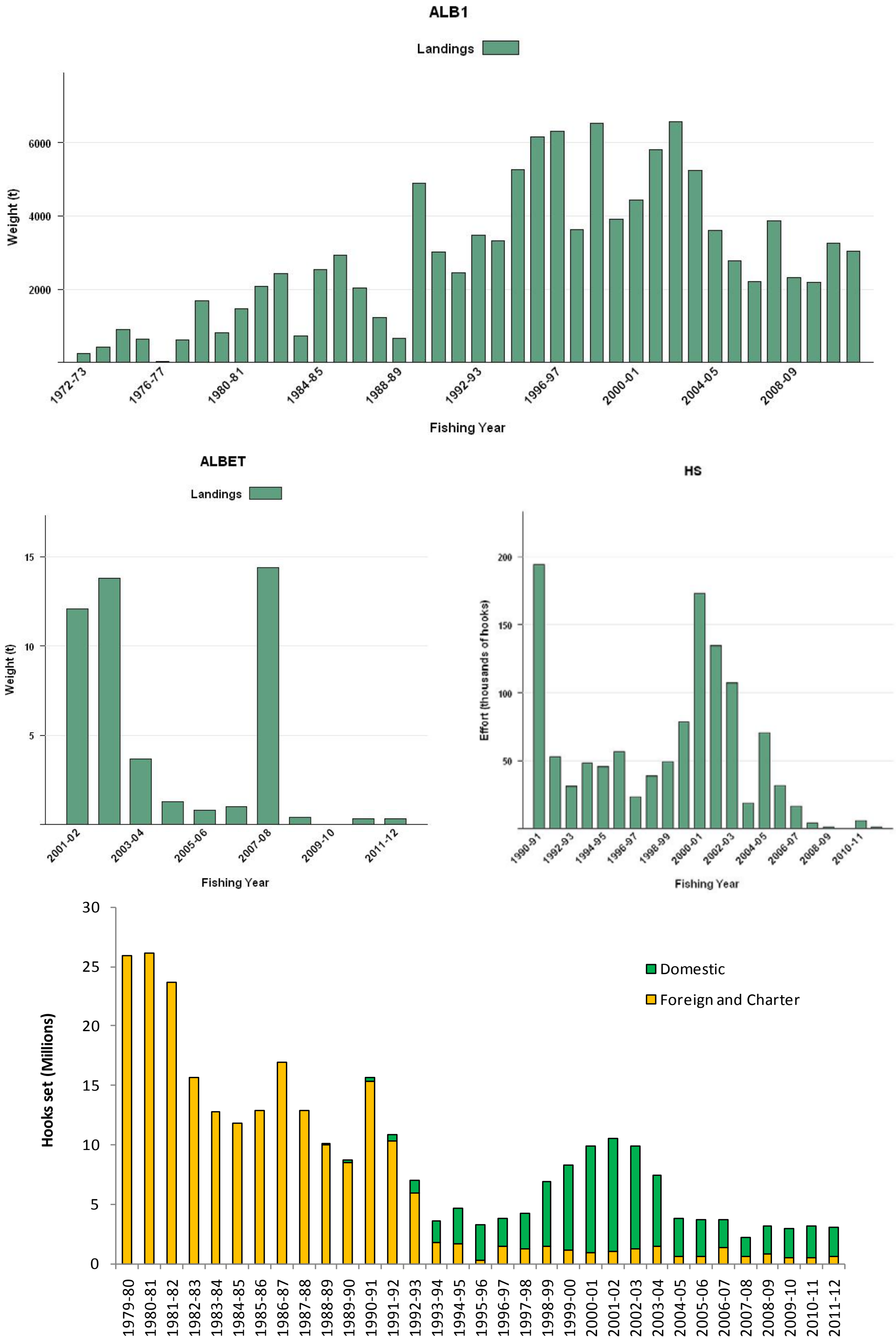


Figure 1: [Top and middle left] Albacore catch from 1972-73 to 2011-12 within NZ waters (ALB1) and 2001-02 to 2011-12 on the high seas (ALBET). [Middle right] Fishing effort (number of hooks set) for all high seas New Zealand flagged surface longline vessels, and [Bottom] domestic vessels (including effort by foreign vessels chartered by NZ fishing companies), from 1990-91 to 2011-12 and 1979-80 to 2011-12, respectively.

The New Zealand albacore fishery, especially the troll fishery has been characterised by periodic poor years that have been linked to poor weather or colder than average summer seasons. Despite this variability, domestic albacore landings have steadily increased since the start of commercial fishing in the 1960s. The average catch in the 1960s (19 t) increased in the 1970s to 705 t, in the 1980s to 2256 t, the 1990s averaged 4571 t but both catch and effort have declined almost continuously through 2000s from a high in 2002-03.

The south Pacific albacore catch in 2010 (88 919 mt) was the highest on record (12 000 mt higher than the previous record in 2009 at 76 500 mt). Catches from within New Zealand fisheries waters in 2010 were about 3% of the South Pacific albacore catch.

Most albacore troll fishery catches are in the 1st and 2nd quarters with the 4th quarter important in some years (1994 to 1996). Most of the troll fishery catch comes from FMA7 off the west coast of the South Island although FMA 1, FMA 2, FMA 8 and FMA 9 have substantial catches in some years. High seas troll catches have been infrequent and a minor component (maximum catch of 42.2 t in 1991) of the New Zealand fishery over the 1991 to 2011 period. Albacore are caught by longline throughout the year as a bycatch on sets targeting bigeye and southern bluefin tuna. Most of the longline albacore catch is reported from FMA 1 and FMA 2 with lesser amounts caught in FMA 9. While albacore are caught regularly by longline in high seas areas, New Zealand effort and therefore catches are small.

Small catches of albacore are occasionally reported using pole-and-line and hand line gear. Pole-and-line catches of albacore have been reported from FMA 1, FMA 2, FMA 5, FMA 7, and FMA 9. Hand line catches have been reported from FMA 1 and FMA 7.

The majority of albacore are caught in the New Zealand surface longline fishery. While 66% of longline fishing effort is directed at bigeye tuna (Figure 2), across all longline fisheries, albacore make up the bulk of the catch (33%) (Figure 3). Albacore catch in longline fisheries is distributed along the east and west coast of the North Island and the west coast of the South Island. The west coast South Island fishery predominantly targets southern bluefin tuna, whereas the North Island fisheries target a range of species including bigeye, swordfish, and southern bluefin tuna. The troll fishery targets albacore and occurs along the entire west coast of the North and south Island with some targeted fishing on the east coast of the North Island (Figure 4).

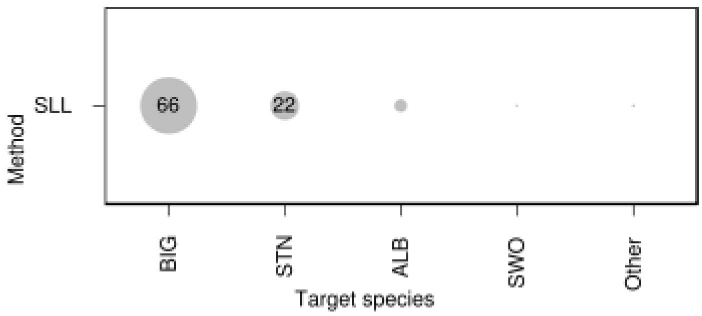


Figure 2: A summary of the proportion of landings of albacore taken by each target fishery and fishing method. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the bobble is the percentage (Bentley *et al.*2012).

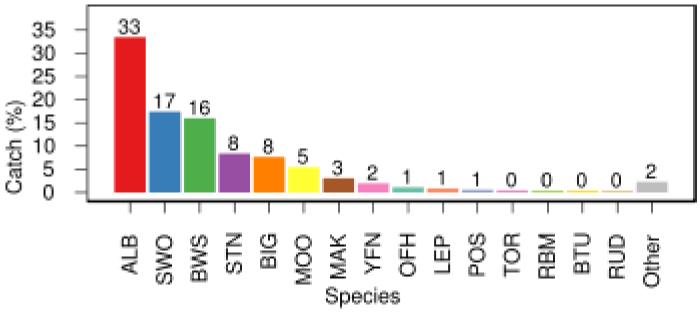


Figure 3: A summary of species composition of the reported surface longline catch. The percentage by weight of each species is calculated for all surface longline trips (Bentley *et al.*2012).

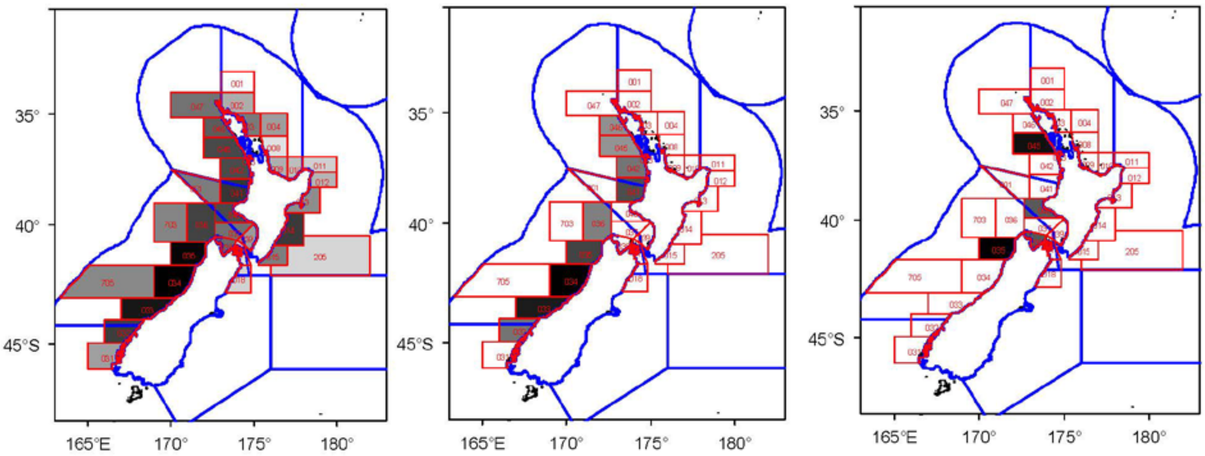


Figure 4: Plots showing the albacore catch by stat area from CELR reporting forms (left); catch sampled in fish processing sheds (centre); and observed catch (right) for the 2011-12 fishing year.

In the longline fishery, 38.2% of albacore tuna were alive when brought to the side of the vessel for all fleets (Table 2). The domestic fleets retained around 96-98% of their albacore tuna catch, while the foreign charter fleet retain almost all the albacore (98-100%). The Australian fleet that fished in New Zealand waters in 2006-07 also retained most of the albacore catch (92.4%) (Table 3).

Table 2: Percentage of albacore (including discards) that were alive or dead when arriving at the longline vessel and observed during 2006–07 to 2009–10, by fishing year, fleet and region. Small sample sizes (number observed < 20) were omitted Griggs and Baird (in press).

Year	Fleet	Area	% alive	% dead	Number
2006-07	Australia	North	21.5	78.5	79
	Charter	North	61.2	38.8	784
		South	77.3	22.7	587
	Domestic	North	28.1	71.9	1 880
	Total		**44.4**	**55.6**	**3 330**
2007-08	Charter	South	71.3	28.7	167
	Domestic	North	22.7	77.3	1 765
	Total		**26.9**	**73.1**	**1 932**
2008-09	Charter	North	84.6	15.4	410
		South	79.5	20.5	112
	Domestic	North	33.7	66.3	1 986
	Total		**44.0**	**56.0**	**2 511**
2009-10	Charter	South	82.1	17.9	78
	Domestic	North	28.8	71.2	1 766
		South	42.9	57.1	42
	Total		**31.3**	**68.7**	**1 886**
Total all strata			**38.2**	**61.8**	**9 659**

Table 3: Percentage albacore that were retained, or discarded or lost, when observed on a longline vessel during 2006–07 to 2009–10, by fishing year and fleet. Small sample sizes (number observed < 20) omitted Griggs and Baird (in press).

Year	Fleet	% retained	% discarded or lost	Number
2006-07	Australia	92.4	7.6	79
	Charter	97.7	2.3	1 448
	Domestic	96.1	3.9	1 882
	Total	**96.7**	**3.3**	**3 409**
2007-08	Charter	98.8	1.2	170
	Domestic	95.9	4.1	1 769
	Total	**96.1**	**3.9**	**1 939**
2008-09	Charter	99.7	0.3	605
	Domestic	97.8	2.2	1 993
	Total	**98.2**	**1.8**	**2 598**
2009-10	Charter	100.0	0.0	89
	Domestic	97.2	2.8	1 814
	Total	**97.3**	**2.7**	**1 903**
Total all strata		**97.1**	**2.9**	**9 849**

1.2 Recreational fisheries

Recreational fishers catch albacore by trolling. There is some uncertainty with all recreational harvest estimates for albacore as presented below. Bradford (1996, 1998) provides estimates of the recreational catch of albacore. While the information provided is restricted to 1993 and 1996 information on where and when catches are made and by what fishing methods is provided. Bradford indicates that recreational albacore catches are made in summer (91%) and autumn (9%) months by a mixture of trolling (73%) and lining from boats (27%) in the parts of FMA 1, FMA 2 and FMA 9 surveyed. The recreational survey in 1996 provides greater area coverage and Bradford provides estimates of the albacore catch from FMA 1, FMA 2, FMA 3, FMA 5, FMA 8 and FMA 9. The available estimates of recreational catch of albacore are presented in Table 4. The historic survey results suggest annual recreational catches of albacore were around 245-260 t.

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; and b) the 1996 and earlier surveys contain a methodological error.

Table 4: Estimates of recreational albacore catch by number and weight (t).

Year	Area	Catch (number)	Catch (t)
1993	MFish. North region	48 000	245
1996	FMA 1	16 000	82
	FMA 2	20 000	102
	FMA 3	< 500	< 2.5
	FMA 5	2 000	10
	FMA 8	5 000	26
	FMA 9	8 000	41
	1996 total	51 000 to 51 500	260 to 263

Source: Bradford (1996, 1998).

1.3 Customary non-commercial fisheries

It is uncertain whether albacore were caught by early Maori, although it is clear that they trolled lures (for kahawai) that are very similar to those still used by Tahitian fishermen for various small tunas. However, given the number of other oceanic species known to Maori, and the early missionary reports of Maori regularly fishing several miles from shore, albacore were probably part of the catch of early Maori.

An estimate of the current customary catch is not available.

1.4 Illegal catch

There is no known illegal catch of albacore in the EEZ or adjacent high seas.

1.5 Other sources of mortality

Discarding of albacore has not been reported in the albacore troll fishery (based on limited observer coverage in the 1980s). Low discard rates (average 3.3%) have been observed in the longline fishery over the period 1991-92 to 1996-97. Of those albacore discarded, the main reason recorded by observers was shark damage. Similarly, the loss of albacore at the side of the vessel was low (0.6%). Mortality in the longline fishery associated with discarding and loss while landing is estimated at 1.8% of the albacore catch by longline.

2. BIOLOGY

The troll fishery catches juvenile albacore typically 5 to 8 kg in size with the mean fork length for 1996-97 to 2006-07 being 63.5 cm (Figure 5). Clear length modes associated with cohorts recruiting the troll fishery are evident in catch length distributions. In 2006-07 three modes with median lengths of 51, 61, and 72 cm were visible, that correspond to the 1, 2, and 3 year old age classes.

The mean length of troll caught albacore in 2009-10 was 61.6 cm. The modal progressions in the available catch length frequency time series from 1996-97 to 2010-11 are of utility for estimating annual variations in albacore recruitment. Longline fleets typically catch much larger albacore over a broader size range (56-105 cm) with variation occurring as a function of latitude and season. The mean length of longline-caught albacore from 1987 to 2007 is 80.4 cm. The smallest longline caught albacore are those caught in May to June immediately north of the Sub-tropical Convergence Zone (STCZ). Fish further north at this time and fish caught in the EEZ in autumn and winter are larger. There is high inter-annual variation in the longline catch length composition although length modes corresponding to strong and weak cohorts are often evident between years.

Sampling of troll caught albacore has been carried out annually (except 2008-09) since the 1996-97 fishing year. The sampling programme aims to sample in the ports of Auckland, Greymouth and New Plymouth which was included in 2003. Initially the programme aimed to sample 1000 fish per month in each port. In 2010 the sample targets were changed and the programme now aims to sample approximately 5000 fish per year and the sample targets (Table 5) are distributed throughout the season to reflect the fishing effort distribution (Figure 5). In addition, in each port and at least 100 fish per month are sub-sampled for weight. Length weight relationships are presented in Table 6 and length frequency distributions are presented in Figure 5.

Table 5: Catch sample targets for length measurements in the New Zealand troll sampling programme.

Month	**Target no of fish**
December	215
January	1 318
February	1 929
March	1 185
April	314
Total	4 961

Histological gonadosomatic index analysis has shown that female albacore from New Caledonian and Tongan waters spawn from November–February.

Farley *et al.* (2012) have recently completed a comprehensive analysis of South Pacific albacore biology. They found that otoliths were more reliable as ageing material then vertebrae. Their work using otoliths (validated by direct marking with oxtyetracycline, and indirect methods) showed that the longevity of albacore was found to be at least 14 years, with significant variation in growth between sexes and across longitudes. They found that growth rates were similar between sexes up until age 4, after which the growth for males was on average greater than that for females, with males reaching an average maximum size more than 8 cm larger than females. Farley *et al.*(2012) content that the different growth rates between sexes may be responsible for the observed dominance of male among fish in the larger size classes (greater than 95 to 100 cm fork length). This study showed that growth rates were also consistently greater at more easterly longitudes than at westerly longitudes for both females and males. While they were not able to determine the determinants of the longitudinal variation in growth of albacore, they suggest that variation in oceanography, particularly the depth of the thermocline, may affect regional productivity and therefore play a role in modifying growth of South Pacific albacore.

Farley *et al.* (2012) found that spawning was synchronised between 10 and 25^{o}S during the austral summer. They confirmed that albacore spawn during the early hours of the morning and that they are capable of spawning daily, although spawning occurs on average every 1.3 days during peak spawning months. The number of eggs released per spawning event averaged 1.2 million oocytes. Although they were not able to sample females monthly in the region east of 175°E, they found no evidence of large variations in the reproduction or spawning dynamics of females across the southwest Pacific Ocean. Farley *et al.* (2012) did, however, demonstrate that the proportion of females mature-at-length varied significantly with latitude in the Australian region, and that this variation was due to different geographic distributions of mature and immature fish during the year. A method was proposed to account for the latitudinal variation in maturity. Preliminary results of that analysis showed that the predicted age-at-50% maturity was 4.5 years, and the predicted age-at-100% maturity was age 7.

Sex ratios appear to vary with fishery from 1:1 (male:female) in the New Zealand troll and longline fishery and, 2:1 to 3:1 in the Tonga–New Caledonia longline fishery.

Estimates of growth parameters from Farley *et al.*(2012) are presented in Table 7.

Table 6: The ln(length)/ln(weight) relationships of albacore [ln(greenweight) = b_0 + b_1 * ln(fork length)]. Weight is in kg and length in cm.

	n	b_0	SE b_0	b_1	SE b_1	R^2
Males	160	-10.56	0.18	2.94	0.04	0.97
Females	155	-10.10	0.26	2.83	0.06	0.93
troll caught	320	-10.44	0.16	2.91	0.03	0.95
longline caught	21 824	-10.29	0.03	2.90	0.01	0.91

Table 7: Parameter estimates (± standard error) from five candidate growth models fitted to length-at-age data for South Pacific albacore. Parameter estimates also given for the logistic model fitted separately to female and male length-at-age data. The small-sample bias-corrected from of Akaike's information criterion AICc are provided for each model fit, and Akaike differences AICcΔi, and Akaike weights *wi* are given for the fit of the five candidate models to all data. Note that the parameters *k* and *t* are defined differently in each model (see text for definitions), such that values are not comparable across models (Farley *et al.*2012).

Sex	Model	L_∞	k	t	p	δ	γ	v	AICc	ΔAICc	w_i
All	VBGM	104.52	0.40	-0.49					11831.67	23.89	0
		(0.44)	(0.01)	(0.05)							
	Gompertz	103.09	0.50	0.47					11811.54	3.77	0.08
		(0.37)	(0.01)	(0.03)							
	Logistic	102.09	0.61	1.12					11807.77	0.00	0.53
		(0.33)	(0.01)	(0.03)							
	Richards	102.30	0.58	0.98	1.32				11809.40	1.63	0.24
		(0.49)	(0.04)	(0.24)	(0.68)						
	Schnute-	101.52	0.05			-0.97	3.54	2.07	11810.25	2.48	0.15
	Richards	(0.60)	(0.08)			(0.08)	(2.65)	(0.76)			
Female	Logistic	96.97	0.69	0.99					5746.90		
		(0.37)	(0.02)	(0.03)							
Male	Logistic	105.34	0.59	1.25					5729.26		
		(0.44)	(0.02)	(0.04)							

3. STOCKS AND AREAS

Two albacore stocks (North and South Pacific) are recognized in the Pacific Ocean based on location and seasons of spawning, low longline catch rates in equatorial waters and tag recovery information. The South Pacific albacore stock is distributed from the coast of Australia and archipelagic waters of Papua New Guinea eastward to the coast of South America south of the equator to at least 49ºS. However, there is some suggestion of gene flow between the North and South Pacific stocks based on an analysis of genetic population structure.

Most catches occur in longline fisheries in the EEZs of other South Pacific states and territories and in high seas areas throughout the geographical range of the stock.

Troll and longline vessels catch albacore in all FMAs in New Zealand and there may be substantial potential for expansion to high seas areas.

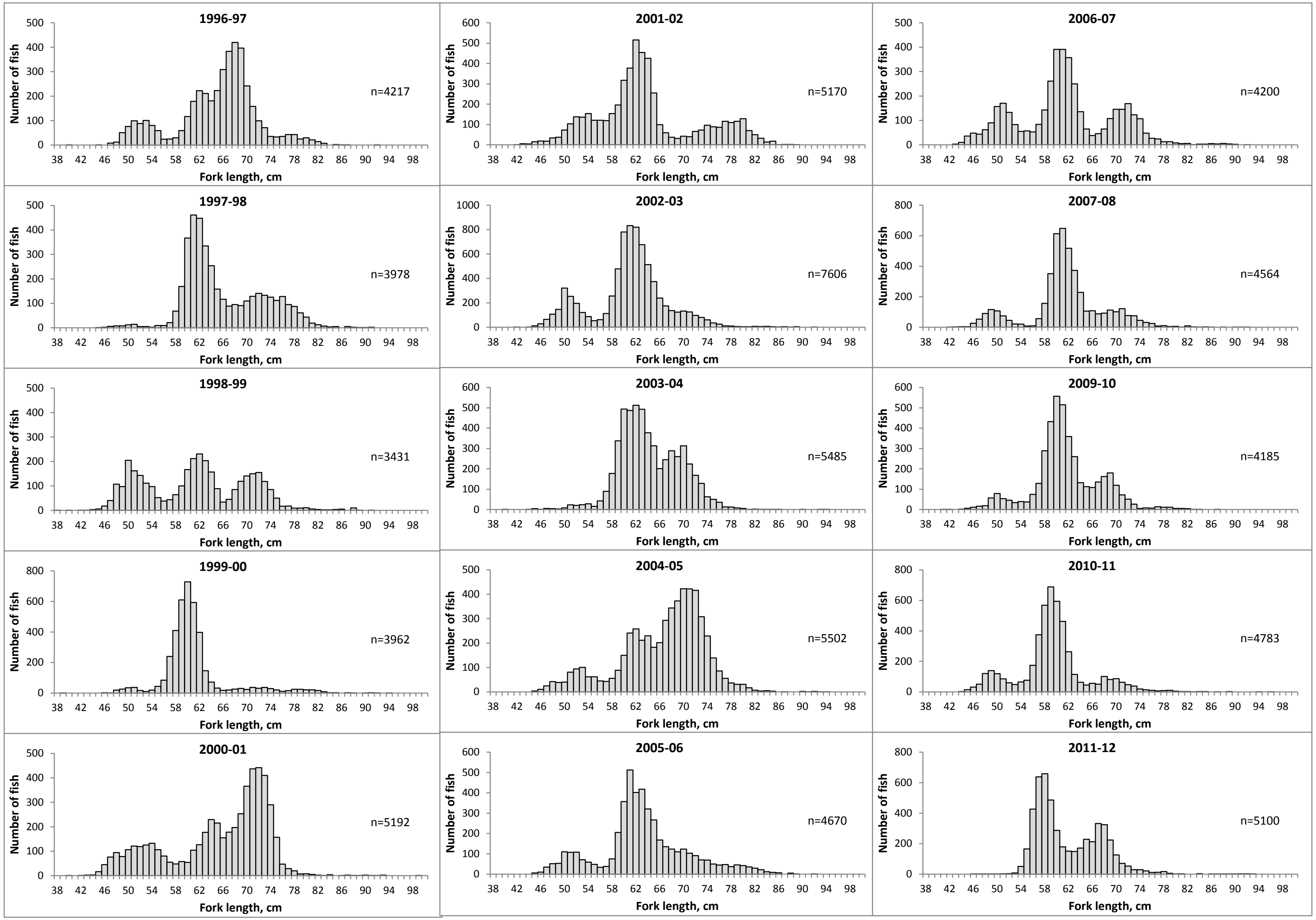


Figure 5: Size composition of albacore taken in the New Zealand domestic commercial troll fishery for 1996-97 to 2011-12.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the November 2012 Fishery Assessment Plenary after review by the Aquatic Environment Working Group. This summary is from the perspective of the albacore longline fishery; a more detailed summary from an issue-by-issue perspective is, or will shortly be, available in the Aquatic Environment & Biodiversity Annual Review where the consequences are also discussed (http://www.mpi.govt.nz/news-resources/publications.aspx).

4.1 Role in the ecosystem

Albacore (*Thunnus alalunga*) are apex predators, found in the open waters of all tropical and temperate oceans, feeding opportunistically on a mixture of fish, crustaceans, squid and juveniles also feed on a variety of zooplankton and micronecton species.

4.2 Incidental catch (seabirds, sea turtles and mammals)

The protected species, capture estimates presented here include all animals recovered onto the deck (alive, injured or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds caught on a hook but not brought onboard the vessel.

4.3 Troll fishery

From 2006 to 2011 the troll catch averages 93% albacore, the remaining 7% is made up mostly of teleosts (Table 8). The observer coverage of the troll fleet has been ongoing since 2006-07 and coverage has averaged 0.7% of the effort during that time, no protected species have been observed as bycatch in this fishery. The shed sampling programme has sampled on average 4.1% of the fishing effort during that time. Rays bream make up the bulk of the bycatch with minor catches of skipjack tuna, barracouta and kahawai (Table 9).

Table 8: Observed species composition of the albacore troll fishery. Number of fish recorded in the observer programme from 2006-07 to 2010-11, number in parentheses is the percentage of total catch.

		Number of fish caught						
Species	Scientific name	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	Total of 6 years
Albacore tuna	*Thunnus alalunga*	1684 (99.82)	1776 (98.89)	1755 (97.39)	5403 (88.01)	4913 (90.28)	2772 (98.68)	18303 (93.03)
Rays bream	*Brama brama*		18 (1.00)	12 (0.67)	537 (8.75)	35 (0.64)	7 (0.25)	609 (3.10)
Skipjack tuna	*Katsuwonus pelamis*	1 (0.06)	2 (0.11)	26 (1.44)	20 (0.33)	359 (6.60)	2 (0.07)	410 (2.08)
Barracouta	*Thyrsites atun*			1 (0.06)		126* (2.32)	13 (0.46)	140 (0.71)
Kahawai	*Arripis trutta*			6 (0.33)		5 (2.32)	14 (0.46)	25 (0.71)
Kingfish	*Seriola lalandi*			2 (0.11)	4 (0.07)	4 (0.07)		10 (0.13)
Dolphinfish	*Coryphaena hippurus*				1 (0.02)			1 (0.01)
Mako shark	*Isurus oxyrinchus*						1 (0.04)	1 (0.01)
Unidentified		2 (0.12)			174 (2.83)			176 (0.89)

*Includes one trip that landed 102 barracouta

Table 9: Number of albacore troll vessels, albacore landings, hooks set, and days fished and observed and the percentage observed, compared with those shed sampled.

	Fished				Observed				% Observed			
ALB-year	Days	Vessels	Landings	Hooks	Days	Vessels	Landings	Hooks	Days	Vessels	Landings	Hooks
2006-07	3 389	134	845	43 096	10	1	1	120	0.3	0.7	0.1	0.3
2007-08	4 479	153	1 296	54 092	8	1	1	120	0.2	0.7	0.1	0.2
2008-09	4 478	161	1 163	56 404	18	3	4	413	0.4	1.9	0.3	0.7
2009-10	3 196	120	856	39 511	49	6	10	637	1.5	5.0	1.2	1.6
2010-11	4 619	154	1 225	58 309	46	5	8	534	1.0	3.2	0.7	0.9
2011-12	4 817	155	1 370	60 592	24	1-2	9	317	0.5	1.3	0.7	0.5
					Shed sampled				% Shed sampled			
ALB-year					Days	Vessels	Landings	Hooks	Days	Vessels	Landings	Hooks
2006-07					125	14	21	1 817	3.7	10.4	2.5	4.2
2007-08					157	22	31	1 992	3.5	14.4	2.4	3.7
2008-09					0	0	0	0	0.0	0.0	0.0	0.0
2009-10					208	30	41	2 691	6.5	25.0	4.8	6.8
2010-11					237	35	48	3 097	5.1	22.7	3.9	5.3
2011-12					207	30	50	2 752	4.3	19.4	3.6	4.5

4.4 Longline

4.4.1 Seabird bycatch

Between 2002–03 and 2010–11, there were 73 observed captures of birds in albacore longline fisheries. Seabird capture rates since 2003 are presented in Figure 6. Seabird bycatch distributions are more frequent off the east coast of the North Island and Kermadec Island regions (see Table 10 and Figure 7). The analytical methods used to estimate capture numbers across the commercial fisheries have depended on the quantity and quality of the data, in terms of the numbers observed captured and the representativeness of the observer coverage. Ratio estimation is used to calculate total captures in longline fisheries by target fishery fleet and area (Baird 2008) and by all fishing methods (Abraham *et al.*2010).

Through the 1990s the minimum seabird mitigation requirement for surface longline vessels was the use of a bird scaring device (tori line) but common practice was that vessels set surface longlines primarily at night. In 2007 a notice was implemented under s 11 of the Fisheries Act 1996 to formalise the requirement that surface longline vessels only set during the hours of darkness and use a tori line when setting. This notice was amended in 2008 to add the option of line weighting and tori line use if setting during the day. In 2011 notices were combined and repromulgated under a new regulation (Regulation 58A of the Fisheries (Commercial Fishing) Regulations 2001) which provides a more flexible regulatory environment under which to set seabird mitigation requirements.

Table 10: Observed seabird captures in albacore longline fisheries, 2002-03 to 2010-11, by species and area (Thompson & Abraham (2012) from http://data.dragonfly.co.nz/psc/). See glossary above for areas used for summarising the fishing effort and protected species captures. 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 albacore using longline gear but rather the total risk for each seabird species.

Species	Risk ratio	Kermadec Islands	Northland and Hauraki	East Coast North Island	Total
Salvin's albatross	2.49	0	0	1	1
Campbell albatross	1.84	0	3	14	17
Southern Buller's albatross	1.28	0	0	8	8
Gibson's albatross	1.25	0	0	7	7
Antipodean albatross	1.11	0	0	3	3
Total albatrosses	**N/A**	**0**	**3**	**33**	**36**
Black petrel	11.15	0	1	0	1
Westland petrel	3.31	0	0	2	2
White chinned petrel	0.79	0	0	2	2
Grey petrel	0.39	0	2	3	5
Sooty shearwater	0.02	0	0	8	8
Great winged petrel	0.01	11	4	2	17
White headed petrel	0.01	2	0	0	2
Total other birds	**N/A**	**13**	**7**	**17**	**37**

Table 11: Effort, observed and estimated seabird captures by fishing year for the albacore fishery within the EEZ. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); the capture rate (captures per thousand hooks); and the mean number of estimated total captures (with 95% confidence interval). The estimation method used was a Bayesian model with 100% of hooks included in the estimate. For more information on the methods used to prepare the data see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures		Estimated captures	
	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002-2003	1 893 010	980 772	51.8	72	0.073	324	217-490
2003-2004	463 164	1 600	0.3	0	0	133	79-215
2004-2005	136 812	4 317	3.2	1	0.232	24	10-48
2005-2006	60 360	600	1	0	0	13	3-29
2006-2007	N/A	0	N/A	0	0	2	0-9
2007-2008	N/A	0	N/A	0	0	0	0-3
2008-2009	7 800	2 100	26.9	0	0	2	0-11
2009-2010	20 350	4 979	24.5	0	0	8	0-33
2010-2011	13 610	1 000	7.3	0	0	4	0-16

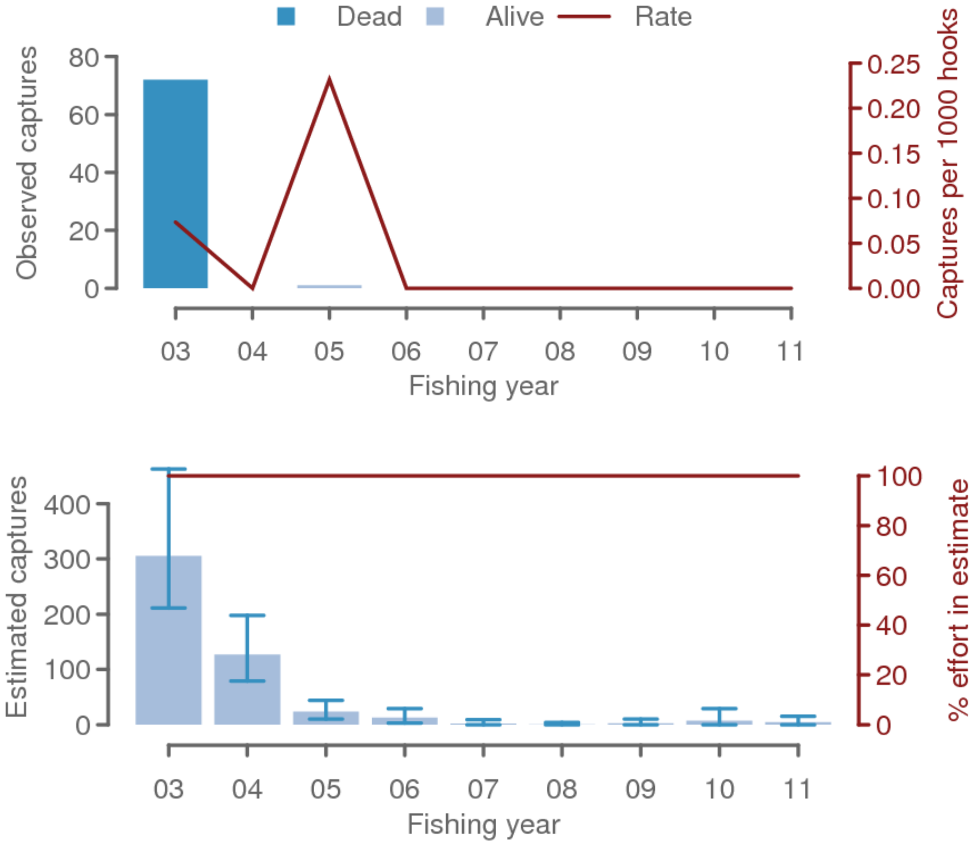


Figure 6: Observed and estimated captures of seabirds in albacore longline fisheries from 2003 to 2011.

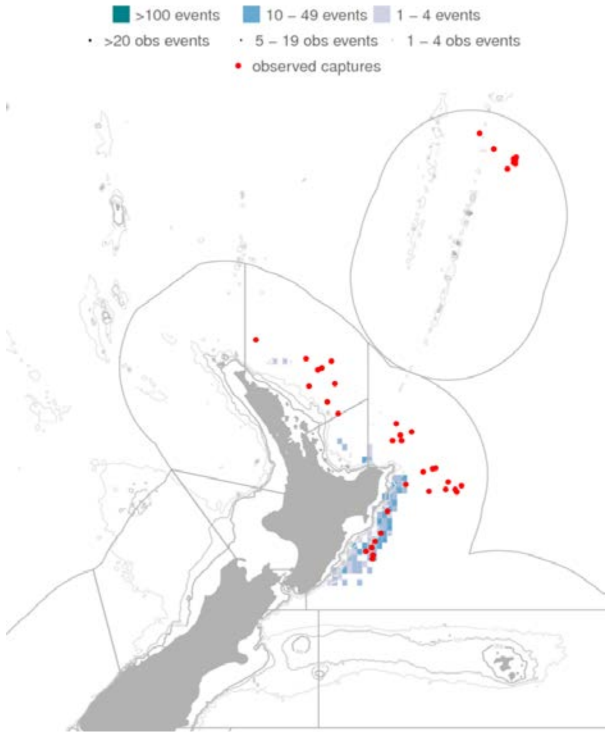


Figure 7: Distribution of fishing effort targeting albacore and observed seabird captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 35.9% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.4.2 Sea turtle bycatch

Between 2002–03 and 2010–11, there were no observed captures of turtles in albacore longline fisheries.

Table 12: Effort and sea turtle captures by fishing year for the albacore fishery within the EEZ. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	1 892 610	980 772	51.8	0	0
2003-2004	462 264	1 600	0.3	0	0
2004-2005	136 812	4 317	3.2	0	0
2005-2006	60 360	600	1.0	0	0
2006-2007	N/A	0	N/A	0	0
2007-2008	N/A	0	N/A	0	0
2008-2009	7 800	2 100	26.9	0	0
2009-2010	20 350	4 979	24.5	0	0
2010-2011	13 610	1 000	7.3	0	0

Figure 8: Distribution of fishing effort targeting albacore and observed sea turtle captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 35.9% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3 Marine Mammals

4.2.3.1 Cetaceans

Cetaceans are dispersed throughout New Zealand waters (Perrin *et al.*2008). The spatial and temporal overlap of commercial fishing grounds and cetacean foraging areas has resulted in cetacean captures in fishing gear (Abraham and Thompson 2009, 2011). Between 2002–03 and 2010–11, there was one observed capture of an unidentified cetacean in the albacore longline fisheries (Table 13 and Figure 9) (Abraham and Thompson 2011). This capture was recorded as being caught and released alive (Thompson and Abraham 2010). The cetacean capture took place in the Northland region (Figure 10).

Table 13: Number of observed cetacean captures in albacore longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson & Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/.

	Northland and Hauraki	Total
Unidentified cetacean	1	1

Table 14: Effort and cetacean captures by fishing year for the albacore fishery within the EEZ. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	1 892 610	980 772	51.8	1	0.001
2003-2004	462 264	1 600	0.3	0	0
2004-2005	136 812	4 317	3.2	0	0
2005-2006	60 360	600	1.0	0	0
2006-2007	N/A	0	N/A	0	0
2007-2008	N/A	0	N/A	0	0
2008-2009	7 800	2 100	26.9	0	0
2009-2010	20 350	4 979	24.5	0	0
2010-2011	13 610	1 000	7.3	0	0

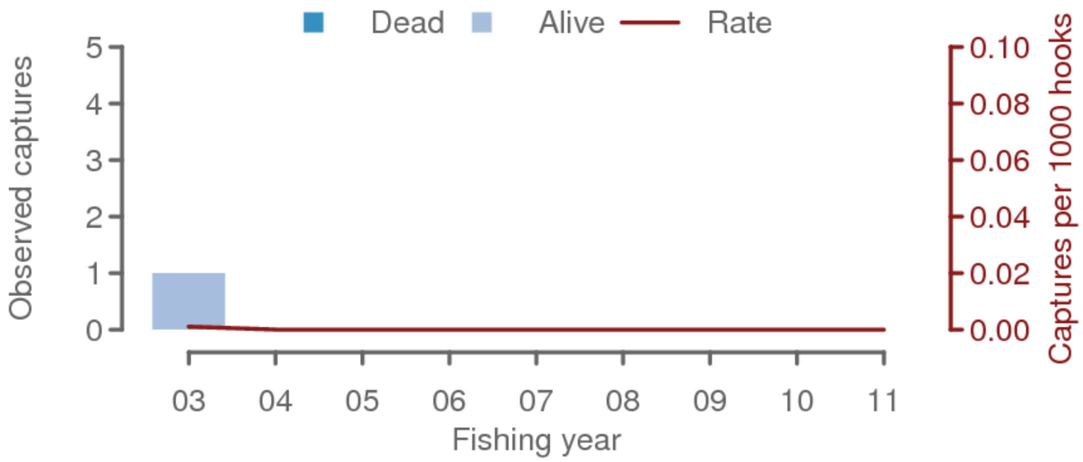


Figure 9: Observed captures of cetaceans in albacore longline fisheries from 2003 to 2011.

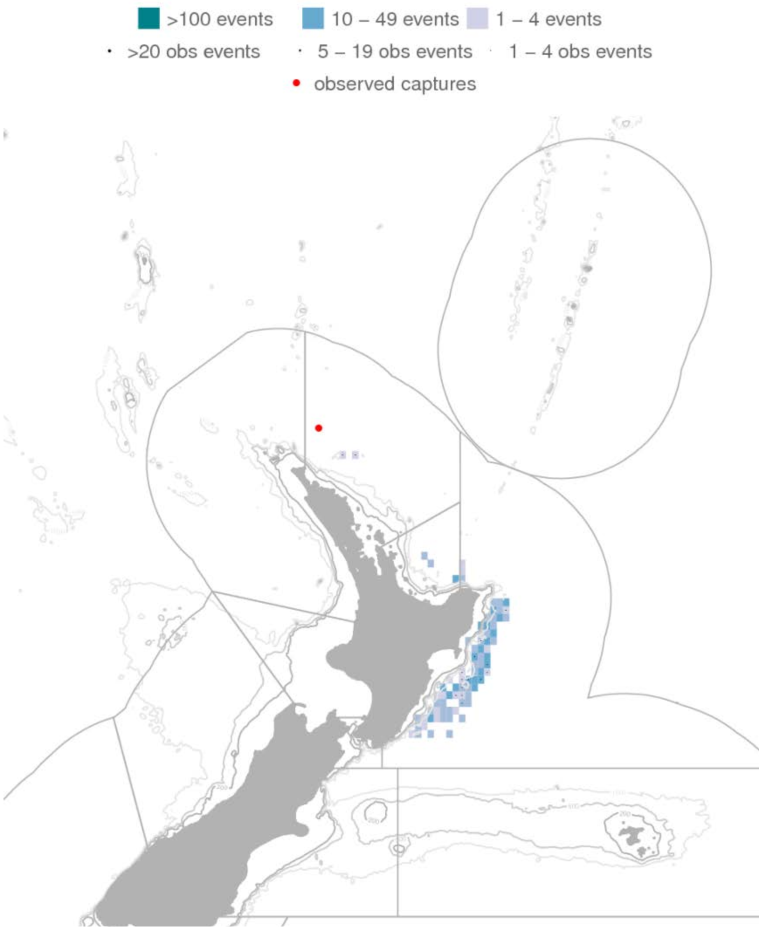


Figure 10: Distribution of fishing effort targeting albacore and observed cetacean captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 35.9% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3.2 New Zealand fur seal bycatch

Currently, New Zealand fur seals are dispersed throughout New Zealand waters, especially in waters south of about 40º S to Macquarie Island. The spatial and temporal overlap of commercial fishing grounds and New Zealand fur seal foraging areas has resulted in New Zealand fur seal captures in fishing gear (Mattlin 1987, Rowe 2009). Most fisheries with observed captures occur in waters over or close to the continental shelf, which around much of the South Island and offshore islands slopes steeply to deeper waters relatively close to shore, and thus rookeries and haulouts. Captures on longlines occur when the seals attempt to feed on the fish and bait catch during hauling. Most New Zealand fur seals are released alive, typically with a hook and short snood or trace still attached.

New Zealand fur seal captures in surface longline fisheries have been generally observed in waters south and west of Fiordland, but also in the Bay of Plenty-East Cape area when the animals have attempted to take bait or fish from the line as it is hauled. Between 2002–03 and 2010–11, there were no observed captures of New Zealand fur seals in albacore longline fisheries (Abraham *et al.*2010) (Table 15 and Figure 11).

Table 15: Effort and captures of New Zealand fur seals by fishing year for the albacore fishery within the EEZ. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	1 892 610	980 772	51.8	0	0
2003-2004	462 264	1 600	0.3	0	0
2004-2005	136 812	4 317	3.2	0	0
2005-2006	60 360	600	1.0	0	0
2006-2007	N/A	0	N/A	0	0
2007-2008	N/A	0	N/A	0	0
2008-2009	7 800	2 100	26.9	0	0
2009-2010	20 350	4 979	24.5	0	0
2010-2011	13 610	1 000	7.3	0	0

Figure 11: Distribution of fishing effort targeting albacore and observed fur seal captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 35.9% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.3 Incidental fish bycatch

See above Section 4.3.

4.4 Benthic interactions

N/A

4.5 Key environmental and ecosystem information gaps

Cryptic mortality is unknown at present but developing a better understanding of this in future may be useful for reducing uncertainty of the seabird risk assessment and could be a useful input into risk assessments for other species groups.

The survival rates of released target and bycatch species is currently unknown.

Observer coverage in the New Zealand fleet is not spatially and temporally representative of the fishing effort.

5. STOCK ASSESSMENT

No assessment is possible for albacore within New Zealand fisheries waters as the proportion of the greater stock found within New Zealand fisheries waters is unknown and likely varies from year to year. With the establishment of WCPFC in 2004, stock assessments of the South Pacific Ocean (SPO) stock of albacore tuna are now undertaken by the Oceanic Fisheries Programme (OFP) of Secretariat of the Pacific Community (SPC) under contract to WCPFC.

The most recent assessment was undertaken in 2012 using MULTIFAN-CL (Hoyle *et al.*2012). A summary of that assessment can be found below:

This assessment uses the same underlying structural assumptions as the 2011 assessment, but used improved knowledge of albacore biology from the Farley *et al.*(2012) study. The main conclusions of the assessment are Hoyle *et al.*(2012):

a) Estimated stock status are based on the median of the grid and is similar to 2009 and 2011 estimates (Table 8; Figures 6-9).
b) "The fishing mortality reference point $F_{current}/F_{MSY}$ has a median estimate of 0.21 (90% CI 0.04-1.08), and on that basis we conclude that there is low risk that overfishing is occurring. The corresponding biomass-based reference points $B_{current}/B_{MSY}$ and $SB_{current}/SB_{MSY}$ are estimated to be above 1.0 (median 1.6 with range of 1.4-1.9, and median 2.6 with range of 1.5-5.2, respectively), and therefore the stock is not in an overfished state.
c) The median estimate of *MSY* from the structural sensitivity analysis (99,085 mt (46,560 – 215,445 mt) is comparable to the recent levels of (estimated) catch from the fishery ($C_{current}$ 78,664 mt, C_{latest} 89,790 mt).
d) There is no indication that current levels of catch are causing recruitment overfishing, particularly given the age selectivity of the fisheries.
e) Longline catch rates are declining, and catches over the last 10 years have been at historically high levels and are increasing. These trends may be significant for management.
f) Management quantities are very sensitive to the estimated growth curve. Given that biological research indicates spatial and sex-dependent variation in growth, which is not included in the model, these uncertainties should be understood when considering estimates of management parameters."

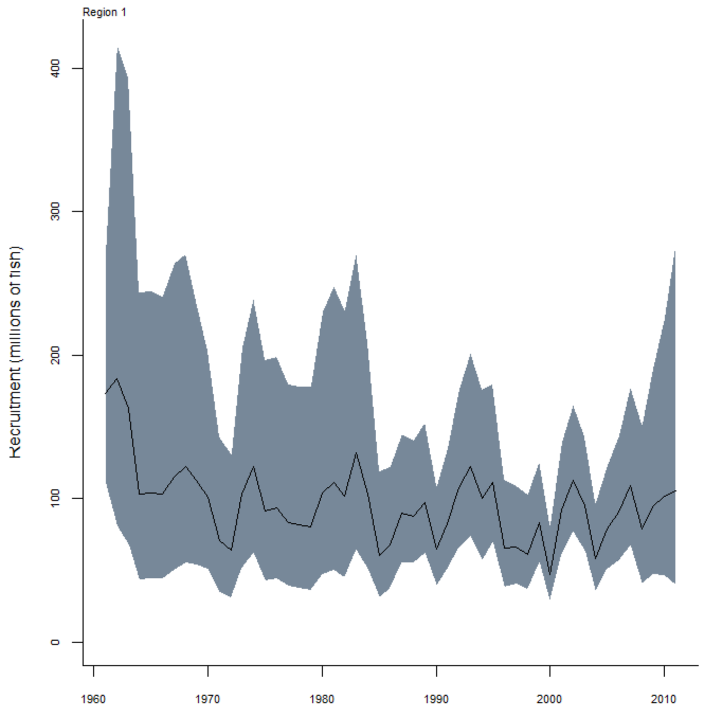


Figure 12: Annual recruitment (number of fish) estimates from the reference case model. The grey area represents parameter uncertainty estimated from the Hessian matrix Hoyle *et al.*(2012).

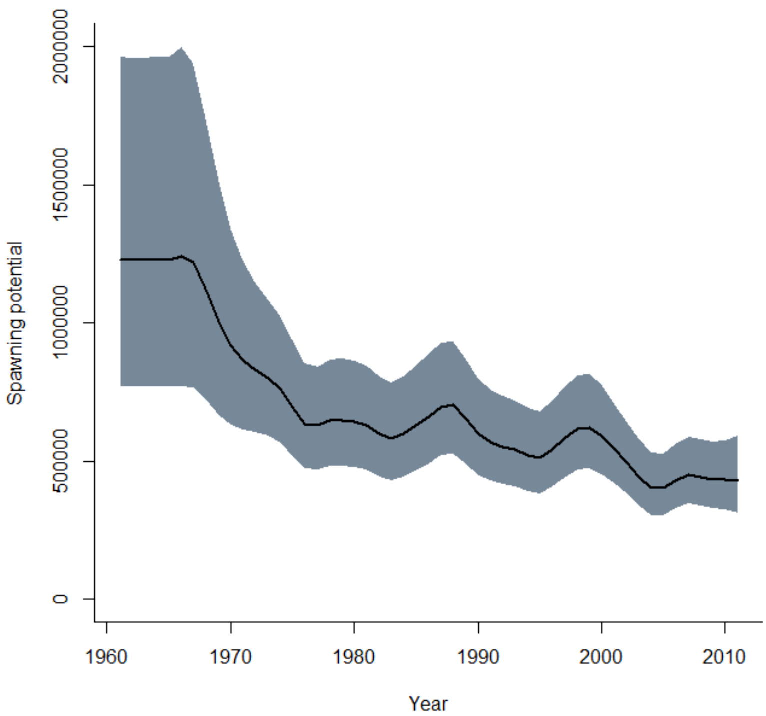


Figure 13: Annual estimates of spawning potential from the reference case model. The grey area represents parameter uncertainty estimated from the Hessian matrix Hoyle *et al.*(2012).

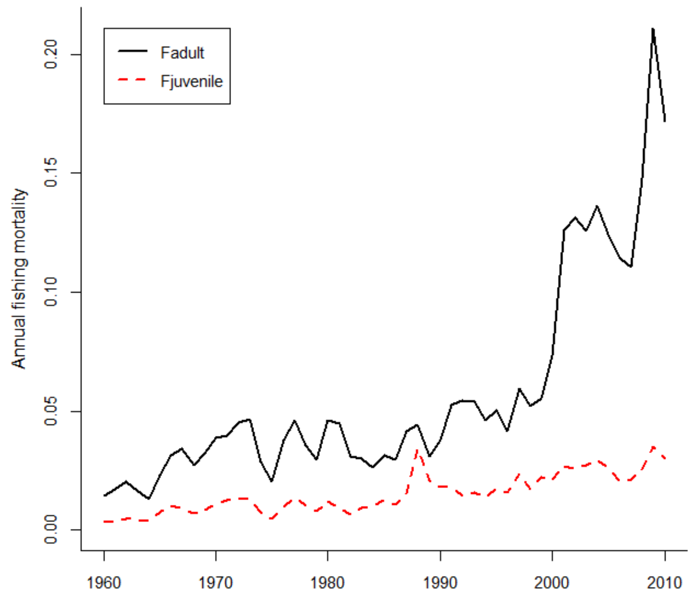


Figure 14: Annual estimates of fishing mortality for juvenile and adult South Pacific albacore from the reference case model Hoyle *et al.*(2012).

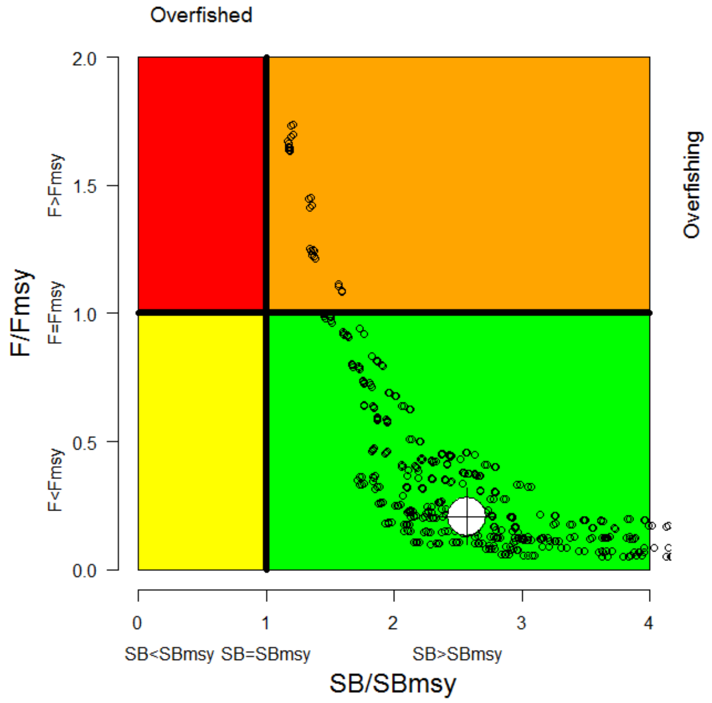


Figure 15: $F_{current}/F_{MSY}$ and $SB_{current}/SB_{MSY}$ for 540 model runs in the uncertainty grid (black hollow circles) and the median (large white circle). Note that some grid model runs extend as far as 7 for $SB_{current}/SB_{MSY}$ Hoyle *et al.*(2012).

Table 16: Management parameters estimated from the 2012 base case (determined as the median from the structural uncertainty grid), the 2011 base case model, and the 2009 assessment, for comparison. Note that the definitions for current change through time Hoyle *et al.*(2012).

Management quantity	2012 base case (grid median)	2011 base case	2009 base case	2009 median
	78,664	54,520	66,869	65,801
	89,790	56,275		
	99,085	85,130	97,610	81,580
	0.79	0.64	0.69	0.80
	0.90	0.66		
	4.81	3.86		
	0.21	0.26	0.25	0.29
SB_0	442,350	400,700	460,400	406,600
	0.23	0.26	0.26	0.24
	0.59	0.59	0.59	0.60
	0.56	0.47		
	2.56	2.25	2.28	2.44
	2.38	1.82		
	0.63	0.63	0.68	0.64
	0.58	0.6		

Based on the assessment results the Scientific Committee concluded in 2012 that the South Pacific albacore stock is currently not overfished and overfishing is not occurring. Current biomass is sufficient to support current levels of catch. However, for several years the Scientific Committee has also noted that any increases in catch or effort are likely to lead to declines in catch rates in some regions, especially for longline catches of adult albacore, with associated impacts on vessel profitability.

Given the recent expansion of the fishery and recent declines in exploitable biomass available to longline fisheries, and given the importance of maintaining catch rates, the SC recommends that longline fishing mortality be reduced if the Commission wishes to maintain economically viable catch rates.

5.1 Catch per unit effort indices (CPUE)

Relative abundance indices are an essential input to stock assessment models and are typically derived from a standardised CPUE time series. Studies have calculated CPUE indices for albacore caught in longline fisheries and for small juveniles caught in troll fisheries with fishing operational variables and environmental effects at appropriate resolution being examined as potentially significant factors in explaining the variance in CPUE models (Kendrick & Bentley 2010).

Catch and effort data collected using the detailed TLCER forms for the tuna longline fishery from 1993 to 2004 was groomed for input to the standardised CPUE analysis. A total of 51,004 data records were available with detailed effort information for individual fishing operations. These data have been linked to a range of environmental variables including remotely sensed observations for sea surface temperature (SST) and ocean colour (chlorophyll) at a spatial resolution corresponding closely with each individual fishing operation. These variables have been expressed in relation to oceanic fronts, climatology and oceanographic indices of mesoscale dynamics on both a seasonal and monthly temporal scale. Other potential explanatory variables include moon brightness (phase), day length, fraction of longline set during night hours, depth and depth variation.

Catch and effort information from the troll fishery, was collated from 1989-90 to 2007-08 fishing years and linked to sea surface temperature (SST) data at the coarser temporal (day) and spatial (Statistical Area) scale of CELR format data. The large fleet (over 700) of troll vessels was reduced to those that had completed at least 5 trips a year in at least four years. This still retained more than 220 vessels and the standardised CPUE analysis was repeated for batches of those vessels.

Longline

The categorical variables: year, quarter, nationality, experience, and target species were significant in explaining catch rate variability. Of the continuous variables sea surface temperature (SST) had the strongest effect, with highest catch rates in the range 18 to 19°C. SST features associated with ocean fronts were of lesser significance. In an albacore CPUE analysis, only a weak relationship was found between CPUE and the southern oscillation index (SOI), and this was largely attributed to recruitment fluctuations in response to SST variability associated with the index.

There is a dramatic decline in the longline albacore CPUE time series from 1998 to 2000 that corresponds closely to a large increase in swordfish catch from 1600 fish in 1997 to over 12 000 in 2001. This reciprocal pattern most likely reflects a shift in fishing practice in the longline fleet towards targeting for swordfish since the mid-1990s (Figure 10). This is likely to have altered the catchability of the longline fishery for albacore through a physical change in the configuration of the fishing gear. Despite this operational factor, the general decline in since the mid-1990s is consistent with the trend observed in Taiwanese longline CPUE in the southern parts of the south Pacific region, and with the substantial decline in biomass since the late 1990s predicted by the regional assessment model. The decline following a peak in catch rates that occurred in 1995, has been attributed to a 7-year cycle in albacore catch rates that has been evident since 1978, and is a result of YCS variation in response to SOI cycles. This explanation describes a process that would potentially affect catch rates of albacore throughout the south Pacific region, and hence, the New Zealand longline fishery. It is therefore possible the factors contributing to the dramatic decline observed in the New Zealand fishery include stock-wide changes in availability, and a change in fishing practices.

Troll

The year effects from models of two independent batches of core vessels resemble each other closely; each describing a series that oscillates in a 3–4 year cycle around unity with no overall upward or downward trend. The error bars around each point are small in comparison with the interannual variance and the effect on observed CPUE of standardising for variance in hours fished, Statistical Area, month and vessel participation is almost indiscernible. Local scale environmental variables including SST were not accepted into either analysis.

Within a troll season there is little contrast in catches among vessels or among the months and areas in which the fishery operates. The large interannual variance however agrees reasonably well with the El Niño/Southern Oscillation (ENSO) index (Figure 11). The availability of juvenile albacore to the troll fishery appears to correspond negatively with El Niño events and to respond positively and quite sensitively to any trend away from that state.

Larger scale environmental effects appear to match many of the extreme shifts in availability and the effect is more likely to happen outside of New Zealand waters and the New Zealand troll season. This conclusion is in contrast to earlier work that suggested oceanographic features on a smaller spatial scale than troll data are collected might be expected to relate strongly to catch rates.

CPUE of troll caught albacore within New Zealand waters is unlikely to be index of abundance of the stock but rather an index of availability of these juvenile fish to New Zealand waters. The effect of SOI does not appear to be selective with respect to the three cohorts observed in the fishery but does negate any additional inference about their relative abundance.

5.2 Estimates of fishery parameters and abundance

There are no fishery-independent indices of abundance for the South Pacific stock. Relative abundance information is available from catch per unit effort data. Returns from tagging programmes provides information on rates of fishing mortality, however, the return rates are very low and lead to highly uncertain estimates of absolute abundance.

5.3 Biomass estimates

Estimates of absolute biomass are highly uncertain, however, relative abundance trends are thought to be more reliable. Spawning potential depletion levels ($SB_{curr}/SB_{curr F=0}$) of albacore were moderate at ~37%. However, depletion levels of the exploitable biomass is estimated between about 10% and 60%, depending on the fishery considered, having increased sharply in recent years particularly in the longline fisheries (Figure 12).

5.4 Estimation of Maximum Constant Yield (*MCY*)

No estimates of *MCY* are available.

5.5 Estimation of Current Annual Yield (*CAY*)

No estimates of *CAY* are available.

5.6 Other yield estimates and stock assessment results

No other yield estimates are available.

5.7 Other factors

Declines in CPUE have been observed in some Pacific Island fisheries. This is problematic for South Pacific states that rely on albacore for their longline fisheries. Given the recent expansion of the Pacific albacore fishery and recent declines in exploitable biomass available to longline fisheries, the importance of maintaining catch rates for Pacific Island states is important for the economic survival of their domestic longline operators.

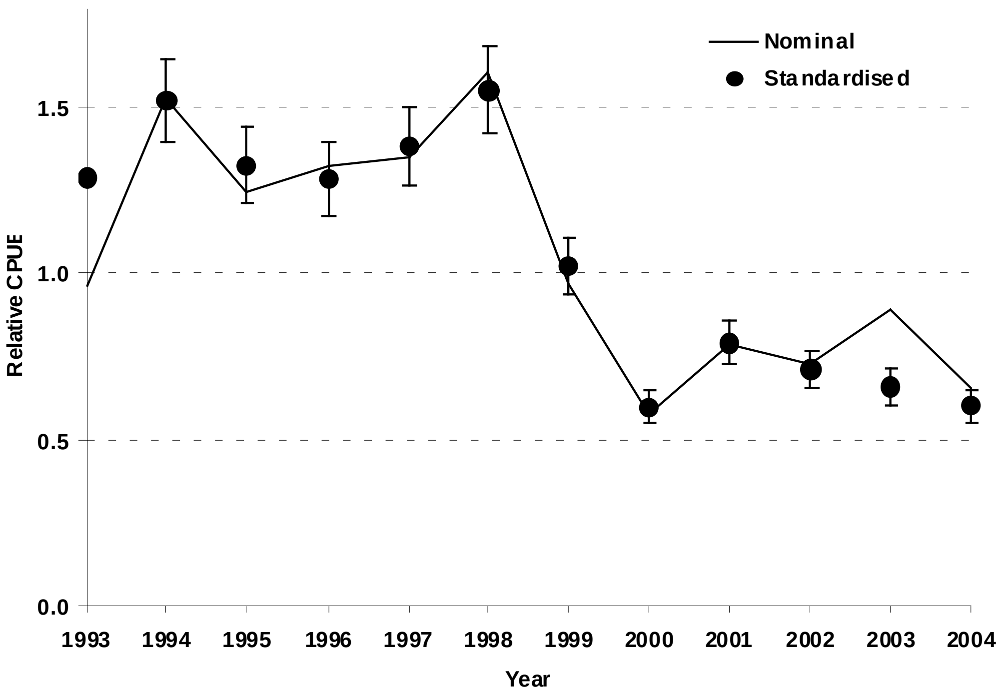


Figure 16: Nominal and standardised annual CPUE indices (normalised about the geometric mean for each time series) for the New Zealand domestic longline fishery, 1993-2004. Vertical bars indicate two standard errors (Unwin *et al.*2005).

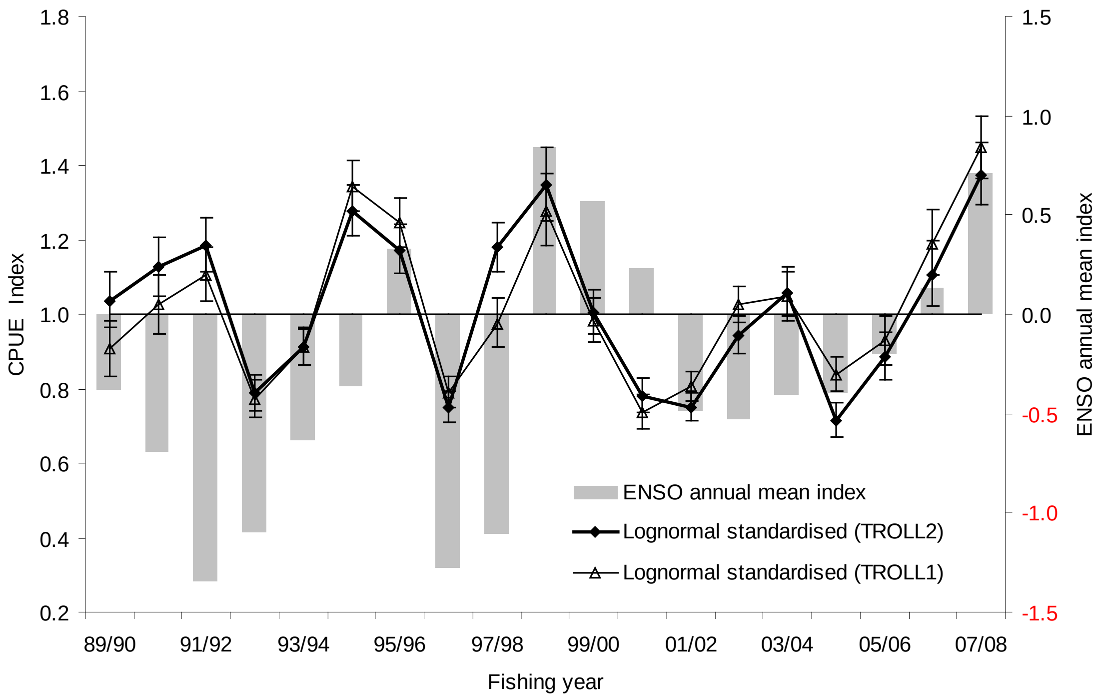


Figure 17: Comparison of annual indices of availability of troll-caught albacore in New Zealand waters (TROLL1 and TROLL2) with annual means of the Multivariate ENSO Index (MEI) an indicator of large climatic shifts affecting the South Pacific. Sign of ENSO index is reversed so that negative values indicate EL Nino events (Kendrick & Bentley 2010).

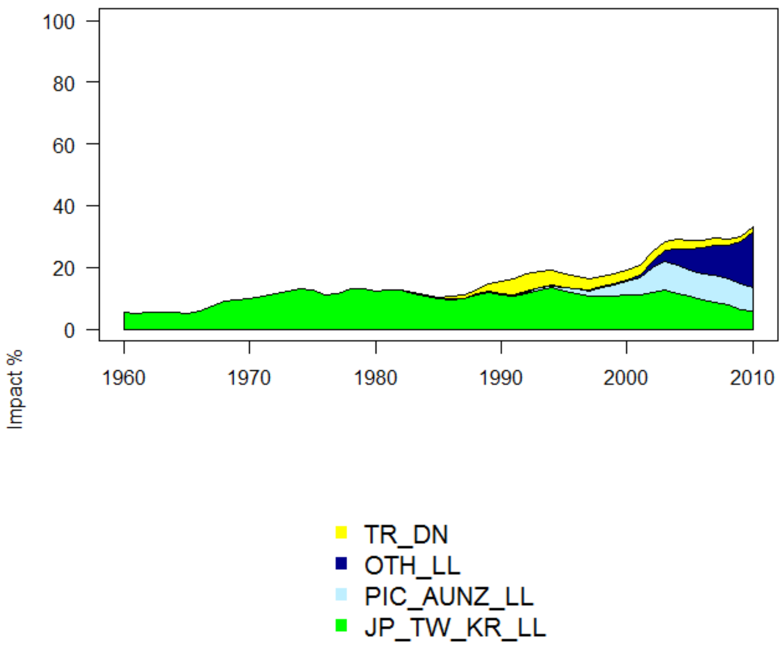


Figure 18: Estimates of reduction in spawning potential due to fishing (fishery impact = 1- $SB_t/SB_{tF=0}$) attributed to various fishery groups (TR_DN = Troll and driftnet fisheries; OTH_LL = 'Other' Longline fisheries; PIC_AUNZ_LL = Pacific Island and Australia and New Zealand longline fisheries; JP_TW_KR_LL = Japanese, Korean and Chinese Taipei distant water longline fisheries) (Hoyle *et al.*2012).

6. STATUS OF THE STOCK

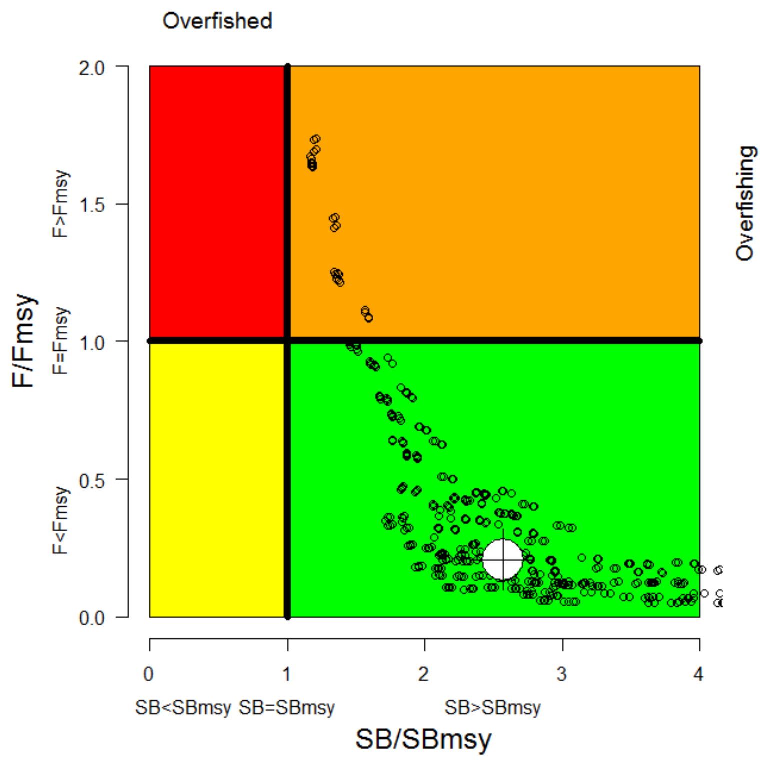
Stock status is summarised from Hoyle (2011).

Stock structure assumptions
In the Western and Central Pacific Ocean, the South Pacific albacore stock is distributed from the coast of Australia and archipelagic waters of Papua New Guinea eastward to the coast of South America south of the equator to at least 49ºS. However, there is some suggestion of gene flow between the North and South Pacific stocks based on an analysis of genetic population structure.

All biomass estimates in this table refer to spawning biomass (SB)

Stock Status	
Year of Most Recent Assessment	A full stock assessment was conducted in 2012.
Assessment Runs Presented	Base case model only
Reference Points	Target: B > B_{MSY} and F < F_{MSY} Soft Limit: Not established by WCPFC; but evaluated using HSS default of 20% SB_0. Hard Limit: Not established by WCPFC; but evaluated using HSS default of 10% SB_0.
Status in relation to Target	Likely (> 60%) that $B > B_{MSY}$ and Very Unlikely (< 10%) that $F > F_{MSY}$
Status in relation to Limits	Soft limit: Unlikely (< 40%) to be below Hard limit: Very Unlikely (< 10%) to be below

Historical Stock Status Trajectory and Current Status



$F_{current}/F_{MSY}$ and $SB_{current}/SB_{MSY}$ for 540 model runs in the uncertainty grid (black hollow circles) and the median (large white circle). Note that some grid model runs extend as far as 7 for $SB_{current}/SB_{MSY}$ Hoyle *et al.*(2012).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The key conclusions of the models presented are that overfishing is not occurring and the stock is not in an overfished state. The assessment conclusions were broadly similar to those in 2011
Recent Trend in Fishing Mortality or Proxy	The key conclusions of the assessment were broadly similar to those in 2011. Depletion levels (relative annual estimated biomass in the absence of fishing) of $F_{2007\text{-}2010}/F_{MSY}$ (0.21) and $SB_{2007\text{-}2010}/SB_{MSY}$ (2.56) do not indicate overfishing above F_{MSY}, nor that the fishery is in an overfished state below SB_{MSY}.
Other Abundance Indices	South Pacific albacore is the only WCPFC species that is assessed with standardised CPUE indices constructed with operational data. There was a rapid decline from the early 1960s until 1975 followed by a slower decline thereafter.
Trends in Other Relevant Indicator or Variables	

Projections and Prognosis		
Stock Projections or Prognosis	There is no indication that current levels of catch are causing recruitment overfishing. However, current levels of fishing mortality may be affecting longline catch rates on adult albacore.	
Probability of Current Catch causing decline below Limits	Soft Limit: Unlikely (< 40%) to drop below ½ B_{MSY} Hard Limit: Very Unlikely (< 10%) to drop below ¼ B_{MSY}	
Assessment Methodology and Evaluation		
Assessment Type	Level 1: Quantitative Stock assessment	
Assessment Method	The assessment uses the stock assessment model and computer software known as MULTIFAN-CL.	
Assessment Dates	Latest assessment: 2012	Next assessment: 2015
Overall assessment quality rank		
Main data inputs (rank)	The model is age structured (20 age-classes) and the catch, effort, size composition and tagging data used in the model are classified by 30 fisheries and quarterly time periods from July 1960 through June 2011.	1 – High Quality
Data not used (rank)	-	-
Changes to Model Structure and Assumptions	The structure of the assessment model was similar to the previous (2011) assessment, but there were some substantial revisions to key data sets which are noted above.	
Major Sources of Uncertainty	CPUE is used as an abundance index in the model. However, in the 1990s there was an increase in standardised CPUE in the west (regions 1 and 3) which was not evident in the east (regions 2 and 4). There was a decline in standardized CPUE for the Taiwan distant-water fleet since 2000 that also occurred in most domestic Pacific Island fisheries. It is not certain whether depressed CPUE since 2002 results from a decline in population abundance or a change in the availability of albacore in the South Pacific that affected the Taiwan fleet and domestic Pacific Island fleets (Bigelow and Hoyle 2009).	

	There is also a conflict between the CPUE index and the longline length frequency data.

Qualifying Comments
Although the latest assessment made some good improvements there is still a need to resolve the conflict between the CPUE and the longline length frequency data.
Fishery Interactions
Although no specific seabird/fishery interactions have been observed or reported for the troll fishery in New Zealand fishery waters, anecdotal reports and expert opinion consider that some albatross species are at risk of capture from this method. The troll fishery has a minor bycatch or Ray's bream. While longline albacore target sets are limited within New Zealand fishery waters interactions with protected species are known to occur in the longline fisheries of the South Pacific, particularly south of 25°S. Seabird bycatch mitigation measures are required in the New Zealand and Australian EEZ's and through the WCPFC Conservation and Management Measure CMM2007-04. Sea turtles are also incidentally captured in longline gear; the WCPFC is attempting to reduce sea turtle interactions through Conservation and Management Measure CMM2008-03. Shark bycatch is common in longline fisheries and largely unavoidable; this is being managed through New Zealand domestic legislation and to a limited extent through Conservation and Management Measure CMM2010-07.

7. FOR FURTHER INFORMATION

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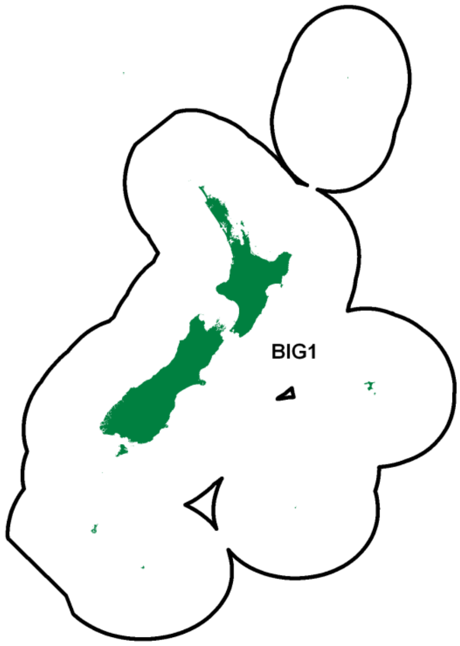
BIGEYE TUNA (BIG)

(Thunnus obesus)



1. FISHERY SUMMARY

Bigeye tuna were introduced into the QMS on 1 October 2004 under a single QMA, BIG 1, with allowances (t), TACC, and TAC in Table 1.

Table 1: Recreational and Customary non-commercial allowances, TACCs and TACs (all in tonnes) by Fishstock.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other mortality	TACC	TAC
BIG 1	8	4	14	714	740

Bigeye were added to the Third Schedule of the 1996 Fisheries Act with a TAC set under s14 because bigeye is a highly migratory species, and it is not possible to estimate MSY for the part of the stock that is found within New Zealand fisheries waters.

Management of the bigeye stock throughout the Western and Central Pacific Ocean (WCPO) is the responsibility of the Western and Central Pacific Fisheries Commission (WCPFC). Under this regional convention New Zealand is responsible for ensuring that the management measures applied within New Zealand fisheries waters are compatible with those of the Commission.

At its second annual meeting (2005) the WCPFC passed a Conservation and Management Measure (CMM) (this is a binding measure that all parties must abide by) relating to conservation and management of tunas. Key aspects of this resolution were presented in the 2006 Plenary document. That measure was reviewed by the Scientific Committee (SC) and further recommendations were made such that at its third annual meeting (2006) the WCPFC passed a new CMM relating to conservation and management of bigeye tuna (http://www.wcpfc.int). A further measure CMM2008-01 was agreed to in December 2008, the aim of which was to:

- “Ensure through the implementation of compatible measures for the high seas and EEZs that bigeye and yellowfin tuna stocks are maintained at levels capable of producing their maximum sustainable yield; as qualified by relevant environmental and economic factors including the special requirements of developing States in the Convention area as expressed by Article 5 of the Convention.

- Achieve, through the implementation of a package of measures, over a three-year period commencing in 2009, a minimum of 30% reduction in bigeye tuna fishing mortality from the annual average during the period 2001-2004 or 2004;
- Ensure that there is no increase in fishing mortality for yellowfin tuna beyond the annual average during the period 2001-2004 average or 2004; and
- Adopt a package of measures that shall be reviewed annually and adjusted as necessary by the Commission taking account of the scientific advice available at the time as well as the implementation of the measures. In addition, this review shall include any adjustments required by Commission decisions regarding management objectives and reference points."

This measure is large and detailed with numerous exemptions and provisions. Despite this effort reductions are being attempted through seasonal fish aggregating device (FAD) closures, and high seas area closures (in high seas pockets) for the purse seine fleets, longline effort reductions as well as other methods. At the 2009, 2010 and 2011 meetings the Scientific Committee recommended that this measure would need to be strengthened if it was to achieve its objectives. The intent is to review the measure in December 2011. The measure received a minor amendment in March 2012, but a full revision of the measure will take place in December 2012.

1.1 Commercial fisheries

Commercial catches by distant water Asian longliners of bigeye tuna, in New Zealand fisheries waters, began in 1962 and continued under foreign license agreements until 1993. Bigeye were not a primary target species for these fleets and catches remained modest with the maximum catch in the 1980s reaching 680 t. Domestic tuna longline vessels began targeting bigeye tuna in 1990. There was an exponential increase in the number of hooks targeting bigeye which reached a high of approximately 6.6 million hooks in 2000-01 and then declined thereafter.

Catches from within New Zealand fisheries waters are very small (0.2% average for 2001-2009) compared to those from the greater stock in the WCPO (Tables 2 & 3). Figures 1 shows historical landings and TACC values for BIG1 and BIGET. Figure 2 shows historical longline fishing effort. In contrast to New Zealand, where bigeye are taken almost exclusively by longline, 40% of the WCPO catches of bigeye are taken by purse seine and other surface gears (e.g., ring nets).

1.2 Recreational fisheries

Recreational fishers make occasional catches of bigeye tuna while trolling for other tunas and billfish, but the recreational fishery does not regularly target this species. There is no information on the size of the catch.

1.3 Customary non-commercial fisheries

An estimate of the current customary catch is not available, but it is considered to be low.

1.4 Illegal catch

There is no known illegal catch of bigeye tuna in the EEZ.

1.5 Other sources of mortality

The estimated overall incidental mortality rate from observed longline effort is 0.23% of the catch. Discard rates are 0.34%on average from observer data, of which approximately 70% are discarded dead (usually because of shark damage). Fish are also lost at the surface in the longline fishery, 0.09% on average from observer data, of which 100% are thought to escape alive.

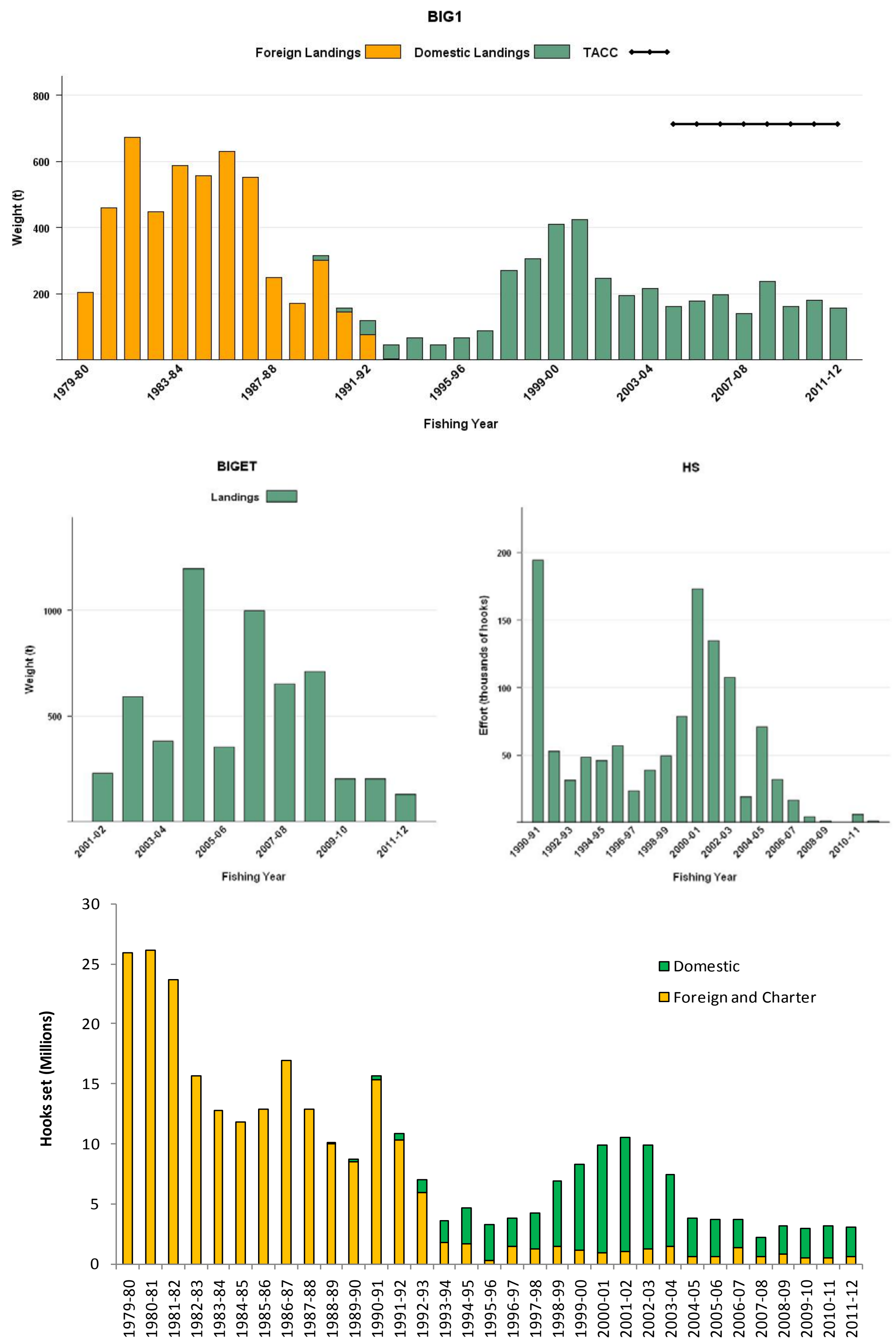


Figure 1: [Top and middle left] Bigeye catch by foreign licensed and New Zealand vessels from 1979-80 to 2011-12 within NZ waters (BIG1) and 2001-02 to 2011-12 for New Zealand vessels fishing on the high seas (BIGET) (Anon 2012). [Middle right and bottom] Fishing effort (number of hooks set) for all high seas New Zealand flagged surface longline vessels, and domestic vessels (including effort by foreign vessels chartered by NZ fishing companies), from 1990-91 to 2011-12 and 1979-80 to 2011-12, respectively.

Table 2: Reported total New Zealand within EEZ landings* (t), landings from the Western and Central Pacific Ocean (t) of bigeye tuna by calendar year from 1991 to present, and NZ ET catch estimates from 2001 to present.

Year	NZ landings (t)	Total landings (t)	NZ ET SPC estimate	Year	NZ landings (t)	Total landings (t)	NZ ET SPC estimate	Year	NZ landings (t)	Total landings (t)	NZ ET SPC estimate
1991	44	73 474		1999	421	115 721		2007	213	137 511	651
1992	39	91 032		2000	422	113 836		2008	133	157 054	713
1993	74	79 665		2001	480	105 238	230	2009	254	118 657	204
1994	71	89 662		2002	200	120 222	593	2010	132	108 997	204
1995	60	83 057		2003	205	110 260	383	2011	174	159 479	131
1996	89	84 107		2004	185	146 069	1 198				
1997	142	113 444		2005	176	129 369	353				
1998	388	113 293		2006	178	134 072	997				

Source: Ministry of Fisheries Licensed Fish Receiver Reports, Solander Fisheries Ltd, Anon. 2006, Lawson 2008, WCPFC5-2008/IP11 (Rev. 2), Williams & Terawasi (2011) and WCPFC Yearbook 2012 Anon (2012).

*New Zealand purse seine vessel operating in tropical regions also catch small levels of bigeye when fishing around Fish Aggregating Devices (FAD). These catches are not included here at this time as the only estimates of catch are based on analysis of observer data across all fleets rather than specific data for NZ vessels. Bigeye catches are combined with yellowfin catches on most catch effort forms.

Table 3: Reported catches or landings (t) of bigeye tuna by fleet and Fishing Year. NZ: New Zealand domestic and charter fleet, ET: catches outside these areas from New Zealand flagged longline vessels, JPNFL: Japanese foreign licensed vessels, KORFL: foreign licensed vessels from the Republic of Korea, and LFRR: Estimated landings from Licensed Fish Receiver Returns.

		BIG 1 (all FMAs)				
Fish Yr	JPNFL	KORFL	NZ/MHR	Total	LFRR	NZ ET
1979/80	205.8			205.8		
1980/81	395.9	65.3		461.2		
1981/82	655.3	16.8		672.1		
1982/83	437.1	11.1		448.2		
1983/84	567.0	21.8		588.8		
1984/85	506.3	51.6		557.9		
1985/86	621.6	10.2		631.8		
1986/87	536.1	17.6		553.7		
1987/88	226.9	22.2		249.1		
1988/89	165.6	5.5		171.1	4.0	
1989/90	302.7		12.7	315.4	30.7	0.4
1990/91	145.6		12.6	158.2	36.0	0.0
1991/92	78.0		40.9	118.9	50.0	0.8
1992/93	3.4		43.8	47.2	48.8	2.2
1993/94			67.9	67.9	89.3	6.1
1994/95			47.2	47.2	49.8	0.5
1995/96			66.9	66.9	79.3	0.7
1996/97			89.8	89.8	104.9	0.2
1997/98			271.9	271.9	339.7	2.6
1998/99			306.5	306.5	391.2	1.4
1999/00			411.7	411.7	466.0	7.6
2000/01			425.4	425.4	578.1	13.6
2001/02			248.9	248.9	276.3	2.0
2002/03			196.1	196.1	195.1	0.6
2003/04			216.3	216.3	217.5	0.8
2004/05*			162.9	162.9	163.6	0.7
2005/06*			177.5	177.5	177.1	0.14
2006/07*			196.7	196.7	201.4	0.05
2007/08*			140.5	140.5	143.8	0
2008/09*			237.2	237.2	240.2	0
2009/10*			161.2	161.2	169.7	9.9
2010/11*			181.1	181.1	201.0	20.3

The majority of bigeye tuna (88%) are caught in the bigeye tuna target surface longline fishery (Figure 2). While bigeye are the target, albacore make up the bulk of the catch (34%) (Figure 3). Longline fishing effort is distributed along the east coast of the North Island and the south west coast of the South Island. The west coast South Island fishery predominantly targets southern bluefin tuna, whereas the east coast of the North Island targets a range of species including bigeye, swordfish, and southern bluefin tuna (Figure 4).

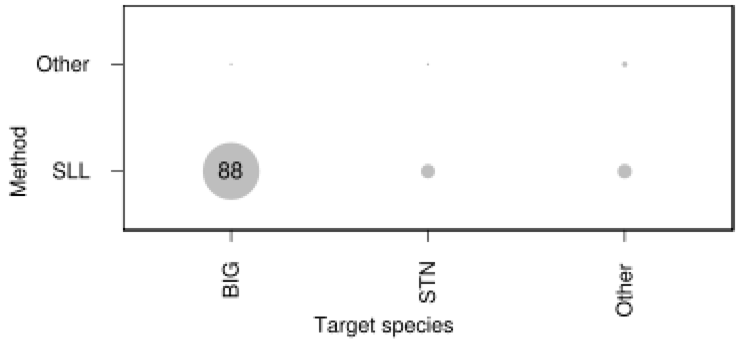


Figure 2: A summary of the proportion of landings of bigeye tuna taken by each target fishery and fishing method. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the bobble is the percentage. SLL = surface longline (Bentley *et al.*2012).

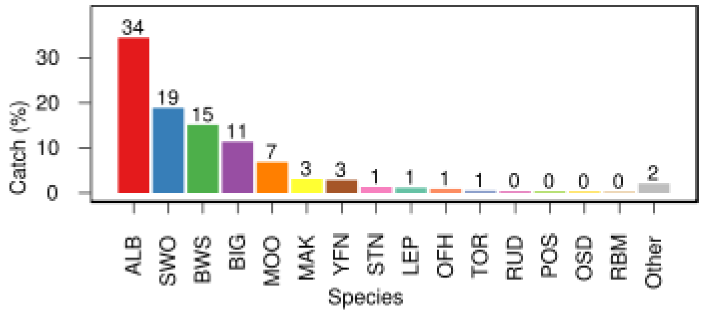


Figure 3: A summary of species composition of the reported bigeye target surface longline catch. The percentage by weight of each species is calculated for all surface longline trips targeting bigeye tuna (Bentley *et al.*2012).

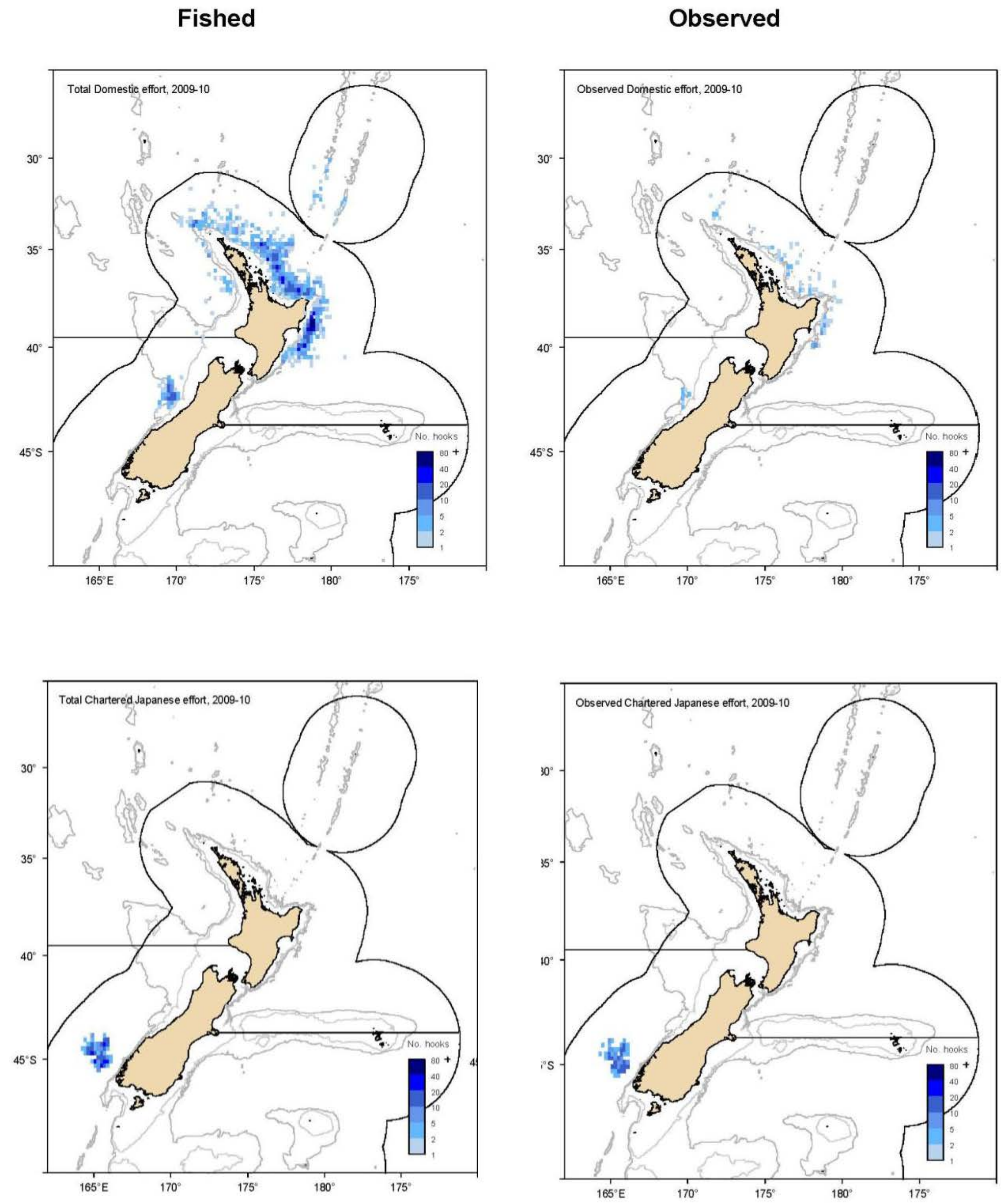


Figure 4: Distribution of fishing positions for domestic (top two panels) and charter (bottom two panels) vessels, for the 2009-10 fishing year, displaying both fishing effort (left) and observer effort (right).

2. BIOLOGY

Bigeye tuna are epi-pelagic opportunistic predators of fish, crustaceans and cephalopods generally found within the upper few hundred meters of the ocean. Tagged bigeye tuna have been shown to be capable of movements of over 4000 nautical miles over periods of one to several years. Juveniles and small adults school near the surface in tropical waters while adults tend to live in deeper water. Individuals found in New Zealand waters are mostly adults. Adult bigeye tuna are distributed broadly across the Pacific Ocean, in both the Northern and Southern Hemispheres and reach a maximum size of 210 kg and maximum length of 250 cm. The maximum reported age is 11 years old and tag recapture data indicate significant numbers of bigeye reach at least 8 years old. Spawning takes place in the equatorial waters of the Western Pacific Ocean (WPO) in spring and early summer.

Natural mortality and growth rates are both estimated within the stock assessment. Natural mortality is assumed to vary with age with values about 0.5 for bigeye larger than 40 cm. A range of von Bertalanffy growth parameters has been estimated for bigeye in the Pacific Ocean depending on area (Table 4).

Table 4: Biological growth parameters for Bigeye, by country.

L_∞ (cm)	K	t_0	Country
169.0	0.608		Mexico
187.0	0.380		French Polynesia
195.0	0.106	-1.13	Japan
196.0	0.167		Hawaii
222.0	0.114		Hawaii
220.0	0.183		Hawaii

3. STOCKS AND AREAS

There are insufficient data available to determine whether there are one or more stocks of bigeye tuna in the Pacific Ocean. The present information, based on tagging data, is summarized in Davies *et al.*(2011) as follows: “Bigeye tuna are distributed throughout the tropical and sub-tropical waters of the Pacific Ocean. There is little information on the extent of mixing across this wide area. Analysis of mtDNA and DNA microsatellites in nearly 800 bigeye tuna failed to reveal significant evidence of widespread population subdivision in the Pacific Ocean (Grewe & Hampton 1998). While these results are not conclusive regarding the rate of mixing of bigeye tuna throughout the Pacific, they are broadly consistent with the results of SPC‘s and IATTC‘s tagging experiments on bigeye tuna. Bigeye tuna tagged in locations throughout the tropical Pacific have displayed movements of up to 4,000 nautical miles over periods of one to several years, indicating the potential for gene flow over a wide area; however, the large majority of tag returns were recaptured much closer to their release points. Recent tagging of bigeye tuna in the central Pacific has shown a similar pattern. The majority of tag returns with verified recapture positions show displacements of less than 1,000 nm (SPC, unpubl. data). In addition, recent tagging experiments in the eastern Pacific Ocean (EPO) using archival tags have so far not demonstrated long-distance migratory behaviour (Schaefer & Fuller 2002) over time scales of up to 3 years; however one recent four-year archival tag return displayed long-distance movements from the EPO to the central Pacific and back in years 3 and 4 of the archival tag record (Schaefer, pers. comm). In view of these results, stock assessments of bigeye tuna are routinely undertaken for the WCPO and EPO separately, however, current bigeye tuna tagging efforts in all areas of the tropical Pacific will provide further opportunity to examine this hypothesis.”

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the November 2012 Fishery Assessment Plenary after review by the Aquatic Environment Working Group. This summary is from the perspective of the bigeye tuna longline fishery; a more detailed summary from an issue-by-issue perspective is, or will shortly be, available in the Aquatic Environment & Biodiversity Annual Review where the consequences are also discussed (http://www.mpi.govt.nz/news-resources/publications.aspx).

4.1 Role in the ecosystem

Bigeye tuna (*Thunnus obesus*) are epi-pelagic opportunistic predators of fish, crustaceans and cephalopods generally found within the upper few hundred meters of the ocean. Bigeye tuna are large pelagic predators, so they are likely to have a 'top down' effect on the fish, crustaceans and squid they feed on.

4.2 Incidental catch (seabirds, sea turtles and mammals)

The protected species, capture estimates presented here include all animals recovered onto the deck (alive, injured or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds caught on a hook but not brought onboard the vessel).

4.2.1 Seabird bycatch

Between 2002–03 and 2010–11, there were 68 observed captures of birds in bigeye target longline fisheries (Table 5). Seabird capture rates since 2003 are presented in Figure 5. Seabird bycatch occurs predominantly off the east coast of the North Island (Figure 6). The analytical methods used to estimate capture numbers across the commercial fisheries have depended on the quantity and quality of the data, in terms of the numbers observed captured and the representativeness of the observer coverage. Ratio estimation was historically used to calculate total captures in longline fisheries by target fishery fleet and area (Baird 2008) and by all fishing methods but recent estimates are either ratio or model based as specified in the tables below (Abraham *et al.*2010).

Table 5: Number of observed seabird captures in bigeye tuna longline fisheries, 2002-03 to 2010-11, by species and area (Thompson & Abraham (2012) from http://data.dragonfly.co.nz/psc/). See glossary above for areas used for summarising the fishing effort and protected species captures. 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 bigeye tuna using longline gear but rather the total risk for each seabird species.

Species	Risk ratio	Kermadec Islands	Northland and Hauraki	Bay of Plenty	East Coast North Island	West Coast North Island	Total
Salvin's albatross	2.49	0	1	1	2	0	4
Northern royal albatross	2.21	0	0	1	0	0	1
Campbell albatross	1.84	0	3	0	0	0	3
Southern Buller's albatross	1.28	0	3	0	4	0	7
Gibson's albatross	1.25	0	5	0	0	1	6
Antipodean albatross	1.1	0	6	1	0	1	8
White capped albatross	0.83	0	1	0	0	0	1
Black browed albatross	-	0	1	0	0	1	2
Wandering albatross	-	0	2	0	1	0	3
Antipodean or Gibson's albatross	N/A	0	2	0	0	0	2
Unidentified albatross	N/A	0	0	0	0	1	1
Total albatrosses	N/A	0	24	3	7	4	38
Black petrel	11.15	1	7	1	0	0	9
Flesh footed shearwater	2.51	0	0	0	9	2	11
White chinned petrel	0.79	0	2	3	0	3	8
Great winged petrel	0.01	0	0	1	0	0	1
Pterodroma petrels	N/A	0	1	0	0	0	1
Total other birds	N/A	1	10	5	9	5	30

Through the 1990s the minimum seabird mitigation requirement for surface longline vessels was the use of a bird scaring device (tori line) but common practice was that vessels set surface longlines primarily at night. In 2007 a notice was implemented under s 11 of the Fisheries Act 1996 to formalise the requirement that surface longline vessels only set during the hours of darkness and use a tori line when setting. This notice was amended in 2008 to add the option of line weighting and tori line use if setting during the day. In 2011 notices were combined and repromulgated under a new regulation (Regulation 58A of the Fisheries (Commercial Fishing) Regulations 2001) which provides a more flexible regulatory environment under which to set seabird mitigation requirements.

Table 6: Effort, observed and estimated seabird captures by fishing year for the bigeye tuna fishery within the EEZ. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); the capture rate (captures per thousand hooks); and the mean number of estimated total captures (with 95% confidence interval). The estimation method used was a Bayesian model with 100% of hooks included in the estimate. For more information on the methods used to prepare the data see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures		Estimated captures	
	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002-2003	5 186 507	80 640	1.6	0	0	1 567	1 094-2 281
2003-2004	3 503 857	120 740	3.4	1	0.008	975	696-1 354
2004-2005	1 644 781	33 116	2	2	0.06	392	269-568
2005-2006	1 866 486	45 100	2.4	6	0.133	525	372-748
2006-2007	1 532 071	84 150	5.5	5	0.059	483	337-713
2007-2008	967 829	26 455	2.7	10	0.378	298	214-411
2008-2009	1 565 517	91 095	5.8	9	0.099	441	320-599
2009-2010	1 247 437	80 009	6.4	34	0.425	520	358-764
2010-2011	1 645 556	87 730	5.3	15	0.171	518	350-761

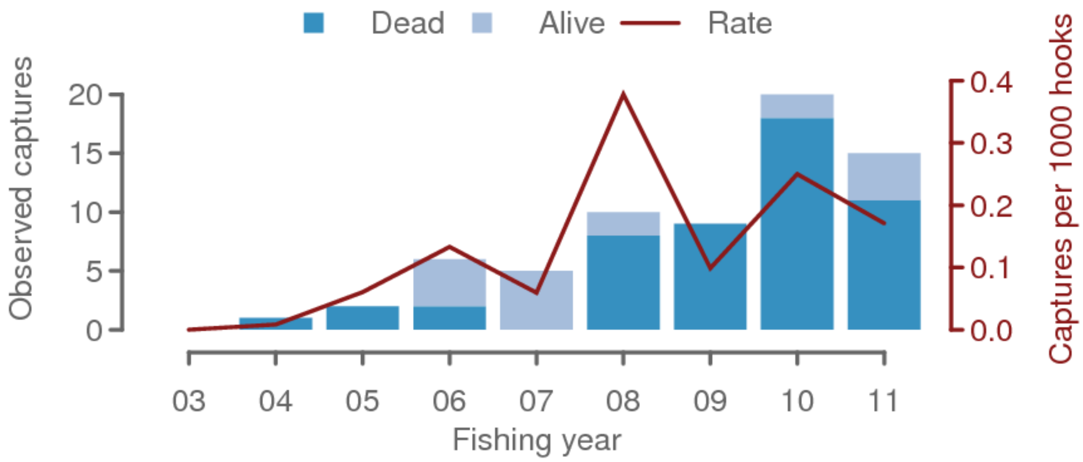


Figure 5: Observed and estimated captures of seabirds in bigeye tuna longline fisheries from 2003 to 2011.

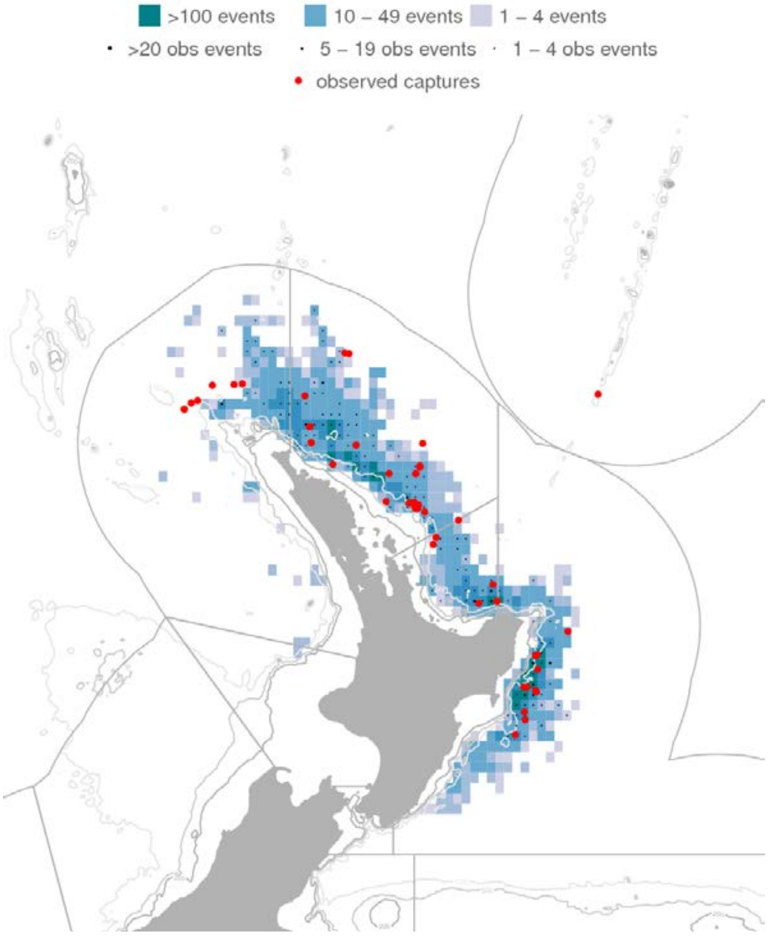


Figure 6: Distribution of fishing effort targeting bigeye tuna and observed seabird captures, 2002-03 to 2010-11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 71.9% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.2 Sea turtle bycatch

Between 2002–03 and 2010–11, there were eight observed captures of turtles in bigeye tuna longline fisheries. Observer recordings documented all sea turtles as captured and released alive. Sea turtle capture distributions do not coincide with fishing effort and are more common on the east coast of the North Island (Figure 8).

Table 7: Number of observed sea turtle captures in bigeye tuna longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson & Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/.

Species	East Coast North Island	Kermadec Islands	West Coast North Island	Total
Leatherback turtle	3	1	3	7
Unidentified turtle	1	0	0	1
Total	4	1	3	8

Table 8: Fishing effort and sea turtle captures in bigeye tuna longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	5 186 507	80 640	1.6	0	0
2003-2004	3 503 857	120 740	3.4	1	0.008
2004-2005	1 644 781	33 116	2.0	2	0.060
2005-2006	1 866 486	45 100	2.4	1	0.022
2006-2007	1 532 071	84 150	5.5	1	0.012
2007-2008	967 829	26 455	2.7	0	0
2008-2009	1 565 517	91 095	5.8	2	0.022
2009-2010	1 247 437	80 009	6.4	0	0
2010-2011	1 645 556	87 730	5.3	1	0.011

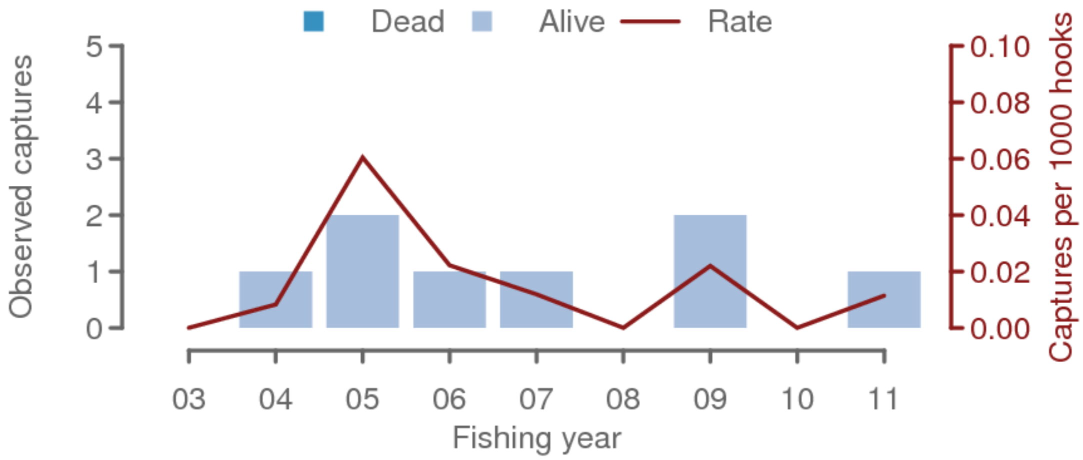


Figure 7: Observed captures of sea turtles in bigeye tuna longline fisheries from 2003 to 2011.

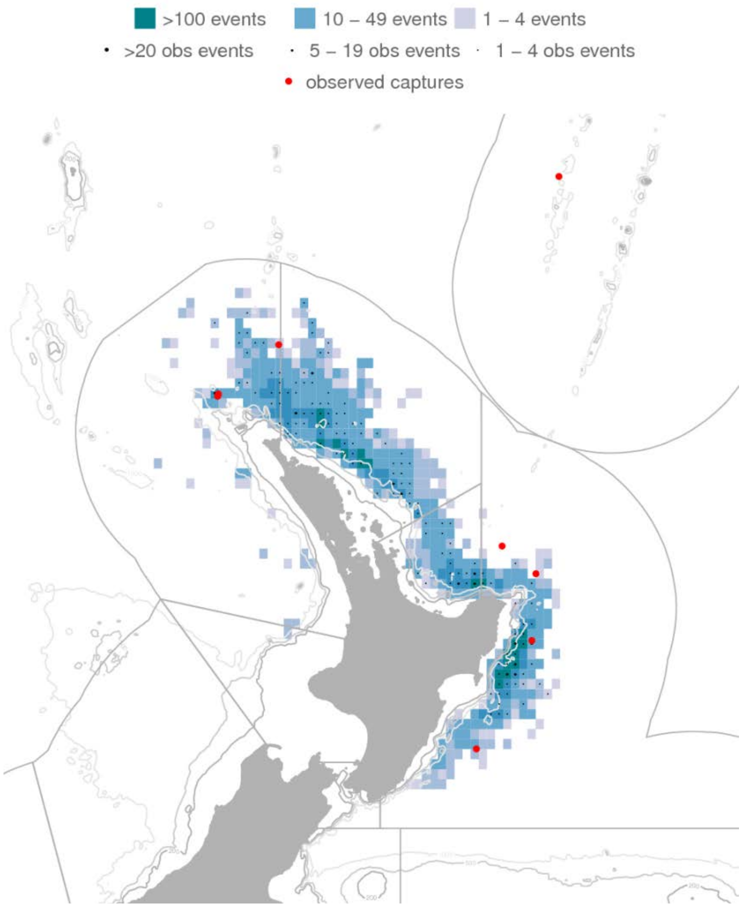


Figure 8: Distribution of fishing effort targeting bigeye tuna and observed sea turtle captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 71.9% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3 Marine Mammals

4.2.3.1 Cetaceans

Cetaceans are dispersed throughout New Zealand waters (Perrin *et al.*2008). The spatial and temporal overlap of commercial fishing grounds and cetacean foraging areas has resulted in cetacean captures in fishing gear (Abraham and Thompson 2009, 2011). The analytical methods used to estimate capture numbers across the commercial fisheries have depended on the quantity and quality of the data, in terms of the numbers observed captured and the representativeness of the observer coverage. Ratio estimation is used to calculate total captures in longline fisheries by target fishery fleet and area (Baird 2008) and by all fishing methods (Abraham *et al.*2010).

Between 2002–03 and 2010–11, there was one observed unidentified cetacean capture in bigeye longline fisheries. This capture took place on the west coast of the North Island (Figures 9 and 10) (Abraham and Thompson 2011). The captured animal recorded was documented as being caught and released alive (Thompson and Abraham 2010).

Table 9: Number of observed cetacean captures in bigeye tuna longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson & Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/.

Species	West Coast North Island	Total
Unidentified cetacean	1	1

Table 10: Effort and cetacean captures by fishing year in bigeye tuna fisheries. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	5 186 507	80 640	1.6	0	0
2003-2004	3 503 857	120 740	3.4	1	0.008
2004-2005	1 644 781	33 116	2.0	0	0
2005-2006	1 866 486	45 100	2.4	0	0
2006-2007	1 532 071	84 150	5.5	0	0
2007-2008	967 829	26 455	2.7	0	0
2008-2009	1 565 517	91 095	5.8	0	0
2009-2010	1 247 437	80 009	6.4	0	0
2010-2011	1 645 556	87 730	5.3	0	0

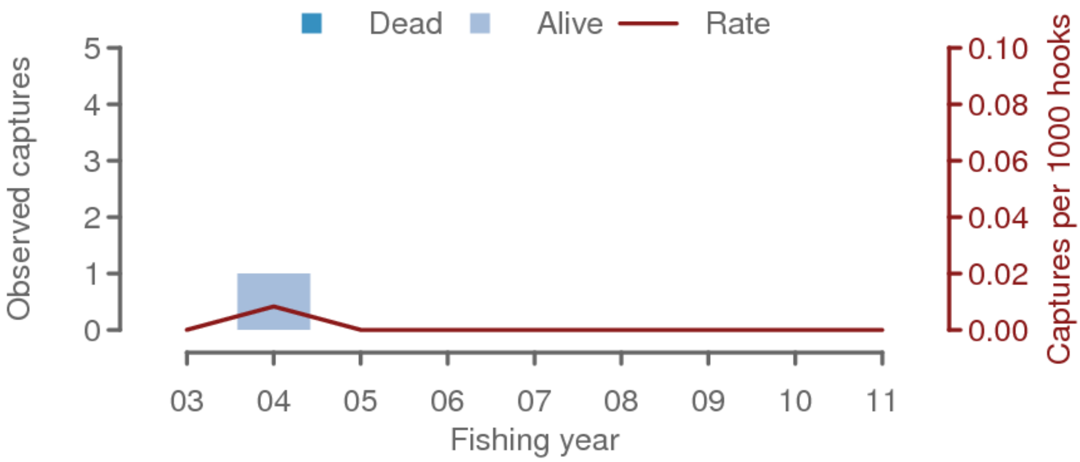


Figure 9: Observed captures of cetaceans in bigeye longline fisheries from 2003 to 2011.

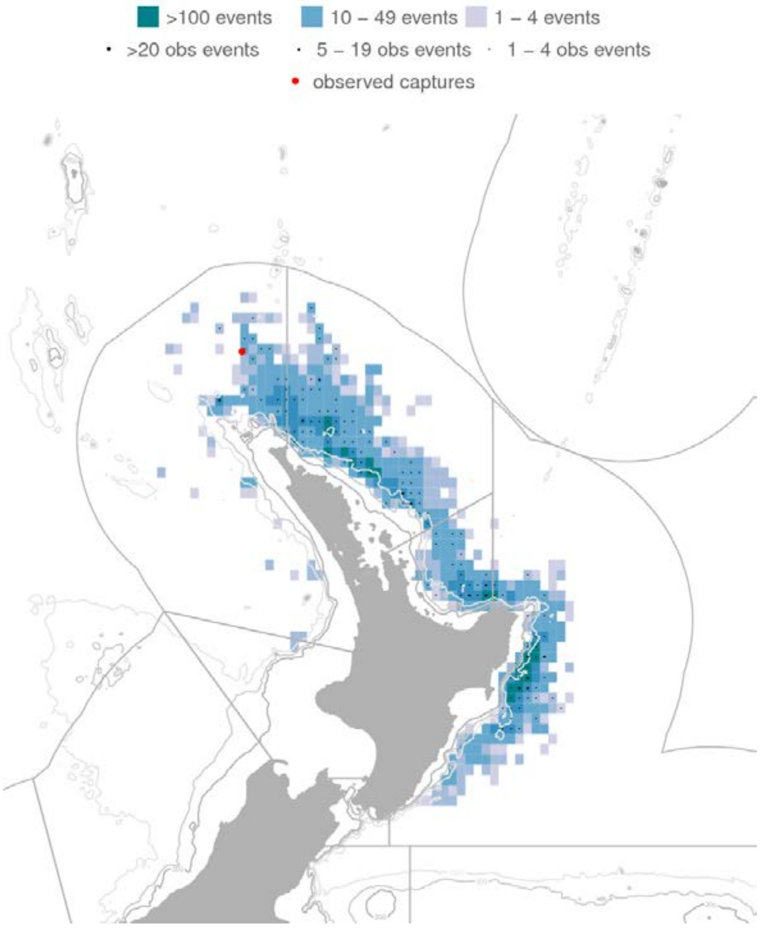


Figure 10: Distribution of fishing effort targeting bigeye tuna and observed cetacean captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 71.9% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.4 New Zealand fur seal bycatch

Currently, New Zealand fur seals are dispersed throughout New Zealand waters, especially in waters south of about 40º S to Macquarie Island. The spatial and temporal overlap of commercial fishing grounds and New Zealand fur seal foraging areas has resulted in New Zealand fur seal captures in fishing gear (Mattlin 1987, Rowe 2009). Most fisheries with observed captures occur in waters over or close to the continental shelf, which around much of the South Island and offshore islands slopes steeply to deeper waters relatively close to shore, and thus rookeries and haulouts. Captures on longlines occur when the seals attempt to feed on the fish and bait catch during hauling. Most New Zealand fur seals are released alive, typically with a hook and short snood or trace still attached.

The analytical methods used to estimate capture numbers across the commercial fisheries have depended on the quantity and quality of the data, in terms of the numbers observed captured and the representativeness of the observer coverage. New Zealand fur seal captures in surface longline fisheries have been generally observed in waters south and west of Fiordland, but also in the Bay of Plenty-East Cape area when the animals have attempted to take bait or fish from the line as it is hauled. These capture rates include animals that are released alive (100% of observed surface longline capture in 2008-09; Thompson and Abraham 2010). Between 2002–03 and 2010–11, there were two observed captures of New Zealand fur seals in bigeye longline fisheries (Tables 11 and 12, Figures 11 and 12).

Table 11: Number of observed New Zealand fur seal captures in bigeye tuna longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson & Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/.

	West Coast North Island	Total
New Zealand fur seal	2	2

Table 12: Effort and captures of New Zealand fur seal by fishing year in bigeye tuna longline fisheries. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	5 186 507	80 640	1.6	0	0
2003-2004	3 503 857	120 740	3.4	0	0
2004-2005	1 644 781	33 116	2.0	0	0
2005-2006	1 866 486	45 100	2.4	0	0
2006-2007	1 532 071	84 150	5.5	0	0
2007-2008	967 829	26 455	2.7	2	0.076
2008-2009	1 565 517	91 095	5.8	0	0
2009-2010	1 247 437	80 009	6.4	0	0
2010-2011	1 645 556	87 730	5.3	0	0

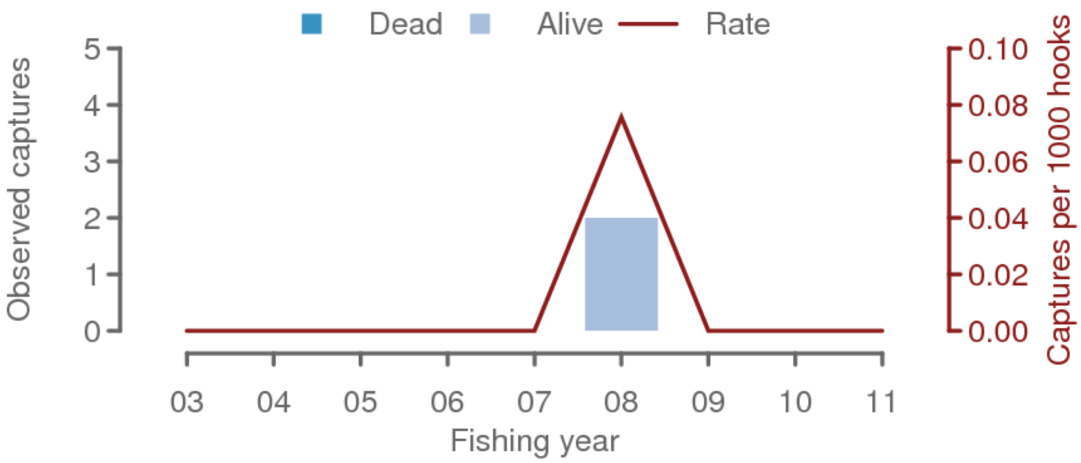


Figure 11: Observed captures of New Zealand fur seal in bigeye tuna longline fisheries from 2003 to 2011.

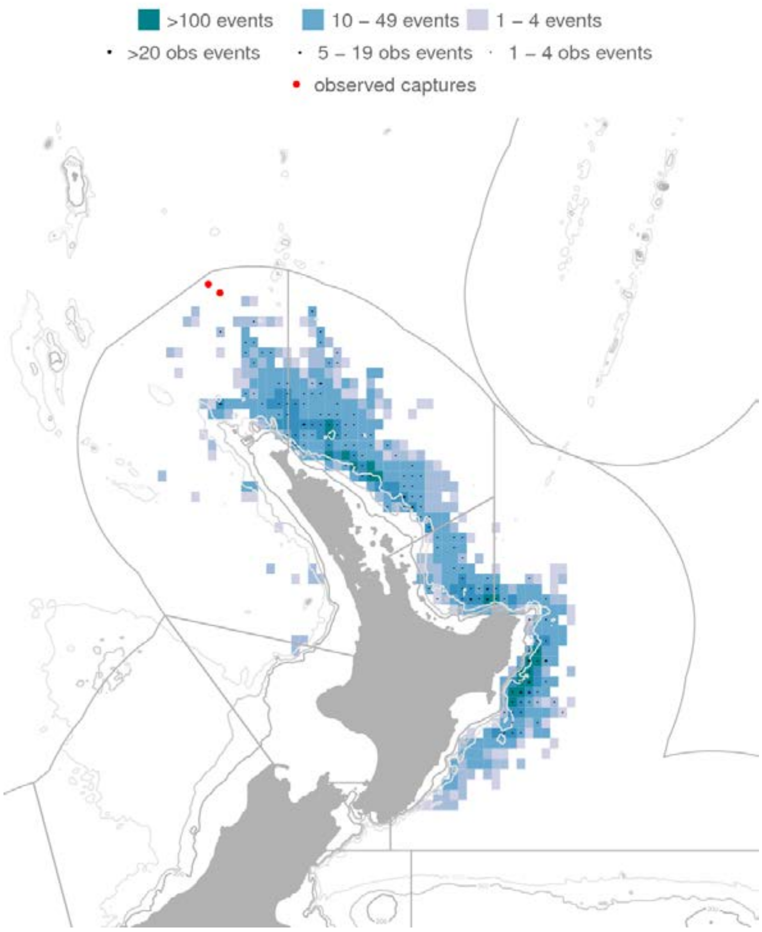


Figure 12: Distribution of fishing effort targeting bigeye tuna and observed New Zealand fur seal captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 71.9% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.3 Incidental fish bycatch

Observer records indicate that a wide range of species are landed by the longline fleets in New Zealand fishery waters. Blue sharks are the most commonly landed species (by number), followed by Ray’s bream (Table 13). Southern bluefin tuna and albacore tuna are the only target species that occur in the top five of the frequency of occurrence.

Table 13: Numbers of the most common fish species observed in the New Zealand longline fisheries during 2009-10 by fleet and area. Species are shown in descending order of total abundance (Griggs and Baird in press).

	Charter	Domestic		Total
Species	South	North	South	number
Blue shark	2 024	4 650	882	7 556
Rays bream	3 295	326	88	3 709
Southern bluefin tuna	3 244	211	179	3 634
Lancetfish	3	2 139	1	2 143
Albacore tuna	90	1 772	42	1 904
Dealfish	882	0	7	889
Swordfish	3	452	2	457
Moonfish	76	339	6	421
Porbeagle shark	72	328	20	420
Mako shark	11	343	7	361
Big scale pomfret	349	4	0	353
Deepwater dogfish	305	0	0	305
Sunfish	7	283	5	295
Bigeye tuna	0	191	0	191
Escolar	0	129	0	129
Butterfly tuna	15	100	3	118
Pelagic stingray	0	96	0	96
Oilfish	2	75	0	77
Rudderfish	39	20	2	61
Flathead pomfret	56	0	0	56
Dolphinfish	0	47	0	47
School shark	34	0	2	36
Striped marlin	0	24	0	24
Thresher shark	7	17	0	24
Cubehead	13	0	1	14
Kingfish	0	10	0	10
Yellowfin tuna	0	9	0	9
Hake	8	0	0	8
Hapuku bass	1	6	0	7
Pacific bluefin tuna	0	5	0	5
Black barracouta	0	4	0	4
Skipjack tuna	0	4	0	4
Shortbill spearfish	0	4	0	4
Gemfish	0	3	0	3
Bigeye thresher shark	0	2	0	2
Snipe eel	2	0	0	2
Slender tuna	2	0	0	2
Wingfish	2	0	0	2
Bronze whaler shark	0	1	0	1
Hammerhead shark	0	1	0	1
Hoki	0	0	1	1
Louvar	0	1	0	1
Marlin, unspecified	0	1	0	1
Scissortail	0	1	0	1
Broadnose seven gill shark	1	0	0	1
Shark, unspecified	0	1	0	1
Unidentified fish	2	30	8	40
Total	10 545	11 629	1 256	23 430

4.4 Benthic interactions

N/A

4.5 Key environmental and ecosystem information gaps

Cryptic mortality is unknown at present but developing a better understanding of this in future may be useful for reducing uncertainty of the seabird risk assessment and could be a useful input into risk assessments for other species groups.

The survival rates of released target and bycatch species is currently unknown.

Observer coverage in the New Zealand fleet is not spatially and temporally representative of the fishing effort.

5. STOCK ASSESSMENT

With the establishment of the WCPFC in 2004, future stock assessments of the WCPO stock of bigeye tuna are undertaken by the Oceanic Fisheries Programme (OFP) of Secretariat of the Pacific Community under contract to WCPFC. As noted above, there is continuing work on a Pacific-wide bigeye assessment.

No assessment is possible for bigeye within the New Zealand EEZ as the proportion of the total stock found within New Zealand fisheries waters is unknown and likely varies from year to year.

A summary of the 2011 assessment undertaken by OFP and reviewed by the WCPFC Scientific Committee in August 2011 is provided below (from Davies *et al.*2011).

"The assessment includes a series of model runs describing stepwise changes from the 2010 assessment (run 3d) to develop a new reference case model (Run3j – Ref.case) and then a series of one-off sensitivity models that represent a single change from the Ref.case model run. A sub-set of key model runs was taken from the sensitivities that represent a set of plausible model runs and were included in a structural uncertainty analysis (grid) for consideration in developing management advice.

Besides updating the input data, the main developments to the inputs compared to the 2010 assessment were: including tagging data from the 2007-2010 PTTP program; standardised CPUE time series derived from operational-level catch-effort data for Japanese longline fisheries; weighting the Japanese longline size frequency data according to the estimated population relative abundance within regions; adjusting purse seine size frequency data using spill-samples to correct for grab-sample bias; and, including more reliable size composition data for Philippines and Indonesian domestic purse seine catches in offshore waters. The main developments to model structural assumptions were to define a separate Indonesian Philippines-based domestic purse seine fishery that operates beyond the national archipelagic waters and to the east of 125° E longitude.

During the Pre-Assessment Workshop held in April 2011 (PAW, SPC 2011), the key assumptions from the base case model from the 2010 assessment were reviewed in light of the developments proposed for the Ref.case model for the 2011 assessment. These and the alternative assumptions in the other key model runs are provided below (Table 14):

Table 14: Key and alternative assumptions from the base case model from the 2010 assessment.

Component	2010 assessment (run 3d)	2011 assessment (run 3j)	2011 alternatives
Longline CPUE	Aggregate indices	Operational indices, temporal weighting of standardised effort	- Exclude all CPUE prior to 1975 - Aggregate indices
Steepness	Estimated	Fixed = 0.8	0.65, 0.95, and estimated
Purse-seine catches	Spill sample corrected	Spill sample corrected (including size data)	Grab sample (SBEST)
Tagging data	Excluded PTTP	Included PTTP	Exclude PTTP
Longline size data	Down-weighted	Full weight	Down -weighted
Natural mortality	Base	Base	Increased for juveniles

In comparing the 2011 Ref.case model results with the 2010 assessment, the decision to fix steepness at a more plausible value (0.8) to that estimated in recent assessments must be considered. Whereas the Ref.case estimates of stock status are not dissimilar from the 2010 base case estimates, the 2011 model most comparable to an update of the 2010 base case was Run15 in which steepness was estimated, and which provided a more optimistic stock status. This difference indicates the effects of the new inputs (in particular the operational CPUE indices). If one compares $F_{current}/F_{MSY}$ and $SB_{current}/\mathrm{SB}_{MSY}$ between a straight-forward update of the 2010 model (Run2b) and Run15, the values are 1.49 and 1.33 versus 1.13 and 1.54, respectively."

The main conclusions of the current assessment (based upon the median of the uncertainty grid estimates, and the sensitivity model runs) are as follows.

i. "The estimated increasing trend in recruitment from recent bigeye assessments appears to have been addressed to a small extent in the current assessment, but remains an issue in region 3 and is primarily the result of conflict (disagreement) among the various data sources, in particular between the longline CPUE indices and the reported catch histories, and between and within some of the size composition data sets. The current assessment has indentified some of these conflicts and includes some model runs that begin to address them.

ii. As in previous assessments, recruitment in almost all models is estimated to have been high during 1995–2005. As suggested in the 2010 assessment, an analysis is presented that estimates the stock-recruitment relationship (with steepness fixed) for this latter period and applied it in the yield analyses. If one considers the recruitment estimates in the second half of the time series to be more plausible and representative of the overall productivity of the bigeye stock, the results of this analysis (Run21) could be used for formulating management advice. In this case $F_{current}/F_{MSY}$ was 1.58 and $SB_{current}/\mathrm{SB}_{MSY}$ was 0.61 indicating that we would conclude that the stock is overfished and overfishing is occurring under this productivity assumption. The main reason for the much lower estimate of $SB_{current}/\mathrm{SB}_{MSY}$ is that SB_{MSY} is approximately doubled because of the higher levels of recruitment being used to estimate it.

iii. Total and spawning biomass for the WCPO are estimated to have declined to about half of their initial levels by the mid-1970s, with total biomass remaining relatively constant since then ($B_{current}$ / B_0= 44%), while spawning biomass has continued to decline ($SB_{current}/\mathrm{SB}_0$=35%). Declines are larger for models that exclude the early periods of the CPUE time series.

iv. When the non-equilibrium nature of recent recruitment is taken into account, we can estimate the level of depletion that has occurred. It is estimated that spawning potential is at 26% of the level predicted to exist in the absence of fishing considering the average over the period 2006-09, and that value is reduced to 23% for the 2010 spawning potential levels.

v. The attribution of depletion to various fisheries or groups of fisheries indicates that the purse seine and other surface fisheries have an equal or greater impact than longline fisheries on the current biomass. The purse seine and Philippines/Indonesian domestic fisheries also have substantial impact in region 3 and to a lesser extent in region 4. The Japanese coastal pole-and-line and purse-seine fisheries are also having a significant impact in their home region (region 1). For the sensitivity analysis with lower purse seine catches, the longline fisheries are estimated to have a higher impact.

vi. Recent catches are well above the *MSY* level of 74,993 mt, but this is mostly due to a combination of above average recruitment and high fishing mortality. When *MSY* is re-calculated assuming recent recruitment levels and recent mix of fisheries persist, catches are still around 7% higher than the re-calculated *MSY* (131,400 mt). **Based on these results, we conclude that current levels of catch are unlikely to be sustainable in the long term even at the recent [high] levels of recruitment estimated for the last two decades**.

vii. Fishing mortality for adult and juvenile bigeye tuna is estimated to have increased continuously since the beginning of industrial tuna fishing. For all of the model runs $F_{current}/F_{MSY}$ is considerably greater than 1. For the grid median, the ratio is estimated at 1.42 indicating that a 30% reduction in fishing mortality is required from the 2006-09 level to reduce fishing mortality to sustainable levels. Using the Ref.case, if we consider historical levels of fishing mortality, a 39% reduction in fishing mortality from 2004 levels is required, and a 28% reduction from average 2001-04 levels. Larger reductions in fishing mortality are indicated when lower values of steepness are assumed. **Based on these results, we conclude that overfishing is occurring in the bigeye tuna stock**.

viii. The reference points that predict the status of the stock under equilibrium conditions are $B_{Fcurrent}/B_{MSY}$ and $SB_{Fcurrent}/SB_{MSY}$. The model predicts that biomass would be reduced to 65% and 60% of the level that supports *MSY*. In terms of the reduction against virgin biomass the declines reach as low as 15% of spawning potential. Current stock status compared to these reference points indicate the current total and spawning biomass are higher than the associated MSY levels ($B_{current}/B_{MSY}$ =1.34 and $SB_{current}/SB_{MSY}$ = 1.37). The structural uncertainty analysis indicates a 13% probability that $SB_{current} < SB_{MSY}$. **Based on these results above, and the recent trend in spawning biomass, we conclude that bigeye tuna is approaching an overfished state. We note however, that if recent recruitment is assumed to represent the true productivity of the bigeye stock (Run21), then the higher levels of Bmsy and SBmsy implied would mean that bigeye tuna is already in an overfished state ($B_{current}/B_{MSY}$ =0.67 and $SB_{current}/SB_{MSY}$ = 0.61).**

ix. Analysis of current levels of fishing mortality and historical patterns in the mix of fishing gears indicates that MSY has been reduced to less than half its levels prior to 1970 through harvest of small juveniles. Because of that and overfishing, considerable potential yield from the bigeye tuna stock is being lost. **Based on these results, we conclude that MSY levels would rise if mortality of small fish were reduced which would allow greater overall yields to be sustainably obtained.**"

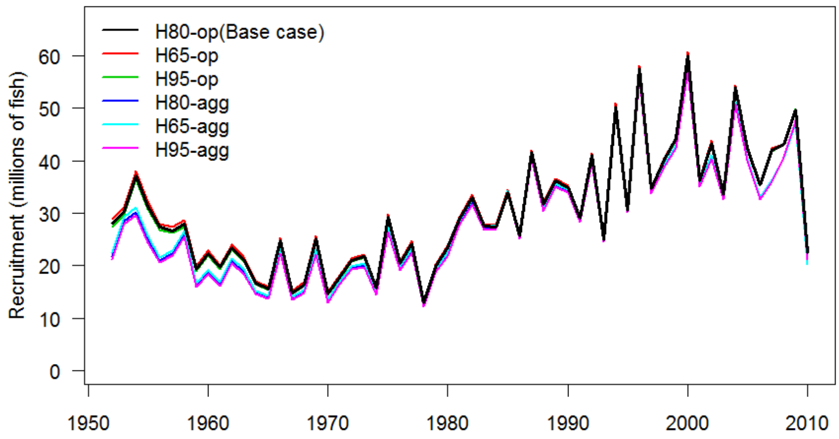


Figure 13: Estimated annual recruitment (millions of fish) for the WCPO obtained from the base case model (run 3j – H80-opp (black line)) and the five combinations of steepness and longline CPUE series.

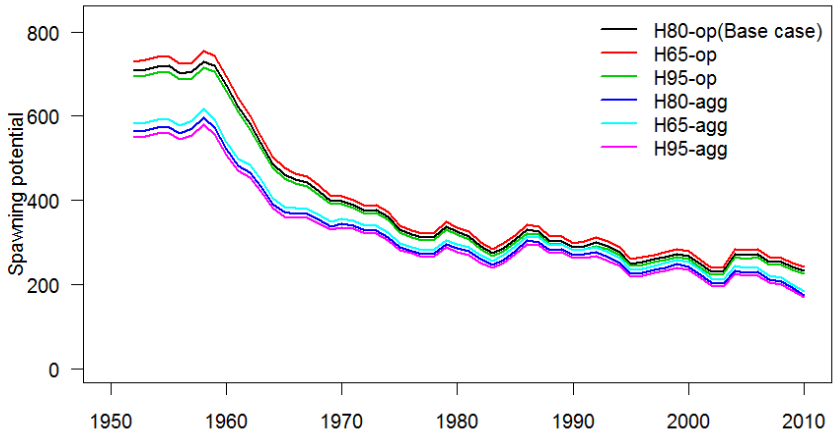


Figure 14: Estimated average annual average spawning potential for the WCPO obtained from the base case model (run 3j – H80-opp (black line)) and the five combinations of steepness and longline CPUE series.

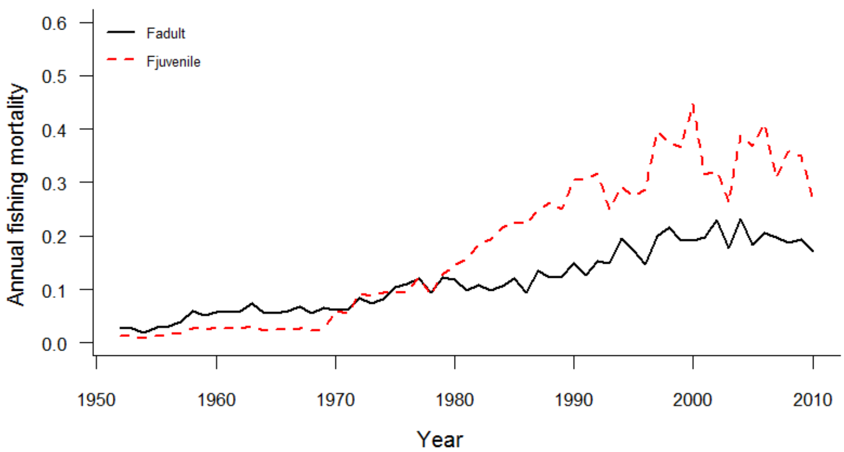


Figure 15: Estimated annual average juvenile and adult fishing mortality for the WCPO obtained from the base case model (run 3j - H80-op).

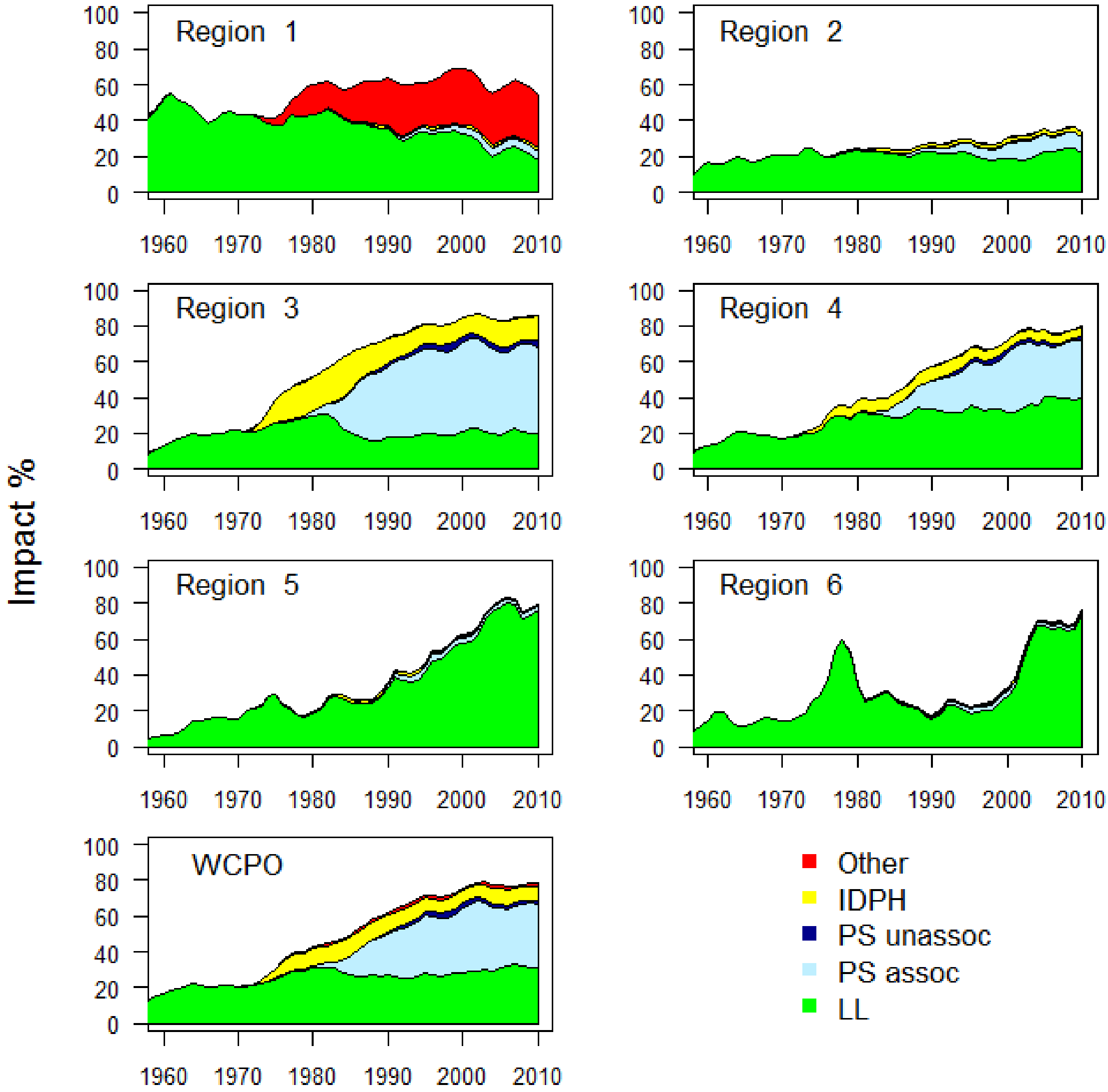


Figure 16: Estimates of reduction in spawning potential due to fishing (fishery impact = 1 – $SB_t/SB_{tF=0}$) by region and for the WCPO attributed to various fishery groups (base case model). LL = all longline fisheries; IDPH = Philippines and Indonesian domestic fisheries; PS assoc = purse-seine log and FAD sets; PS unassoc = purse-seine school sets; Other = pole-and-line fisheries and coastal Japan purse-seine.

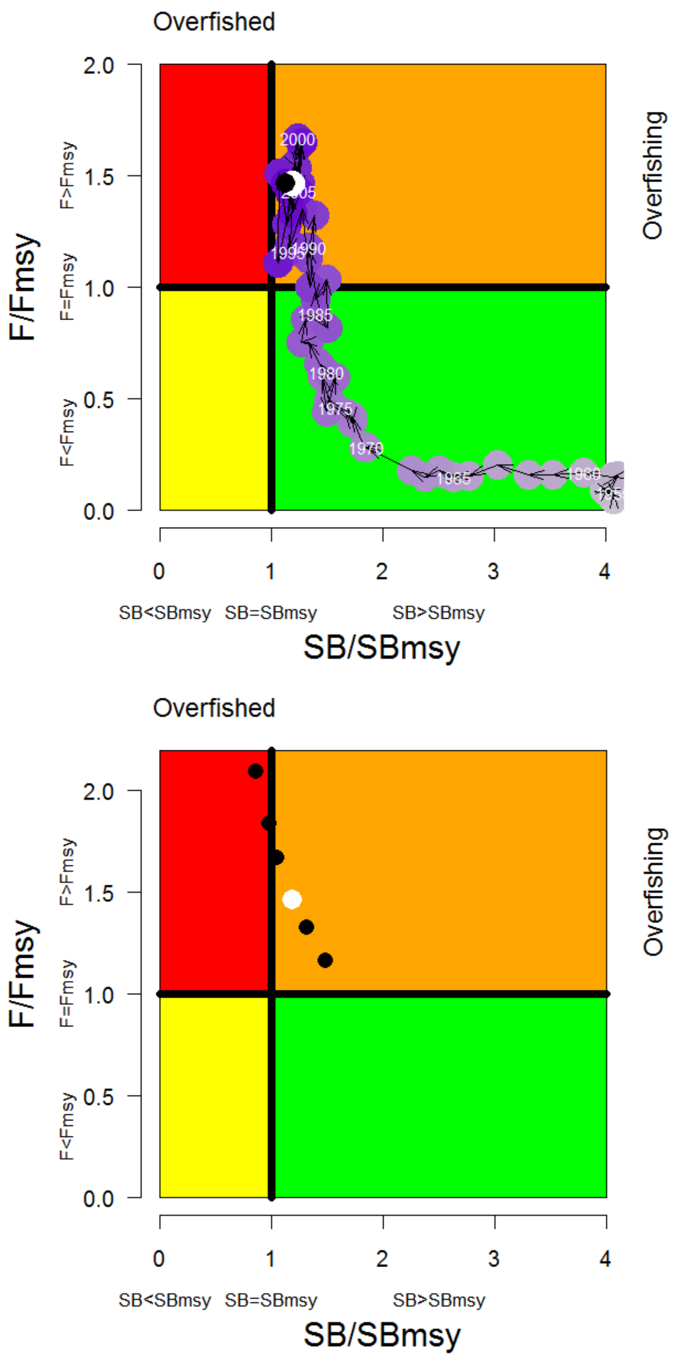


Figure 17: Temporal trend in annual stock status, relative to SB_{MSY} (x-axis) and F_{MSY} (y-axis) reference points for the base case (top) and $F_{current}/F_{MSY}$ and $SB_{current}/SB_{MSY}$ for the base case (white circle) and the five combinations of steepness and longline CPUE series. See Table 5 to determine the individual model runs.

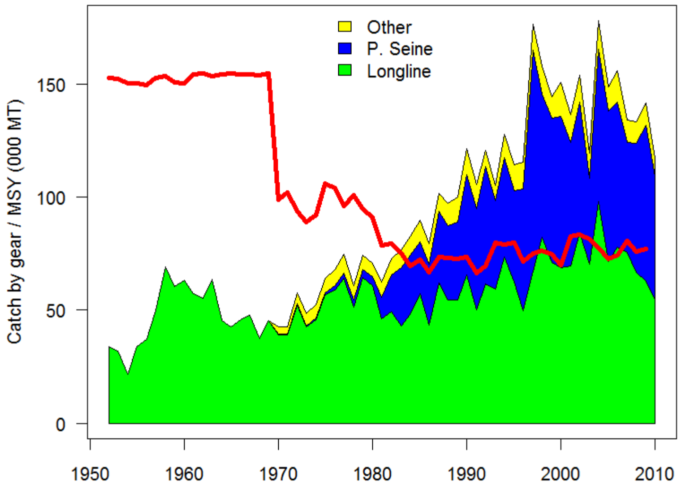


Figure 18: History of annual estimates of MSY compared with catches of three major fisheries sectors. Declining MSY results from the change in selectivity of fishing gear and increases in catches of small bigeye.

Table 15. Estimates of management quantities for selected stock assessment models from the 2011 base case model (run 3j – H80-op) and the five combinations of steepness and longline CPUE series. For the purpose of this assessment, "current" is the average over the period 2006–2009 and "latest" is 2010 [*C* = catch; F_{mult} - The amount that $F_{current}$ needs to be scaled to obtain F_{MSY}].

	H80-op (Base case)	H65-op	H95-op	H80-agg	H65-agg	H95-agg
	141 160	141 365	141 029	141 561	141 805	141 356
	116 868	117 118	116 712	117 558	117 843	117 320
	76 760	70 080	83 720	74 120	68 360	80 360
	1.84	2.02	1.68	1.91	2.07	1.76
	1.52	1.67	1.39	1.59	1.72	1.46
	0.68	0.54	0.86	0.60	0.48	0.75
	1.46	1.84	1.16	1.67	2.10	1.33
	739 900	810 000	698 500	688 400	762 000	644 200
	0.29	0.33	0.24	0.29	0.33	0.24
	0.35	0.33	0.36	0.30	0.29	0.32
	0.31	0.30	0.32	0.26	0.24	0.26
	1.19	0.98	1.49	1.05	0.86	1.32
	1.08	0.89	1.36	0.88	0.72	1.10
	0.23	0.23	0.22	0.20	0.20	0.19
	0.21	0.22	0.21	0.17	0.18	0.17
Steepness (*h*)	0.80	0.65	0.95	0.80	0.65	0.95

Table 16. Comparison of WCPO bigeye tuna reference points from the 2011 reference case model and the range of the six models in Table 5; the 2010 base case model (steepness estimated as 0.98) - shown in parentheses is the alternative 2010 run (steepness assumed as 0.75); ranges of six sensitivity analyses in the 2009 assessment; and the base model and sensitivity analyses from the 2008 assessment.

Management quantity	2011 assessment Base case (uncertainty)	2010 assessment Run3d (Run4b)	2009 Assessment	2008 Assessment
Most recent catch	116 868 mt (2010)	126 769 mt (2009)	134 315 mt (2008)	143 059 mt (2007)
MSY	76 760 mt (68 360 – 83 720)	73 840 mt (65 640 mt)	Range: 52 120 ~ 67 800 mt	Base case: 64 600 mt Range: 56 800~65 520 mt
$F_{current}/F_{MSY}$	1.46 (1.16-2.10)	1.41 (1.97)	Range: 1.51 ~ 2.55	Base case: 1.44 Range: 1.33 ~ 2.09
$B_{current}/B_{MSY}$	1.25 (0.96-1.48)	1.39 (1.09)	Range: 1.11 ~ 1.55	Base case: 1.37 Range: 1.02 ~ 1.37
$SB_{current}/SB_{MSY}$	1.19 (0.86-1.49)	1.34 (0.97)	Range: 0.85 ~ 1.42	Base case: 1.19 Range: 0.76 ~ 1.20
$Y_{Fcurrent}/MSY$	0.89 (0.34-0.99)	0.94 (0.56)	Range: 0.12 ~ 0.92	Base case: 0.94 Range: 0.50 ~ 0.97
$B_{current}/B_{current, F=0}$	0.29 (0.25-0.30)	0.23 (0.24)	Range: 0.18 ~ 0.29	Base case: 0.26 Range: 0.20 ~ 0.28
$SB_{current}/SB_{current, F=0}$	0.23 (0.19-0.23)	0.17 (0.18)	Range 0.11 – 0.19	Not available

5.1 Estimates of fishery parameters and abundance

There are no fishery independent indices of abundance for the bigeye stock. Relative abundance information is available from longline catch per unit effort data, though there is no agreement on the best method to standardise these data and several methods are compared. Returns from a large scale tagging programme undertaken in the early 1990s, and an updated programme from 2007-2009 undertaken by the SCP provide information on rates of fishing mortality which in turn has improved estimates of abundance.

5.2 Biomass estimates

The stock assessment results and conclusions of the six-region model show $B_{current}$ / B_{MSY} estimated at 1.25 in 2010. This estimate applies to the WCPO portion of the stock or an area that is approximately equivalent to the waters west of 150°W. Total biomass for the WCPO is estimated to have declined to about half of its initial level by about 1970 and has continued to decline since then.

5.3 Estimation of Maximum Constant Yield (MCY)

No estimates of MCY are available.

5.4 Estimation of Current Annual Yield (CAY)

No estimates of CAY are available.

5.5 Other yield estimates and stock assessment results

Though no reference points have yet been agreed by the WCPFC, stock status conclusions are generally presented in relation to two criteria. The first reference point relates to “overfished” which compares the current biomass level to that necessary to produce the maximum sustainable yield (MSY). The second relates to “over-fishing” which compares the current fishing mortality rate to that which would move the stock towards a biomass level necessary to produce the MSY. The first criteria is similar to that required under the New Zealand Fisheries Act while the second has no equivalent in our legislation and relates to how hard a stock can be fished.

Because recent catch data are often unavailable, these measures are calculated based on the average fishing mortality/biomass levels in the 'recent past', e.g., 2006-2009 for the 2011 assessment.

Recent catches (116 868 t in 2010) are well above the MSY level of 76 760 t, this is mostly due to a combination of above average recruitment and high fishing mortality. When MSY is re-calculated assuming recent recruitment levels, catches are still around 20% higher than the re-calculated MSY. The ratio of $F_{current}$ compared with F_{MSY} (the fishing mortality level that would keep the stock at MSY) is greater than 1.0 in all model runs indicating that current fishing mortality levels are high and there is a very high chance that $F_{current}$ is greater than F_{MSY} and that over-fishing is occurring.

5.6 Other factors

There are three areas of concern with the bigeye stock:

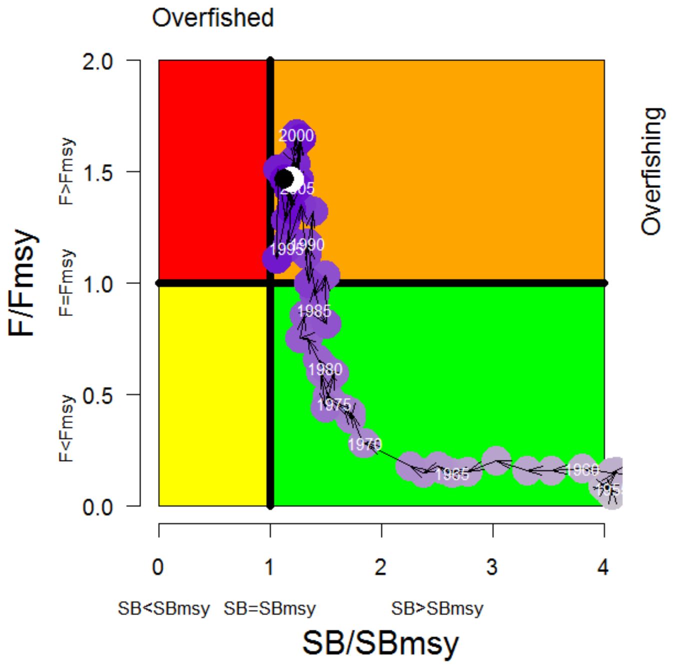
- juveniles occur in mixed schools with small yellowfin and also with skipjack tunas throughout the equatorial Pacific Ocean. As a result, they are vulnerable to large-scale purse seine fishing, particularly when fish aggregating devices (FADs) are set on. Catches of juveniles can be a very high proportion of total removals in numbers from the stock;
- the historic and continuing large catch of adults by the longline fishery that dramatically reduced the spawning stock over time. At present, there is uncertainty about some of the key data inputs to the assessment and as a result the true stock status could be better or worse than currently estimated; and
- several consecutive weak year classes have been observed in neighbouring 'stock' of bigeye tuna in the EPO leading to a dramatic decline in abundance. A similar decline in recruitment in the WCPO or a shift of effort from the EPO would increase the risk to the WCPO stock.

6. STATUS OF THE STOCKS

Stock structure assumptions

Western and Central Pacific Ocean
All estimates of biomass in this table refer to spawning biomass (SB)

Stock Status	
Year of Most Recent Assessment	A full stock assessment was conducted in 2011.
Assessment Runs Presented	Base case model only
Reference Points	Target: $SB > SB_{MSY}$ and $F < F_{MSY}$ Soft Limit: Not established by WCPFC; but evaluated using HSS default of 20% SB_0. Hard Limit: Not established by WCPFC; but evaluated using HSS default of 10% SB_0.
Status in relation to Target	About as Likely as Not (40- 60%) that $SB > SB_{MSY}$ and Very Likely (> 90%) that $F > F_{MSY}$
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Unlikely (< 40%) to be below

Historical Stock Status Trajectory and Current Status

Temporal trend in annual stock status, relative to *SB_{MSY}* (x-axis) and *F_{MSY}* (y-axis) reference points. The colour of the points is graduated from mauve (1972) to dark purple (2010). The black circle represents the B_{2010}/B_{MSY} and the F_{2010} / F_{MSY} the white circle represents the $B_{2006\text{-}2009}$ / B_{MSY} and $_{F2006\text{-}2009}$ / F_{MSY} (Davies *et al.*2011)

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass has decreased consistently since the 1950s to levels below SB_{MSY} in recent years. Total and spawning biomass for the WCPO are estimated to have declined to about half of their initials levels by about 1970, with total biomass remaining relatively constant since then ($B_{current}/B_0$ = 0.44) where “current” is the average over the period 2006-2009, while spawning biomass has continued to decline ($SB_{current}/SB_0$ = 0.35).
Recent Trend in Fishing Mortality or Proxy	Fishing mortality has generally increased and has recently escalated to levels near or above $F_{current}/F_{MSY}$ = 1.46.
Other Abundance Indices	
Trends in Other Relevant Indicator or Variables	Recruitment in all analyses is estimated to have been high during the last two decades. This result was similar to that of previous assessments, and appears to be partly driven by conflicts between some of the CPUE, catch, and size data inputs.

Projections and Prognosis	
Stock Projections or Prognosis	The bigeye stock status is concluded to not to be overfished but overfishing is taking place, under the current levels of effort the stock is expected to fall below B_{MSY} in the next few years.
Probability of Current Catch or TACC causing decline below limits	Soft Limit: Likely (> 60%) in the next five years Hard Limit: About as Likely as Not (40-60%) in the next five years

Assessment Methodology and Evaluation		
Assessment Type	Level 1- Quantitative Stock Assessment	
Assessment Method	The assessment uses the stock assessment model and computer software known as MULTIFAN-CL.	
Assessment Dates	Latest assessment: 2011	Next assessment: 2014
Overall assessment quality rank		
Main data inputs (rank)	- Catch and effort data; - Size data; - Growth data; and tagging data.	1 - High Quality
Data not used (rank)		
Changes to Model Structure and Assumptions	Changes to the data from the 2010 assessment included: • tagging data from the 2007-2010 Pacific tuna tagging programme (PTTP); • standardised CPUE time series derived from operational-level catch-effort data for Japanese longline fisheries; • weighting the Japanese longline size frequency data according to the estimated population relative abundance within regions; • adjusting purse seine size frequency data using spill-samples to correct for grab-sample bias; and • including more reliable size composition data for Philippines and Indonesian domestic purse seine catches in offshore waters. The main developments to model structural assumptions were to define a separate Indonesian Philippines-based domestic purse seine fishery that operates beyond the national archipelagic waters and to the east of 125° E longitude.	
Major Sources of Uncertainty	Catch estimated from the most recent years is uncertain as some catch has still not been reported. There are high levels of uncertainty regarding the recruitment estimates and the resulting estimates of steepness.	

Qualifying Comments
-

Fishery Interactions
Interactions with protected species are known to occur in the longline fisheries of the South Pacific, particularly south of 25°S. Seabird bycatch mitigation measures are required in the New Zealand and Australian EEZs and through the WCPFC Conservation and Management Measure CMM2007-04. Sea turtles also get incidentally captured in longline gear; the WCPFC is attempting to reduce sea turtle interactions through Conservation and Management Measure CMM2008-03. Shark bycatch is common in longline fisheries and largely unavoidable; this is being managed through New Zealand domestic legislation and to a limited extent through Conservation and Management Measure CMM2010-07.

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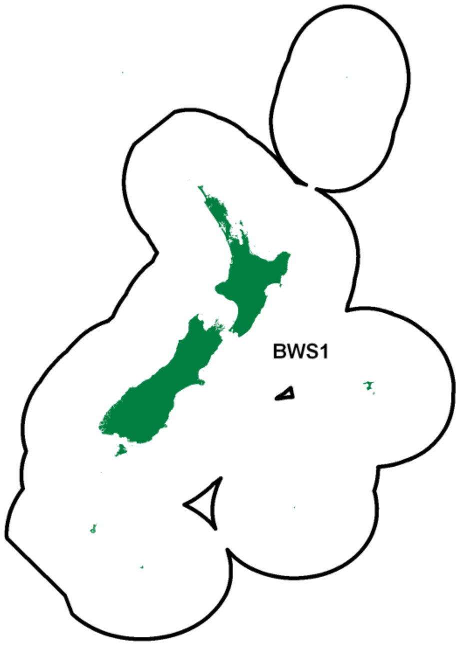
BLUE SHARK (BWS)

(*Prionace glauca*)



1. FISHERY SUMMARY

Blue shark was introduced into the QMS on 1 October 2004 under a single QMA, BWS 1, with allowances, TACC, and TAC in Table 1.

Table 1: Recreational and Customary non-commercial allowances, other mortalities, TACCS and TACs (all in tonnes) for blue shark.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other mortality	TACC	TAC
BWS 1	20	10	190	1 860	2 080

Blue shark was added to the Third Schedule of the 1996 Fisheries Act with a TAC set under s14 because blue shark is a highly migratory species and it is not possible to estimate MSY for the part of the stock that is found within New Zealand fisheries waters.

Blue shark was also added to the Sixth Schedule of the 1996 Fisheries Act with the provision that:

> "A commercial fisher may return any blue shark to the waters from which it was taken from if –
>
> (a) that blue shark is likely to survive on return; and
>
> (b) the return takes place as soon as practicable after the blue shark is taken."

Management of blue sharks throughout the western and central Pacific Ocean (WCPO) is the responsibility of the Western and Central Pacific Fisheries Commission (WCPFC). Under this regional convention New Zealand is responsible for ensuring that the management measures applied within New Zealand fisheries waters are compatible with those of the Commission.

1.1 Commercial fisheries

Most of the blue shark catch in the New Zealand EEZ is caught in the tuna surface longline fishery. Relatively little blue shark is caught by other methods. Data collected by the Ministry for

Primary Industries (MPI) Fishery Observer Services from the tuna longline fishery suggest that most of the blue shark catch is processed (72% of the observed catch), although usually only the fins are retained and the rest of the carcass is dumped (> 99% of the processed, observed catch). Greenweight (total weight) is obtained by applying species specific conversion factors to the weight of the fins landed. Figure 1 shows historical landings and fishing effort for BWS1 and BWSET.

Landings of blue sharks reported on Catch Effort Landing Returns (CELRs), Catch Landing Returns (CLRs), and Licensed Fish Receiver Returns (LFRRs) are given in Table 2. Total weights reported by fishers (CELR and CLRs) were 551–1167 t per annum during 1997–98 to 2008–09. Processors (LFRRs) reported 525–1415 t per annum during the same period. Estimated catches in the tuna longline fishery calculated by scaling-up observed catches to the entire fleet are considerably higher than reported landings in all fishing years for which these estimates are available. However, these estimates are imprecise and probably biased, as MPI observer coverage of the domestic fleet (which accounts for most of the fishing effort) has been low (just below 10% in the last years 2007-2011).

In addition to catches within New Zealand fisheries waters, small catches are taken by New Zealand vessels operating on the high seas (Figure 1).

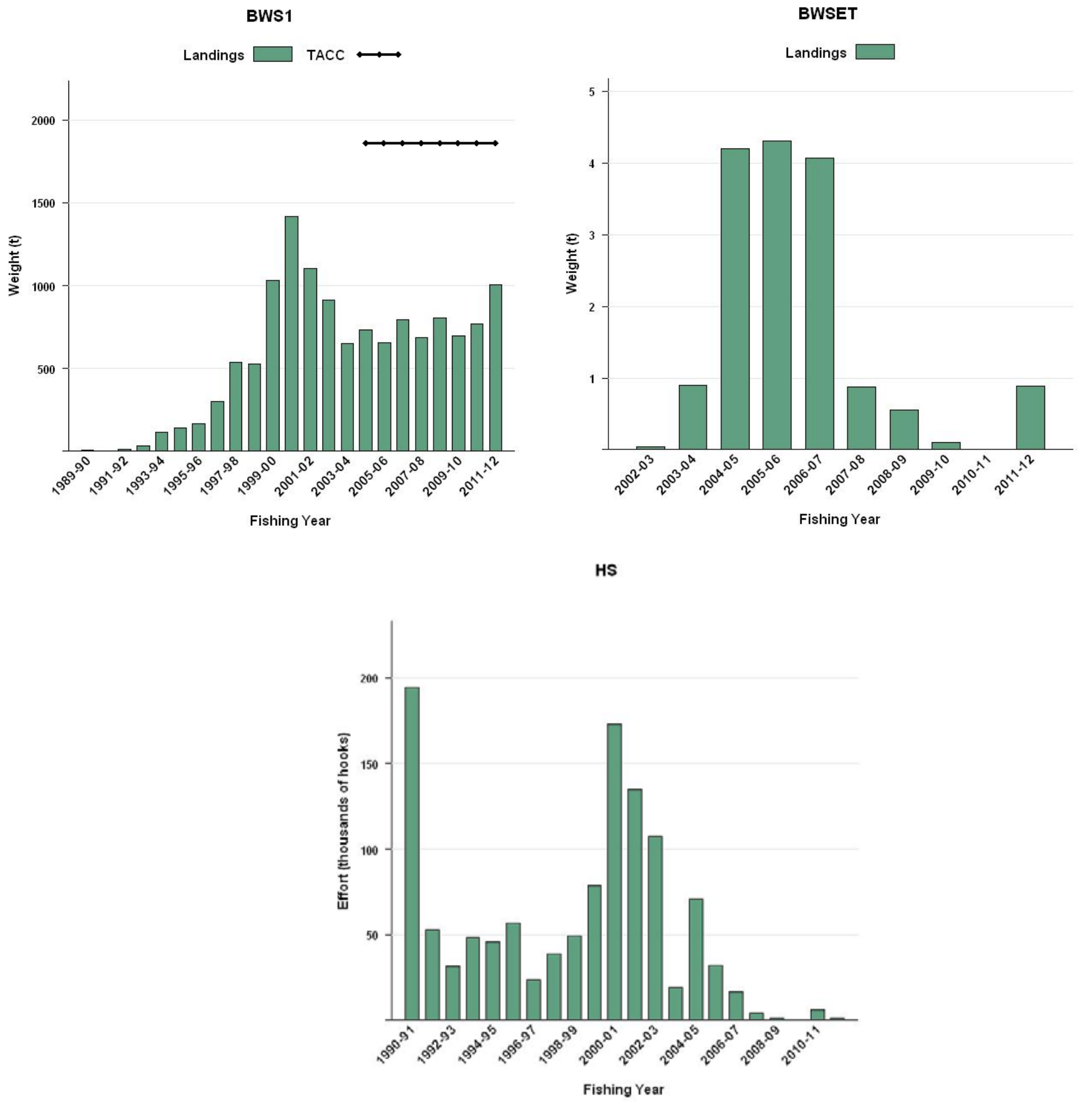


Figure 1: [Top] Blue Shark catch from 1989-90 to 2011-12 within NZ waters (BWS1), and 2002-03 to 2011-12 on the high seas (BWSET). [Bottom] Fishing effort (number of hooks set) for high seas New Zealand flagged surface longline vessels, from 1990-91 to 2011-12.

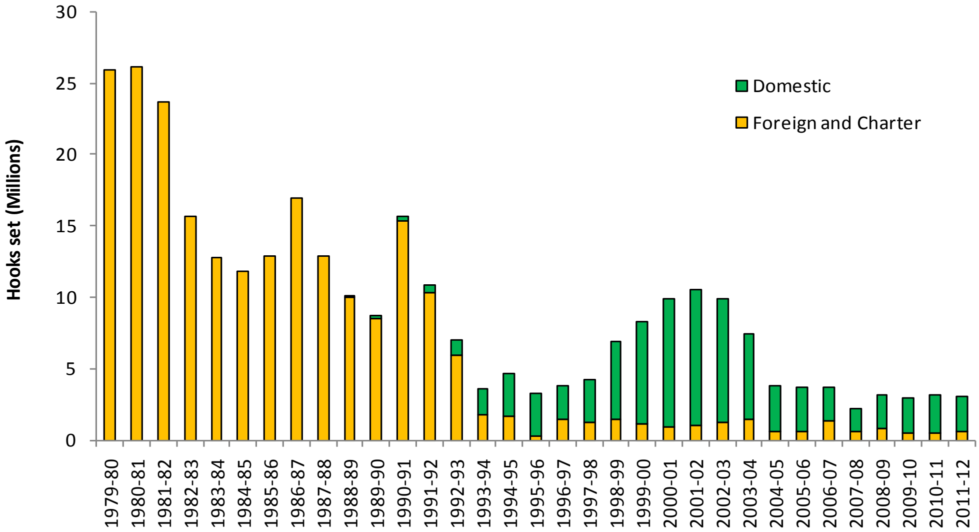


Figure 1 [Continued]: Fishing effort (number of hooks set) for all domestic vessels (including effort by foreign vessels chartered by NZ fishing companies), from 1988-89 to 2011-12.

The majority of blue sharks (60%) are caught in the bigeye tuna fishery (Figure 2), however, across all longline fisheries albacore make up the bulk of the catch (33%) (Figure 3). Longline fishing effort is distributed along the east coast of the North Island and the south west coast of the South Island. The west coast South Island fishery predominantly targets southern bluefin tuna, whereas the east coast of the North Island targets a range of species including bigeye, swordfish, and southern bluefin tuna (figure 4).

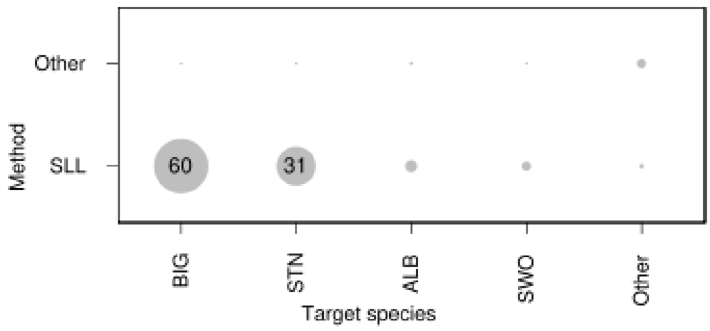


Figure 2: A summary of the proportion of landings of blue shark taken by each target fishery and fishing method. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the bobble is the percentage. SLL = surface longline (Bentley *et al.* 2012).

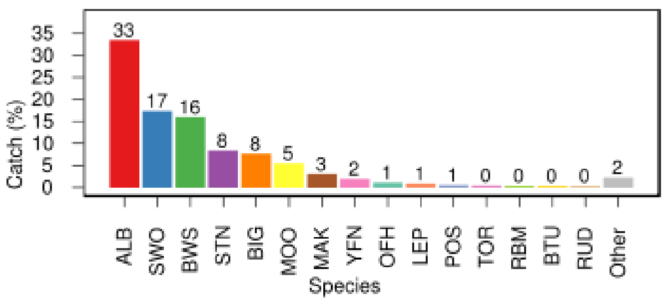


Figure 3: A summary of species composition of the reported surface longline catch. The percentage by weight of each species is calculated for all surface longline trips (Bentley *et al.* 2012).

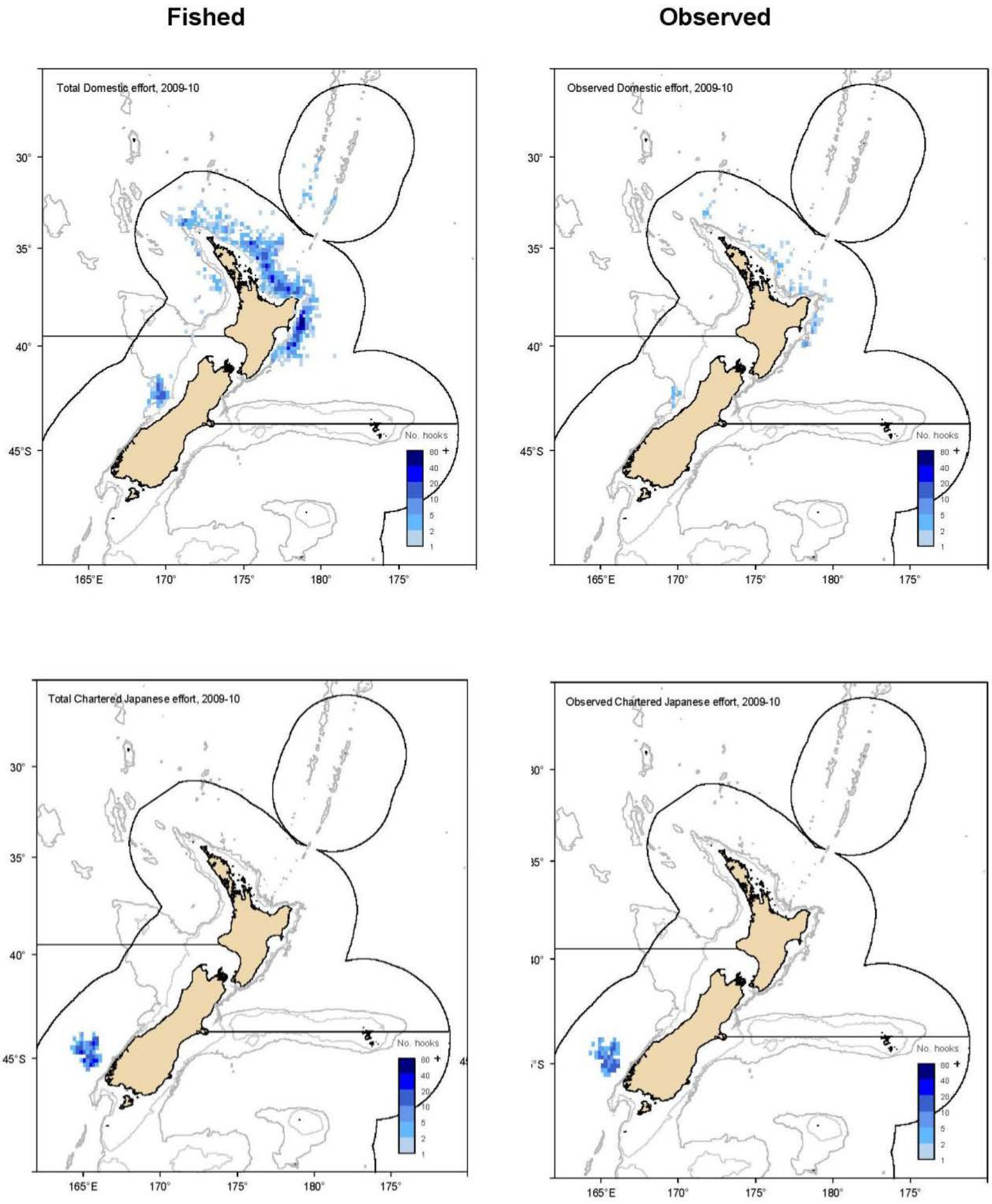


Figure 4: Distribution of fishing positions for domestic (top two panels) and charter (bottom two panels) vessels, for the 2009-10 fishing year, displaying both fishing effort (left) and observer effort (right).

Table 2: New Zealand estimated commercial landings (t) reported by fishers (CELRs and CLRs) and processors (LFRRs) by fishing year. Also shown for some years are the estimated numbers of blue sharks caught by tuna longliners, as reported to WCPFC (2008).

Year	Total reported	LFRR/MHR	Estimated catch by tuna longliners
1989–90	12	5	
1990–91	2	3	
1991–92	18	13	
1992–93	39	33	
1993–94	371	118	
1994–95	254	140	
1995–96	152	166	
1996–97	161	303	
1997–98	551	537	
1998–99	576	525	
1999–00	641	1 031	
2000–01	1 167	1 415	
2001–02	1 076	1 105	
2002-03*	968	914	
2003-04*	649	649	
2004-05*	734	734	
2005-06*	656	656	98 912
2006-07*	790	794	53 297
2007-08*	681	687	
2008-09*		804	
2009-10*		696	
2010-11*		770	
2011-12*		1 006	

[1] Note that there may be some misreporting of blue shark catches (MPI species code "BWS") as bluenose (*Hyperoglyphe antarctica*; MPI species code "BNS") and vice versa. *MHR rather than LFRR data.

Table 3: Percentage of blue shark (including discards) that were alive or dead when arriving at the longline vessel and observed during 2006–07 to 2009–10, by fishing year, fleet and region. Small sample sizes (number observed < 20) were omitted Griggs and Baird (in press).

Year	Fleet	Area	% alive	% dead	Number
2006-07	Australia	North	95.4	4.6	131
	Charter	North	89.8	10.2	2 155
		South	93.4	6.6	5 025
	Domestic	North	87.9	12.1	3 991
	Total		**90.8**	**9.2**	**11 302**
2007-08	Charter	South	89.2	10.8	2 560
	Domestic	North	88.6	11.4	5 599
	Total		**88.8**	**11.2**	**8 159**
2008-09	Charter	North	94.5	5.5	1 317
		South	95.1	4.9	4 313
	Domestic	North	92.0	8.0	3 935
		South	94.9	5.1	98
	Total		**93.7**	**6.3**	**9 663**
2009-10	Charter	South	95.6	4.4	2 004
	Domestic	North	85.7	14.3	2 853
		South	94.0	6.0	882
	Total		**90.5**	**9.5**	**5 739**
Total all strata			**91.1**	**8.9**	**34 863**

In the longline fishery most of the blue sharks were alive when brought to the side of the vessel for all fleets (90%) (Table 3). The domestic fleets retain around 30-50% of their blue shark catch, mostly for the fins, while the foreign charter fleet retain most of the blue sharks (85-95%) (mostly for fins), the Australian fleet that fished in New Zealand waters in 2006-07 discarded most (97%) of their blue sharks (Table 4).

Table 4: Percentage of blue shark that were retained, or discarded or lost, when observed on a longline vessel during 2006–07 to 2009–10, by fishing year and fleet. Small sample sizes (number observed < 20) omitted Griggs and Baird (in press).

Year	Fleet	% retained or finned	% discarded or lost	Number
2006-07	Australia	3.0	97.0	132
	Charter	85.1	14.9	8 272
	Domestic	33.2	66.8	3 994
	Total	**67.5**	**32.5**	**12 398**
2007-08	Charter	91.8	8.2	2 638
	Domestic	59.5	40.5	5 650
	Total	**69.8**	**30.2**	**8 288**
2008-09	Charter	87.5	12.5	5 723
	Domestic	54.0	46.0	4 049
	Total	**73.6**	**26.4**	**9 772**
2009-10	Charter	91.7	8.3	2 023
	Domestic	37.6	62.4	5 531
	Total	**52.1**	**47.9**	**7 554**
Total all strata		**66.5**	**33.5**	**38 012**

Catches of blue sharks observed by the MPI Observer Services aboard tuna longline vessels are concentrated off the west and south-west coasts of the South Island, and the north-east coast of the North Island, extending northwards to the Kermadec Islands. However, these apparent distributions are biased by the spatial distribution of MPI Observer Services coverage; blue sharks are probably caught by tuna longline vessels throughout most of the New Zealand EEZ. Most of the blue shark landings reported by fishers (CELR and CLR forms) are concentrated in FMAs 1 & 2.

1.2 Recreational fisheries

Blue sharks are caught in relatively large numbers by recreational fishers in the NZ EEZ. Although not as highly regarded as other large, pelagic sharks such as mako in northern New Zealand, blue sharks are the primary target gamefish in southern New Zealand. Several hundred blue sharks were tagged and released each year by the New Zealand Gamefish Tagging Programme, an ongoing tag and release programme that operates in New Zealand’s recreational gamefish fisheries. About 100 blue sharks have been tagged per year for the last 9 years. The total recreational catch is unknown but most are released.

1.3 Customary non-commercial fisheries

Prior to European settlement, Maori caught large numbers of cartilaginous fishes, including blue sharks. However, there are no estimates of current Maori customary catch.

1.4 Illegal catch
There is no known illegal catch of blue sharks.

1.5 Other sources of mortality
About 90% of all observed blue sharks caught in the tuna longline fishery are retrieved alive. About 53% of all observed blue sharks are discarded. The proportion of sharks discarded dead is unknown. Mortality rates of blue sharks tagged and released by the New Zealand Gamefish Tagging Programme are also unknown.

2. BIOLOGY

Blue sharks (*Prionace glauca*) are large, highly migratory, pelagic carcharhinids found throughout the world's oceans in all tropical and temperate waters from about 50° N to 50° S. They are slender in build, rarely exceeding 3 m in total length and 200 kg in weight. They feed opportunistically on a range of living and dead prey, including bony fishes, smaller sharks, squid and carrion.

In New Zealand waters, male blue sharks are sexually mature at about 190–195 cm fork length (FL) and females at about 170–190 cm FL. Gestation in female blue sharks lasts between 9–12 months and between 4–135 pups (averaging 26–56) are born alive, probably during the spring. Pups are probably born at about 50 cm FL. The few embryos from New Zealand fisheries waters examined to date consisted of mid-term pups 21–37 cm FL collected in July and a full-term pup 54 cm FL collected in February. Blue sharks 50–70 cm FL are caught year-round in New Zealand fisheries waters but only in small numbers.

Age and growth estimates are available for blue sharks in New Zealand waters. These estimates were derived from counts of opaque growth zones in X-radiographs of sectioned vertebrae with the assumption that one opaque zone is formed per year. This assumption is untested. Female blue sharks appear to approach a lower mean asymptotic maximum length and grow at a faster rate than males. This differs from the age and growth analyses of blue shark from other oceans, where females typically approach a larger mean asymptotic maximum length than males. This is thought to result from the presence of relatively few large (> 250 cm FL), old female blue sharks in the length-at-age dataset analysed.

Table 5: Estimates of biological parameters.

Fishstock	Estimate					Source
1. Natural mortality (M)						
BWS 1	0.19–0.21					Manning & Francis (2005)
2. Weight = a (length)^{b} (Weight in kg, length in cm fork length)						
		a	b			
BWS 1 males		1.578×10^{-6}	3.282			Ayers *et al.*(2004)
BWS 1 females		6.368×10^{-7}	3.485			
3. Von Bertalanffy model parameter estimates						
	k	t_0	L_∞			
BWS 1 males	0.0668	-1.7185	390.92			Manning & Francis (2005)
BWS 1 females	0.1106	-1.2427	282.76			
4. Schnute model (case 1) parameter estimates (are provided for comparison with the von Bertalanffy estimates above)						
	L_1	L_2	κ	γ	L_∞	
BWS 1 males	65.21	217.48	0.1650	0.1632	297.18	Manning & Francis (2005)
BWS 1 females	63.50	200.60	0.2297	0.0775	235.05	

The MPI observer data suggest that large (> 250 cm FL) female blue sharks are missing from the catch, despite reliable personal observations to the contrary from commercial and recreational fishers. There is evidence of size and sex segregation in the distributions of blue sharks in the

North Pacific, with large, pregnant females tending to be found nearer the equator than males or smaller females. It is possible that large female blue sharks occur in New Zealand but have not been adequately sampled by observers.

Growth rates estimated for New Zealand blue sharks are broadly comparable with overseas studies. Males and females appear to grow at similar rates until about seven years of age, when their growth appears to diverge. Age-at-maturity is estimated at 8 years for males and 7-9 years for females. The maximum recorded ages of male and female blue sharks in New Zealand waters are 22 and 19 years, respectively. Blue sharks appear to be fully recruited to the commercial longline fishery by the end of their second year. The commercial catch sampled by the MPI observers consists of both immature and mature fish.

Estimates of biological parameters for blue sharks in New Zealand waters are given in Table 5.

3. STOCKS AND AREAS

The New Zealand Gamefish Tagging Programme has tagged and released 4394 blue sharks between 1979-80 and 2011-12 in the New Zealand EEZ. Most tagged sharks were captured and released off the east coast of the South Island. A total of 81 tagged sharks have been recaptured since the start of the tagging programme. The recapture data show dispersal of tagged sharks away from their release point, although the relationship between time at liberty and dispersal is unclear. While some tagged sharks have been recaptured with little apparent movement away from their release point, others have been recaptured off Australia, Fiji, and French Polynesia. The longest movement recorded from a blue shark released in New Zealand was from a fish recaptured off Chile.

Although the data are relatively sparse, an overview of tagging data from Australia, New Zealand, the Central Pacific and California suggest population exchange between not only the eastern and western South Pacific, but also between the South Pacific, south Indian, and even South Atlantic oceans. This suggests that blue sharks in the South Pacific constitute a single biological stock, although whether this is part of a single larger Southern Hemisphere stock is unclear.

No other data are available on blue shark stock structure in the South Pacific.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the November 2012 Fishery Assessment Plenary after review by the Aquatic Environment Working Group. This summary is from the perspective of blue shark but there is no directed fishery for them and the incidental catch sections below reflect the New Zealand longline fishery as a whole and are not specific to this species; a more detailed summary from an issue-by-issue perspective is, or will shortly be, available in the Aquatic Environment & Biodiversity Annual Review where the consequences are also discussed.
(http://www.mpi.govt.nz/news-resources/publications.aspx).

4.1 Role in the ecosystem

Blue shark (*Prionace glauca*) are active pelagic predators of bony fishes and squid. Small blue sharks (<1m) feed predominantly on squid but switch to a diet dominated by fish as they grow (Figure 5) (Giggs *et al.*2007).

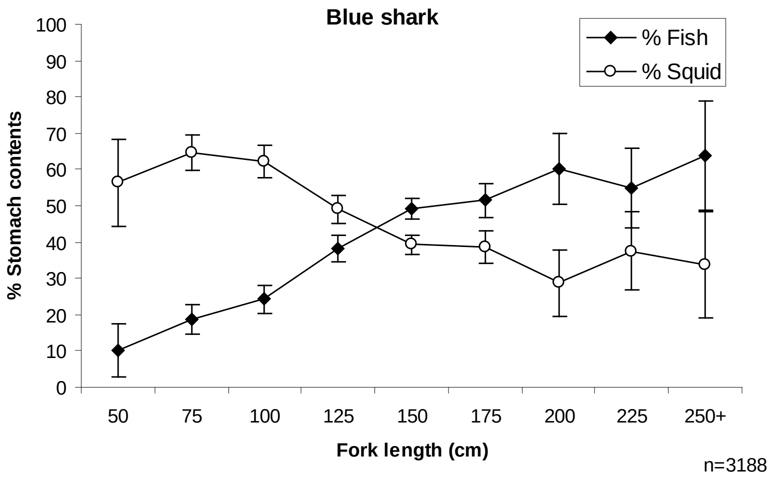


Figure 5: Change in percentage of fish and squid in stomachs of blue shark.

4.2 Incidental catch (seabirds, sea turtles and mammals)

The protected species, capture estimates presented here include all animals recovered onto the deck (alive, injured or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds caught on a hook but not brought onboard the vessel).

4.2.1 Seabird bycatch

Between 2002–03 and 2010–11, there were 731 observed captures of birds across all surface longline fisheries. Seabird capture rates since 2003 are presented in Figure 6. While the seabird capture distributions largely coincide with fishing effort that are more frequent off the south west coast of the South Island (Figure 7). The analytical methods used to estimate capture numbers across the commercial fisheries have depended on the quantity and quality of the data, in terms of the numbers observed captured and the representativeness of the observer coverage. Ratio estimation was historically used to calculate total captures in longline fisheries by target fishery fleet and area (Baird 2008) and by all fishing methods but recent estimates are either ratio or model based as specified in the tables below (Abraham *et al.*2010a).

Through the 1990s the minimum seabird mitigation requirement for surface longline vessels was the use of a bird scaring device (tori line) but common practice was that vessels set surface longlines primarily at night. In 2007 a notice was implemented under s 11 of the Fisheries Act 1996 to formalise the requirement that surface longline vessels only set during the hours of darkness and use a tori line when setting. This notice was amended in 2008 to add the option of line weighting and tori line use if setting during the day. In 2011 notices were combined and repromulgated under a new regulation (Regulation 58A of the Fisheries (Commercial Fishing) Regulations 2001) which provides a more flexible regulatory environment under which to set seabird mitigation requirements.

Table 5: Number of observed seabird captures in surface longline fisheries, 2002-03 to 2010-11, by species and area (Thompson & Abraham (2012) from http://data.dragonfly.co.nz/psc/). See glossary above for areas used for summarising the fishing effort and protected species captures. 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 blue shark using longline gear but rather the total risk for each seabird species.

Species	Risk ratio	Kermadec Islands	Northland and Hauraki	Bay of Plenty	East Coast North Island	Stewart Snares Shelf	Fiordland	West Coast South Island	West Coast North Island	Total
Salvin's albatross	2.49	0	1	1	6	0	0	0	0	8
Northern royal albatross	2.21	0	0	1	0	0	0	0	0	1
Light-mantled sooty albatross	2.18	0	0	0	0	0	0	1	0	1
Campbell albatross	1.84	0	8	0	26	0	3	3	0	40
Southern Buller's albatross	1.28	0	3	1	26	0	251	31	0	312
Gibson's albatross	1.25	4	10	0	11	0	3	1	1	30
Antipodean albatross	1.11	12	9	1	7	0	0	0	1	30
White capped albatross	0.83	0	1	0	3	10	54	25	0	93
Southern royal albatross	0.74	0	0	0	0	0	4	0	0	4
Black browed albatrosses	-	2	1	0	0	0	0	0	1	4
Pacific albatross	-	0	0	0	1	0	0	0	0	1
Southern black-browed albatross	-	0	0	0	2	0	0	0	0	2
Wandering albatross	-	0	2	0	6	0	3	0	0	11
Antipodean and Gibson's albatrosses	N/A	5	2	0	0	0	0	0	0	7
Unidentified albatross	N/A	33	0	0	1	0	0	0	1	35
Total albatrosses	**N/A**	**56**	**37**	**4**	**89**	**10**	**318**	**61**	**4**	**579**
Black petrel	11.15	1	9	1	0	0	0	0	1	12
Westland petrel	3.31	0	0	0	2	0	1	5	0	8
Flesh footed shearwater	2.51	0	0	0	10	0	0	0	2	12
White chinned petrel	0.79	2	2	3	3	1	19	0	3	33
Cape petrels	0.76	0	0	0	2	0	0	0	0	2
Grey petrel	0.39	3	3	2	38	0	0	0	0	46
Sooty shearwater	0.02	1	0	0	8	3	1	0	0	13
Great winged petrel	0.01	12	5	1	2	0	0	0	0	20
White headed petrel	0.01	2	0	0	0	0	0	0	0	2
Pterodroma petrels	-	0	1	0	0	0	0	0	0	1
Southern giant petrel	-	0	0	0	2	0	0	0	0	2
Unidentified seabird	N/A	0	0	0	0	0	1	0	0	1
Total other birds	**N/A**	**21**	**20**	**7**	**67**	**4**	**22**	**5**	**6**	**152**

Table 6: Effort, observed and estimated seabird captures by fishing year for the surface longline fishery within the EEZ. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); the capture rate (captures per thousand hooks); and the mean number of estimated total captures (with 95% confidence interval). The estimation method used was a Bayesian model with 100% of hooks included in the estimate. For more information on the methods used to prepare the data see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures		Estimated captures	
	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002-2003	10 764 588	2 195 152	20.4	115	0.052	2490	1817-3461
2003-2004	7 380 779	1 607 304	21.8	71	0.044	1665	1259-2220
2004-2005	3 676 365	783 812	21.3	41	0.052	687	507-936
2005-2006	3 687 339	705 945	19.1	37	0.052	816	607-1120
2006-2007	3 738 362	1 040 948	27.8	187	0.18	949	725-1304
2007-2008	2 244 339	426 310	19	41	0.096	521	408-681
2008-2009	3 115 633	937 233	30.1	57	0.061	721	562-934
2009-2010	2 992 285	665 883	22.3	149	0.224	1014	777-1345
2010-2011	3 164 159	674 522	21.3	47	0.07	824	607-1152

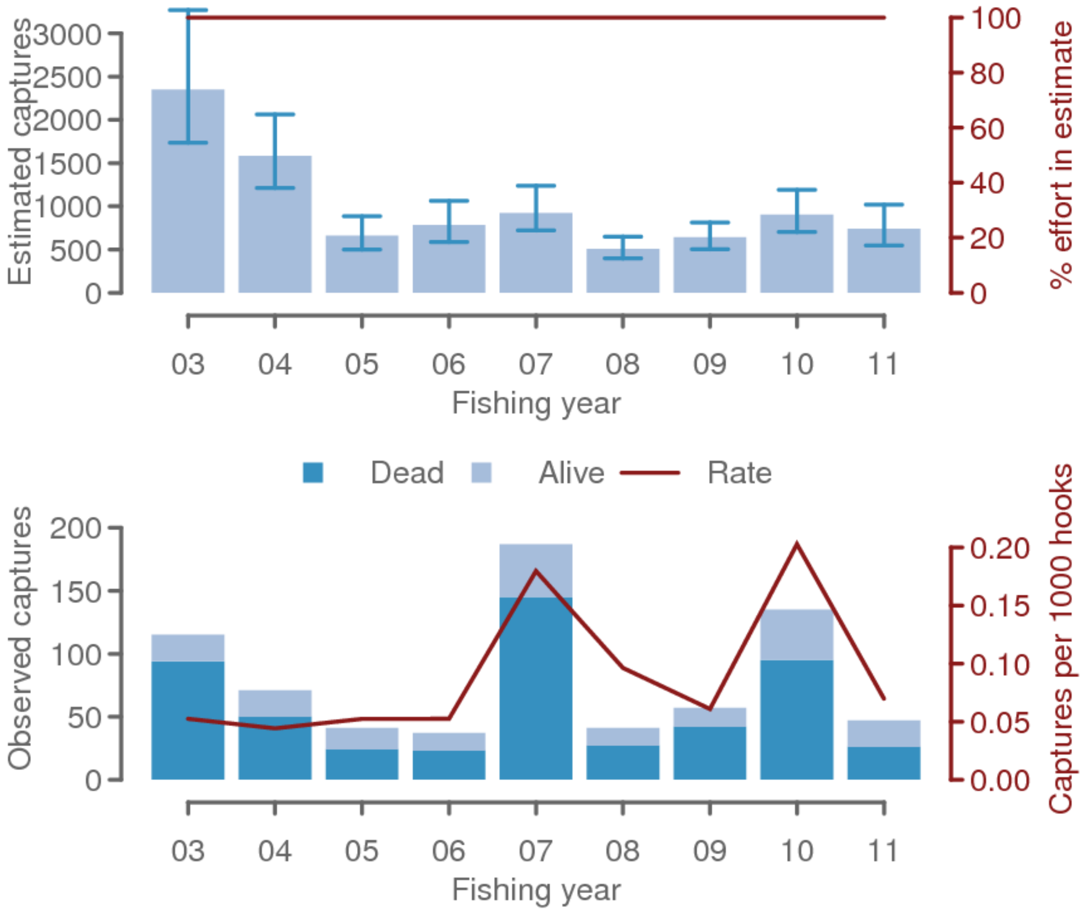


Figure 6: Observed and estimated captures of seabirds in surface longline fisheries from 2003 to 2011.

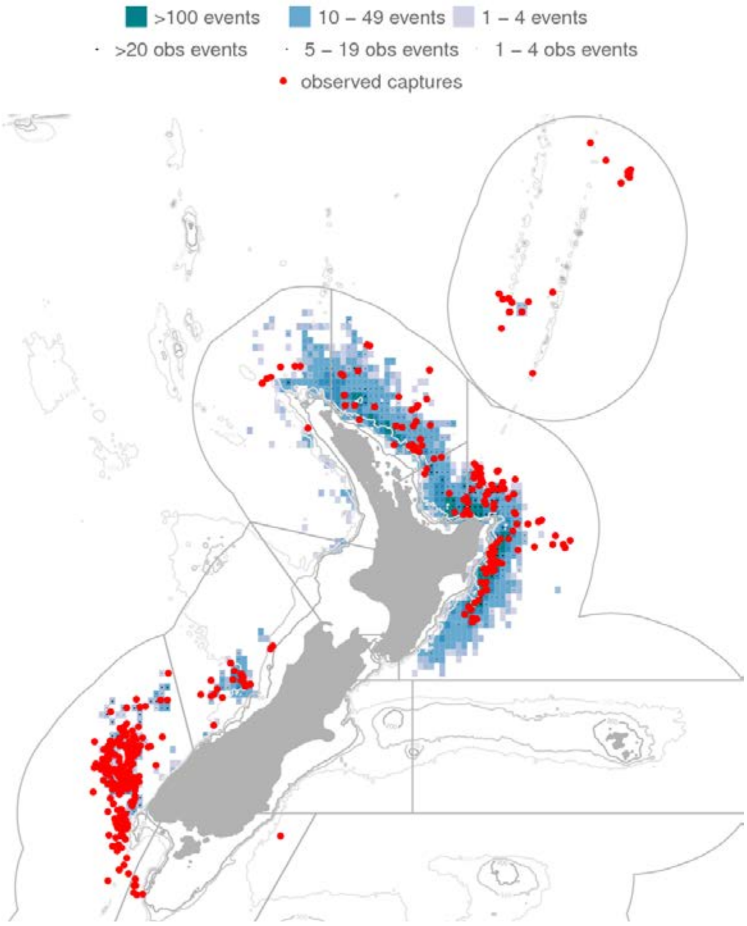


Figure 7: Distribution of fishing effort in surface longline fisheries and observed seabird captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.2 Sea turtle bycatch

Between 2002–03 and 2010–11, there were 13 observed captures of sea turtles across all surface longline fisheries (Tables 7 and 8, Figure 8). Observer records documented all but one sea turtle as captured and released alive. Sea turtle capture distributions predominantly occur throughout the east coast of the North Island and Kermadec Island fisheries (Figure 9).

Table 7: Number of observed sea turtle captures in surface longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson and Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/.

Species	Bay of Plenty	East Coast North Island	Kermadec Islands	West Coast North Island	Total
Leatherback turtle	1	4	3	3	11
Olive ridley turtle	0	1	0	0	1
Unknown turtle	0	1	0	0	1
Total	**1**	**6**	**3**	**3**	**13**

Table 8: Effort and sea turtle captures in surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	10 764 588	2 195 152	20.4	0	0
2003-2004	7 380 779	1 607 304	21.8	1	0.001
2004-2005	3 676 365	783 812	21.3	2	0.003
2005-2006	3 687 339	705 945	19.1	1	0.001
2006-2007	3 738 362	1 040 948	27.8	2	0.002
2007-2008	2 244 339	426 310	19.0	1	0.002
2008-2009	3 115 633	937 233	30.1	2	0.002
2009-2010	2 992 285	665 883	22.3	0	0
2010-2011	3 164 159	674 522	21.3	4	0.006

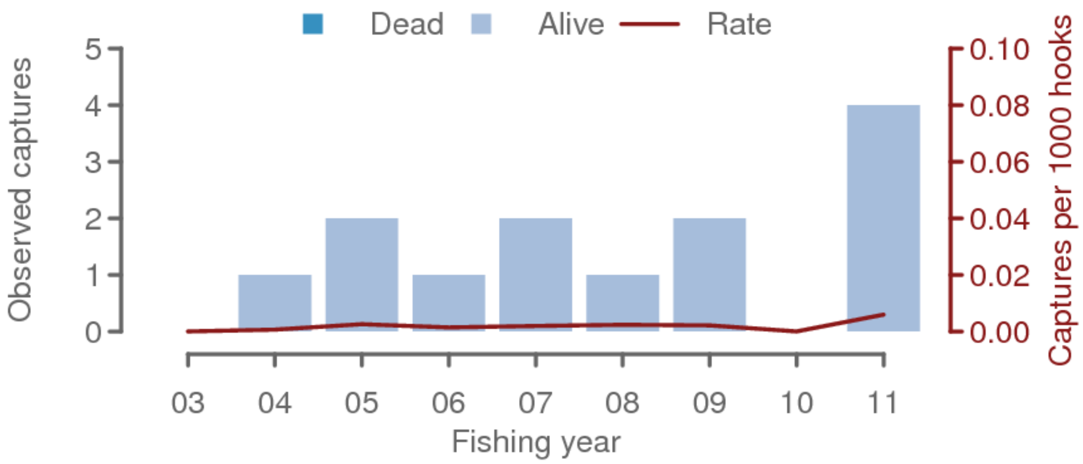


Figure 8: Observed captures of sea turtles in surface longline fisheries from 2003 to 2011.

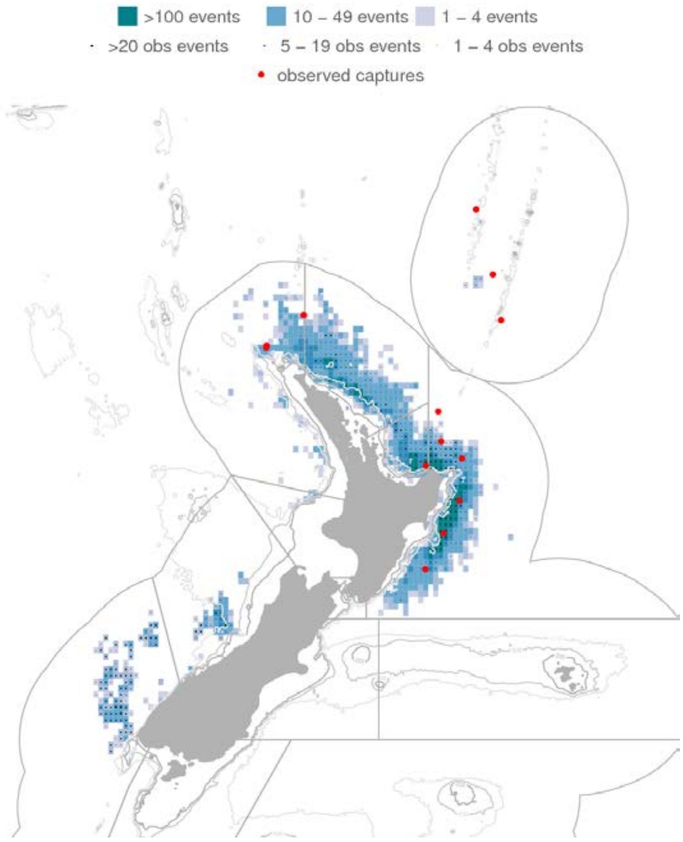


Figure 9: Distribution of fishing effort in surface longline fisheries and observed sea turtle captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3 Marine Mammals

4.2.3.1 Cetaceans

Cetaceans are dispersed throughout New Zealand waters (Perrin *et al.*2008). The spatial and temporal overlap of commercial fishing grounds and cetacean foraging areas has resulted in cetacean captures in fishing gear (Abraham and Thompson 2009, 2011).

Between 2002–03 and 2010–11, there were seven observed captures of whales and dolphins in surface longline fisheries. Observed captures included 5 unidentified cetaceans and 2 long-finned Pilot whales (Tables 9 and 10, Figure 10) (Abraham and Thompson 2011). All captured animals recorded were documented as being caught and released alive (Thompson and Abraham 2010)(Figure 10). Cetacean capture distributions are more frequent off the east coast of the North Island (Figure 11).

Table 9: Number of observed cetacean captures in surface longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson and Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/.

Species	Bay of Plenty	East Coast North Island	Fiordland	Northland and Hauraki	West Coast North Island	West Coast South Island	Total
Long-finned pilot whale	0	1	0	0	0	1	2
Unidentified cetacean	1	1	1	1	1	0	5
Total	**1**	**2**	**1**	**1**	**1**	**1**	**7**

Table 10: Effort and captures of cetaceans in surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	10 764 588	2 195 152	20.4	1	0.0005
2003-2004	7 380 779	1 607 304	21.8	4	0.002
2004-2005	3 676 365	783 812	21.3	1	0.001
2005-2006	3 687 339	705 945	19.1	0	0
2006-2007	3 738 362	1 040 948	27.8	0	0
2007-2008	2 244 339	426 310	19.0	1	0.002
2008-2009	3 115 633	937 233	30.1	0	0
2009-2010	2 992 285	665 883	22.3	0	0
2010-2011	3 164 159	674 522	21.3	0	0

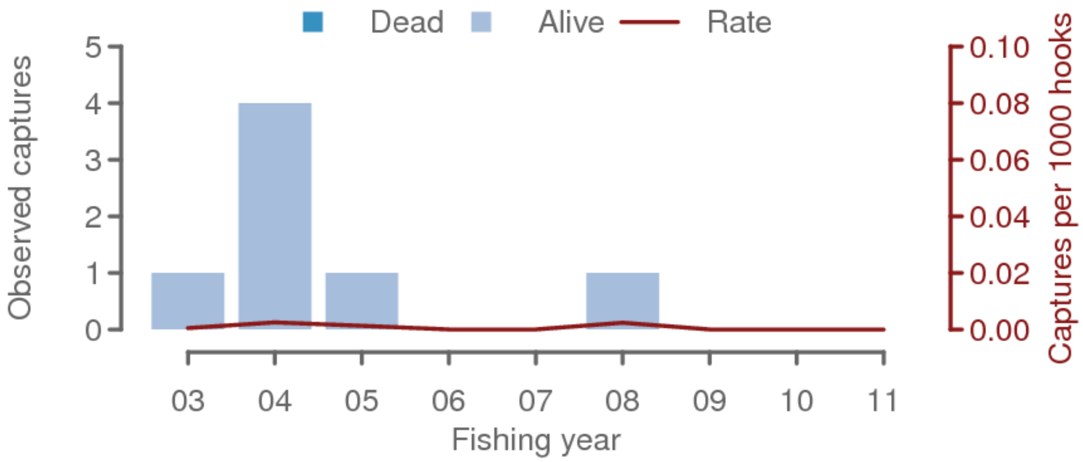


Figure 10: Observed captures of cetaceans in surface longline fisheries from 2003 to 2011.

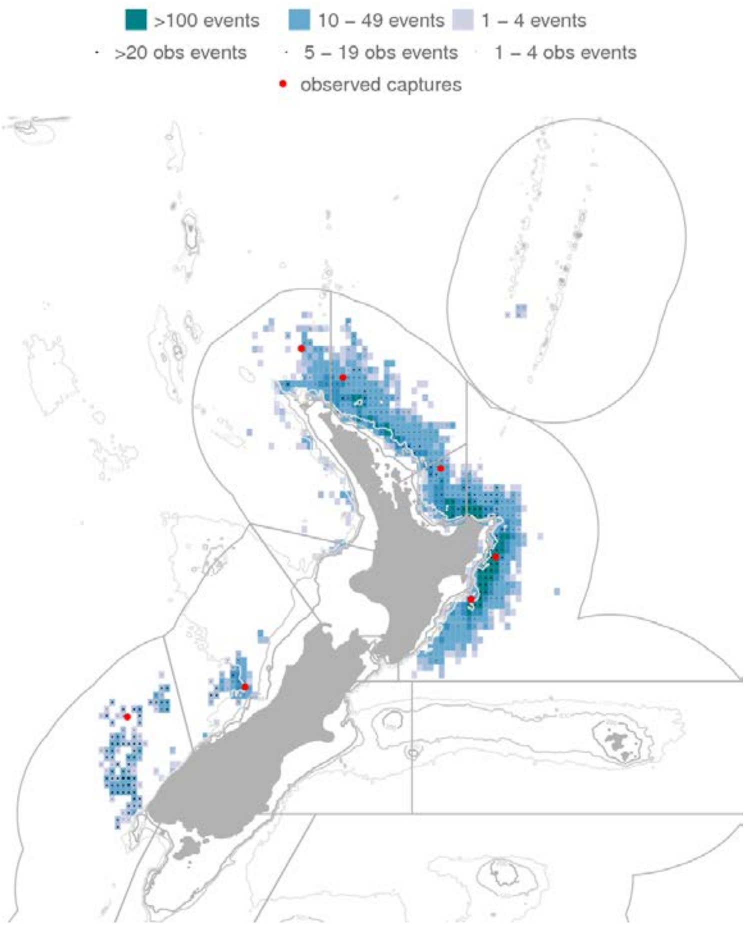


Figure 11: Distribution of fishing effort in surface longline fisheries and observed cetacean captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3.2 New Zealand fur seal bycatch

Currently, New Zealand fur seals are dispersed throughout New Zealand waters, especially in waters south of about 40º S to Macquarie Island. The spatial and temporal overlap of commercial fishing grounds and New Zealand fur seal foraging areas has resulted in New Zealand fur seal captures in fishing gear (Mattlin 1987, Rowe 2009). Most fisheries with observed captures occur in waters over or close to the continental shelf, which around much of the South Island and offshore islands slopes steeply to deeper waters relatively close to shore, and thus rookeries and haulouts. Captures on longlines occur when the seals attempt to feed on the fish and bait catch during hauling. Most New Zealand fur seals are released alive, typically with a hook and short snood or trace still attached.

New Zealand fur seal captures in surface longline fisheries have been generally observed in waters south and west of Fiordland, but also in the Bay of Plenty-East Cape area when the animals have attempted to take bait or fish from the line as it is hauled. These capture rates include animals that are released alive (100% of observed surface longline capture in 2008-09; Thompson and Abraham 2010). Bycatch rates in 2010-11 are low and lower than they were in the early 2000s (Figure 12). While fur seal captures have occurred throughout the range of this fishery most New Zealand captures have occurred off the Southwest coast of the South Island (Figure 13). Between 2002–03 and 2010–11, there were 206 observed captures of New Zealand fur seal in surface longline fisheries (Tables 11 and 12).

Table 11: Number of observed New Zealand fur seal captures in surface longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson and Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/.

	Bay of Plenty	East Coast North Island	Fiordland	Northland and Hauraki	Stewart Snares Shelf	West Coast North Island	West Coast South Island	Total
New Zealand fur seal	10	16	139	3	4	2	32	206

Table 12: Effort and captures of New Zealand fur seal in surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	10 764 588	2 195 152	20.4	56	0.026
2003-2004	7 380 779	1 607 304	21.8	40	0.025
2004-2005	3 676 365	783 812	21.3	20	0.026
2005-2006	3 687 339	705 945	19.1	12	0.017
2006-2007	3 738 362	1 040 948	27.8	10	0.010
2007-2008	2 244 339	426 310	19.0	10	0.023
2008-2009	3 115 633	937 233	30.1	22	0.023
2009-2010	2 992 285	665 883	22.3	19	0.029
2010-2011	3 164 159	674 522	21.3	17	0.025

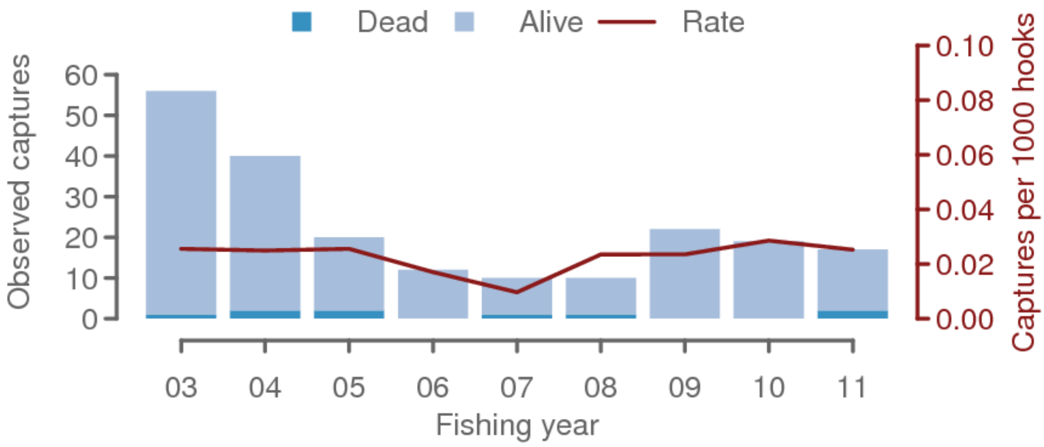


Figure 12: Observed captures of New Zealand fur seal in surface longline fisheries from 2003 to 2011.

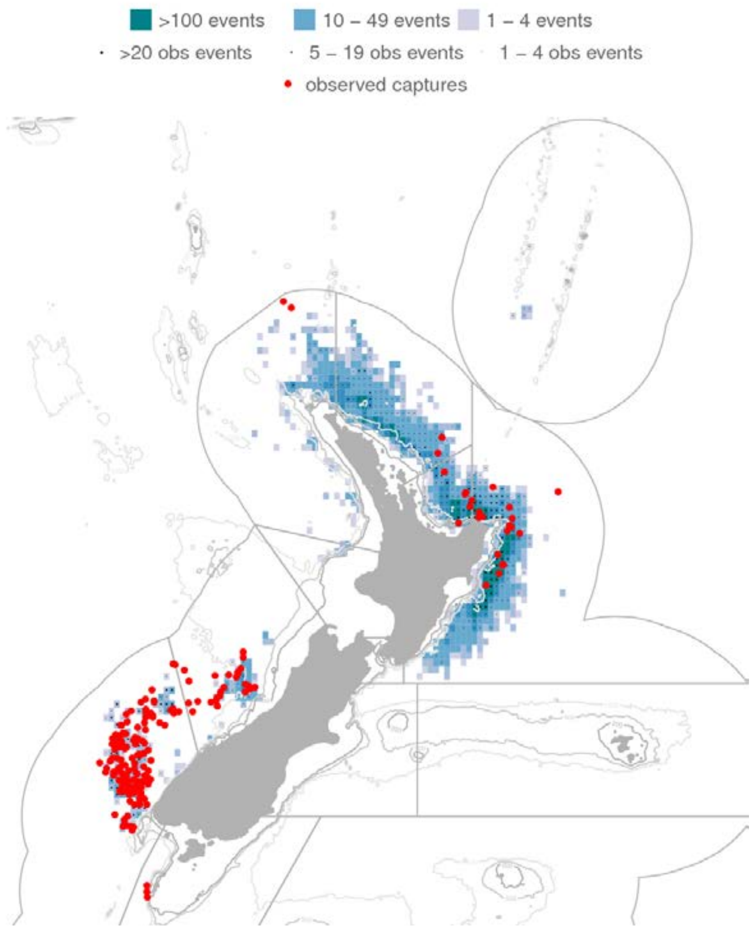


Figure 13: Distribution of fishing effort in surface longline fisheries and observed New Zealand fur seal captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.3 Incidental fish bycatch

Observer records indicate that a wide range of species are landed by the longline fleets in New Zealand fishery waters. Blue sharks are the most commonly landed species (by number), followed by Ray's bream (Table 13). Southern bluefin tuna and albacore tuna are the only target species that occur in the top five of the frequency of occurrence.

Table 13: Numbers of the most common fish species observed in the New Zealand longline fisheries during 2009-10 by fleet and area. Species are shown in descending order of total abundance (Griggs and Baird in press).

	Charter	Domestic		Total
Species	South	North	South	number
Blue shark	2 024	4 650	882	7 556
Rays bream	3 295	326	88	3 709
Southern bluefin tuna	3 244	211	179	3 634
Lancetfish	3	2 139	1	2 143
Albacore tuna	90	1 772	42	1 904
Dealfish	882	0	7	889
Swordfish	3	452	2	457
Moonfish	76	339	6	421
Porbeagle shark	72	328	20	420
Mako shark	11	343	7	361
Big scale pomfret	349	4	0	353
Deepwater dogfish	305	0	0	305
Sunfish	7	283	5	295
Bigeye tuna	0	191	0	191
Escolar	0	129	0	129
Butterfly tuna	15	100	3	118
Pelagic stingray	0	96	0	96
Oilfish	2	75	0	77
Rudderfish	39	20	2	61
Flathead pomfret	56	0	0	56
Dolphinfish	0	47	0	47
School shark	34	0	2	36
Striped marlin	0	24	0	24
Thresher shark	7	17	0	24
Cubehead	13	0	1	14
Kingfish	0	10	0	10
Yellowfin tuna	0	9	0	9
Hake	8	0	0	8
Hapuku bass	1	6	0	7
Pacific bluefin tuna	0	5	0	5
Black barracouta	0	4	0	4
Skipjack tuna	0	4	0	4
Shortbill spearfish	0	4	0	4
Gemfish	0	3	0	3
Bigeye thresher shark	0	2	0	2
Snipe eel	2	0	0	2
Slender tuna	2	0	0	2
Wingfish	2	0	0	2
Bronze whaler shark	0	1	0	1
Hammerhead shark	0	1	0	1
Hoki	0	0	1	1
Louvar	0	1	0	1
Marlin, unspecified	0	1	0	1
Scissortail	0	1	0	1
Broadnose seven gill shark	1	0	0	1
Shark, unspecified	0	1	0	1
Unidentified fish	2	30	8	40
Total	10 545	11 629	1 256	23 430

4.4 Benthic interactions

N/A

4.5 Key environmental and ecosystem information gaps

Cryptic mortality is unknown at present but developing a better understanding of this in future may be useful for reducing uncertainty of the seabird risk assessment and could be a useful input into risk assessments for other species groups.

The survival rates of released target and bycatch species is currently unknown.

Observer coverage in the New Zealand fleet is not spatially and temporally representative of the fishing effort.

5. STOCK ASSESSMENT

With the establishment of the WCPFC in 2004, future stock assessments of the western and central Pacific Ocean stock of blue shark will be reviewed by the WCPFC.

Quantitative stock assessments of blue sharks outside the New Zealand EEZ have been mostly limited to standardised CPUE analyses, although quantitative assessment models have been developed using conventional age-structured and MULTIFAN-CL methods. There have been no quantitative stock assessments of blue sharks in New Zealand waters and no quantitative stock assessments are possible with the current data.

Unstandardised CPUE indices computed from tuna longline catches recorded by the MPI observers in the NZ EEZ are highly variable (Figure 14). CPUE estimates were calculated for each fleet and area stratum in which eight or more sets were observed and at least 2% of the hooks were observed. CPUE estimates were calculated for blue sharks for each fleet and area in 2006–07 to 2009–10 and added to the time series for 1988–89 to 2005–06 (Griggs *et al.*2008) and these are shown in Figure 14 (Griggs and Baird in press). The CPUE results from the Domestic fleet should be interpreted with caution due to the lower observer coverage of this fleet. CPUE estimates for the Charter fleet can be considered reliable from 1992–93 onwards (Griggs *et al.*2007). Overall the CPUE trend for blue sharks in New Zealand follows the effort trends with CPUE increases coinciding with increases in fishing effort.

Blue sharks are the most heavily fished of the three large pelagic shark species (blue, mako, and porbeagle sharks) commonly caught in the tuna longline fishery. Compared to mako and porbeagle sharks, however, blue sharks are relatively fecund, fast growing, and widely distributed. Nevertheless, there is some concern about the impact of a rapid increase in domestic fishing effort in the late 1990s and the early 2000s. This has now been ameliorated in New Zealand by a substantial decline in tuna longline fishing effort since 2002-03. The status of the stock is uncertain.

Observed length frequency distributions of blue sharks by area and sex are shown in Figure 15 for fish measured in 2006–07 to 2009–10. Length frequency distributions of blue sharks showed differences in size composition between North and South areas (Figure 15). There were more female blue sharks (59.5% over the four year period) caught than males, with a higher proportion of females in the South (77.5% over the four years) than the North (40.5 %). Based on the length-frequency distributions and approximate mean lengths at maturity of 192.5 cm fork length for males and 180 cm for females (Francis & Duffy 2005), most blue sharks were immature (91.1% of males and 92.9% of females, overall). Greater proportions of mature male blue sharks were found in the North (12.1% mature in the North and 1.1% in the south), while more similar proportions of mature females were found in the North and South (4.5% and 8.4% respectively).

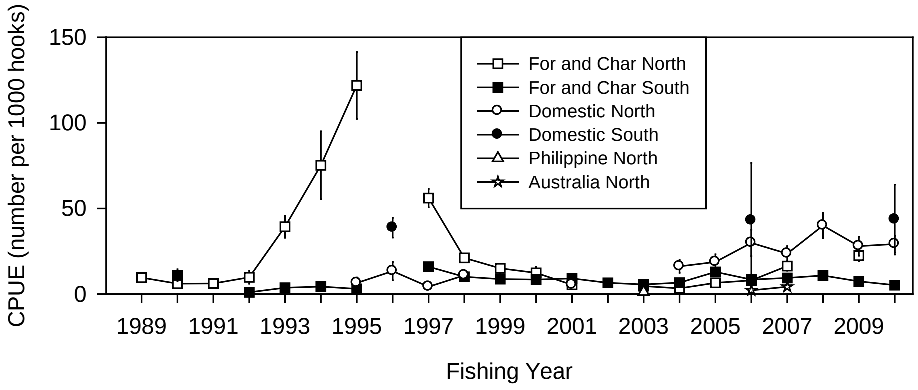


Figure 14: Annual variation in CPUE by fleet and area. Plotted values are the mean estimates with 95% confidence limits. Fishing year 1989 = October 1988 to September 1989.

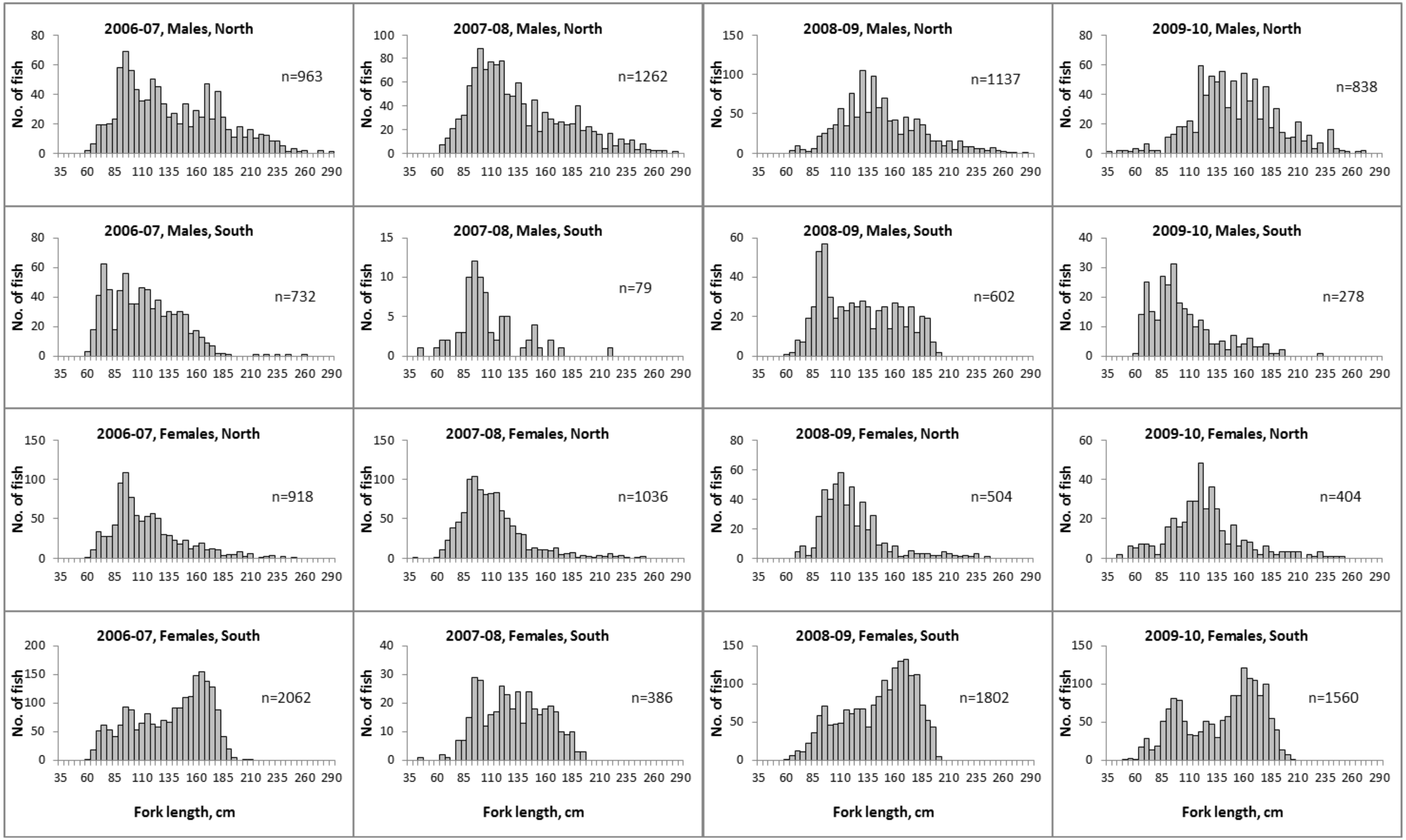


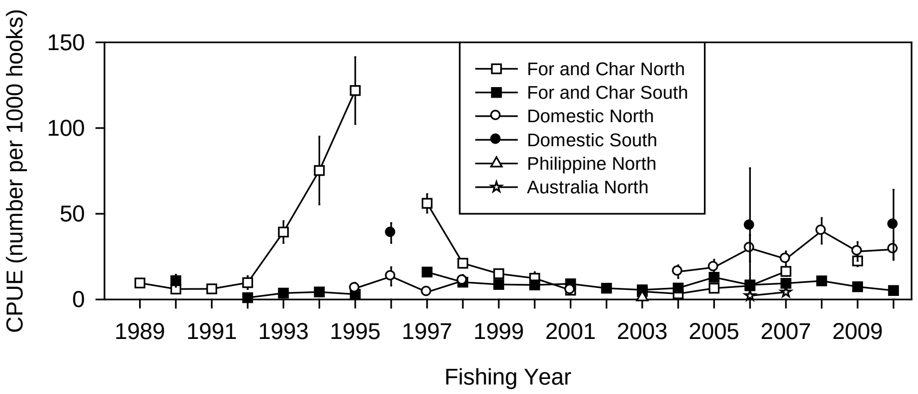
Figure 15: Length-frequency distributions sampled by observers of blue shark by fishing year, sex, and region (Griggs and Baird in press).

6. STATUS OF THE STOCK

Stock structure assumptions

BWS1 is assumed to be part of the wider South Western Pacific Ocean stock but the assessment below relates only to the New Zealand component of that stock.

Stock Status	
Year of Most Recent Assessment	2008
Assessment Runs Presented	Base case model only
Reference Points	Target: Not established Soft Limit: Not established by WCPFC; but evaluated using HSS default of 20% SB_0. Hard Limit: Not established by WCPFC; but evaluated using HSS default of 10% SB_0.
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Historical Stock Status Trajectory and Current Status	



Annual variation in CPUE by fleet and area. Plotted values are the mean estimates with 95% confidence limits. Fishing year 1989 = October 1988 to September 1989.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	CPUE analyses have been undertaken in New Zealand but are not considered to have generated reliable estimates of abundance.
Trends in Other Relevant Indicator or Variables	Catches in New Zealand increased from the early 1990s to a peak in the early 2000s but declined slightly in the mid 2000s and have remained relatively stable since that time.

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch causing decline below limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 3- Qualitative Evaluation: Fishery characterisation with evaluation of fishery trends (e.g., catch, effort and nominal CPUE) - there is no agreed index of abundance.	
Assessment Method	CPUE analysis	
Assessment Dates	Latest assessment: 2008	Next assessment: 2013 (SPC)
Overall assessment quality rank	2 – Medium or Mixed Quality: information has been subjected to peer review and has been found to have some shortcomings.	
Main data inputs (rank)	- commercial reported catch and effort	1 - High quality for the charter fleet but low for all the other fleets.
Data not used (rank)		
Changes to Model Structure and Assumptions		
Major Sources of Uncertainty	Historical catch recording may not be accurate.	

Qualifying Comments
The Western and Central Pacific Fisheries Commission will be attempting a WCPO assessment in 2012.
Fishery Interactions
Interactions with protected species are known to occur in the longline fisheries of the South Pacific, particularly south of 25°S. Seabird bycatch mitigation measures are required in the New Zealand and Australian EEZ's and through the WCPFC Conservation and Management Measure CMM2007-04. Sea turtles also get incidentally captured in longline gear; the WCPFC is attempting to reduce sea turtle interactions through Conservation and Management Measure CMM2008-03.

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DREDGE OYSTER (OYU 5)-Foveaux Strait

(*Ostrea chilensis*)

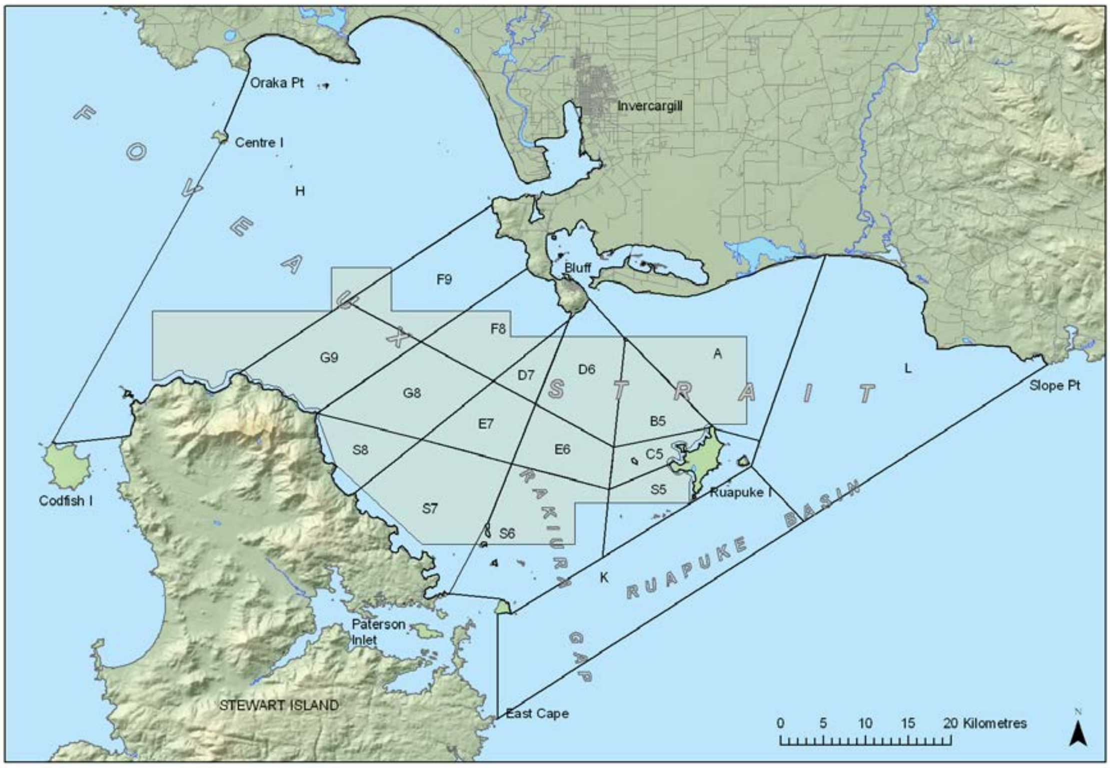


Figure 1: Foveaux Strait (OYU 5) stock boundary and outer boundary of the 1999 dredge survey area encompassing almost all the commercial fishery.

1. FISHERY SUMMARY

The Foveaux Strait oyster fishery OYU 5 was introduced into the Quota Management System in 1998 with a TAC of 20 300 000 million oysters (Table 1).

Table 1: Total Allowable Commercial Catch (individuals) declared for OYU 5 since introduction into the QMS since 1998.

Year	TAC	Customary	Recreational	Other Mortality	TACC
1998 - present	20 300 000	–	–	–	14 950 000

1.1 Commercial fishery

The Foveaux Strait dredge oyster fishery has been fished for over 140 years. From the late 1880s to 1962 the fishery was managed by limiting the number of vessels licensed to fish. During this period vessel numbers varied between 5 and 12. The fishery was de-licensed in 1962 and boat numbers increased to 30 by 1969. Boundaries of statistical areas for recording catch and effort were established in 1960 and the outer boundary of the licensed oyster fishery in 1979. The western fishery boundary in Foveaux Strait is a line from Oraka Point to Centre Island to Black Rock Point (Codfish Island) to North Head (Stewart Island). The eastern boundary is from Slope Point, south to East Cape (Stewart Island). The OYU 5 stock boundaries and statistical reporting areas are shown in Figure 1.

Catch limits were introduced in 1963. In 1970, vessel numbers were limited to 23 by regulation. The catch limits were evenly divided between the 23 vessels. Before 1992, landings and catch limits in this fishery were recorded in sacks. Sacks contained an average of 774 oysters and weighed 79 kg.

Catch and effort has been traditionally recorded in sacks per hour dredged. Total landings of oysters between the 1880s and 1962 ranged between 15 and 77 million oysters. Reported landings for the period 1907–1962 are shown in Table 2. Catch limits and total landings for 1963–92 are shown in Table 3.

Table 2: Reported landings of Foveaux Strait oysters 1907–1962 (millions of oysters; sacks converted to numbers using a conversion rate of 774 oysters per sack). (Data summarised by Dunn, (2005) from Marine Department Annual Reports).

Year	Catch	Year	Catch	Year	Catch	Year	Catch	Year	Catch
1907	18.83	1919	16.56	1931	28.28	1943	56.59	1955	60.84
1908	17.34	1920	20.67	1932	29.01	1944	49.50	1956	58.63
1909	19.19	1921	19.01	1933	32.64	1945	58.85	1957	60.14
1910	18.20	1922	21.11	1934	40.44	1946	69.16	1958	64.44
1911	18.90	1923	22.28	1935	38.48	1947	63.09	1959	77.00
1912	19.00	1924	18.42	1936	49.08	1948	73.10	1960	96.85
1913	26.26	1925	20.01	1937	51.38	1949	75.34	1961	84.30
1914	19.15	1926	21.54	1938	52.05	1950	58.09	1962	53.42
1915	25.42	1927	16.26	1939	58.16	1951	70.15		
1916	22.61	1928	30.03	1940	51.08	1952	72.51		
1917	17.20	1929	30.44	1941	57.86	1953	55.44		
1918	19.36	1930	33.11	1942	56.87	1954	51.29		

Table 3: Reported landings and catch limits for the Foveaux Strait dredge oyster fishery from 1963–1992 (millions of oysters; sacks converted to numbers using a conversion rate of 774 oysters per sack). Catch rate shown in sacks per hour. (Data summarised by Dunn, (2005) from Marine Department Annual Reports).

Year	Reported landings		Catch limit	Catch rate	Year	Reported Landings		Catch limit	Catch rate
1963	58		132	6.0	1978	96	[2]	89	17.1
1964	73		132	6.8	1979	88		89	16.6
1965	95		132	7.9	1980	88		89	15.2
1966	124		132	10.6	1981	89		89	13.4
1967	127		132	9.3	1982	88		89	13.2
1968	114		121	7.7	1983	89		89	12.3
1969	51		94	6.5	1984	89		89	13.8
1970	88		89	7.3	1985	82		89	12.1
1971	89		85	6.9	1986	60	[3]	89	10.5
1972	77		85	6.7	1987	48	[4]	50	10.9
1973	97	[1]	85	10.0	1988	68		71	10.0
1974	92	[1]	85	11.5	1989	66		89	10.7
1975	89		89	11.9	1990	36		36	6.4
1976	89		89	13.4	1991	42	[5]	36	5.8
1977	92	[2]	89	15.9	1992	5	[6]	14	3.4

1 Landings include catch given as incentive to explore 'un-fished' areas.
2 Landings include catch given as an incentive to fish Area A.
3 Season closed early after diagnosis of *B. exitiosa* infection confirmed.
4 Catch limit reduced by the proportion of the fishery area with oysters infected by *B. exitiosa* and closed.
5 Landings include catch given as an incentive to fish a 'firebreak' to stop the spread of *B. exitiosa*.
6 Fishing only permitted in outer areas of fishery.

In 1986, *Bonamia exitiosa* (bonamia) was identified as the cause of high mortality in the oyster population and the epizootic reduced oyster density, and the size and number of commercial fishery areas over the next six years (see Cranfield *et al*. 2005, Doonan *et al*. 1994). Over that period, management of the fishery used changes to catch limits (Table 3) and spatial fishing strategies to minimise the effects of disease mortality and the spread of infection. In 1993 the oyster fishery was closed to allow the population to recover. The fishery was reopened in 1996 with a catch limit of 14.95 million oysters. This catch limit was converted to a catch quota of 1475 t using a conversion factor of 801 oysters per 79 kg sack, based on Bluff Oyster Enhancement Company data. From 1996, catches were recorded as numbers of oysters. Catch limits and total landings for 1996–to present are shown in Table 4. Another *B. exitiosa* epizootic confirmed in March 2000 caused a decline in the oyster population and further reduced landings from 2003 (Table 4). Between 2003 and 2008, the

Bluff Oyster Management Company (BOMC) shelved half of the TACC, harvesting about 7.5 million oysters annually.

The Bluff Oyster Enhancement Company Ltd (BOEC) was established in 1992 to facilitate an oyster enhancement programme in attempts to rebuild the OYU 5 stock back to its pre-1985 level. In 1997, BOEC was renamed the Bluff Oyster Management Company Limited (BOMC), that became a commercial stakeholder organisation (CSO) to represent the combined interests of owners of individual transferable quota (ITQ) shares in the Bluff Oyster fishery (OYU 5). In April 1997, individual quotas were granted, and quota holders were permitted to fish their entire quota on one vessel. The quota shares were evenly allocated based on the 23 vessel licences. At the same time, the Crown purchased 20% of the available quota from quota holders by tender from willing sellers and transferred it to the Waitangi Fisheries Commission.

The commercial fishing year for the oyster fishery is from 1 October to 30 September however, oysters have been traditionally harvested over a six-month season, 1 March to 31 August. Commercial and recreational fishery data is reported by calendar year and customary fishing by fishing year (1 October to 30 September) as customary permits are issued out of season.

Table 4: Reported landings and catch limit for the Foveaux Strait dredge oyster fishery from 1996–to present. TACC was 14.95 million oysters over this period. Landings and catch limits reported in numbers (millions) of oysters. Reported catch rate based on number of sacks landed in CELR data, and revised catch rate based on numbers of oysters landed and converted to sacks (774 oysters per sack). Catch rate does not include oysters taken by crew as recreational catch. The numbers of oysters per sack can vary considerably depending on the sizes of oysters and epifauna attached. Some oysters are landed in bins, and bins converted to sacks using a conversion factor of 0.5.

Year	Reported landings	Catch limit including voluntary Catch limits from 2003	Reported catch rate	Revised catch rate
1996	13.41	14.95	5.9	5.8
1997	14.82	14.95	7 0	7.0
1998	14.85	14.95	8.3	**6.7**
1999	14.94	14.95	7.5	**6.8**
2000	14.43	14.95	7.2	**6.4**
2001	15.11	14.95	7.0	**6.8**
2002	14.45	14.95	3.2	**3.3**
2003	7.46	7.475 [1]	2.3	**2.6**
2004	7.48	7.475 [1]	2.2	**2.5**
2005	7.57	7.475 [1]	1.7	**1.8**
2006	7.44	7.475 [1]	1.9	**1.9**
2007	7.37	7.475 [1]	2.2	**2.4**
2008	7.49	7.475 [1]	3.3 [2]	**3.3**
2009	8.22	8.22 [3]	3.9 [2, 4]	**3.0**
2010	9.54	9.53	4.2 [2, 4]	**4.4**
2011	10.6[5]	10.6[5]	4.2 [2, 4]	–[6]
2012	11.6	11.6	4.2 [2, 4]	–[6]

1 Fifty percent of the TACC was shelved for the season
2 Fishers given incentive to sort above MSL to increase market value, and changes in sorting potentially result in lower catch rates compared to previous years.
3 BOMC unshelved 10% of their shelved quota.
4 Catch reported in bins and sacks, bins converted to sacks by a conversion factor of 0.5.
*5 Landings d*ata for 2011 includes 1.0 million oysters caught under a special permit for the Rugby World Cup.
6 Data for 2011 and 2012 not available

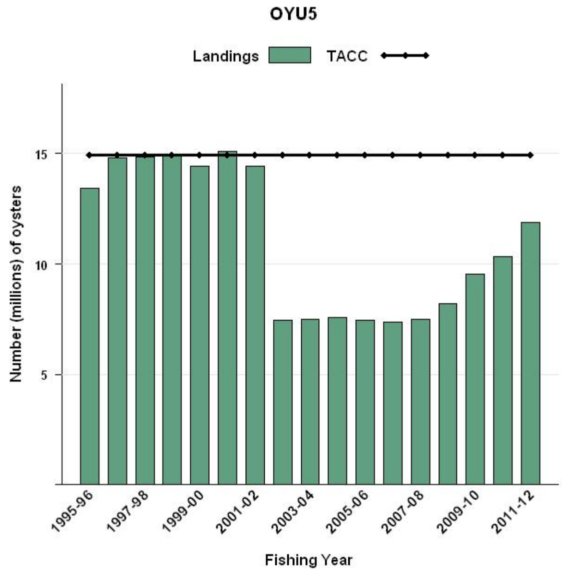


Figure 2: Landings of oysters from OYU5 (millions of oysters) from 1995-96 to 2011-12.

1.2 Recreational fisheries

In 2002, Fisheries Officers estimated that between 70 and 100 recreational vessels were fishing from Bluff and smaller numbers from Riverton and Colac Bay. Recreational fishers may take 50 oysters per day during the open season (March–August). A charter boat fleet (approximately 17 vessels) based at Stewart Island, Bluff, and Riverton also targets oysters during the oyster season.

Four surveys of recreational fishing have been conducted to estimate recreational harvest: the South region 1991–92 survey and the 1996 (Bradford 1998), 1999-2001 (MFish Recreational database) and 2000-01 (MFish Recreational database) national telephone diary surveys. However, the catch of oysters cannot be reliably quantified from these surveys because of the small number of local respondents who reported catches of oysters in their diaries. The Southland Recreational Marine Fishers Association estimated that the annual recreational catch of oysters in Foveaux Strait in 1995 to be about 300 000 oysters.

Table 5: Reported annual recreational catch (numbers of oysters) taken from commercial vessels March to August 2002–09 (Ministry of Fisheries CELR data) and reported customary catch (numbers of oysters) October to September 1998–2009 (Tangata taiki data collected by Ngai Tahu).

Year	Recreational catch from commercial vessels	Customary catch	
1998	N/A	143 940	*1*
1999	N/A	177 360	
2000	N/A	223 332	
2001	N/A	259 243	
2002	236 103	184 335	
2003	282 645	157 980	
2004	146 567	127 708	
2005	190 345	76 464	
2006	139 252	85 312	
2007	90 544	109 260	
2008	141 587	202 952	
2009	182 331	347 390	
2010	N/A	N/A	*2*
2011	N/A	N/A	*2*

1 Customary catch reported for the period 1 July to 31 December only.
2 Data for 2011 not available at time of printing November Plenary.

The commercial oyster fleet are a major contributor to the level of recreational harvest. Commercial fishers are entitled to 50 oysters each day (subject to approval under s111 of the Fisheries Act 1996), with each commercial vessel's crew potentially taking up to 400 oysters as recreational catch each day. Recreational catches from commercial vessels have, in the past, been reported in Catch and Effort Returns (CELR); and since 2002, have been separately reported on returns and not included in commercial catch effort statistics. Commercial fishers took 182 331 oysters under recreational bag limits during the 2009 oyster season. Recreational catch taken on commercial vessels is shown in Table 5.

1.3 Customary non-commercial fisheries

Reporting of Maori customary harvest is specified in the Fisheries (South Island Customary Fisheries) Regulations 1999. Ngai Tahu administers the reporting of customary catch of Foveaux Strait oysters to the Ministry of Fisheries. Customary catch is reported in the quarter it is summarized, landing dates are not reported for catches under customary permits). A small amount of customary fishing is believed to take place between 31 August and 30 September, and no customary permits are issued for the quarter 1 October to 31 December while oysters are spawning. Reported customary catch for 1998 to 2009 is given in Table 5.

1.4 Illegal catch

There are no estimates of illegal catch for OYU 5.

1.5 Other Sources of Mortality

1.5.1 Mortality caused by *Bonamia exitiosa*

Bonamia exitiosa is a haemocritic, haplosporid parasite (infects mainly haemocytes or blood cells) of flat oysters. It is known to infect *Ostrea chilensis* in New Zealand and Chile; *Ostrea angasi* in Australia; *Ostrea puelchana* in Argentina; *Ostrea* (*Ostreola*) *conchaphila* in California, USA; *Ostrea edulis* in Atlantic Spain, probably Gulf of Manfredonia (Italy); *Ostrea stentina* in Tunisia, and possibly northern New Zealand (this isolate is also similar to *Bonamia. roughleyi*); and *Crassostrea ariakensis* in North Carolina, USA (Mike Hine, pers. comm.). Further, an unknown species of bonamia has been identified in two species of native oysters from Hawaii.

Mortality of oysters from *B. exitiosa* is a recurrent feature of the Foveaux Strait oyster population and the main driver of oyster abundance during epizootics. Large numbers of new clocks (shells of oysters that had died within six months) and oysters in poor condition (both indicative of *B. exitiosa* epizootics), were recorded as long ago as 1906. *B. exitiosa* has been identified in preserved oyster tissues sampled in 1964, at the end of an epizootic that caused a downturn in the fishery (Cranfield *et al* 2005) and originally attributed to *Bucephalus longicornutus* (Hine & Jones 1994). A *B. exitiosa* epizootic occurred in the Foveaux Strait oyster fishery in 1986–92 and again in 2000–09. Prevalence of infection between 1996 and 2000 was not sampled, but is thought to be low (almost undetectable) from the low numbers of new clocks that were recorded in biennial oyster population surveys in that period.

The annual cycle of infection is described by Hine (1991). The parasite transmits directly, oyster to oyster, and disease spread is thought to be related to oyster density. Some oysters appear more tolerant of infection than others (Hine 1996). The relationship between the intensity and prevalence of infection in one year, the density of oysters, and the probability of oyster mortality the following year are poorly understood (Sullivan *et al*. 2005).

It is not known whether other disease agents (including an apicomplexan, *Bucephalus* sp., coccidian, and microsporidian) contributed to or caused mortality in oysters during the 1986–92 and 2000–12 epizootics. No direct and immediate effect of oyster dredging on disease status can be determined.

Oyster mortality from bonamia is still considerably higher than the commercial catch. Based on the number of oysters sampled with fatal infections, the projected mortality of recruit-sized oysters between surveys and the oyster seasons have been estimated at 14, 43, 23, 46, 40, 53, and

81 million oysters for years 2006 to 2012 respectively. Relatively small bonamia surveys are undertaken in years between triennial stock assessment surveys in key commercial fishery areas, and the size of these surveys may not estimate population size well. The February 2012 survey was a stock assessment survey. Oyster mortality over the summer of 2012 estimated from new clocks and gapers showed that 30.0 million recruit-sized oysters died immediately prior to the survey, and based on fatal (category 3 and higher see Diggles *et al*. 2003) infections, another 81 million oysters would probably die early into the 2012 oyster season. The post-survey mortality was expected to reduce the recruited oyster population from 918.4 million oysters (95% CI 600.1−1383.7) at the time of the survey to 837.3 million oysters (95% CI 546.3–1262.6) at the start of the season, a post survey mortality of 8.8%.

1.5.2 Incidental mortality caused by heavy dredges

Since 1965, heavy double bit, double ring bag dredges have been used in the Foveaux Strait oyster fishery. These dredges weighed around 410 kg when first introduced. Each oyster skipper fine tunes their dredges and current dredge weights range from 460 kg to 530 kg. These dredges are heavier than the single bit, single ring bag dredges employed between 1913 and 1964.

Incidental mortality of oysters from dredging with light (320 kg) and heavy (550 kg) dredges was compared experimentally in March 1997 (Cranfield *et al*. 1997). Oysters in the experiment had only a single encounter with the dredge. Numbers of dead oysters were counted seven days after dredging. The experiment found that mortality was inversely proportional to the size of oysters damaged and that lighter dredges damaged and killed fewer oysters. Recruit size oysters appeared to be quite robust (1–2% mortality) and few were damaged. Smaller oysters (10–57 mm in length) were less robust (6–8% mortality), but spat were very fragile and many were killed especially by the heavy commercial dredge (mortality of spat below 10 mm in height ranged from 19–36%). Incidental mortality from dredging may reduce subsequent recruitment in heavily fished areas but is unlikely to be important once oysters are recruited. The mortality demonstrated experimentally here has not been scaled to the size of the fishery and therefore its importance cannot be assessed.

2. BIOLOGY

Ostrea chilensis is a protandrous hermaphrodite that may breed all year round, but breeding peaks in the spring and summer months. Females produce few large (280–290 μm) yolky eggs, which after fertilisation continue to develop to pediveligers in the inhalant chamber for 18–32 days (depending on temperature). Most larvae are thought to settle immediately on release (at a size of 444–521 μm) and thought to seldom disperse more than a few centimetres from the parent oyster. Some larvae are released early, at smaller sizes and spend some time in the plankton, and are capable of dispersing widely. Little is known about the timing and proportion of larvae released early in the plankton, and how this strategy may vary spatially and temporally, both within natal populations and the fishery. In Foveaux Strait, spat settlement is primarily during the summer months from December to February. Mean fertility of incubating oysters in Foveaux Strait was determined to be 5.09×10^4 larvae, and only 6–18% of the sexually mature oysters spawned as females each year.

Little data are available on recruitment. Stock recruitment relationships for the Foveaux Strait dredge oyster are unknown, but most oysters surviving post settlement, are typically found on live oysters, and to a lesser extent, on oyster shells and on the circular saw *Astraea heliotropium* (Keith Michael, NIWA, pers. comm.). Generally, recruitment of sessile organisms is highly variable and often environmentally and predation driven (Cranfield 1979). About 2% of oyster spat survive the first winter; most mortality appears to result from predation by polychaetes, crabs, and small gastropods. Although settlement predominates on under-surfaces of oysters and shell, most surviving spat are attached to the left (curved and generally uppermost) valve of living oysters. Mean density of six month old oyster spat settled on spat plates at six sites in western and eastern Foveaux Strait over the summer of 1999–2000 was 1 700 m^2 (range 850–2 900 m^2) (Cranfield *et al*. unpublished data).

Growth rate of oysters varies between years and between areas of Foveaux Strait. Spat generally grow 5 to 10 mm in height by the winter after settlement. Mean height after one year is 18 to 25, 25 to 35 mm after two years, 30 to 51 mm after three years, 40 to 65 mm after four years, and 65 to 75 mm after the fifth year. Oysters recruit to the legal-sized population (a legal-sized oyster will not pass through a 58 mm diameter ring, i.e., it must be at least 58 mm in the smaller of the two dimensions of height or length) at ages of 4–8 years. There was evidence for strong seasonal variation in growth (Dunn *et al*. 1998a).

Dunn *et al*. (1998a) modelled the growth of a sample of oysters from four areas, grown in cages. Length-based growth parameters from this study are shown in Table 6.

Jeffs & Hickman (2000) estimated measures of maturity from the re-analysis of sectioned oyster gonads sampled at around monthly intervals from four sites in Foveaux Strait from April 1970 to April 1971. Analysis of these samples revealed that oysters were protandrous, maturing first as males to 20 mm in shell height. Beyond 50 mm, most oysters developed ova while continuing to produce sperm, although oysters did not begin brooding larvae until 60 mm. Considerable quantities of ova were present in oysters throughout the year, but only a very small proportion of oysters spawned ova from July to December with a peak in October. Oysters commonly contained and released sperm throughout the year, although peak spawning was from November to March. The phagocytosis of reproductive material from the follicles of oysters was present in a small proportion of oysters throughout the year. However, it was much more common from January to March amongst both male and female reproductive material, including smaller (less than 50 mm), solely-male oysters.

Table 6: Estimates of biological parameters.

Fishstock	Estimate	Source
1. Natural mortality (*M*)		
OYU 5	0.042	Dunn *et al*. (1998b)
	Assumed 0.1	Allen (1979)
	Assumed 0.1	Dunn (2007)

2. Length-based growth parameters from Dunn *et al*. 1998a

Length-based growth as estimated from model 3, is presented below. Growth is given for change in diameter.

$$\Delta l = (L_{\infty_{area}} - l1)(1 - e^{-k_{area + year}(\Delta t + \phi)}) - \varepsilon$$

Estimated parameter values (and 95% confidence intervals)

L_∞	Area A	92.2 mm (86.7-97.9)
	Bird I.	76.2 mm (73.5-78.9)
	Lee Bay	77.8 mm (73.4-81.4)
	Saddle	81.0 mm (77.3-84.9)

Estimated parameter values (and 95% confidence intervals)

k	1979	(reference year)
	1980	-0.29 (-0.33– -0.25)
	1981	0.02 (-0.02 – 0.06)
	Area A	0.48 (0.41-0.54)
	Bird I.	0.85 (0.76-0.94)
	Lee Bay	0.77 (0.68-0.86)
	Saddle	0.51 (0.50-0.52)
ϕ		-0.03

3. Size at sexual maturity (Females)		
50 mm diameter (49 mm height)		Cranfield & Allen (1979)
50 mm in length		Jeffs & Hickman (2000)
4. Percentage of population breeding as females annually		
Foveaux Strait	6-18%	Cranfield & Allen (1979)
Foveaux Strait	~50%	Jeffs & Hickman (2000)

3. STOCKS AND AREAS

The Foveaux Strait oyster fishery has been managed as a single stock, and current stock assessments are undertaken in a fishery area defined by the 1999 survey area. Oyster growth is “plastic” and influenced by habitat. Sub populations within the fishery have different morphological characteristics, but are considered a single genetic stock. There has been considerable translocation of oysters from Foveaux Strait to Fiordland and the Catlins to establish natal populations or supplement existing populations, but no records of reverse translocations.

4. STOCK ASSESSMENT

Surveys of the Foveaux Strait oyster population have been reported since 1906 (Dunn 2005) and see Sullivan *et al.* (2005) for details since 1960. Early surveys 1906, 1926–1945 are summarised by Sorensen (1968).

4.1 Estimates of fishery parameters and abundance

Estimates of fishery parameters used for stock assessment are given in Fu & Dunn (2009). CPUE data are used unstandardised. Fishery practices have changed from fishing for the highest catch rate to fishing for high meat quality at much lower catch rates to satisfy market requirements. These practices have resulted in more conservative estimates of CPUE and oyster density from catch and effort data. Interannual recruitment to the oyster population can vary markedly (Unpub. data). Oyster spat settle and survive almost exclusively on live oysters in Foveaux Strait.

4.2 Biomass Estimates

Before 2004 the Foveaux Strait oyster fishery was managed by current annual yield (CAY, Method 1, see Sullivan *et al*. 2005) based on survey estimates of the population in designated commercial fishery areas. Since 2004, the TACC has been based on estimates of recruit size stock abundance from the Foveaux Strait oyster stock assessment model (Dunn 2005, 2007) and projections of future recruit size stock abundance under different catch limits and levels of mortality from *B. exitiosa*.

In 2004, Dunn (2005) presented a Bayesian, length-based single-sex, stock assessment model for Foveaux Strait dredge oysters using the general-purpose stock assessment program CASAL (Bull *et al*. 2005). That model was updated in 2007 (Dunn unpublished) to account for new data available, and a more complex variant of that model was also investigated. For more detailed information on the model structure, data and parameter inputs, sensitivity runs, results and discussion refer to Fu & Dunn 2009. The assessment was updated to include data up to the 2010 fishing year and the abundance indices from the February 2010 survey.

The population model partitioned Foveaux Strait oysters into a single sex population, with length (i.e., the anterior-posterior axis) classes 2 mm to 100 mm, in groups of 2 mm, with the last group defined as oysters ≥ 100 mm. The stock was assumed to reside in a single, homogeneous area. The partition accounted for numbers of oyster by length class within an annual cycle, where movement between length classes was determined by the growth parameters. Oysters entered the partition following recruitment and were removed by natural mortality including disease mortality, and fishing mortality. The models annual cycle was divided into two time steps (Table 7).

Table 7: Annual cycle of the population model, 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 together within a time step occur after all other processes, with 50% of the natural mortality for that time step occurring before and 50% after the fishing mortality.

Step	Period	Process	Proportion in time step
1	Oct–Feb	Maturation	1.0
		Growth	1.0
		Natural mortality	0.5
		Fishing (summer) mortality	1.0
		B. exitiosa mortality	1.0
2	Mar–Sep	Recruitment	1.0
		Natural mortality	0.5
		Fishing (winter) mortality	1.0

Oysters were assumed to recruit at age 1+, with a Beverton-Holt stock recruitment relationship (with steepness 0.9) and length at recruitment defined by a normal distribution with mean 15.5 mm and C.V. 0.4. Relative year class strengths were assumed known and equal to initial recruitment for the years up to 1984 — nine years before the first available length and abundance data on small (oysters < 50 mm minimum diameter) and pre-recruits (oysters between ≥ 50 to < 58 mm minimum diameter) were available; otherwise relative year class strengths were assumed to average 1.0. Growth rates and natural mortality (M) were assumed known. Disease mortality is assumed to be zero in the years where there were no reports of unusual mortality, and otherwise estimated.

The models used seven selectivity ogives: the commercial fishing selectivity (assumed constant over all years and time steps of the fishery, aside from changes in the definition of legal size); a survey selectivity, which was then partitioned into three selectivities (one for each for each of the size-groups) - small (< 50 mm minimum diameter), pre-recruit (≥ 50 mm and < 58 mm minimum diameter), and recruit (≥ 58 mm minimum diameter); maturity ogive; and disease selectivity - assumed to follow a logistic curve equal to the maturity ogive. The selectivity ogives for fishing selectivity, maturity, and disease mortality were all assumed to be logistic. The survey selectivity ogives were assumed to be compound logistic with an additional parameter amin that describes the minimum possible value of the logistic curve. Selectivity functions were fitted to length data from the survey proportions-at-length (survey selectivities), and to the commercial catch proportions-at-length (fishing selectivity).

The maximum exploitation rate (i.e., the ratio of the maximum catch to vulnerable numbers of oysters in any year) was assumed to be relatively high, and was set at 0.5. No data are available on the maximum exploitation rate, but the choice of this value can have the effect of determining the minimum possible virgin stock size (B_0) allowed by the model.

The model was run for the years 1907–2010. Catch data were available for the years 1907–2010, with the catch for 2010 estimated to be 9.5 million oysters. Catches occurred in both time steps - with special permit and some customary catch assigned to the first time step (summer fishing mortality), and commercial, recreational, remaining customary, and illegal catch assigned to the second time step (winter fishing mortality).

The priors assumed for most parameters are summarised in Table 8. In general, ogive priors were chosen to be non-informative and were uniform across wide bounds. The prior for disease mortality was defined so that estimates of disease mortality were encouraged to be low. An informed prior was used when estimating the survey catchability, where a reasonably strong lognormal prior was used, with mean 1.0 and C.V. 0.2.

Table 8: The priors assumed for key parameters. The parameters are mean and CV for lognormal (in natural space); and mean and s.d. for normal.

Parameter	Distribution	Parameters		Bounds	
CPUE *q*	Uniform-log	–	–	1x10^{-8}	0.1
1976 survey *q*	Lognormal	0.5	0.3	0.15	0.95
Mark-recapture survey *q*	Lognormal	0.5	0.3	0.10	0.90
YCS	Lognormal	1.0	1.0	0.01	100.0
Disease mortality	Normal	-0.2	0.2	0.00	0.80

4.2.1 Stock assessment results

Model estimates of numbers of oysters were made using the biological parameters and model input parameters described above. A full assessment in 2009 considered two model runs, the basic model and the revised model. The '2009 basic model' updated the basic model used in the 2007 assessment with catch and CPUE data for the 2007 and 2008 fishing years, the inclusion of the February 2009 biomass survey indices, and an assumed catch of 7.5 million oysters in 2009. The '2009 revised model' updated the 2007 revised model with similar input data. Table 9 described the two model runs.

The basic model suggested the virgin equilibrium spawning stock population size to be about 4240 (3790–4820) million oysters, and the current spawning stock size to be 1070 (940–1210) million oysters (Figure 3). The recruit-sized population was estimated at 820 (720–920) million.

Table 9: Model run labels and descriptions.

Model run	Description
2009 basic model	Growth parameters assumed fixed; annual disease rates estimated as independent variables; the disease selectivity was the same as the maturity ogive; Relative catchability *q* for the abundance surveys was fixed to be 1.
2009 revised model	Growth parameters estimated using tag-recapture data; annual disease rates assumed to be cubic-smooth; maturity and disease selectivity ogive decoupled; Estimated relative catchability *q* for the abundance surveys;

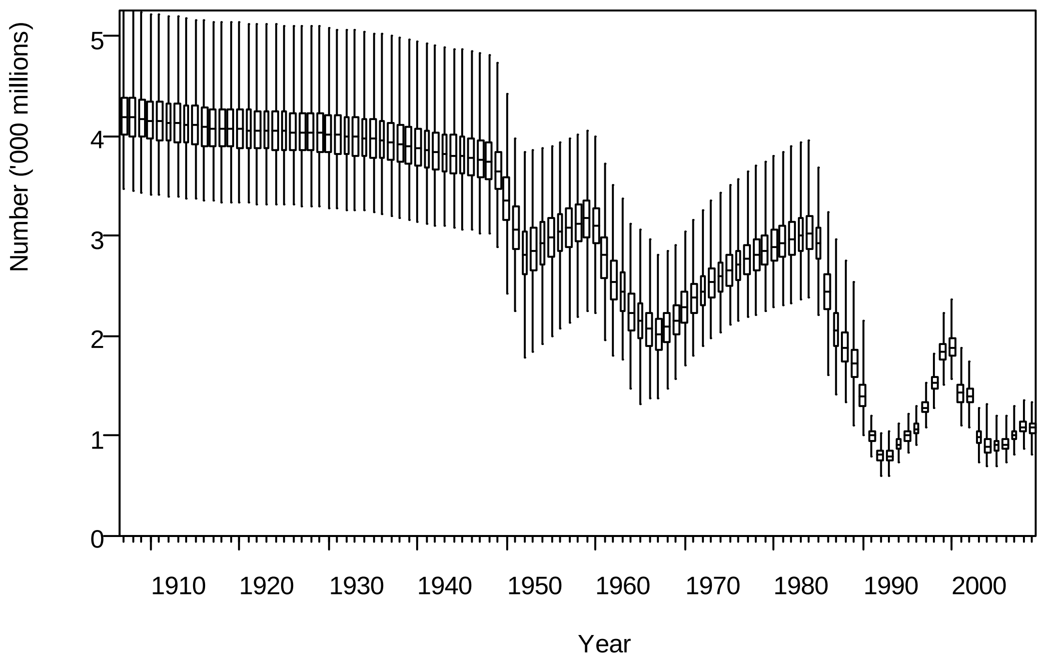


Figure 3: Estimated posterior distributions of SSBs from the 2009 full stock assessment. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

The revised model run suggested a similar stock status as for the basic model, with slightly higher productivity resulting from a slightly faster growth rate. The relative estimates of B_0 from these model runs suggested much greater variability in the estimates of the initial population size, but estimates of the current status and recent change in the current status were very similar (see Table 10). Applying a smoothing penalty to the estimated annual disease mortality rates had little impact on the key estimated parameters of the model.

Full triennial, stock assessments update these two models with data on catch history (total landings), unstandardised CPUE, commercial catch sampling for size structure, and abundance indices from population surveys. In years between triennial stock assessments, these models are partially updated with total landings, catch rate, and catch size structure, but no new estimates of population size (abundance indices). The full 2009 assessment was updated in 2010.

The 2010 basic model update suggested the virgin equilibrium spawning stock population size to be about 3 820 (3 440–4 290) million oysters, and the current spawning stock size to be 1 060 (940–1 230) million oysters (Table 10). The 2010 revised model suggested higher virgin equilibrium spawning stock population size to be about 4 500 (2 740−7 800) million oysters, and the current spawning stock size lower at 1 210 (700−2090) million oysters (Table 10).

Table 10: Bayesian median and 95% credible intervals of B_0 (millions) and SSBs (millions) for 2009, and 2010 from basic and revised models. The 2010 stock assessment partly updated the 2009 assessment with catch rate, total landings, and size structure from catch sampling, but there have been no new estimates of population size since 2009.

Model	B_0	B_{2009}	B_{2010}
2010 basic model	3 820 (3 440−4 290)	1 060 (940−1 230)	1 070 (920−1 230)
2010 revised model	4 500 (2 740−7 800)	1 210 (700−2090)	1 210 (700−2 090)

Projected stock estimates were made assuming that future recruitment will be log-normally distributed with mean 1.0 and standard deviation equal to the standard deviation of log of recruitment between 1985 and 2010 (i.e., 0.34 with 95% range 0.29–0.39). Projections were made assuming no future disease mortality and with future disease mortality assumed to be 0.10 y^{-1} and 0.20 y^{-1}. Two future catch levels were considered each with 9.5 million oysters in 2010, and a future annual commercial catch of either 7.5 or 15 million oysters. Future customary, recreational and illegal catch were assumed equal to levels assumed for 2009. Projected output quantities are summarised in Tables 11–14. The plot of the median expected recruit sized population is given in Figure 4.

Under the assumptions of future disease mortality, model projections of commercial catch at either 7.5 or 15 million showed little difference in expected population size. For example, the projected population size in 2012 with a commercial catch of 7.5 million was less than 2% higher than that with a commercial catch of 15 million oysters. Depending on the level of assumed disease mortality, projected status in 2013 ranged from about 33% more than current levels (assuming no disease mortality) to a level about 26% less than the current level (assuming disease mortality of 0.2 y^{-1}) for the 2010 basic model, and from about 50% more than current levels (assuming no disease mortality) to a level about 13% less than the current level (assuming disease mortality of 0.2 y^{-1}) for the revised 2010 model.

Table 11: Basic model. 2010 basic model median and 95% credible intervals of current spawning biomass 2010 (B_{2010}), and projected spawning stock biomass for 2011–13 (B_{2011}–B_{2013}) as a percentage of B_0 with an assumption of a future catch of 7.5 or 15 million oysters in 2011–13, and disease mortality of 0.0, 0.1, or 0.2 y^{-1}. The 2010 stock assessment partly updated the 2009 assessment with catch rate, total landings, and size structure from catch sampling, but there have been no new estimates of population size since 2009.

Disease mortality	Catch (millions)	B_{2010} (% B_0)	B_{2011} (% B_0)	B_{2012} (% B_0)	B_{2013} (% B_0)
0.00	7.5	28.9 (24.2–34.7)	31.1 (24.1–38.8)	35.2 (27.6–45.0)	39.5 (31.3–51.3)
	15.0	28.9 (24.2–34.7)	31.1 (24.1–38.8)	35.1 (27.4–44.8)	39.2 (31.0–51.0)
0.10	7.5	28.9 (24.2– 34.7)	30.1 (23.4–37.6)	30.5 (23.9–39.2)	31.2 (24.6–40.9)
	15.0	28.9 (24.2–34.7)	30.1 (23.4–37.6)	30.4 (23.7–39.1)	30.9 (24.4–40.6)
0.20	7.5	28.9 (24.2–34.7)	29.2 (22.7–36.5)	26.7 (20.8–34.5)	25.0 (19.6–33.3)
	15.0	28.9 (24.2–34.7)	29.2 (22.7–36.5)	26.6 (20.7–34.4)	24.8 (19.4–33.1)

Table 12: Basic model. Median and 95% credible intervals of expected recruit-sized stock abundance for 2011–2013 with a catch of 9.5 million oysters in 2010 and a future catch of 7.5 or 15 million oysters in 2011–2013, and disease mortality rate of 0.0, 0.1, or 0.2 y^{-1} for the 2010 basic model. The 2010 stock assessment partly updated the 2009 assessment with catch rate, total landings, and size structure from catch sampling, but there have been no new estimates of population size since 2009.

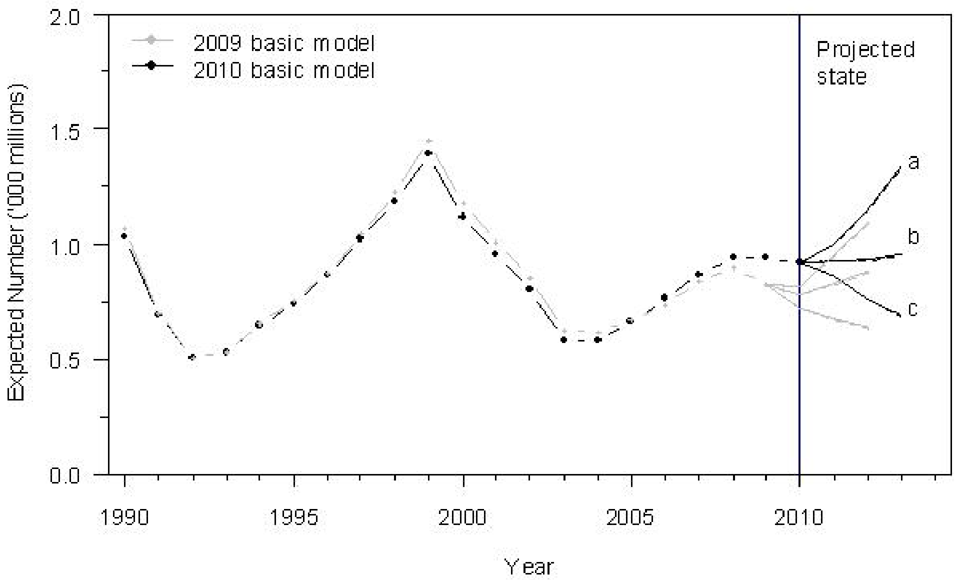
Disease mortality	Catch (millions)	rB_{2010}/rB_{2010}	rB_{2011}/rB_{2010}	rB_{2012}/rB_{2010}	rB_{2013}/rB_{2010}
0.00	7.5	1.00 (1.00–1.00)	1.09 (0.96–1.20)	1.26 (1.09–1.51)	1.45 (1.22–1.82)
	15.0	1.00 (1.00–1.00)	1.09 (0.96–1.20)	1.25 (1.08–1.51)	1.44 (1.21–1.81)
0.10	7.5	1.00 (1.00–1.00)	1.01 (0.89–1.12)	1.02 (0.87–1.23)	1.04 (0.86–1.32)
	15.0	1.00 (1.00–1.00)	1.01 (0.89–1.12)	1.01 0.87–1.22)	1.03 0.85–1.30)
0.20	7.5	1.00 (1.00–1.00)	0.94 (0.83–1.03)	0.82 (0.70–0.99)	0.75 (0.61–0.96)
	15.0	1.00 (1.00–1.00)	0.94 (0.83–1.03)	0.82 (0.70–0.99)	0.74 (0.6– 0.95)

Table 13: Revised model. Median and 95% credible intervals of current spawning stock biomass 2010 (B_{2010}), and projected spawning stock biomass for 2011–2013 (B_{2011}–B_{2013}) as a percentage of B_0 with a catch of 9.5 million oysters in 2010 and a future catch of 7.5 or 15 million oysters in 2011–2013, and disease mortality rate of 0.0, 0.1, or 0.2 y^{-1} for the 2010 revised model. The 2010 stock assessment partly updated the 2009 assessment with catch rate, total landings, and size structure from catch sampling, but there have been no new estimates of population size since 2009.

Disease mortality	Catch (millions)	B_{2010} (% B_0)	B_{2011} (% B_0)	B_{2012} (% B_0)	B_{2013} (% B_0)
0.00	7.5	28.8 (23.7–36.3)	31.3 (24.0–41.3)	35.8 (27.7–47.5)	40.0 (31.0–53.6)
	15.0	28.8 (23.7–36.3)	31.3 (24.0–41.3)	35.6 27.6–47.4)	39.7 (30.7–53.3)
0.10	7.5	28.8 (23.7–36.3)	30.5 (23.4–40.4)	31.8 (24.7–42.7)	32.8 (25.4–44.2)
	15.0	28.8 (23.7–36.3)	30.5 (23.4–40.4)	31.7 (24.6–42.6)	32.6 (25.1–44.0)
0.20	7.5	28.8 (23.7–36.3)	29.8 (22.8–39.5)	28.4 (22.0–38.3)	27.3 (20.9–37.1)
	15.0	28.8 (23.7–36.3)	29.8 (22.8–39.5)	28.3 (21.9–38.1)	27.1 (20.7–36.9)

Table 14: Revised model. Median and 95% credible intervals of expected recruit-sized stock abundance for 2011–2013 with catch of 9.5 million oysters in 2010 and 7.5 or 15 million oysters in 2011–2013, and disease mortality rate of 0.0, 0.1, or 0.2 y^{-1} for the 2010 revised model. The 2010 stock assessment partly updated the 2009 assessment with catch rate, total landings, and size structure from catch sampling, but there have been no new estimates of population size since 2009.

Disease mortality	Catch (millions)	rB_{2010}/rB_{2010}	rB_{2011}/rB_{2010}	rB_{2012}/rB_{2010}	rB_{2013}/rB_{2010}
0.00	7.5	1.00 (1.00–1.00)	1.12 (1.00–1.22)	1.30 (1.14–1.51)	1.50 (1.27–1.82)
	15.0	1.00 (1.00–1.00)	1.12 (1.00–1.22)	1.29 (1.14–1.50)	1.50 (1.27–1.83)
0.10	7.5	1.00 (1.00–1.00)	1.05 (0.94–1.14)	1.09 (0.96–1.28)	1.14 (0.97–1.40)
	15.0	1.00 (1.00–1.00)	1.05 (0.94 –1.14)	1.09 (0.95–1.27)	1.13 (0.95–1.39)
0.20	7.5	1.00 (1.00–1.00)	0.98 (0.88–1.08)	0.92 (0.80–1.08)	0.88 (0.73–1.09)
	15.0	1.00 (1.00–1.00)	0.98 (0.88–1.08)	0.92 (0.80–1.07)	0.87 (0.73–1.09)



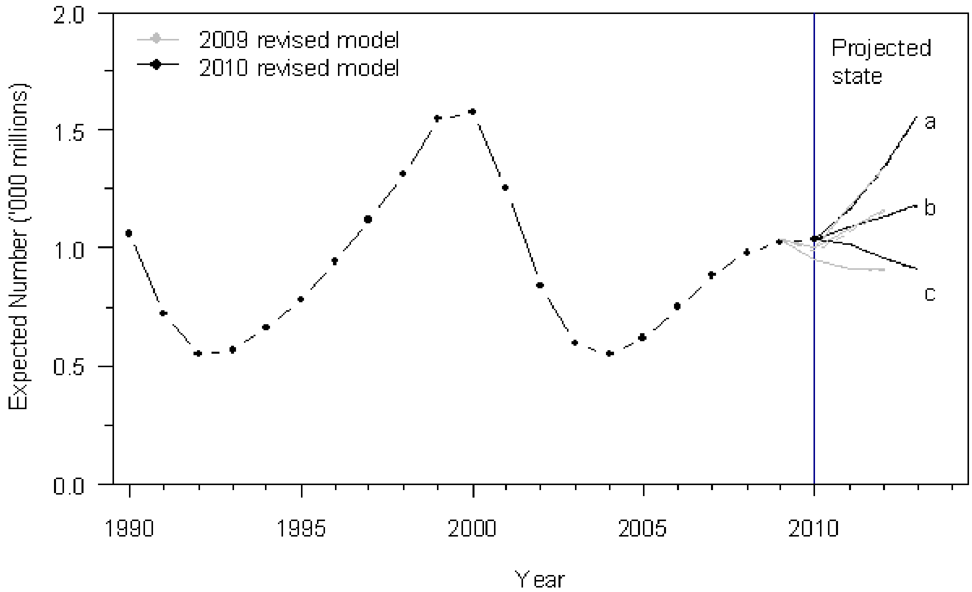


Figure 4: Model estimates of recent recruit-sized stock abundance and projected recruit-sized stock abundance for 2011–13 with catch of 7.5 (black) and 15 million oysters (grey), under assumptions of (a) no disease mortality, (b) disease mortality of 0.10 y^{-1}, and (c) disease mortality of 0.20 y^{-1}, for the 2009 and 2010 basic models (top) and revised models for the same years respectively (bottom).

5. STATUS OF THE STOCKS

Stock Structure Assumptions

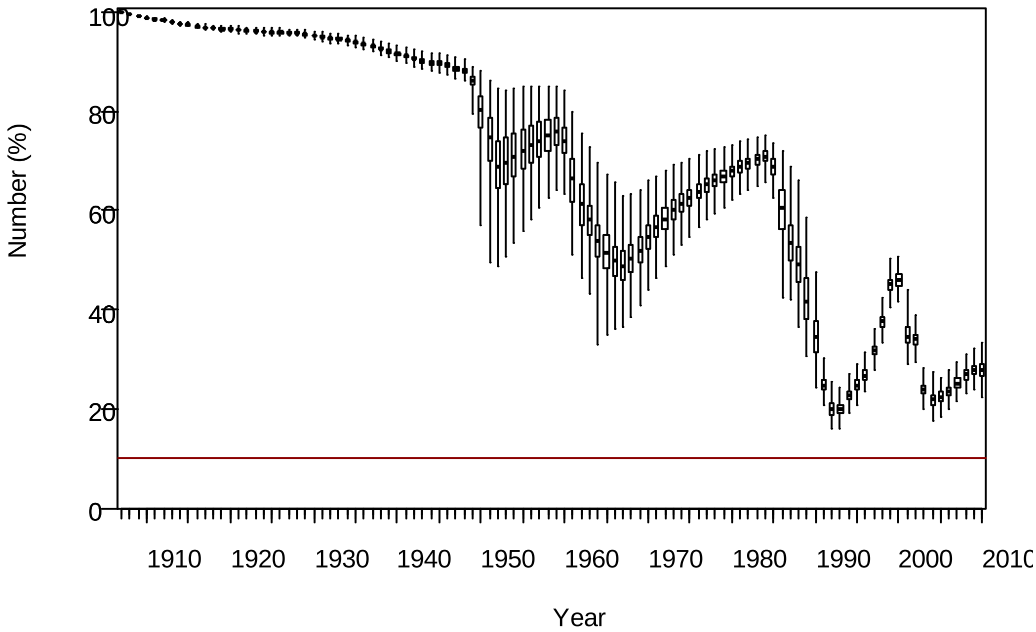
OYU 5 is assessed as a single stock defined by the survey boundaries.

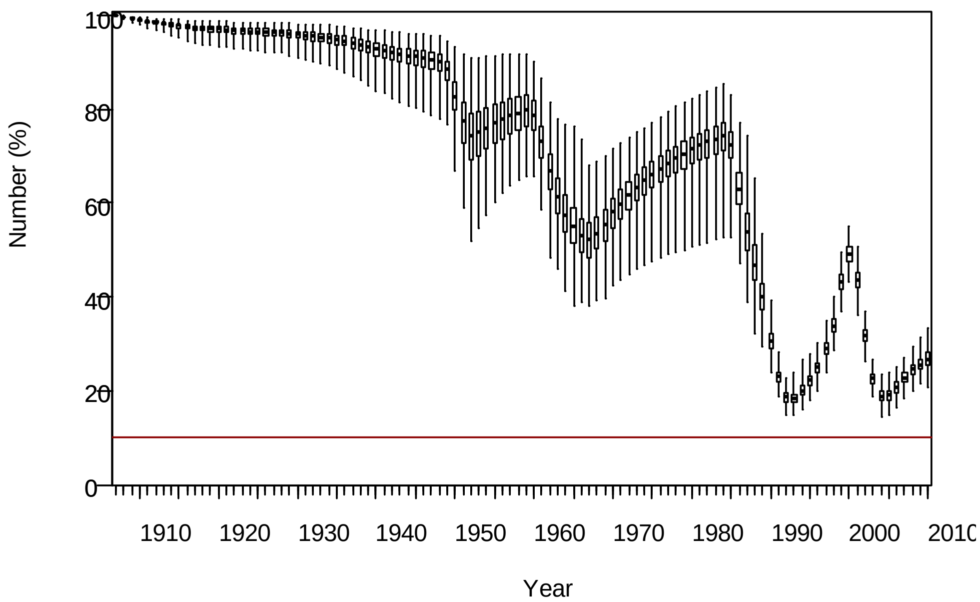
Foveaux Strait Oysters OYU 5

Stock Status	
Year of Most Recent Assessment	2009 assessment partially updated with total landings, catch rate, and catch size structure in 2010, but no new estimates of population size.
Assessment Runs Presented	Basic model (absolute biomass) and revised model (relative biomass)

Reference Points	Target(s): 40% Bo, with at least a 50% probability of achieving the target. Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Unlikely (< 40%) to be at or above the target.
Status in relation to Limits	Model B0 B2010 %B0 2010 basic 3820 1070 28.0% 2010 revised 4500 1210 26.9% Unlikely (< 40%) to be below the Soft Limit and Very Unlikely (< 10%) to be below the Hard Limit.

Historical Stock Status Trajectory and Current Status





2010 basic model (top) and revised model (bottom) estimated posterior distributions of Spawning Stock Biomass (as a percent of B_0). Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median. Significant declines in population size are attributed to epizootics of *Bonamia exitisoa.*

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Stock size reached a low point in 2005, which is near the historical minimum, but has been increasing since.
Recent Trend in Fishing Mortality or Proxy	The TACC has been 14.95 million oysters since 1996. Bluff oyster management company shelved 50% of the ACE from 2003−2008, and since 2009 have progressively unshelved part of the 50% originally shelved. Landings have increased from 7.5 million oysters to over 10 million in 2011.
Other Abundance Indices	Unstandardised catch and effort data are a good proxy for oyster density and reflect the status of commercial fishery areas. Commercial catch rates have been increasing since 2005 from 1.8 sacks per hour to 4.0 sacks per hour in 2010, and have been similar (4.2 sacks per hour) in 2011 and 2012. The recent practice of high grading has probably resulted in more conservative estimates of catch and effort.
Trends in Other Relevant Indicators or Variables	Since 2005, mortality from bonamia has been relatively low (less than10% of recruited oysters) and recruitment to the fishery has exceeded *B. exitiosa* mortality, and the population size of recruited oysters has continued to increase. In 2012, bonamia infection was still widespread, but patchily distributed in the fishery area. Post survey mortality (8.8%) in February 2012 is slightly higher than the levels between 2007and 2011: 6.9%, 3.3%, 6.3%, 6.6%, and 6.7% respectively. At this range of bonamia mortality, the oyster population has continued to rebuild.

Projections and Prognosis		
Stock Projections or Prognosis	While recruitment is expected to increase towards the long-term fishery mean, there was some uncertainty around the effects of continuing bonamia mortality on recruitment. The model trajectories and the most recent bonamia survey show the population size is continuing to increase and stock size is rebuilding.	
Probability of Current Catch or TACC causing decline below Limits	While uncertainty exists in levels of future recruitment and continued *B. exitiosa* related mortality, projections from the Foveaux Strait oyster stock assessment model indicate that current catch limits are unlikely to have any significant negative effect on future stock levels.	
Assessment Methodology		
Assessment Type	Full Triennial, Quantitative Stock assessment with annual updates.	
Assessment Method	Bayesian length based stock assessment model	
Assessment Dates	Latest assessment: Full in 2009 and updated in 2010.	Next full assessment: 2012.
Overall Assessment Quality (rank)	1- High Quality	
Main data inputs (rank)	• catch history (total landings) • unstandardised CPUE • commercial catch length frequency sampling • abundance indices from population surveys	1 1 1 1
Changes to Model Structure and Assumptions	The model may be reviewed in the future.	
Major Sources of	Stock size is highly dependent on the levels of mortality from	

Uncertainty	bonamia and continued recruitment around the long-term average. Interannual and spatial variabilty in oyster growth rates may affect transitions of pre-recruit oysters to the recruited oyster population.

Qualifying Comments
In the absence of disease mortality, the fishery has shown an ability to rebuild quickly at the level of the TACC.

Fishery Interactions
There is some overlap between oyster dredging and bottom trawling. Bycatch data are recorded from population and bonamia surveys, and in fishers' logbooks.

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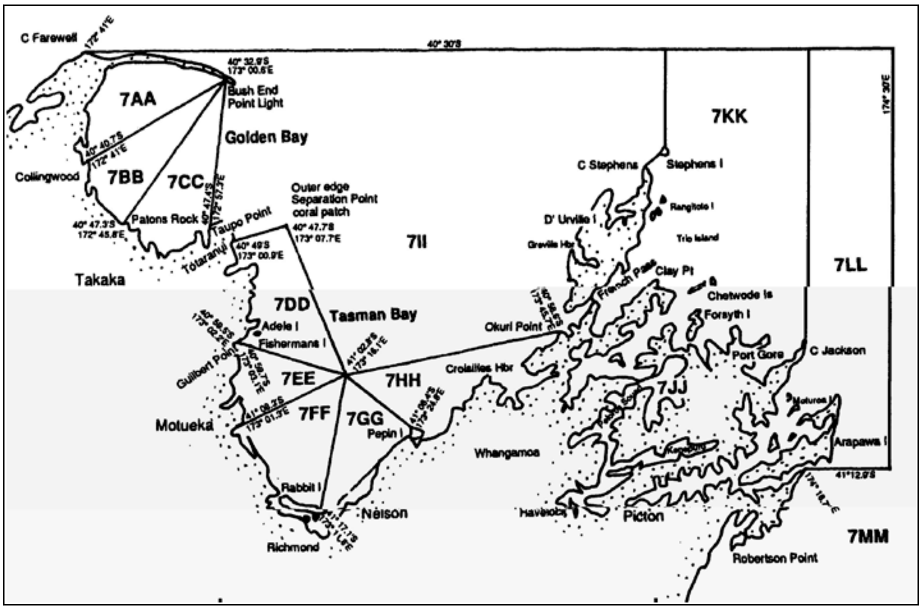
DREDGE OYSTERS (OYS7) – Nelson/Marlborough

(*Ostrea chilensis*)



1. FISHERY SUMMARY

OYS 7 was introduced into the QMS on 1 October 1996 with a TACC of 505 t. There is no TAC for this fishery (Table 1).

Table 1: Total Allowable Commercial Catch (TACC, t) declared for OYS 7 since introduction into the QMS in 1996.

Year	TAC	Customary	Recreational	Other Mortality	TACC
1996 - present	–	–	–	–	505

1.1 Commercial fishery

Dredge oysters in the Nelson/Marlborough area were first exploited in 1845. From 1963 to 1981 oysters were landed mainly as bycatch, firstly by the green-lipped mussel (*Perna canaliculus*) dredge fishery and subsequently by the scallop (*Pecten novaezelandiae*) fishery (Drummond 1994a). In 1981 the Challenger scallop fishery was closed and commercial dredge operators started targeting oysters.

Shellfish dredging in Tasman Bay, Golden Bay, and the Marlborough Sounds is now a multi-species fishery with oysters, scallops, and green-lipped mussels caught together. Until 1999, oyster and scallop seasons did not overlap and this prevented both species being landed together. Since then a relaxation of seasonal restrictions has meant there is now potential for the seasons to overlap.

In 1983, fishery regulations and effort restrictions were updated (Drummond 1994a). Fishery regulations included a minimum size (legal sized oysters could not pass through a 58 mm internal diameter ring), an open season (1 March to 31 August), area closures, and a prohibition on dredging at night. A 500 t (greenweight) catch restriction was implemented for Tasman Bay in 1986 and extended to include Golden Bay in 1987 (Drummond 1987). The 500 t catch restriction was revoked in 1996 and a TACC of 505 t set when oysters were brought in to the Quota Management System (Annala et. al. 1998). The commercial oyster season was extended to 12 months and since 1 October 1999 catch has been reported by fishing year which runs from 1 October to 30 September. Fishers had been required to land all legal sized oysters, but approval was given to return such oysters to the sea as long as they are likely to survive. The OYS 7 fishery comprises the area from Cape Farewell in Golden Bay, throughout Tasman Bay and the Marlborough Sounds to West Head, Tory Channel (see area map). OYS 7 is considered a separate fishery from OYS 7C on the basis of differences in habitat and environmental parameters. Landings for OYS 7 are reported in greenweight.

From 1980, catches of oysters, from Tasman Bay, Golden Bay, and the Marlborough Sounds were recorded on weekly dredge forms for each Shellfish Management Area (Table 2). In 1992, the Nelson-Marlborough dredge oyster statistical areas were established (see area map) by adopting the scallop reporting areas for this fishery. Prior to 1999 when the oyster season ran from 1 March to 31 August catch data was presented by calendar year (Table 3). Thereafter reported landings are given by fishing year, 1 October to 30 September. Data from 1989 to 1999 show oysters landed out of season and these data have been included in the summaries shown in Tables 2–4. Most of the catch in OYS 7 comes from Tasman Bay, with small landings from Golden Bay.

In recent years, the industry has voluntarily restricted catch levels according to the biomass and distribution of the population estimated in the annual biomass survey, and the economics of catch per unit effort during the season.

Table 2: Reported and adjusted catch (t, greenweight) in the Challenger fishery, 1963–1988 (from Annala *et al.*2001). Sourced from MAF Marine Dept. Report on Fisheries between 1963 and 1980, the FSU database between 1981 and 1986, and Quota Monitoring System (QMS) in 1987 and 1988. Catches adjusted to account for non-reporting of factory reject oysters (16.2% by number) and use of an incorrect conversion factor.

Year	Reported catch	Adjusted catch	Year	Reported catch	Adjusted catch	Year	Reported catch	Adjusted catch
1963	3	3	1972	65	82	1981	389	492
1964	6	8	1973	190	240	1982	432	546
1965	0	0	1974	78	99	1983	593	750
1966	24	33	1975	136	172	1984	259	328
1967	44	57	1976	392	496	1985	405	512
1968	69	87	1977	212	268	1986	527	667
1969	22	28	1978	40	51	1987	380	–
1970	74	94	1979	83	105	1988	256	–
1971	34	43	1980	160	202			

Table 3: Reported landings (t, greenweight) in the Challenger fishery for the 1989–1999 oyster seasons (1 March to 31 August). Data extracted from MPI database, originally reported on Quota Monitoring Returns (QMR).

Year	QMR	Year	QMR
1989	538	1995	694
1990	206	1996	572
1991	187	1997	447
1992	290	1998	436
1993	476	1999	335
1994	584		

Table 4: Reported landings (t, greenweight) in the Challenger fishery after October 1999 when the fishing season was extended to a full year (1 October–30 September). Data extracted from MPI database, originally reported on Quota Monitoring Returns (QMR) for 1999-00 and 2000-01 and on Monthly Harvest Returns (MHR) thereafter.

Fishing year	QMR	MHR
1999–00	132	–
2000–01	25	–
2001–02	–	1.4
2002–03	–	183.0
2003–04	–	97.5
2004–05	–	146.8
2005–06	–	170.9
2006–07	–	132.1
2007–08	–	21.0
2008–09	–	< 0.1
2009–10	–	0.0
2010–11	–	5.9
2011–12	–	0.0

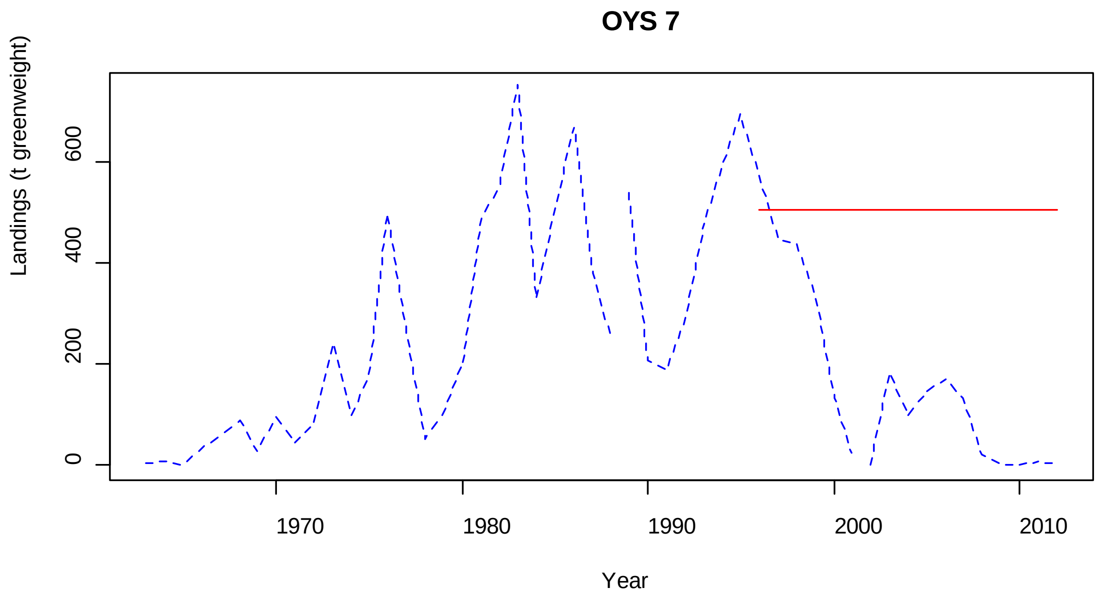


Figure 1: Landings of oysters from OYS7 (t, green weight). Oyster season 1 March to 31 August for years 1963 to 1999. No seasonal restrictions from the 1999−2000 fishing year (October stock) shown as year 2000 onwards. Adjusted catch 1963−1986; reported catch 1987−1988; Quota Monitoring Returns (QMR) 1989–2001; and Monthly Harvest Returns (MHR) 2002 to present. TACC from 1996 (solid red line).

1.2 Recreational fishery

The recreational daily bag limit for oysters in the Challenger fishery area is 50 per person. Oysters that cannot pass through a 58 mm internal diameter solid ring are deemed legal size. The recreational season for dredge oysters in the Challenger area is all year round. Oysters must be landed in their shells. Recreational fishers take oysters in Tasman and Golden Bays by diving and dredging. A survey of the recreational catch of scallops and dredge oysters in Golden and Tasman Bay conducted in 2003-04 estimated that 5800 (95% CI 3800-8400) oysters were taken recreationally during that season (Cole *et al.*2006).

1.3 Customary fisheries

There are no data available on the customary catch.

1.4 Illegal catch

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

1.5 Other sources of mortality

The Nelson/Marlborough area occasionally experiences blooms of diatoms, which result in an anaerobic slime that smothers benthic fauna (Bradford 1998, Mackenzie *et al.*1983, Tunbridge 1962). The level of dredge oyster mortality from this source is unknown.

Bonamia exitiosa is a haemocritic, haplosporid parasite (infects mainly haemocytes or blood cells) of flat oysters and is known to infect *Ostrea chilensis* in New Zealand and Chile and various other species of *Ostrea* in other countries. *Bonamia* has caused catastrophic mortality in the Foveaux Strait oyster fishery and is endemic in oysters in the OSY 7 area (Hine *pers. comm.*). *Apicomplexan* has also been identified in poor condition oysters dredged from Tasman Bay. *Apicomplexan* is a group of obligate pathogens that are thought to predispose oysters to infection by *Bonamia*. The level of mortality caused by disease agents in OYS 7 is unknown.

Drummond & Bull (1993) reported some incidental mortality from dredging. No other data are available on incidental mortality of oysters in OYS 7 caused by fishing. A study on incidental mortality of oysters was completed by Cranfield *et al* 1997 however, this work was specific to the Foveaux Strait oyster fishery so may or may not have relevance to OYS 7.

2. BIOLOGY

The biology of *O. chilensis* was summarised by Handley & Michael (2001), and further biological data was presented in Brown *et al.*(2008). Most of the parameters required for management purposes are based on the Foveaux Strait fishery described by Cranfield & Allen (1979).

Oysters in OYU 5 (Foveaux) and OYS 7C (Cloudy Bay/Clifford Bay) occur in discrete patches on a predominantly sandy substrate, whereas OYS 7 (Tasman Bay) oysters tend to be more uniformly distributed at a lower density on muddy habitat. Environmental factors such as hydrodynamics, seasonal water temperature and riverine inputs differ substantially among the OYS 7, OYS 7C and OYU 5 areas and these factors will influence the biological characteristics of these oyster populations.

Oyster stocks in the OYS 7 area are generally low and seasonally variable, suggesting high variability in recruitment (Osborne 1999). Challenger oysters are reported to spawn at temperatures above 12°C (Brown *et al.*2008). Compared to the Foveaux Strait fishery, in Tasman and Golden Bay significantly smaller and less developed larvae have been collected in the plankton, implying that Challenger oysters appear to release their larvae into the plankton for longer periods (Cranfield & Michael 1989). Cranfield & Michael (1989) estimated that the larvae could disperse 20 km in 5–12 days, but a more recent study concluded that although a small proportion may travel several kilometres, the majority of the larvae disperse no further than a few hundred meters from the parent population (Brown *et al.*2008). Tunbridge (1962), Stead (1976) and Drummond (1994a) all pointed out that the productivity of the fishery is likely to be limited by a paucity of settlement substrate in the soft sediment habitat of Tasman and Golden Bay. A recent study demonstrated increased oyster productivity where shell material was placed on the seabed as a settlement substrate for oyster larvae, and oyster productivity was higher in areas enhanced with brood stock (Brown *et al.*2008).

The variability in shell shapes and high variability in growth rate between individuals, between areas within the OYS 7 fishery, and between years require careful consideration in describing growth. Assuming the minimum legal size of oysters could range in diameter (1/2 length + height) from 58 mm to 65 mm, data from Drummond (1994b) indicated that Tasman Bay oysters could grow to legal size in two to three years. Modelling of limited data from Tasman Bay in Brown *et al.*(2008) indicated that 77% of three year old oysters and 82% of 4 year old oysters would attain lengths greater than the minimum legal size of 58 mm length at the start of the fishing season. Osborne (1999) used results from a MAF Fisheries study conducted between 1990 and 1994 to construct a von Bertalanffy equation describing oyster growth in the OYS 7 fishery. Estimated biological parameters including instantaneous natural mortality (*M*) from Drummond (1993, 1994b) and growth parameters for von Bertalanffy equations from Osborne (1999) and from Brown *et al.*(2008) are given in Table 5. Mortality estimates by Drummond (1994b) and growth parameters in Osborne (1999) were derived from a tagging study conducted in Tasman Bay between 1990 and 1992 (Drummond 1993). Von Bertalanffy growth parameters in Brown *et al.*(2008) were estimated based on a limited data set from enhanced habitat experiments, and describe growth of young oysters. Estimates of *M* based on experimental data from Foveaux and Tasman Bay ranged from 0.042 (Dunn *et al* 1998b) to 0.92 (Drummond *et al.*1994b). However, after some discussion the Shellfish Working Group (SFWG) concluded that those figures were not realistic, and that *M* was likely to lie between 0.1 and 0.3.

Table 5: Estimated biological parameters for oysters in OYS 7. Mortality (M) estimates from Drummond (1993, 1994b). Parameters derived for von Bertalanffy equations describing growth of oysters (mm diameter) in Tasman Bay from Osborne (1999) and Brown *et al.*(2008).

Parameter	Estimate	Uncertainty		Source
	mean	sd	95%CI	
M	0.92	-	0.48	Drummond (1994)
M	0.2	-	-	Drummond (1993)
k	0.99	0.16	-	Brown *et al.*(2008)
k	0.597	-	-	Osborne (1999)
L_{inf}	67.52	3.91	-	Brown *et al.*(2008)
L_{inf}	85.43	-	-	Osborne (1999)
t_0	0.11	0.02	-	Brown *et al.*(2008)

3. STOCKS AND AREAS

Patches of commercial densities of oysters within the OYS 7 fishery are largely restricted to Tasman Bay. The stock is likely to be biologically isolated from the Foveaux Strait population on the basis of geographical distance. The populations in OYS 7 and OYS 7C could be biologically distinct due to their geographical separation and limited larval dispersal.

4. STOCK ASSESSMENT

Scallop and oyster surveys that estimated oyster densities from 1959 are shown in Table 6. Surveys between 1959 and 1995 used different dredges, survey designs and methods and are not comparable. Surveys since 1996 have estimated oyster biomass concurrently with scallops from one or two-phase, stratified random designs, but strata have not been optimised for oysters. Although surveys of oyster biomass are comparable from 1996, the high c.v.s limit the usefulness of these survey data to establish meaningful trends in the fishery.

Table 6: Surveys of oysters in Tasman (TB) and Golden Bays (GB) from 1959 to present. Surveys either targeted oysters (Target species) to estimate oyster density and distribution or sampled oysters concurrently in surveys targeting scallops (Scallops), but without optimising survey designs for oysters.

Survey	Location	Target species	Survey design	Reference
1959-1960	TB	Scallops	Targeted	Choat (1960)
1961	TB, GB	Oysters	Grid and targeted	Tunbridge (1962)
1969-75	TB, GB	Oysters	Targeted	Stead (1976)
1984–86	TB, GB	Oysters	Grid	Drummond (unpub. Report)
1996	TB, GB	Scallops	Two-phase stratified random	Cranfield *et al.*(1996)
1997	TB, GB	Scallops	Two-phase stratified random	Cranfield *et al.*(1997)
1998	TB, GB	Scallops	Two-phase stratified random	Osborne (1998)
1999	TB, GB	Scallops	Two-phase stratified random	Breen & Kendrick (1999)
2000	TB, GB	Scallops	Two-phase stratified random	Breen (2000)
2001	TB, GB	Scallops	Two-phase stratified random	Horn (2001)
2002	TB, GB	Scallops	Two-phase stratified random	Horn (2002)
2003	TB, GB	Scallops	Two-phase stratified random	Horn (2003)
2004	TB, GB	Scallops	Two-phase stratified random	Horn (2004)
2005	TB, GB	Scallops	Two-phase stratified random	Horn (2005)
2006	TB, GB	Scallops	Two-phase stratified random	Horn (2006)
2007	TB, GB	Scallops	Two-phase stratified random	Brown (2007)
2008	TB, GB	Scallops	Two-phase stratified random	Brown (2008)
2009	TB	Scallops	Single-phase stratified random	Williams *et al* (2009)
2010	TB	Oysters	Grid and targeted	Michael (2010)
2010	TB	Scallops	Single-phase stratified random	Williams *et al* (2010)
2011	TB	Scallops	Single-phase stratified random	Williams & Michael (2011)
2012	TB	Oysters	Single-phase stratified random	Williams & Bian (2012)

4.1 Estimates of fishery parameters and abundance

Growth and mortality are poorly estimated for oysters from OYS 7. Growth estimates from Drummond's (1994b) mark recapture data and estimates from Osborne (1999) give von Bertalanffy parameter estimates of 79.6 and 85.4 for L_∞, and 2.03 and 0.60 for k respectively. Drummond (1994b) estimated M=0.92 (considered unlikely by the Shellfish Working Group) and M=0.17. The Shellfish Working Group considers M is most likely to lie between 0.1 and 0.3.

Estimates of the numbers of recruits (oysters unable to pass through a 58 mm ring) and pre-recruits (less than 58 mm) from Tasman Bay and Golden Bay since 1998 are shown in Table 7.

Table 7: Relative estimates (millions) uncorrected for dredge efficiency of recruited and pre-recruit oysters in Tasman and Golden Bays from surveys (1998 to present).

	Tasman Bay				Golden Bay			
Year	Recruits	CV	Pre-recruits	CV	Recruits	CV	Pre-recruits	CV
1998	28.7	7.3	30.4	10.1	1.4	13.3	0.4	18.7
1999	24.7	8.6	39.6	13.6	1.9	23.7	1.2	24.8
2000	21.8	8.9	33.5	9.9	1	14.3	0.5	17.6
2001	17.8	9	23.1	9.1	0.4	20.1	0.4	28.1
2002	15.9	10.6	24.5	11.2	0.4	21.4	0.3	27.1
2003	12.4	9.7	34.3	13.4	0.4	27.1	0.4	27.6
2004	10.9	6.7	16.1	8.1	0.4	25.4	0.2	18.8
2005	11.3	10.2	25.2	17.7	0.3	38.8	0.3	41.6
2006	10.7	8.6	18.5	14.8	0.1	29.1	0.04	46.6
2007	14.8	14.3	6.5	19.4	0.1	32	0.04	32.3
2008	9.6	20.5	8.9	25.2	0.04	47.1	0.01	39.5
2009	14.7	20	18.8	36	–•	–•	–•	–•
2010	14	26	9	54	–•	–•	–•	–•
2011	8	48	19	61	–•	–•	–•	–•
2012	6.8	22	21	21	–•	–•	–•	–•

• Golden Bay has not been surveyed since 2009 because this area has not been targeted for commercial fishing

4.2 Biomass estimates

Estimates of the recruited biomass (≥ 58 mm) of oysters in both Tasman Bay and Golden Bay (made from surveys of oysters and scallops combined) show a general decline from 1998 to 2011 (Table 8).

Table 8: Estimates of relative biomass (t) of recruited oysters from Tasman and Golden Bays (1998 to present).

	Tasman Bay		Golden Bay		OYS 7			
Year	Biomass (t)	CV	Biomass (t)	CV	Total Biomass (t)	References	Total catch (t)	Exploitation rate (catch/biomass)
1998	2 214	7.3	113	11.5	2 327	Osborne (1999)	436	0.19
1999	2 012	8.1	151	22.1	2 163	Breen & Kendrick (1999)	335	0.15
2000	1 810	8.8	86	15.4	1 895	Breen (2000)	132	0.07
2001	1 353	9.7	25	20.3	1 378	Horn (2001)	25	0.02
2002	1 134	10	28	21.9	1 162	Horn (2002)	1	0.00
2003	1 019	10	23	26.6	1 042	Horn (2003)	183	0.18
2004	894	6.9	28	22.4	921	Horn (2004)	98	0.11
2005	932	11.3	24	30.8	956	Horn (2005)	147	0.15
2006	817	26.1	10	8.0	827	Horn (2006)	171	0.21
2007	1 275	13.5	10	31.4	1 285	Brown (2007)	132	0.10
2008	744	20.8	3	52.0	747	Tuck & Brown (2008)	21	0.03
2009	1 208	19	–•	–•	1 208	Williams *et al* (2009)	0	0.00
2010	1 259	27	–•	–•	1 259	Williams *et al* (2010)	0	0.00
2011	622	42	–•	–•	622	Williams & Michael (2011)	6	0.01
2012	567	23	–•	–•	567	Williams & Bian (2012)	0	0.00

• Golden Bay has not been surveyed since 2009 because this area has low densities of oysters and is not targeted for commercial fishing.

4.3 Estimates of Maximum Constant Yield (MCY)

Drummond (1994) estimated a MCY of 300 tonnes using method 4 in Annala *et al.*(2001), but Osborne concluded that catch levels in OYS 7 appear to be driven by the economics of the catch rates (Osborne 1999). She used equation 2 of Annala *et al.*(2001) to estimate MCY (Table 9):

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

Where B_{AV} = 1191 tonnes (from relative biomass estimates from CSEC surveys 1998 to 2012). The natural mortality (*M*) values used in the yield calculations were restricted to the range 0.1 to 0.3. This was reduced from the previous range of 0.042 to 0.9 because the extreme values were considered, by the SFWG, to be very unlikely. These estimates are not corrected for dredge efficiency (assumed to be 100%) and are likely to be conservative.

Table 9: Estimates of $F_{0.1}$ and MCY for M 0.1-0.3. MCY 1 was estimated using $F_{0.1}$ 1 from Osborne (1999), MCY 2 from $F_{0.1}$ 2 estimated from von Bertalanffy growth parameters estimated by Osborne (1999), growth data from Drummond (1994b) and Foveaux Strait oyster size weight data, and MCY 3 from $F_{0.1}$ 3 estimated von Bertalanffy growth parameters from GROTAG using the same growth and size weight data.

M	$F_{0.1}$ 1	MCY 1	$F_{0.1}$ 2	MCY 2	$F_{0.1}$ 3	MCY 3
0.1	0.29	173	0.17	101	0.22	131
0.2	–		–		0.38	226
0.3	0.45	268	0.38	226	0.55	327

4.4 Estimation of Current Annual Yield (CAY)

CAY was estimated for OYS 7 using Method 1 (Annala *et al.*2001) assuming dredge oysters are landed over the year, and using $F_{0.1}$ estimated by three different methods, a range of assumed *M* (0.1 to 0.3), and the 2012 estimate of recruited biomass (567 t; Table 10).

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

Table 10: Estimates of CAY for OYS7 using different estimates of $F_{0.1}$ over a range of assumed values for *M* (0.1–0.3), and an estimate of recruited biomass in 2012 (567 t). CAY 1 was estimated using $F_{0.1}$ 1 from Osborne (1999), CAY 2 from $F_{0.1}$ 2 estimated from von Bertalanffy growth parameters estimated by Osborne (1999) using growth data (Drummond, 1994b) and Foveaux Strait oyster size weight data, CAY 3 from $F_{0.1}$ 3 estimated von Bertalanffy growth parameters from GROTAG using the same growth and size weight data.

M	$F_{0.1}$ 1	CAY 1	$F_{0.1}$ 2	CAY 2	$F_{0.1}$ 3	CAY 3
0.1	0.29	136	0.17	84	0.22	107
0.2	–		–		0.38	163
0.3	0.45	180	0.38	156	0.55	210

The risk to the stock associated with harvesting at the estimated CAYs cannot be determined.

4.5 Other yield estimates and stock assessment results

There are no other yield estimates and stock assessments

4.6 Other factors

The challenger dredge oyster fishery is thought to be recruitment-limited. Drummond (1994a) Stead (1976) and Tunbridge (1962) attributed the lack of dense aggregations of oysters in the Challenger fishery (compared to Foveaux Strait) to a scarcity of suitable settlement surface. Challenger Oyster Enhancement Company (COEC) initiated habitat enhancement trials in 2008, aimed at boosting productivity of the fishery (Brown *et al.*2008), but these areas have been bottom trawled and there has been no monitoring to determine the effectiveness of the enhancement.

5. STATUS OF THE STOCKS

Stock Structure Assumptions

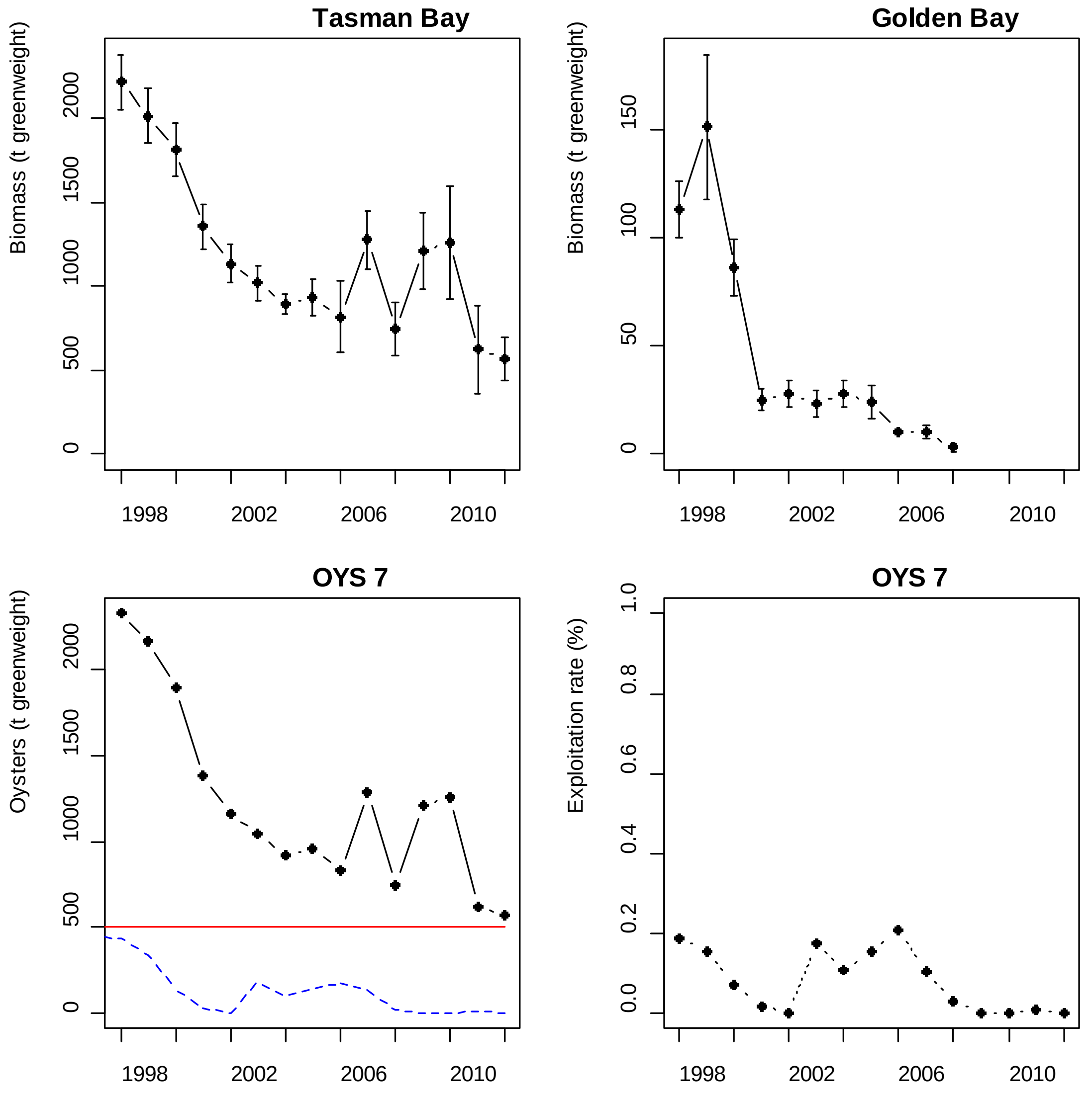
Current management assumes that the Challenger oyster fishery is separate from the other New Zealand oyster fisheries (i.e., Foveaux Strait (OYU 5), Tory Channel, Cloudy and Clifford Bays (OYS 7C), and the Chatham Islands (OYS4)). The stock structure of OYS 7 is assumed to be a single biological stock, although the extent to which the populations in Tasman Bay, Golden Bay, and the Marlborough Sounds are separate reproductively or functionally is not known. Localised patches of oysters in commercial densities within the OYS 7 fishery are largely restricted to Tasman Bay, which is likely to be a single stock.

Stock Status	
Year of Most Recent Assessment	2012
Reference Points	Target: default = 40% Bo, with at least a 50% probability of achieving the target. Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Unlikely (< 40%) to be at or above the target.
Status in relation to Limits	Likely (> 60%) to be below Soft Limit Unknown in regards to Hard Limit

Fishery and Stock Trends	
Trend in Biomass or Proxy	The current biomass of the OYS 7 stock is probably at its lowest level since the CSEC survey time series started in 1998. The estimated biomass of recruited oysters in Tasman Bay decreased from over 2000 t in 1998 to less than 1000 t in 2004, apparently fluctuated around that level until 2010, and declined to just above 500 t since then. Recruited oyster biomass in Golden Bay has shown a similar downturn, albeit

	with a much more rapid decline between 1999 and 2001, followed by a period of relative stability at a low level up to 2005, and a gradual decline to a negligible level in 2010.
Recent trend in Fishing Mortality or Proxy	The exploitation rate on recruited oysters in OYS 7 was about 15% for the periods 1998–99 and 2002–2006, but was negligible in 2000–01 and 2007–10.

Historical Stock Status Trajectory and Current Status



Top panel: Estimated (mean and c.v. of) recruited oyster biomass (t greenweight) in Tasman Bay and Golden Bay since 1998. Bottom left: Total estimated recruited biomass (solid symbols and black line), TACC (solid red line), and reported landings (dashed blue line) in t greenweight since 1998. Biomass estimates uncorrected for dredge efficiency; oysters were not surveyed in Golden Bay in 2009–12. Landings data sourced from QMRs for 1998 to 2001, and from MHRs for 2002 to present. Bottom right: Exploitation rate (catch to biomass ratio) for Golden Bay and Tasman Bay combined since 1998.

Other Abundance Indices	The abundance of pre-recruit oysters has declined at a similar rate to the recruited abundance.
Trends in Other Relevant Indicator or Variables	None
Projections and Prognosis	
Stock Projections or Prognosis	No projections have been done.
Probability of Current Catch	Soft Limit: Unknown

causing decline below Limits	Hard Limit: Unknown	
Probability of TACC causing decline below Limits	Soft Limit: The TACC is higher than the maximum estimates of CAY and MCY and catches at this level are Very Likely (> 90%) to cause the biomass to remain below the Soft Limit in the near term. Hard Limit: Catches at the level of the TACC are also Likely (> 60%) to cause the stock to drop below the Hard Limit in the near term.	
Assessment Methodology and Evaluation		
Assessment Type	Level 2: Partial Quantitative Stock Assessment - annual random stratified dredge surveys.	
Assessment Method	Yields are estimated as a proportion of the survey biomass for a range of assumed values of natural mortality and with assumed dredge efficiency of 100%.	
Assessment Dates	Latest assessment: 2012	Next assessment: unknown
Overall Assessment Quality Rank	1 – High quality	
Main data inputs (rank)	Biomass survey: 2012	1 – High quality
Data not used (rank)	Not Applicable	
Changes to Model Structure and Assumptions	The natural mortality (*M*) values used in the yield calculations were restricted to the range 0.1 to 0.3. This was reduced from the previous range of 0.042 to 0.9 because the extreme values were considered very unlikely.	
Major Sources of Uncertainty	Natural mortality (*M*) and dredge efficiency are poorly known but are integral parameters of the method used to estimate yield.	

Qualifying Comments
The OYS 7 dredge oyster fishery has a lack of dense aggregations of oysters (compared to Foveaux Strait); this is attributed to a scarcity of suitable settlement surface. Recruited biomass is being used as proxy for spawning biomass. Other benthic fisheries (e.g., bottom trawl, scallop, green-lipped mussel) occur in OYS 7 and probably interact with oysters and their habitat. The cause of the declines in these shellfish is unknown, but is probably associated with factors other than simply the magnitude of direct removals by fishing. It may be a combination of natural (e.g., oceanographic) and anthropogenic (e.g., indirect effects of fishing, land-based) factors.

Fishery Interactions
Bycatch data are collected routinely during the annual surveys. Bycatch can include scallops, green-lipped mussels, and a range of other benthic invertebrates. The bycatch of the fishery is likely to be similar to that of the survey.

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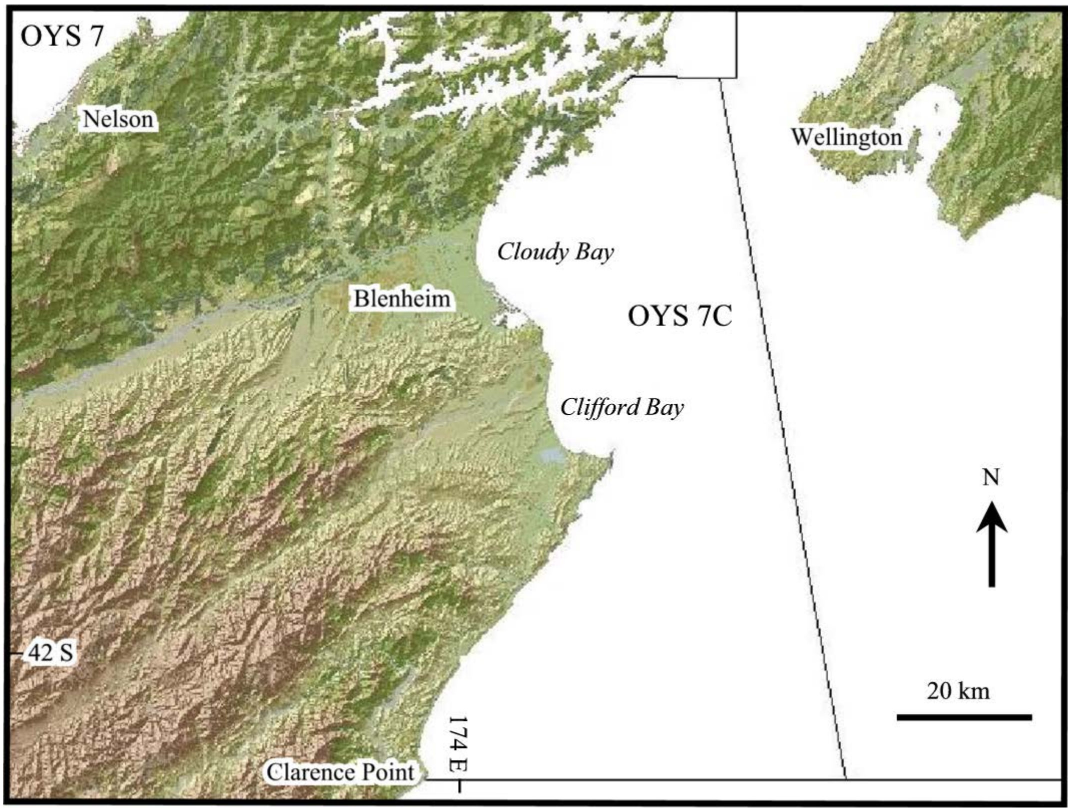
DREDGE OYSTERS (OYS 7C) – Challenger Marlborough

(Ostrea chilensis)



1. FISHERY SUMMARY

Oysters in the area Clarence Point to West Head, Tory Channel, were introduced into the QMS as OYS 7C in October 2005 with a TAC of 5 t and a TACC of 2 t. Following a survey in April 2007, the TAC was increased to 50 t with a TACC of 43 t on 1 October 2007. On 1 October 2009 the TAC was further increased to 72 t with a TACC of 62 t (Table 1) based on industry catch and CPUE data. The Shellfish Working Group (30 March 2009) suggested that raising the TACC by a further 15-20 tonnes was unlikely to be detrimental to the fishery in the short-term, however without improved estimates of mortality, growth, and dredge efficiency, it was difficult to predicted the effects the current TACC or an increased TACC would have on the status of the fishery in the medium to long-term, and that a research strategy for improved assessment was required.

Table 1: Total Allowable Commercial Catch (TACC, t) declared for OYS 7C since introduction into the QMS in 2005.

Fishing year	TAC	TACC	Customary	Recreational	Other
2005–07	5	2	–	–	–
2007-09	50	43	–	–	–
2009-present	72	62	1	1	8

1.1 Commercial fishery

OYS 7C encompasses an area from West Head, Tory Channel in the north to Clarence Point in the south including Cloudy Bay and Clifford Bay. OYS7 and OYS 7C are considered separate fisheries on the basis of differences in habitat and environmental parameters.

There is historical evidence of limited exploitation of oyster beds within Port Underwood as early as the 1800s (K. Wright pers. comm. in Drummond 1994a). Limited fishing under a special permit took place south of Tory Channel on the east coast of the South Island in 1990 and 1991.

The fishing year runs from 1 October to 30 September and fishers can harvest year round (there is no oyster season defined by regulations). Since 2005, catch has been reported via Monthly Harvest Returns (Table 2). During the 2007-08 season fishing took place over 30 fishing days from December to February and in 2008-09 fishing took place from January to April.

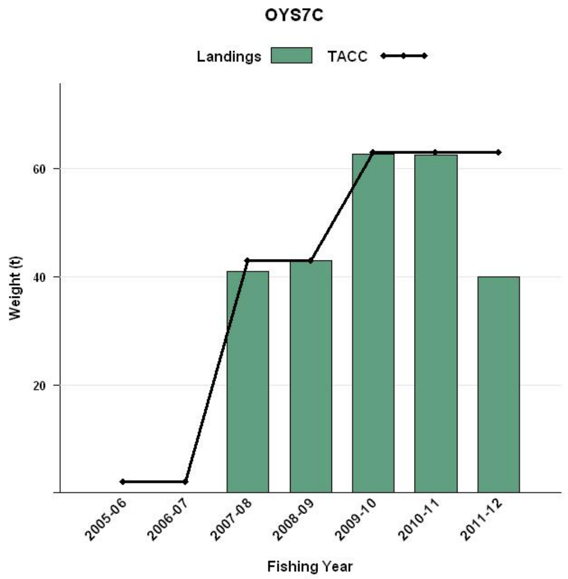


Figure 1: Reported landings and TACC for OYS7C from 2005-06 to 2011-12.

Table 2: Reported landings (t) in the OYS 7C fishery since October 2005 (QMS). Reported catch is landed green weight summarised from Monthly Harvest Returns.

Fishing year	TACC	Reported Landings (MHR)
2005–06	2	0.1
2006–07	2	0
2007–08	43	40.9
2008–09	43	38.2
2009–10	62	62.7
2010–11	62	62.5
2011-12	62	39.9

1.2 Recreational fishery
The recreational catch allowance for OYS 7C is 1 tonne. The recreational daily bag limit for oysters in the Challenger fishery area is 50 per person. Oysters that cannot pass through a 58 mm internal diameter solid ring are deemed legal size. The recreational season for dredge oysters in the Challenger area is all year round. Oysters must be landed in their shells. There is no data available on the recreational catch within OYS 7C.

1.3 Customary fisheries
The customary catch allowance for OYS 7C is 1 tonne. There are no data available on the customary catch.

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

1.5 Other sources of mortality

Bonamia exitiosa is a haemocritic, haplosporid parasite (infects mainly haemocytes or blood cells) of flat oysters and is known to infect *Ostrea chilensis* in New Zealand and Chile and various other species of *Ostrea* in other countries. *Bonamia* has caused catastrophic mortality in the Foveaux Strait oyster fishery and is endemic in oysters in the OSY 7 area (Hine *pers. comm.*). The level of mortality caused by disease is unknown.

An allowance of 8t for incidental fishing mortality, heightened natural mortality (disease mortality), and illegal harvest is included in the TAC.

2. BIOLOGY

There are no biological studies of *O. chilensis* specific to the OYS 7C area. In the absence of area-specific estimates, parameters required for management purposes are based on the Foveaux Strait fishery described by Cranfield & Allen (1979) or the OYS 7 (Tasman Bay) fishery. The biology of oysters in the neighbouring area OYS 7 (Tasman and Golden Bay) was summarised by Handley & Michael (2001), and further biological data was presented in Brown *et al.*(2008). Work on oyster biology from OYS 7 is summarised below.

Oysters in OYS 7C (Cloudy Bay/Clifford Bay) and OYU 5 (Foveaux) both comprise rather discrete patches of oysters on a predominantly sandy substrate whereas OYS 7 (Tasman Bay) oysters tend to be more uniformly distributed at a lower density on muddy habitat. Environmental factors such as hydrodynamics, seasonal water temperature and riverine inputs differ substantially among the OYS 7, OYS 7C and OYU 5 areas and are likely to influence the biological characteristics of those oyster populations. Oysters in OYS 7C are generally more abundant and occur at higher densities than in OYS 7 (Brown & Horn 2007).

The variability in shell shapes and high variability in growth rate between individuals, between areas within the OYS 7 fishery, and between years require careful consideration in describing growth. Assuming the minimum legal size could range in diameter (1/2 length + height) from 58 mm to 65 mm, data from Drummond (1994b) indicated that Tasman Bay oysters could grow to legal size in two to three years. Modelling of limited data from Tasman Bay in Brown *et al.*(2008) indicated that 77% of three year old oysters and 82% of 4 year old oysters would attain lengths greater than the minimum legal size of 58 mm length at the start of the fishing season. Osborne (1999) used results from a MAF Fisheries study conducted between 1990 and 1994 to construct a von Bertalanffy equation describing oyster growth in the OYS 7 fishery. Estimated biological parameters including instantaneous natural mortality (*M*) from Drummond (1993, 1994b) and growth parameters for von Bertalanffy equations from Osborne (1999) and from Brown *et al.*(2008) are given in Table 3. Mortality estimates by Drummond (1994b) and growth parameters in Osborne (1999) were derived from a tagging study conducted in Tasman Bay between 1990 and 1992 (Drummond 1993). von Bertalanffy growth parameters in Brown *et al.*(2008) were estimated based on a limited data set from enhanced habitat experiments, and describe growth of young oysters. Estimates of *M* based on experimental data from Foveaux and Tasman Bay ranged from 0.042 (Dunn *et al.*1998b) to 0.92 (Drummond *et al.*1994). However, after some discussion the Shellfish Working Group concluded that those figures were not realistic, and that *M* was likely to lie between 0.1 and 0.3.

Table 3: Estimated biological parameters for oysters in OYS 7 and OYU 5. In the absence of data specific to OYS 7C these estimates are used for management purposes in OYS 7C.

1. Natural Mortality (M)

Area	Estimate	Source
Tasman Bay	0.920	Drummond (1994b)
Tasman Bay	0.200	Drummond (1993)
Foveaux Strait	0.042	Dunn *et al.*(1998b)
Foveaux Strait	0.100	Allen (1979)

2. von Bertalanffy growth (change in diameter mm) parameter estimates from OYS 7. t_0 not provided by Osborne (1999).

K	L_{inf}	t_0	Source
0.597	85.43	-	Osborne (1999)
0.99 +/- 0.16 (sd)	67.52	0.11	Brown *et al.*(2008)

3. STOCKS AND AREAS

Fishing within OYS 7C has been limited to two discrete areas; one in parts of Clifford and Cloudy Bays and the other immediately south of Tory Channel, and commercial oyster fishing has not extended south of Cape Campbell. The OYS 7C stock can be considered biologically isolated from the Foveaux Strait population on the basis of geographical distance. The populations in OYS 7 and OYS 7C could be biologically distinct due to their geographical separation and limited larval dispersal.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

A survey of oysters carried out in 2007 (Brown & Horn 2007) estimated the number of recruits (oysters unable to pass through a 58 mm ring) and pre-recruits (less than 58 mm) from Clifford and Cloudy Bay (Table 4). Dredge efficiency was assumed to be 100% for the purposes of the survey.

Table 4: Estimate of number of recruit and pre-recruit oysters from Brown & Horn (2007).

Year	Area (Ha)	Recruit No. estimate	CV %	Pre-recruit No. estimate	CV %
2007	43 709	19.5 Million	19	14 Million	19

4.2 Biomass estimates

The recruited biomass (≥ 58 mm) of oysters in Cloudy Bay and Clifford Bay was estimated in a survey carried out in 2007 (Brown & Horn 2007; Table 5).

Table 5: Estimate of relative recruited oyster (≥ 58 mm) biomass (t) in OYS 7C (Brown & Horn 2007).

Year	Area (Ha)	Biomass estimate	CV %
2007	43 709	1 778	19

4.3 Estimates of Maximum Constant Yield (MCY)

For new fisheries where there are insufficient data to conduct a yield per recruit analysis, yield can be estimated using the formula from Mace (1988) recommended by the Ministry of Fisheries Science Group (MFish 2008) for calculation of Maximum Constant Yield (MCY).

$$MCY = 0.25MB_0$$

where B_0 is an estimate of virgin recruited biomass (here assumed to equal the recruited biomass estimate from the survey, divided by dredge efficiency) and *M* is an estimate of natural mortality.

A range of MCY estimates are given in Table 6 using values for dredge efficiency of 100% and 64% (Bull 1989), and values for *M* ranging from 0.1 to 0.3 taken from studies conducted in the Foveaux and Nelson-Marlborough oyster fisheries.

Where B_0 = 1778 tonnes (Brown & Horn 2007).

Table 6: Estimates of MCY for *M* of 0.042–0.9. MCY 1 was estimated using Dredge efficiency of 64% from Bull (1989) and MCY 2 using dredge efficiency of 100%.

M	MCY 1	MCY 2
0.1	69	44
0.2	139	89
0.3	208	133

4.4 Estimation of Current Annual Yield (CAY)

There are no CAY estimates for OYS 7C

4.5 Other Yield Estimates

There are no other yield estimates or stock assessments

4.6 Other Factors

Dredging for oysters will have an impact on the soft sediment habitats within Cloudy and Clifford Bays, and will affect both the dredge oyster beds and other species found in association with these beds. In addition, various areas within the fishery (mainly around coastal rocky reefs) are understood to support a range of sensitive invertebrate species including soft corals, large erect and divaricating bryozoans, starfish, horse mussels, and crabs. The impacts of dredging are likely to be more severe on these habitats than on soft sediments, and will increase with increasing fishing effort, but there is insufficient information to quantify the degree of impact under any given TAC. There may be some overlap with other fisheries that contact the bottom in this area, but this has not been quantified.

Industry has proposed to voluntarily restrict fishing to two discrete areas to mitigate the effects of fishing. These areas are where oyster densities are highest. By-catch of benthic invertebrates was collected during the biomass survey and could be analysed to help to determine the distribution of sensitive habitats.

5. STOCK STATUS

Stock Structure Assumptions

The stock is likely to be biologically isolated from the Foveaux Strait population on the basis of geographical distance. The populations in OYS 7 and OYS 7C could also be biologically distinct due to their geographical separation and limited larvae dispersal. Survey data suggest that the patchy distribution of oysters in the commercial fishery area in OYS 7C may comprise mainly self-recruiting stocks.

Stock Status	
Year of Most Recent Assessment	2009
Reference Points	Target: Default = 40% B_0, with at least a 50% probability of achieving the target. Soft Limit: 20% B_0

	Hard Limit: 10% B_0
Status in relation to Target	Very likely to be at or above the target
Status in relation to Limits	Based on annual oyster removals of 5% of the stock, the status is likely to be close to virgin size and Exceptionally Unlikely (< 1%) to be below the soft and hard limits.

Fishery and Stock Trends	
Recent trend in Biomass or Proxy	The commercial OYS7C fishery got underway in 2007 and no biomass trend have yet been established. Only one biomass survey has been conducted prior to the increase in TAC in 2007.
Recent trend in Fishing Mortality or Proxy	In 2007 exploitation rate was estimated at 2.5% per year (assuming 100% dredge efficiency).
Other Abundance Indices	None
Trends in Other Relevant Indicator or Variables	None

Projections and Prognosis		
Stock Projections or Prognosis	Quantitative stock projections are unavailable. The FAWG was asked to evaluate the implications of raising the TACC by 15–20 t. In 2009 it was considered Very Unlikely (< 10%) that an increase in the TACC of this amount would cause the biomass to decline below the Soft Limit in the next 3 to 5 years.	
Probability of Current Catch / TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown	
Assessment Methodology		
Assessment Type	Level 2: Partial Quantitative Stock Assessment:	
Assessment Method	Yields are estimated as a proportion of the survey biomass for a range of assumed values of natural mortality and dredge efficiency.	
Assessment Dates	Latest assessment: 2009	Next assessment: Unknown
Overall Assessment Quality Rank	1 - High Quality	
Main data inputs (rank)	Biomass survey: 2007	1 – High Quality
Period of Assessment	Latest assessment: 2009	Next assessment: Unknown
Data not used (rank)	Not Applicable	
Changes to Model Structure and Assumptions		
Major Sources of Uncertainty	There has been only a single biomass survey of this fishstock and repeat surveys should be scheduled at regular intervals. Natural mortality (M) and dredge efficiency are poorly known but are integral parameters of the method used to estimate yield. The response of localised populations to fishing.	

Qualifying Comments
Some of the surveyed area was not actively fished up to 2009. There are areas of potential oyster habitat which are not fished due to sanitation concerns and substrate which is marginal for fishing.
Fishery Interactions
There may be some overlap with other fisheries that contact the bottom in this area, but this has not been quantified.

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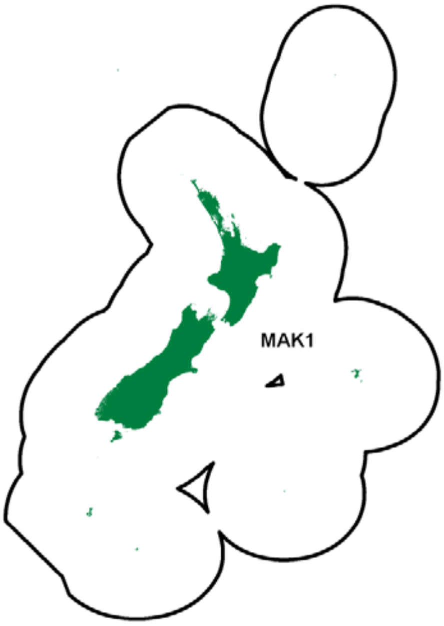
MAKO SHARK (MAK)

(*Isurus oxyrinchus)*
Mako



1. FISHERY SUMMARY

Mako shark were introduced into the QMS on 1 October 2004 under a single QMA, MAK 1, with a TAC of 542 t, a TACC of 406 t and a recreational allowance of 50 t. The TAC was reviewed in 2012 with the reduced allocation and allowances applied from 1 October 2012 in Table 1. The decrease was in response to sustainability concerns that mako shark is considered to be a risk of overfishing internationally because of its low productivity.

Table 1: Recreational and Customary non-commercial allowances, TACCS and TACs (all in tonnes) for mako shark.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other mortality	TACC	TAC
MAK 1	30	10	36	200	276

Mako shark was added to the Third Schedule of the 1996 Fisheries Act with a TAC set under s14 because mako shark is a highly migratory species and it is not possible to estimate MSY for the part of the stock that is found within New Zealand fisheries waters.

Mako shark was also added to the Sixth Schedule of the 1996 Fisheries Act with the provision that:

> "A commercial fisher may return any mako shark to the waters from which it was taken from if –
> (a) that mako shark is likely to survive on return; and
> (b) the return takes place as soon as practicable after the mako shark is taken."

Management of the mako shark throughout the western and central Pacific Ocean (WCPO) is the responsibility of the Western and Central Pacific Fisheries Commission (WCPFC). Under this regional convention New Zealand is responsible for ensuring that the management measures applied within New Zealand fisheries waters are compatible with those of the Commission.

1.1 Commercial fisheries

Most of the commercial catch of mako sharks is taken by tuna longliners and bottom longliners and they are also incidental bycatch of bottom and mid-water trawlers. About 25% of mako sharks caught by tuna longliners are processed and the rest are discarded.

Landings of mako sharks reported on CELR (landed), CLR, LFRR, and MHR forms are shown in Table 2. The total weights reported by fishers were 74–295 t during 1997–98 to 2008–09. Processors reported 74–319 t on LFRRs during the same period. There was a steady increase in the weight of mako shark landed between 1997–98 and 2000–01, resulting from a large increase in domestic fishing effort in the tuna longline fishery, and probably also improved reporting. Landings have since declined to one-quarter of the peak landings. Estimates of the catch of mako sharks aboard tuna longliners, based on scaled up observer records, are imprecise, and possibly biased, because the observer coverage of the domestic fleet (which accounts for most of the fishing effort) has been low (just below 10% in the last years 2007-2011) and may not have adequately covered the spatial and temporal distribution of the fishery.

In addition to catch taken within New Zealand fisheries waters, a small amount (about 1 t) is taken by New Zealand longline vessels fishing on the high seas.

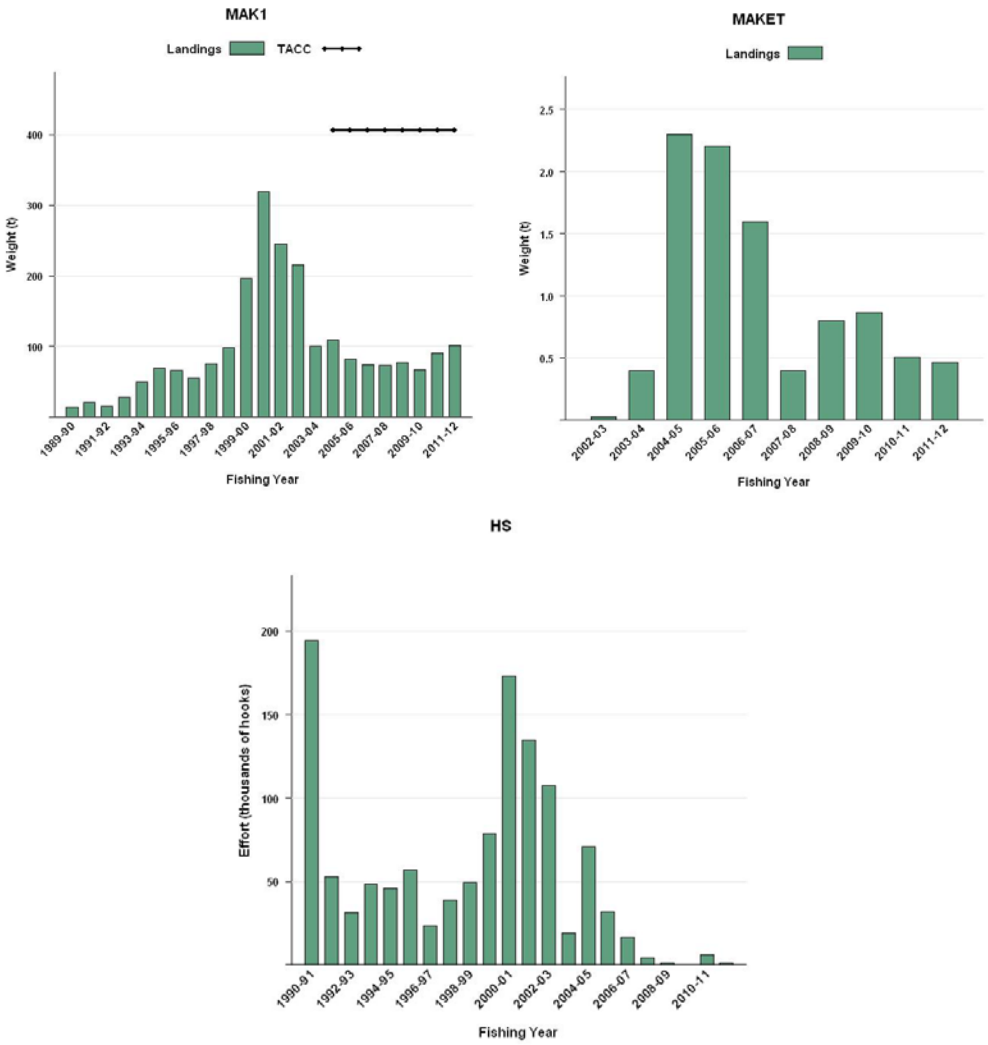


Figure 1: [Top] Mako Shark catch from 1989-90 to 2011-12 within NZ waters (MAK1) and 2002-03 to 2011-12 on the high seas (MAKET). [Bottom] Fishing effort (number of hooks set) for high seas New Zealand flagged surface longline vessels, from 1990-91 to 2011-12.

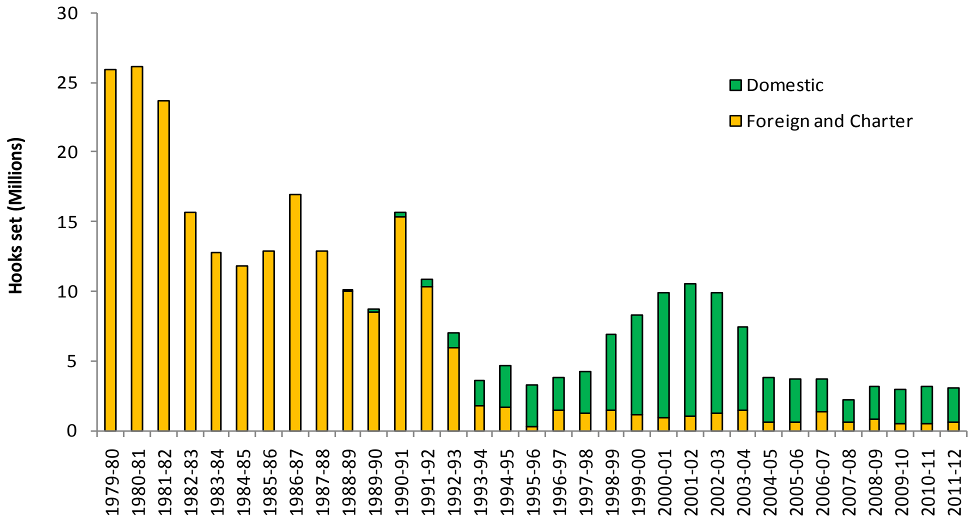


Figure 1 [Continued]: Fishing effort (number of hooks set) for all domestic vessels (including effort by foreign vessels chartered by NZ fishing companies), from 1979-80 to 2011-12.

Table 2: New Zealand commercial landings (t) of mako sharks reported by fishers (CELRs and CLRs) and processors (LFRRs) by fishing year. Also shown for some years are the estimated numbers of makos caught by tuna longliners, as reported to the WCPFC

Year	Total reported	LFRR/MHR	Estimated catch by tuna longliners
1989-90	11	15	
1990-91	15	21	
1991-92	17	16	
1992-93	24	29	
1993-94	44	50	
1994-95	63	69	
1995-96	67	66	
1996-97	51	55	
1997-98	86	76	
1998-99	93	98	
1999-00	148	196	
2000-01	295	319	
2001-02	242	245	
2002-03*	233	216	
2003-04*	100	100	
2004-05*	107	112	
2005-06*	83	84	6 560
2006-07*	76	75	3 859
2007-08*	72	74	
2008-09*	82	78	
2009-10*		67	
2010-11*		91	
2011-12*		101	

*MHR rather than LFRR data.

Catches of mako sharks reported by Ministry of Fisheries Observer Services aboard tuna longliners are concentrated off the west and southwest coast of South Island, and the northeast coast of North Island. However, these apparent distributions are biased by the spatial distribution of observer coverage. Mako sharks are probably taken by tuna longliners throughout New Zealand fishery waters. The target species for this fishery are mainly southern bluefin, bigeye, swordfish and albacore tuna. Most of the mako landings reported on CELR and CLR forms were taken in FMAs 1 and 2.

The majority of mako shark (58%) are caught in the bigeye tuna target surface longline fishery (Figure 2), however, across all longline fisheries albacore make up the bulk of the catch (33%) (Figure 3). Longline fishing effort is distributed along the east coast of the North Island and the south west coast of the South Island. The west coast South Island fishery predominantly targets southern bluefin tuna, whereas the east coast of the North Island targets a range of species including bigeye, swordfish, and southern bluefin tuna (Figure 4).

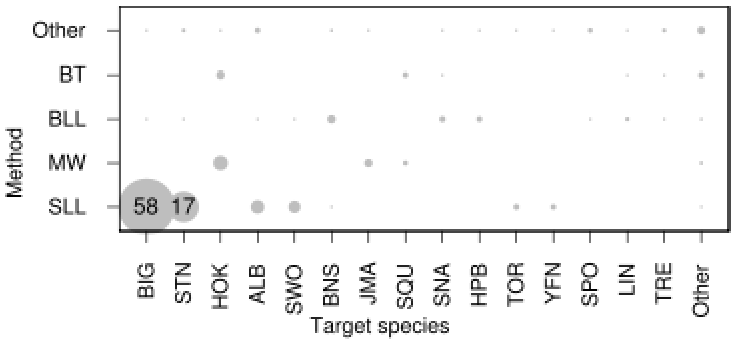


Figure 2: A summary of the proportion of landings of mako shark taken by each target fishery and fishing method. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the bobble is the percentage. SLL = surface longline, MW = mid-water trawl, BLL = bottom longline, BT = bottom trawl (Bentley *et al.* 2012).

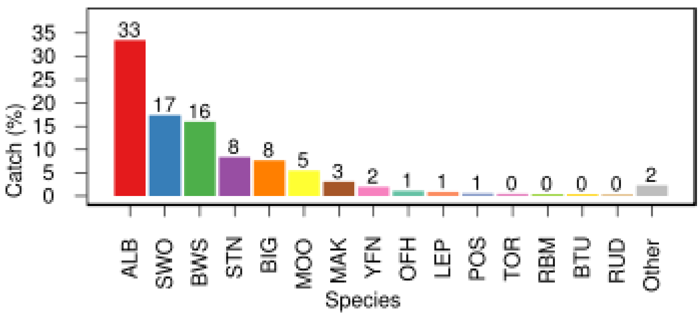


Figure 3: A summary of species composition of the reported surface longline catch. The percentage by weight of each species is calculated for all surface longline trips (Bentley *et al.* 2012).

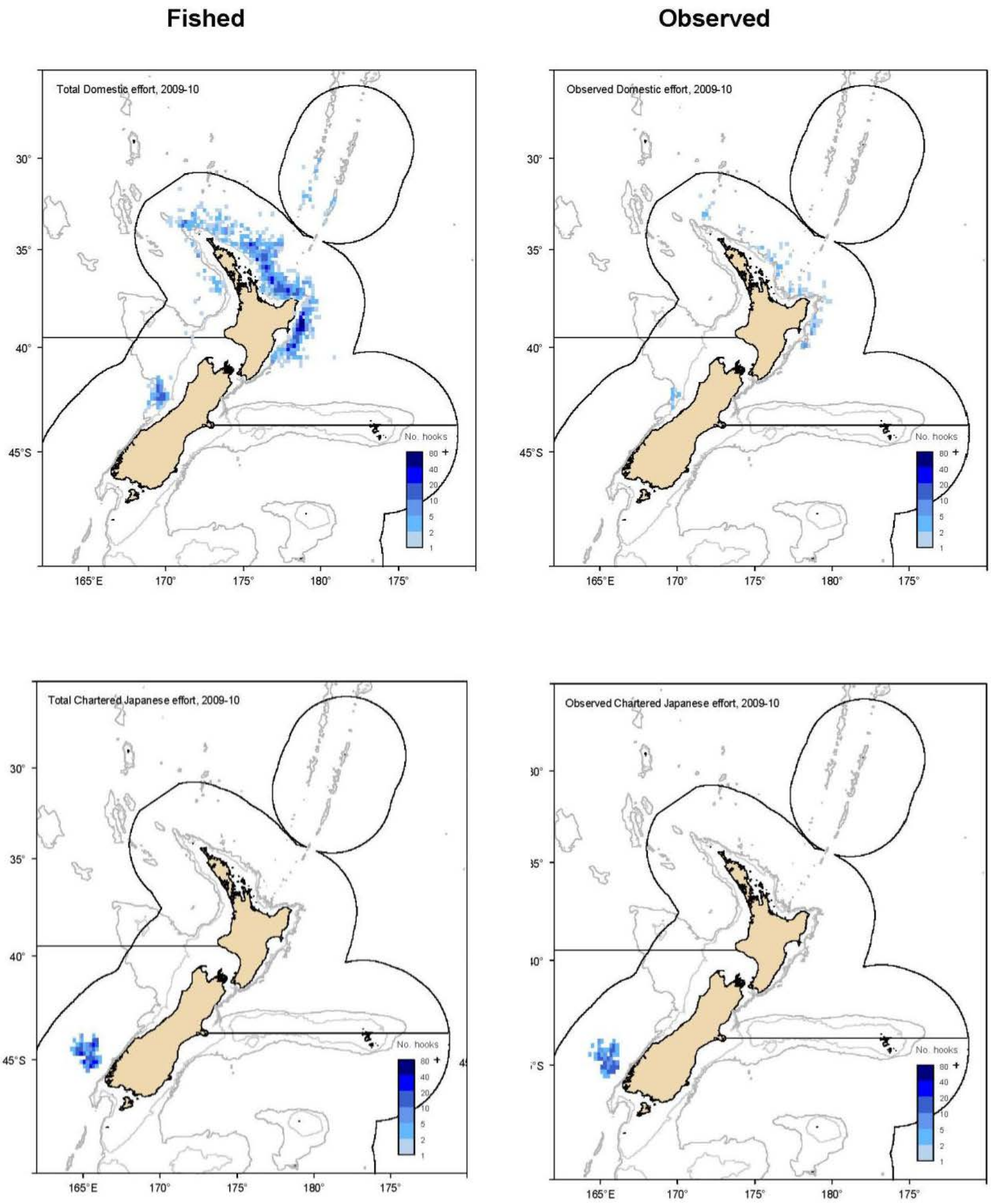


Figure 4: Distribution of fishing positions for domestic (top two panels) and charter (bottom two panels) vessels, or the 2009-10 fishing year, displaying both fishing effort (left) and observer effort (right).

In the longline fishery 73.6% of the mako sharks were alive when brought to the side of the vessel for all fleets (Table 3). The domestic fleets retain around 19-67% of their mako shark catch, mostly for the fins, while the foreign charter fleet retain most of the blue sharks (94-100%) (mostly for fins), the Australian fleet that fished in New Zealand waters in 2006-07 retained most (93.8%) of their mako sharks (Table 4).

Table 3: Percentage of mako shark (including discards) that were alive or dead when arriving at the longline vessel and observed during 2006–07 to 2009–10, by fishing year, fleet and region. Small sample sizes (number observed < 20) were omitted Griggs and Baird (in press).

Year	Fleet	Area	% alive	% dead	Number
2006-07	Australia	North	82.1	17.9	28
	Charter	North	83.0	17.0	276
		South	93.1	6.9	29
	Domestic	North	67.6	32.4	262
	Total		**76.6**	**23.4**	**595**
2007-08	Domestic	North	63.8	36.2	304
	Total		**64.7**	**35.3**	**320**
2008-09	Charter	North	88.6	11.4	44
		South	100.0	0.0	31
	Domestic	North	69.6	30.4	289
	Total		**74.4**	**25.6**	**367**
2009-10	Domestic	North	76.1	23.9	330
	Total		**75.9**	**24.1**	**348**
Total all strata			**73.6**	**26.4**	**1 630**

Table 4: Percentage of mako shark that were retained, or discarded or lost, when observed on a longline vessel during 2006–07 to 2009–10, by fishing year and fleet. Small sample sizes (number observed < 20) omitted Griggs and Baird (in press).

Year	Fleet	% retained or finned	% discarded or lost	Number
2006-07	Australia	17.9	82.1	28
	Charter	93.8	6.2	323
	Domestic	37.0	63.0	262
	Total	**66.1**	**33.9**	**613**
2007-08	Domestic	66.6	33.4	305
	Total	**68.2**	**31.8**	**321**
2008-09	Charter	100.0	0.0	85
	Domestic	58.7	41.3	293
	Total	**68.0**	**32.0**	**378**
2009-10	Domestic	19.1	80.9	350
	Total	21.6	78.4	361
Total all strata		**57.3**	**42.7**	**1 673**

1.2 Recreational fisheries

Historically there was a recreational target fishery for mako sharks and they were highly prized as a sport fish. Most mako sharks are now taken as a bycatch while targeting other species. Reported catch has declined since the mid 1990s. Fishing clubs affiliated to the New Zealand Sports Fishing Council have reported landing about 40 makos per year over the last five seasons. In addition recreational fishers tag and release 300 to 500 makos per season.

1.3 Customary non-commercial fisheries

There are no estimates of Maori customary catch of mako sharks. Traditionally, makos were highly regarded by Maori for their teeth, which were used for jewellery. Target fishing trips were made, with sharks being caught by flax rope nooses to avoid damaging the precious teeth.

1.4 Illegal catch

There is no known illegal catch of mako sharks.

1.5 Other sources of mortality

Many of the mako sharks caught by tuna longliners (about 75%) are alive when the vessel retrieves the line. It is not known how many of the sharks that are returned to the sea alive under the provisions of Schedule 6 of the Fisheries Act survive.

2. BIOLOGY

Mako sharks occur worldwide in tropical and warm temperate waters, mainly between latitudes 50^{o}N and 50^{o}S. In the South Pacific, makos are rarely caught south of 40^{o}S in winter–spring (August–November) but in summer–autumn (December–April) they penetrate at least as far as 55^{o}S. Makos occur throughout the New Zealand EEZ (to at least 49^{o}S), but are most abundant in the north, especially during the colder months.

Mako sharks produce live young around 57–69 cm fork length (FL). In New Zealand, male mako sharks mature at about 1980 cm fork length (Francis 2005) (Figure 5) and female makos mature at about 275–285 cm FL (Francis 2005) (Figure 6). The length of the gestation period is uncertain, but is thought to be 18 months with a resting period between pregnancies leading to a two- or three-year pupping cycle. Only one pregnant female has been recorded from New Zealand, but newborn young are relatively common. Litter size is 4–18 embryos. If the reproductive cycle lasts three years, and mean litter size is 12, mean annual fecundity would be 4 pups per year.

Estimates of mako shark age and growth in New Zealand were derived by counting vertebral growth bands, and assuming that one band is formed each year. This assumption has recently been validated for North Atlantic mako sharks. Males and females grow at similar rates until age 7–9 years, after which the relative growth of males declines. In New Zealand, males mature at about 7–9 years and females at 19–21 years. The maximum ages recorded are 29 and 28 years for males and females respectively.

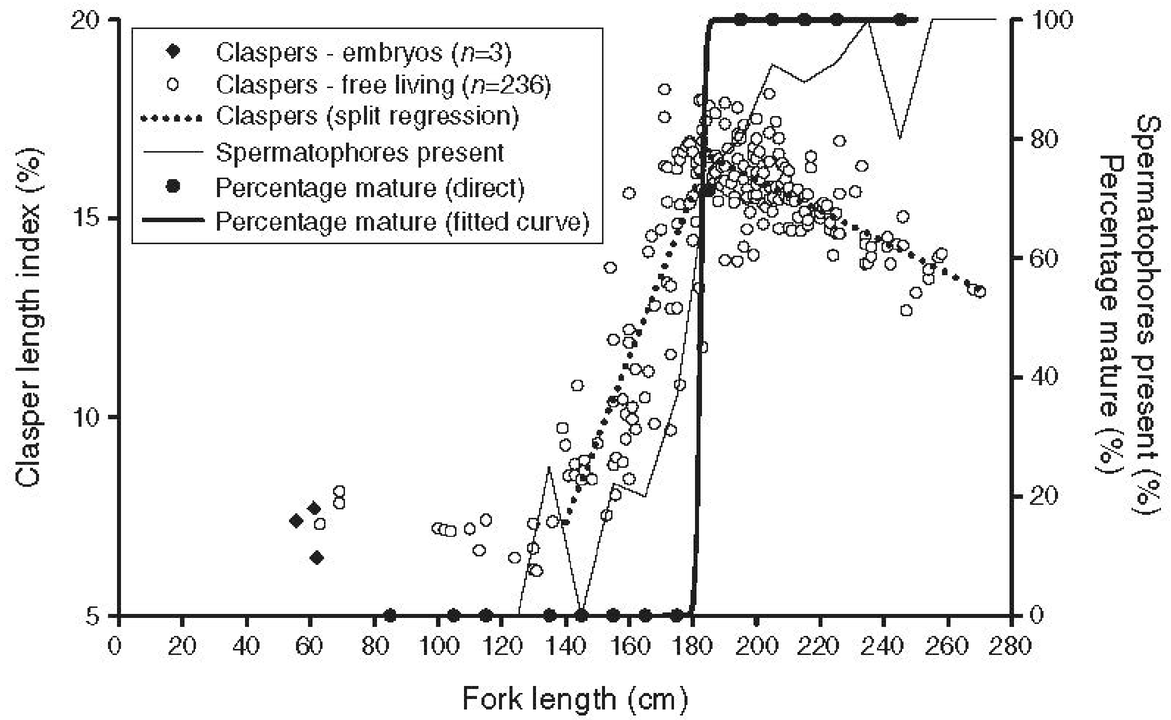


Figure 5: Maturation of male shortfin mako sharks (*Isurus oxyrinchus*): variation in clasper development, presence of spermatophores in the reproductive tract, and direct maturity estimation determined from a suite of maturity indicators (Francis 2005).

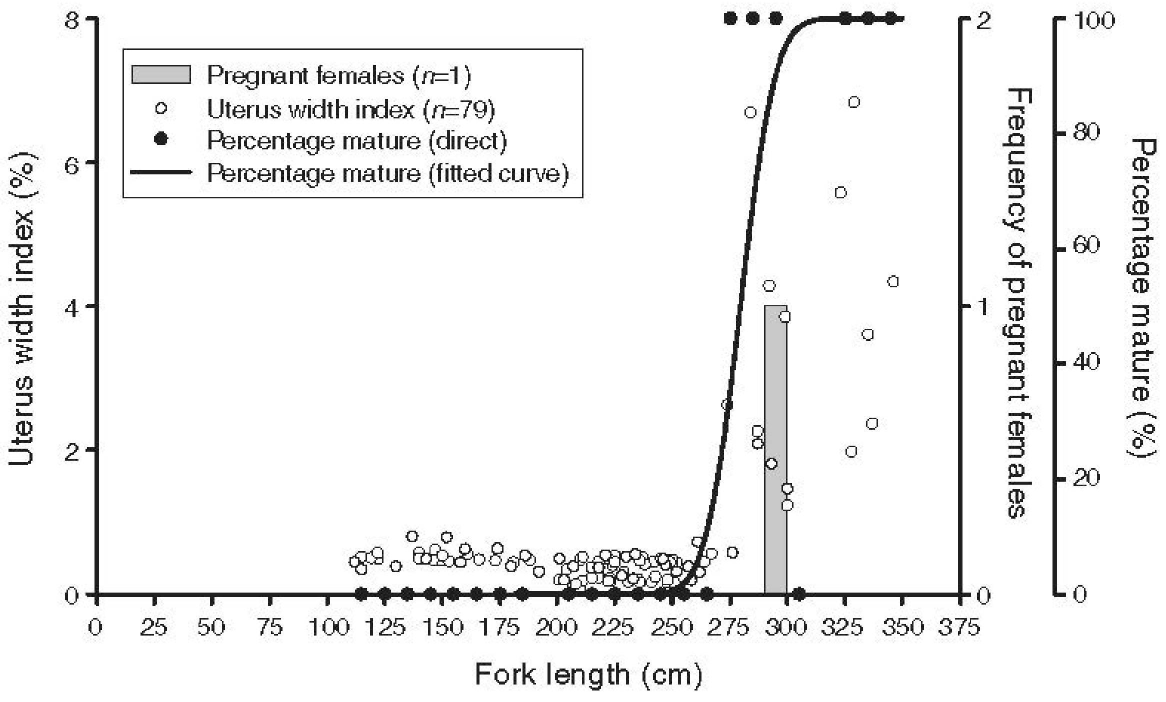


Figure 6: Maturation of female shortfin mako sharks (*Isurus oxyrinchus*): variation in uterus width index, and direct maturity estimation from a suite of maturity indicators. The only pregnant female recorded from New Zealand waters is also indicated (Francis 2005).

The longest reliably measured mako appears to be a 351 cm FL female from the Indian Ocean, but it is likely that they reach or exceed 366 cm FL. In New Zealand, makos recruit to commercial fisheries during their first year at about 70 cm FL, and much of the commercial catch is immature. Sharks less than 150 cm FL are rarely caught south of Cook Strait, where most of the catch by tuna longliners consists of sub-adult and adult males.

Makos are active pelagic predators of other sharks and bony fishes, and to a lesser extent squid. As top predators, makos probably associate with their main prey, but little is known of their relationships with other species.

Estimates of biological parameters are given in Table 5.

Table 5: Estimates of biological parameters.

Fishstock	Estimate				Source
1. Natural mortality (M)					
MAK 1	0.10-0.15				Bishop *et al.* (2006)
2. Weight = a(length)^b (Weight in kg, length in cm fork length)					
Both sexes combined	a		b		
MAK 1	2.388×10^{-5}		2.847		Ayers *et al.* (2004)
3. Schnute growth parameters	L_1	L_{10}	κ	γ	
MAK 1 males	100.0	192.1	-	3.40	Bishop *et al.* (2006)
MAK 1 females	99.9	202.9	-0.07	3.67	Bishop *et al.* (2006)

3. STOCKS AND AREAS

Up to June 2012, 13 551 makos had been tagged and released in New Zealand waters and 341 recaptured. Most of the tagged fish in recent years were small to medium sharks with estimated total weights at 90 kg or less, with a mode at 40 to 50 kg, and they were mainly tagged off east Northland and the west coast of the North Island. Most recaptures have been within 500 km of the release site, with sharks remaining around east Northland or travelling to the Bay of Plenty and the west coast of North Island. However, long distance movements out of the New Zealand EEZ are frequent, with makos travelling to Australia or the western Tasman Sea (1500–2000 km), the tropical islands north of New Zealand (New Caledonia, Fiji, Tonga, Solomon Islands; 1500–2400 km) and to the Marquesas Islands in French Polynesia (4600 km).

DNA analysis of mako sharks collected in the North-east Pacific, South-west Pacific (Australia), North Atlantic and South-west Atlantic oceans showed that North Atlantic makos were genetically isolated from those found elsewhere, but there was no significant difference among the remaining sites.

The stock structure of mako sharks in the Southern Hemisphere is unknown. However, given the scale of movements of tagged sharks, it seems likely that sharks in the South-west Pacific comprise a single stock. There is no evidence to indicate whether this stock also extends to the eastern South Pacific or the North Pacific.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the November 2012 Fishery Assessment Plenary after review by the Aquatic Environment Working Group. This summary is from the perspective of mako shark but there is no directed fishery for them and the incidental catch sections below reflect the New Zealand longline fishery as a whole and are not specific to this species; a more detailed summary from an issue-by-issue perspective is, or will shortly be, available in the Aquatic Environment & Biodiversity Annual Review where the consequences are also discussed. (http://www.mpi.govt.nz/news-resources/publications.aspx).

4.1 Role in the ecosystem

Mako sharks (*Isurus oxyrinchus*) are active pelagic predators of other sharks and bony fishes, and to a lesser extent squid (Figure 7 and Figure 8) (Giggs *et al.* 2007). Throughout their life the diet remains dominated by fish with squid making up a small percentage of their gut contents.

4.2 Diet

Mako shark

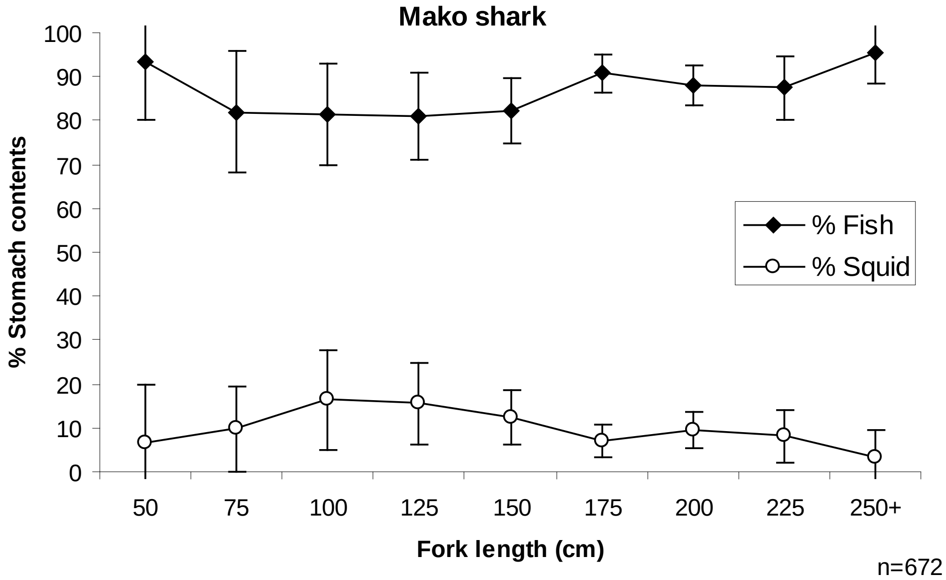


Figure 7: Changes in percentage of fish and squid in stomachs of mako sharks with fork length.

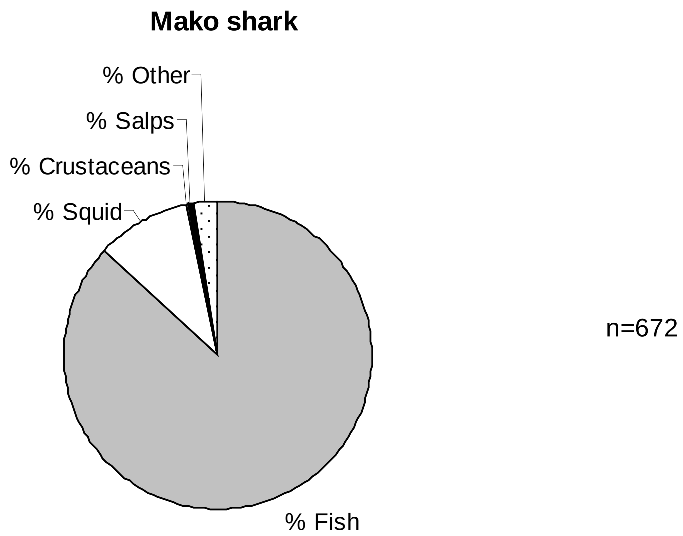


Figure 8: Percentage composition of stomach contents (estimated volumetric) or make sharks sampled in New Zealand fishery waters.

4.3 Incidental catch (seabirds, sea turtles and mammals)

The protected species, capture estimates presented here include all animals recovered onto the deck (alive, injured or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds caught on a hook but not brought onboard the vessel).

4.3.1 Seabird bycatch

Between 2002–03 and 2010–11, there were 731 observed captures of birds across all surface longline fisheries. Seabird capture rates since 2003 are presented in Figure 9. While the seabird capture distributions largely coincide with fishing effort that are more frequent off the south west coast of the South Island (Figure 10). The analytical methods used to estimate capture numbers across the commercial fisheries have depended on the quantity and quality of the data, in terms of the numbers observed captured and the representativeness of the observer coverage. Ratio estimation was historically used to calculate total captures in longline fisheries by target fishery fleet and area (Baird 2008) and by all fishing methods but recent estimates are either ratio or model based as specified in the tables below (Abraham *et al.* 2010a).

Through the 1990s the minimum seabird mitigation requirement for surface longline vessels was the use of a bird scaring device (tori line) but common practice was that vessels set surface longlines primarily at night. In 2007 a notice was implemented under s 11 of the Fisheries Act 1996 to formalise the requirement that surface longline vessels only set during the hours of darkness and use a tori line when setting. This notice was amended in 2008 to add the option of line weighting and tori line use if setting during the day. In 2011 notices were combined and repromulgated under a new regulation (Regulation 58A of the Fisheries (Commercial Fishing) Regulations 2001) which provides a more flexible regulatory environment under which to set seabird mitigation requirements.

Table 6: Number of observed seabird captures in surface longline fisheries, 2002-03 to 2010-11, by species and area (Thompson & Abraham (2012) from http://data.dragonfly.co.nz/psc/). See glossary above for areas used for summarising the fishing effort and protected species captures. 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 mako shark using longline gear but rather the total risk for each seabird species.

Species	Risk ratio	Kermadec Islands	Northland and Hauraki	Bay of Plenty	East Coast North Island	Stewart Snares Shelf	Fiordland	West Coast South Island	West Coast North Island	Total
Salvin's albatross	2.49	0	1	1	6	0	0	0	0	8
Northern royal albatross	2.21	0	0	1	0	0	0	0	0	1
Light-mantled sooty albatross	2.18	0	0	0	0	0	0	1	0	1
Campbell albatross	1.84	0	8	0	26	0	3	3	0	40
Southern Buller's albatross	1.28	0	3	1	26	0	251	31	0	312
Gibson's albatross	1.25	4	10	0	11	0	3	1	1	30
Antipodean albatross	1.11	12	9	1	7	0	0	0	1	30
White capped albatross	0.83	0	1	0	3	10	54	25	0	93
Southern royal albatross	0.74	0	0	0	0	0	4	0	0	4
Black browed albatrosses	-	2	1	0	0	0	0	0	1	4
Pacific albatross	-	0	0	0	1	0	0	0	0	1
Southern black-browed albatross	-	0	0	0	2	0	0	0	0	2
Wandering albatross	-	0	2	0	6	0	3	0	0	11
Antipodean and Gibson's albatrosses	N/A	5	2	0	0	0	0	0	0	7
Unidentified albatross	N/A	33	0	0	1	0	0	0	1	35
Total albatrosses	**N/A**	**56**	**37**	**4**	**89**	**10**	**318**	**61**	**4**	**579**
Black petrel	11.15	1	9	1	0	0	0	0	1	12
Westland petrel	3.31	0	0	0	2	0	1	5	0	8
Flesh footed shearwater	2.51	0	0	0	10	0	0	0	2	12
Cape petrels	0.76	0	0	0	2	0	0	0	0	2
White chinned petrel	0.79	2	2	3	3	1	19	0	3	33
Grey petrel	0.39	3	3	2	38	0	0	0	0	46
Sooty shearwater	0.02	1	0	0	8	3	1	0	0	13
Great winged petrel	0.01	12	5	1	2	0	0	0	0	20
White headed petrel	0.01	2	0	0	0	0	0	0	0	2
Pterodroma petrels	-	0	1	0	0	0	0	0	0	1
Southern giant petrel	-	0	0	0	2	0	0	0	0	2
Unidentified seabird	N/A	0	0	0	0	0	1	0	0	1
Total other birds	**N/A**	**21**	**20**	**7**	**67**	**4**	**22**	**5**	**6**	**152**

Table 7: Effort, observed and estimated seabird captures by fishing year for the surface longline fishery within the EEZ. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); the capture rate (captures per thousand hooks); and the mean number of estimated total captures (with 95% confidence interval). The estimation method used was a Bayesian model with 100% of hooks included in the estimate. For more information on the methods used to prepare the data see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures		Estimated captures	
	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002-2003	10 764 588	2 195 152	20.4	115	0.052	2490	1817-3461
2003-2004	7 380 779	1 607 304	21.8	71	0.044	1665	1259-2220
2004-2005	3 676 365	783 812	21.3	41	0.052	687	507-936
2005-2006	3 687 339	705 945	19.1	37	0.052	816	607-1120
2006-2007	3 738 362	1 040 948	27.8	187	0.18	949	725-1304
2007-2008	2 244 339	426 310	19	41	0.096	521	408-681
2008-2009	3 115 633	937 233	30.1	57	0.061	721	562-934
2009-2010	2 992 285	665 883	22.3	149	0.224	1014	777-1345
2010-2011	3 164 159	674 522	21.3	47	0.07	824	607-1152

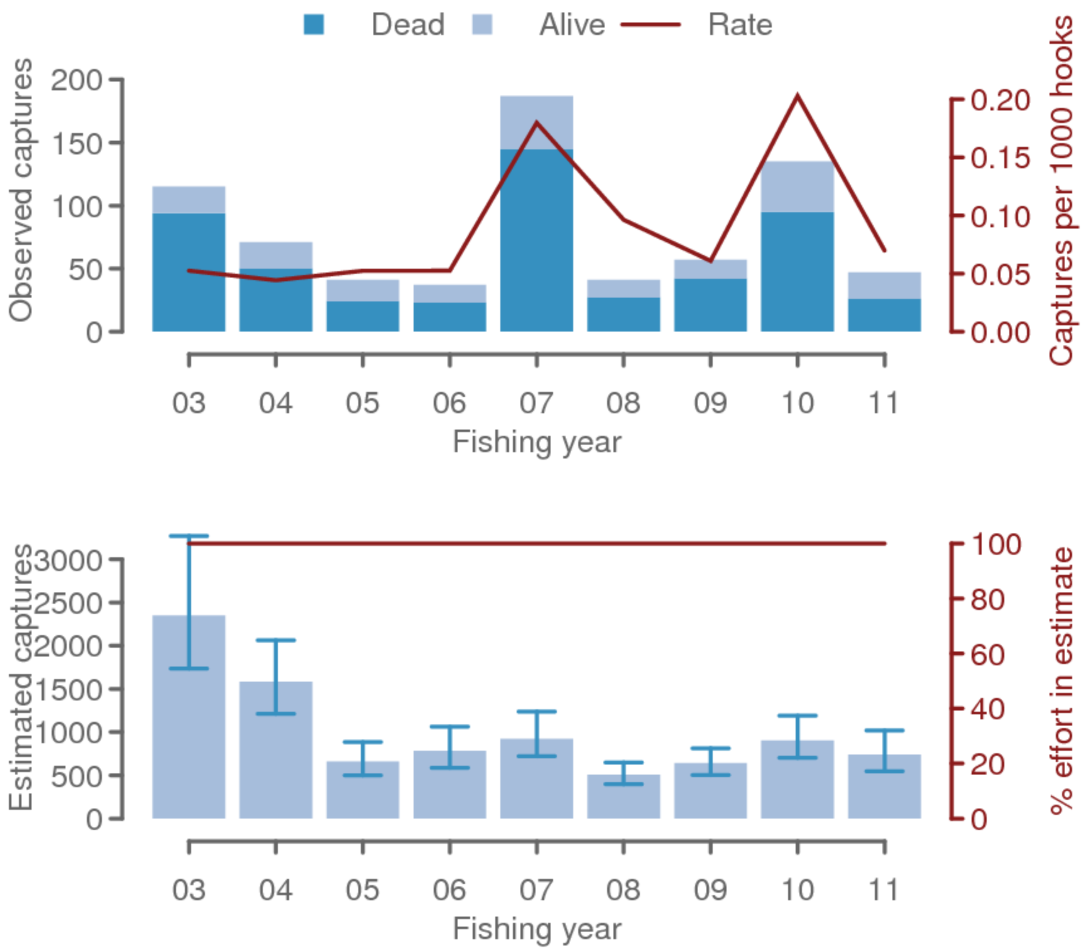


Figure 9: Observed and estimated captures of seabirds in surface longline fisheries from 2003 to 2011.

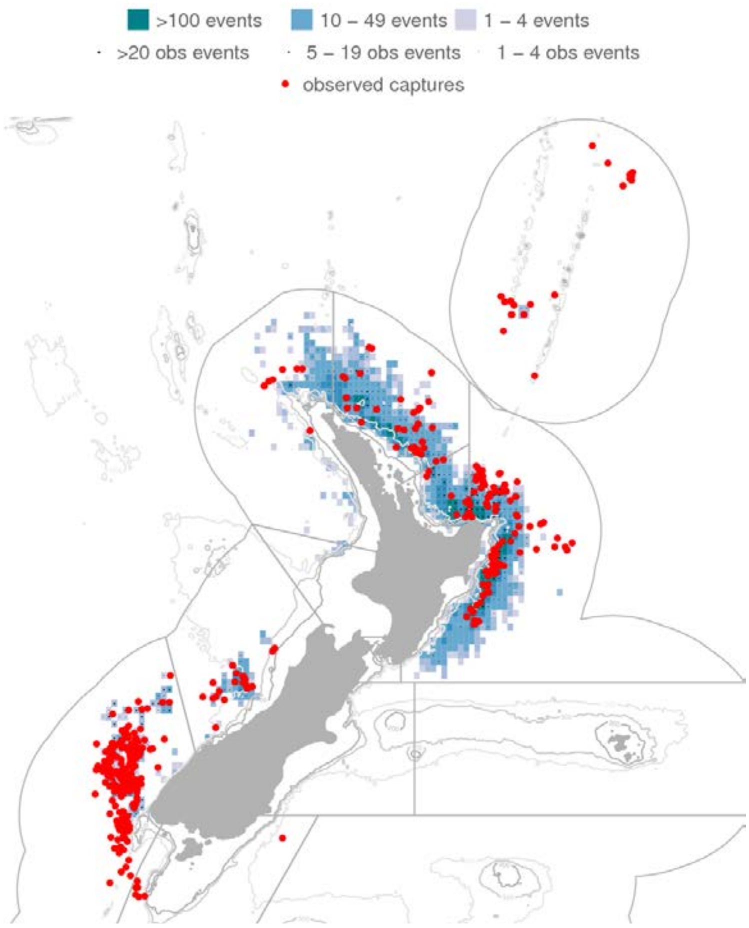


Figure 10: Distribution of fishing effort in surface longline fisheries and observed seabird captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.3.2 Sea turtle bycatch

Between 2002–03 and 2010–11, there were 13 observed captures of sea turtles across all surface longline fisheries (Tables 8 and 9, Figure 11). Observer records documented all but one sea turtle as captured and released alive. Sea turtle capture distributions predominantly occur throughout the east coast of the North Island and Kermadec Island fisheries (Figure 12).

Table 8: Number of observed sea turtle captures in surface longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson and Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/.

Species	Bay of Plenty	East Coast North Island	Kermadec Islands	West Coast North Island	Total
Leatherback turtle	1	4	3	3	11
Olive ridley turtle	0	1	0	0	1
Unknown turtle	0	1	0	0	1
Total	**1**	**6**	**3**	**3**	**13**

Table 9: Effort and sea turtle captures in surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	10 764 588	2 195 152	20.4	0	0
2003-2004	7 380 779	1 607 304	21.8	1	0.001
2004-2005	3 676 365	783 812	21.3	2	0.003
2005-2006	3 687 339	705 945	19.1	1	0.001
2006-2007	3 738 362	1 040 948	27.8	2	0.002
2007-2008	2 244 339	426 310	19.0	1	0.002
2008-2009	3 115 633	937 233	30.1	2	0.002
2009-2010	2 992 285	665 883	22.3	0	0
2010-2011	3 164 159	674 522	21.3	4	0.006

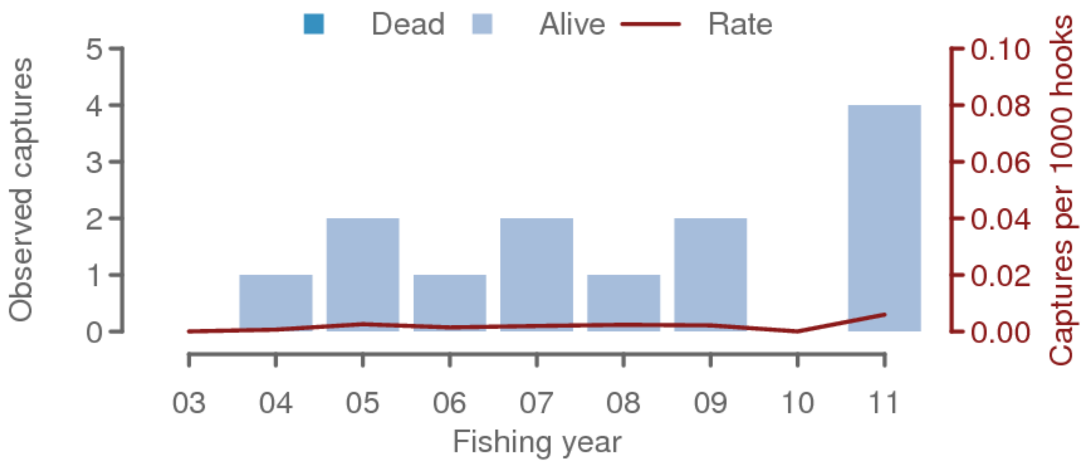


Figure 11: Observed captures of sea turtles in surface longline fisheries from 2003 to 2011.

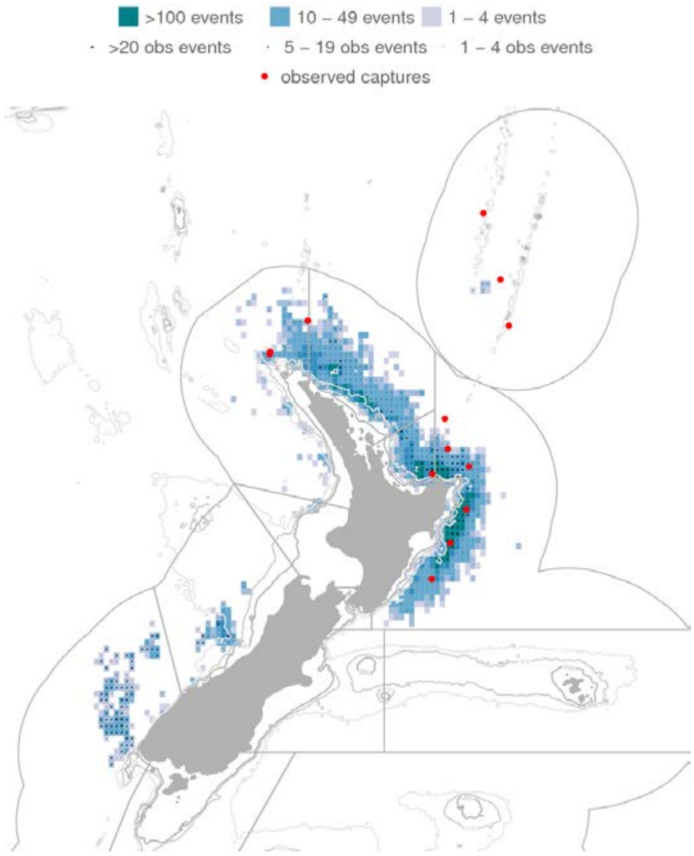


Figure 12: Distribution of fishing effort in surface longline fisheries and observed sea turtle captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.3.3 Marine Mammals

4.3.3.1 Cetaceans

Cetaceans are dispersed throughout New Zealand waters (Perrin *et al.* 2008). The spatial and temporal overlap of commercial fishing grounds and cetacean foraging areas has resulted in cetacean captures in fishing gear (Abraham and Thompson 2009, 2011).

Between 2002–03 and 2010–11, there were seven observed captures of whales and dolphins in surface longline fisheries. Observed captures included 5 unidentified cetaceans and 2 long-finned Pilot whales (Tables 10 and 11, Figure 13) (Abraham and Thompson 2011). All captured animals recorded were documented as being caught and released alive (Thompson and Abraham 2010). Cetacean capture distributions are more frequent off the east coast of the North Island (Figure 14).

Table 10: Number of observed cetacean captures in surface longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson and Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/.

Species	Bay of Plenty	East Coast North Island	Fiordland	Northland and Hauraki	West Coast North Island	West Coast South Island	Total
Long-finned pilot whale	0	1	0	0	0	1	2
Unidentified cetacean	1	1	1	1	1	0	5
Total	**1**	**2**	**1**	**1**	**1**	**1**	**7**

Table 11: Effort and captures of cetaceans in surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	10 764 588	2 195 152	20.4	1	0.0005
2003-2004	7 380 779	1 607 304	21.8	4	0.002
2004-2005	3 676 365	783 812	21.3	1	0.001
2005-2006	3 687 339	705 945	19.1	0	0
2006-2007	3 738 362	1 040 948	27.8	0	0
2007-2008	2 244 339	426 310	19.0	1	0.002
2008-2009	3 115 633	937 233	30.1	0	0
2009-2010	2 992 285	665 883	22.3	0	0
2010-2011	3 164 159	674 522	21.3	0	0

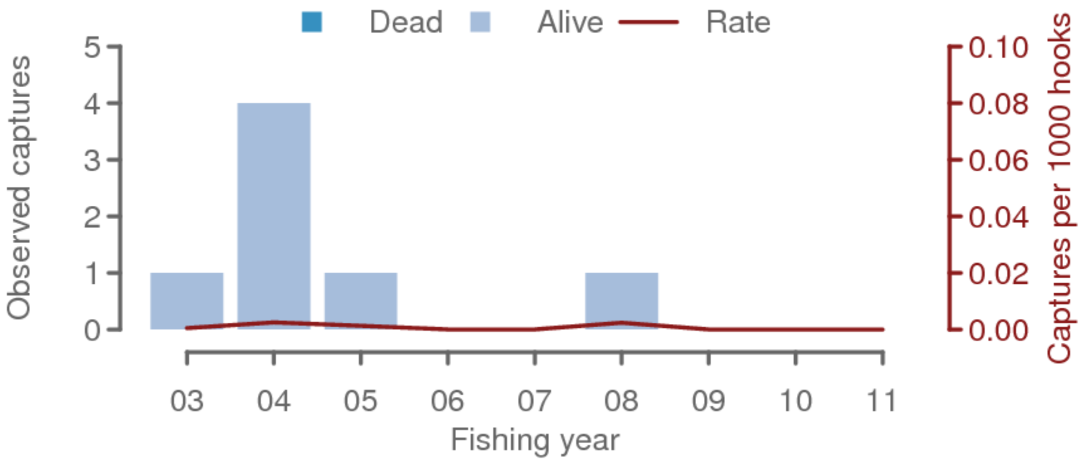


Figure 13: Observed captures of cetaceans in surface longline fisheries from 2003 to 2011.

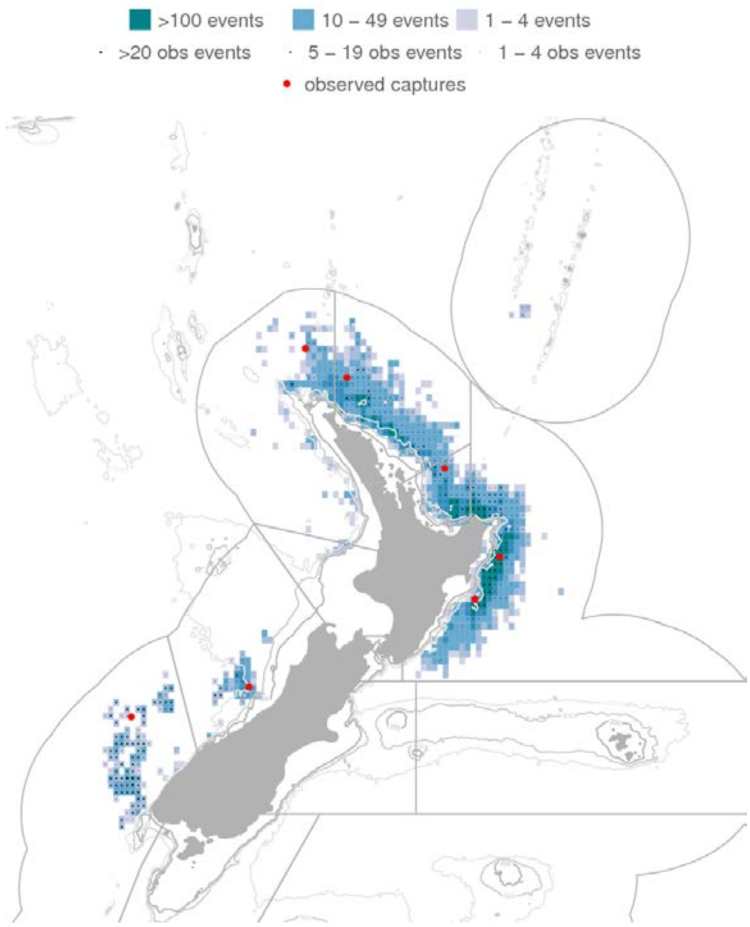


Figure 14: Distribution of fishing effort in surface longline fisheries and observed cetacean captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.3.3.2 New Zealand fur seal bycatch

Currently, New Zealand fur seals are dispersed throughout New Zealand waters, especially in waters south of about 40º S to Macquarie Island. The spatial and temporal overlap of commercial fishing grounds and New Zealand fur seal foraging areas has resulted in New Zealand fur seal captures in fishing gear (Mattlin 1987, Rowe 2009). Most fisheries with observed captures occur in waters over or close to the continental shelf, which around much of the South Island and offshore islands slopes steeply to deeper waters relatively close to shore, and thus rookeries and haulouts. Captures on longlines occur when the seals attempt to feed on the fish and bait catch during hauling. Most New Zealand fur seals are released alive, typically with a hook and short snood or trace still attached.

New Zealand fur seal captures in surface longline fisheries have been generally observed in waters south and west of Fiordland, but also in the Bay of Plenty-East Cape area when the animals have attempted to take bait or fish from the line as it is hauled. These capture rates include animals that are released alive (100% of observed surface longline capture in 2008-09; Thompson and Abraham 2010). Bycatch rates in 2010-11 are low and lower than they were in the early 2000s (Figure 15). While fur seal captures have occurred throughout the range of this fishery most New Zealand captures have occurred off the Southwest coast of the South Island (Figure 16). Between 2002–03 and 2010–11, there were 206 observed captures of New Zealand fur seal in surface longline fisheries (Tables 12 and 13).

Table 12: Number of observed New Zealand fur seal captures in surface longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson and Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/.

	Bay of Plenty	East Coast North Island	Fiordland	Northland and Hauraki	Stewart Snares Shelf	West Coast North Island	West Coast South Island	Total
New Zealand fur seal	10	16	139	3	4	2	32	206

Table 13: Effort and captures of New Zealand fur seal in surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	10 764 588	2 195 152	20.4	56	0.026
2003-2004	7 380 779	1 607 304	21.8	40	0.025
2004-2005	3 676 365	783 812	21.3	20	0.026
2005-2006	3 687 339	705 945	19.1	12	0.017
2006-2007	3 738 362	1 040 948	27.8	10	0.010
2007-2008	2 244 339	426 310	19.0	10	0.023
2008-2009	3 115 633	937 233	30.1	22	0.023
2009-2010	2 992 285	665 883	22.3	19	0.029
2010-2011	3 164 159	674 522	21.3	17	0.025

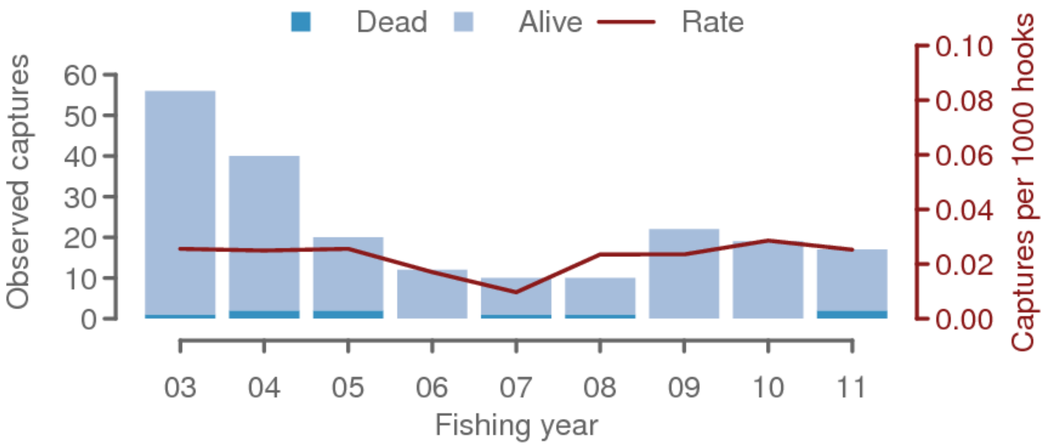


Figure 15: Observed captures of New Zealand fur seal in surface longline fisheries from 2003 to 2011.

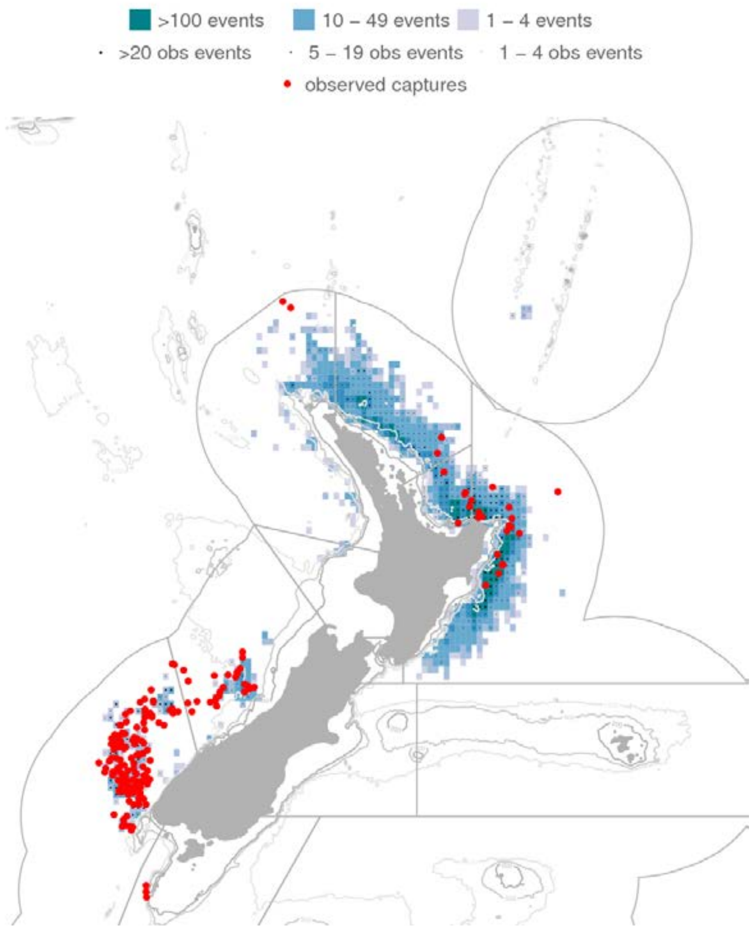


Figure 16: Distribution of fishing effort in surface longline fisheries and observed New Zealand fur seal captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.4 Incidental fish bycatch

Observer records indicate that a wide range of species are landed by the longline fleets in New Zealand fishery waters. Blue sharks are the most commonly landed species (by number), followed by Ray’s bream (Table 14). Southern bluefin tuna and albacore tuna are the only target species that occur in the top five of the frequency of occurrence.

Table 14: Numbers of the most common fish species observed in the New Zealand longline fisheries during 2009-10 by fleet and area. Species are shown in descending order of total abundance (Griggs and Baird in press).

	Charter	Domestic		Total
Species	South	North	South	number
Blue shark	2 024	4 650	882	7 556
Rays bream	3 295	326	88	3 709
Southern bluefin tuna	3 244	211	179	3 634
Lancetfish	3	2 139	1	2 143
Albacore tuna	90	1 772	42	1 904
Dealfish	882	0	7	889
Swordfish	3	452	2	457
Moonfish	76	339	6	421
Porbeagle shark	72	328	20	420
Mako shark	11	343	7	361
Big scale pomfret	349	4	0	353
Deepwater dogfish	305	0	0	305
Sunfish	7	283	5	295
Bigeye tuna	0	191	0	191
Escolar	0	129	0	129
Butterfly tuna	15	100	3	118
Pelagic stingray	0	96	0	96
Oilfish	2	75	0	77
Rudderfish	39	20	2	61
Flathead pomfret	56	0	0	56
Dolphinfish	0	47	0	47
School shark	34	0	2	36
Striped marlin	0	24	0	24
Thresher shark	7	17	0	24
Cubehead	13	0	1	14
Kingfish	0	10	0	10
Yellowfin tuna	0	9	0	9
Hake	8	0	0	8
Hapuku bass	1	6	0	7
Pacific bluefin tuna	0	5	0	5
Black barracouta	0	4	0	4
Skipjack tuna	0	4	0	4
Shortbill spearfish	0	4	0	4
Gemfish	0	3	0	3
Bigeye thresher shark	0	2	0	2
Snipe eel	2	0	0	2
Slender tuna	2	0	0	2
Wingfish	2	0	0	2
Bronze whaler shark	0	1	0	1
Hammerhead shark	0	1	0	1
Hoki	0	0	1	1
Louvar	0	1	0	1
Marlin, unspecified	0	1	0	1
Scissortail	0	1	0	1
Broadnose seven gill shark	1	0	0	1
Shark, unspecified	0	1	0	1
Unidentified fish	2	30	8	40
Total	10 545	11 629	1 256	23 430

4.5 Benthic interactions

N/A

4.6 Key environmental and ecosystem information gaps

Cryptic mortality is unknown at present but developing a better understanding of this in future may be useful for reducing uncertainty of the seabird risk assessment and could be a useful input into risk assessments for other species groups.

The survival rates of released target and bycatch species is currently unknown.

Observer coverage in the New Zealand fleet is not spatially and temporally representative of the fishing effort.

5. STOCK ASSESSMENT

With the establishment of the WCPFC in 2004, future stock assessments of the western and central Pacific Ocean stock of mako shark will be reviewed by the WCPFC. There is currently a shark research plan that has been developed within the context of the Western and Central Pacific Fisheries Commission but mako sharks will not be a focus of that plan in the near future.

There have been no stock assessments of mako sharks in New Zealand, or elsewhere in the world. No estimates of yield are possible with the currently available data.

CPUE estimates were calculated for each fleet and area stratum in which eight or more sets were observed and at least 2% of the hooks were observed. CPUE estimates were calculated for blue sharks for each fleet and area in 2006–07 to 2009–10 and added to the time series for 1988–89 to 2005–06 (Griggs *et al.* 2008) and these are shown in Figure 17 (Griggs and Baird in press). The CPUE results from the Domestic fleet should be interpreted with caution due to the lower observer coverage of this fleet. CPUE estimates for the Charter fleet can be considered reliable from 1992–93 onwards (Griggs and Baird in press).Unstandardised CPUE analysis of tuna longline catches recorded by observers show no long-term trends over the period 1992–93 to 2009–10 (Figure 17).

Compared with a wide range of shark species, the productivity of mako sharks is very low. Females have a high age-at-maturity, moderately high longevity (and therefore low natural mortality rate) and low annual fecundity. The low fecundity is cause for serious concern, as the ability of the population to replace sharks removed by fishing is very limited.

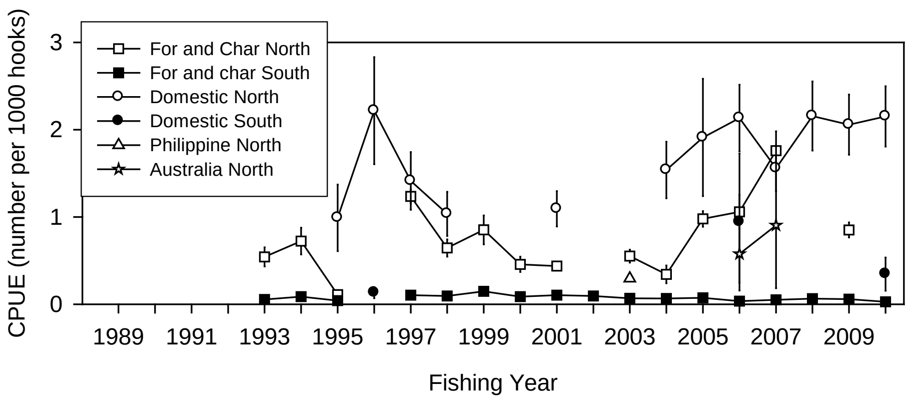


Figure 17: Annual variation in CPUE by fleet and area. Plotted values are the mean estimates with 95% confidence limits. Fishing year 1989 = October 1988 to September 1989.

Observer records show that there were few mako sharks were observed in the South. The distributions were roughly bimodal with a wide size range and no discernible difference between males and females (Figure 18). There were more females (60.9%) than males. With mean length of maturity of 182.5 cm FL for males and 280 cm fork length for females (Francis & Duffy 2005), most mako sharks were immature (85.1% of males and 100.0% of females, overall) (Griggs and Baird in Press).

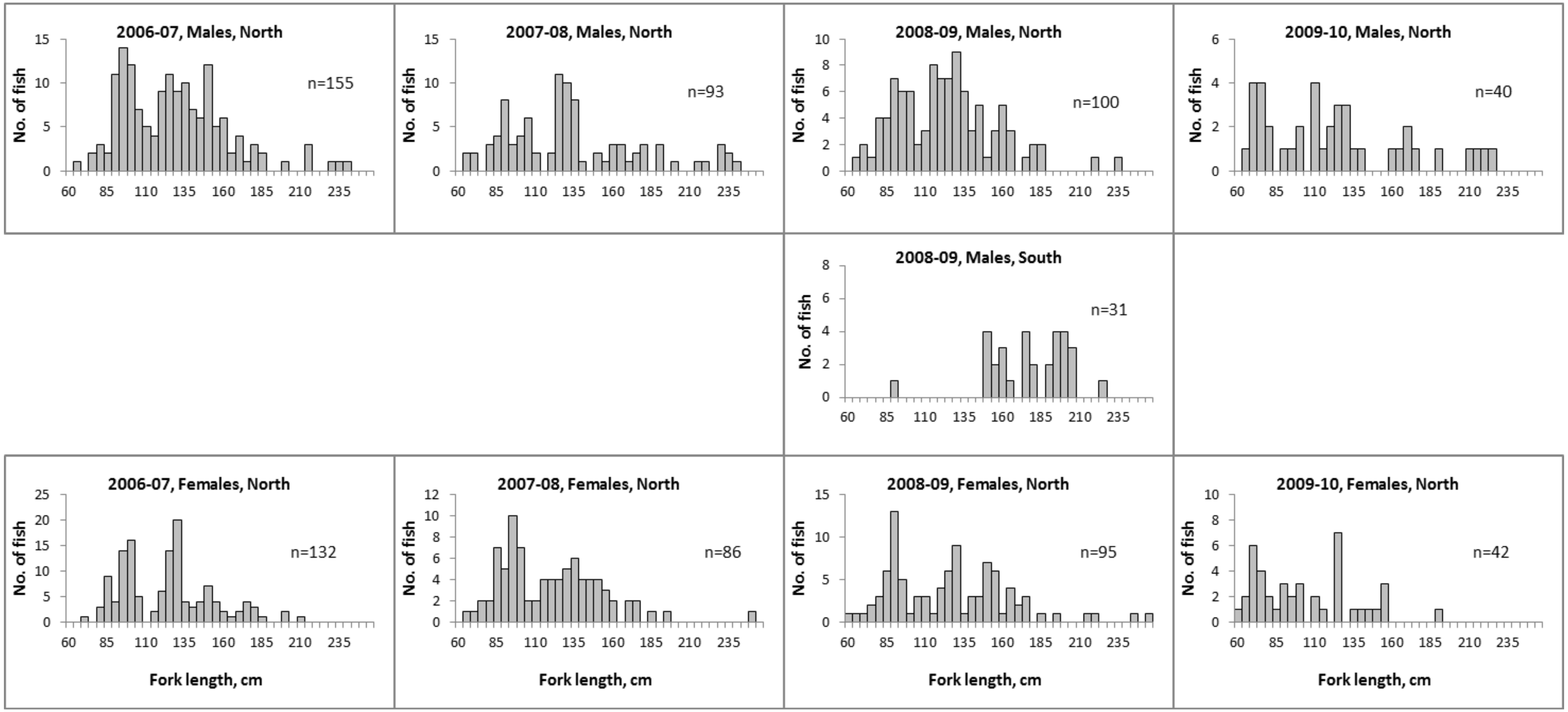


Figure 18: Length-frequency distributions of mako shark by fishing year, sex, and region. Sample sizes of less than 20 fish not shown (Griggs and Baird in press).

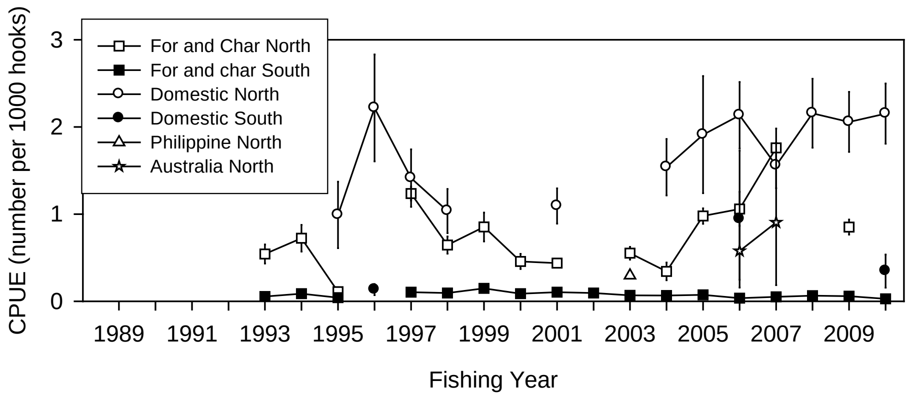
6. STATUS OF THE STOCK

Stock structure assumptions

MAK1 is assumed to be part of the wider South Western Pacific Ocean stock but the assessment below relates only to the New Zealand component of that stock.

Stock Status	
Year of Most Recent Assessment	2008
Assessment Runs Presented	Base case model only
Reference Points	Target: Not established Soft Limit: Not established by WCPFC; but evaluated using HSS default of 20% SB_0. Hard Limit: Not established by WCPFC; but evaluated using HSS default of 10% SB_0.
Status in relation to Target	Unknown
Status in relation to Limits	Unknown

Historical Stock Status Trajectory and Current Status



Annual variation in CPUE by fleet and area. Plotted values are the mean estimates with 95% confidence limits. Fishing year 1989 = October 1988 to September 1989.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	CPUE analyses have been undertaken in New Zealand but are not considered to have generated reliable estimates of abundance.
Trends in Other Relevant Indicator or Variables	Catches in New Zealand increased from the early 1980s to a peak in the early 2000s but have declined from highs of 295 t to 74 t in 2007-08, This decline in catch coincides with a decline in longline fishing effort.

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

Assessment Methodology and Evaluation		
Assessment Type	Level 3- Qualitative Evaluation: Fishery characterisation with evaluation of fishery trends (e.g., catch, effort and nominal CPUE) - there is no agreed index of abundance.	
Assessment Method	CPUE analysis	
Assessment Dates	Latest assessment: 2008	Next assessment: 2014[1] (SPC)
Overall assessment quality rank	2 – Medium or Mixed Quality: information has been subjected to peer review and has been found to have some shortcomings	
Main data inputs (rank)	- Commercial reported catch and effort	1 - High quality for the charter fleet but low for all the other fleets.
Data not used (rank)		
Changes to Model Structure and Assumptions		
Major Sources of Uncertainty	Historical catch recording may not be accurate.	
Qualifying Comments		
-		

Fishery Interactions
Interactions with protected species are known to occur in the longline fisheries of the South Pacific, particularly south of 25°S. Seabird bycatch mitigation measures are required in the New Zealand and Australian EEZ's and through the WCPFC Conservation and Management Measure CMM2007-04. Sea turtles also get incidentally captured in longline gear; the WCPFC is attempting to reduce sea turtle interactions through Conservation and Management Measure CMM2008-03.

7. FOR FURTHER INFORMATION

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[1] Contingent upon funding approval for the Shark Research Plan beyond December 2013 being agreed at WCPFC9.

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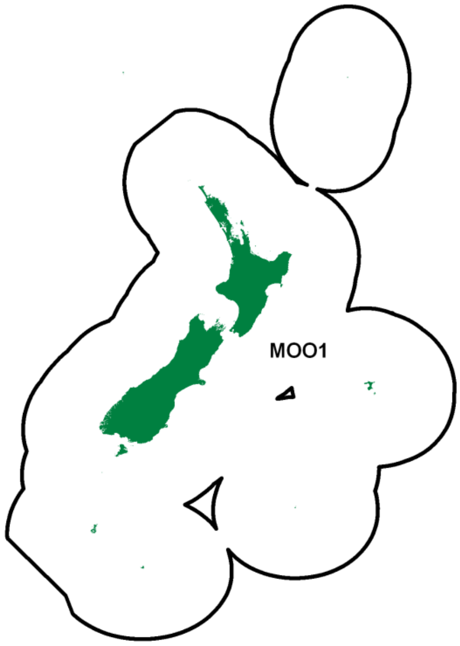
MOONFISH (MOO)

(Lampris guttatus)



1. FISHERY SUMMARY

Moonfish were introduced into the QMS on 1 October 2004 under a single QMA, MOO 1, with the TAC equal to the TACC (Table 1).

Table 1: Recreational and Customary non-commercial allowances, TACCs and TACs (all in tonnes) of moonfish.

Fishstock	Recreational Allowance (t)	Customary non-commercial Allowance (t)	Other mortality (t)	TACC (t)	TAC (t)
MOO 1	0	0	0	527	527

Moonfish were added to the Third Schedule of the 1996 Fisheries Act with a TAC set under s14.

1.1 Commercial fisheries

Most moonfish (70%) are caught as bycatch in surface longlines fisheries (the 7th most common bycatch species in the surface longline fishery). The main fisheries catching moonfish by surface longlining are targeting bigeye tuna (*Thunnus obesus*) and, to a lesser extent, southern bluefin tuna (*T. maccoyii*), albacore (*T. alalunga*) and yellowfin tuna (*T. albacares*). Mid-water trawling accounts for 18% of the catch, bottom trawling 8% and bottom longlining 1%. The main target fisheries using mid-water trawling are for southern blue whiting (*Micromesistius australis*) and hoki (*Macruronus novaezelandiae*), and bottom trawling for hoki and gemfish (*Rexea solandri*).

When caught on tuna longlines most moonfish are alive (79.8%). Most moonfish catch is kept and landed, as there is a market demand. It is likely that landing data for moonfish reasonably represents actual catches, although it may include small amounts (< 1%) of the less common *Lampris* spp. and the more southerly occurring species (*Lampris immaculatus*) because of misidentification. Most of the catch taken by the tuna longline fishery was aged 2 to 14 years, and most (71%) of the commercial catch appears to be of adult fish. Figure 1 shows the historic landings and longline fishing effort of the two moonfish stocks.

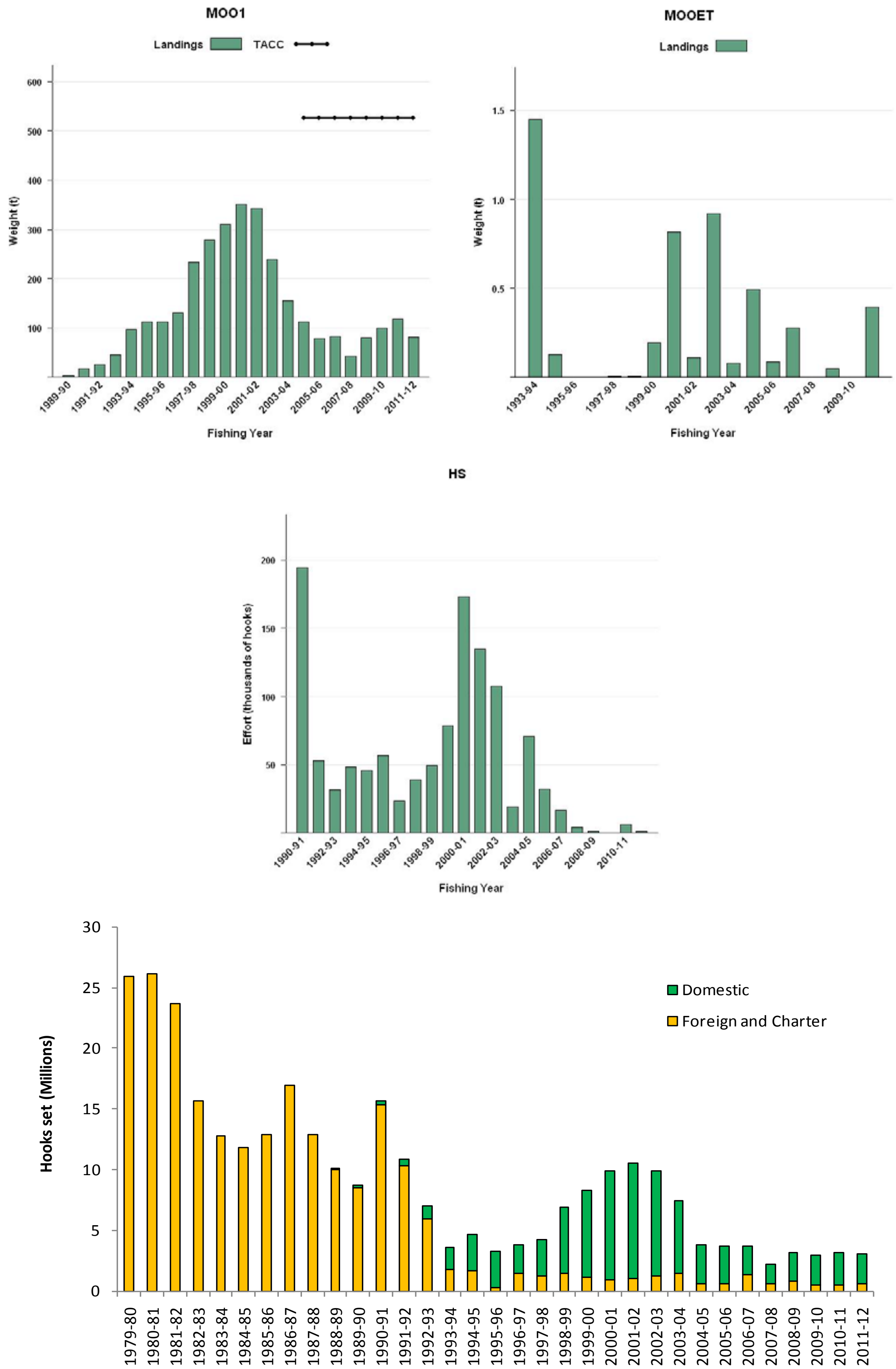


Figure 1: [Top] Moonfish catch from 1989-90 to 2011-12 within NZ waters (MOO1) and 1993-94 to 2010-11 on the high seas (MOOET). [Middle and bottom] Fishing effort (number of hooks set) for all high seas New Zealand flagged surface longline vessels and domestic vessels (including effort by foreign vessels chartered by NZ fishing companies), from 1990-91 to 2011-12 and 1979-80 to 2011-12, respectively.

Between 1989-90 to 1998-99, reported landings in New Zealand increased each year from 2 to a maximum of 351 t in 2000-01, but have declined since then as a result of decreasing effort in the surface longline fishery (Table 2). From 2005-6 to 2011-12 landings have averaged around 84 t. New Zealand landings of moonfish appear to represent about 70% of the reported catch of moonfish in the wider South Pacific area based on Food and Agriculture Organisation of the United Nations statistics. Alternately, this may reflect non-reporting of bycatch by others.

Table 2: Reported landings (t) of moonfish (CELR, CLR and LFRR data from 1989-90 to 2000-01, MHR data from 2001-02 onwards).

Fishing year	MOO 1 (all FMAs)
1989-90	3
1990-91	18
1991-92	26
1992-93	46
1993-94	97
1994-95	112
1995-96	112
1996-97	130
1997-98	234
1998-99	278
1999-00	311
2000-01	351
2001-02	342
2002-03	239
2003-04	156
2004-05	112
2005-06	80
2006-07	82
2007-08	43
2008-09	80
2009-10	100
2010-11	118
2011-12	82

The majority of moonfish are caught in the bigeye tuna (77%) and southern bluefin tuna (12%) surface longline fisheries (Figure 2). Across all longline fisheries albacore make up the bulk of the catch (33%) (Figure 3). Longline fishing effort is distributed along the east coast of the North Island and the south west coast of the South Island. The west coast South Island fishery predominantly targets southern bluefin tuna, whereas the east coast of the North Island targets a range of species including bigeye, swordfish, and southern bluefin tuna (Figure 4).

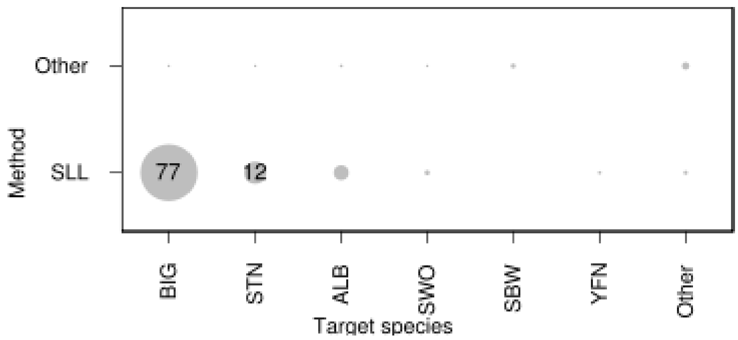


Figure 2: A summary of the proportion of landings of moonfish taken by each target fishery and fishing method. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the bobble is the percentage. SLL = surface longline (Bentley *et al.* 2012).

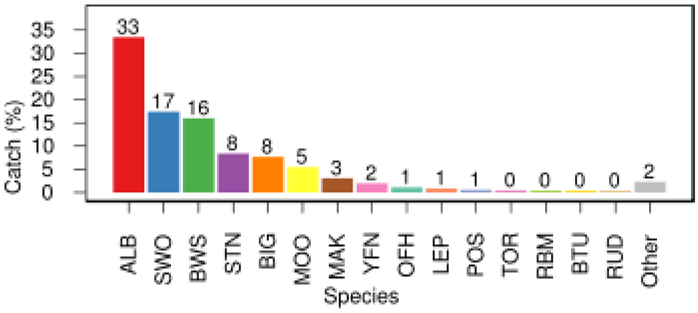


Figure 3: A summary of species composition of the reported surface longline catch. The percentage by weight of each species is calculated for all surface longline trips (Bentley *et al.* 2012).

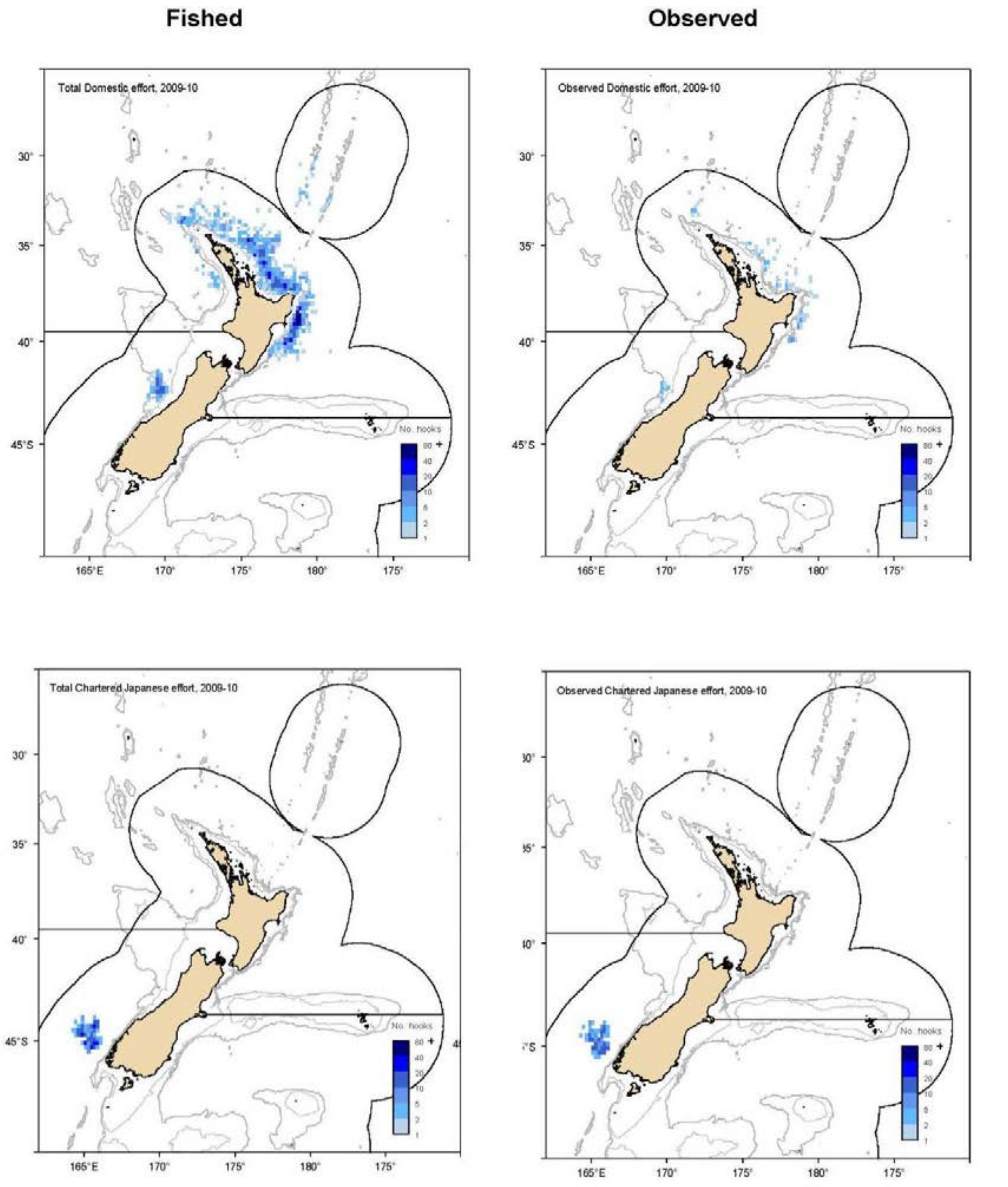


Figure 4: Distribution of fishing positions for domestic (top two panels) and charter (bottom two panels) vessels, for the 2009-10 fishing year, displaying both fishing effort (left) and observer effort (right).

In the longline fishery 79.8% of the moonfish were alive when brought to the side of the vessel for all fleets (Table 3). The domestic fleets retain around 96.5-100% of their moonfish catch, while the foreign charter fleets retain a slightly lower percentage range (92-100%) of moonfish, the Australian fleet that fished in New Zealand waters in 2006-07 retained 100% of their moonfish catch (Table 4).

Table 3: Percentage of moonfish (including discards) that were alive or dead when arriving at the longline vessel and observed during 2006–07 to 2009–10, by fishing year, fleet and region. Small sample sizes (number observed < 20) were omitted Griggs and Baird (in press).

Species	Year	Fleet	Area	% alive	% dead	Number
Moonfish	**2006-07**	Australia	North	80.0	20.0	20
		Charter	North	85.2	14.8	472
			South	84.2	15.8	114
		Domestic	North	65.6	34.4	180
		Total		**80.4**	**19.6**	**786**
	2007-08	Charter	South	100.0	0.0	41
		Domestic	North	78.4	21.6	97
		Total		**84.8**	**15.2**	**138**
	2008-09	Charter	North	100.0	0.0	60
			South	100.0	0.0	30
		Domestic	North	72.6	27.4	201
		Total		**81.1**	**18.9**	**291**
	2009-10	Charter	South	98.6	1.4	69
		Domestic	North	71.5	28.5	333
		Total		**76.0**	**24.0**	**408**
	Total all strata			**79.8**	**20.2**	**1 623**

Table 4: Percentage moonfish that were retained, or discarded or lost, when observed on a longline vessel during 2006–07 to 2009–10, by fishing year and fleet. Small sample sizes (number observed < 20) omitted Griggs and Baird (in press).

Year	Fleet	% retained	% discarded or lost	Number
2006-07	Australia	100.0	0.0	20
	Charter	91.6	8.4	616
	Domestic	97.2	2.8	180
	Total	**93.0**	**7.0**	**816**
2007-08	Charter	100.0	0.0	41
	Domestic	100.0	0.0	96
	Total	**100.0**	**0.0**	**137**
2008-09	Charter	100.0	0.0	107
	Domestic	98.5	1.5	201
	Total	**99.0**	**1.0**	**308**
2009-10	Charter	100.0	0.0	76
	Domestic	96.5	3.5	345
	Total	**97.1**	**2.9**	**421**
Total all strata		**95.7**	**4.3**	**1 682**

1.2 Recreational fisheries

There is no information on recreational catch levels of moonfish. Moonfish has not been recorded from recreational surveys conducted by the Ministry for Primary Industries (MPI).

1.3 Customary non-commercial fisheries

There is no information on customary catch, although customary fishers consider moonfish good eating and may have used moonfish in the past.

1.4 Illegal catch

There is no known illegal catch of moonfish.

1.5 Other sources of mortality

There is no information on other sources of mortality although moonfish are occasional prey of blue and mako sharks in New Zealand waters, suggesting there may be some unobserved shark depredation of longline caught moonfish.

2. BIOLOGY

Until recently, little was known about the biology of moonfish in New Zealand waters. Recent studies have examined growth rates, natural mortality, and maturity for moonfish.

Age and growth of moonfish (*Lampris guttatus*) in New Zealand waters was assessed using counts of growth bands on cross sections of the second dorsal fin ray. MPI observers working on tuna longline vessels collected fin samples. Observers also collected maturity data, and length-frequency data were obtained from the longline observer database.

Thin sections were cut from fin rays 3.5–4 times the condyle width above the fin base. Sections were read blind (without knowing the fish length) by two readers. Readability scores were poor and the four readers who examined the fin rays came to two different interpretations.

Length-at-age data did not show any marked differences between males and females. von Bertalanffy growth curves were fitted to the age estimates of both readers individually, and also to the mean ages of the two readers. The mean age provides the best available age estimate for moonfish samples. However, because of differences between readers, and the un-validated nature of the estimates, the growth curves must be interpreted with caution, especially for younger fish.

The growth curves suggest rapid early growth. The maximum age estimated in this study was 13 or 14 years depending on the reader, but this is probably an underestimate of true longevity. Using a maximum age of 14 years, Hoenig's method provides an M estimate of 0.30. If moonfish live to 20 years, this would reduce to 0.21. The Chapman-Robson estimate of Z is 0.13–0.14 for ages at recruitment of 2–4 years. However, the sample was not randomly selected and so this is probably unreliable. The best estimate of M may be around 0.20–0.25.

Length and age-at-maturity could not be accurately determined due to insufficient data, but it appears that fish longer than about 80 cm fork length are mature. The corresponding age-at-maturity would be 4.3 years. Sexual maturity may therefore be attained at about 4–5 years. A few spawning females were collected in the Kermadec region, and at East Cape, suggesting that moonfish spawn in northern New Zealand. Identification of the location and timing of spawning are important areas of further research and are a pre-requisite for obtaining good estimates of length and age at maturity.

Moonfish in New Zealand waters may be a species complex of *L. guttatus* and a new species large eye moonfish. This needs clarification in New Zealand.

3. STOCKS AND AREAS

There is no information on the stock structure of moonfish.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the November 2012 Fishery Assessment Plenary after review by the Aquatic Environment Working Group. This summary is from the perspective of moonfish but there is no directed fishery for them and the incidental catch sections below reflect the New Zealand longline fishery as a whole and are not specific to this species; a more detailed summary from an issue-by-issue perspective is, or will shortly be, available in the Aquatic Environment & Biodiversity Annual Review where the consequences are also discussed. (http://www.mpi.govt.nz/news-resources/publications.aspx).

4.1 Role in the ecosystem

Moonfish (*Lampris guttatus*) are a mid-water pelagic fish, found between 50-400m depth. They often exhibit vertical behaviour like many other large pelagic visual predators, including swordfish and bigeye tuna, with deeper day and shallower night depth distributions (Polovina *et al.* 2004). While no published data exists on *L. guttatus* diet in the South Pacific, a study on the diet of southern moonfish (*Lampris immaculatus*) along the Patagonia Shelf showed they had a narrow range of prey items with the most common being the deepwater onychoteuthid squid (*Moroteuthis ingens*) (Jackson *et al.* 2000; Polovina *et al.* 2004). Large pelagic sharks such as great white and mako are thought to prey on moonfish.

4.2 Incidental catch (seabirds, sea turtles and mammals)

The protected species, capture estimates presented here include all animals recovered onto the deck (alive, injured or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds caught on a hook but not brought onboard the vessel).

4.2.1 Seabird bycatch

Between 2002–03 and 2010–11, there were 731 observed captures of birds across all surface longline fisheries. Seabird capture rates since 2003 are presented in Figure 5. While the seabird capture distributions largely coincide with fishing effort that are more frequent off the south west coast of the South Island (Figure 6). The analytical methods used to estimate capture numbers across the commercial fisheries have depended on the quantity and quality of the data, in terms of the numbers observed captured and the representativeness of the observer coverage. Ratio estimation was historically used to calculate total captures in longline fisheries by target fishery fleet and area (Baird 2008) and by all fishing methods but recent estimates are either ratio or model based as specified in the tables below (Abraham *et al.* 2010a).

Through the 1990s the minimum seabird mitigation requirement for surface longline vessels was the use of a bird scaring device (tori line) but common practice was that vessels set surface longlines primarily at night. In 2007 a notice was implemented under s 11 of the Fisheries Act 1996 to formalise the requirement that surface longline vessels only set during the hours of darkness and use a tori line when setting. This notice was amended in 2008 to add the option of line weighting and tori line use if setting during the day. In 2011 notices were combined and repromulgated under a new regulation (Regulation 58A of the Fisheries (Commercial Fishing) Regulations 2001) which provides a more flexible regulatory environment under which to set seabird mitigation requirements.

Table 5: Number of observed seabird captures in the New Zealand surface longline fisheries, 2002-03 to 2010-11, by species and area (Thompson & Abraham (2012) from http://data.dragonfly.co.nz/psc/). See glossary above for a description of the areas used for summarising the fishing effort and protected species captures. 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 moonfish using longline gear but rather the total risk for each seabird species.

Species	Risk ratio	Kermadec Islands	Northland and Hauraki	Bay of Plenty	East Coast North Island	Stewart Snares Shelf	Fiordland	West Coast South Island	West Coast North Island	Total
Salvin's albatross	2.49	0	1	1	6	0	0	0	0	8
Northern royal albatross	2.21	0	0	1	0	0	0	0	0	1
Light-mantled sooty albatross	2.18	0	0	0	0	0	0	1	0	1
Campbell albatross	1.84	0	8	0	26	0	3	3	0	40
Southern Buller's albatross	1.28	0	3	1	26	0	251	31	0	312
Gibson's albatross	1.25	4	10	0	11	0	3	1	1	30
Antipodean albatross	1.11	12	9	1	7	0	0	0	1	30
White capped albatross	0.83	0	1	0	3	10	54	25	0	93
Southern royal albatross	0.74	0	0	0	0	0	4	0	0	4
Black browed albatrosses	-	2	1	0	0	0	0	0	1	4
Pacific albatross	-	0	0	0	1	0	0	0	0	1
Southern black-browed albatross	-	0	0	0	2	0	0	0	0	2
Wandering albatross	-	0	2	0	6	0	3	0	0	11
Antipodean and Gibson's albatrosses	N/A	5	2	0	0	0	0	0	0	7
Unidentified albatross	N/A	33	0	0	1	0	0	0	1	35
Total albatrosses	**N/A**	**56**	**37**	**4**	**89**	**10**	**318**	**61**	**4**	**579**
Black petrel	11.15	1	9	1	0	0	0	0	1	12
Westland petrel	3.31	0	0	0	2	0	1	5	0	8
Flesh footed shearwater	2.51	0	0	0	10	0	0	0	2	12
Cape petrels	0.76	0	0	0	2	0	0	0	0	2
White chinned petrel	0.79	2	2	3	3	1	19	0	3	33
Grey petrel	0.39	3	3	2	38	0	0	0	0	46
Sooty shearwater	0.02	1	0	0	8	3	1	0	0	13
Great winged petrel	0.01	12	5	1	2	0	0	0	0	20
White headed petrel	0.01	2	0	0	0	0	0	0	0	2
Pterodroma petrels	-	0	1	0	0	0	0	0	0	1
Southern giant petrel	-	0	0	0	2	0	0	0	0	2
Unidentified seabird	N/A	0	0	0	0	0	1	0	0	1
Total other birds	**N/A**	**21**	**20**	**7**	**67**	**4**	**22**	**5**	**6**	**152**

Table 6: Effort, observed and estimated seabird captures by fishing year for the New Zealand surface longline fishery within the EEZ. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); the capture rate (captures per thousand hooks); and the mean number of estimated total captures (with 95% confidence interval). The estimation method used was a Bayesian model with 100% of hooks included in the estimate. For more information on the methods used to prepare the data see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures		Estimated captures	
	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002-2003	10 764 588	2 195 152	20.4	115	0.052	2490	1817-3461
2003-2004	7 380 779	1 607 304	21.8	71	0.044	1665	1259-2220
2004-2005	3 676 365	783 812	21.3	41	0.052	687	507-936
2005-2006	3 687 339	705 945	19.1	37	0.052	816	607-1120
2006-2007	3 738 362	1 040 948	27.8	187	0.18	949	725-1304
2007-2008	2 244 339	426 310	19	41	0.096	521	408-681
2008-2009	3 115 633	937 233	30.1	57	0.061	721	562-934
2009-2010	2 992 285	665 883	22.3	149	0.224	1014	777-1345
2010-2011	3 164 159	674 522	21.3	47	0.07	824	607-1152

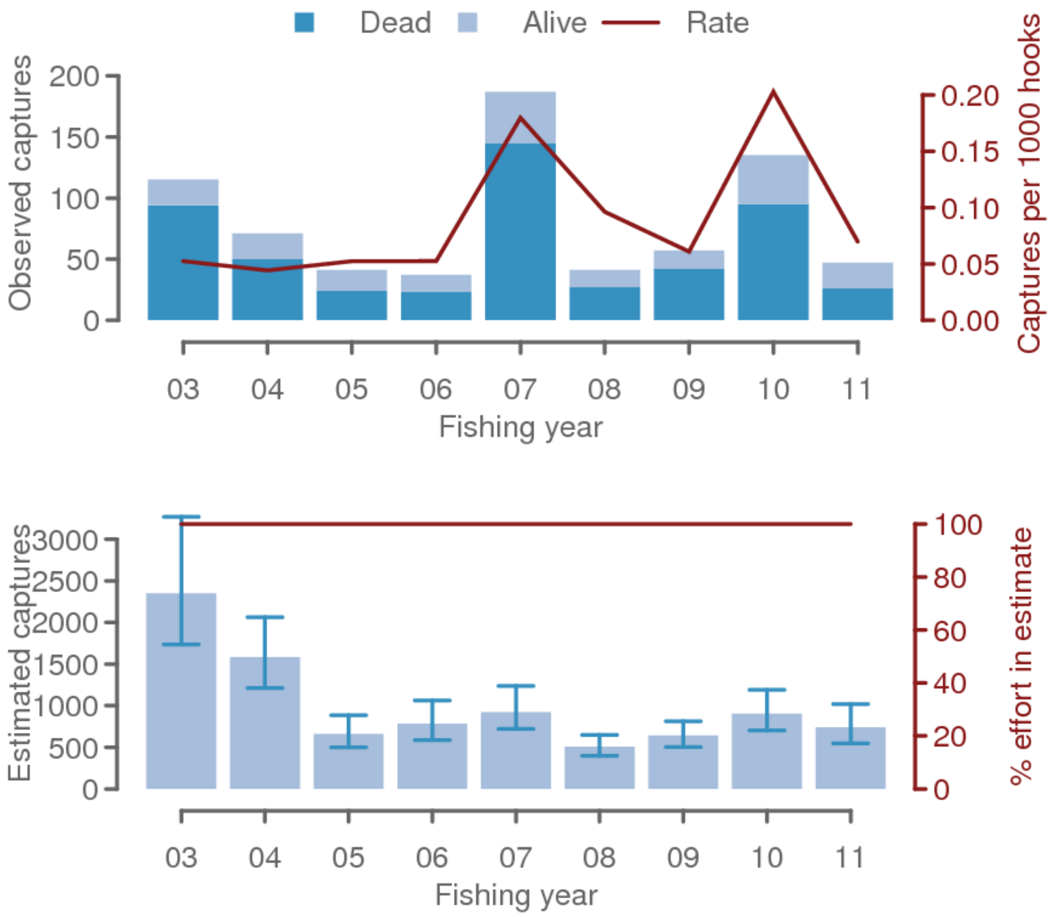


Figure 5: Observed and estimated captures of seabirds in the New Zealand surface longline fisheries from 2003 to 2011.

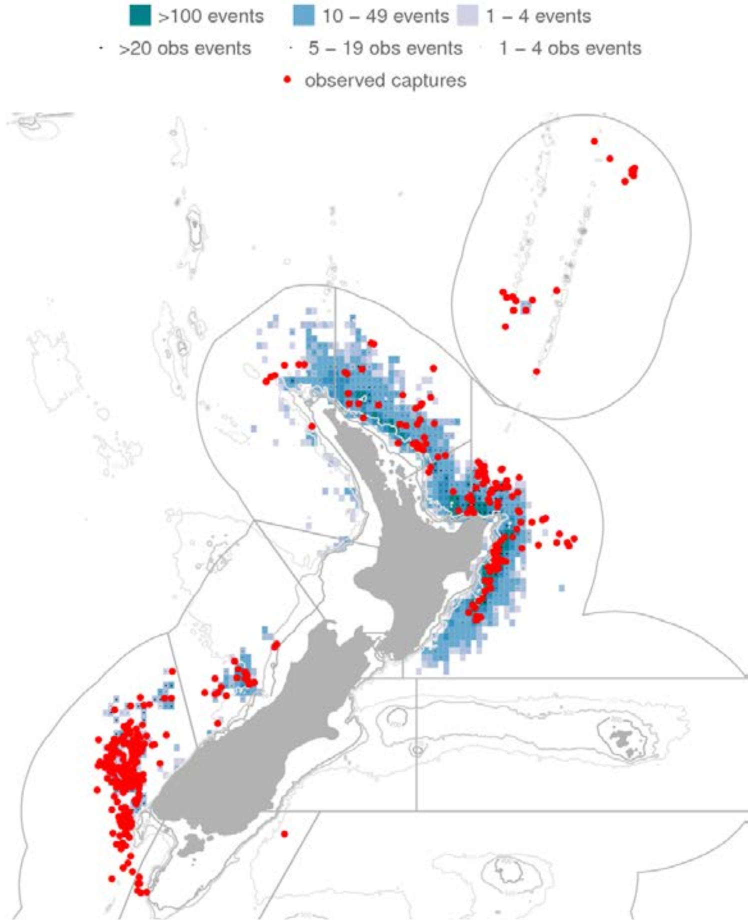


Figure 6: Distribution of fishing effort in the New Zealand surface longline fisheries and observed seabird captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.2 Sea turtle bycatch

Between 2002–03 and 2010–11, there were 13 observed captures of sea turtles across all surface longline fisheries (Tables 7 and 8, Figure 7). Observer records documented all but one sea turtle as captured and released alive. Sea turtle capture distributions predominantly occur throughout the east coast of the North Island and Kermadec Island fisheries (Figure 8).

Table 7: Number of observed sea turtle captures in the New Zealand surface longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson and Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

Species	Bay of Plenty	East Coast North Island	Kermadec Islands	West Coast North Island	Total
Leatherback turtle	1	4	3	3	11
Olive ridley turtle	0	1	0	0	1
Unknown turtle	0	1	0	0	1
Total	**1**	**6**	**3**	**3**	**13**

Table 8: Effort and sea turtle captures in surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	10 764 588	2 195 152	20.4	0	0
2003-2004	7 380 779	1 607 304	21.8	1	0.001
2004-2005	3 676 365	783 812	21.3	2	0.003
2005-2006	3 687 339	705 945	19.1	1	0.001
2006-2007	3 738 362	1 040 948	27.8	2	0.002
2007-2008	2 244 339	426 310	19.0	1	0.002
2008-2009	3 115 633	937 233	30.1	2	0.002
2009-2010	2 992 285	665 883	22.3	0	0
2010-2011	3 164 159	674 522	21.3	4	0.006

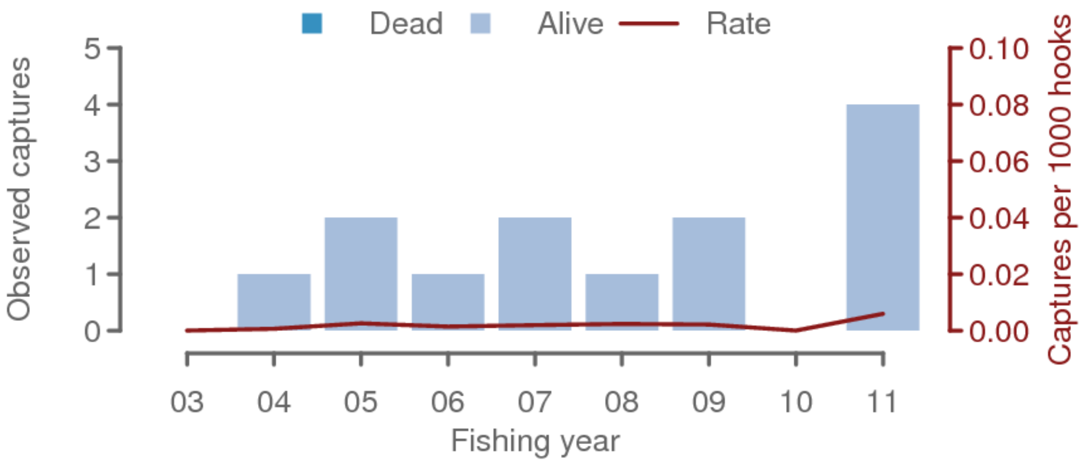


Figure 7: Observed captures of sea turtles in the New Zealand surface longline fisheries from 2003 to 2011.

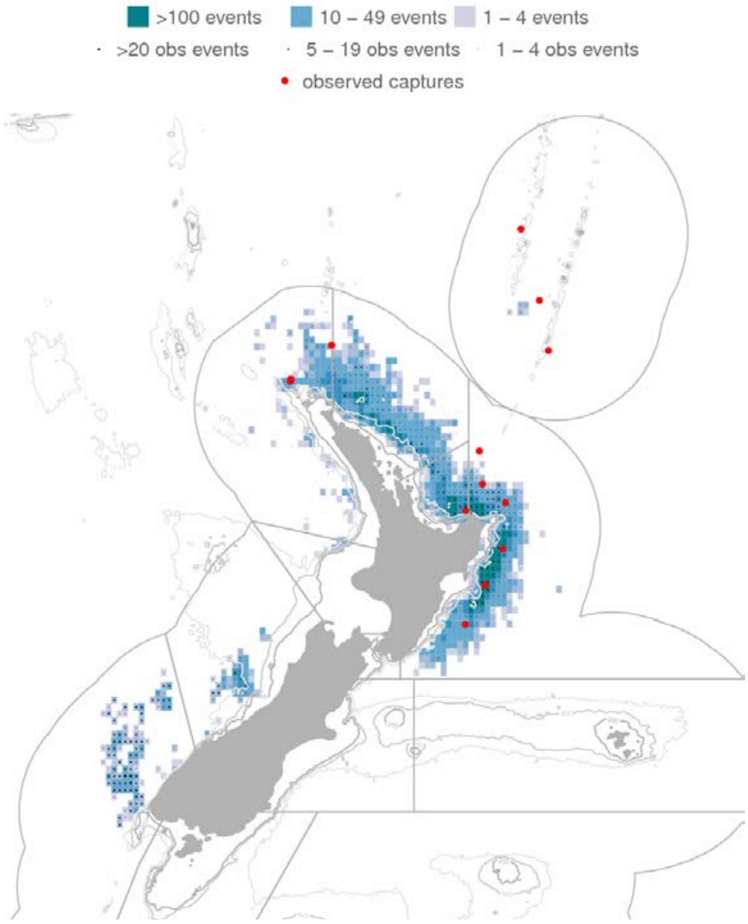


Figure 8: Distribution of fishing effort in the New Zealand surface longline fisheries and observed sea turtle captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3 Marine Mammals

4.2.3.1 Cetaceans

Cetaceans are dispersed throughout New Zealand waters (Perrin *et al.* 2008). The spatial and temporal overlap of commercial fishing grounds and cetacean foraging areas has resulted in cetacean captures in fishing gear (Abraham and Thompson 2009, 2011).

Between 2002–03 and 2010–11, there were seven observed captures of whales and dolphins in surface longline fisheries. Observed captures included 5 unidentified cetaceans and 2 long-finned Pilot whales (Tables 9 and 10, Figure 9) (Abraham and Thompson 2011). All captured animals recorded were documented as being caught and released alive (Thompson and Abraham 2010). Cetacean capture distributions are more frequent off the east coast of the North Island (Figure 10)

Table 9: Number of observed cetacean captures in the New Zealand surface longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson and Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

Species	Bay of Plenty	East Coast North Island	Fiordland	Northland and Hauraki	West Coast North Island	West Coast South Island	Total
Long-finned pilot whale	0	1	0	0	0	1	2
Unidentified cetacean	1	1	1	1	1	0	5
Total	**1**	**2**	**1**	**1**	**1**	**1**	**7**

Table 10: Effort and captures of cetaceans in surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	10 764 588	2 195 152	20.4	1	0.0005
2003-2004	7 380 779	1 607 304	21.8	4	0.002
2004-2005	3 676 365	783 812	21.3	1	0.001
2005-2006	3 687 339	705 945	19.1	0	0
2006-2007	3 738 362	1 040 948	27.8	0	0
2007-2008	2 244 339	426 310	19.0	1	0.002
2008-2009	3 115 633	937 233	30.1	0	0
2009-2010	2 992 285	665 883	22.3	0	0
2010-2011	3 164 159	674 522	21.3	0	0

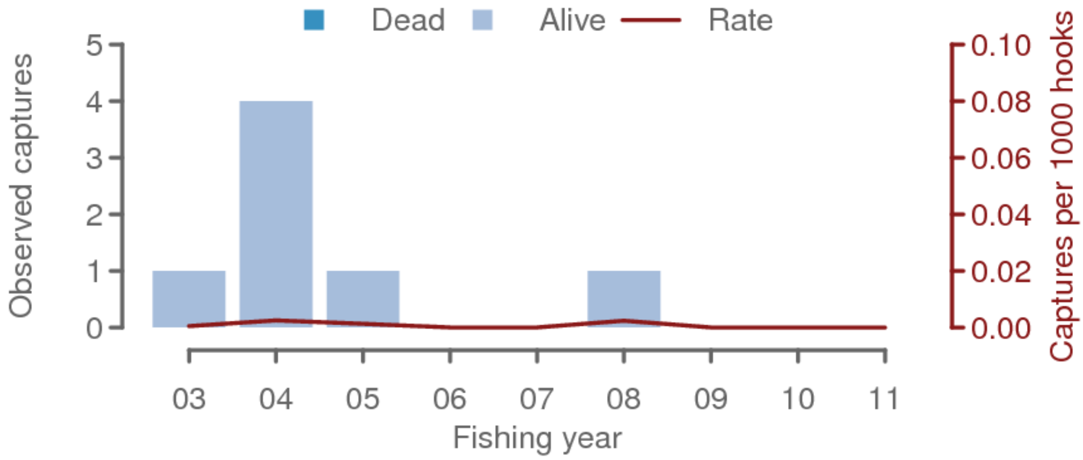


Figure 9: Observed captures of cetaceans in the New Zealand surface longline fisheries from 2003 to 2011.

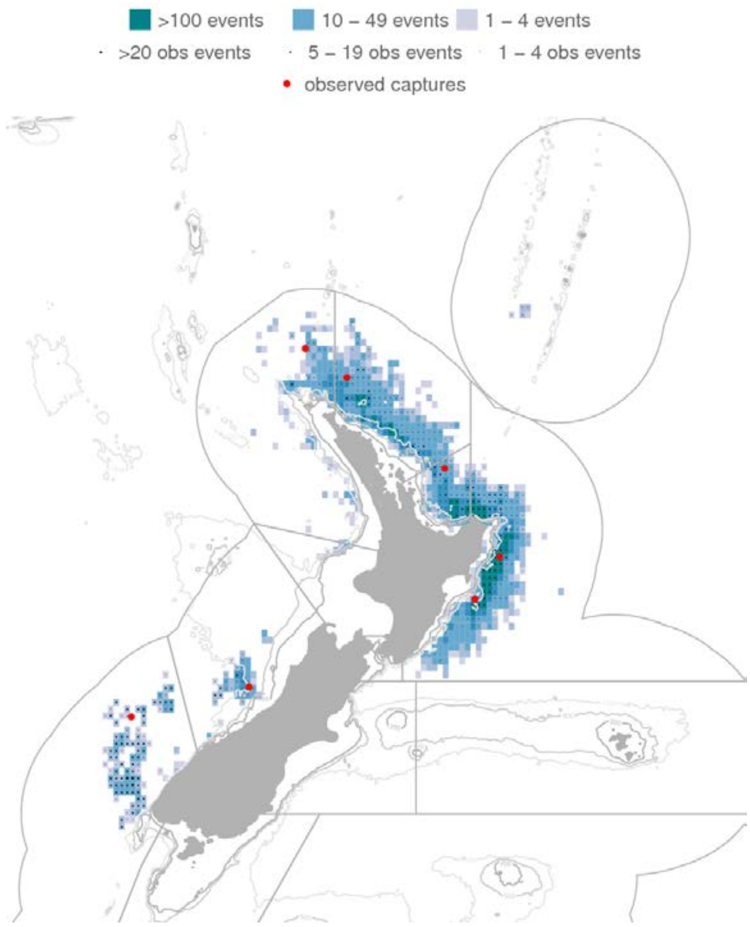


Figure 10: Distribution of fishing effort in the New Zealand surface longline fisheries and observed cetacean captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3.2 New Zealand fur seal bycatch

Currently, New Zealand fur seals are dispersed throughout New Zealand waters, especially in waters south of about 40º S to Macquarie Island. The spatial and temporal overlap of commercial fishing grounds and New Zealand fur seal foraging areas has resulted in New Zealand fur seal captures in fishing gear (Mattlin 1987, Rowe 2009). Most fisheries with observed captures occur in waters over or close to the continental shelf, which around much of the South Island and offshore islands slopes steeply to deeper waters relatively close to shore, and thus rookeries and haulouts. Captures on longlines occur when the seals attempt to feed on the fish and bait catch during hauling. Most New Zealand fur seals are released alive, typically with a hook and short snood or trace still attached.

New Zealand fur seal captures in surface longline fisheries have been generally observed in waters south and west of Fiordland, but also in the Bay of Plenty-East Cape area when the animals have attempted to take bait or fish from the line as it is hauled. These capture rates include animals that are released alive (100% of observed surface longline capture in 2008-09; Thompson and Abraham 2010). Bycatch rates in 2010-11 are low and lower than they were in the early 2000s (Figure 11). While fur seal captures have occurred throughout the range of this fishery most New Zealand captures have occurred off the Southwest coast of the South Island

(Figure 12). Between 2002–03 and 2010–11, there were 206 observed captures of New Zealand fur seal in surface longline fisheries (Tables 11 and 12).

Table 11: Number of observed New Zealand fur seal captures in the New Zealand surface longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson and Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

	Bay of Plenty	East Coast North Island	Fiordland	Northland and Hauraki	Stewart Snares Shelf	West Coast North Island	West Coast South Island	Total
New Zealand fur seal	10	16	139	3	4	2	32	206

Table 12: Effort and captures of New Zealand fur seal in the New Zealand surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	10 764 588	2 195 152	20.4	56	0.026
2003-2004	7 380 779	1 607 304	21.8	40	0.025
2004-2005	3 676 365	783 812	21.3	20	0.026
2005-2006	3 687 339	705 945	19.1	12	0.017
2006-2007	3 738 362	1 040 948	27.8	10	0.010
2007-2008	2 244 339	426 310	19.0	10	0.023
2008-2009	3 115 633	937 233	30.1	22	0.023
2009-2010	2 992 285	665 883	22.3	19	0.029
2010-2011	3 164 159	674 522	21.3	17	0.025

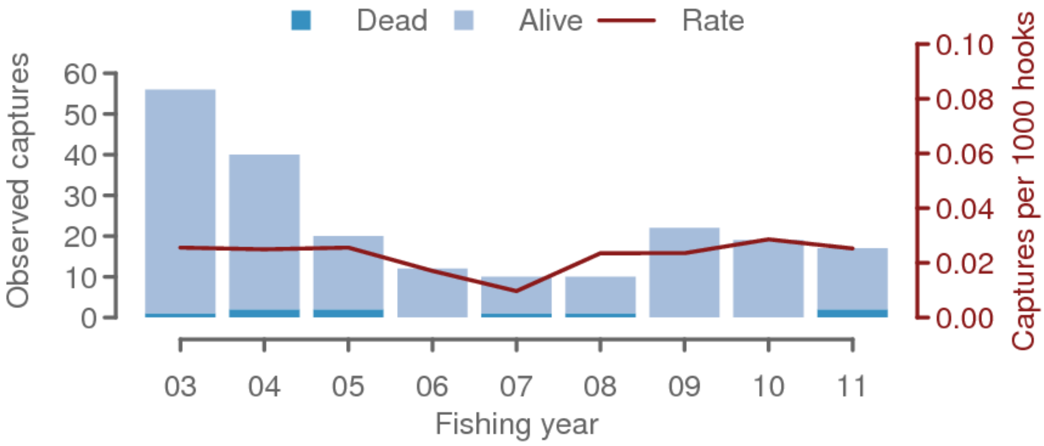


Figure 11: Observed captures of New Zealand fur seal in the New Zealand surface longline fisheries from 2003 to 2011.

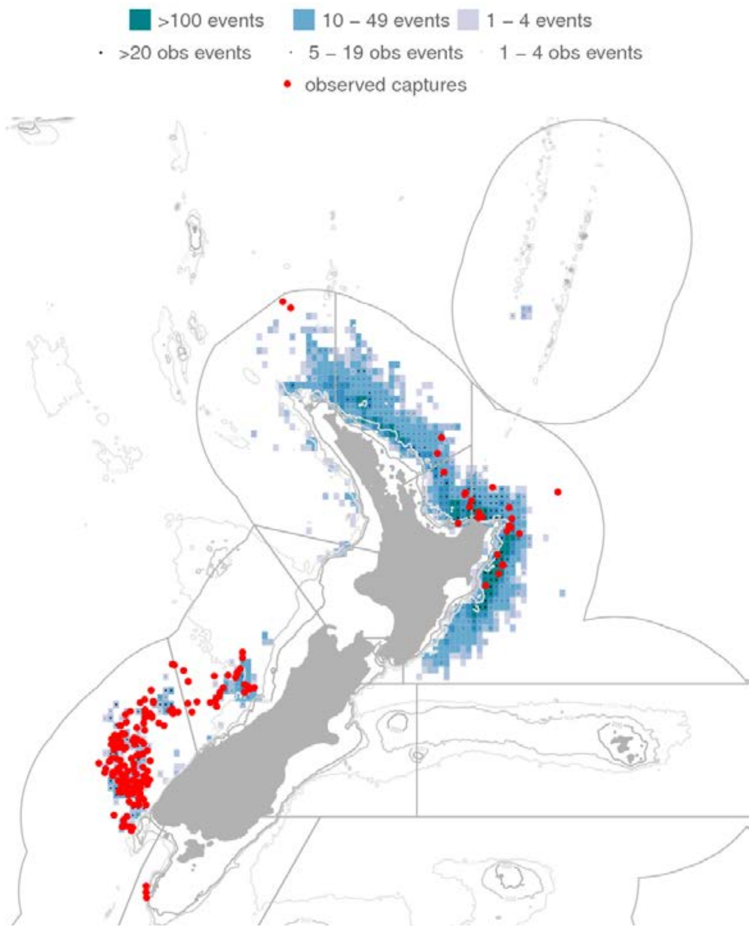


Figure 12: Distribution of fishing effort in the New Zealand surface longline fisheries and observed New Zealand fur seal captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.3 Incidental fish bycatch

Observer records indicate that a wide range of species are landed by the longline fleets in New Zealand fishery waters. Blue sharks are the most commonly landed species (by number), followed by Ray's bream (Table 13). Southern bluefin tuna and albacore tuna are the only target species that occur in the top five of the frequency of occurrence.

Table 13: Numbers of the most common fish species observed in the New Zealand longline fisheries during 2009-10 by fleet and area. Species are shown in descending order of total abundance (Griggs and Baird in press).

	Charter	Domestic		Total
Species	South	North	South	number
Blue shark	2 024	4 650	882	7 556
Rays bream	3 295	326	88	3 709
Southern bluefin tuna	3 244	211	179	3 634
Lancetfish	3	2 139	1	2 143
Albacore tuna	90	1 772	42	1 904
Dealfish	882	0	7	889
Swordfish	3	452	2	457
Moonfish	76	339	6	421
Porbeagle shark	72	328	20	420
Mako shark	11	343	7	361
Big scale pomfret	349	4	0	353
Deepwater dogfish	305	0	0	305
Sunfish	7	283	5	295
Bigeye tuna	0	191	0	191
Escolar	0	129	0	129
Butterfly tuna	15	100	3	118
Pelagic stingray	0	96	0	96
Oilfish	2	75	0	77
Rudderfish	39	20	2	61
Flathead pomfret	56	0	0	56
Dolphinfish	0	47	0	47
School shark	34	0	2	36
Striped marlin	0	24	0	24
Thresher shark	7	17	0	24
Cubehead	13	0	1	14
Kingfish	0	10	0	10
Yellowfin tuna	0	9	0	9
Hake	8	0	0	8
Hapuku bass	1	6	0	7
Pacific bluefin tuna	0	5	0	5
Black barracouta	0	4	0	4
Skipjack tuna	0	4	0	4
Shortbill spearfish	0	4	0	4
Gemfish	0	3	0	3
Bigeye thresher shark	0	2	0	2
Snipe eel	2	0	0	2
Slender tuna	2	0	0	2
Wingfish	2	0	0	2
Bronze whaler shark	0	1	0	1
Hammerhead shark	0	1	0	1
Hoki	0	0	1	1
Louvar	0	1	0	1
Marlin, unspecified	0	1	0	1
Scissortail	0	1	0	1
Broadnose seven gill shark	1	0	0	1
Shark, unspecified	0	1	0	1
Unidentified fish	2	30	8	40
Total	10 545	11 629	1 256	23 430

4.4 Benthic interactions

N/A

4.5 Key environmental and ecosystem information gaps

Cryptic mortality is unknown at present but developing a better understanding of this in future may be useful for reducing uncertainty of the seabird risk assessment and could be a useful input into risk assessments for other species groups.

The survival rates of released target and bycatch species is currently unknown.

Observer coverage in the New Zealand fleet is not spatially and temporally representative of the fishing effort.

5. STOCK ASSESSMENT

There is insufficient information to conduct a stock assessment of moonfish.

CPUE estimates were calculated for each fleet and area stratum in which eight or more sets were observed and at least 2% of the hooks were observed. CPUE estimates were calculated for blue sharks for each fleet and area in 2006–07 to 2009–10 and added to the time series for 1988–89 to 2005–06 (Griggs *et al.* 2008) and these are shown in Figure 13 (Griggs and Baird in press). The CPUE results from the Domestic fleet should be interpreted with caution due to the lower observer coverage of this fleet. CPUE estimates for the Charter fleet can be considered reliable from 1992–93 onwards (Griggs *et al.* 2007). The CPUE trends show high catch rates in the 1990s and there is some indication that these are increasing aging in the late 2000s (Figure 13).

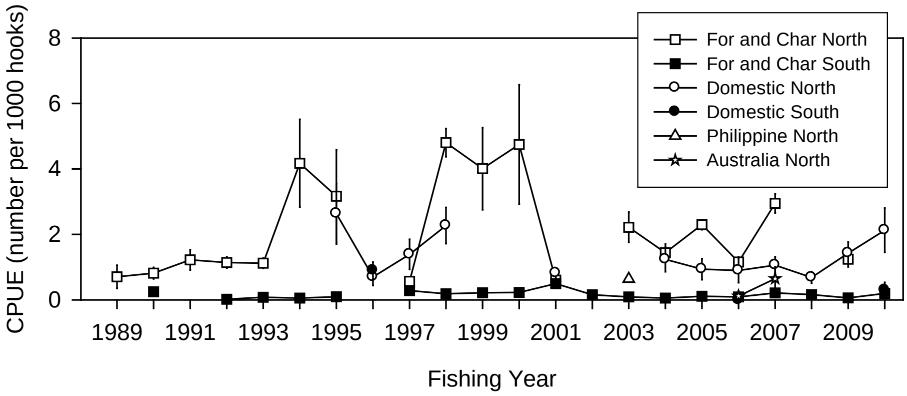


Figure 13: Annual variation in moonfish CPUE by fleet and area. Plotted values are the mean estimates with 95% confidence limits. Fishing year 1989 = October 1988 to September 1989 (Griggs and Baird in press).

5.1 Estimates of fishery parameters and abundance

There are no estimates of relevant fisheries parameters or abundance indices for moonfish.

5.2 Biomass estimates

There are no biomass estimates for moonfish.

5.3 Other yield estimates and stock assessment results

There are no other yield estimates or stock assessment results.

5.4 Other factors

While there is little information on stock status, available data suggests that moonfish are moderately productive and that most (71%) of New Zealand's catches are of mature fish. Provided that juvenile moonfish are not experiencing high fishing mortality elsewhere in their range, it is unlikely that the stock is currently depleted.

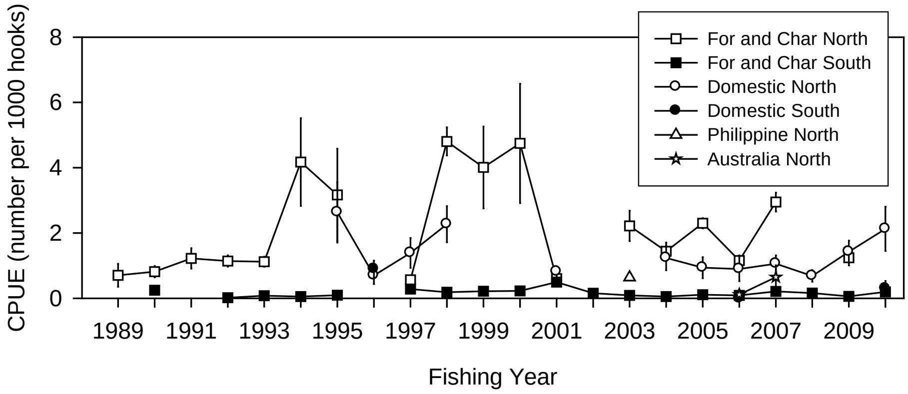
6. STATUS OF THE STOCKS

Stock structure assumptions

MOO1 is assumed to be part of the wider South Western Pacific Ocean stock but the text below relates only to the New Zealand component of that stock.

Stock Status	
Year of Most Recent Assessment	No assessment
Assessment Runs Presented	Base case model only
Reference Points	Target: Not established Soft Limit: Not established by WCPFC; but evaluated using HSS default of 20% SB_0. Hard Limit: Not established by WCPFC; but evaluated using HSS default of 10% SB_0.
Status in relation to Target	Unknown
Status in relation to Limits	Unknown

Historical Stock Status Trajectory and Current Status



Annual variation in moonfish CPUE by fleet and area. Plotted values are the mean estimates with 95% confidence limits. Fishing year 1989 = October 1988 to September 1989 (Griggs and Baird in press).

Fishery and Stock Trends	
Recent trend in Biomass or Proxy	Unknown
Recent trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	Unknown
Trends in Other Relevant Indicators or Variables	Catches in New Zealand increased from the late 1980s to 2000 but have declined from 351 t in 2000/01 to 43 t in 2007/08, This decline in catch coincides with a decline in longline fishing effort.

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

Assessment Methodology and Evaluation		
Assessment Type	Level 4: Low information evaluation - There are only data on catch and TACC, with no other fishery indicators.	
Assessment Method	2 – Medium or Mixed Quality: information has been subjected to peer review and has been found to have some shortcomings.	
Assessment Dates	Latest assessment: 2012	Next assessment:
Overall assessment quality rank		
Main data inputs (rank)	- Commercial reported catch	1 - High quality for the charter

	and effort	fleet but low for all the other fleets.
Data not used (rank)		
Changes to Model Structure and Assumptions		
Major Sources of Uncertainty		

Qualifying Comments
This fishery is largely a bycatch fishery. There are some issues associated with species identification with a new species recently described as the big-eye moonfish.

Fishery Interactions
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7. FOR FURTHER INFORMATION

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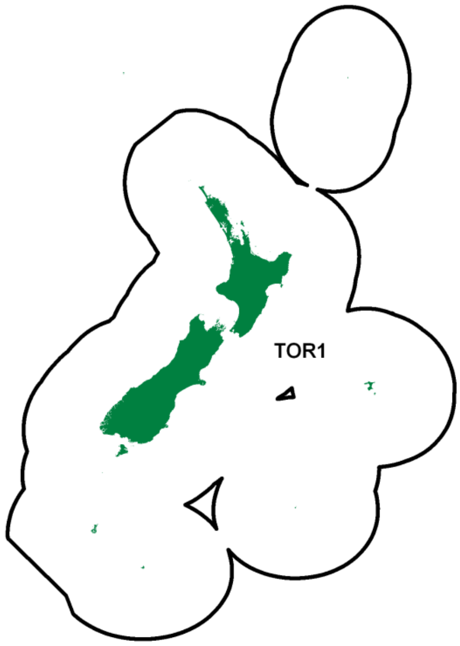
PACIFIC BLUEFIN TUNA (TOR)

(Thunnus orientalis)



1. FISHERY SUMMARY

Pacific bluefin tuna was introduced into the QMS on 1 October 2004 under a single QMA, TOR 1, with allowances, TACC, and TAC in Table 1.

Table 1: Recreational and Customary non-commercial allowances, TACCs and TACs (all in tonnes) for Pacific bluefin tuna.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other mortality	TACC	TAC
TOR 1	25	0.50	3.5	116	145

Pacific bluefin tuna were added to the Third Schedule of the 1996 Fisheries Act with a TAC set under s14 because Pacific bluefin tuna is a highly migratory species and it is not possible to estimate MSY for the part of the stock that is found within New Zealand fisheries waters.

Pacific bluefin tuna is believed to be a single Pacific-wide stock and is covered by two regional fisheries management organisations, the Western and Central Pacific Fisheries Commission (WCPFC), and the Inter-American Tropical Tuna Commission (IATTC). They will cooperate in the management of the Pacific bluefin tuna stock throughout the Pacific Ocean. Under the WCPFC Convention, New Zealand is responsible for ensuring that the management measures applied within New Zealand fisheries waters are compatible with those of the Commission.

1.1 Commercial fisheries

Pacific bluefin tuna was not widely recognised as a distinct species until the late 1990s. It was previously regarded as a sub-species of *Thunnus thynnus* (northern bluefin tuna, NTU). Prior to June 2001, catches of this species were either recorded as NTU or misidentified as southern bluefin tuna. Fishers have since become increasingly able to accurately identify TOR and, from June 2001, catch reports have rapidly increased. Catches of TOR may still be under reported to some degree as there is still some reporting against the NTU code. Recent genetic work suggests that true NTU (*Thunnus thynnus*) are not taken in the New Zealand fishery (see Biology section below for further details). Figure 1 shows the historical landings and domestic longline fishing effort for TOR1.

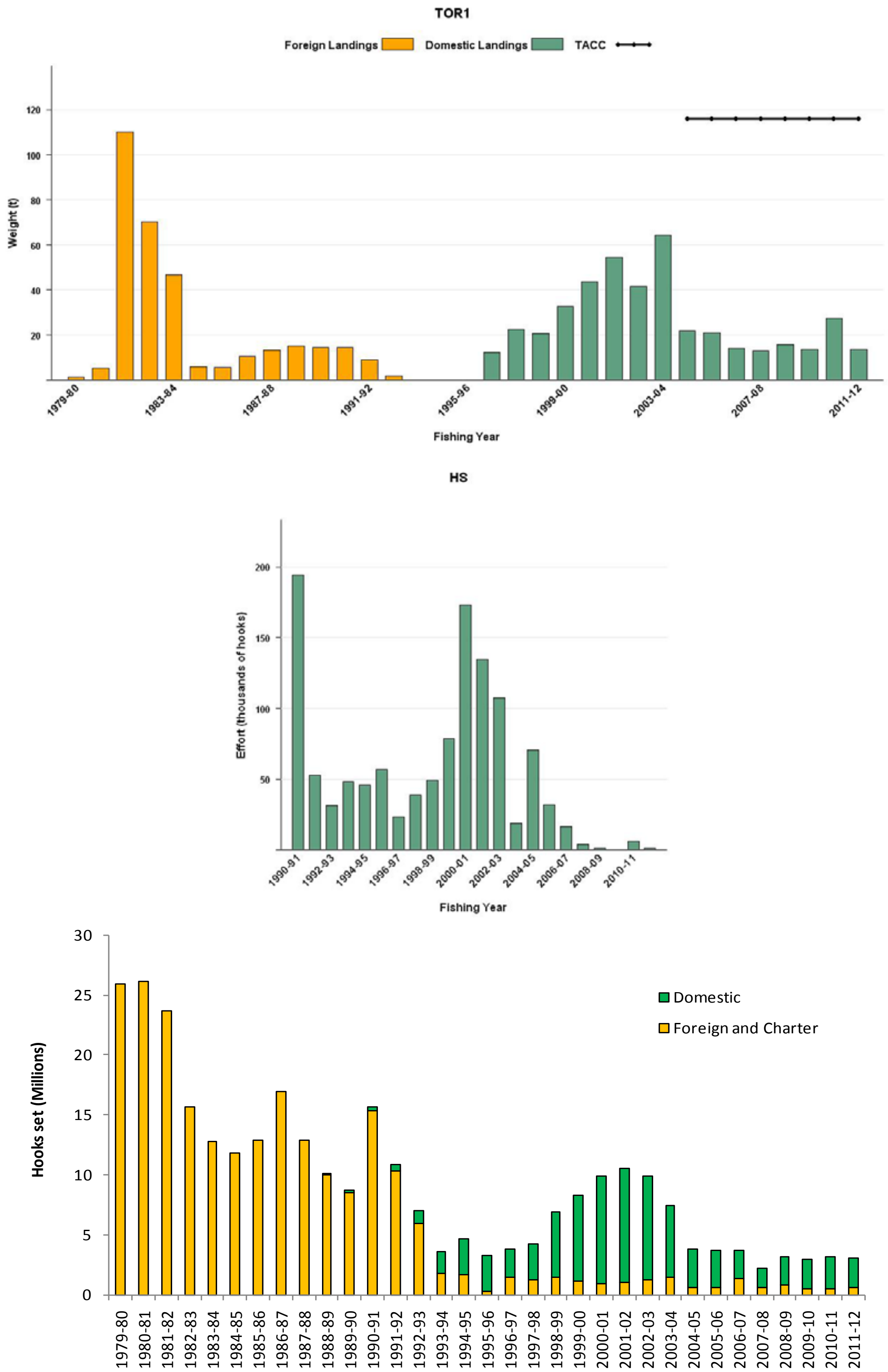


Figure 1: [Top]Commercial catch of pacific bluefin tuna by foreign licensed and New Zealand vessels from 1979-80 to 2011-12 within NZ waters (TOR1). [Middle] Fishing effort (number of hooks set) for high seas New Zealand flagged surface longline vessels, from 1990-91 to 2011-12, and [Bottom] fishing effort (number of hooks set) for all domestic vessels (including effort by foreign vessels chartered by NZ fishing companies) from 1979-80 to 2011-12.

Table 2: Reported total New Zealand landings (t) of Pacific bluefin tuna (includes landings attributed to NTU), 1991 – present and total Pacific Ocean catches.

Year	NZ landings (t)	Total stock (t)	Year	NZ landings (t)	Total stock (t)	Year	NZ landings (t)	Total stock (t)
1991	1.5	15 781	1999	21.2	29 153	2007	14	21 189
1992	0.3	13 995	2000	20.9	33 900	2008	14.0	24 794
1993	5.6	10 811	2001	49.8	18 712	2009	16.0	19 928
1994	1.9	16 961	2002	55.4	18 959	2010	13.6	18 057
1995	1.8	29 225	2003	40.8	18 419	2011	27.4	17 651
1996	4.2	23 519	2004	67.3	25 357	2012	13.7	
1997	14.3	24 632	2005	20.1	28 988			
1998	20.4	15 763	2006	21.1	26 074			

Source: NZ landings, for 1991-2002 Ministry of Fisheries Licensed Fish Receiver Reports and Solander Fisheries Ltd. 2003-2010 Ministry of Fisheries MHR data. Total Pacific landings for ISC members from http://isc.ac.affrc.go.jp/index.html. This covers most catches from this stock, but does not include South Pacific catches by coastal states in the South Pacific.

Pacific bluefin has been fished in the New Zealand EEZ since at least 1960, with some catch likely but undocumented prior to that time. New Zealand catches, while increasing, are small compared to total stock removals (Table 2).

Table 3: Reported catches or landings (t) of Pacific bluefin tuna by fleet and Fishing Year. NZ: New Zealand domestic and charter fleet, MHR data from 2001-02 to present ET: catches from New Zealand flagged longline vessels outside these areas, JPNFL: Japanese foreign licensed vessels, KORFL: foreign licensed vessels from the Republic of Korea, and LFRR: Estimated landings from Licensed Fish Receiver Returns.

	TOR 1 (all FMAs)				
Fish Yr	JPNFL	NZ/MHR	Total	LFRR	NZ ET
1979-80	1.5		1.5		
1980-81	5.3		5.3		
1981-82	110.1		110.1		
1982-83	70.1		70.1		
1983-84	47		47		
1984-85	6		6		
1985-86	5.7		5.7		
1986-87	10.6		10.6	0.0	
1987-88	13.5		13.5	0.0	
1988-89	15.1		15.1	0.0	
1989-90	14.7		14.7	0.0	
1990-91	14.5		14.5	1.5	
1991-92	9.1		9.1	0.3	
1992-93	2.1		2.1	5.6	
1993-94	0.1		0.1	1.9	
1994-95			0	1.8	
1995-96			0	4.0	
1996-97		12.5	12.5	13.0	
1997-98		22.5	22.5	20.9	0.4
1998-99		20.6	20.6	17.9	0.1
1999-00		32.6	32.6	23.1	0.1
2000-01		43.9	43.9	51.8	1.0
2001-02		54.4	54.4	53.3	0.0
2002-03		41.6	41.6	39.8	0.0
2003-04		64.3	64.3	58.1	0.0
2004-05		22.9	22.9	22.9	0.0
2005-06		21.1	21.1	20.3	0.0
2006-07		14.3	14.3	14.5	0.0
2007-08		13.1	13.1	11.9	0.0
2008-09		15.7	15.7	15.5	0.0
2009-10		13.6	13.6	12.4	0.0
2010-11		27.4	27.4	26.7	0.0
2011-12		13.7	13.7	13.4	0.0

Catches from within New Zealand fisheries waters are very small compared to those from the greater stock in the Pacific Ocean (0.14% average for 1999-2009 of the Pacific wide catch). In contrast to New Zealand, where Pacific bluefin tuna are taken almost exclusively by longline, the majority of catches are taken in purse seine fisheries in the Western and Central Pacific Ocean (WCPO) (Japan and Korea) and Eastern Pacific Ocean EPO (Mexico). Much of the fish taken by the Mexican fleet are grown in sea pens.

Prior to the introduction to the QMS, the highest catches have been made in FMA 1 and FMA 2. While it is possible to catch Pacific bluefin as far south as 48ºS, few catches are made in the colder southern FMAs. Although recent catches have occurred in FMA 7 fish have been in poor condition with little commercial value. Catches are almost exclusively by tuna longlines, typically as a bycatch of sets targeting bigeye tuna. Catches by fishing year and fleet are provided in Table 3.

The majority of Pacific bluefin tuna are caught in the bigeye tuna surface longline fishery (59%), with about 18% of the catch coming from the southern bluefin tuna surface longline fishery (18%) (Figure 2). There is no targeted commercial fishery for Pacific bluefin tuna in New Zealand. In New Zealand longline fisheries Pacific bluefin tuna make up less than 1% of the com catch (Figure 3). Longline fishing effort is distributed along the east coast of the North Island and the south west coast of the South Island. The west coast South Island fishery predominantly targets southern bluefin tuna, whereas the east coast of the North Island targets a range of species including bigeye, swordfish, and southern bluefin tuna (Figure 4).

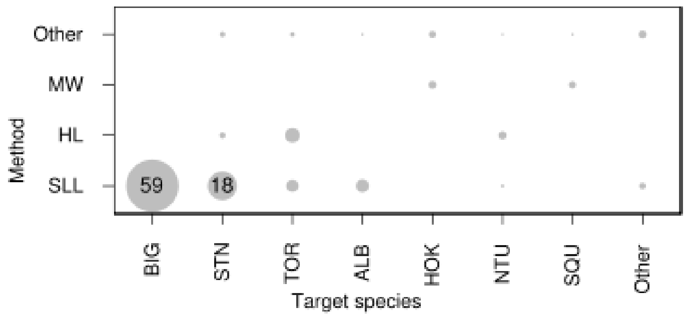


Figure 2: A summary of the proportion of landings of pacific bluefin tuna taken by each target fishery and fishing method. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the bobble is the percentage. SLL = surface longline MW = mid-water trawl and HL = hand line (Bentley *et al.* 2012).

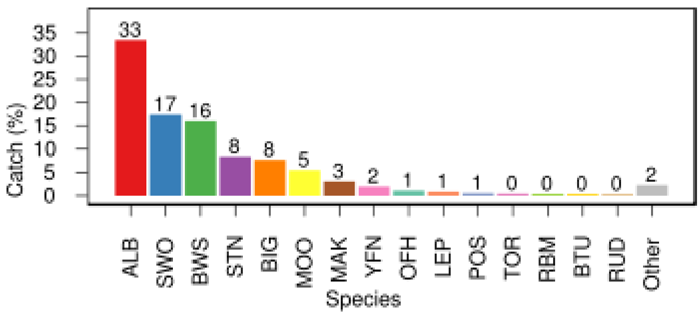


Figure 3: A summary of species composition of the reported surface longline catch. The percentage by weight of each species is calculated for all surface longline trips (Bentley *et al.* 2012).

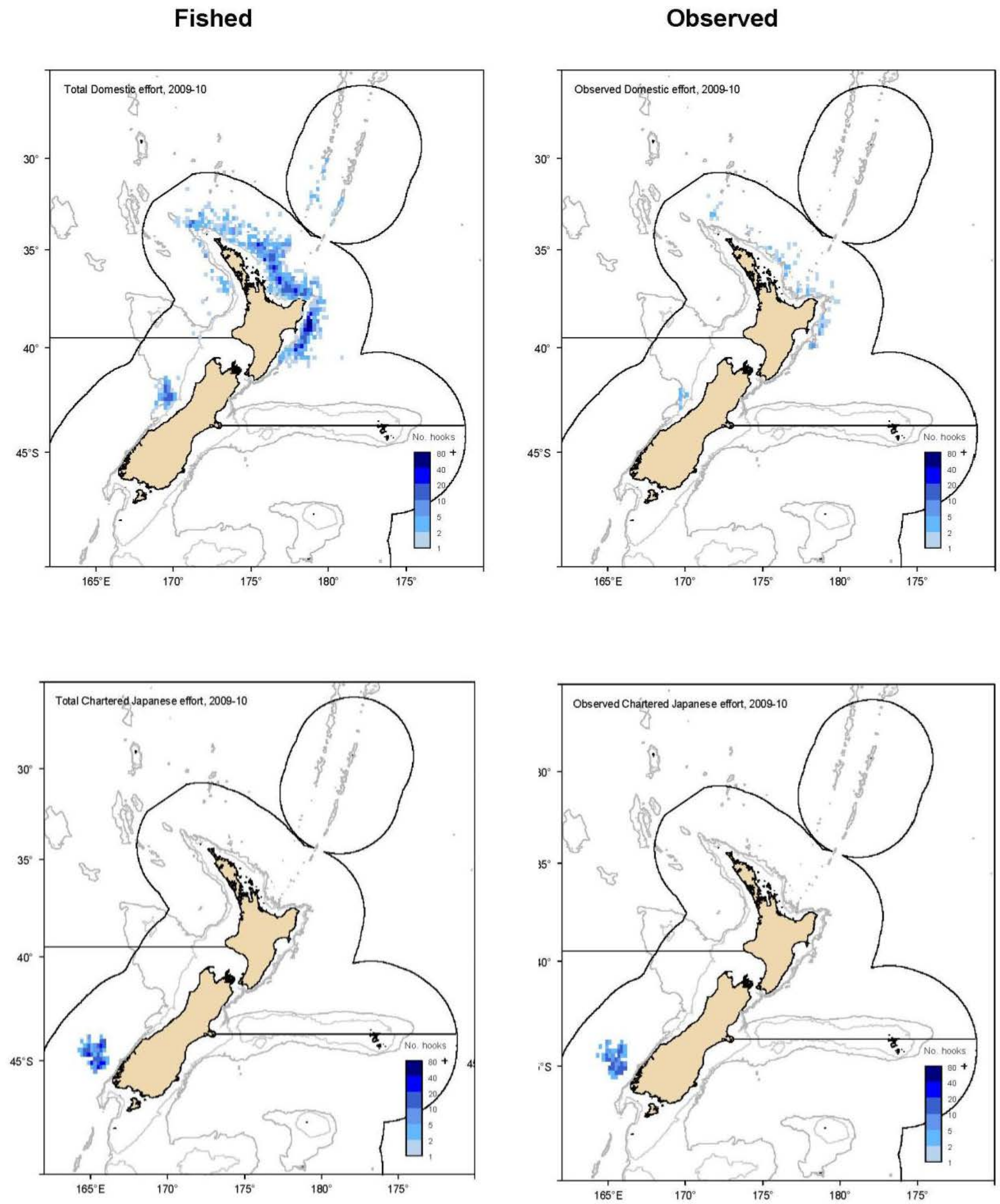


Figure 4: Distribution of fishing positions for the New Zealand domestic (top two panels) and charter (bottom two panels) vessels, for the 2009-10 fishing year, displaying both fishing effort (left) and observer effort (right).

1.2 Recreational fisheries

Recreational fishers make occasional catches of Pacific bluefin tuna. In 2004 a target recreational fishery developed off the west coast of the South Island targeting large Pacific bluefin tuna that feed on spawning aggregations of hoki (*Macruronus novaezealandiae*) that are targeted by commercial trawl vessels offshore between July and September. Fish taken in this fishery have been submitted for various world records for this species. Some information on charter vessel catch has been collected by MPI through voluntary reporting. The recreational allowance for Pacific bluefin was increased from 1 t to 25 t per year from 1 October 2011 to recognise the growth in this fishery. There is no information on the size of catch from the National Surveys of recreational fishers. The recreational charter boat reporting scheme collects catch and effort information from most vessels participating in this fishery in future. A small number of private vessels are also active.

1.3 Customary non-commercial fisheries

There is no quantitative information available to allow the estimation of the harvest of Pacific bluefin tuna by customary fishers; however, the Maori customary catch of Pacific bluefin is probably negligible because of the species seasonal and offshore distribution.

1.4 Illegal catch

There is no known illegal catch of Pacific bluefin tuna in New Zealand fisheries waters.

1.5 Other sources of mortality

There is likely to be a low level of shark damage and discard mortality of Pacific bluefin caught on tuna longlines that may be on the order of 1-2% assuming all tuna species are subject to equivalent levels of incidental mortality. There have been reports that some fish hooked in the target recreational fishery have been lost due to entanglement of the fishing line with trawl warps. The survival of these lost fish is not known. An allowance of 3.5 t has been made for other sources of mortality.

2. BIOLOGY

Pacific bluefin tuna are epi-pelagic opportunistic predators of fish, crustaceans and cephalopods found within the upper few hundred meters of the water column. Individuals found in New Zealand fisheries waters are mostly adults. Adult Pacific bluefin occur broadly across the Pacific Ocean, especially the waters of the North Pacific Ocean.

There has been some uncertainty among fishers regarding bluefin tuna taken in New Zealand waters. Some fishers believe that three species of bluefin tuna are taken in New Zealand waters with some small catches of true “Northern” Atlantic tuna (*Thunnus thynnus*) in addition to Pacific and southern bluefin tuna. This belief is based on several factors include differences in morphology and the prices obtained for certain fish on the Japanese market.

To address this issue, muscle tissue samples were taken from 20 fish for which there was uncertainty as to whether the fish was a Pacific bluefin tuna (*Thunnus orientalis*) or an Atlantic bluefin tuna. A further sample from a fish thought to be a southern bluefin tuna was also included. The tissue samples were sequenced for the COI region of DNA, and the sequences compared with COI sequences for the three species of tuna held in GenBank. All of the DNA sequences, except one, matched with sequences for Pacific bluefin tuna. The final sample was confirmed as a southern bluefin tuna. Therefore, based on DNA analysis, there is presently no evidence that Atlantic bluefin tuna are taken in New Zealand waters. Further tissue samples from fish thought by fishers to be NTU will be collected by scientific observers.

Adult Pacific bluefin reach a maximum size of 550 kg and lengths of 300 cm. Maturity is reached at 3 to 5 years of age and individuals live to 15+ years old. Spawning takes place between Japan and the Philippines in April, May and June, spreading to the waters off southern Honshu in July and to the Sea of Japan in August. Pacific bluefin of 270 to 300 kg produce about 10 million eggs but there is no information on the frequency of spawning. Juveniles make extensive migrations north and eastwards across the Pacific Ocean as 1-2 year old fish. Pacific bluefin caught in the southern hemisphere, including those caught in New Zealand waters, are primarily adults.

Natural mortality is assumed to vary from about 0.1 to 0.4 and to be age specific in assessments undertaken by the IATTC. A range of von Bertalanffy growth parameters have been estimated for Pacific bluefin based on length frequency analysis, tagging and reading of hard parts (Table 4).

Table 4: von Bertalanffy growth parameters for Pacific bluefin tuna.

Method	L infinity	*k*	t_0
length frequencies	300.0		
scales	320.5	0.1035	- 0.7034
scales	295.4		
tagging	219.0	0.211	

The length weight relationship of Pacific bluefin based on observer data from New Zealand caught fish yields the following:

whole weight = 8.058 $e^{0.015\ \mathrm{length}}$ $R^2 = 0.895$, n = 49 (weight is in kg and length is in cm).

Although the sample size of genetically confirmed Pacific bluefin that has been sexed by observers is small (50 fish), the sex ratio in New Zealand waters is not significantly different from 1:1.

3. STOCKS AND AREAS

Pacific bluefin tuna constitutes a single Pacific-wide stock that is primarily distributed in the northern hemisphere.

Between 2006 and 2008 42 Pacific bluefin were tagged from recreational charter vessels in New Zealand waters using Pop-off Satellite Archival Tags (PSATs), and all tags that have ‘reported’ to date indicate that these fish survived catch and release and spend several months within the New Zealand or Australian EEZs and adjacent waters over spring and summer. The full results of this work will be published in 2012.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the November 2012 Fishery Assessment Plenary after review by the Aquatic Environment Working Group. This summary is from the perspective of pacific bluefin tuna but there is no directed fishery for them and the incidental catch sections below reflect the New Zealand longline fishery as a whole and are not specific to this species; a more detailed summary from an issue-by-issue perspective is, or will shortly be, available in the Aquatic Environment & Biodiversity Annual Review where the consequences are also discussed.
(http://www.mpi.govt.nz/news-resources/publications.aspx).

4.1 Role in the ecosystem

Pacific bluefin tuna (*Thunnus thynnus orientalis,*) is one of the largest teleost fish species (Kitagawa *et al.* 2004), comprising a single population that spawns only to the south of Japan and in the Sea of Japan (Sund *et al.*, 1981). The pacific bluefin tuna are large pelagic predators, so they are likely to have a ‘top down’ effect on the fish, crustaceans and squid they feed on.

4.2 Incidental catch (seabirds, sea turtles and mammals)

The protected species, capture estimates presented here include all animals recovered onto the deck (alive, injured or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds caught on a hook but not brought onboard the vessel).

4.2.1 Seabird bycatch

Between 2002–03 and 2010–11, there were 731 observed captures of birds across all surface longline fisheries. Seabird capture rates since 2003 are presented in Figure 5. While the seabird capture distributions largely coincide with fishing effort that are more frequent off the south west coast of the South Island (Figure 6). The analytical methods used to estimate capture numbers across the commercial fisheries have depended on the quantity and quality of the data, in terms of the numbers observed captured and the representativeness of the observer coverage. Ratio estimation was historically used to calculate total captures in longline fisheries by target fishery fleet and area (Baird 2008) and by all fishing methods but recent estimates are either ratio or model based as specified in the tables below (Abraham *et al.* 2010a).

Through the 1990s the minimum seabird mitigation requirement for surface longline vessels was the use of a bird scaring device (tori line) but common practice was that vessels set surface longlines primarily at night. In 2007 a notice was implemented under s 11 of the Fisheries Act 1996 to formalise the requirement that surface longline vessels only set during the hours of darkness and use a tori line when setting. This notice was amended in 2008 to add the option of line weighting and tori line use if setting during the day. In 2011 notices were combined and repromulgated under a new regulation (Regulation 58A of the Fisheries (Commercial Fishing) Regulations 2001) which provides a more flexible regulatory environment under which to set seabird mitigation requirements.

Table 5: Number of observed seabird captures in the New Zealand surface longline fisheries, 2002-03 to 2010-11, by species and area (Thompson & Abraham (2012) from http://data.dragonfly.co.nz/psc/). See glossary above for a description of the areas used for summarising the fishing effort and protected species captures. 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 pacific bluefin tuna using longline gear but rather the total risk for each seabird species.

Species	Risk ratio	Kermadec Islands	Northland and Hauraki	Bay of Plenty	East Coast North Island	Stewart Snares Shelf	Fiordland	West Coast South Island	West Coast North Island	Total
Salvin's albatross	2.49	0	1	1	6	0	0	0	0	8
Northern royal albatross	2.21	0	0	1	0	0	0	0	0	1
Light-mantled sooty albatross	2.18	0	0	0	0	0	0	1	0	1
Campbell albatross	1.84	0	8	0	26	0	3	3	0	40
Southern Buller's albatross	1.28	0	3	1	26	0	251	31	0	312
Gibson's albatross	1.25	4	10	0	11	0	3	1	1	30
Antipodean albatross	1.11	12	9	1	7	0	0	0	1	30
White capped albatross	0.83	0	1	0	3	10	54	25	0	93
Southern royal albatross	0.74	0	0	0	0	0	4	0	0	4
Black browed albatrosses	-	2	1	0	0	0	0	0	1	4
Pacific albatross	-	0	0	0	1	0	0	0	0	1
Southern black-browed albatross	-	0	0	0	2	0	0	0	0	2
Wandering albatross	-	0	2	0	6	0	3	0	0	11
Antipodean and Gibson's albatrosses	N/A	5	2	0	0	0	0	0	0	7
Unidentified albatross	N/A	33	0	0	1	0	0	0	1	35
Total albatrosses	**N/A**	**56**	**37**	**4**	**89**	**10**	**318**	**61**	**4**	**579**
Black petrel	11.15	1	9	1	0	0	0	0	1	12
Westland petrel	3.31	0	0	0	2	0	1	5	0	8
Flesh footed shearwater	2.51	0	0	0	10	0	0	0	2	12
Cape petrels	0.76	0	0	0	2	0	0	0	0	2
White chinned petrel	0.79	2	2	3	3	1	19	0	3	33
Grey petrel	0.39	3	3	2	38	0	0	0	0	46
Sooty shearwater	0.02	1	0	0	8	3	1	0	0	13
Great winged petrel	0.01	12	5	1	2	0	0	0	0	20
White headed petrel	0.01	2	0	0	0	0	0	0	0	2
Pterodroma petrels	-	0	1	0	0	0	0	0	0	1
Southern giant petrel	-	0	0	0	2	0	0	0	0	2
Unidentified seabird	N/A	0	0	0	0	0	1	0	0	1
Total other birds	**N/A**	**21**	**20**	**7**	**67**	**4**	**22**	**5**	**6**	**152**

Table 6: Effort, observed and estimated seabird captures by fishing year for the New Zealand surface longline fishery within the EEZ. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); the capture rate (captures per thousand hooks); and the mean number of estimated total captures (with 95% confidence interval). The estimation method used was a Bayesian model with 100% of hooks included in the estimate. For more information on the methods used to prepare the data see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures		Estimated captures	
	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002-2003	10 764 588	2 195 152	20.4	115	0.052	2490	1817-3461
2003-2004	7 380 779	1 607 304	21.8	71	0.044	1665	1259-2220
2004-2005	3 676 365	783 812	21.3	41	0.052	687	507-936
2005-2006	3 687 339	705 945	19.1	37	0.052	816	607-1120
2006-2007	3 738 362	1 040 948	27.8	187	0.18	949	725-1304
2007-2008	2 244 339	426 310	19	41	0.096	521	408-681
2008-2009	3 115 633	937 233	30.1	57	0.061	721	562-934
2009-2010	2 992 285	665 883	22.3	149	0.224	1014	777-1345
2010-2011	3 164 159	674 522	21.3	47	0.07	824	607-1152

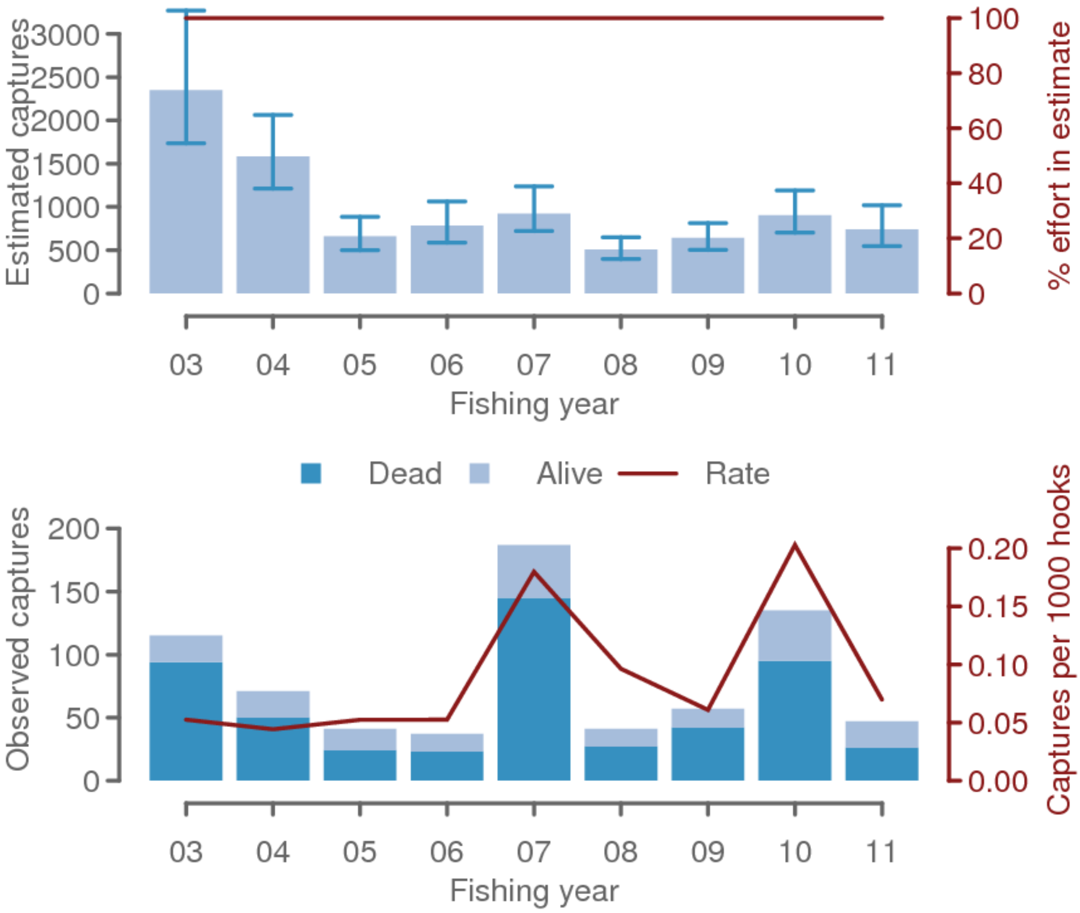


Figure 5: Observed and estimated captures of seabirds in the New Zealand surface longline fisheries from 2003 to 2011.

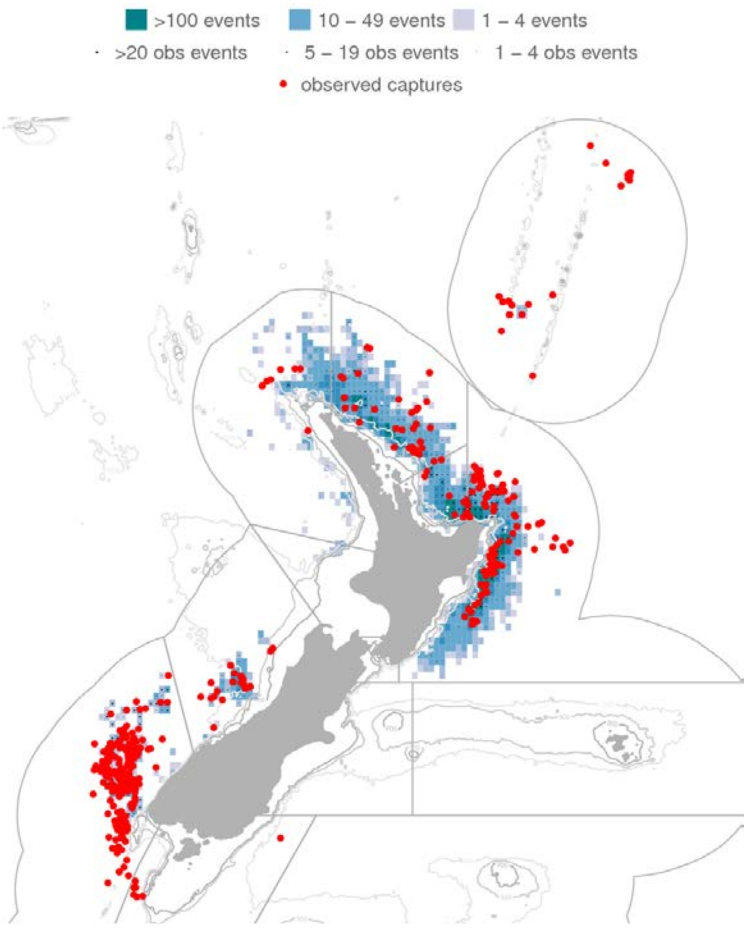


Figure 6: Distribution of fishing effort in the New Zealand surface longline fisheries and observed seabird captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.2 Sea turtle bycatch

Between 2002–03 and 2010–11, there were 13 observed captures of sea turtles across all surface longline fisheries (Tables 7 and 8, Figure 7). Observer records documented all but one sea turtle as captured and released alive. Sea turtle capture distributions predominantly occur throughout the east coast of the North Island and Kermadec Island fisheries (Figure 8).

Table 7: Number of observed sea turtle captures in the New Zealand surface longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson and Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

Species	Bay of Plenty	East Coast North Island	Kermadec Islands	West Coast North Island	Total
Leatherback turtle	1	4	3	3	11
Olive ridley turtle	0	1	0	0	1
Unknown turtle	0	1	0	0	1
Total	**1**	**6**	**3**	**3**	**13**

Table 8: Effort and sea turtle captures in surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	10 764 588	2 195 152	20.4	0	0
2003-2004	7 380 779	1 607 304	21.8	1	0.001
2004-2005	3 676 365	783 812	21.3	2	0.003
2005-2006	3 687 339	705 945	19.1	1	0.001
2006-2007	3 738 362	1 040 948	27.8	2	0.002
2007-2008	2 244 339	426 310	19.0	1	0.002
2008-2009	3 115 633	937 233	30.1	2	0.002
2009-2010	2 992 285	665 883	22.3	0	0
2010-2011	3 164 159	674 522	21.3	4	0.006

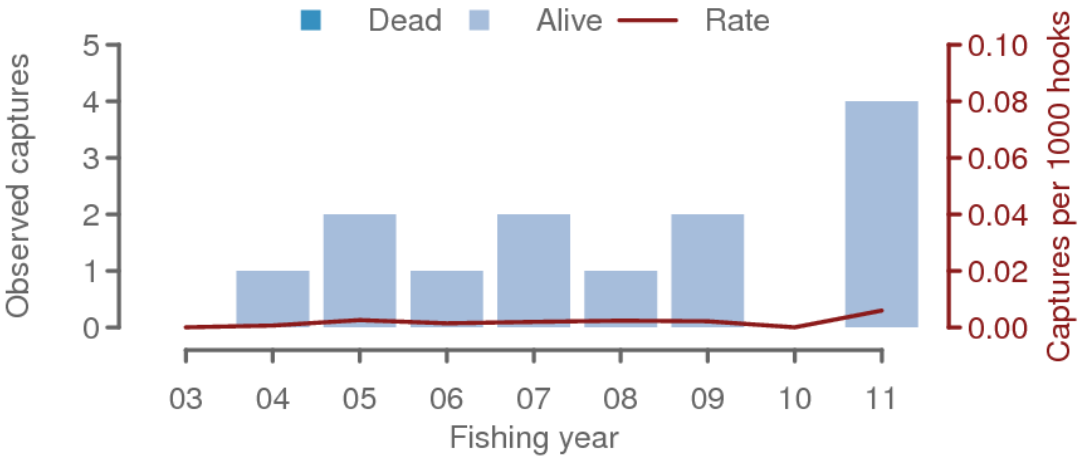


Figure 7: Observed captures of sea turtles in the New Zealand surface longline fisheries from 2003 to 2011.

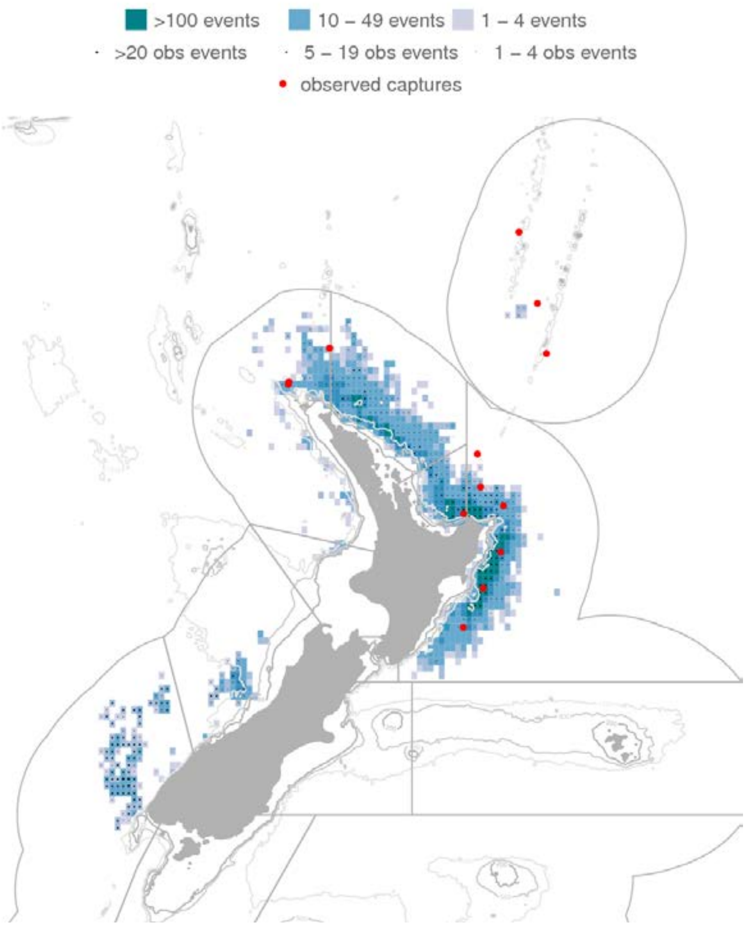


Figure 8: Distribution of fishing effort in the New Zealand surface longline fisheries and observed sea turtle captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3 Marine Mammals

4.2.3.1 Cetaceans

Cetaceans are dispersed throughout New Zealand waters (Perrin *et al.* 2008). The spatial and temporal overlap of commercial fishing grounds and cetacean foraging areas has resulted in cetacean captures in fishing gear (Abraham and Thompson 2009, 2011).

Between 2002–03 and 2010–11, there were seven observed captures of whales and dolphins in surface longline fisheries. Observed captures included 5 unidentified cetaceans and 2 long-finned Pilot whales (Tables 9 and 10, Figure 9) (Abraham and Thompson 2011). All captured animals recorded were documented as being caught and released alive (Thompson and Abraham 2010). Cetacean capture distributions are more frequent off the east coast of the North Island (Figure 10).

Table 9: Number of observed cetacean captures in the New Zealand surface longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson and Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

Species	Bay of Plenty	East Coast North Island	Fiordland	Northland and Hauraki	West Coast North Island	West Coast South Island	Total
Long-finned pilot whale	0	1	0	0	0	1	2
Unidentified cetacean	1	1	1	1	1	0	5
Total	**1**	**2**	**1**	**1**	**1**	**1**	**7**

Table 10: Effort and captures of cetaceans in surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	10 764 588	2 195 152	20.4	1	0.0005
2003-2004	7 380 779	1 607 304	21.8	4	0.002
2004-2005	3 676 365	783 812	21.3	1	0.001
2005-2006	3 687 339	705 945	19.1	0	0
2006-2007	3 738 362	1 040 948	27.8	0	0
2007-2008	2 244 339	426 310	19.0	1	0.002
2008-2009	3 115 633	937 233	30.1	0	0
2009-2010	2 992 285	665 883	22.3	0	0
2010-2011	3 164 159	674 522	21.3	0	0

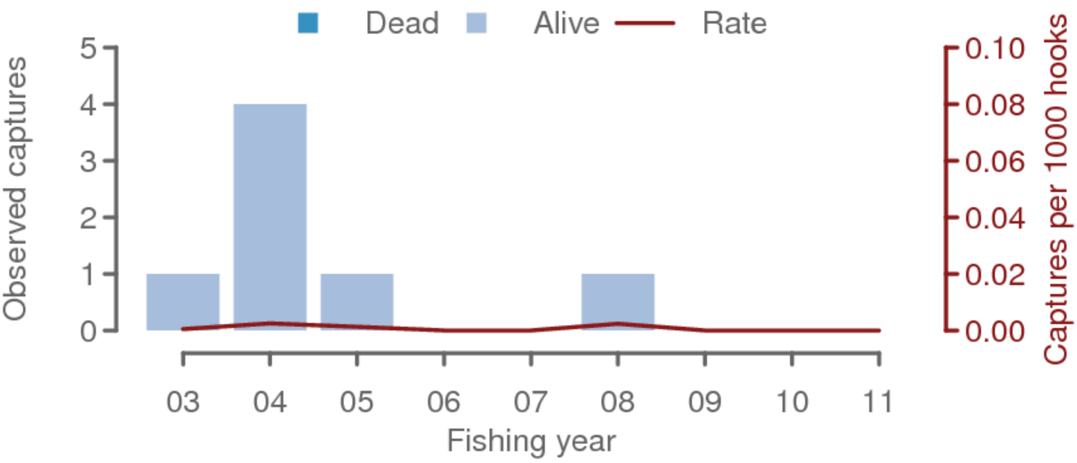


Figure 9: Observed captures of cetaceans in the New Zealand surface longline fisheries from 2003 to 2011.

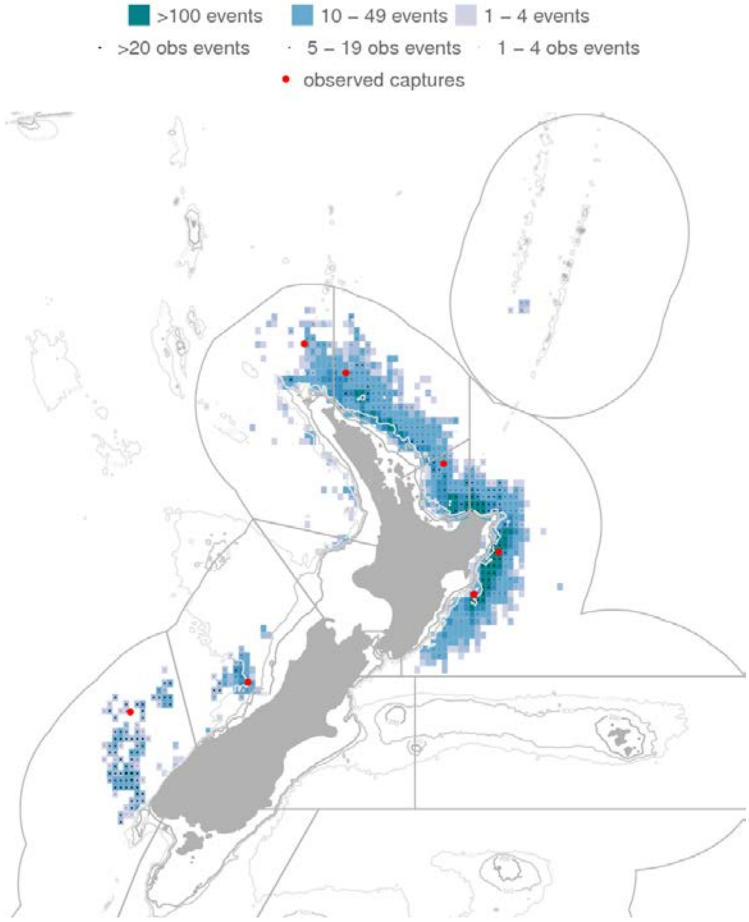


Figure 10: Distribution of fishing effort in the New Zealand surface longline fisheries and observed cetacean captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3.2 New Zealand fur seal bycatch

Currently, New Zealand fur seals are dispersed throughout New Zealand waters, especially in waters south of about 40º S to Macquarie Island. The spatial and temporal overlap of commercial fishing grounds and New Zealand fur seal foraging areas has resulted in New Zealand fur seal captures in fishing gear (Mattlin 1987, Rowe 2009). Most fisheries with observed captures occur in waters over or close to the continental shelf, which around much of the South Island and offshore islands slopes steeply to deeper waters relatively close to shore, and thus rookeries and haulouts. Captures on longlines occur when the seals attempt to feed on the fish and bait catch during hauling. Most New Zealand fur seals are released alive, typically with a hook and short snood or trace still attached.

New Zealand fur seal captures in surface longline fisheries have been generally observed in waters south and west of Fiordland, but also in the Bay of Plenty-East Cape area when the animals have attempted to take bait or fish from the line as it is hauled. These capture rates include animals that are released alive (100% of observed surface longline capture in 2008-09; Thompson and Abraham 2010). Bycatch rates in 2010-11 are low and lower than they were in the early 2000s (Figure 11). While fur seal captures have occurred throughout the range of this fishery most New Zealand captures have occurred off the Southwest coast of the South Island

(Figure 12). Between 2002–03 and 2010–11, there were 206 observed captures of New Zealand fur seal in surface longline fisheries (Tables 11 and 12).

Table 11: Number of observed New Zealand fur seal captures in the New Zealand surface longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson and Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

	Bay of Plenty	East Coast North Island	Fiordland	Northland and Hauraki	Stewart Snares Shelf	West Coast North Island	West Coast South Island	Total
New Zealand fur seal	10	16	139	3	4	2	32	206

Table 12: Effort and captures of New Zealand fur seal in the New Zealand surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see [Abraham and Thompson (2011)](#).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	10 764 588	2 195 152	20.4	56	0.026
2003-2004	7 380 779	1 607 304	21.8	40	0.025
2004-2005	3 676 365	783 812	21.3	20	0.026
2005-2006	3 687 339	705 945	19.1	12	0.017
2006-2007	3 738 362	1 040 948	27.8	10	0.010
2007-2008	2 244 339	426 310	19.0	10	0.023
2008-2009	3 115 633	937 233	30.1	22	0.023
2009-2010	2 992 285	665 883	22.3	19	0.029
2010-2011	3 164 159	674 522	21.3	17	0.025

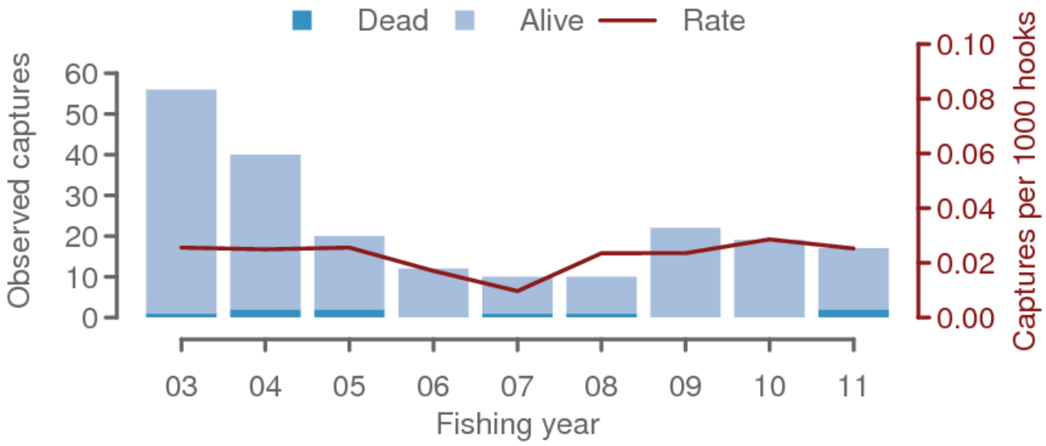


Figure 11: Observed captures of New Zealand fur seal in the New Zealand surface longline fisheries from 2003 to 2011.

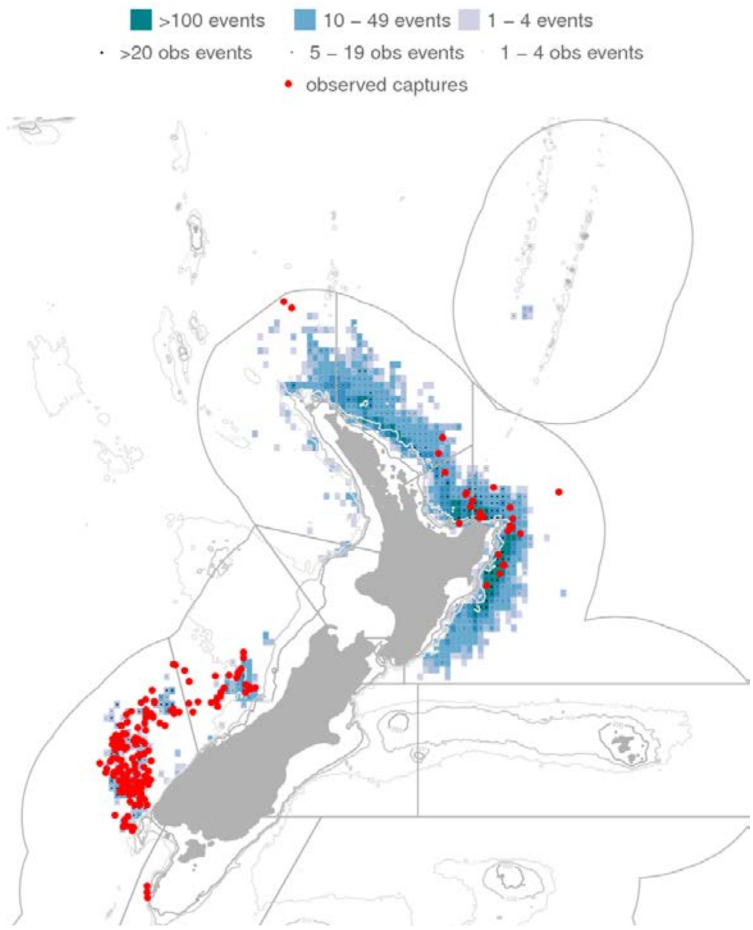


Figure 12: Distribution of fishing effort in the New Zealand surface longline fisheries and observed New Zealand fur seal captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.3 Incidental fish bycatch

Observer records indicate that a wide range of species are landed by the longline fleets in New Zealand fishery waters. Blue sharks are the most commonly landed species (by number) in followed by Ray's bream (Table 12), southern bluefin tuna and albacore tuna are the only target species that occur in the top five of the frequency of occurrence.

Table 12: Numbers of the most common fish species observed in the New Zealand longline fisheries during 2009-10 by fleet and area. Species are shown in descending order of total abundance (Griggs and Baird in press).

	Charter	Domestic		Total
Species	South	North	South	number
Blue shark	2 024	4 650	882	7 556
Rays bream	3 295	326	88	3 709
Southern bluefin tuna	3 244	211	179	3 634
Lancetfish	3	2 139	1	2 143
Albacore tuna	90	1 772	42	1 904
Dealfish	882	0	7	889
Swordfish	3	452	2	457
Moonfish	76	339	6	421
Porbeagle shark	72	328	20	420
Mako shark	11	343	7	361
Big scale pomfret	349	4	0	353
Deepwater dogfish	305	0	0	305
Sunfish	7	283	5	295
Bigeye tuna	0	191	0	191
Escolar	0	129	0	129
Butterfly tuna	15	100	3	118
Pelagic stingray	0	96	0	96
Oilfish	2	75	0	77
Rudderfish	39	20	2	61
Flathead pomfret	56	0	0	56
Dolphinfish	0	47	0	47
School shark	34	0	2	36
Striped marlin	0	24	0	24
Thresher shark	7	17	0	24
Cubehead	13	0	1	14
Kingfish	0	10	0	10
Yellowfin tuna	0	9	0	9
Hake	8	0	0	8
Hapuku bass	1	6	0	7
Pacific bluefin tuna	0	5	0	5
Black barracouta	0	4	0	4
Skipjack tuna	0	4	0	4
Shortbill spearfish	0	4	0	4
Gemfish	0	3	0	3
Bigeye thresher shark	0	2	0	2
Snipe eel	2	0	0	2
Slender tuna	2	0	0	2
Wingfish	2	0	0	2
Bronze whaler shark	0	1	0	1
Hammerhead shark	0	1	0	1
Hoki	0	0	1	1
Louvar	0	1	0	1
Marlin, unspecified	0	1	0	1
Scissortail	0	1	0	1
Broadnose seven gill shark	1	0	0	1
Shark, unspecified	0	1	0	1
Unidentified fish	2	30	8	40
Total	10 545	11 629	1 256	23 430

4.4 Benthic interactions
N/A

4.5 Key environmental and ecosystem information gaps
Cryptic mortality is unknown at present but developing a better understanding of this in future may be useful for reducing uncertainty of the seabird risk assessment and could be a useful input into risk assessments for other species groups.

The survival rates of released target and bycatch species is currently unknown.

Observer coverage in the New Zealand fleet is not spatially and temporally representative of the fishing effort.

5. STOCK ASSESSMENT

A new assessment using Stock Synthesis was undertaken by the International Scientific Committee for tuna and tuna-like species (ISC). This is summarised in Anon (2008) as follows:

"New age and growth data from otolith annuli were available for inclusion in the assessment. The assessment spans the period 1952-2005 and incorporates troll and longline CPUE indices; a fixed growth curve; age specific natural mortality (fixed) with very high natural mortality for youngest age class; and full maturity at age 5 years. The main fisheries occur around Japan, including longline fisheries in the spawning season, purse-seine fisheries, set net fisheries, and troll fisheries. Recent catches have been dominated by small fish (0+ and 1+ years old) and there have been recent increases in catch by Mexico and Korea. Total annual catches are currently about 23 000 t per year.

Longline CPUE has been strongly influenced by changes in the operation of the fishery, particularly changes in species targeting and areas fished. There is no single CPUE index spanning the entire time period of the model and a number of separate indices, covering different and, in some cases, non-overlapping periods are incorporated in the model.

The stock assessment model estimates variable recruitment through the model period, resulting in three major peaks in spawning biomass through the model period. There has been an increase in fishing mortality rates during the last 10 years, principally for the youngest age classes. Sensitivities with respect to the natural mortality schedule revealed recruitment and spawning biomass strongly influenced by the model assumptions. Other key sources of uncertainties are the level of fishing mortality and recruitment estimates for the recent year classes. A retrospective analysis indicated that the model is underestimating the most recent year's (2005) recruitment. This in turn affects the reliability of the stock projections. Assumptions regarding the magnitude of the 2005 recruitment influence the stock status (spawning biomass) in the medium term. Projections also investigated the effect of increasing or decreasing fishing mortality.

Given the conclusions of the May–June 2008 stock assessment with regards to the current level of F relative to potential target and limit reference points, and residual uncertainties associated with key model parameters it is important that the current level of F is not increased. If F remains at the current level and environmental conditions remain favourable, then recruitment should be sufficient to maintain current yields well into the future. Increases in F above the current level, and/or unfavourable changes in environmental conditions, may result in recruitment levels that are insufficient to sustain the current productivity of the stock."

5.1 Estimates of fishery parameters and abundance
None are available at present.

5.2 Biomass estimates
Estimates of current and reference biomass are not available.

5.3 Estimation of Maximum Constant Yield (MCY)
No estimates of MCY are available.

5.4 Estimation of Current Annual Yield (CAY)
No estimates of CAY are available.

6. STATUS OF THE STOCKS

Stock structure assumptions
Western and Central Pacific Ocean
All biomass in this Table refer to spawning biomass (SB).

Stock Status	
Year of Most Recent Assessment	2008
Assessment Runs Presented	Base case model only
Reference Points	Target: Not established; default = B_{MSY} Soft Limit: Not established by WCPFC or IATTC; but evaluated using HSS default of 20% SB_0. Hard Limit: Not established by WCPFC or IATTC; but evaluated using HSS default of 10% SB_0.
Status in relation to Target	About as Likely as Not (40-60%) to be at or above B_{MSY}. About as Likely as Not that $F>F_{MSY}$
Status in relation to Limits	Unlikely (< 40%) to be below the soft and hard limits.
Historical Stock Status Trajectory and Current Status	

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass in 1995 was estimated to have rebuilt from a historic low in the mid-1980's, but has declined slightly since that time.
Recent Trend in Fishing Mortality or Proxy	F's on recruits (age 0) and on juveniles (ages 1-3) have been generally increasing for more than a decade (1990-2005). The catch (in weight) is dominated by recruits and juveniles (ages 0-3).
Other Abundance Indices	
Trends in Other Relevant Indicator or Variables	Recruitment has fluctuated without trend over the assessment period (1952-2006), and does not appear to have been adversely affected by the relatively high rate of exploitation. Recent recruitment (2005-present) is highly uncertain, making short-term forecasting difficult. In particular, the 2005 year class strength may have been underestimated in this assessment.

Projections and Prognosis	
Stock Projections or Prognosis	Using the new M values, preliminary results of the future stock projection suggest that in the short-term (2009-2010) and under recent levels of F, SB will decline, but in the longer-term SB will attain its historical median level.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 1: Quantitative Stock assessment	
Assessment Method	Quantitative assessment in Stock Synthesis.	
Assessment Dates	Latest assessment: 2008	Next assessment: 2012
Overall assessment quality rank		

Main data inputs (rank)	- 1952-2005 (Fishing year, July 1 to June 30) - Quarterly catch time series of 10 fleets - 4 Longline CPUE trends (3 Japan, 1 Chinese-Taipei)	- 1 Troll CPUE trend - Growth curve was fixed to new growth curve obtained from otolith annulus counts
Data not used (rank)		
Changes to Model Structure and Assumptions		
Major Sources of Uncertainty	The assumed natural mortality rate. Recruitment strength (and F on recruits) in the most recent year (2005) of the stock assessment. The assessment is not well documented.	

Qualifying Comments
The assessment is not well documented, and has not had sufficient review by the WCPFC Scientific Committee.

Fishery Interactions
Interactions with protected species are known to occur in the longline fisheries of the South Pacific, particularly south of 25°S. Seabird bycatch mitigation measures are required in the New Zealand and Australian EEZ's and through the WCPFC Conservation and Management Measure CMM2007-04. Sea turtles also get incidentally captured in longline gear; the WCPFC is attempting to reduce sea turtle interactions through Conservation and Management Measure CMM2008-03. Shark bycatch is common in longline fisheries and largely unavoidable; this is being managed through New Zealand domestic legislation and to a limited extent through Conservation and Management Measure CMM2010-07.

7. FOR FURTHER INFORMATION

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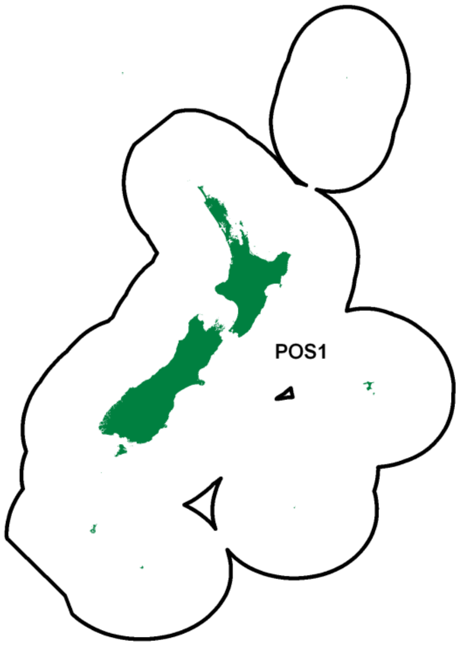
PORBEAGLE SHARK (POS)

(*Lamna nasus)*



1. FISHERY SUMMARY

Porbeagle shark were introduced into the QMS on 1 October 2004 under a single QMA, POS 1, with a TAC of 249 t, a TACC of 215 t and a recreational allowance of 10 t. The TAC was reviewed in 2012 with the reduced allocation and allowances applied from 1 October 2012 in Table 1. The decrease was in response to sustainability concerns surrounding porbeagle sharks which are slow growing and have low fecundity, making them particularly vulnerable to overexploitation.

Table 1: Recreational and Customary non-commercial allowances, TACCs and TACs (all in tonnes) for porbeagle shark.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other mortality	TACC	TAC
POS 1	6	2	11	110	129

Porbeagle shark was added to the Third Schedule of the 1996 Fisheries Act with a TAC set under s14 because porbeagle shark is a highly migratory species and it is not possible to estimate MSY for the part of the stock that is found within New Zealand fisheries waters.

Porbeagle shark was also added to the Sixth Schedule of the 1996 Fisheries Act with the provision that:

> "A commercial fisher may return any porbeagle shark to the waters from which it was taken from if –
> (a) that porbeagle shark is likely to survive on return; and
> (b) the return takes place as soon as practicable after the porbeagle shark is taken."

Management of the porbeagle shark throughout the western and central Pacific Ocean (WCPO) is the responsibility of the Western and Central Pacific Fisheries Commission (WCPFC). Under this regional convention New Zealand is responsible for ensuring that the management measures applied within New Zealand fisheries waters are compatible with those of the Commission.

1.1 Commercial fisheries

About half of the commercial catch of porbeagle shark is taken by tuna longliners, and most of the rest by mid-water and bottom trawlers. About 50% of porbeagle sharks caught by tuna longliners are processed, and the rest are discarded. Of the sharks that are processed, about 80% are finned only, and 20% are processed for their flesh and fins. Figure 1 shows historical landings and longline fishing effort for POS1.

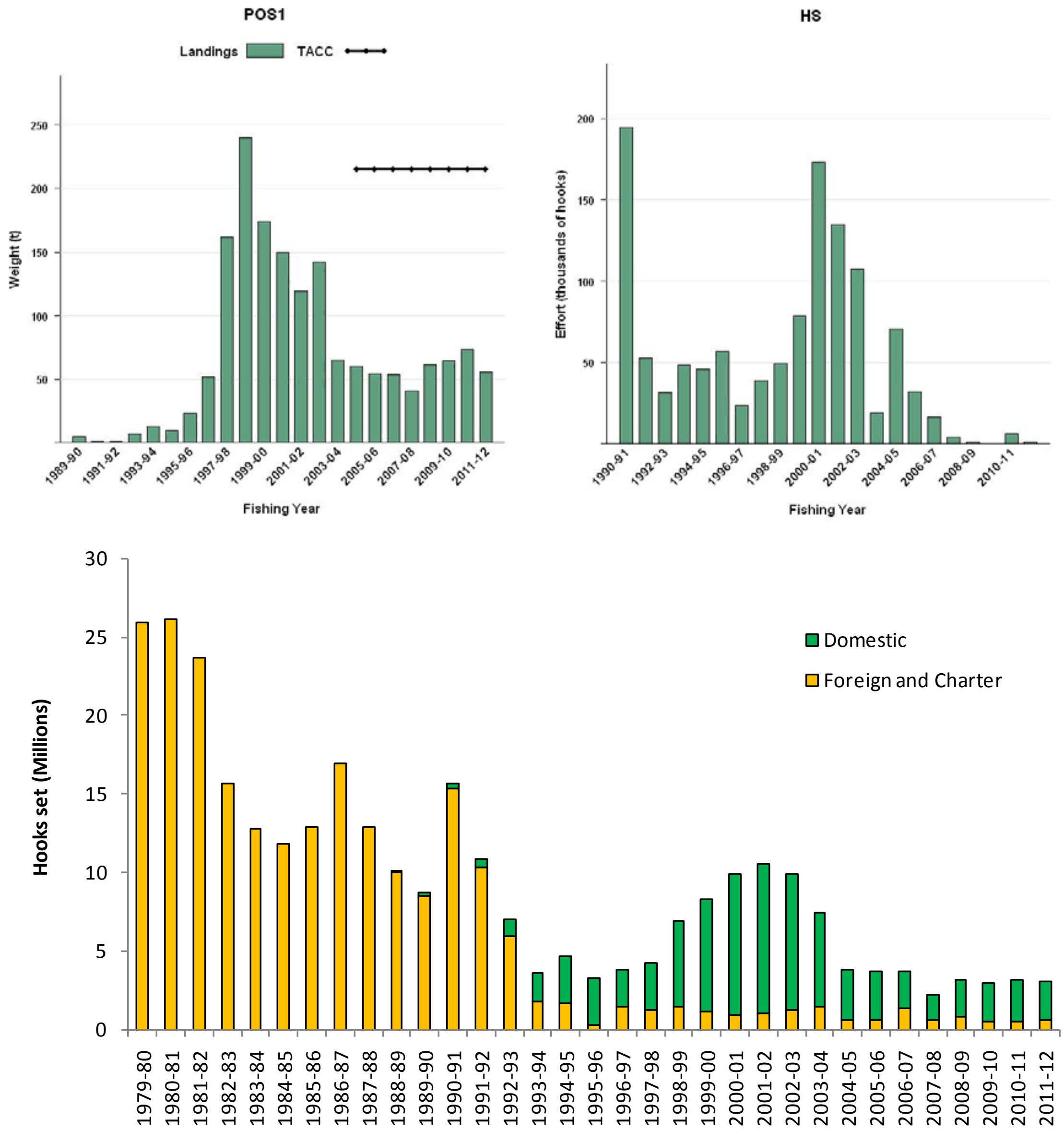


Figure 1: [Top left] Catch of porbeagle sharks from 1989-90 to 2011-12 within NZ waters (POS1). [Top right] Fishing effort (number of hooks set) for high seas New Zealand flagged surface longline vessels, and [Bottom] all domestic vessels (including effort by foreign vessels chartered by NZ fishing companies), from 1990-91 to 2011-12 and 1979-80 to 2011-12, respectively.

Landings of porbeagle sharks reported on CELR (landed), CLR, and LFRR forms are shown in Table 2. The total weights reported by fishers were 152–301 t during 1997–98 to 2002-03. Processors reported 119–240 t on LFRRs during the same period. There has been an 86% decline in the total weight of porbeagle shark reported since 1998–99, to a low of 41 t in 2007-08. This decline began during a period of rapidly increasing domestic fishing effort in the tuna longline fishery, but has accelerated since tuna longline effort dropped in the 2003-04 fishing year. Estimates of the catch of porbeagle sharks aboard tuna longliners, based on scaled-up scientific observer records, were lower than reported by either fishers or processors in the most recent years for which comparable data are available (2000–01 and 2001–02). However, the observer-based estimates are imprecise, and possibly biased, because the observer coverage of the domestic fleet (which accounts for most of the fishing effort) has been low (just below 10% in 2007-2010). Some porbeagle catch is mistakenly reported by fishers as porae (species code POR), and is not included in Table 2; however, the amount is likely to be small (annual reported landings of porae are about 60–70 t).

Catches of porbeagle sharks reported by scientific observers aboard tuna longliners are concentrated off the west and southwest coast of South Island, and the northeast coast of North Island. However, these apparent distributions are biased by the spatial distribution of observer coverage. Porbeagle sharks are taken by tuna longliners around most of mainland New Zealand where these fisheries occur. The target species for this fishery are mainly southern bluefin, bigeye and albacore tuna. Most of the porbeagle landings reported on CELR and CLR forms were taken in FMA 7, with significant amounts also coming from trawl fisheries in FMAs 3, 5 and 6.

Table 2: New Zealand commercial landings (t) of porbeagle sharks reported by fishers (CELRs and CLRs) and processors (LFRRs) by fishing year. Also shown for some years are the estimated quantities of porbeagles caught by tuna longliners, based on scaled-up scientific observer records (– no data available).

Year	Total reported	LFRR/MHR	Estimated catch by tuna longliners
1989–90	–	5	
1990–91	1	1	
1991–92	1	1	
1992–93	7	7	
1993–94	10	13	
1994–95	16	10	
1995–96	26	23	
1996–97	39	52	
1997–98	205	162	
1998–99	301	240	
1999–00	215	174	
2000–01	188	150	
2001–02	161	119	
2002-03*	152	142	
2003-04*	84	65	
2004-05*	62	60	
2005-06*	54	55	2 817
2006-07*	53	54	2 743
2007-08*	43	41	
2008-09*	64	61	
2009-10*		65	
2010-11*		73	
2011-12*		55	

*MHR rather than LFRR data.

The majority of porbeagle shark are caught in the southern bluefin tuna target surface longline fishery (34%), followed by bigeye tuna (19%) and a small proportion (11%) are landed in the hoki target mid-water trawl fishery (Figure 2). Across all surface longline fisheries albacore make up the bulk of the catch (33%) (Figure 3). Longline fishing effort is distributed along the east coast of the North Island and the south west coast of the South Island. The west coast South Island fishery predominantly targets southern bluefin tuna, whereas the east coast of the North Island targets a range of species including bigeye, swordfish, and southern bluefin tuna (Figure 4).

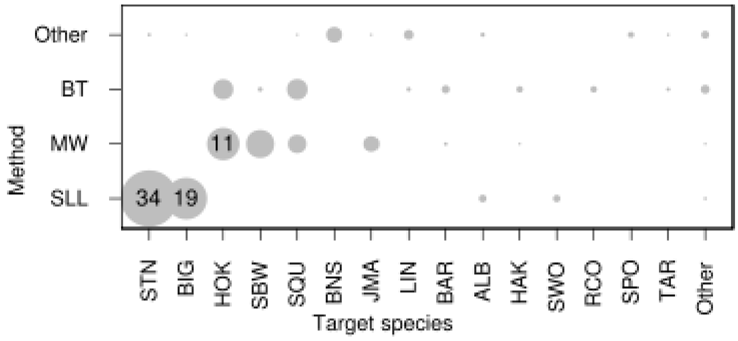


Figure 2: A summary of the proportion of landings of porbeagle shark taken by each target fishery and fishing method. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the bobble is the percentage (Bentley *et al.* 2012).

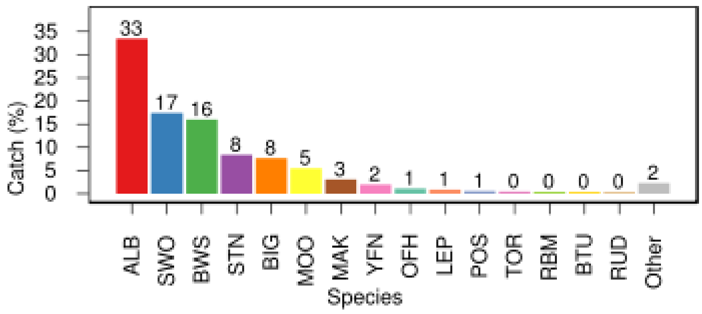


Figure 3: A summary of species composition of the reported surface longline fishery catch. The percentage by weight of each species is calculated for all trips classified under the activity (Bentley *et al.* 2012).

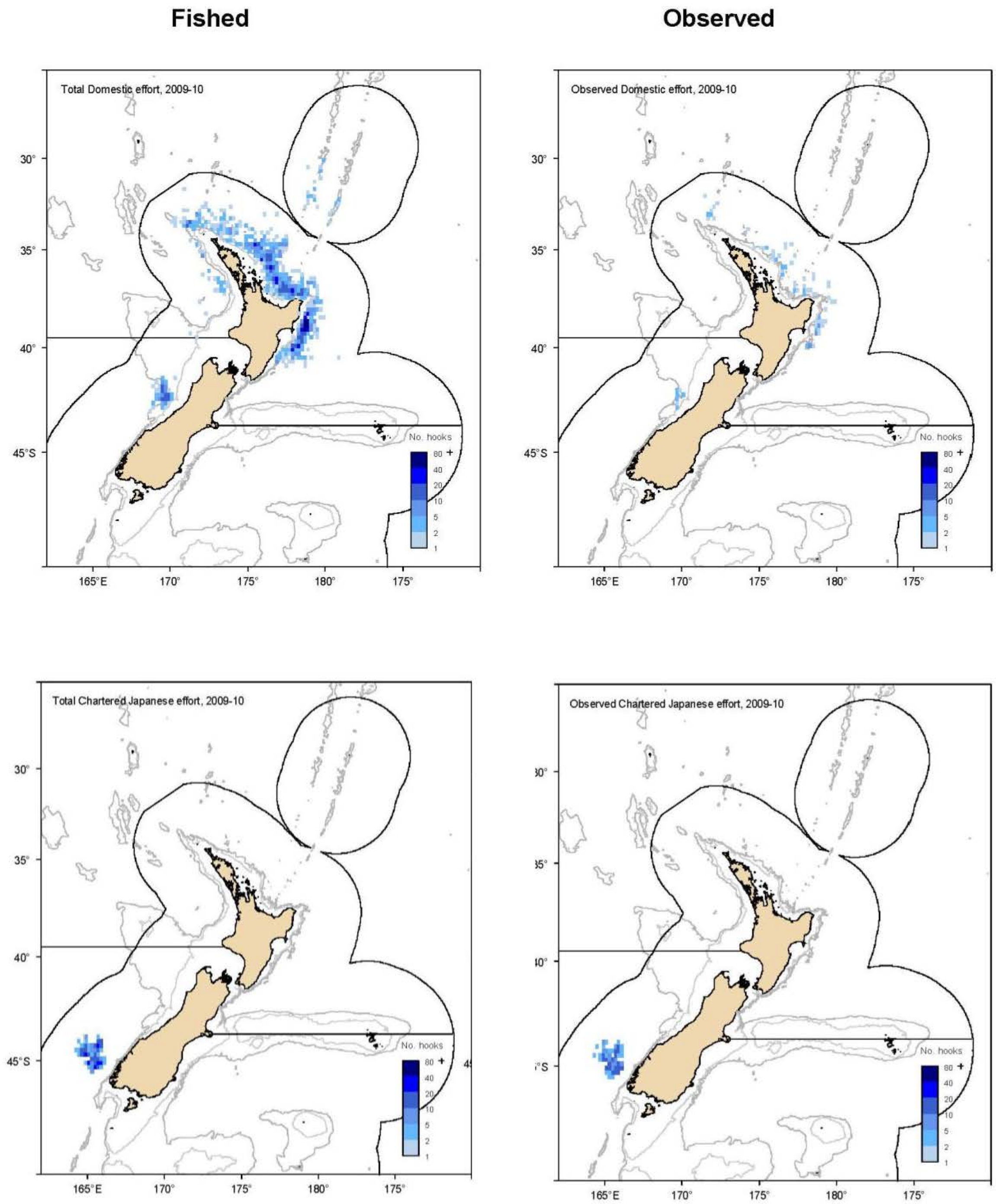


Figure 4: Distribution of fishing positions for domestic (top two panels) and charter (bottom two panels) vessels, for the 2009-10 fishing year, displaying both fishing effort (left) and observer effort (right).

In the longline fishery 64.2% of the porbeagle sharks were alive when brought to the side of the vessel for all fleets (Table 3). The domestic fleets retain around 35-47% of their porbeagle shark catch, mostly for the fins, while the foreign charter fleet retain most of the porbeagle sharks (79-92%) (mostly for fins; Table 4).

Table 3: Percentage of porbeagle shark (including discards) that were alive or dead when arriving at the longline vessel and observed during 2006–07 to 2009–10, by fishing year, fleet and region. Small sample sizes (number observed < 20) were omitted Griggs and Baird (in press).

Year	Fleet	Area	% alive	% dead	Number
2006-07	Charter	North	60.5	39.5	223
		South	87.3	12.7	370
	Domestic	North	44.8	55.2	134
	Total		**71.3**	**28.7**	**727**
2007-08	Charter	South	77.6	22.4	49
	Domestic	North	59.6	40.4	488
	Total		**61.3**	**38.7**	**537**
2008-09	Charter	North	91.0	9.0	78
		South	85.4	14.6	158
	Domestic	North	57.9	42.1	254
	Total		**71.5**	**28.5**	**494**
2009-10	Charter	South	82.4	17.6	68
	Domestic	North	40.4	59.6	322
		South	30.0	70.0	20
	Total		**46.8**	**53.2**	**410**
Total all strata			**64.2**	**35.8**	**2 168**

Table 4: Percentage of porbeagle shark that were retained, or discarded or lost, when observed on a longline vessel during 2006–07 to 2009–10, by fishing year and fleet. Small sample sizes (number observed < 20) omitted Griggs and Baird (in press).

Year	Fleet	% retained or finned	% discarded or lost	Number
2006-07	Charter	86.6	13.4	628
	Domestic	38.1	61.9	134
	Total	**78.1**	**21.9**	**762**
2007-08	Charter	89.8	10.2	49
	Domestic	35.7	64.3	488
	Total	**40.6**	**59.4**	**537**
2008-09	Charter	91.1	8.9	257
	Domestic	46.9	53.1	258
	Total	**68.9**	**31.1**	**515**
2009-10	Charter	79.2	20.8	72
	Domestic	46.0	54.0	348
	Total	**51.7**	**48.3**	**420**
Total all strata		**62.0**	**38.0**	**2 234**

1.2 Recreational fisheries

An estimate of the recreational harvest is not available. The recreational catch of porbeagle sharks is probably negligible, because they usually occur over the outer continental shelf or beyond. They are occasionally caught by gamefishers but most are tagged and released. In 2001, 40 porbeagle sharks were tagged by recreational fishers but numbers have dwindled from this peak to one or two per year.

1.3 Customary non-commercial fisheries
An estimate of the current customary catch is not available. The Maori customary catch of porbeagle sharks is probably negligible, because they usually occur over the outer continental shelf or beyond.

1.4 Illegal catch
There is no known illegal catch of porbeagle sharks.

1.5 Other sources of mortality
Many of the porbeagle sharks caught by tuna longliners (about 64%) are alive when the vessel retrieves the line, but it is not known how many of the released, discarded sharks survive.

2. BIOLOGY

Porbeagles live mainly in the latitudinal bands 30–50°S and 30–70°N. They occur in the North Atlantic Ocean, and in a circumglobal band in the Southern Hemisphere. Porbeagles are absent from the North Pacific Ocean, where the closely related salmon shark, *Lamna ditropis*, fills their niche. In the South Pacific Ocean, porbeagles are caught north of 30°S in winter–spring only; in summer they are not found north of about 35°S. They appear to penetrate further south during summer and autumn, and are found near many of the sub-Antarctic islands in the Indian and South-west Pacific Oceans. Porbegle sharks are not found in the equatorial tropics.

Porbeagles are live-bearers (aplacental viviparous), and the length at birth is 58–67 cm fork length (FL) in the South-west Pacific. Females mature at around 170–180 cm FL and males at about 140–150 cm FL. The gestation period is about 8–9 months. In the North-west Atlantic, all females sampled in winter were pregnant, suggesting that there is no extended resting period between pregnancies, and that the female reproductive cycle lasts for one year. Litter size is usually four embryos, with a mean litter size in the South-west Pacific of 3.75. If the reproductive cycle lasts one year, annual fecundity would be about 3.75 pups per female.

A study of the age and growth of New Zealand porbeagles produced growth curves and estimates of the natural mortality rate (Table 5). However, attempts to validate ages using bomb radiocarbon analysis were unsuccessful, but suggested that the ages of porbeagles older than about 20 years were progressively under-estimated; for the oldest sharks the age under-estimation may have been as much as 50%. Consequently, the growth parameters provided in Table 5 are probably only accurate for ages up to about 20 years. Males mature at 8–11 years, and females mature at 15–18 years. Longevity is unknown but may be about 65 years.

In New Zealand, porbeagle sharks recruit to commercial fisheries during their first year at about 70 cm FL, and much of the commercial catch is immature. Most sharks caught by tuna longliners are 70-170 cm FL. The size and sex distribution of both sexes is similar up to about 150 cm, but larger individuals are predominantly male; few mature females are caught. Regional differences in length composition suggest segregation by size. The size and sex composition of sharks caught by trawlers are unknown.

Porbeagles are active pelagic predators of fish and cephalopods. Pelagic fish dominate the diet but squid are also commonly eaten, especially by the small sharks.

Table 5: Estimates of biological parameters.

Fishstock	Estimate			Source
1. Natural mortality (M)				
POS 1	0.05–0.10			Francis (unpub. data)
2. Weight = a (length)^b (Weight in kg, length in cm fork length)				
		a	*b*	
POS 1, both sexes		2.143×10^{-5}	2.924	Ayers *et al.* (2004)
3. Von Bertalanffy model parameter estimates				
	k	t_0	L_∞	
POS 1 males	0.112	-4.75	182.2	Francis *et al.* (2007)
POS 1 females	0.060	-6.86	233.0	Francis *et al.* (2007)

3. STOCKS AND AREAS

In the North-west Atlantic, most tagged sharks moved short to moderate distances (up to 1500 km) along continental shelves, though one moved about 1800 km off the shelf into the mid-Atlantic Ocean. Sharks tagged off southern England were mainly recaptured between Denmark and France, with one shark moving 2370 km to northern Norway. Only one tagged shark has crossed the Atlantic: it travelled 4260 km from South-west Eire to 52°W off eastern Canada. Thus porbeagles from the northwest and northeast Atlantic appear to form two distinct stocks. There have been no genetic studies to determine the number of porbeagle stocks, but based on the disjunct (antitropical) geographical distribution and differences in biological parameters, North Atlantic porbeagles are probably reproductively isolated from Southern Hemisphere porbeagles.

The stock structure of porbeagle sharks in the Southern Hemisphere is unknown. However, given the scale of movements of tagged sharks, it seems likely that sharks in the South-west Pacific comprise a single stock. There is no evidence to indicate whether this stock extends to the eastern South Pacific or Indian Ocean.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the November 2012 Fishery Assessment Plenary after review by the Aquatic Environment Working Group. This summary is from the perspective of the porbeagle shark but there is no directed fishery for them and the incidental catch sections below reflect the New Zealand longline fishery as a whole and are not specific to this species; a more detailed summary from an issue-by-issue perspective is, or will shortly be, available in the Aquatic Environment & Biodiversity Annual Review where the consequences are also discussed. (http://www.mpi.govt.nz/news-resources/publications.aspx).

4.1 Role in the ecosystem

4.1.1 Diet

Porbeagle shark (*Lamna nasus*) are active pelagic predators of fish and cephalopods. Porbeagle sharks less than 75cm feed mostly on squid but their diet changes to fish as they grow, with fish comprising more than 60% of the diet for porbeagle sharks 75 cm and over (Figure 5) (Giggs *et al.* 2007).

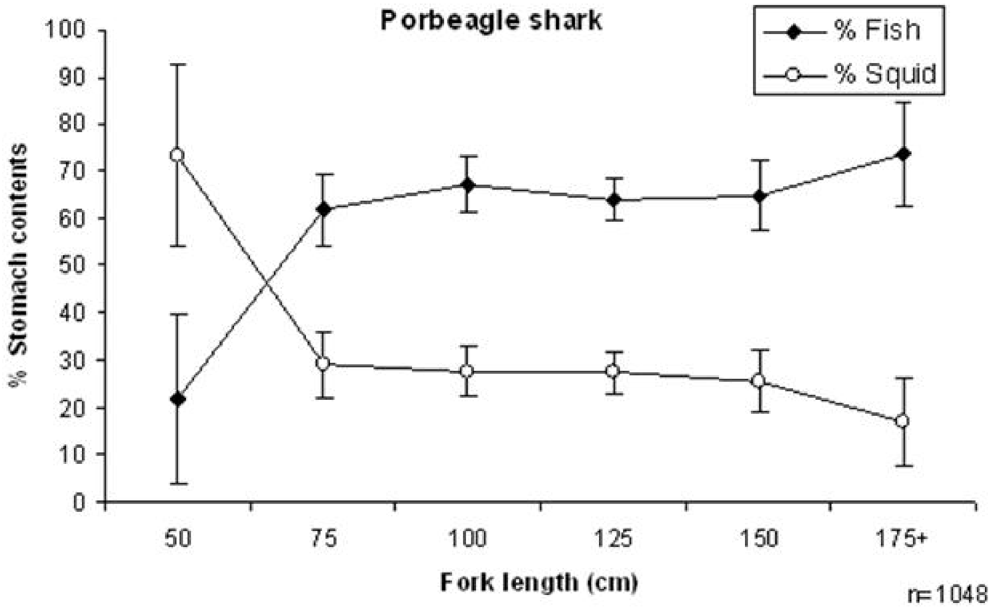


Figure 5: Changes is percentage of fish and squid in stomachs of porbeagle sharks.

4.2 Incidental catch (seabirds, sea turtles and mammals)

The protected species, capture estimates presented here include all animals recovered onto the deck (alive, injured or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds caught on a hook but not brought onboard the vessel).

4.2.1 Seabird bycatch

Between 2002–03 and 2010–11, there were 731 observed captures of birds across all surface longline fisheries. Seabird capture rates since 2003 are presented in Figure 6. While the seabird capture distributions largely coincide with fishing effort that are more frequent off the south west coast of the South Island (Figure 7). The analytical methods used to estimate capture numbers across the commercial fisheries have depended on the quantity and quality of the data, in terms of the numbers observed captured and the representativeness of the observer coverage. Ratio estimation was historically used to calculate total captures in longline fisheries by target fishery fleet and area (Baird 2008) and by all fishing methods but recent estimates are either ratio or model based as specified in the tables below (Abraham *et al.* 2010a).

Through the 1990s the minimum seabird mitigation requirement for surface longline vessels was the use of a bird scaring device (tori line) but common practice was that vessels set surface longlines primarily at night. In 2007 a notice was implemented under s 11 of the Fisheries Act 1996 to formalise the requirement that surface longline vessels only set during the hours of darkness and use a tori line when setting. This notice was amended in 2008 to add the option of line weighting and tori line use if setting during the day. In 2011 notices were combined and repromulgated under a new regulation (Regulation 58A of the Fisheries (Commercial Fishing) Regulations 2001) which provides a more flexible regulatory environment under which to set seabird mitigation requirements.

Table 6: Number of observed seabird captures in surface longline fisheries, 2002-03 to 2010-11, by species and area (Thompson & Abraham (2012) from http://data.dragonfly.co.nz/psc/). See glossary above for areas used for summarising the fishing effort and protected species captures. 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 porbeagle shark using longline gear but rather the total risk for each seabird species.

Species	Risk ratio	Kermadec Islands	Northland and Hauraki	Bay of Plenty	East Coast North Island	Stewart Snares Shelf	Fiordland	West Coast South Island	West Coast North Island	Total
Salvin's albatross	2.49	0	1	1	6	0	0	0	0	8
Northern royal albatross	2.21	0	0	1	0	0	0	0	0	1
Light-mantled sooty albatross	2.18	0	0	0	0	0	0	1	0	1
Campbell albatross	1.84	0	8	0	26	0	3	3	0	40
Southern Buller's albatross	1.28	0	3	1	26	0	251	31	0	312
Gibson's albatross	1.25	4	10	0	11	0	3	1	1	30
Antipodean albatross	1.11	12	9	1	7	0	0	0	1	30
White capped albatross	0.83	0	1	0	3	10	54	25	0	93
Southern royal albatross	0.74	0	0	0	0	0	4	0	0	4
Black browed albatrosses	-	2	1	0	0	0	0	0	1	4
Pacific albatross	-	0	0	0	1	0	0	0	0	1
Southern black-browed albatross	-	0	0	0	2	0	0	0	0	2
Wandering albatross	-	0	2	0	6	0	3	0	0	11
Antipodean and Gibson's albatrosses	N/A	5	2	0	0	0	0	0	0	7
Unidentified albatross	N/A	33	0	0	1	0	0	0	1	35
Total albatrosses	**N/A**	**56**	**37**	**4**	**89**	**10**	**318**	**61**	**4**	**579**
Black petrel	11.15	1	9	1	0	0	0	0	1	12
Westland petrel	3.31	0	0	0	2	0	1	5	0	8
Flesh footed shearwater	2.51	0	0	0	10	0	0	0	2	12
Cape petrels	0.76	0	0	0	2	0	0	0	0	2
White chinned petrel	0.79	2	2	3	3	1	19	0	3	33
Grey petrel	0.39	3	3	2	38	0	0	0	0	46
Sooty shearwater	0.02	1	0	0	8	3	1	0	0	13
Great winged petrel	0.01	12	5	1	2	0	0	0	0	20
White headed petrel	0.01	2	0	0	0	0	0	0	0	2
Pterodroma petrels	-	0	1	0	0	0	0	0	0	1
Southern giant petrel	-	0	0	0	2	0	0	0	0	2
Unidentified seabird	N/A	0	0	0	0	0	1	0	0	1
Total other birds	**N/A**	**21**	**20**	**7**	**67**	**4**	**22**	**5**	**6**	**152**

Table 7: Effort, observed and estimated seabird captures by fishing year for the surface longline fishery within the EEZ. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); the capture rate (captures per thousand hooks); and the mean number of estimated total captures (with 95% confidence interval). The estimation method used was a Bayesian model with 100% of hooks included in the estimate. For more information on the methods used to prepare the data see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures		Estimated captures	
	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002-2003	10 764 588	2 195 152	20.4	115	0.052	2490	1817-3461
2003-2004	7 380 779	1 607 304	21.8	71	0.044	1665	1259-2220
2004-2005	3 676 365	783 812	21.3	41	0.052	687	507-936
2005-2006	3 687 339	705 945	19.1	37	0.052	816	607-1120
2006-2007	3 738 362	1 040 948	27.8	187	0.18	949	725-1304
2007-2008	2 244 339	426 310	19	41	0.096	521	408-681
2008-2009	3 115 633	937 233	30.1	57	0.061	721	562-934
2009-2010	2 992 285	665 883	22.3	149	0.224	1014	777-1345
2010-2011	3 164 159	674 522	21.3	47	0.07	824	607-1152

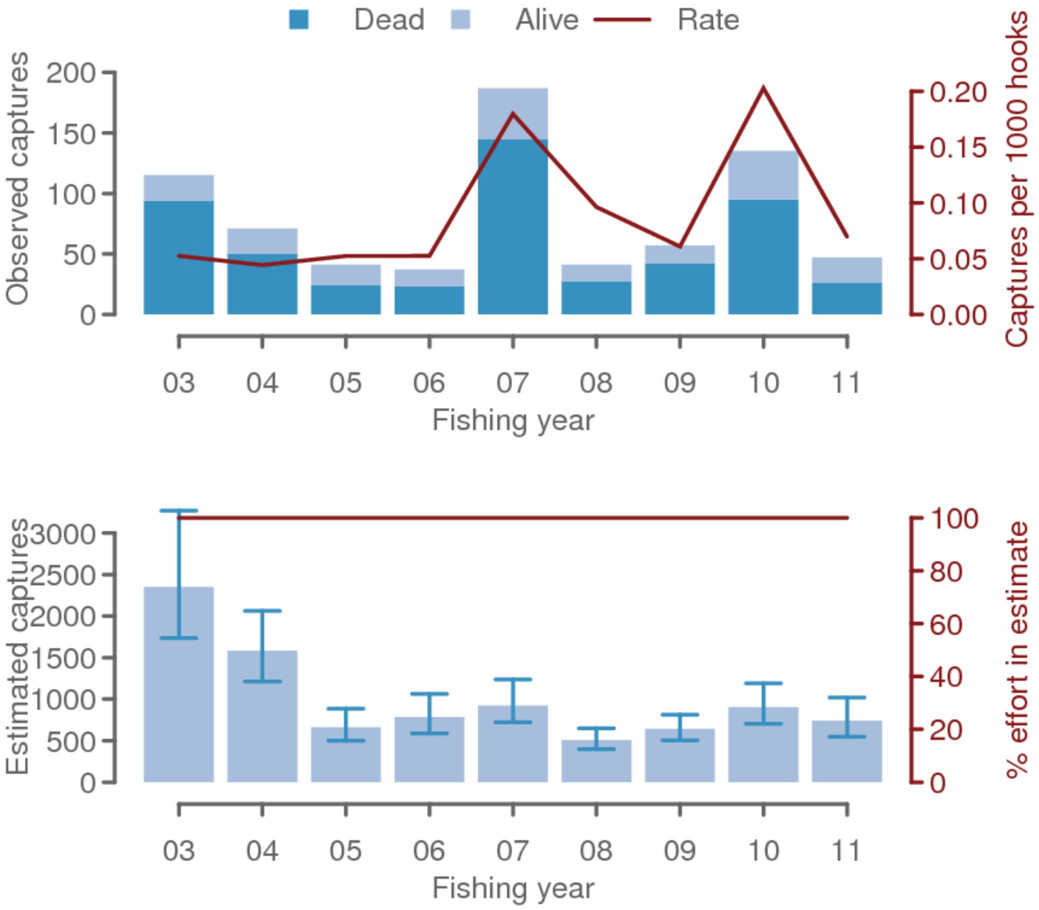


Figure 6: Observed and estimated captures of seabirds birds in surface longline fisheries from 2003 to 2011.

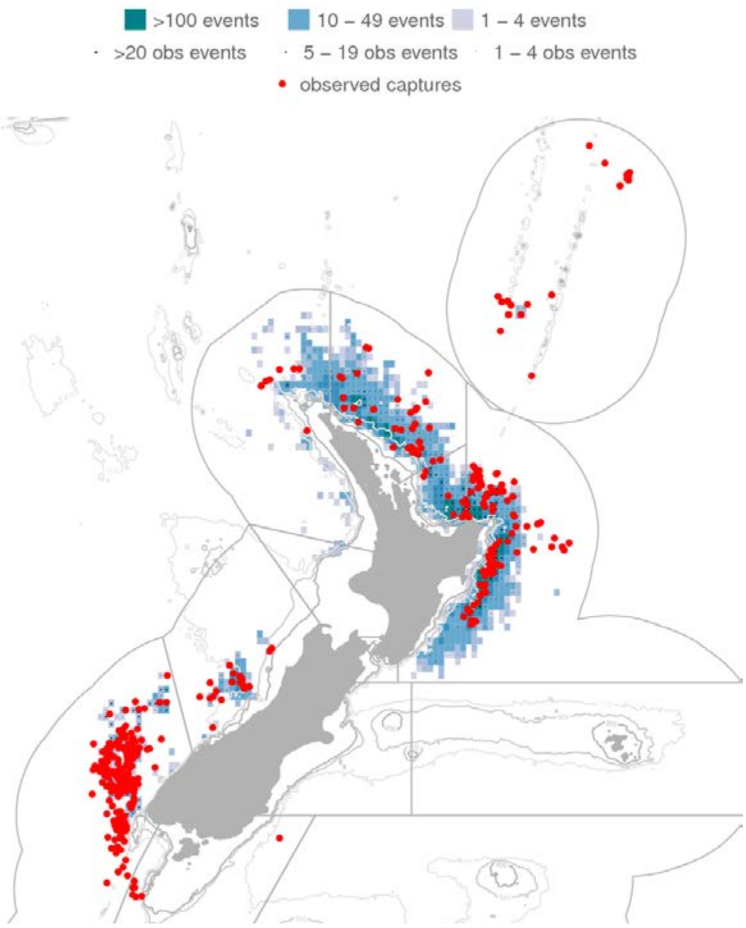


Figure 7: Distribution of fishing effort in surface longline fisheries and observed seabird captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.2 Sea turtle bycatch

Between 2002–03 and 2010–11, there were 13 observed captures of sea turtles across all surface longline fisheries (Tables 8 and 9, Figure 8). Observer records documented all but one sea turtle as captured and released alive. Sea turtle capture distributions predominantly occur throughout the east coast of the North Island and Kermadec Island fisheries (Figure 9).

Table 8: Number of observed sea turtle captures in surface longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson and Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/.

Species	Bay of Plenty	East Coast North Island	Kermadec Islands	West Coast North Island	Total
Leatherback turtle	1	4	3	3	11
Olive ridley turtle	0	1	0	0	1
Unknown turtle	0	1	0	0	1
Total	**1**	**6**	**3**	**3**	**13**

Table 9: Effort and sea turtle captures in surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	10 764 588	2 195 152	20.4	0	0
2003-2004	7 380 779	1 607 304	21.8	1	0.001
2004-2005	3 676 365	783 812	21.3	2	0.003
2005-2006	3 687 339	705 945	19.1	1	0.001
2006-2007	3 738 362	1 040 948	27.8	2	0.002
2007-2008	2 244 339	426 310	19.0	1	0.002
2008-2009	3 115 633	937 233	30.1	2	0.002
2009-2010	2 992 285	665 883	22.3	0	0
2010-2011	3 164 159	674 522	21.3	4	0.006

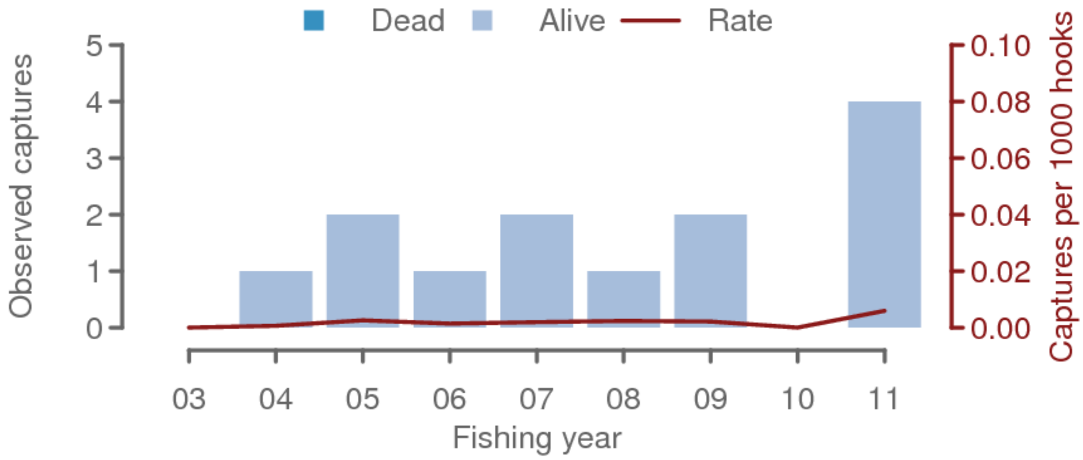


Figure 8: Observed captures of sea turtles in surface longline fisheries from 2003 to 2011.

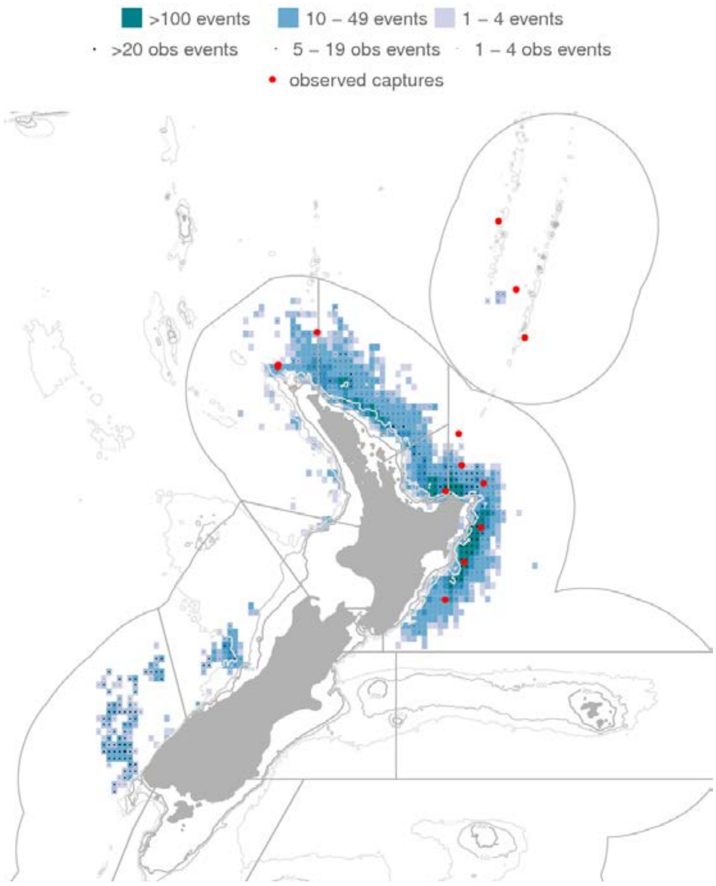


Figure 9: Distribution of fishing effort in surface longline fisheries and observed sea turtle captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3 Marine Mammals

4.2.3.1 Cetaceans

Cetaceans are dispersed throughout New Zealand waters (Perrin *et al.* 2008). The spatial and temporal overlap of commercial fishing grounds and cetacean foraging areas has resulted in cetacean captures in fishing gear (Abraham and Thompson 2009, 2011).

Between 2002–03 and 2010–11, there were seven observed captures of whales and dolphins in surface longline fisheries. Observed captures included 5 unidentified cetaceans and 2 long-finned Pilot whales (Tables 10 and 11, Figure 10) (Abraham and Thompson 2011). All captured animals recorded were documented as being caught and released alive (Thompson and Abraham 2010). Cetacean capture distributions are more frequent off the east coast of the North Island (Figure 11).

Table 10: Number of observed cetacean captures in surface longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson and Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/.

Species	Bay of Plenty	East Coast North Island	Fiordland	Northland and Hauraki	West Coast North Island	West Coast South Island	Total
Long-finned pilot whale	0	1	0	0	0	1	2
Unidentified cetacean	1	1	1	1	1	0	5
Total	**1**	**2**	**1**	**1**	**1**	**1**	**7**

Table 11: Effort and captures of cetaceans in surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	10 764 588	2 195 152	20.4	1	0.0005
2003-2004	7 380 779	1 607 304	21.8	4	0.002
2004-2005	3 676 365	783 812	21.3	1	0.001
2005-2006	3 687 339	705 945	19.1	0	0
2006-2007	3 738 362	1 040 948	27.8	0	0
2007-2008	2 244 339	426 310	19.0	1	0.002
2008-2009	3 115 633	937 233	30.1	0	0
2009-2010	2 992 285	665 883	22.3	0	0
2010-2011	3 164 159	674 522	21.3	0	0

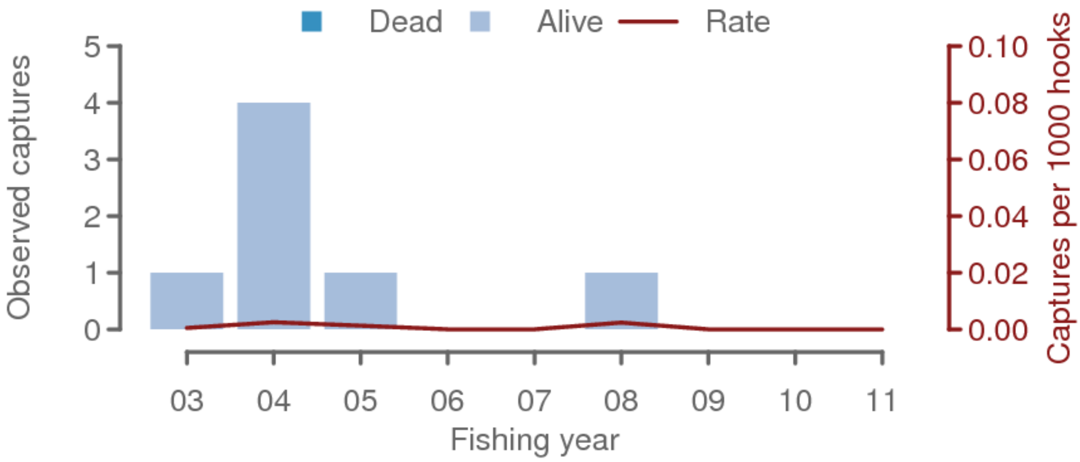


Figure 10: Observed captures of cetaceans in surface longline fisheries from 2003 to 2011.

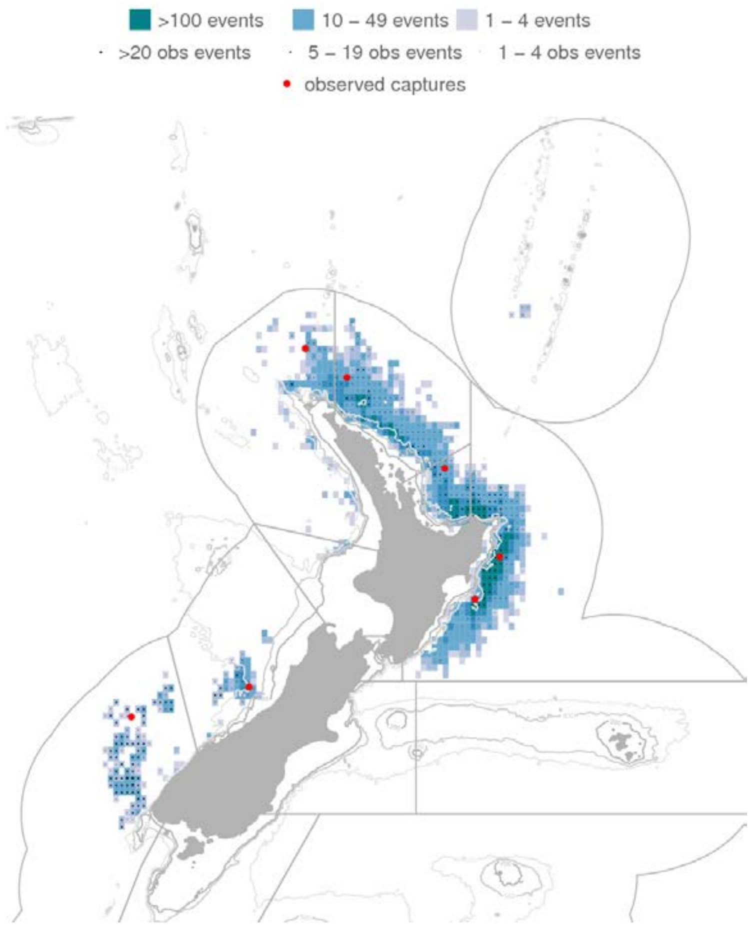


Figure 11: Distribution of fishing effort in surface longline fisheries and observed cetacean captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3.2 New Zealand fur seal bycatch

Currently, New Zealand fur seals are dispersed throughout New Zealand waters, especially in waters south of about 40º S to Macquarie Island. The spatial and temporal overlap of commercial fishing grounds and New Zealand fur seal foraging areas has resulted in New Zealand fur seal captures in fishing gear (Mattlin 1987, Rowe 2009). Most fisheries with observed captures occur in waters over or close to the continental shelf, which around much of the South Island and offshore islands slopes steeply to deeper waters relatively close to shore, and thus rookeries and haulouts. Captures on longlines occur when the seals attempt to feed on the fish and bait catch during hauling. Most New Zealand fur seals are released alive, typically with a hook and short snood or trace still attached.

New Zealand fur seal captures in surface longline fisheries have been generally observed in waters south and west of Fiordland, but also in the Bay of Plenty-East Cape area when the animals have attempted to take bait or fish from the line as it is hauled. These capture rates include animals that are released alive (100% of observed surface longline capture in 2008-09; Thompson and Abraham 2010). Bycatch rates in 2010-11 are low and lower than they were in the early 2000s (Figure 12). While fur seal captures have occurred throughout the range of this fishery most New Zealand captures have occurred off the Southwest coast of the South Island (Figure 13). Between 2002–03 and 2010–11, there were 206 observed captures of New Zealand fur seal in surface longline fisheries (Table 12 and 13).

Table 12: Number of observed New Zealand fur seal captures in surface longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson and Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/.

	Bay of Plenty	East Coast North Island	Fiordland	Northland and Hauraki	Stewart Snares Shelf	West Coast North Island	West Coast South Island	Total
New Zealand fur seal	10	16	139	3	4	2	32	206

Table 13: Effort and captures of New Zealand fur seal in surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	10 764 588	2 195 152	20.4	56	0.026
2003-2004	7 380 779	1 607 304	21.8	40	0.025
2004-2005	3 676 365	783 812	21.3	20	0.026
2005-2006	3 687 339	705 945	19.1	12	0.017
2006-2007	3 738 362	1 040 948	27.8	10	0.010
2007-2008	2 244 339	426 310	19.0	10	0.023
2008-2009	3 115 633	937 233	30.1	22	0.023
2009-2010	2 992 285	665 883	22.3	19	0.029
2010-2011	3 164 159	674 522	21.3	17	0.025

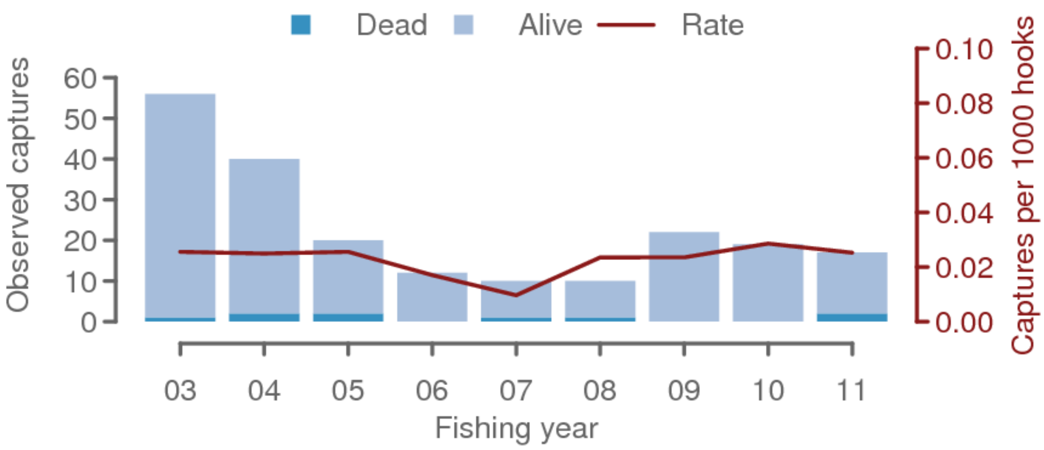


Figure 12: Observed captures of New Zealand fur seal in surface longline fisheries from 2003 to 2011.

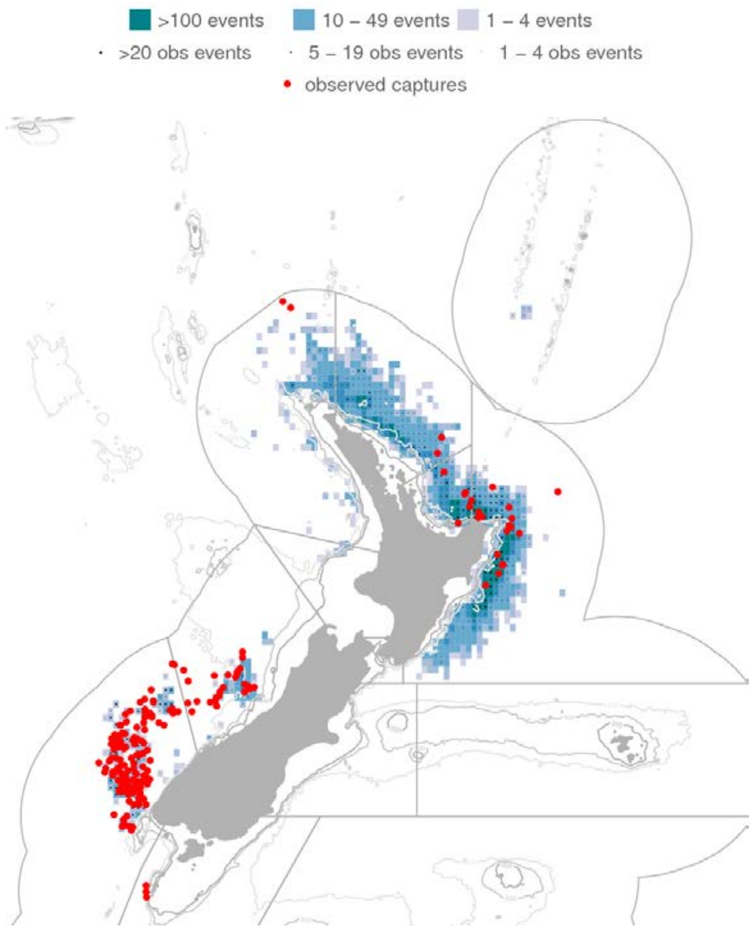


Figure 13: Distribution of fishing effort in surface longline fisheries and observed New Zealand fur seal captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.3 Incidental fish bycatch

Observer records indicate that a wide range of species are landed by the longline fleets in New Zealand fishery waters. Blue sharks are the most commonly landed species (by number), followed by Ray's bream (Table 14). Southern bluefin tuna and albacore tuna are the only target species that occur in the top five of the frequency of occurrence.

Table 14: Numbers of the most common fish species observed in the New Zealand longline fisheries during 2009-10 by fleet and area. Species are shown in descending order of total abundance (Griggs and Baird in press).

	Charter	Domestic		Total
Species	South	North	South	number
Blue shark	2 024	4 650	882	7 556
Rays bream	3 295	326	88	3 709
Southern bluefin tuna	3 244	211	179	3 634
Lancetfish	3	2 139	1	2 143
Albacore tuna	90	1 772	42	1 904
Dealfish	882	0	7	889
Swordfish	3	452	2	457
Moonfish	76	339	6	421
Porbeagle shark	72	328	20	420
Mako shark	11	343	7	361
Big scale pomfret	349	4	0	353
Deepwater dogfish	305	0	0	305
Sunfish	7	283	5	295
Bigeye tuna	0	191	0	191
Escolar	0	129	0	129
Butterfly tuna	15	100	3	118
Pelagic stingray	0	96	0	96
Oilfish	2	75	0	77
Rudderfish	39	20	2	61
Flathead pomfret	56	0	0	56
Dolphinfish	0	47	0	47
School shark	34	0	2	36
Striped marlin	0	24	0	24
Thresher shark	7	17	0	24
Cubehead	13	0	1	14
Kingfish	0	10	0	10
Yellowfin tuna	0	9	0	9
Hake	8	0	0	8
Hapuku bass	1	6	0	7
Pacific bluefin tuna	0	5	0	5
Black barracouta	0	4	0	4
Skipjack tuna	0	4	0	4
Shortbill spearfish	0	4	0	4
Gemfish	0	3	0	3
Bigeye thresher shark	0	2	0	2
Snipe eel	2	0	0	2
Slender tuna	2	0	0	2
Wingfish	2	0	0	2
Bronze whaler shark	0	1	0	1
Hammerhead shark	0	1	0	1
Hoki	0	0	1	1
Louvar	0	1	0	1
Marlin, unspecified	0	1	0	1
Scissortail	0	1	0	1
Broadnose seven gill shark	1	0	0	1
Shark, unspecified	0	1	0	1
Unidentified fish	2	30	8	40
Total	10 545	11 629	1 256	23 430

4.4 Benthic interactions
N/A

4.5 Key environmental and ecosystem information gaps
Cryptic mortality is unknown at present but developing a better understanding of this in future may be useful for reducing uncertainty of the seabird risk assessment and could be a useful input into risk assessments for other species groups.

The survival rates of released target and bycatch species is currently unknown.

Observer coverage in the New Zealand fleet is not spatially and temporally representative of the fishing effort.

5. STOCK ASSESSMENT

With the establishment of the WCPFC in 2004, future stock assessments of porbeagle shark in the western and central Pacific Ocean stock will be reviewed by the WCPFC. There is currently a shark research plan that has been developed within the context of the Western and Central Pacific Fisheries Commission but porbeagle sharks will not be a focus of that plan in the near future.

There have been no stock assessments of porbeagle sharks in New Zealand. No estimates of yield are possible with the currently available data.

CPUE estimates were calculated for each fleet and area stratum in which eight or more sets were observed and at least 2% of the hooks were observed. CPUE estimates were calculated for blue sharks for each fleet and area in 2006–07 to 2009–10 and added to the time series for 1988–89 to 2005–06 (Griggs *et al.* 2008) and these are shown in Figure 14 (Griggs and Baird in press). The CPUE results from the Domestic fleet should be interpreted with caution due to the lower observer coverage of this fleet. CPUE estimates for the Charter fleet can be considered reliable from 1992–93 onwards (Griggs *et al.* 2007). Porbeagle CPUE was higher in the South than the North, but porbeagle CPUE has been very low for the past nine years in the South, and there has been a recent increase in the North.

Relative to a wide range of shark species, the productivity of porbeagle sharks is very low. Females have a high age-at-maturity, high longevity (and therefore low natural mortality rate) and low annual fecundity. The low fecundity is cause for strong concern, as the ability of the stock to replace sharks removed by fishing is very limited.

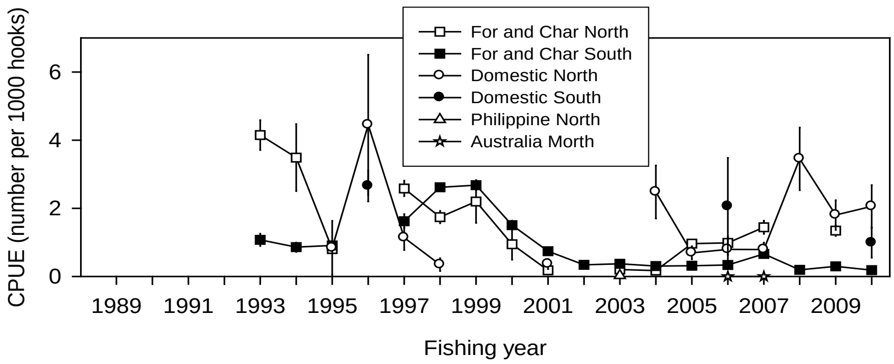


Figure 14: Annual variation in CPUE by fleet and area. Plotted values are the mean estimates with 95% confidence limits. Fishing year 1989 = October 1988 to September 1989 (Griggs and Baird in press).

Observed length frequency distributions of porbeagle sharks by area and sex are shown in Figure 3 for fish measured in 2006–07 to 2009–10 (Griggs and Baird in press). The proportion of porbeagles caught in the South was less than the North, unlike other years, and the fish were smaller than seen previously (Francis *et al.* 2004, Ayers *et al.* 2004, Griggs et al, 2007, 2008). In this four year period there is a mode at about 75–100 cm each year in both sexes and few larger fish (Figure 15), while in previous years there had been a bimodal distribution with a dominant mode between 110–140 cm (Francis *et al.* 2004, Ayers *et al.* 2004). This larger mode has been less predominant in the previous five years, 2002–03 to 2005–06 (Griggs *et al.* 2007, 2008). Based on length-frequencies and mean lengths at maturity of 145 cm FL for males and 175 cm fork length for females (Francis & Duffy 2005), most porbeagle sharks were immature (86.4% of males and 97.4% of females, overall). Sex ratios were similar (Griggs and Baird in press) (Figure 15).

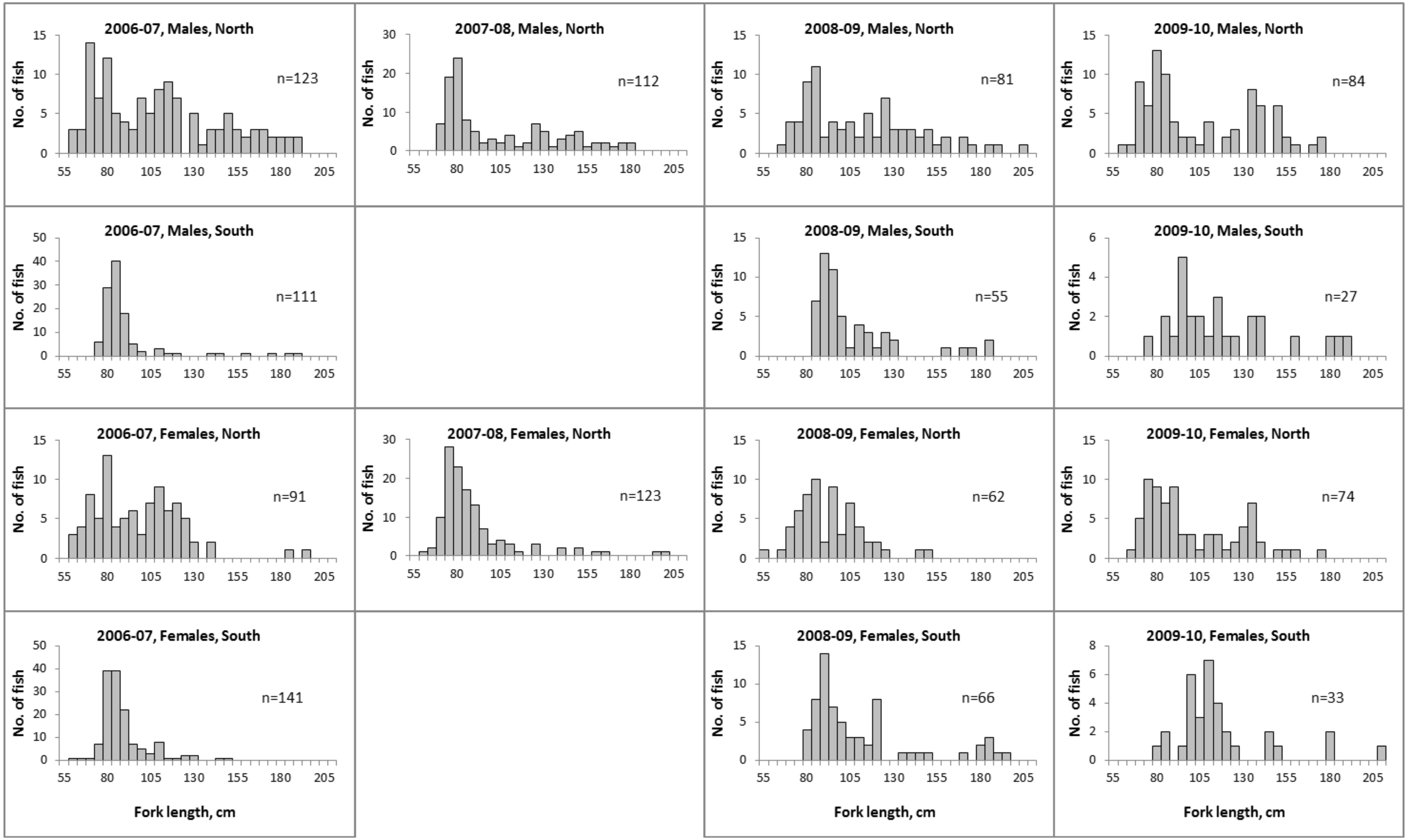


Figure 15: Length-frequency distributions of porbeagle shark by fishing year, sex, and region. Sample sizes of less than 20 fish not shown (Griggs and Baird in press).

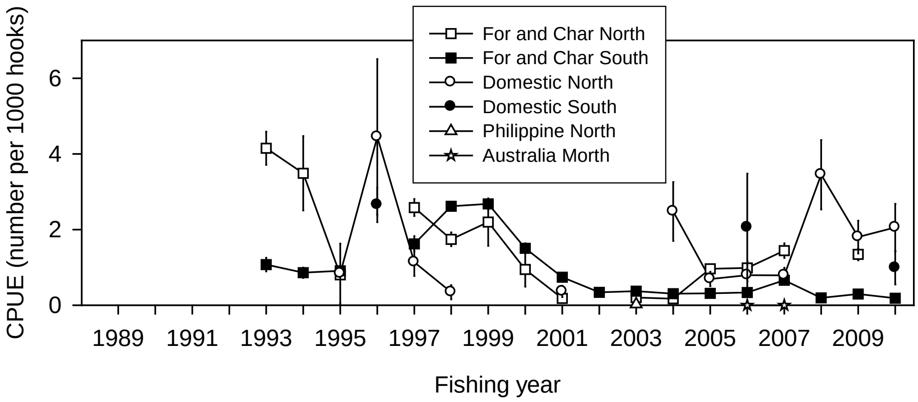
6. STATUS OF THE STOCK

Stock structure assumptions

POS1 is assumed to be part of the wider South Western Pacific Ocean stock.

Stock Status	
Year of Most Recent Assessment	2008
Assessment Runs Presented	Base case model only
Reference Points	Target: Not established; but B_{MSY} assumed Soft Limit: Not established by WCPFC; but evaluated using HSS default of 20% SB_0. Hard Limit: Not established by WCPFC; but evaluated using HSS default of 10% SB_0.
Status in relation to Target	Unlikely (< 40%) to be at or above B_{MSY}. Likely that $F>F_{MSY}$
Status in relation to Limits	Unknown

Historical Stock Status Trajectory and Current Status



Annual variation in CPUE by fleet and area. Plotted values are the mean estimates with 95% confidence limits. Fishing year 1989 = October 1988 to September 1989 (Griggs and Baird in press).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	CPUE analyses have been undertaken in New Zealand but are not considered to have generated reliable estimates of abundance.
Trends in Other Relevant Indicator or Variables	Catches in New Zealand increased from the late 1980s to a peak in the 1998/99 of 301t and then declined to 41t in 2007-08. This decline in catch coincides with a decline in longline fishing effort.

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

Assessment Methodology and Evaluation		
Assessment Type	Level 3: Qualitative Evaluation: Fishery characterization with evaluation of fishery trends (e.g. catch, effort and nominal CPUE) - there is no agreed index of abundance.	
Assessment Method	CPUE analysis	
Assessment Dates	Latest assessment: 2008	Next assessment:?
Overall assessment quality rank	2 – Medium or Mixed Quality: information has been subjected to peer review and has been found to have some shortcomings.	
Main data inputs (rank)	- Commercial reported catch and effort	1 - High quality for the charter fleet but low for all the other fleets.
Data not used (rank)		
Changes to Model Structure and Assumptions		
Major Sources of Uncertainty	Historical catch recording may not be accurate.	

Qualifying Comments
Relative to a wide range of shark species, the productivity of porbeagle sharks is very low. Females have a high age-at-maturity, high longevity (and therefore low natural mortality rate) and low annual fecundity. The low fecundity and high longevity are cause for strong concern, as the ability of the stock to replace sharks removed by fishing is very limited, as a result, this stock is Likely to be below B_{MSY}.
Fishery Interactions
Interactions with protected species are known to occur in the longline fisheries of the South Pacific, particularly south of 30^{o}S. Seabird bycatch mitigation measures are required in the New Zealand and Australian EEZ's and through the WCPFC Conservation and Management Measure CMM2007-04. Sea turtles also get incidentally captured in longline gear; the WCPFC is attempting to reduce sea turtle interactions through Conservation and Management Measure CMM2008-03.

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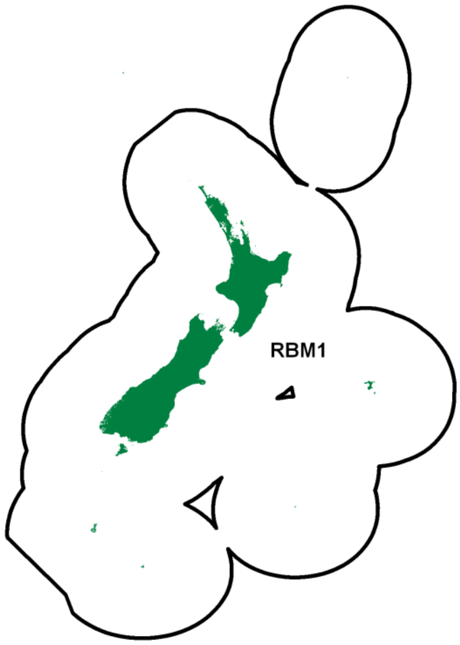
RAY'S BREAM (RBM)

(Brama brama)



1. FISHERY SUMMARY

Ray's bream (*Brama brama*) was introduced into the QMS on 1 October 2004 under a single QMA, RBM 1, with allowances, TACC and TAC in Table 1.

Table 1: Recreational and Customary non-commercial allowances, TACCs and TACs (all in tonnes) for Ray's bream.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other mortality	TACC	TAC
RBM 1	10	5	50	980	1045

At least two closely related species (*Brama brama* and *Brama australis*) are thought to be caught in New Zealand fisheries. Southern Ray's bream (*Brama australis*), which is difficult to distinguish using external features from *B. Brama*, has been reported in both catch statistics and research surveys but the actual proportions of the two species in the catch is unknown. A third closely related species, bronze bream (*Xenobrama microlepis*), is more easily distinguished from the other two, but is also likely to have been recorded as Ray's bream in catch statistics.

1.1 Commercial fisheries

Ray's bream is a highly migratory species and has a wide distribution, being found throughout the subtropical to sub-antarctic waters across the whole South Pacific between New Zealand and Chile. The catch of Ray's bream, while fluctuating, appears to be have declined marginally within New Zealand fisheries waters, and has averaged around 217 t for from 2000-01 to 2011-12 (Table 3). Over the period 1996-97 to 2007-08, the nominal total weight of Ray's bream reported by fishers (including tuna longlining catch effort returns where the catch cannot be adjusted to whole weight) has declined from a high of 1001 t in 2000-01 to 143 t in 2011-12. Licensed fish receiver returns indicate between 119 and 926 t were processed for the same period.

Based on records since 2003-04, most (46%) Ray's bream is caught by mid-water trawl. Bottom trawling accounts for 27%, surface longlining 18%, trolling 5% and bottom longlining 3%. Ray's bream is caught by mid-water trawlers in all FMAs around the South Island, with the largest amount in mid-water trawls being taken from Stewart-Snares shelf (FMA 5) and the Chatham Rise (FMA 3). The major catches by bottom trawling have occurred on the Chatham Rise (FMA 3). Ray’s bream is taken on surface tuna longlines on the east coast of the North Island, especially in the Bay of Plenty-East Cape (FMA 1). Most of the South Island longline catch comes from the west coast in FMAs 5 and 7. It is also taken by tuna trolling, especially on the west coast of the South Island (FMA 7). While observer coverage of the troll fleet is limited (0.5% of fishing days), observer records for the troll vessels have identified 100% of the Rays bream in the troll catch as *B. Brama*. Figure 1 shows historical landings and longline fishing effort for the two Ray’s bream fisheries.

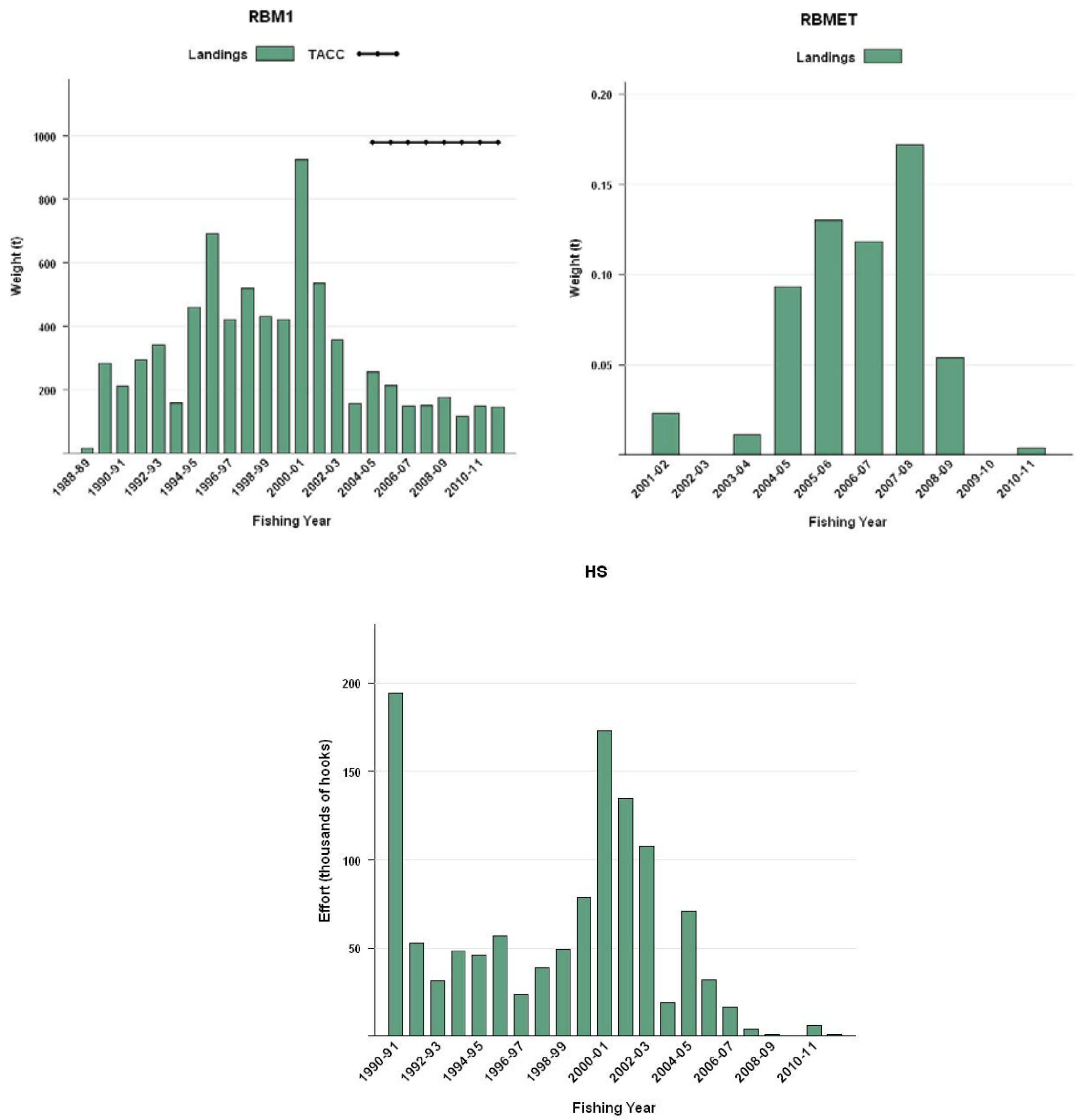


Figure 1: [Top] Ray’s Bream catch from 1988-89 to 2011-12 within NZ waters (RBM1) and on the high seas (RBMET). [Bottom] Fishing effort (number of hooks set) for high seas New Zealand flagged surface longline vessels from 1990-91 to 2011-12.

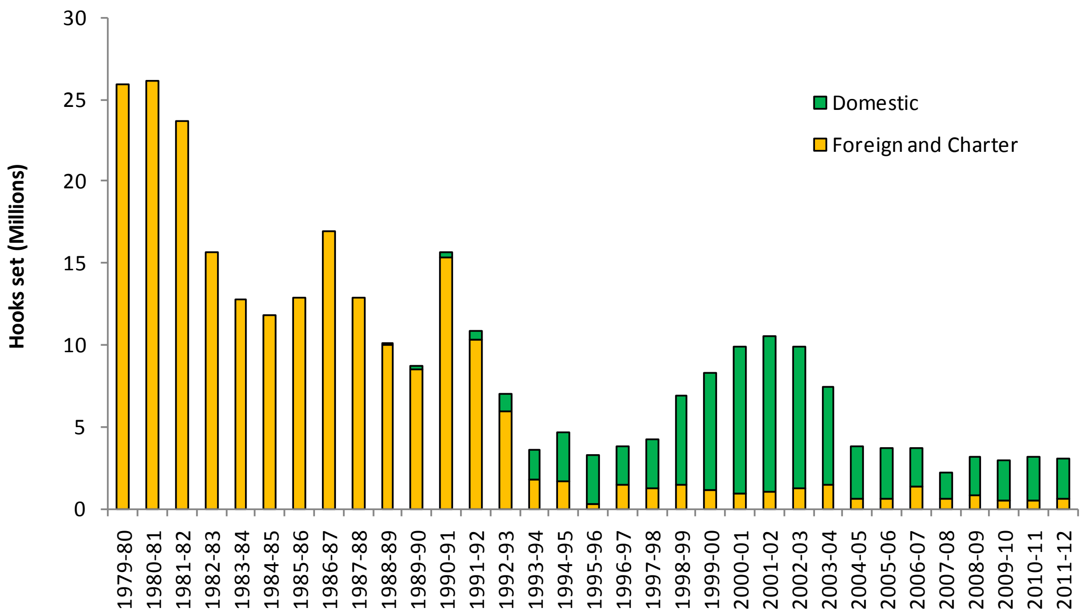


Figure 1: [Continued] Fishing effort (number of hooks set) for all domestic vessels (including effort by foreign vessels chartered by NZ fishing companies) from 1979-80 to 2011-12.

Table 2: Reported commercial landings and discards (t) of Ray's bream from CELRs and CLRs, and LFRRs (processor records) by fishing year.

	Reported by fishers			
	CELR and CLR		Total	Processed
Year	Landed	Discarded	reported	LFRR
1988-89	9	0	9	16
1989-90	328	< 1	328	284
1990-91	239	< 1	239	211
1991-92	297	< 1	297	295
1992-93	340	1	341	342
1993-94	151	3	154	160
1994-95	462	8	470	460
1995-96	717	3	720	693
1996-97	356	7	362	421
1997-98	546	8	554	520
1998-99	425	10	435	431
1999-00	444	23	467	423
2000-01	941	60	1001	926

Table 3: LFRR and MHR data on Ray's bream catches by fishing year.

Year	LFRR Data	MHR Data
2001-02	541	536
2002-03	347	357
2003-04	154	157
2004-05	257	259
2005-06	212	215
2006-07	149	149
2007-08	149	152
2008-09	176	179
2009-10	119	119
2010-11	137	150
2011-12	143	146

The majority of Ray's bream are caught in the New Zealand squid, hoki and Jack mackerel mid-water trawl fisheries with 10% of the Ray's bream landings coming from the Southern bluefin target surface longline fishery with small amounts coming from a range of other fisheries (Figure 2). Ray's bream make up less than 1% of the surface longline catch by weight (Figure 3). Most of the New Zealand Rays bream catch is landed on the west coast of the South Island and Sub-Antarctic islands (Figure 4).

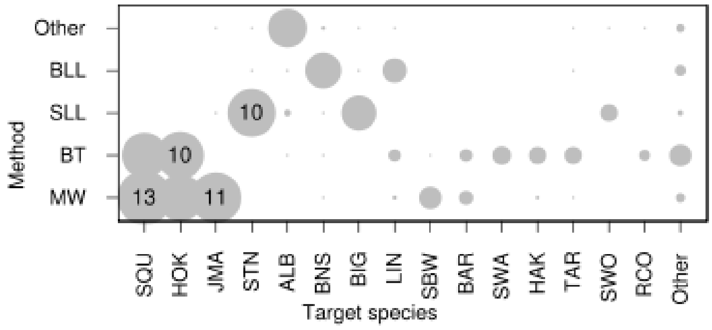


Figure 2: A summary of the proportion of landings of Ray's bream taken by each target fishery and fishing method. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the bobble is the percentage. SLL = surface longline MW = mid-water trawl, BLL = bottom longline, BT = bottom trawl (Bentley *et al.* 2012).

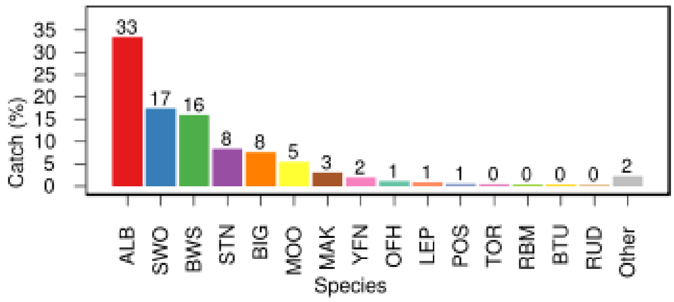


Figure 3: A summary of species composition of the reported surface longline catch. The percentage by weight of each species is calculated for all surface longline trips (Bentley *et al.* 2012).

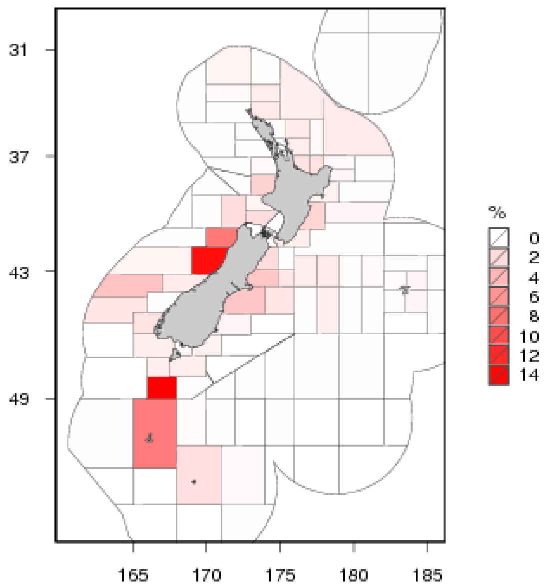


Figure 4: Distribution of catch of Ray's bream by statistical area for all years and all fishing gears. (Bentley *et al.* 2012).

In the longline fishery most of the Ray's bream were alive when brought to the side of the vessel for all fleets (95%) (Table 4). The domestic fleets retain around 95-99% of their Ray's bream catch, while the foreign charter fleet retained 97-99% of their Ray's bream catch (Table 5).

Table 4: Percentage of Ray's bream (including discards) that were alive or dead when arriving at the longline vessel and observed during 2006–07 to 2009–10, by fishing year, fleet and region. Small sample sizes (number observed < 20) were omitted Griggs and Baird (in press).

Year	Fleet	Area	% alive	% dead	Number
2006-07	Charter	North	87.0	13.0	215
		South	96.0	4.0	10 350
	Domestic	North	65.8	34.2	442
	Total		**94.6**	**5.4**	**11 019**
2007-08	Charter	South	95.7	4.3	3 680
	Domestic	North	70.2	29.8	151
	Total		**94.6**	**5.4**	**3 831**
2008-09	Charter	North	90.1	9.9	313
		South	97.9	2.1	4 277
	Domestic	North	78.8	21.2	551
		South	94.1	5.9	34
	Total		**95.4**	**4.6**	**5 175**
2009-10	Charter	South	96.3	3.7	3 259
	Domestic	North	85.6	14.4	264
		South	92.0	8.0	88
	Total		**95.5**	**4.5**	**3 611**
Total all strata			**94.9**	**5.1**	**23 636**

Table 5: Percentage Ray's bream that were retained, or discarded or lost, when observed on a longline vessel during 2006–07 to 2009–10, by fishing year and fleet. Small sample sizes (number observed < 20) omitted Griggs and Baird (in press).

Year	Fleet	% retained	% discarded or lost	Number
2006-07	Charter	96.8	3.2	11 744
	Domestic	95.7	4.3	442
	Total	**96.8**	**3.2**	**12 198**
2007-08	Charter	96.8	3.2	3 714
	Domestic	98.7	1.3	152
	Total	**96.9**	**3.1**	**3 866**
2008-09	Charter	98.7	1.3	4 646
	Domestic	98.3	1.7	585
	Total	**98.7**	**1.3**	**5 231**
2009-10	Charter	98.8	1.2	3 291
	Domestic	95.3	4.7	361
	Total	**98.4**	**1.6**	**3 652**
Total all strata		**97.4**	**2.6**	**24 947**

1.3 Recreational fisheries
Recreational fishers take Ray's bream infrequently, generally as bycatch when targeting bluenose, hapuku and bass over deep reefs. The recreational harvest is assumed low, and is likely insignificant in the context of the total landings.

1.4 Customary non-commercial fisheries
There is no quantitative information available to allow the estimation of the harvest of Ray's bream by customary fishers, however, the harvest is assumed to be insignificant in the context of the commercial landings.

1.5 Illegal catch
There is no known illegal catch of Ray's bream.

1.6 Other sources of mortality
Ray's bream is a desirable species, and only a small percentage (about 1-5% annually) has been reported or observed as having been discarded. Most of the trawl catch of Ray's bream that is reported on CELR and CLR forms is retained. Most of the discarding appears to occur in the tuna fisheries, but those fisheries only take a small proportion of the total catch of Ray's bream. There may be some unobserved shark and cetacean depredation of longline caught Ray's bream.

2. BIOLOGY

Until recently, little was known about the biology of Ray's bream in New Zealand waters. A recent study examined growth rates, natural mortality and maturity for Ray's bream. Unfortunately, the actual species examined in this study could not be determined. It is possible that more than one species was involved, and the one (or more) species may not have been representative of the New Zealand catch recorded as Ray's bream. Until further samples are collected, the identification cannot be confirmed, but it is likely that the study was based wholly or partly on Southern Ray's bream (*Brama australis*).

It is expected that the main biological characteristics of Ray's bream will be similar to Southern Ray's bream, so the general findings of the recent study are reported here (Table 6). The small otoliths proved to be extremely difficult to age; notwithstanding this, Southern Ray's bream appear to have rapid initial growth, reaching 40-50 cm in 3-5 years, with little increase in length after this time. The maximum age observed was 25 years.

Table 6: Estimates of biological parameters.

Parameter		Estimate		Source
1. Weight = $a \cdot (\text{length})^b$ (Weight in t, length in cm)				
	Both sexes	$a = 5.31 \times 10^{-9}$	$b = 3.320$	Livingston *et al.* 2004

3. STOCKS AND AREAS

Ray's bream probably come from a wide-ranging single stock found throughout the South Pacific Ocean and southern Tasman Sea. The catch of Ray's bream elsewhere in the South Pacific needs to be considered when assessing the status of Ray's bream within New Zealand's fisheries waters.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the November 2012 Fishery Assessment Plenary after review by the Aquatic Environment Working Group. This summary is from the perspective of Ray's bream but there is no directed fishery for them and the incidental catch sections below reflect the New Zealand longline fishery as a whole and are not specific to this species; a more detailed summary from an issue-by-issue perspective is, or will shortly be, available in the Aquatic Environment & Biodiversity Annual Review where the consequences are also discussed. (http://www.mpi.govt.nz/news-resources/publications.aspx).

4.1 Role in the ecosystem

Ray's bream (*Brama brama*) is found in mid-water depths down to 1000 m. The Ray's bream undertakes daily vertical migrations (Lobo and Erzini 2001) and is thought to feed opportunistically on small fish and cephalopods. It is known to be predated on by deepwater sharks such as the deepwater dogfish species *Centrophorus squamosus* and *Centroscymnus owstonii,* and the school shark *Galeorhinus galeus* (Dunn *et al.* 2010).

4.2 Incidental catch (seabirds, sea turtles and mammals)

The protected species, capture estimates presented here include all animals recovered onto the deck (alive, injured or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds caught on a hook but not brought onboard the vessel).

4.2.1 Seabird bycatch

Between 2002–03 and 2010–11, there were 731 observed captures of birds across all surface longline fisheries. Seabird capture rates since 2003 are presented in Figure 5. While the seabird capture distributions largely coincide with fishing effort that are more frequent off the south west coast of the South Island (Figure 6). The analytical methods used to estimate capture numbers across the commercial fisheries have depended on the quantity and quality of the data, in terms of the numbers observed captured and the representativeness of the observer coverage. Ratio estimation was historically used to calculate total captures in longline fisheries by target fishery fleet and area (Baird 2008) and by all fishing methods but recent estimates are either ratio or model based as specified in the tables below (Abraham *et al.* 2010a).

Through the 1990s the minimum seabird mitigation requirement for surface longline vessels was the use of a bird scaring device (tori line) but common practice was that vessels set surface longlines primarily at night. In 2007 a notice was implemented under s 11 of the Fisheries Act 1996 to formalise the requirement that surface longline vessels only set during the hours of darkness and use a tori line when setting. This notice was amended in 2008 to add the option of line weighting and tori line use if setting during the day. In 2011 notices were combined and repromulgated under a new regulation (Regulation 58A of the Fisheries (Commercial Fishing) Regulations 2001) which provides a more flexible regulatory environment under which to set seabird mitigation requirements.

Table 7: Number of observed seabird captures in the New Zealand surface longline fisheries, 2002-03 to 2010-11, by species and area (Thompson & Abraham (2012) from http://data.dragonfly.co.nz/psc/). See glossary above for a description of the areas used for summarising the fishing effort and protected species captures. 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 Ray’s bream using longline gear but rather the total risk for each seabird species.

Species	Risk ratio	Kermadec Islands	Northland and Hauraki	Bay of Plenty	East Coast North Island	Stewart Snares Shelf	Fiordland	West Coast South Island	West Coast North Island	Total
Salvin's albatross	2.49	0	1	1	6	0	0	0	0	8
Northern royal albatross	2.21	0	0	1	0	0	0	0	0	1
Light-mantled sooty albatross	2.18	0	0	0	0	0	0	1	0	1
Campbell albatross	1.84	0	8	0	26	0	3	3	0	40
Southern Buller's albatross	1.28	0	3	1	26	0	251	31	0	312
Gibson's albatross	1.25	4	10	0	11	0	3	1	1	30
Antipodean albatross	1.11	12	9	1	7	0	0	0	1	30
White capped albatross	0.83	0	1	0	3	10	54	25	0	93
Southern royal albatross	0.74	0	0	0	0	0	4	0	0	4
Black browed albatrosses	-	2	1	0	0	0	0	0	1	4
Pacific albatross	-	0	0	0	1	0	0	0	0	1
Southern black-browed albatross	-	0	0	0	2	0	0	0	0	2
Wandering albatross	-	0	2	0	6	0	3	0	0	11
Antipodean and Gibson's albatrosses	N/A	5	2	0	0	0	0	0	0	7
Unidentified albatross	N/A	33	0	0	1	0	0	0	1	35
Total albatrosses	**N/A**	**56**	**37**	**4**	**89**	**10**	**318**	**61**	**4**	**579**
Black petrel	11.15	1	9	1	0	0	0	0	1	12
Westland petrel	3.31	0	0	0	2	0	1	5	0	8
Flesh footed shearwater	2.51	0	0	0	10	0	0	0	2	12
Cape petrels	0.76	0	0	0	2	0	0	0	0	2
White chinned petrel	0.79	2	2	3	3	1	19	0	3	33
Grey petrel	0.39	3	3	2	38	0	0	0	0	46
Sooty shearwater	0.02	1	0	0	8	3	1	0	0	13
Great winged petrel	0.01	12	5	1	2	0	0	0	0	20
White headed petrel	0.01	2	0	0	0	0	0	0	0	2
Pterodroma petrels	-	0	1	0	0	0	0	0	0	1
Southern giant petrel	-	0	0	0	2	0	0	0	0	2
Unidentified seabird	N/A	0	0	0	0	0	1	0	0	1
Total other birds	**N/A**	**21**	**20**	**7**	**67**	**4**	**22**	**5**	**6**	**152**

Table 8: Effort, observed and estimated seabird captures by fishing year for the New Zealand surface longline fishery within the EEZ. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); the capture rate (captures per thousand hooks); and the mean number of estimated total captures (with 95% confidence interval). The estimation method used was a Bayesian model with 100% of hooks included in the estimate. For more information on the methods used to prepare the data see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures		Estimated captures	
	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002-2003	10 764 588	2 195 152	20.4	115	0.052	2490	1817-3461
2003-2004	7 380 779	1 607 304	21.8	71	0.044	1665	1259-2220
2004-2005	3 676 365	783 812	21.3	41	0.052	687	507-936
2005-2006	3 687 339	705 945	19.1	37	0.052	816	607-1120
2006-2007	3 738 362	1 040 948	27.8	187	0.18	949	725-1304
2007-2008	2 244 339	426 310	19	41	0.096	521	408-681
2008-2009	3 115 633	937 233	30.1	57	0.061	721	562-934
2009-2010	2 992 285	665 883	22.3	149	0.224	1014	777-1345
2010-2011	3 164 159	674 522	21.3	47	0.07	824	607-1152

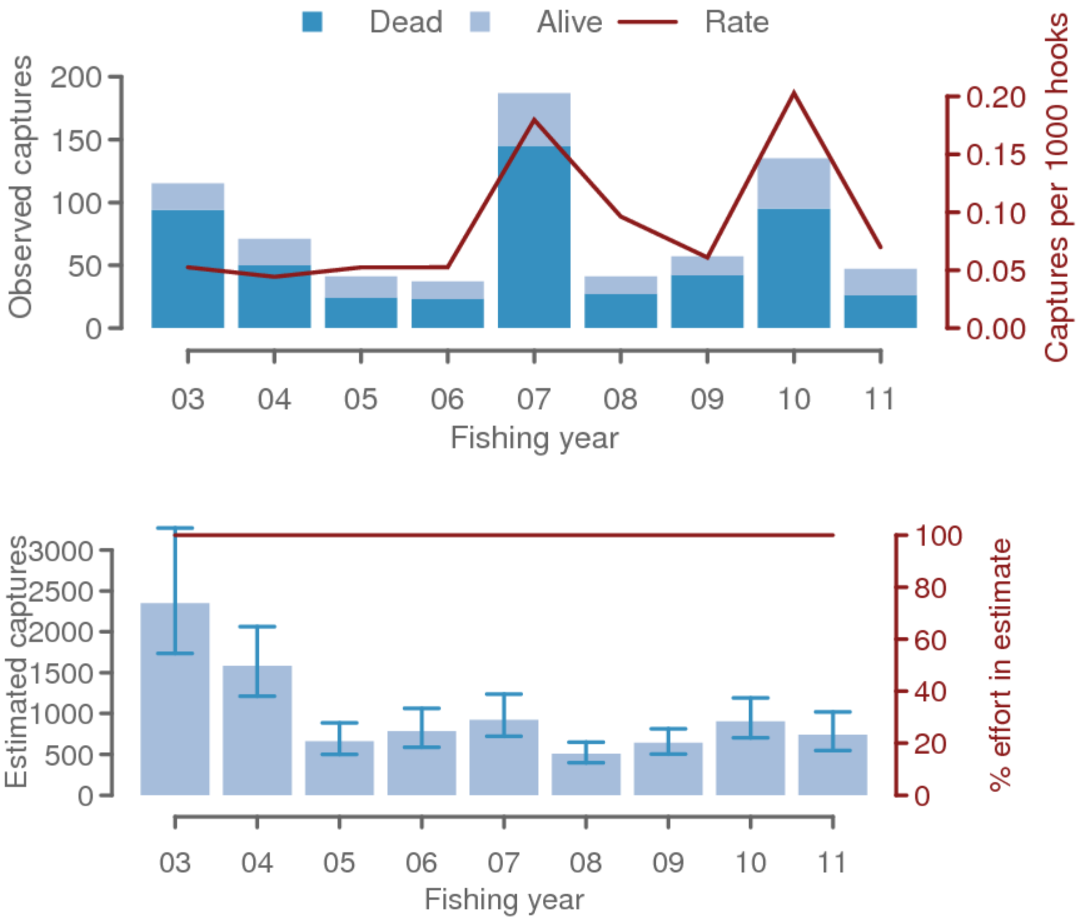


Figure 5: Observed and estimated captures of seabirds birds in the New Zealand surface longline fisheries from 2003 to 2011.

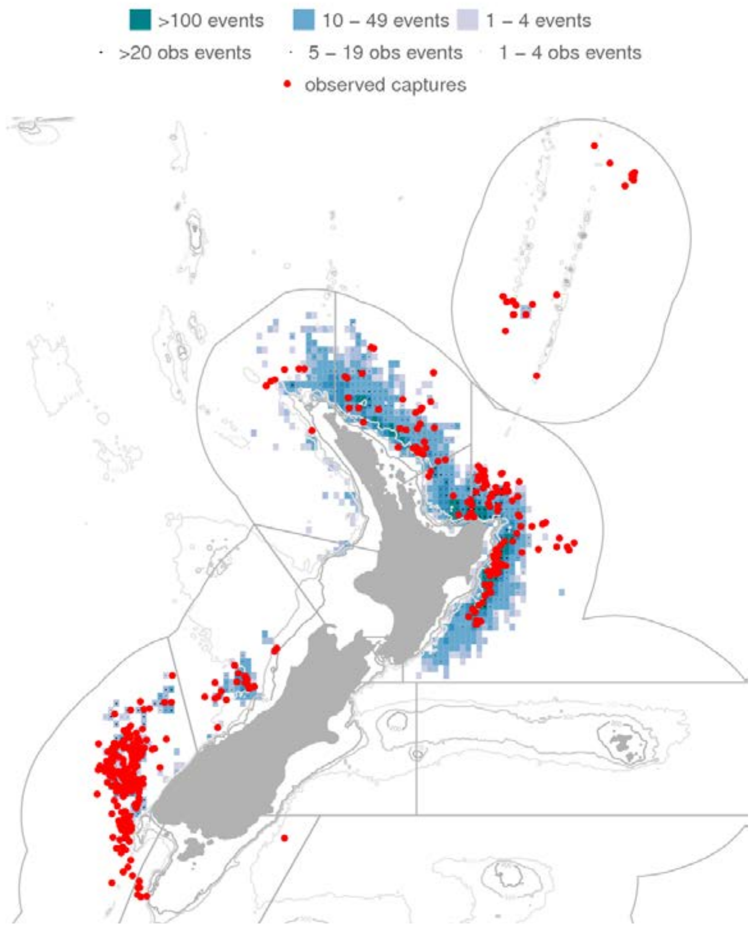


Figure 6: Distribution of fishing effort in the New Zealand surface longline fisheries and observed seabird captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.2 Sea turtle bycatch

Between 2002–03 and 2010–11, there were 13 observed captures of sea turtles across all surface longline fisheries (Tables 9 and 10, Figure 7). Observer records documented all but one sea turtle as captured and released alive. Sea turtle capture distributions predominantly occur throughout the east coast of the North Island and Kermadec Island fisheries (Figure 8).

Table 9: Number of observed sea turtle captures in the New Zealand surface longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson and Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

Species	Bay of Plenty	East Coast North Island	Kermadec Islands	West Coast North Island	Total
Leatherback turtle	1	4	3	3	11
Olive ridley turtle	0	1	0	0	1
Unknown turtle	0	1	0	0	1
Total	**1**	**6**	**3**	**3**	**13**

Table 10: Effort and sea turtle captures in surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	10 764 588	2 195 152	20.4	0	0
2003-2004	7 380 779	1 607 304	21.8	1	0.001
2004-2005	3 676 365	783 812	21.3	2	0.003
2005-2006	3 687 339	705 945	19.1	1	0.001
2006-2007	3 738 362	1 040 948	27.8	2	0.002
2007-2008	2 244 339	426 310	19.0	1	0.002
2008-2009	3 115 633	937 233	30.1	2	0.002
2009-2010	2 992 285	665 883	22.3	0	0
2010-2011	3 164 159	674 522	21.3	4	0.006

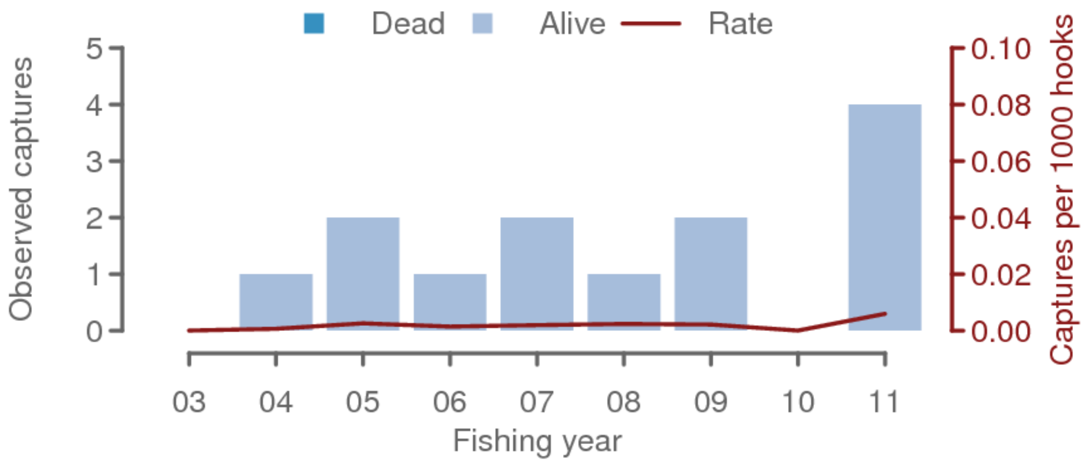


Figure 7: Observed captures of sea turtles in the New Zealand surface longline fisheries from 2003 to 2011.

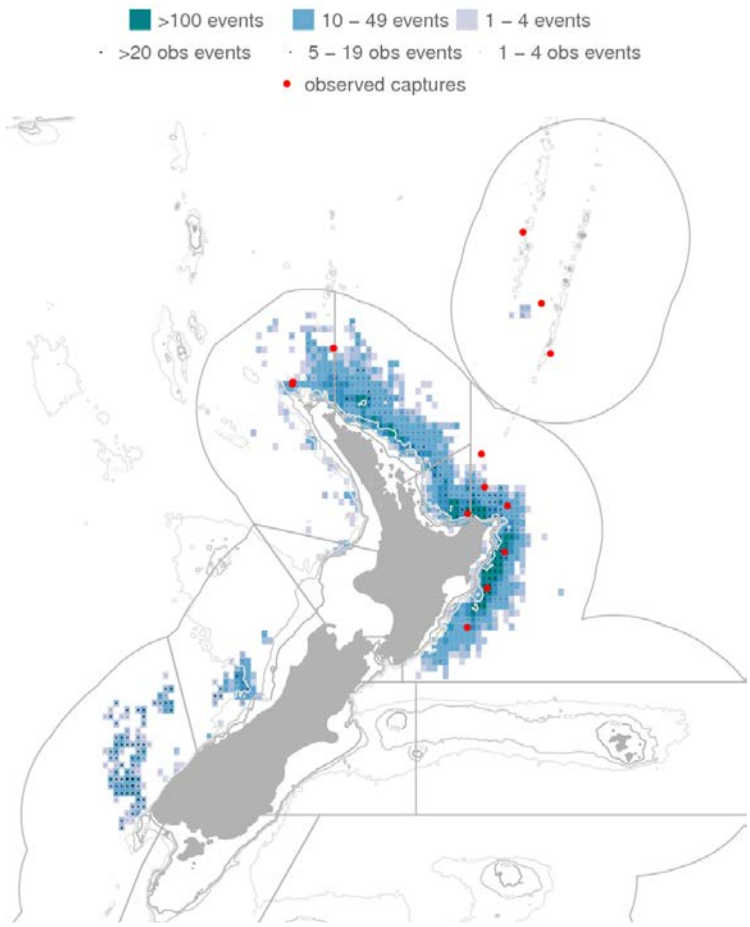


Figure 8: Distribution of fishing effort in the New Zealand surface longline fisheries and observed sea turtle captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3 Marine Mammals

4.2.3.1 Cetaceans

Cetaceans are dispersed throughout New Zealand waters (Perrin *et al.* 2008). The spatial and temporal overlap of commercial fishing grounds and cetacean foraging areas has resulted in cetacean captures in fishing gear (Abraham and Thompson 2009, 2011).

Between 2002–03 and 2010–11, there were seven observed captures of whales and dolphins in surface longline fisheries. Observed captures included 5 unidentified cetaceans and 2 long-finned Pilot whales (Tables 11 and 12, Figure 9) (Abraham and Thompson 2011). All captured animals recorded were documented as being caught and released alive (Thompson and Abraham 2010). Cetacean capture distributions are more frequent off the east coast of the North Island (Figure 10)

Table 11: Number of observed cetacean captures in the New Zealand surface longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson and Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

Species	Bay of Plenty	East Coast North Island	Fiordland	Northland and Hauraki	West Coast North Island	West Coast South Island	Total
Long-finned pilot whale	0	1	0	0	0	1	2
Unidentified cetacean	1	1	1	1	1	0	5
Total	**1**	**2**	**1**	**1**	**1**	**1**	**7**

Table 12: Effort and captures of cetaceans in surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	10 764 588	2 195 152	20.4	1	0.0005
2003-2004	7 380 779	1 607 304	21.8	4	0.002
2004-2005	3 676 365	783 812	21.3	1	0.001
2005-2006	3 687 339	705 945	19.1	0	0
2006-2007	3 738 362	1 040 948	27.8	0	0
2007-2008	2 244 339	426 310	19.0	1	0.002
2008-2009	3 115 633	937 233	30.1	0	0
2009-2010	2 992 285	665 883	22.3	0	0
2010-2011	3 164 159	674 522	21.3	0	0

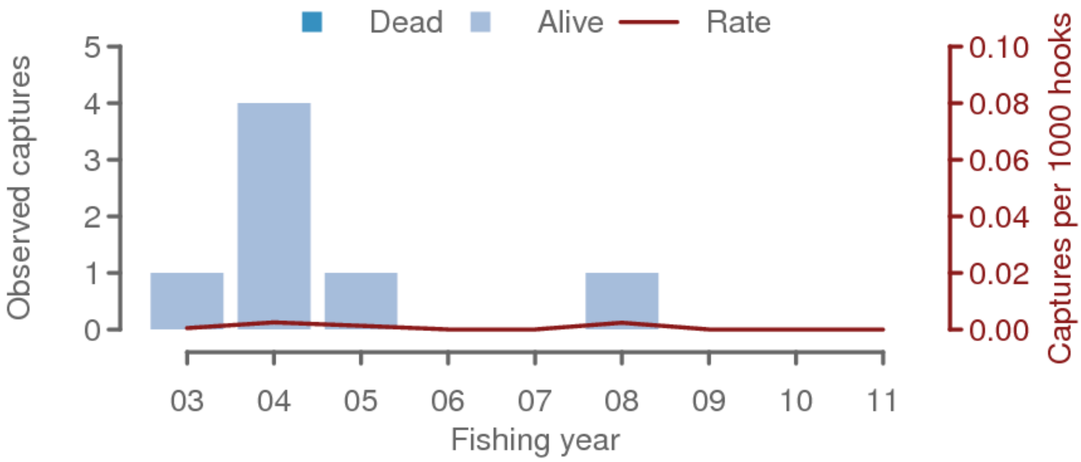


Figure 9: Observed captures of cetaceans in the New Zealand surface longline fisheries from 2003 to 2011.

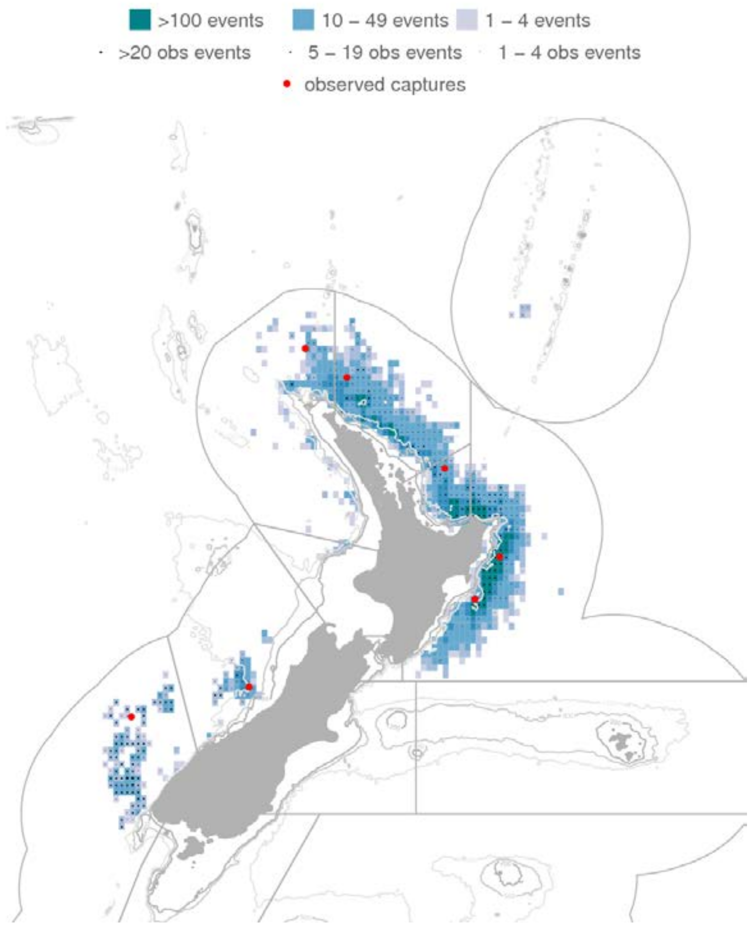


Figure 10: Distribution of fishing effort in the New Zealand surface longline fisheries and observed cetacean captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3.2 New Zealand fur seal bycatch

Currently, New Zealand fur seals are dispersed throughout New Zealand waters, especially in waters south of about 40º S to Macquarie Island. The spatial and temporal overlap of commercial fishing grounds and New Zealand fur seal foraging areas has resulted in New Zealand fur seal captures in fishing gear (Mattlin 1987, Rowe 2009). Most fisheries with observed captures occur in waters over or close to the continental shelf, which around much of the South Island and offshore islands slopes steeply to deeper waters relatively close to shore, and thus rookeries and haulouts. Captures on longlines occur when the seals attempt to feed on the fish and bait catch during hauling. Most New Zealand fur seals are released alive, typically with a hook and short snood or trace still attached.

New Zealand fur seal captures in surface longline fisheries have been generally observed in waters south and west of Fiordland, but also in the Bay of Plenty-East Cape area when the animals have attempted to take bait or fish from the line as it is hauled. These capture rates include animals that are released alive (100% of observed surface longline capture in 2008-09; Thompson and Abraham 2010). Bycatch rates in 2010-11 are low and lower than they were in the early 2000s (Figure 11). While fur seal captures have occurred throughout the range of this fishery most New Zealand captures have occurred off the Southwest coast of the South Island

(Figure 12). Between 2002–03 and 2010–11, there were 206 observed captures of New Zealand fur seal in surface longline fisheries (Tables 13 and 14).

Table 13: Number of observed New Zealand fur seal captures in the New Zealand surface longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson and Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

	Bay of Plenty	East Coast North Island	Fiordland	Northland and Hauraki	Stewart Snares Shelf	West Coast North Island	West Coast South Island	Total
New Zealand fur seal	10	16	139	3	4	2	32	206

Table 14: Effort and captures of New Zealand fur seal in the New Zealand surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see [Abraham and Thompson (2011)]().

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	10 764 588	2 195 152	20.4	56	0.026
2003-2004	7 380 779	1 607 304	21.8	40	0.025
2004-2005	3 676 365	783 812	21.3	20	0.026
2005-2006	3 687 339	705 945	19.1	12	0.017
2006-2007	3 738 362	1 040 948	27.8	10	0.010
2007-2008	2 244 339	426 310	19.0	10	0.023
2008-2009	3 115 633	937 233	30.1	22	0.023
2009-2010	2 992 285	665 883	22.3	19	0.029
2010-2011	3 164 159	674 522	21.3	17	0.025

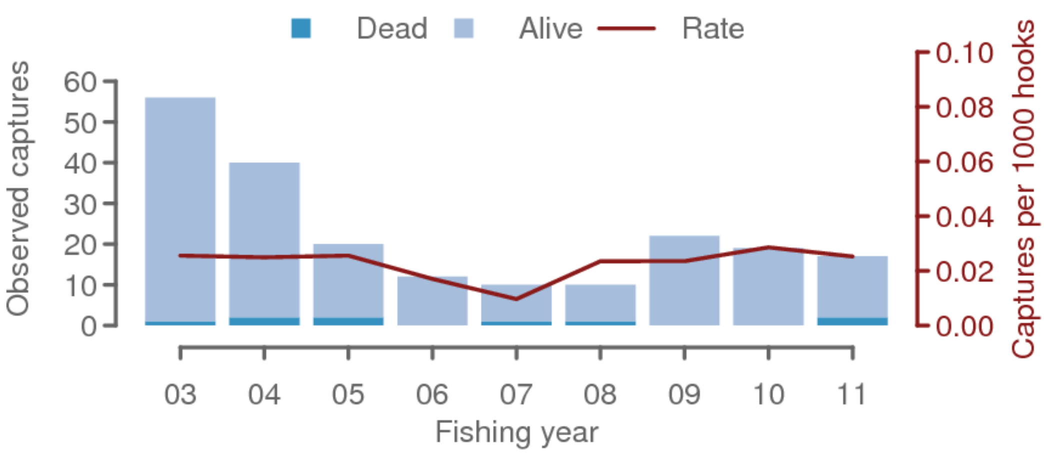


Figure 11: Observed captures of New Zealand fur seal in the New Zealand surface longline fisheries from 2003 to 2011.

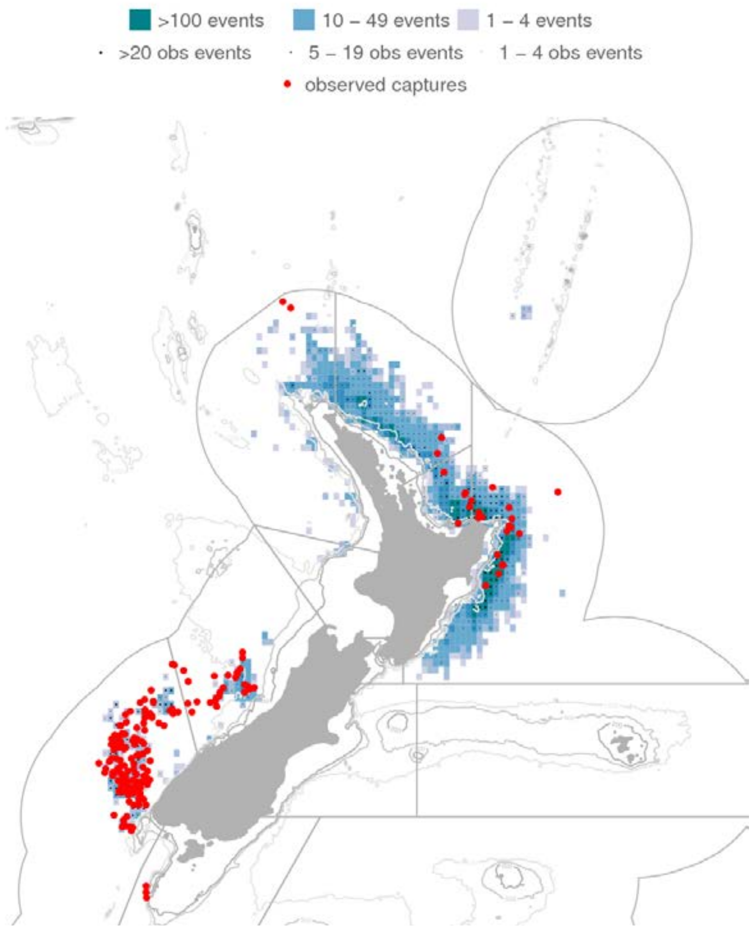


Figure 12: Distribution of fishing effort in the New Zealand surface longline fisheries and observed New Zealand fur seal captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.3 Incidental fish bycatch

Observer records indicate that a wide range of species are landed by the longline fleets in New Zealand fishery waters. Blue sharks are the most commonly landed species (by number), followed by Ray's bream (Table 15). Southern bluefin tuna and albacore tuna are the only target species that occur in the top five of the frequency of occurrence.

Table 15: Numbers of the most common fish species observed in the New Zealand longline fisheries during 2009-10 by fleet and area. Species are shown in descending order of total abundance (Griggs and Baird in press).

	Charter	Domestic		Total
Species	South	North	South	number
Blue shark	2 024	4 650	882	7 556
Rays bream	3 295	326	88	3 709
Southern bluefin tuna	3 244	211	179	3 634
Lancetfish	3	2 139	1	2 143
Albacore tuna	90	1 772	42	1 904
Dealfish	882	0	7	889
Swordfish	3	452	2	457
Moonfish	76	339	6	421
Porbeagle shark	72	328	20	420
Mako shark	11	343	7	361
Big scale pomfret	349	4	0	353
Deepwater dogfish	305	0	0	305
Sunfish	7	283	5	295
Bigeye tuna	0	191	0	191
Escolar	0	129	0	129
Butterfly tuna	15	100	3	118
Pelagic stingray	0	96	0	96
Oilfish	2	75	0	77
Rudderfish	39	20	2	61
Flathead pomfret	56	0	0	56
Dolphinfish	0	47	0	47
School shark	34	0	2	36
Striped marlin	0	24	0	24
Thresher shark	7	17	0	24
Cubehead	13	0	1	14
Kingfish	0	10	0	10
Yellowfin tuna	0	9	0	9
Hake	8	0	0	8
Hapuku bass	1	6	0	7
Pacific bluefin tuna	0	5	0	5
Black barracouta	0	4	0	4
Skipjack tuna	0	4	0	4
Shortbill spearfish	0	4	0	4
Gemfish	0	3	0	3
Bigeye thresher shark	0	2	0	2
Snipe eel	2	0	0	2
Slender tuna	2	0	0	2
Wingfish	2	0	0	2
Bronze whaler shark	0	1	0	1
Hammerhead shark	0	1	0	1
Hoki	0	0	1	1
Louvar	0	1	0	1
Marlin, unspecified	0	1	0	1
Scissortail	0	1	0	1
Broadnose seven gill shark	1	0	0	1
Shark, unspecified	0	1	0	1
Unidentified fish	2	30	8	40
Total	10 545	11 629	1 256	23 430

4.4 Benthic interactions
N/A

4.5 Key environmental and ecosystem information gaps
Cryptic mortality is unknown at present but developing a better understanding of this in future may be useful for reducing uncertainty of the seabird risk assessment and could be a useful input into risk assessments for other species groups.

The survival rates of released target and bycatch species is currently unknown.

Observer coverage in the New Zealand fleet is not spatially and temporally representative of the fishing effort.

5. STOCK ASSESSMENT

No assessments are available for Ray’s bream; therefore estimates of biomass and yield are not available.

5.1 Estimates of fishery parameters and abundance

A time series of relative abundance estimates is available from the Chatham Rise trawl survey, but these estimates may not be a reliable index of relative abundance because Ray’s bream are thought to reside in the mid-water and their vulnerability to the trawl survey gear is unknown, and could be extremely low. Similarly, a time series of unstandardised CPUE from the tuna longline fishery is highly variable and may not reflect relative abundance.

CPUE estimates were calculated for the longline fishery by each fleet and area stratum in which eight or more sets were observed and at least 2% of the hooks were observed (Griggs and Baird in press). CPUE estimates were calculated for blue sharks for each fleet and area in 2006–07 to 2009–10 and added to the time series for 1988–89 to 2005–06 (Griggs *et al.* 2008) and these are shown in Figure 13 (Griggs and Baird in press). The CPUE results from the Domestic fleet should be interpreted with caution due to the lower observer coverage of this fleet. CPUE estimates for the Charter fleet can be considered reliable from 1992–93 onwards (Griggs *et al.* 2007). CPUE of Ray’s bream, was highest in the South and for the Charter fleet. CPUE of Ray’s bream increased to a peak in 2004–05, and remained high but has since decreased in the most recent years. However, as the surface longline catch of Ray’s bream accounts for only a small proportion of the catch (Figure 13) the longline CPUE is unlikely to be sufficient to represent stock status and trends in abundance for the stock as a whole.

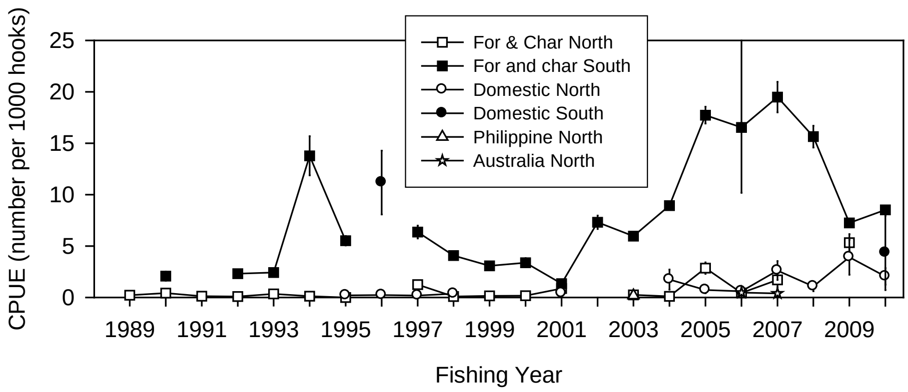


Figure 13: Annual variation in Ray’s bream CPUE by fleet and area. Plotted values are the mean estimates with 95% confidence limits. Fishing year 1989 = October 1988 to September 1989 (Griggs and Baird in press).

5.2 Biomass estimates

No biomass estimates are available for Ray’s bream.

5.3 Other yield estimates and stock assessment results

There are no other yield estimates or stock assessment results available for Ray’s bream.

5.4 Other factors

At least three closely related species are thought to be caught in New Zealand fisheries. Two species from the genus *Brama*, Ray’s bream (*Brama brama*) and southern Ray’s bream (*Brama australis*), are difficult to distinguish from external features and have been reported together in both catch statistics and research survey data in unknown ratios. A third closely related species, bronze bream (*Xenobrama microlepis*), is more easily distinguished from the other two, but is also likely to have been recorded as Ray’s bream in catch statistics.

As none of the reported catch is from target fishing, the quota allocated under the QMS system will cover bycatch of mid-water trawl fisheries for squid, hoki, and jack mackerels, and target tuna longline fisheries.

The distributions of Ray's bream for each year in the North and South regions are shown in Figure 14. Ray's bream are usually kept whole and not sexed, but in 2006–07 and 2009–10 fish were further processed and the fish were sexed, and distributions are shown for 2006–07 and 2009–10 by region and sex. There are differences in the North/South distributions, with South fish being larger, but the distributions for males and females are similar (Figure 14). Female Ray's bream mature at about 43 cm (Francis *et al.* 2004), and most females were probably mature (78.7% over the four year period).

It is not known if observers are distinguishing Ray's bream from Southern Ray's bream (*Brama australis*) and it is possible that there are two species with different distributions. However observer training and fish identification guides used by the observers should allow for correct identification as a result the incidents of misidentification in recent years is likely to be low.

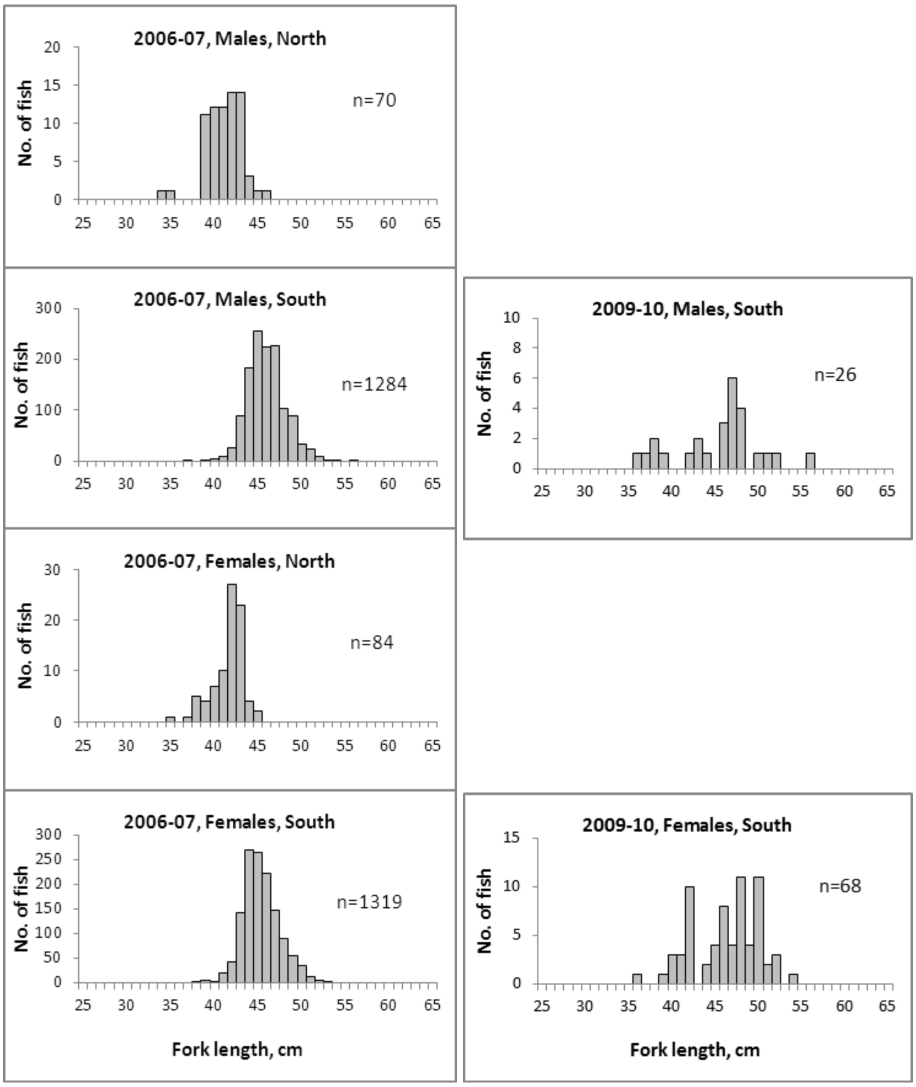


Figure 14: Length-frequency distributions of Ray's bream by fishing year, sex, and region. Sample sizes of less than 20 fish not shown (Griggs and Baird in press).

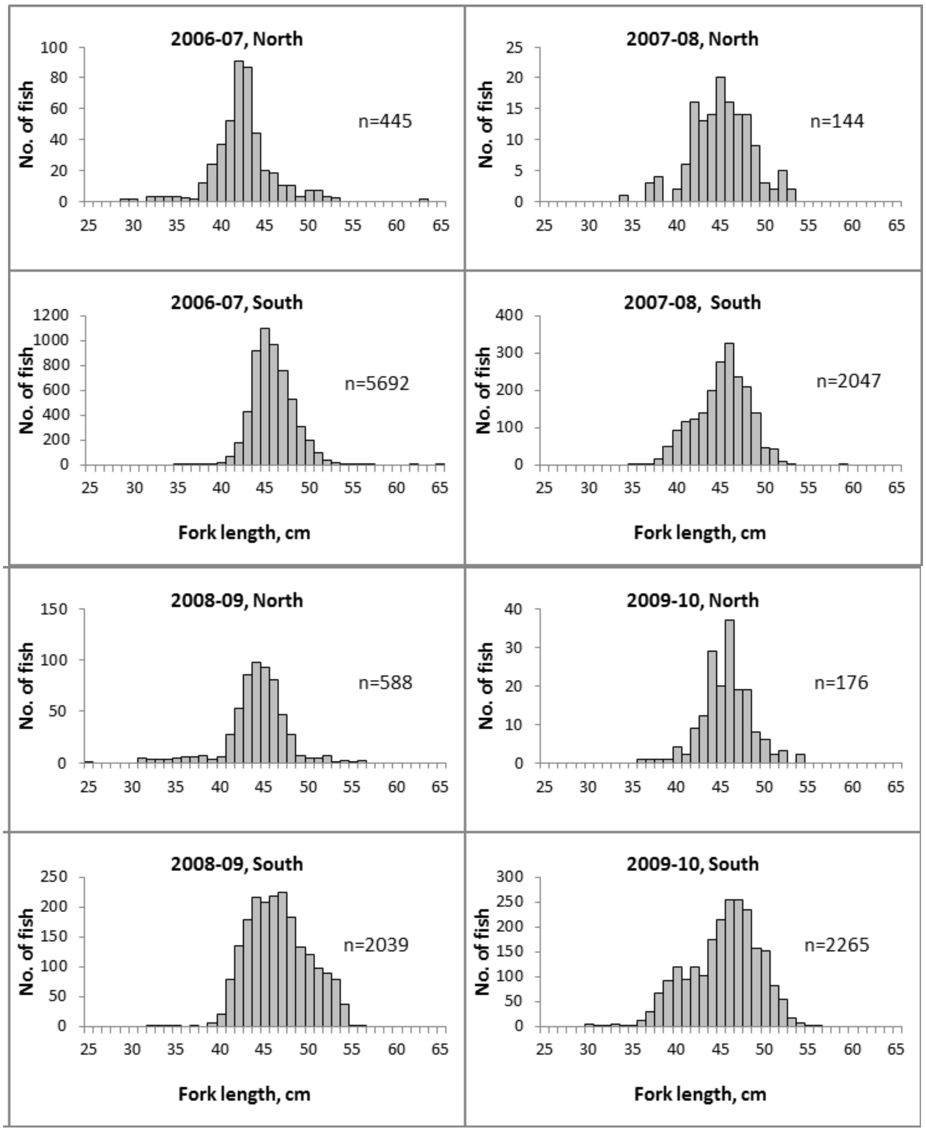


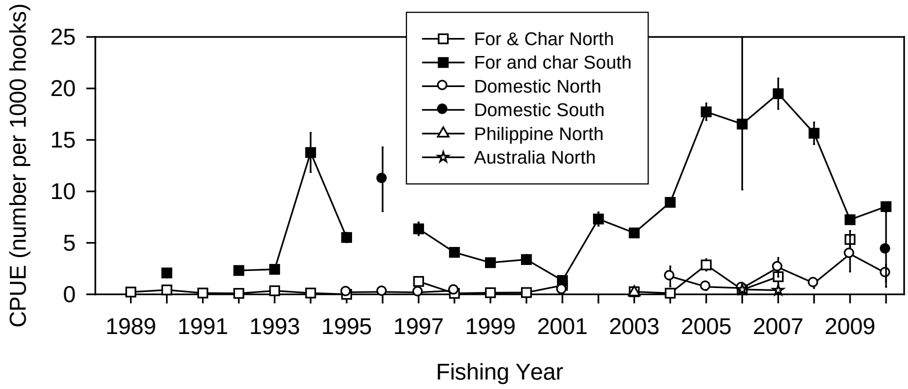
Figure 14 (continued).

6. STATUS OF THE STOCKS

Stock structure assumptions
RBM1 is assumed to be part of the wider South Western Pacific Ocean stock but the assessment below relates only to the New Zealand component of that stock.

Stock Status	
Year of Most Recent Assessment	No assessment
Assessment Runs Presented	Base case model only
Reference Points	Target: Not established Soft Limit: Not established but evaluated using HSS default of 20% SB_0. Hard Limit: Not established but evaluated using HSS default of 10% SB_0.
Status in relation to Target	Unknown
Status in relation to Limits	Unknown

Historical Stock Status Trajectory and Current Status



Annual variation in Ray's bream CPUE by fleet and area. Plotted values are the mean estimates with 95% confidence limits. Fishing year 1989 = October 1988 to September 1989 (Griggs and Baird in press).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	Catches in New Zealand increased from the late 1980s to 2000 but have declined from highs of 1001 t in the early 2000s to 150 t in 2010/11.
Trends in Other Relevant Indicator or Variables	Unknown

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

Assessment Methodology and Evaluation		
Assessment Type	Level 4: Low information evaluation - There are only data on catch and TACC, with no other fishery indicators.	
Assessment Method		
Assessment Dates	Latest assessment:	Next assessment:
Overall assessment quality rank		
Main data inputs (rank)		
Data not used (rank)		
Changes to Model Structure and Assumptions		
Major Sources of Uncertainty		

Qualifying Comments
There is no target fishery for Ray's bream but it is a bycatch in mid-water trawl, bottom trawl, surface longlining, trolling and bottom longlining.

Fishery Interactions
-

7. FOR FURTHER INFORMATION

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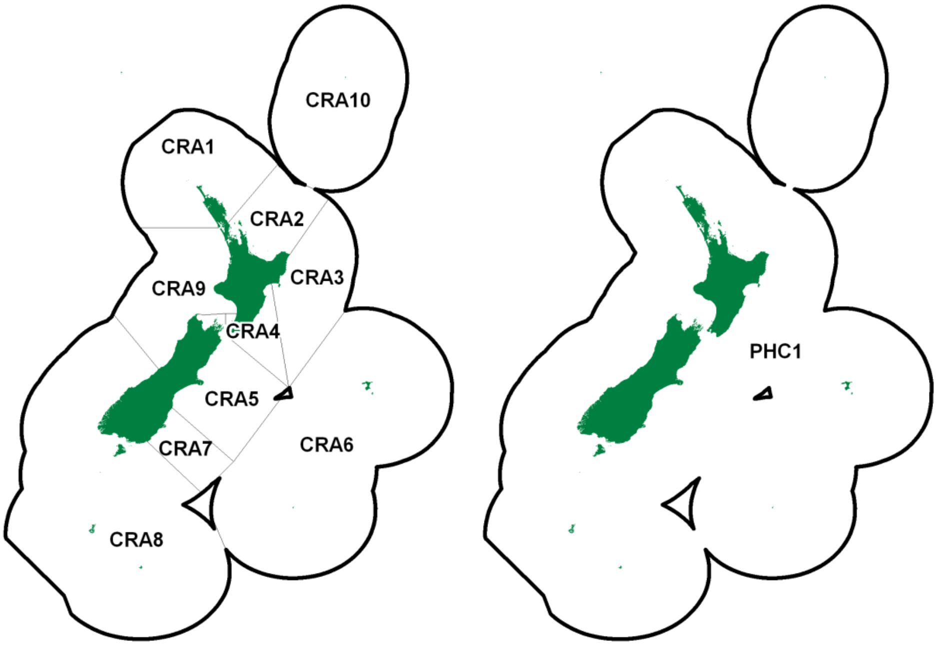
ROCK LOBSTER (CRA and PHC)

(*Jasus edwardsii*, *Sagmariasus verreauxi*)
Koura papatea, Pawharu



1. FISHERY SUMMARY

Two species of rock lobsters are taken in New Zealand coastal waters. The red rock lobster (*Jasus edwardsii*) supports nearly all the landings and is caught all around the North and South Islands, Stewart Island and the Chatham Islands. The packhorse rock lobster (*Sagmariasus verreauxi*) is taken mainly in the north of the North Island. Packhorse lobsters (PHC) grow to a much larger size than do red rock lobsters (CRA) and have different shell colouration and shape.

The rock lobster fisheries were brought into the Quota Management System (QMS) on 1 April 1990, when Total Allowable Commercial Catches (TACCs) were set for each Quota Management Area (QMA) shown above. Before this, rock lobster fishing was managed by input controls, including minimum legal size (MLS) regulations, a prohibition on the taking of berried females and soft-shelled lobsters, and some local area closures. Most of these input controls have been retained, but the limited entry provisions were removed and allocation of individual transferable quota (ITQ) was made to the previous licence holders based on catch history.

Historically, three rock lobster stocks were recognised for stock assessment purposes:
- NSI – the North and South Island (including Stewart Island) red rock lobster stock
- CHI – the Chatham Islands red rock lobster stock
- PHC – the New Zealand packhorse rock lobster stock

In 1994, the Rock Lobster Fishery Assessment Working Group (RLFAWG) agreed to divide the historical NSI stock into three substocks based on groupings of the existing QMAs (without assigning CRA 9):
- NSN – the northern stocks CRA 1 and 2
- NSC – the central stocks CRA 3, 4 and 5
- NSS – the southern stocks CRA 7 and 8

Since 2001, these historical stock definitions have not been used and assessments have been carried out at the Fishstock level, i.e. for CRA 1, CRA 2 etc. The fishing year runs from 1 April to 31 March.

The management of four of the nine rock lobster QMAs involves the operation of "management procedures" (MPs), also known as "decision rules". These are rules that use data observations to specify catch limits, and which have been evaluated to meet the requirements of the Fisheries Act. The five QMAs which use this methodology are CRA 3, CRA 4, CRA 5, CRA 7 and CRA 8, all of which use standardised CPUE to specify a commercial fishery catch limit (see Section 4 for a detailed discussion of each rule). CRA 1 and CRA 2 currently rely on formal stock assessments to make changes in catch limits. Neither CRA 6 nor CRA 9 have used formal stock assessments to set catch limits. The TACC for CRA 10 is nominal because it is not fished commercially. The TACC for PHC 1 increased from 30 t in 1990 to its current value of 40.3 t at the beginning of the 1992–93 fishing year following appeals.

Summary of management actions by QMA since 1990 for rock lobster:

QMA	Type of management	Frequency of review	Year MP implemented	Year of TACC changes since 1990
CRA 1 (Northland)	Formal stock assessment	Unspecified	Not applicable	1991, 1992, 1993
CRA 2 (Bay of Plenty)	Formal stock assessment	Unspecified	Not applicable	1991, 1992, 1997
CRA 3 (Gisborne)	Management procedure (MP)	5 years	2008	1991, 1992, 1993, 1996, 1997, 1998, 2005, 2009, 2012
CRA 4 (Wairarapa)	Management procedure (MP)	5 years	2007 [1]	1991, 1992, 1999, 2009, 2010, 2011 [1]
CRA 5 (Marlborough/Kaikoura)	Management procedure (MP)	5 years	2008[2]	1991, 1992, 1993, 1999
CRA 6 (Chatham Islands	Not assessed	Unspecified	Not applicable	1991, 1993, 1997, 1998
CRA 7 (Otago)	Management procedure (MP)	5 years	1996 [3]	1991, 1992, 1993, 1999, 2001, 2004, 2006, 2008, 2009, 2010, 2011, 2012
CRA 8 (Stewart Island/Fiordland)	Management procedure (MP)	5 years	1996 [3]	1991, 1992, 1993, 1999, 2001, 2004, 2006, 2008, 2009, 2011
CRA 9 (Westland, Taranaki)	Not assessed	Unspecified	Not applicable	1991, 1992
CRA 10 (Kermadec Island)	Not assessed	Unspecified	Not applicable	–
PHC 1 (all NZ)	Not assessed	Unspecified	Not applicable	1991, 1992

[1] voluntary TACC reductions based on an MP were made by the CRA 4 Industry in 2007 and 2008. The MP was implemented by MPI in 2009
[2] the CRA 5 MP was implemented by MPI in 2012 but industry had operated a voluntary rule since 2008
[3] currently under review for implementation in 2013

TACs (Total Allowable Catch, which includes all non-commercial catches) were set for the first time in 1997–98 for three CRA QMAs (Table 1). Setting TACs is a requirement under the Fisheries Act 1996 and consequently TACs have been set since 1997–98 whenever adjustments have been made to the TACCs. Figure 1 shows historical landings and TACC values for all CRA stocks.

The MLS in the commercial fishery for red rock lobster is based on tail width (TW), except in the Otago fishery. For Otago (CRA 7), the MLS for commercial fishing is a tail length (TL) of 127 mm, which applies to both sexes. The female MLS in all other rock lobster QMAs except Southern (CRA 8) has been 60 mm TW since mid-1992. For Southern (CRA 8), the female MLS has been 57 mm TW since 1990. The male MLS has been 54 mm TW since 1988, except in Otago (MLS described above) and Gisborne (CRA 3), where it is 52 mm TW for the June-August period.

A closed season applies in CRA 6 from 01 March to 30 April in each year. The commercial fishing season in CRA 7 currently runs from 1 June to 19 November.

Special conditions have applied to the Gisborne (CRA 3) fishery from April 1993. During June, July and August, commercial fishers are permitted to retain males at least 52 mm TW. These measures changed the commercial CRA 3 fishery to a mainly winter fishery for male lobsters from 1993 to 2002. The fishery was closed to all users from September to the end of November from 1993. This changed in 2000, when the beginning date for the closure was changed to 1 October. In 2002, the closed season was shortened further and CRA 3 now remains officially closed to commercial fishers only in May (May has been closed to commercial operators in CRA 3 since 1993). Since 2008-09 commercial fishers have closed, by voluntary agreement, Statistical Areas 909 and 910 from the beginning of September to mid-January and Statistical Area 911 from mid-December to mid-January. Fishers in Statistical Area 911 have voluntarily landed only males above 54 mm TW in June to August for each of 2009, 2010 and 2011.

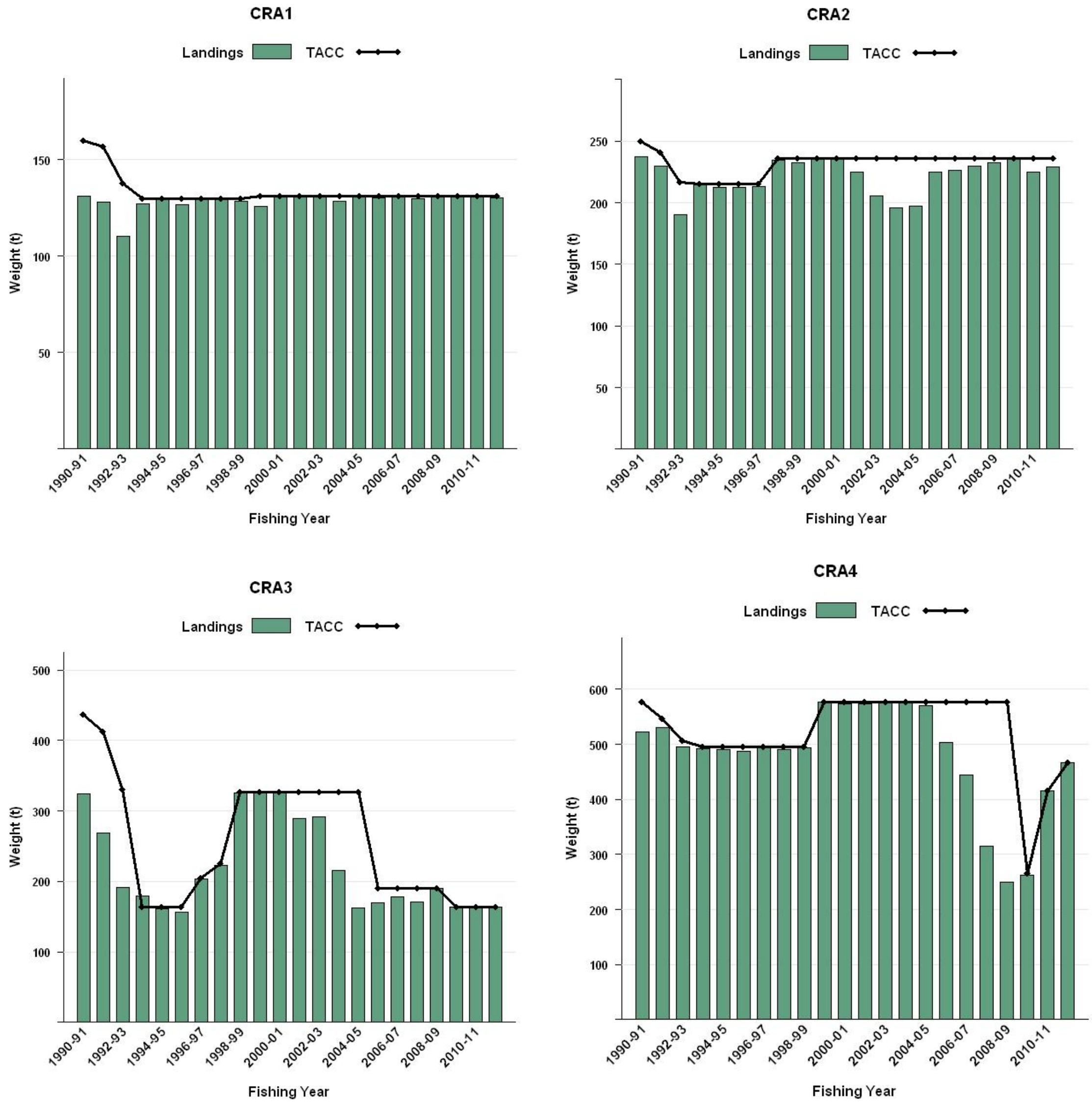


Figure 1: Historical landings and TACC for the 9 main CRA stocks and PHC 1. **[Continued on next page]**

Figure 1 [cont]: Historical landings and TACC for the 9 main CRA stocks and PHC 1.

For recreational fishers, the red rock lobster MLS has been 54 mm TW for males since 1990 and 60 mm TW for females since 1992 in all areas of NZ. The commercial and recreational MLS measure for packhorse rock lobster is 216 mm TL for both sexes.

1.1 Commercial fisheries

Table 1 provides a summary by fishing year of the reported commercial catches, TACCs and TACs by Fishstock (CRA). The Quota Management Reports (QMRs) and their replacement Monthly Harvest Reports (MHRs; since 1 October 2001) provide the most accurate information on landings. Other sources of annual catch estimates include the Licensed Fish Receiver Returns (LFRRs) and the Catch, Effort, and Landing Returns (CELRs).

Problems with rock lobster commercial catch and effort data

There are two types of data on the Catch Effort Landing Return (CELR) form: the top part of each form contains the fishing effort and an estimated catch associated with that effort. The bottom part of the form contains the landed catch and other destination codes, which may span several records of effort. Estimated catches from the top part of the CELR form may show differences from the catch totals on the bottom part of the form, particularly in some QMAs such as CRA 5 and CRA 8 (Vignaux & Kendrick 1998; Bentley et al. 2005). Substantial discrepancies were identified in 1997 between the estimated and weighed catches in CRA 5 (Vignaux & Kendrick 1998) and were attributed to fishers including all rock lobster catch in the estimated total, including those returned to the sea. This led to an overestimate of CPUE, but this problem appeared to be confined to CRA 5, which was remedied by providing additional instruction to fishers on how to properly complete the forms.

After 1998, all CELR catch data used in stock assessments have been modified to reflect the landed catch (bottom of form) rather than the estimated catch (top of form). This resulted in changes to the CPUE values compared to those reported before 1998.

In 2003, it was concluded that the method used to correct estimated to landed catch (“Method C1”, Bentley et al. 2005) was biased because it dropped trips with no reported landings, leading to estimates of CPUE which were too high. In some areas, this bias was getting worse because of an increasing trend of passing catches through holding pots to maximise the value of the catch. The catch/effort data system operated by MPI does not maintain the link between catch derived from the effort expended on a trip with the landings recorded from the trip. Therefore, catches from previous trips, held in holding pots, can be combined with landings from the active trip, which in turn means that tracing capture from the fishing event to the landing event for the same lobster is not possible under the current system.

Beginning in 2003, the catch and effort data used in these analyses were calculated using a revised procedure described as “Method B4” in Bentley et al. (2005). This procedure sums all landings and effort for a vessel within a calendar month and allocates the landings to statistical areas based on the reported area distribution of the estimated catches. The method assumes that landings from holding pots tend to even out at the level of a month. In the instances where there are vessel/month combinations with no landings, the method drops all data for the vessel in the month with zero landings and in the following month, with the intent of excluding uncertain data in preference to incorrectly reallocating landings.

Table 1: Reported commercial catch (t) from QMRs or MHRs (after 1 October 2001), commercial TACC (t) and total TAC (t) (where this quantity has been set) for *Jasus edwardsii* by rock lobster QMA for each fishing year since the species was included in the QMS on 1 April 1990. –:TAC not set for QMA; N/A: catch not available (current fishing year).

	CRA 1			CRA 2			CRA 3			CRA 4		
Fishing Year	Catch	TACC	TAC	Catch	TACC	TAC	Catch	TACC	TAC	Catch	TACC	TAC
1990–91	131.1	160.1	–	237.6	249.5	–	324.1	437.1	–	523.2	576.3	–
1991–92	128.3	146.8	–	229.7	229.4	–	268.8	397.7	–	530.5	529.8	–
1992–93	110.5	137.4	–	190.3	214.6	–	191.5	327.5	–	495.7	495.7	–
1993–94	127.4	130.5	–	214.9	214.6	–	179.5	163.7	–	492.0	495.7	–
1994–95	130.0	130.5	–	212.8	214.6	–	160.7	163.7	–	490.4	495.7	–
1995–96	126.7	130.5	–	212.5	214.6	–	156.9	163.7	–	487.2	495.7	–
1996–97	129.4	130.5	–	213.2	214.6	–	203.5	204.7	–	493.6	495.7	–
1997–98	129.3	130.5	–	234.4	236.1	452.6	223.4	224.9	379.4	490.4	495.7	–
1998–99	128.7	131.1	–	232.3	236.1	452.6	325.7	327.0	453.0	493.3	495.7	–
1999–00	125.7	131.1	–	235.1	236.1	452.6	326.1	327.0	453.0	576.5	577.0	771.0
2000–01	130.9	131.1	–	235.4	236.1	452.6	328.1	327.0	453.0	573.8	577.0	771.0
2001–02	130.6	131.1	–	225.0	236.1	452.6	289.9	327.0	453.0	574.1	577.0	771.0
2002–03	130.8	131.1	–	205.7	236.1	452.6	291.3	327.0	453.0	575.7	577.0	771.0
2003–04	128.7	131.1	–	196.0	236.1	452.6	215.9	327.0	453.0	575.7	577.0	771.0
2004–05	130.8	131.1	–	197.3	236.1	452.6	162.0	327.0	453.0	569.9	577.0	771.0
2005–06	130.5	131.1	–	225.2	236.1	452.6	170.1	190.0	319.0	504.1	577.0	771.0
2006–07	130.8	131.1	–	226.7	236.1	452.6	178.7	190.0	319.0	444.6	577.0	771.0
2007–08	129.8	131.1	–	229.7	236.1	452.6	172.4	190.0	319.0	315.2	577.0	771.0
2008–09	131.0	131.1	–	232.3	236.1	452.6	189.8	190.0	319.0	249.4	577.0	771.0
2009–10	130.9	131.1	–	235.2	236.1	452.6	164.0	164.0	293.0	262.2	266.0	461.0
2010–11	130.8	131.1		224.8	236.1	452.6	163.7	164.0	293.0	414.8	415.6	610.6
2011–12	130.4	131.1	–	229.0	236.1	452.6	163.9	164.0	293.0	466.2	466.9	661.9
2012–13	N/A	131.1	–	N/A	236.1	452.6	N/A	193.3	322.3	N/A	466.9	661.9

	CRA 5			CRA 6			CRA 7			CRA 8		
Fishing Year	Catch	TACC	TAC	Catch	TACC	TAC	Catch	TACC	TAC	Catch	TACC	TAC
1990–91	308.6	465.2	–	369.7	518.2	–	133.4	179.4	–	834.5	1152.4	–
1991–92	287.4	426.8	–	388.3	503.0	–	177.7	164.7	–	962.7	1054.6	–
1992–93	258.8	336.9	–	329.4	503.0	–	131.6	153.1	–	876.5	986.8	–
1993–94	311.0	303.2	–	341.8	530.6	–	138.1	138.7	–	896.1	888.1	–
1994–95	293.9	303.2	–	312.5	530.6	–	120.3	138.7	–	855.6	888.1	–
1995–96	297.6	303.2	–	315.3	530.6	–	81.3	138.7	–	825.6	888.1	–
1996–97	300.3	303.2	–	378.3	530.6	–	62.9	138.7	–	862.4	888.1	–
1997–98	299.6	303.2	–	338.7	400.0	480.0	36.0	138.7	–	785.6	888.1	–
1998–99	298.2	303.2	–	334.2	360.0	370.0	58.6	138.7	–	808.1	888.1	–
1999–00	349.5	350.0	467.0	322.4	360.0	370.0	56.5	111.0	131.0	709.8	711.0	798.0
2000–01	347.4	350.0	467.0	342.7	360.0	370.0	87.2	111.0	131.0	703.4	711.0	798.0
2001–02	349.1	350.0	467.0	328.7	360.0	370.0	76.9	89.0	109.0	572.1	568.0	655.0
2002–03	348.7	350.0	467.0	336.3	360.0	370.0	88.6	89.0	109.0	567.1	568.0	655.0
2003–04	349.9	350.0	467.0	290.4	360.0	370.0	81.4	89.0	109.0	567.6	568.0	655.0
2004–05	345.1	350.0	467.0	323.0	360.0	370.0	94.2	94.9	114.9	603.0	603.4	690.4
2005–06	349.5	350.0	467.0	351.7	360.0	370.0	95.0	94.9	114.9	603.2	603.4	690.4
2006–07	349.8	350.0	467.0	352.1	360.0	370.0	120.2	120.2	140.2	754.9	755.2	842.2
2007–08	349.8	350.0	467.0	356.0	360.0	370.0	120.1	120.2	140.2	752.4	755.2	842.2
2008–09	349.7	350.0	467.0	355.3	360.0	370.0	120.3	123.9	143.9	966.0	966.0	1053.0
2009–10	349.9	350.0	467.0	345.2	360.0	370.0	136.5	189.0	209.0	1018.3	1019.0	1110.0
2010–11	350.0	350.0	467.0	357.4	360.0	370.0	74.8	84.5	104.5	1018.3	1019.0	1110.0
2011–12	350.0	350.0	467.0	359.1	360.0	370.0	45.7	75.7	95.7	961.2	962.0	1053.0
2012–13	N/A	350.0	467.0	N/A	360.0	370.0	N/A	63.9	83.9	N/A	962.0	1053.0

	CRA 9			Total		
Fishing Year	Catch	TACC	TAC	Catch[1]	TACC[1]	TAC[1]
1990–91	45.3	54.7	–	2907.4	3793.0	–
1991–92	47.5	50.2	–	3020.9	3502.9	–
1992–93	45.7	47.0	–	2629.9	3201.9	–
1993–94	45.5	47.0	–	2746.2	2912.1	–
1994–95	45.2	47.0	–	2621.5	2912.1	–
1995–96	45.4	47.0	–	2548.6	2912.1	–
1996–97	46.9	47.0	–	2690.5	2953.1	–
1997–98	46.7	47.0	–	2584.2	2864.1	1312.0
1998–99	46.9	47.0	–	2726.0	2926.8	1275.6
1999–00	47.0	47.0	–	2748.5	2850.2	3442.6
2000–01	47.0	47.0	–	2795.9	2850.2	3442.6
2001–02	46.8	47.0	–	2593.0	2685.2	3277.6
2002–03	47.0	47.0	–	2591.1	2685.2	3277.6
2003–04	45.9	47.0	–	2451.5	2685.2	3277.6
2004–05	47.0	47.0	–	2472.3	2726.4	3318.8
2005–06	46.6	47.0	–	2475.8	2589.4	3184.8
2006–07	47.0	47.0	–	2604.8	2766.6	3362.0
2007–08	47.0	47.0	–	2472.5	2766.6	3362.0
2008–09	47.0	47.0	–	2640.7	2981.0	3576.5
2009–10	46.6	47.0	–	2688.8	2762.2	3362.6
2010–11	47.0	47.0	–	2781.7	2807.3	3407.7
2011–12	47.0	47.0	–	2752.5	2792.8	3393.2
2012–13	N/A	47.0	–	N/A	2810.3	3410.7

[1]ACE was shelved voluntarily by the CRA 4 Industry: to 340 t in 2007–08 and 250 t in 2008–09

Table 2: Reported standardised CPUE (kg/potlift) for *Jasus edwardsii* by QMA from 1979–80 to 2011–12. Sources of data: from 1979–80 to 1988–89 from the QMS-held FSU data; from 1989–90 to 2011–12 from the CELR data held by the Ministry for Primary Industries, using the "B4" algorithm corrected for "L" destination code landings (see text for definition). See Booth et al. (1994) for a discussion of problems with the QMS-held FSU data; see Starr (2012) for a discussion of the standardisation methodology, including the procedure for preparing the data for analysis.

Fishing year	CRA 1	CRA 2	CRA 3	CRA 4	CRA 5	CRA 6	CRA 7	CRA 8	CRA 9
1979–80	0.81	0.52	0.80	0.82	0.63	2.16	0.98	2.00	1.19
1980–81	0.97	0.62	0.88	0.80	0.77	2.00	0.86	1.74	1.28
1981–82	0.92	0.52	0.87	0.85	0.68	2.27	0.73	1.67	0.99
1982–83	0.99	0.43	0.94	0.92	0.75	1.64	0.47	1.43	0.83
1983–84	0.94	0.35	0.86	0.83	0.67	1.61	0.41	1.07	0.86
1984–85	0.87	0.34	0.70	0.76	0.68	1.28	0.55	1.04	0.82
1985–86	0.81	0.40	0.67	0.72	0.56	1.36	0.73	1.23	0.72
1986–87	0.79	0.36	0.58	0.77	0.49	1.49	0.83	1.09	0.84
1987–88	0.75	0.31	0.41	0.67	0.41	1.29	0.70	1.15	0.86
1988–89	0.65	0.34	0.42	0.56	0.36	1.25	0.41	0.86	0.83
1989–90	0.65	0.35	0.46	0.54	0.38	1.13	0.34	0.78	0.75
1990–91	0.54	0.47	0.42	0.50	0.37	1.17	0.43	0.80	0.83
1991–92	0.64	0.43	0.29	0.50	0.31	1.20	0.95	0.76	0.87
1992–93	0.54	0.42	0.25	0.48	0.30	1.16	0.41	0.68	0.96
1993–94	0.62	0.44	0.49	0.54	0.37	1.04	0.61	0.92	1.12
1994–95	0.80	0.53	0.91	0.67	0.38	1.03	0.46	0.83	0.89
1995–96	1.22	0.77	1.41	0.86	0.45	1.05	0.27	0.86	1.09
1996–97	1.18	0.90	1.88	1.18	0.61	1.11	0.23	0.81	0.98
1997–98	1.17	1.02	2.64	1.40	0.87	1.05	0.17	0.69	0.84
1998–99	1.36	1.11	2.01	1.56	1.11	1.29	0.26	0.71	1.10
1999–00	1.12	0.84	1.88	1.47	1.13	1.32	0.27	0.73	0.92
2000–01	1.12	0.74	1.39	1.26	1.33	1.19	0.35	0.87	1.09
2001–02	1.28	0.54	1.06	1.10	1.48	1.18	0.45	0.94	1.06
2002–03	1.12	0.42	0.73	1.19	1.56	1.28	0.62	1.17	1.25
2003–04	1.13	0.42	0.57	1.22	1.70	1.21	0.61	1.77	1.79
2004–05	1.27	0.48	0.49	0.95	1.52	1.34	0.84	1.74	2.33
2005–06	1.31	0.48	0.59	0.82	1.39	1.44	1.24	2.09	2.14
2006–07	1.41	0.56	0.57	0.68	1.34	1.64	1.76	2.69	2.22
2007–08	1.73	0.55	0.60	0.59	1.34	1.61	1.61	2.90	1.85
2008–09	1.79	0.51	0.69	0.71	1.46	1.59	2.01	3.85	1.26
2009–10	1.64	0.46	0.89	1.03	1.83	1.40	0.98	3.84	1.50
2010–11	1.26	0.41	1.17	1.03	1.64	1.54	0.71	2.74	1.48
2011–12	1.20	0.38	1.75	1.27	1.62	1.53	0.62	2.86	1.68

In 2012 the rock lobster WG agreed to change from method "B4" to "Method F2", a new procedure designed to correct estimated catch data to reflect landings. The new procedure is thought to better represent the estimation/landing process and should be more robust to data errors and other uncertainties. The "F2" method uses annual estimates, by vessel, of the ratio of landed catch divided by estimated catch to correct every landing record in a QMA for the vessel. Vessels are removed entirely from the analysis when the ratio is less than 0.8 (overestimates of landed catch) or greater than 1.2 (underestimates of landed catch). Testing of the "F2" method was undertaken to establish that CPUE series based on the new procedure did not differ substantially from previous series. In general, the differences tended to be minor for most QMAs, with the exception of CRA 1 and particularly CRA 9, where there were greater differences (Starr in prep). The WG requires more time to check these differences therefore in this WG report the CPUE indices have been reported as previously from Method B4. It is thought that the "F2" procedure will be more reliable for CRA 9 because the integrity of the actual QMA landings is maintained, while the QMA is only inferred from the statistical area of capture in the "B4" method and this latter procedure may introduce bias because some statistical areas are not unique to CRA 9.

The data used to calculate the standardised (Table 2) and arithmetic (Table 4) CPUE estimates have been subjected to error screening (Bentley et al. 2005) and the estimated catches have been scaled to the landings made to Licensed Fish Receivers ("L" destination code). All other destination codes have been dropped. The addition of Destination Codes "F" and "X" in the scaling procedure is proposed for implementation in 2013. The RLFAWG has accepted the use of these additional destination codes because of the increasing practice of returning legal lobsters to the sea as overall abundance has increased. Otherwise, the relative estimates of CPUE would be biased if discarded legal fish were not included in the analysis. The reporting of releases using Destination Code “X” only became mandatory on 1 April 2009, so this correction was not available prior to then.

Methods for calculating the standardised and arithmetic CPUE estimates are documented in Starr (2012).

Descriptions of Fisheries

***Jasus edwardsii*, CRA 1 and CRA 2**

CPUE levels in CRA 1 and CRA 2 differ: CRA 1 has always had higher catch rates than CRA 2, even in the 1980s when catch rates were lower. CPUE in CRA 1 has been near to or above 1.5 kg/potlift since 2005–06, compared to 0.6 kg/potlift or less in CRA 2 since 2000–01 (Table 2). CRA 2 presently has the lowest CPUE of all nine CRA QMAs, and has been below 0.5 kg/potlift for 7 of the most recent 10 fishing years.

***Jasus edwardsii*, CRA 3, CRA 4 and CRA 5**

Trends in CPUE have differed between these three QMAs, with CRA 3 CPUE peaking in 1997–98, CRA 4 in 1998–99, and CRA 5 in 2009–10 (Table 2). However, these QMAs all show approximately the same pattern: low CPUEs in the 1980s (below 1 kg/potlift) followed by a strong rise in CPUE beginning in the early 1990s (first in CRA 3, followed closely by CRA 4 and finally by CRA 5 in the late 1990s). CRA 3 and CRA 4 dropped from their respective peaks in the late 1990s to lows in the mid-2000s followed by a rising trend to 2011–12 in both QMAs. CRA 5 remained high throughout the 2000s (Table 2).

***Jasus edwardsii*, CRA 7 and CRA 8**

Catch rates are relatively low in CRA 7 compared with those in CRA 8. CPUE in CRA 7 was stable but low (often below 0.5 kg/potlift) until the early 2000s, while CRA 8 showed a similar pattern, but at a higher level (Table 2). Both QMAs then showed spectacular increases in CPUE, peaking in the late 2000s at around 1.8 kg/potlift in CRA 7 and rising to more than 4 kg/potlift in CRA 8. The CRA 8 annual CPUEs of greater than 4.0 kg/potlift observed in 2008–09 and 2009–10 are the highest of any of the rock lobster QMAs over the 33 years of record (Table 2). CPUE declined by 61% in CRA 7 from 2008–09 to 2011–12 while the decline in CRA 8 was 20% between 2009–10 and 2011–12.

The CRA 7 fishery comprises Statistical Areas 920 and 921 on the southern part of the east coast of the South Island, extending from the southern end of the Canterbury Bight to the Catlins (Figure 2). The CRA 8 fishery comprises Statistical Areas 922 to 928, extending from the Catlins to past Jackson Bay north of the fiords.

TACs were first set in April 1999 for both CRA 7 and CRA 8, when the TACC was reduced by 25% in both QMAs with the first implementation of the NSS Decision Rule. Since then, the TACC and TAC have been changed 8 times in CRA 7 and 6 times in CRA 8 due to the operation of decision rules (see Table 1). Initially in 1997, both CRA 7 and CRA 8 were governed by a joint decision rule, reflecting the combining of these two QMAs into a single stock. This situation was reviewed in 2002, resulting in a combined management procedure for CRA 7 and CRA 8, but which was based on a CPUE trajectory for CRA 8 only (page 9, Bentley et al. 2003). Separate decision rules were implemented for CRA 7 and CRA 8 in 2008, following a 2006 assessment which assessed these QMAs separately but which linked the stocks through movement (Breen et al. 2006).

In the 2010–11 fishing year there were 16 vessels in CRA 7 and 64 vessels in CRA 8 (Starr 2012). These fisheries support processing and export operations in Dunedin, Invercargill, Te Anau and Christchurch.

The recreational catch history is unknown but was assumed as described in Section 1.2 (below), based on recreational surveys operated in 1992, 1996, 2000 and 2001. Most recreational catch is taken in summer by potting and diving.

Stock monitoring for the CRA 7 fishery has been done by observer catch sampling while fisher logbooks predominate in CRA 8. Early (pre-1993) stock monitoring in CRA 8 was done using observers and there has been periodic observer sampling in CRA 8 since then. Each year the stock assessment team assigns samples to CRA 7 statistical areaXquarterly blocks based on the previous year's fishing pattern with 15 sampling days assigned to CRA 7 in 2010–11. The CRA 8 voluntary logbook programme in 2010–11 had 15 participants operating from 15 vessels who sampled rock lobster on 906 trips, measuring 28,000 lobsters from over 3,000 potlifts. There is a rich data set of tag recapture data for CRA 8, comprising over 8,000 usable release-recovery pairs collected between 1966 and the present. The available tag data are much less in CRA 7, with only 173 usable release-recovery pairs, most of which were collected in 2007, along with about 50 from 1965.

Jasus edwardsii, CRA 9

Mean annual CPUE has been near to or less than 1.0 kg per potlift from 1981–82 to 1997–98, followed by a strong increase that peaked in 2004–05 and 2005–06, with CPUE exceeding 3 kg/potlift from 2004–05 to 2006–07 and lying at 2.7 kg/potlift in 2011–12 (Table 2). CPUE values for CRA 9 show the greatest differences compared to previous year among the CRA QMAs, with the adoption of the new algorithm for processing rock lobster catch/effort data.

Jasus edwardsii, CRA 6

Mean annual CPUE in the Chatham Island fishery was higher than in the other New Zealand QMAs in the 1980s (Table 2). However, CPUE declined since the mid-1980s to levels similar to those observed in other QMAs (Table 2). CPUE has fluctuated around 1.5 kg/potlift since 2001–02, peaking at 1.8 kg/potlift in 2009–10, the highest value in the series.

Sagmariasus verreauxi, PHC stock

QMS reported landings of the PHC stock halved between 1998–99 and 2001–02 and were below 30 t/year up to 2007–08 (Table 3). Landings have exceeded 30 t/year since 2007–08.

Jasus edwardsii CPUE by statistical area

Table 4 shows the CPUE for the most recent six years within each CRA QMA for each rock lobster statistical area reported on the CELR forms (Figure 2). The values of CPUE and the trends in the fisheries vary within and between CRA areas.

Table 3: Reported landings and TACC for *Sagmariasus verreauxi* from 1990–91 to 2010–11. Data from QMR or MHR (after 1 Oct 2001).

Fishing Year	Landings (t)	TACC (t)	Fishing Year	Landings (t)	TACC (t)
1990–91	7.4	30.5 [1]	2001–02	3.4	40.3
1991–92	23.6	30.5	2002–03	8.6	40.3
1992–93	11.1	40.3	2003–04	16.4	40.3
1993–94	5.7	40.3	2004–05	20.8	40.3
1994–95	7.9	40.3	2005–06	25.0	40.3
1995–96	23.8	40.3	2006–07	25.4	40.3
1996–97	16.9	40.3	2007–08	34.0	40.3
1997–98	16.2	40.3	2008–09	36.4	40.3
1998–99	16.2	40.3	2009–10	35.7	40.3
1999–00	12.6	40.3	2010–11	32.8	40.3
2000–01	9.8	40.3	2011–12	31.6	40.3

[1] entered QMS at 27 t in 1990–91, but raised immediately to 30.5 in first year of operation due to quota appeals

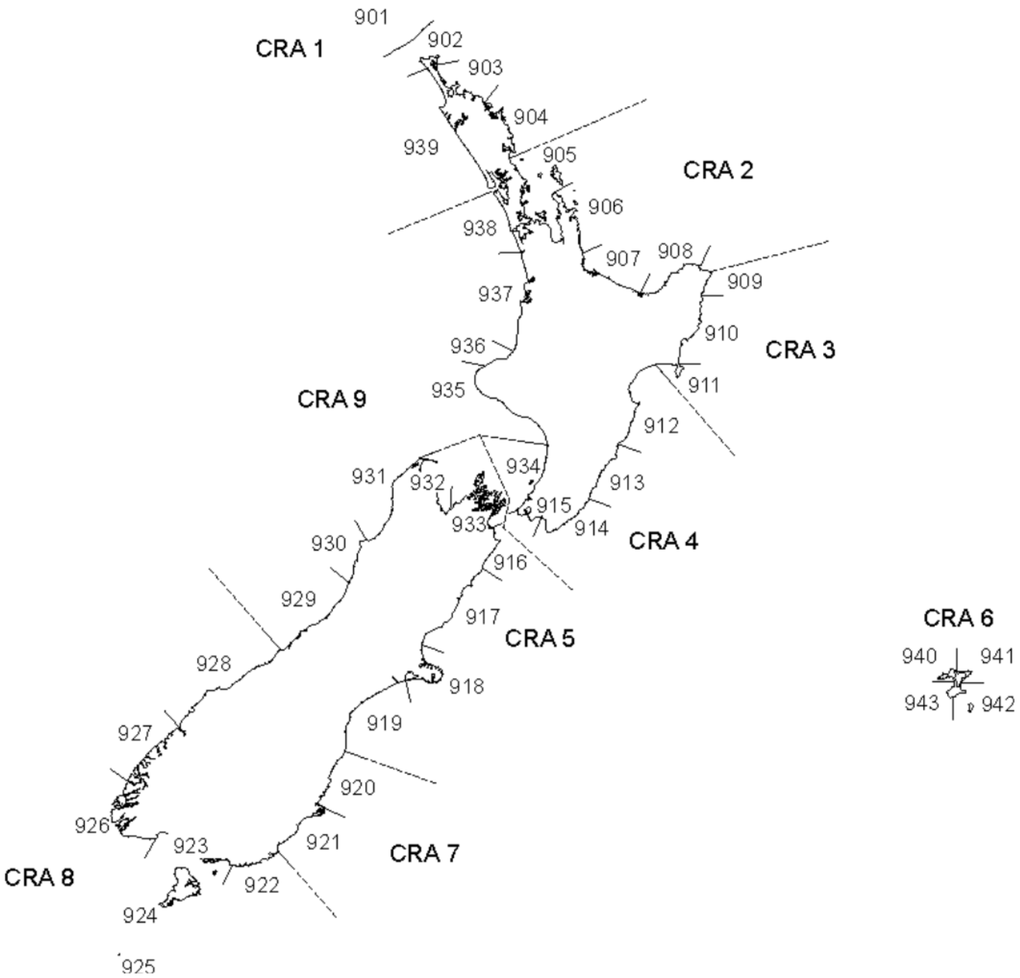


Figure 2: Rock lobster statistical areas as reported on CELR forms.

Table 4: Arithmetic CPUE (kg/potlift) for each statistical area for the six most recent fishing years. Data are from the Ministry for Primary Industries CELR database and estimated catches have been corrected by the amount of fish landed from the bottom part of the form using the "B4" algorithm scaled to the "L" destination code (see Section 1 in text for explanation). '–' value withheld because fewer than three vessels were fishing or there was no fishing.

CRA	Stat Area	06/07	07/08	08/09	09/10	10/11	11/12	CRA	Stat Area	06/07	07/08	08/09	09/10	10/11	11/12
1	901	2.96	3.48	3.99	3.50	2.88	2.56	6	940	1.23	1.37	1.35	1.08	1.30	1.32
1	902	–	2.46	1.69	2.35	1.83	1.37	6	941	1.00	1.13	1.31	1.16	1.37	1.24
1	903	1.33	1.47	1.19	0.90	0.81	0.72	6	942	1.89	1.96	1.63	1.61	1.41	1.59
1	904	–	0.62	–	–	0.47	0.44	6	943	1.91	1.39	1.44	1.23	1.50	1.57
1	939	0.86	1.08	1.28	2.05	1.51	1.97	7	920	1.34	1.13	1.66	0.80	0.57	0.60
2	905	0.60	0.57	0.60	0.53	0.40	0.36	7	921	2.02	1.99	2.02	1.73	0.99	0.57
2	906	0.51	0.54	0.44	0.40	0.38	0.35	8	922	–	–	–	1.12	–	–
2	907	0.56	0.61	0.82	0.69	0.60	0.56	8	923	2.07	4.16	3.32	–	0.62	–
2	908	0.55	0.43	0.48	0.45	0.42	0.46	8	924	4.04	3.18	3.17	4.13	2.96	3.70
3	909	0.97	1.00	1.04	1.19	1.06	1.69	8	925	–	2.87	–	–	–	–
3	910	0.47	0.60	0.71	0.88	1.12	1.47	8	926	2.63	2.28	2.92	2.60	2.53	2.76
3	911	0.60	0.50	0.57	0.70	1.00	1.58	8	927	1.72	2.89	3.65	4.09	2.61	2.03
4	912	0.55	0.62	0.68	0.75	0.75	0.85	8	928	2.13	5.33	6.25	4.22	3.73	4.05
4	913	0.74	0.69	0.80	1.05	1.16	1.56	9	929	–	–	–	–	–	–
4	914	0.55	0.44	0.56	1.11	1.06	1.30	9	930	–	–	–	–	–	–
4	915	0.67	0.78	0.83	1.25	0.93	1.22	9	931	2.94	–	–	–	1.97	–
4	934	1.50	0.86	–	–	–	–	9	935	1.69	1.77	2.39	–	1.31	1.72
5	916	2.09	2.09	2.41	2.20	2.22	2.05	9	936	–	–	–	–	–	–
5	917	1.22	1.34	1.44	2.02	1.94	2.41	9	937	–	–	–	–	–	–
5	918	–	–	1.68	–	–	–	9	938	–	–	–	–	–	–
5	919	–	–	–	–	–	–								
5	932	–	–	–	–	–	–								
5	933	0.72	0.72	0.74	0.76	0.71	0.69								

Table 5: All available estimates of recreational rock lobster harvest (in numbers and in tonnes by QMA, where available) from regional telephone and diary surveys in 1992, 1993, 1994, 1996, 2000 and 2001 (Bradford 1997, 1998; Teirney et al. 1997). Data were provided by the chairman of the Recreational Fisheries Fishery Assessment Working Group (Peter Todd, MPI; pers. comm.).

QMA/FMA	Number	c.v. (%)	Nominal point estimate (t)
Recreational Harvest South Region 1 Sept 1991 to 30 Nov 1992			
CRA5	65 000	31	40
CRA7	8 000	29	7
CRA8	29 000	28	21
Recreational Harvest Central Region 1992–93			
CRA1	1 000		
CRA2	4 000		
CRA3	8 000		
CRA4	65 000	21	40
CRA5	11 000	32	10
CRA8	1 000		
Northern Region Survey 1993–94			
CRA1	56 000	29	38
CRA2	133 000	29	82
CRA9	6 000		
1996 Survey			
CRA1	74 000	18	51
CRA2	223 000	10	138
CRA3	27 000		
CRA4	118 000	14	73
CRA5	41 000	16	35
CRA7	3 000		
CRA8	22 000	20	16
CRA9	26 000		
2000 Survey			
CRA1	107 000	59	102.3
CRA2	324 000	26	235.9
CRA3	270 000	40	212.4
CRA4	371 000	24	310.9
CRA5	151 000	34	122.3
CRA7	1 000	63	1.3
CRA8	13 000	33	23.3
CRA9	65 000	64	52.8
2001 Roll Over Survey			
CRA1	161 000	68	153.5
CRA2	331 000	27	241.4
CRA3	215 000	48	168.7
CRA4	419 000	22	350.5
CRA5	226 000	22	182.4
CRA7	10 000	67	9.4
CRA8	29 000	43	50.9
CRA9	34 000	68	27.7

1.2 Recreational fisheries

Recreational catches have been estimated from a series of regional and national surveys based on telephone interviews and a sub-sample of diarists. Each survey estimated the New Zealand recreational catch by scaling up the reported catch in numbers by diarists with the ratio of diarists to the total estimated New Zealand population. The catch in numbers was converted to catch in weight using mean weights of recruited lobsters observed in the appropriate catch sampling or voluntary logbook programs during the survey years. Results for rock lobster from each of these recreational surveys – South region (1991–92), Central region (1992–93), North region (1993–94), the 1996 National Diary Survey, and the 1999–2000 National survey – are presented in Table 5.

In previous assessments, the RLFAWG has not accepted the results from the 1999–2000 national survey and the subsequent "roll-over" survey (Table 5), both of which tended to have much higher catch estimates in most of the QMAs when compared to the earlier surveys (with the exception of CRA 7 and CRA 8). Table 6 presents the recreational catch estimates used in all recent rock lobster stock assessments and Table 7 presents the rationale used when setting the levels presented in Table 6. The RLFAWG has little confidence in these estimates of recreational catch.

Table 6: Historical recreational and customary catch estimates used in recent CRA assessments. All ramped catches started from 20% of the "best recreational estimate". The rationales for setting these catches are presented in Table 7.

QMA	First year	Last year	"Best" Recreational catch (t)	Notes: Recreational Catch	Customary catch (t)	Notes: Customary catch
CRA 1 [1]	1945	2001	47.19	Ramped from 1945; constant from 1979	10	Constant from 1945
CRA 2 [1]	1945	2001	122.64	Ramped from 1945; constant from 1979	10	Constant from 1945
CRA 3 [2]	1945	2007	20.0	Constant from 1945	20	Constant from 1945
CRA 4 [3]	1945	2010	46.709	Ramped from 1945; after 1979, the "best recreational catch" was scaled by the ratio of the CRA 4 standardised SS CPUE relative to the mean 1994/1996 SS CPUE	20	Constant from 1945
CRA 5 [4]	1945	2009	30.424	Ramped from 1945; after 1979, the "best recreational catch" was scaled by the ratio of the arithmetic SS CPUE for Area 917 relative to the mean 1994/1996 SS CPUE for Area 917	10	Constant from 1945
CRA 6	–	–	–	Not used	–	–
CRA 7 [5]	1976	2011	4.362	Ramped from 1945; after 1979, the "best recreational catch" was scaled by the ratio of the CRA 7 standardised SS CPUE relative to the mean 1992/1996/2000/2001 SS CPUE	1	Constant from 1974
CRA 8 [5]	1976	2011	15.549	Ramped from 1945; after 1979, the "best recreational catch" was scaled by the ratio of the CRA 8 standardised SS CPUE relative to the mean 1992/1996/2000/2001 SS CPUE	6	Constant from 1974
CRA 9	–	–	–	Not used	–	–

[1] Starr et al. (2003);[2] Starr et al. (2009); [3] Starr et al. (2012); [4] Starr et al. (2011); [5] See Section 1.3

Table 7: Basis for setting recreational and customary catch estimates used in recent CRA assessments. SS: spring/summer. The recreational survey estimates are provided in Table 6.

QMA	Notes: Recreational Catch	Notes: Customary Catch
CRA 1 and CRA 2 [1]	Mean of 1994 and 1996 recreational survey estimates in numbers X 1994/96 SS mean weight from catch sampling	MPI Compliance estimate
CRA 3 [2]	By WG agreement	MPI Compliance estimate
CRA 4 [3]	Mean of 1994 and 1996 recreational survey estimates in numbers X 1994/96 SS mean weight from catch sampling. The maximum of catches declared under the 1996 Fisheries Act Section 111 (Table 9) was added to the calculated time series.	MPI Compliance estimate, supported by returns of numbers of lobster harvested under Kaimoana regulations
CRA 5 [4]	Mean of 1994 and 1996 recreational survey estimates in numbers X 1994/96 SS mean weight from catch sampling. The maximum of catches declared under the 1996 Fisheries Act Section 111 (Table 9) was added to the calculated time series.	By WG agreement
CRA 6	Not used	Not used
CRA 7 [5] CRA 8 [5]	Mean of recreational survey estimates (mean in numbers: 1992/1996 and 2000/2001) X mean SS weight from catch sampling in same years. The maximum of catches declared under the 1996 Fisheries Act Section 111 (Table 9) was then added to the survey estimates	Expanded from estimates provided by MPI Compliance which were thought to be too low by the WG
CRA 9	No assessment	No assessment

[1] Starr et al. (2003);[2] Breen et al. (2009); [3] see Section 5; [4] Starr et al. (2011); [5] Breen et al. (2007)

1.3 CRA 7 and CRA 8 recreational catch

Recreational catch estimates were required for the 2012 CRA 7 and CRA 8 assessments. The RLFAWG agreed to use an approach consistent with that used in 2010 for CRA 5 and in 2011 for CRA 4, allowing recreational catch to vary with abundance, as reflected by the spring-summer standardised CPUE index series. Recreational catch was calculated by scaling the mean SS CPUE for 1994/1996 to the SS CPUE in each year multiplied by the mean CRA 7 or CRA 8 catches in Table 8.

Table 8. Information used to estimate recreational catch for CRA 7 and CRA 8.

Category	CRA 7	CRA 8
Catch estimates in numbers		
1992	8 000	29 000
1996	3 000	22 000
2000	1 000	13 000
2001	10 000	29 000
Derived values		
1992/1996 average numbers	5,500	25 500
1992/1996 SS mean weight (kg)	0.669	0.663
2000/2001 average numbers	5 500	21 000
2000/2001 SS mean weight (kg)	0.917	0.676
Mean (1992, 1996, 2000, 2001) catch (kg)	4 362	15 549
Reconstructed catch in 1979 (kg)	9 457	33 737
20% of 1979 catch (kg)	1 891	6 747
Maximum Section 111 catch (kg)	1 675	14 775

The RLFAWG agreed to use the following algorithm to represent the CRA 7 and CRA 8 recreational catches :

$$
\begin{aligned}
&{}^{q}\overline{W}_{92,96,00,01} = \left({}^{q}\overline{w}_{92,96} * {}^{q}\overline{N}_{92,96} + {}^{q}\overline{w}_{00,01} * {}^{q}\overline{N}_{00,01} \right) \Big/ 2 \\
&{}^{q}\hat{W}_{i} = \frac{{}^{q}CPUE_{i} * {}^{q}\overline{W}_{92,96,00,01}}{\left({}^{q}CPUE_{92} + {}^{q}CPUE_{96} + {}^{q}CPUE_{00} + {}^{q}CPUE_{01} \right) \Big/ 4} \quad \text{if } i >= 1979 \\
&{}^{q}\hat{W}_{1945} = 0.2 * {}^{q}\hat{W}_{1979} \\
&{}^{q}\hat{W}_{i} = {}^{q}\hat{W}_{i-1} + \frac{({}^{q}\hat{W}_{1979} - {}^{q}\hat{W}_{1945})}{(1979-1945)} \quad \text{if } i > 1945 \,\&\, i < 1979
\end{aligned}
$$

where

${}^{q}\overline{W}_{92,96,00,01} =$ mean recreational catch weight for 1992, 1996, 2000 & 2001 for QMA q

${}^{q}\overline{w}_{92,96} =$ mean spring/summer weight >= MLS for sampled lobster for 1992 & 1996 for QMA q

${}^{q}\overline{N}_{92,96} =$ mean numbers lobster from 1992 & 1996 diary surveys for QMA q

${}^{q}\overline{w}_{00,01} =$ mean spring/summer weight >= MLS for sampled lobster for 2000 & 2001 for QMA q

${}^{q}\overline{N}_{92,96} =$ mean numbers lobster from 2000 & 2001 diary surveys for QMA q

${}^{q}CPUE_{i} =$ spring/summer standardised CPUE from 1979 to 2011 for QMA q

${}^{q}\hat{W}_{i} =$ estimated recreational catch by weight for year i for QMA q

This algorithm is similar to that adopted by the RLFAWG for the 2011 CRA 4 stock assessments, including basing the scaling on the total SS CPUE for each QMA. This was done in acknowledgement that the recreational fisheries in both QMAs are spread over a large part of each QMA rather than being concentrated in one statistical area. The resulting recreational catch trajectories (Figure 3) reflect the low abundances in the 1990s, followed by a strong increase to the mid to late 2000s and a subsequent drop. The largest annual catch since 1979–80 was estimated at 27 t for CRA 7 in 2005–06 and at 105 t in 2008–09 for CRA 8. The average recreational catch from 1979 to 2011 has been 10 t/year for CRA 7 and 46 t/year in CRA 8, including the additional Section 111 landings (see following Section).

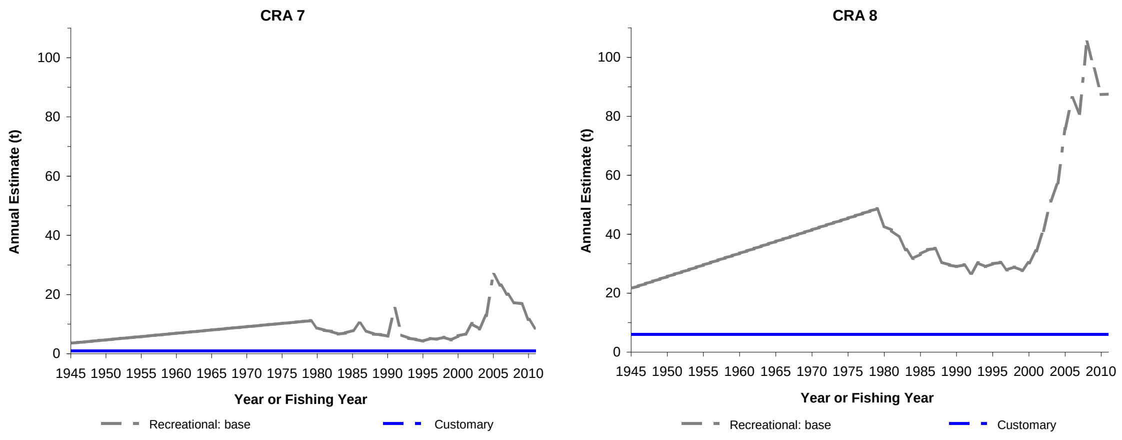


Figure 3. Recreational (grey) and customary (blue) catch trajectories (kg) for the 2012 stock assessments of CRA 7 [left panel] and CRA 8 [right panel]. Section 111 catches have been added to the 2012 recreational catch trajectory. Recreational catches were made proportional to the standardised SS CPUE after 1979, scaled to the mean catch weight estimated from the 1992, 1996, 2000 and 2001 recreational diary surveys.

1.4 Section 111 commercial landings

Commercial fishermen are allowed to take home lobsters for personal use under the provisions of Section 111 of the Fisheries Act. These lobsters are required to be declared on landing forms using the destination code "F". The maximum total in any fishing year for these landings by QMA has ranged from less than 1 t (CRA 6) to nearly 15 t (CRA 8) (Table 9).

Table 9: Section 111 commercial landings (in kg, summed from landing destination code "F") by fishing year and QMA.

Fishing Year	CRA1	CRA2	CRA3	CRA4	CRA5	CRA6	CRA7	CRA8	CRA9
1992-93	5	–	–	–	–	–	–	–	–
1999-2000	–	–	–	–	8	–	–	–	–
2000–01	3	–	–	–	30	–	–	–	–
2001–02	111	227	136	648	465	–	77	253	5
2002–03	489	609	495	2 660	1 960	–	152	1 954	907
2003–04	2 221	1 025	372	3 399	2 907	60	93	1 679	973
2004–05	3 554	733	311	3 706	3 191	87	95	3 505	1 636
2005–06	3 083	775	993	3 680	4 388	2	153	4 572	2 133
2006–07	5 016	1 284	981	3 110	5 102	19	289	5 813	1 219
2007–08	3 831	1 032	1 167	2 706	5 412	411	929	7 786	1 461
2008–09	3 628	1 185	1 374	2 188	6 110	538	1 498	9 571	1 597
2009–10	4 010	1 370	2 253	3 222	6 244	299	1 688	10 721	2 264
2010–11	3 669	1 186	2 182	4 699	6 584	284	429	13 538	1 851
2011–12	5 008	1 169	2 214	4 730	4 826	449	80	14 886	1 899
Maximum	5 016	1 370	2 253	4 730	6 584	538	1 688	14 886	2 264

1.5 Customary non-commercial fisheries

The Ministry of Fisheries provided preliminary estimates of the Mäori customary catch for some Fishstocks for the 1995–96 fishing year. The estimates for the 1995–96 fishing year were: CRA 1, 2.0 t, CRA 2, 16.5 t; CRA 8, 0.2 t; CRA 9, 2.0 t; and PHC 1, 0.5 t.

MPI provided tables of customary permits and realised catches for the CRA 7 and CRA 8 stock assessments, some by weight and some by numbers of lobsters. On the basis of the information in these tables, MPI concluded for CRA 7: "*Based on the information supplied above, the Ministry considers it appropriate to continue to use a 1 tonne constant customary catch estimate for CRA 7*" (Alicia McKinnon, MPI, *pers. comm.*). For CRA 8, MPI came to a different conclusion: "*For CRA 8, available information from the 2006/07 to 2011/12 fishing years suggests the actual quantity of rock lobsters harvested under the customary regulations ranged from approximately 2 to 12 tonnes, with an average of 6 tonnes (using an arbitrary weight of 0.5 kg for each rock lobster). This information suggests that the 2 tonne constant customary catch estimate for CRA 8,* *which has been used in previous assessments, should be increased. I suggest the details of this increase are discussed further by the RLFAWG*" (Alicia McKinnon, MPI, *pers. comm.*).

Given this information, the 2012 stock assessments used constant catch levels of 1 t/year for CRA 7 and 6 t/year for CRA 8 to represent the customary catches in each stock assessment (Table 6; Figure 3). Table 6 presents the customary catch estimates used in all recent rock lobster stock assessments and Table 7 presents the rationale used when setting the levels presented in Table 6. The RLFAWG has little confidence in these estimates.

1.6 Illegal catch

MPI (previously MPI) Compliance has in the past provided estimates of illegal catch in two categories: catch that subsequently was reported against quota (columns labelled 'R' in Table 10) and catch which is outside of the MPI catch reporting system (columns labelled 'NR' in Table 10). Table 10 shows all the available illegal catch estimates by CRA QMA. When these data are used in stock assessments, missing cells are filled in by interpolation (for missing years) or by extrapolation (to extend the series after 2004–05). The illegal catches for these filled-in years are apportioned between the 'R' and 'NR' categories within each QMA (q) using the mean proportion $r_q = \sum R_{q,y} \Big/ \sum I_{q,y}$, where $R_{q,y}$ is the "reported" ('R') catch for those years with MPI Compliance estimates in the QMA and $I_{q,y}$ is the total illegal catch in the same years. This quantity is then subtracted from the total reported QMR/MHR catch to avoid counting the same catch twice when using these catches in stock assessments and the total illegal catch is summed.

Table 10: Available estimates of illegal catches (t) by CRA QMA from 1990, as provided by MPI Compliance over a number of years. R (reported): illegal catch that will eventually be processed though the legal catch/effort system; NR (not reported): illegal catch outside of the catch/effort system. Cells without data or missing rows have been deliberately left blank.

Fishing	CRA 1		CRA 2		CRA 3		CRA 4		CRA 5		CRA 6		CRA 7		CRA 8		CRA 9	
Year	R	NR	R	NR	R	NR	R	NR	R	NR	R	NR	R	NR	R	NR	R	NR
1990		38		70		288.2		160.1		178		85	34	9.6	25	5		12.8
1992		11		37		250		30		180		70	34	5	60	5		31
1994		15		70	5	37		70		70		70		25		65		18
1995		15		60	0	63		64		70		70		15		45		12
1996	0	72	5	83	20	71	0	75	0	37	70	0	15	5	30	28	0	12
1997					4	60												
1998					4	86.5												
1999					0	136								23.5		54.5		
2000					3	75		64										
2001		72		88	0	75												
2002					0	75	9	51		40		10		1		18		1
2003					0	89.5			5	47								
2004							10	30										
2005																		
2006																		
2007																		
2008																		
2009																		
2010																		
2011														1		3		

MPI provided estimates of current and historical illegal catches for the CRA 7 and CRA 8 stock assessments, as well as an estimate of the proportion of illegal catch that was eventually reported as legal catch in each QMA. MPI pointed to estimates given in the past (Table 10) and suggested the following for CRA 7 and CRA 8:

<u>CRA 7:</u> "*With respect to a current illegal take estimate for the CRA 7 fishery, anecdotal information from the Ministry's Compliance and Response team suggests illegal activity in the CRA 7 fishery is currently low, which is potentially related to the current state of low abundance. The Ministry considers that a 1 tonne illegal catch estimate is reasonable for this fishery at this time.*" (Alicia McKinnon, MPI, *pers. comm.*)

CRA 8: "*The last illegal catch estimate that was supplied by the Ministry for CRA 8 was for 18 tonnes in 2002. Monitoring and enforcement information from the Ministry's Compliance and Response team suggests a more realistic figure for the CRA 8 fishery at this time is in the vicinity of 3 tonnes (unreported to the QMS). Reasons for this lower figure are potentially related to the introduction of an amateur accumulation limit within the Fiordland Marine Area in 2005 and current industry dynamics.*" (Alicia McKinnon, MPI, *pers. comm.*)

Given this advice from MPI, the stock assessments used constant illegal catches of 1 t/year for CRA 7 to fill in the missing years between 2002 to 2011 (Table 10). For CRA 8, 3 t was used as the estimate for 2011 and the missing years between 2002 to 2011 were filled in by interpolating the illegal catch down from 18 t estimated for 2002 to 3 t for 2011.

Illegal catch estimates prior to 1990 have been derived from unpublished estimates of discrepancies between reported catch totals and total exported weight that were developed for the period 1974 to 1980 (Table 11; McKoy pers. comm.). For years prior to 1973 and from 1981–82 to 1989–90, illegal catch was estimated using the average ratio of annual exports of rock lobster relative to the reported catch in each year from 1974 to 1980 (Table 11). This ratio was calculated for each QMA by assuming that the exports are distributed by QMA in the same proportion as the reported catches. This procedure is not available for CRA 9 because there are no commercial catch estimates available for this QMA from 1974 to 1978.

Table 11: Export discrepancy estimates by year for all of New Zealand (McKoy, pers. comm.). The QMA export discrepancy catch is calculated using the fraction for the reported QMA commercial catch $C_{q,y}$ relative to the total NZ commercial catch C_y, starting with the total NZ export discrepancy for that year I_y: $I_{q,y} = I_y \left(C_{q,y} / C_y \right)$. This calculation is not performed for CRA 9 as there were no estimates of commercial catch available from 1974 to 1978. The average ratio of the export discrepancy catch for each QMA $\bar{P}_q$ relative to the reported QMA commercial catches is used in each CRA QMA to estimate illegal catches prior to 1990: $I_{q,y} = \bar{P}_q C_{q,y}$ if $y<1974 \| \left(y>1980 \& y<1990 \right)$.

Year	Estimates of total export discrepancies (t) I_y	QMA	$\bar{P}_q = \sum_{y=1974}^{1980} I_{q,y} \Big/ \sum_{y=1974}^{1980} C_{q,y}$
1974	463	CRA 1	0.192
1975	816	CRA 2	0.171
1976	721	CRA 3	0.164
1977	913	CRA 4	0.183
1978	1146	CRA 5	0.187
1979	383	CRA 6	0.181
1980	520	CRA 7	0.183
		CRA 8	0.187
		CRA 9	–

The RLFAWG members have little confidence in the estimates of illegal catch because the estimates cannot be verified.

1.7 Other sources of mortality

Other sources of mortality include handling mortality caused by the return of under-sized and berried female lobsters to the water, and predation by octopus and other predators within pots. Although these mortalities cannot be quantified, all rock lobster assessments assume that handling mortality is 10% of returned lobsters.

1.8 Time series of mortalities

Plots of rock lobster catches from 1945 are presented in Figure 4A and Figure 4B. Commercial catches prior to 1979 have been obtained from unpublished reports (Annala, pers. comm.). Historical estimates of recreational, customary and illegal catches have been generated for each stock assessment and these have been extended using the same rules for those assessments that are not current. In some instances (notably CRA 6 and CRA 9), there has never been a stock assessment and some catch components are missing for this QMA. Finally, a TAC is plotted for the 7 CRA QMAs which have one.

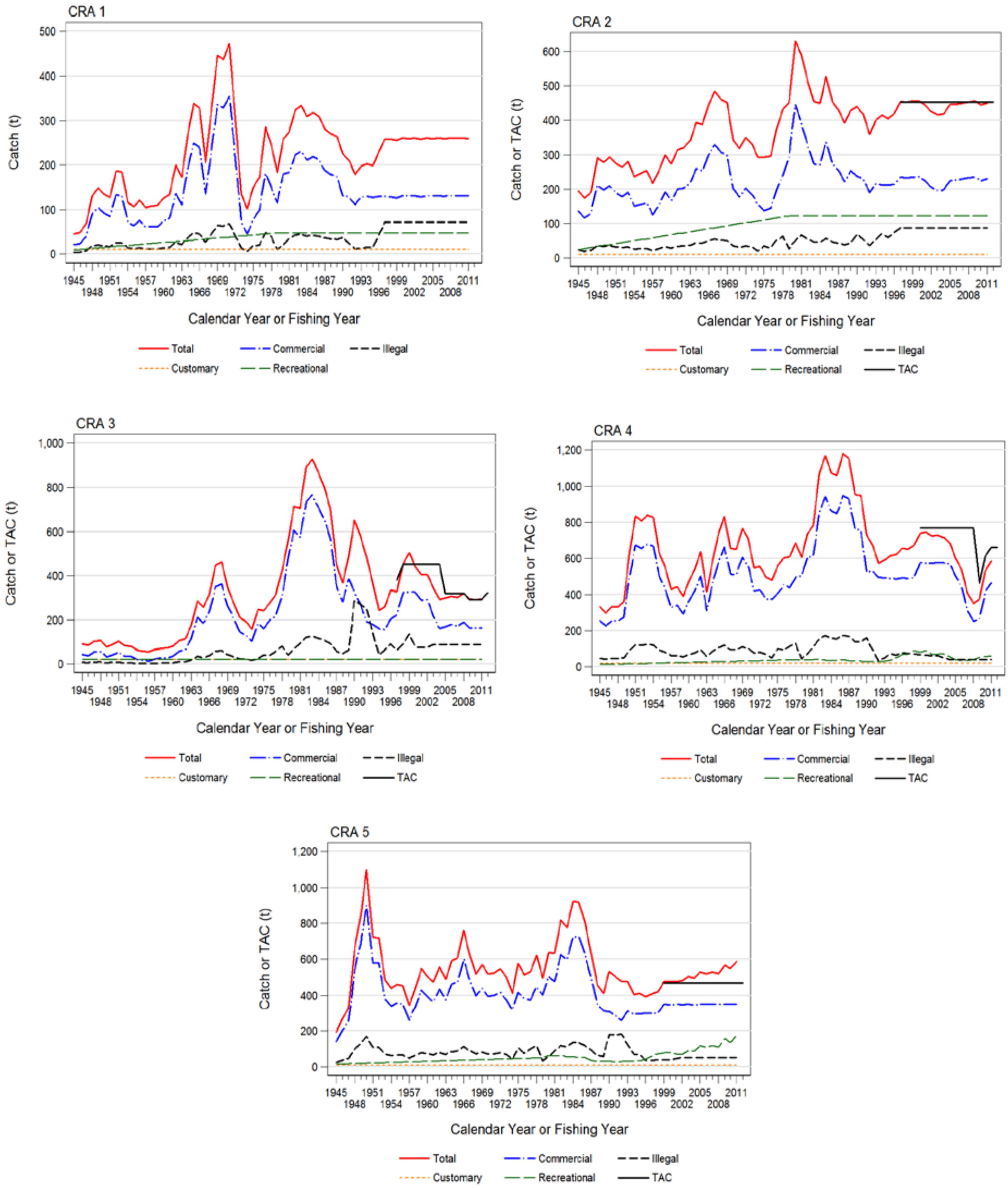


Figure 4A: Catch trajectories (t) from 1945 to 2011 and TACs (if in place) from the year of establishment to 2012 for CRA 1 to CRA 5, showing current best estimates for commercial, recreational, customary and illegal categories. Also shown is the sum of these four catch categories. Note that calendar year catches are plotted from 1945 to 1977. Statutory fishing years (1 April to 31 March) catches are plotted from 1979 on. Catches for 1978 are for 15 months, including January to March 1979.

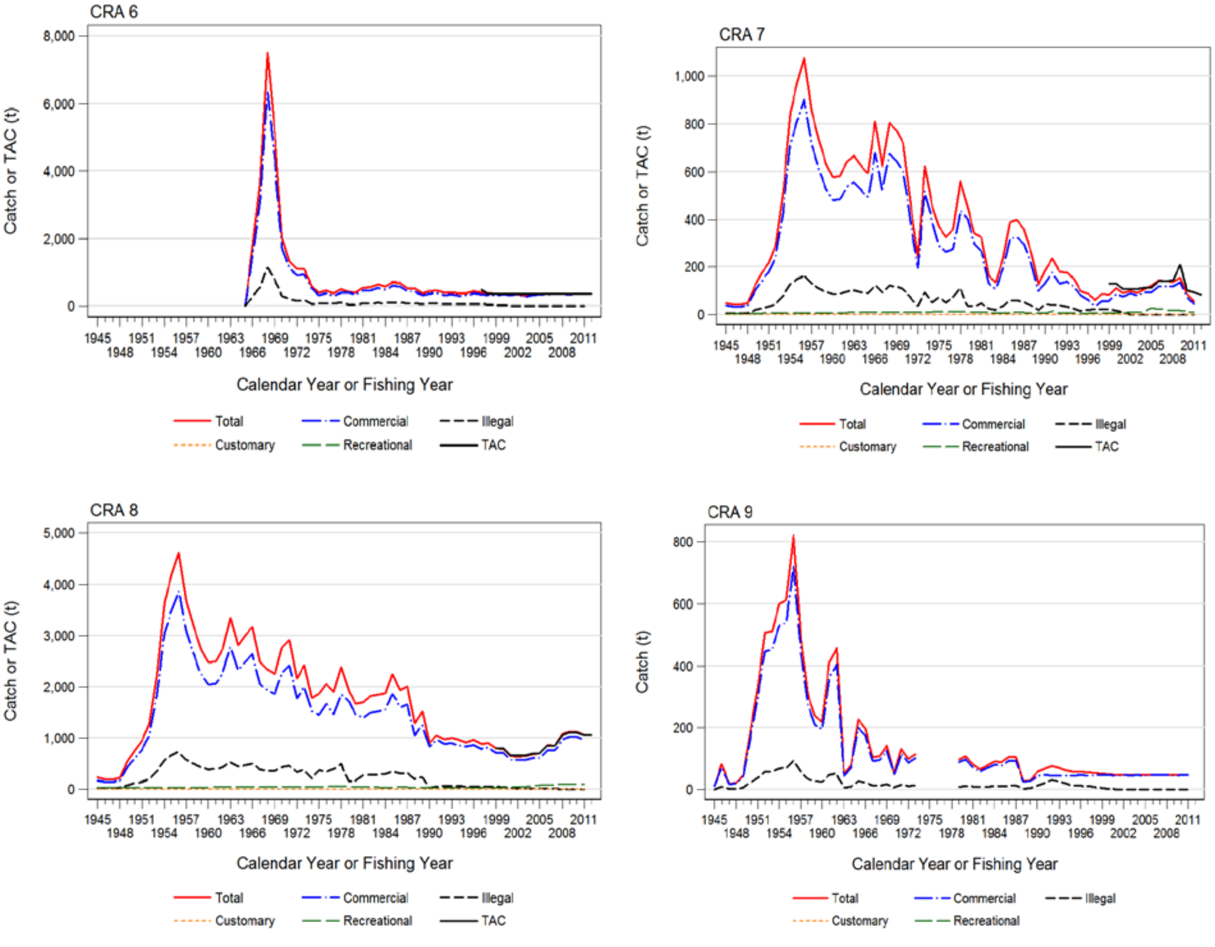


Figure 4B: Catch trajectories (t) from 1945 to 2011 for CRA 6 to CRA 9 (see Figure 4A for caption). There are no catch estimates for CRA 9 from 1974 to 1978.

2. BIOLOGY

Although lobsters cannot be easily aged in numbers sufficient for use in fishery assessments, they are thought to be relatively slow-growing and long-lived. *J. edwardsii* and *S. verreauxi* occur both in New Zealand and southern Australia. The following summary applies only to *J. edwardsii* in New Zealand.

Sexual maturity in females is reached from 34–77 mm TW (about 60–120 mm carapace length), depending on locality within New Zealand. For instance, in CRA 3, 50% maturity appears to be realised near 40 mm TW while most females in the south and south-east of the South Island do not breed before reaching MLS.

Mating takes place after moulting in autumn, and the eggs hatch in spring into the short-lived naupliosoma larvae. Most of the phyllosoma larval development takes place in oceanic waters tens to hundreds of kilometres offshore over at least 12 months. Near the edge of the continental shelf the final-stage phyllosoma metamorphoses into the settling stage, the puerulus. Puerulus settlement takes place mainly at depths less than 20 m, but not uniformly over time or between regions. Settlement indices measured on collectors can fluctuate widely from year to year.

Values used for some biological parameters in stock assessments are shown in Table 12.

Table 12: Values used for some biological parameters.

1. Natural mortality (*M*) [1]

Area	Both Sexes
CRA 1, 2 ,3, 4, 5	0.12
NSS	0.12

[1] This value has been used as the mean of an informative prior; *M* was estimated as a parameter of the model.

2. Fecundity = a TW^b (TW in mm) (Breen & Kendrick 1998)[2]

Area	*a*	*b*
NSN	0.21	2.95
CRA 4 & CRA 5	0.86	2.91
NSS	0.06	3.18

[2] Fecundity has not been used by post-1999 assessment models.

3. Weight = a TW^b (weight in kg, TW in mm) (Breen & Kendrick, Ministry of Fisheries unpublished data)

	Females		Males	
Area	***a***	***b***	***a***	***b***
CRA 1, 2, 3, 4, 5	1.30 E-05	2.5452	4.16 E-06	2.9354
NSS	1.04 E-05	2.6323	3.39 E-06	2.9665

Long-distance migrations of rock lobsters have been observed in some areas. During spring and early summer, variable proportions of usually small males and immature females move various distances against the current from the east and south coasts of the South Island towards Fiordland and south Westland.

Growth modelling

The primary source of information for growth is tag-recapture data. Lobsters have been caught, measured, tagged and released, then recaptured and re-measured at some later time (and in some instances re-released and re-recaptured later). Since 1998, statistical length-based models have been used to estimate the expected increment-at-size, which is represented stochastically by growth transition matrices for each sex. Growth increments-at-size are assumed to be normally distributed with means and variances determined from the growth model. The transition matrices contain the probabilities that a lobster will move into specific size bins given its initial size.

The growth model contains parameters for expected increment at 50 mm and 80 mm TW, a shape parameter (1 = linear), the c.v. of the increment for each sex, the minimum standard deviation and the observation error. This model is over-parameterised if all parameters are estimated, so the final two and sometimes three parameters are fixed.

Since 2006, the growth model applied to the tag-recapture data has been a continuous model – giving a predicted growth increment for any time at liberty greater than 30 days – whereas the older versions assumed specific moulting periods between which growth did not occur. For assessment models developed since 2006, tag-recapture records from lobsters at liberty for fewer than 30 days have been excluded. Other basic data grooming is performed, but the robust likelihood fitting procedure precludes the need for extensive grooming of outliers. Growth parameters are estimated simultaneously with other parameters of the assessment model in an integrated way, so that growth estimates might be affected by the size frequency and CPUE data as well as the tag-recapture data.

Settlement indices

Annual levels of puerulus settlement have been collected from 1979 at sites in Gisborne, Napier, Castlepoint, Kaikoura, Moeraki, Halfmoon Bay, and Jackson Bay (Table 13). Each site has at least one group of five collectors that are checked monthly when possible, resulting in a monthly mean catch per group of collectors, which in turn is used as the basis for producing a standardised index of settlement (Forman et al. 2011). Standardised settlement indices are available for each major site, as well as for combined CRA 8 (Halfmoon Bay and Jackson Bay) (Table 14, Figure 5).

Table 13.: Location of collector groups used for the standardisation of puerulus settlement indices, the years of operation, and the number of collectors monitored within each group.

QMA	Key site	Collector groups	Years of operation	Number of collectors
CRA 3	Gisborne	Whangara (GIS002)	1991–Present	5
		Tatapouri (GIS003)	1994–2006	5
		Kaiti (GIS004)	1994–Present	5
CRA 4	Napier	Port of Napier (NAP001)	1979–Present	5
		Westshore (NAP002)	1991–1999	3
		Cape Kidnappers (NAP003)	1994–Present	5
		Breakwater (NAP004)	1991–2002	3
CRA 4	Castlepoint	Castlepoint (CPT001)	1983–Present	9
		Mataikona (CPT002)	1991–2006	5
		Orui (CPT003)	1991–Present	5
CRA 5	Kaikoura	South peninsula (KAI001)	1981–Present	5
		South peninsula (KAI002)	1988–2003	3
		North peninsula (KAI003)	1980–Present	5
		North peninsula (KAI004)	1992–2003	3
CRA 7	Moeraki	Wharf (MOE002)	1990–2006	3
		Pier (MOE007)	1998–Present	15
CRA 8	Halfmoon Bay	Wharf (HMB001)	1980–Present	8
		Thompsons (HMB002)	1988–2002	3
		Old Mill (HMB003)	1990–2002	3
		The Neck (HMB004)	1992–2002	3
		Mamaku Point (HMB005)	1992–2002	3
CRA 8	Jackson Bay	Wharf (JAC001)	1999–Present	5
		Jackson Head (JAC002)	1999–2006	3

Table 14: Standardised puerulus settlement indices (source: J. Forman & A. McKenzie, NIWA). '–': no usable sampling was done; 0: no observed settlement. All indices represent a calendar year.

	Gisborne CRA 3	Napier CRA 4	Castlepoint CRA 4	Kaikoura CRA 5	Moeraki CRA 7	Halfmoon Bay CRA 8	Jackson Bay CRA8	Combined CRA 8
1979	–	0.84	–	–	–	–	–	–
1980	–	1.51	–	0.00	–	1.77	–	0.81
1981	–	2.04	–	1.48	–	7.66	–	8.60
1982	–	0.99	–	0.04	–	0.36	–	0.32
1983	–	1.23	1.42	1.19	–	4.28	–	3.78
1984	–	0.41	1.35	0.35	–	0.36	–	0.34
1985	–	0.19	0.87	0.49	–	0.00	–	0.00
1986	–	–	0.50	0.15	–	0.10	–	0.09
1987	–	–	1.70	1.70	–	1.53	–	1.25
1988	–	1.49	0.98	0.75	–	0.20	–	0.18
1989	–	1.07	1.52	1.25	–	0.51	–	0.53
1990	–	1.13	0.93	0.42	0.77	0.42	–	0.39
1991	1.63	2.26	1.95	8.26	0.00	0.80	–	0.72
1992	2.36	2.39	2.41	9.57	0.15	0.59	–	0.49
1993	2.01	1.90	1.47	4.84	0.00	0.00	–	0.00
1994	3.07	1.42	0.93	1.29	0.00	1.06	–	0.92
1995	1.20	1.05	0.88	1.52	0.12	0.30	–	0.27
1996	1.11	1.67	1.31	1.14	1.14	0.30	–	0.27
1997	1.15	1.28	1.14	2.41	0.68	0.51	–	0.45
1998	1.60	1.09	1.67	3.19	0.66	0.25	–	0.22
1999	0.11	0.29	0.34	2.13	0.14	0.23	0.74	0.30
2000	1.04	0.66	0.56	1.86	3.93	1.14	0.75	0.65
2001	1.25	1.38	0.76	0.69	2.44	1.63	0.81	0.91
2002	1.22	1.11	0.68	1.82	0.95	1.25	3.07	1.60
2003	2.45	1.28	0.75	7.72	7.46	3.34	1.53	1.45
2004	0.84	1.08	0.65	2.66	0.43	0.12	0.32	0.18
2005	2.71	1.25	1.16	3.46	0.11	0.00	3.58	1.70
2006	0.41	0.59	0.64	2.89	0.06	0.13	0.41	0.28
2007	0.34	1.04	0.88	1.94	0.04	0.44	0.50	0.38
2008	0.77	0.59	0.88	3.65	0.10	0.08	0.34	0.19
2009	1.13	0.76	0.92	0.78	0.46	0.91	0.29	0.58
2010	0.62	1.30	1.60	2.87	1.40	1.60	4.50	2.44
2011	0.24	0.36	0.89	0.63	0.97	0.13	4.62	1.72

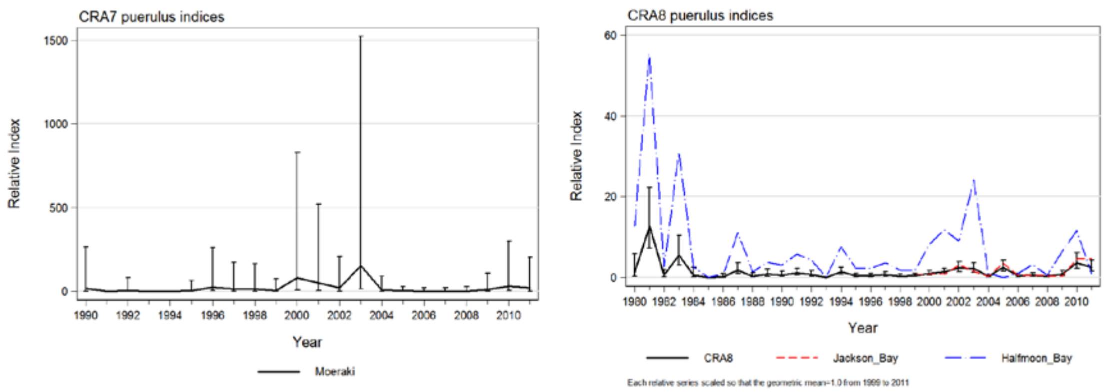


Figure 5. Comparative plot of the standardised puerulus series for CRA 7 [left panel] and CRA 8 [right hand], using the series presented in Table 14, normalised relative to each other as indicated in the note printed at the bottom of the figure.

3. STOCKS AND AREAS

There is no evidence for genetic subdivision of lobster stocks within New Zealand based on biochemical genetic and mtDNA studies. The observed long-distance migrations in some areas and the long larval life probably result in genetic homogeneity among areas. Gene flow at some level probably occurs to New Zealand from populations in Australia (Chiswell et al. 2003).

Subdivision of stocks on other than genetic grounds has been considered (Booth & Breen 1992; Bentley & Starr 2001). There are geographic discontinuities in the prevalence of antennal banding, size at onset of maturity in females, migratory behaviour, fishery catch and effort patterns, phyllosoma abundance patterns and puerulus settlement levels. These observations led to division of the historical NSI stock into three substocks (NSN, NSC, and NSS) for assessments in the 1990s. Cluster analysis based on similarities in CPUE trends between rock lobster statistical areas provided support for those stock definitions (Bentley & Starr 2001).

Since 2001 these historical stock definitions have not been used, and rock lobsters in each of the CRA QMA areas have been assumed to constitute separate Fishstocks for the purposes of stock assessment and management.

Sagmariasus verreauxi forms one stock centred in northern New Zealand and may be genetically subdivided from populations of the same species in Australia.

4. DECISION RULES AND MANAGEMENT PROCEDURES

This section presents evaluations of the existing CRA 3, CRA 4, CRA 5, CRA 7 and CRA 8 management procedures (MP) for the 2013-14 fishing year, based on CPUE data extracted in early November 2012 and standardised as described below. The CRA 7 and CRA 8 MPs described in this document are under review and may be replaced for the 2013–14 fishing year; the review outcome will be reported in next year's Report. New management procedures for CRA 4, CRA 5 and CRA 7 were implemented in 2012 and are new to this section of the Report.

4.1 Data preparation

Data were obtained from the Ministry of Fisheries catch/effort mandatory reporting system, groomed (Bentley et al. 2005) and the estimated catches scaled to the LFR ("L") landings using the "B4" procedure described in Section 1.3, in Bentley et al. (2005) and Starr (2012). The new data preparation procedures described in Section 1.3 are not required because the existing MPs were developed using the "B4" procedure scaled to "L" landings. These data were aggregated by fishing year, month, rock lobster statistical area and vessel prior to being processed by the standardisation procedure (Maunder & Starr 1995; Bentley et al. 2005), which uses month, statistical area and year as explanatory variables. Each QMA analysis was done separately.

These MPs use annual standardised CPUE estimates based on an "offset year" which is the AW season combined with the preceding SS season, whereas the statutory rock lobster fishing year consists of the SS season and the preceding AW season. All rule evaluations below are based on the offset year extending from 1 October 2011 to 30 September 2012 to set a TAC or TACC (depending on the rule) applying to the next fishing year which begins on 1 April 2013 and extends to 31 March 2014.

Standardisation for the offset year management procedure analyses follows the suggestion of Francis (1999) and calculates "canonical" coefficients and standard errors for each year, which allows calculation of standard errors for every coefficient including the base year coefficient. Each standardised index is then scaled by the geometric mean of the simple arithmetic CPUE indices (using the summed annual catch divided by summed annual effort for each offset year). The geometric mean CPUE is preferred to the arithmetic mean because it is less affected by outliers than the arithmetic mean. This procedure scales the standardised indices to CPUE levels consistent with those observed by fishermen.

4.3 Management Procedure for CRA 3

In 2009, an operating model based on the 2008 stock assessment model (Breen et al. 2009), updated with an additional year of catch and CPUE data, was used to develop a management procedure for CRA 3. Length frequency data were not updated, and all other model assumptions, modelling choices and inputs were unchanged. There had been no previous management procedure for this stock. After consideration of base case and robustness trial results, a small set of final candidates was presented to the statutory consultation round, and the Minister chose Rule 2a. This management procedure is specified as follows:

1. A conditional initial fixed TAC applies for 3 years (2010–11, 2011–12 and 2012–13) and is set at 293 tonnes, unless offset-year CPUE falls below 0.75 kg/potlift or increases above 1.08 kg/potlift. If the CPUE falls outside these limits, the initial TAC expires and the harvest control rule equations determine the TAC;
2. The conditional initial fixed TAC will expire after the 2012–13 fishing year and the harvest control rule equations will determine the TAC;
3. Offset-year standardised CPUE, calculated in November will be used as input to the rule to determine the TAC for the statutory fishing year that begins in the following April;
4. The management procedure is to be evaluated every year (no "latent year"), based on offset-year CPUE;
5. The provisional TAC (before minimum and maximum change rules operate, and exclusive of considering the initial fixed TAC determined by the rule), is given by:

Eq. 1A $$TAC'_{y+1} = 275\left(\frac{I_y+3}{4}\right)^3$$ **for** $0 < I_y \le 1$ **and**

Eq. 1B $$TAC'_{y+1} = 275\left(1+\frac{0.5\left(I_y-1\right)}{0.6}\right)$$ **for** $I_y > 1$

where TAC'_{y+1} is the provisional TAC result from the rule and I_y is the input offset-year CPUE.

6. After the initial fixed TAC expires, if the procedure results in a TAC that does not change by more than 5%, no change will be made; and if the procedure results in a TAC that changes by more than 10%, the TAC will be changed by 10% only.

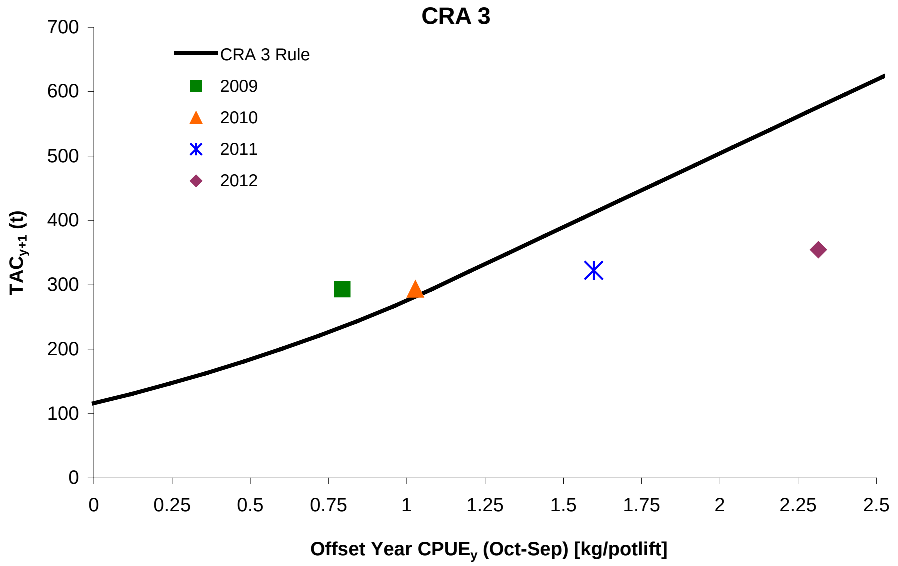


Figure 6: The CRA 3 management procedure, showing the provisional TAC in year *y+1* as a function of offset year CPUE in year *y*, and showing the TACs resulting from the rule evaluations performed in 2009 through 2012 for the 2010–11, 2011–12, 2012–13 and 2013-14 fishing years.

This decision rule was evaluated using the B4 algorithm scaled to the "L" destination code landings.

The relation between CPUE and provisional TAC (before minimum and maximum change limits operate, and ignoring the initial fixed TAC) is illustrated by the solid line in Figure 6. Figure 6 also shows the results of the first four years of operation of the CRA 3 MP.

The Minister accepted and implemented this management procedure from the 2010-11 fishing year. The standardised offset-year CPUE for 2008–09 was 0.794 kg/pot. Because this was greater than the 0.75 kg/potlift threshold and less than the 1.08 kg/potlift threshold, the 2010–11 TAC remained at the conditional initial fixed TAC of 293 t. The TACC was determined by subtracting non-commercial allowances of 129 t, to obtain 164 t (Table 15). In November 2011, standardised offset-year CPUE was 1.597 kg/potlift, above the upper threshold of 1.08 kg/potlift, so the fixed initial TAC expired. The provisional TAC was 411.74 t; this was a greater increase than the maximum of 10%, so the TAC was increased by 10% to 322.3 t.

Table 15: History of the CRA 3 management procedure. "Rule result" is the result of the management procedure after operation of all its components including thresholds; '–': to be determined by the Minister

Year of analysis	Applied to fishing year	Offset-year CPUE at time of analysis (kg/potlift)	Rule result: TAC (t)	TACC (t)	TAC (t)
2009	2010–11	0.794	293	164	293
2010	2011–12	1.027	293	164	293
2011	2012–13	1.597	322.3	193.3	322.3
2012	2013–14 (proposed)	2.314	354.53	–	–

In November 2012, the standardised offset-year CPUE was 2.314 kg/potlift. The TAC was determined by the harvest control rule equation Eq. 1B, which evaluated to a TAC of 576.20 t.

This was a greater increase than the maximum increase of 10%, so the TAC could increase only by 10% to 354.53 t.

4.4 Management Procedure for CRA 4

The management procedure for CRA 4 is based on a stock assessment and MP evaluations completed in 2011 (Breen et al. 2012). Specifications for the CRA 4 MP include:

a) the output variable is TACC (tonnes) and the input variable is offset year (October–September) standardised CPUE (kg/potlift), calculated in November and scaled to the "L" destination code using the "B4" data preparation procedure

b) the management procedure is to be evaluated every year (no "latent year"); and

c) there are no thresholds for minimum and maximum change, except a maximum 25% increase limit below the first plateau.

Figure 7 shows the relationship between CPUE and the TACC for the CRA 4 MP: below a CPUE of 0.5 kg/potlift, the TACC is zero (Eq. 2A); between a CPUE of 0.5 and 0.9 kg/potlift, the TACC increases linearly with CPUE to a plateau of 467 tonnes (Eq. 2B), which extends to a CPUE of 1.3 kg/potlift (Eq. 2C). As CPUE increases above 1.3 kg/potlift, TACC increases in steps with a width of 0.1 kg/potlift and a height of 7% of the preceding TACC (Eq. 2D).

Eq. 2A $$TACC'_{y+1} = 0 \qquad \textbf{for } I_y \le 0.5$$

Eq. 2B $$TACC'_{y+1} = \left(\frac{467}{0.9-0.5}\right)\left(I_y - 0.5\right) \qquad \textbf{for } 0.5 < I_y \le 0.9$$

Eq. 2C $$TACC'_{y+1} = 467 \qquad \textbf{for } 0.9 < I_y \le 1.3$$

Eq. 2D $$TACC'_{y+1} = 467\left(1.07^{\mathrm{int}\left(\left(I_y-1.3\right)/0.1\right)+1}\right) \qquad \textbf{for } I_y > 1.3$$

where $TACC'_{y+1}$ is the provisional TACC result from the rule and I_y is the input offset-year CPUE.

The Minister accepted and implemented this management procedure from the 2012–13 fishing year. The input CPUE from 2010-11 was 1.194, giving a TACC of 466.9 t and a TAC of 661.9 t when the non-commercial allowances of 195 t were added (Table 16). For 2013–14, the rule generated a proposed TACC of 499.69 t (Table 16).

Table 16: History of the CRA 4 management procedure, showing proposed limits to the commercial fishery in the 2012–13 and 2013–14 fishing years. "Rule result" is the result of the management procedure after operation of all its components including thresholds; '–': to be determined by the Minister

Year of analysis	Applied to fishing year	Offset-year CPUE at time of analysis (kg/potlift)	Rule result: TACC (t)	TACC (t)	TAC (t)
2011	2012–13	1.194	466.9	466.9	661.9
2012	2013–14 (proposed)	1.374	499.69	–	–

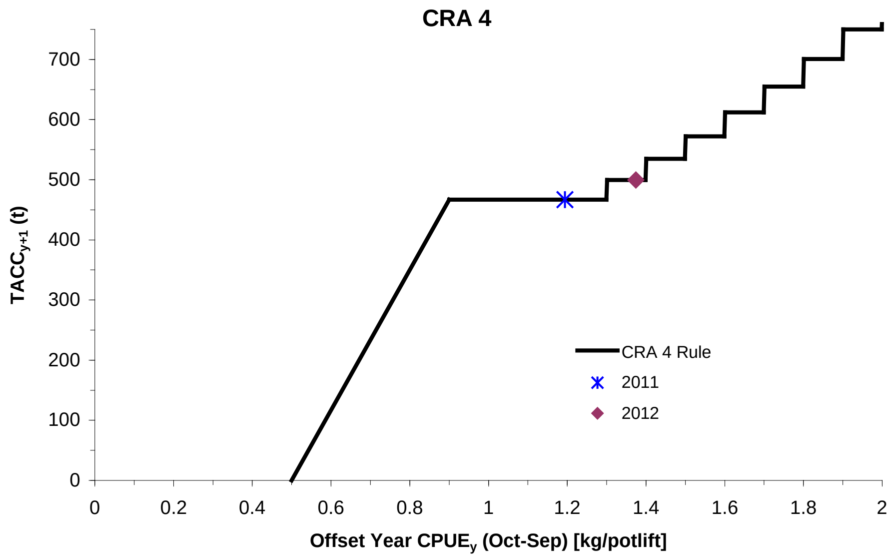


Figure 7: The CRA 4 management procedure, showing the TACC in year *y+1* as a function of offset year CPUE in year *y*, and showing the TACCs resulting from the rule evaluations performed in 2011 and 2012 for the 2012–13 and 2013-14 fishing years.

4.5 Management Procedure for CRA 5

The management procedure for CRA 5 is based on a stock assessment and MP evaluation completed in 2010 (Breen et al. 2011). Specifications for the CRA 5 MP include:

a) the output variable is TACC (tonnes) and that offset year (October–September) standardised CPUE (kg/potlift), calculated in November and scaled to the "L" destination code using the "B4" data preparation procedure, is to be used as the input variable;

b) the management procedure is to be evaluated every year (no "latent year"); and

c) there are no thresholds for minimum and maximum change.

Figure 8 shows the relationship between CPUE and the TACC for the CRA 5 MP: below a CPUE of 0.3 kg/potlift, the TACC is zero (Eq. 3A); between a CPUE of 0.3 and 1.4 kg/potlift, the TACC increases linearly with CPUE to a plateau of 350 tonnes (Eq. 3B), which extends to a CPUE of 2.0 kg/potlift (Eq. 3C). As CPUE increases above 2.0 kg/potlift, TACC increases in steps with a width of 0.2 kg/potlift and a height of 5% of the preceding TACC (Eq. 3D).

Eq. 3A $TACC'_{y+1} = 0$ **for** $I_y \le 0.3$

Eq. 3B $TACC'_{y+1} = \left(\frac{350}{1.4-0.3}\right)\left(I_y - 0.3\right)$ **for** $0.3 < I_y \le 1.4$

Eq. 3C $TACC'_{y+1} = 350$ **for** $1.4 < I_y \le 2.0$

Eq. 3D $TACC'_{y+1} = 350\left(1.05^{\mathrm{int}\left(\left(I_y - 2.0\right)/0.2\right)+1}\right)$ **for** $I_y > 2.0$

where $TACC'_{y+1}$ is the TACC result from the rule and I_y is the input offset-year CPUE.

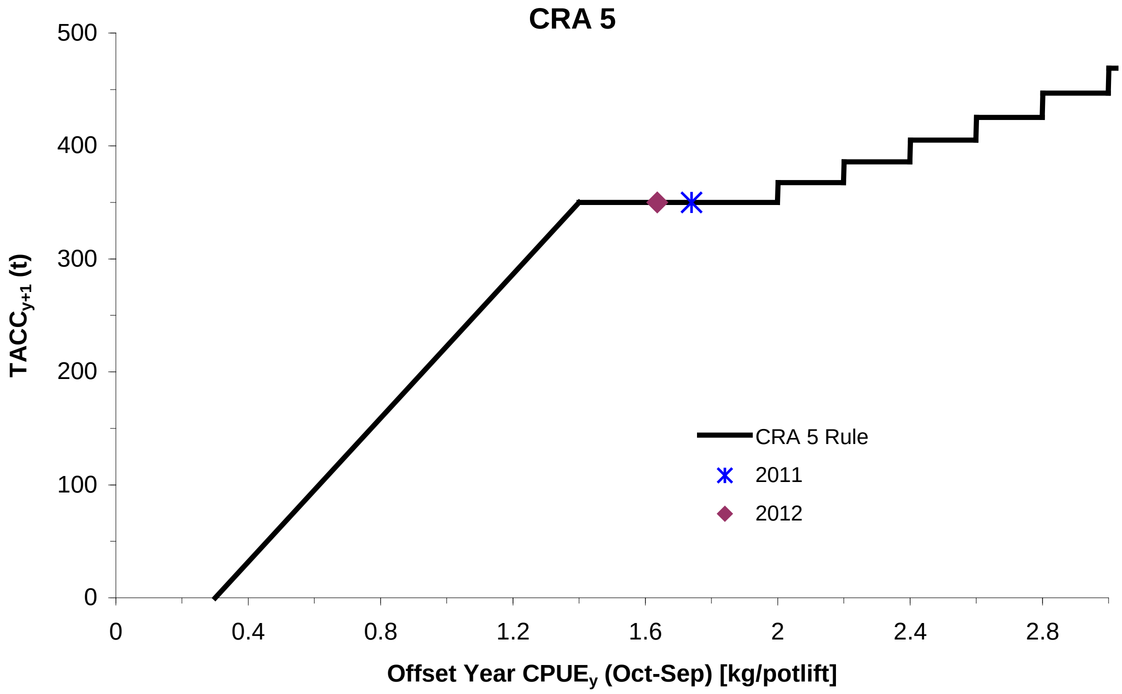


Figure 8: The CRA 5 management procedure, showing the TACC in year *y+1* as a function of offset year CPUE in year *y*, and showing the TACCs resulting from the rule evaluations performed in 2011 and 2012 for the 2012–13 and 2013-14 fishing years.

The Minister accepted and implemented this management procedure from the 2012-13 fishing year. The 2010-11 CPUE of 1.74 kg/potlift gave a TACC of 350 t, which became a TAC of 467 t after non-commercial allowances of 117 t were added. For 2013–14, the rule generated a proposed TACC of 350 t (Table 17).

Table 17: History of the CRA 5 management procedure, showing proposed limits to the commercial fishery in the 2012–13 and 2013–14 fishing years. "Rule result" is the result of the management procedure after operation of all its components including thresholds; '–': to be determined by the Minister

Year of analysis	Applied to fishing year	Offset-year CPUE in year of analysis (kg/potlift)	Rule result: TACC (t)	TACC (t)	TAC (t)
2011	2012–13	1.740	350	350	467
2012	2013–14 (proposed)	1.636	350	–	–

4.6 Management Procedure for CRA 7

CRA 7 has been managed since 1996 using management procedures based on observed CPUE, originally CRA 8 CPUE. These have been revised several times, including in 2007, when separate management procedures were accepted by the Minister for CRA 7 and CRA 8 for the 2008–09 fishing year. A replacement management procedure for CRA 7 was implemented for 2012–13, based on MP evaluations completed in 2010, using the 2007 operating model (Breen 2011). Specifications for the CRA 7 MP are:

a) the output variable is TAC (tonnes) and the input variable is offset year standardised CPUE (kg/potlift), calculated in November and scaled to the "L" destination code using the "B4" data preparation procedure;

b) the TAC can decrease in any year, but cannot increase if a change (either an increase or a decrease) was made to the TAC in the previous year (asymmetric latent year);

c) if the change is less than 10%, no change is made; and,

d) if the change is greater than 50%, the change is capped at 50%.

Figure 9 shows the relation between CPUE and the provisional TAC for the CRA 7 MP: the TAC increases linearly to a plateau of a 120 tonnes at CPUE values below 1.0 kg/potlift (Eq. 4A); it remains at 120 t at CPUE values between 1.0 and 2.0 kg/potlift (Eq. 4B), and increases linearly with increasing CPUE at CPUE values above 2.0 kg/potlift, using the same slope as below 1.0 kg/potlift (Eq. 4C).

Eq. 4A $TAC'_{y+1} = 120I_y$ **for** $I_y < 1.0$

Eq. 4B $TAC'_{y+1} = 120$ **for** $1.0 \le I_y \le 2.0$

Eq. 4C $TAC'_{y+1} = 120\left(I_y - 1.0\right)$ **for** $I_y > 2.0$

where TAC'_{y+1} is the provisional TAC result from the rule and I_y is the input offset-year CPUE.

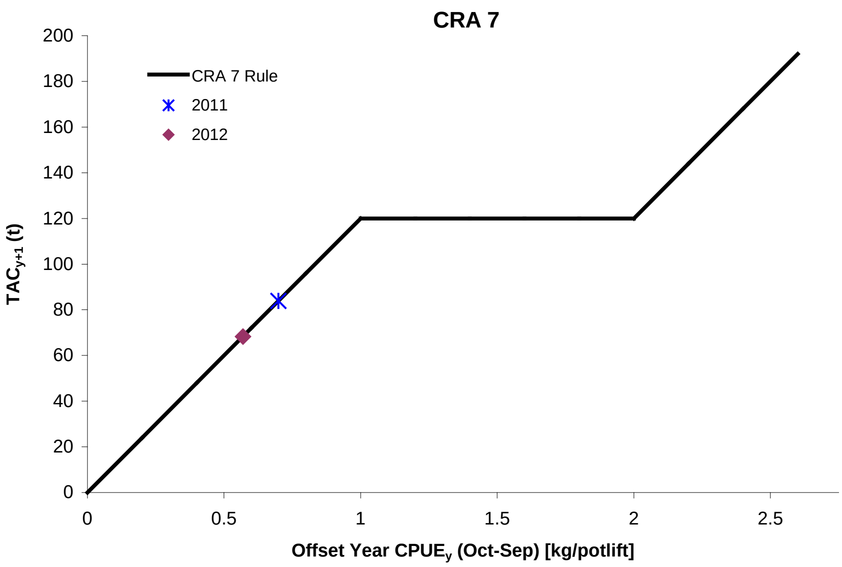


Figure 9: The CRA 7 management procedure, showing the TACC in year *y+1* as a function of offset year CPUE in year *y*, and showing the TACCs resulting from the rule evaluations performed in 2011 and 2012 for the 2012–13 and 2013-14 fishing years.

The Minister accepted and implemented this management procedure from the 2012-13 fishing year. The input CPUE was 0.699 kg/potlift, which generated a TAC of 83.9 t, which in turn generated a TACC of 63.9 t when the non-commercial allowances of 20 t were subtracted (Table 18). For 2013–14, the rule generated a provisional TAC of 68.264 t from an input CPUE of 0.569 (Table 18). This represented a 29% decrease, above the minimum threshold of 10% and below the maximum threshold of 50%.

Table 18: History of the CRA 7 management procedure, showing proposed limits to the commercial fishery in the 2012–13 and 2013–14 fishing years. "Rule result" is the result of the management procedure after operation of all its components including thresholds; '–': to be determined by the Minister

Year of analysis	Applied to fishing year	Offset-year CPUE in year of analysis (kg/potlift)	Rule result: TAC (t)	TACC (t)	TAC (t)
2011	2012–13	0.699	83.9	63.9	83.9
2012	2013–14 (proposed)	0.569	68.264	–	–

4.6 Management Procedure for CRA 8

CRA 8 has been managed since 1996 using management procedures based on the observed CPUE in the fishery. These have been revised several times, most recently in 2007, when separate management procedures were accepted by the Minister for CRA 7 and CRA 8 for the 2008–09 fishing year. The current management procedure uses the most recent offset-year standardised CPUE as input to generate a proposed TAC. There is no latent year; the minimum change threshold is 5% and the maximum change threshold is 50%.

The harvest control rule driving the CRA 8 management procedure is shown in Figure 10. TAC is constant over a wide range of CPUE; decreasing at a faster rate than CPUE when CPUE is below a threshold (1.9 kg/potlift) and increasing more slowly when CPUE is above a threshold (3.2 kg/potlift). The plateau affords stability of TACC, a performance quality requested by the CRA 8 commercial industry.

Formally, this rule is given by:

Eq. 5

$$TAC'_{y+1} = \begin{cases} \max\left(0, \left(1053 - 1.2\left(1.9 - I_y\right)\dfrac{1053}{1.9}\right)\right), & I_y < 1.9, \\ 1053, & 1.9 \le I_y \le 3.2, \\ 1053 + 0.16\left(I_y - 3.2\right)\dfrac{1053}{1.9}, & I_y > 3.2. \end{cases}$$

where TAC'_{y+1} is the rule's specified provisional TAC for the next fishing year, before the operation of minimum and maximum change thresholds, and I_y is standardised CPUE from the most recent offset year.

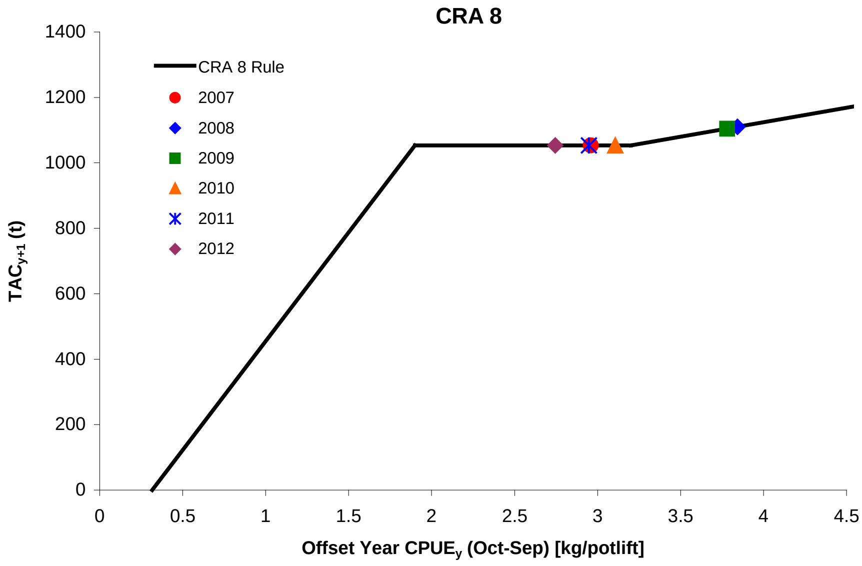


Figure 10: The CRA 7 management procedure, showing the provisional TAC in year *y+1* as a function of offset year CPUE in year *y*, and showing the TACs resulting from the rule evaluations performed in 2009 through 2012 for the 2010–11, 2011–12, 2012–13 and 2013-14 fishing years.

Table 19: History of the CRA 8 management procedure, showing proposed limits to the commercial fishery in each of five years. "Rule result" is the result of the management procedure after operation of all its components including thresholds; '–': to be determined by the Minister

Year of analysis	Applied to fishing year	Offset-year CPUE at time of analysis (kg/potlift)	Rule result: TAC (t)	TACC (t)	TAC (t)
2007	2008–09	2.960	1053	966	1053
2008	2009–10	3.844	1110	1019	1110
2009	2010–11	3.781	1110	1019	1110
2010	2011–12	3.107	1053	1053	962
2011	2012–13	2.947	1053	1053	962
2012	2013–14 (proposed)	2.745	1053	–	–

The history of the current CRA 8 management procedure is shown in Table 19. In 2012, the offset-year standardised CPUE estimate was 2.745 kg/pot, putting TAC on the plateau because it was above the 1.9 kg/potlift threshold at the lower end, but below the 3.2 kg/potlift threshold at the upper end of the plateau. Under the CRA 8 management procedure, the TAC remained at 1053 t.

5. ENVIRONMENTAL EFFECTS OF FISHING

This section is updated for the November 2012 Plenary after review by the Aquatic Environment Working Group. This summary is from the perspective of the rock lobster fisheries; a more detailed summary from an issue-by issue perspective is available in the Ministry's Aquatic Environment and Biodiversity Annual Review (http://www.mpi.govt.nz/news-resources/publications.aspx).

The environmental effects of rock lobster fishing have been covered more extensively by Breen (2005) and only those issues deemed most important there, or of particular relevance to fisheries management are covered here.

5.1 Ecosystem role

Rock lobsters are predominantly nocturnal (Williams and Dean 1989). Their diet is reported to be comprised primarily of molluscs and other invertebrates (Booth 1986; Andrew and Francis 2003). Survey and experimental work has shown that predation by rock lobsters in marine reserves is capable of influencing the demography of surf clams of the genus *Dosinia* (Langlois, Anderson et al. 2005; Langlois, Anderson et al. 2006).

Predation by rock lobsters has been implicated in contributing to trophic cascades in a number of studies in New Zealand and overseas (Mann and Breen 1972; Babcock, Kelly *et al.* 1999; Edgar and Barrett 1999). For example, in Leigh marine reserve rock lobsters and snapper preyed on urchins, the densities of urchins decreased and kelp beds re-established in the absence of urchin grazing (Shears and Babcock 2003). This implies that rock lobster fishing is one of a number of factors that may alter the ecosystem from one more dominated by kelp beds to one more dominated by urchin barrens. Trophic cascades are hard to demonstrate however, as controlled experiments are difficult, food webs are complex and environmental factors are changeable (Breen 2005).

Published scientific observations support predation upon rock lobsters by octopus (Brock *et al.* 2003), rig (King &Clarke 1984), blue cod, groper, southern dogfish (Pike 1969) and seals (Yaldwyn 1958, cited in Kensler 1967).

5.2 Fishery interactions (fish and invertebrates)

The levels of incidental catch landed from rock lobster potting were analysed for the period from 1989 to 2003 (Table 26, Bentley *et al.* 2005). Non- rock lobster catch landed ranged from 2 to 11 percent of the estimated rock lobster catch weight per QMA over this period. These percentages are based on estimated catches only and it is likely that not all bycatch is reported (only the top five species are requested) and that the quality of the weight estimates will vary between species There were 129 species recorded landed from lobster pots over this period. The most frequently reported incidental species caught (comprising on average greater than 99% of the bycatch per QMA) were, in decreasing order of catch across all stocks: octopus, conger eel, blue cod, trumpeter, sea perch, red cod, butterfish and leatherjackets.

5.3 Fishery interactions (seabirds and mammals)

Recovery of shags from lobster pots has been documented in New Zealand. One black shag (*Phalacrcorax carbo*) of 41 recovered dead from a Wairarapa banding study was found drowned in a crayfish pot hauled up from 12m depth (Sim and Powlesland 1995). A survey of rock lobster fishers on the Chatham Islands (Bell 2012) reported no shag bycatch in the past 5 years (2007/08 to 2011/12 fishing season), only 2 shag captures between 5-10 years ago (2001/02 to 2006/07 fishing season) and 18 shags caught more than 10 years ago (prior to 2000/01 season). The fishers suggested the lack of reported shag captures in the past five years was attributable to changes in pot design and baiting methodologies.

From January 2000 there have been eighteen reported entanglements of sixteen marine mammals attributed to commercial or recreational rock lobster pot lines from around New Zealand, mainly around Kaikoura (DOC Marine Mammal Entanglement Database, available for the DOC Kaikoura office). No mortalities were observed, although mortalities are likely to be caused by prolonged entanglement, and therefore might not be observed within the same area. CRA 5 commercial fishermen work to a voluntary code of practice to avoid entanglements, recreational fishers do not. The commercial fishermen in CRA 5 also cooperate with the Department of Conservation to assist releases when entanglements occur.

5.4 Benthic impacts

Potting is the main method of targeting rock lobster and is usually assumed to have very little direct impact on non-target species. No information exists regarding the benthic impacts of potting in New Zealand.

A study on the impacts of lobster pots was completed in a report on the South Australian rock lobster fisheries (Casement and Svane 1999). This fishery is likely to be the most comparable to New Zealand as the same species of rock lobster is harvested and many of the same species are present, although the details of pots and how they are fished may differ. The report concluded that the mass of algae removed in pots probably has no ecological significance.

Two other studies provide results from other parts of the world, but the comparability of these studies to New Zealand is questionable given differences in species and fishing techniques. The Western Australia Fishery Department calculated the proportion of corals (the most sensitive fauna) likely to be impacted by potting and concluded they were low; i.e. between 0.1 and 0.3% per annum (Department of Fisheries Western Australia 2007). This kind of calculation for the New Zealand fishery would require better habitat maps than currently exist for most parts of the coast (Breen 2005) as well as finer scale catch information than the Ministry currently possesses. Direct effects of potting on the benthos have been studied in Great Britain (Eno *et al.* 2001) and 4 weeks of intensive potting resulted in no significant effects on any of the rocky-reef fauna quantified. Observations in this paper indicated sea pens were bent (but not damaged) and one species of coral was damaged by pots.

The only regulatory limitation on where lobster pots can be used is inside marine reserve boundaries; however, in Fiordland four areas within marine reserves have been designated for commercial pot storage due to the shortage of suitable space (Fiordland Marine Guardians 2008). Likewise, in the Taputeranga marine reserve (Wellington) an area is designated for vessel mooring and the storage of 'holding pots' by commercial fishermen.

5.5 Other considerations
An area near North Cape is currently closed to packhorse lobster fishing to mitigate sub-legal handling disturbance in this area. This closure was generated due to the smaller sizes of animals there and results from a tagging study that showed movement away from this area into nearby fished areas (Booth 1979).

5.6 Key information gaps
Breen (2005) identified that the most likely areas to cause concern for rock lobster fishing in a detailed risk assessment were: ghost fishing, everyday bycatch and its effect on bycatch species, effects on habitats and protected species, and indirect effects on marine communities caused by the removal of large predators. At this time no prioritisation has been applied to this list.

6. STOCK ASSESSMENT

New stock assessments were completed in 2012 for CRA 7 and CRA 8. This section also reports stock assessment results for other stocks from previous Mid-Year Plenary documents. The text relating to these other stocks has not been updated from the original and reflects the TAC, TACC and allowances that were current at the time each assessment was completed.

6.1 CRA 1 and CRA 2

This section reports assessments for *J. edwardsii* for CRA 1 and CRA 2 from the NSN substock taken from the 2002 Mid-year Plenary report (Sullivan & O'Brien 2002).

Model structure
The size-based model used in 2001, which was fully described by Breen et al. (2002), has been revised and improved for the 2002 assessment. The model is fitted to two series of catch rate indices from different periods, to size frequency and tagging data. There are no settlement data for the NSN stock.

An important structural feature of the model is the division of the year into two seasons (autumn-winter: April to September, and spring-summer: October to March). This captures more accurately several biological processes: a) season- and sex-specific moult patterns; b) possible differential vulnerability of both sexes between each other and between the two seasons; and c) a reduction in the vulnerability of mature females in the autumn-winter season because of their egg-bearing status. The seasonal structure is important to incorporate because several fisheries have changed from predominantly spring/summer fisheries to autumn/winter fisheries which catch mostly male lobsters.

Significant catches occurred in the early part of the time series for CRA 1 and CRA 2. Different regulations existed at this time and pots were not required to have escape gaps. We therefore incorporated historical information for CRA 1 and CRA 2: a time series of sex-specific MLS regulations, time series of catch per day estimates for the 1960s and early 1970s, and some early size frequency data, including market sampling data. These data and their sources are listed in Table 20. It was possible to estimate recruitment deviations beginning in 1960.

Major changes made to the 2002 model were:

- The CV of the expected growth increment was changed to a sex-specific parameter.
- The catch dynamics were changed to operate in two parts during each 6-month period so that proportions-at-length could be calculated from the mid-season length structure. The

dynamics of the SL and NSL fisheries (fisheries respecting or not respecting the size limit) were both improved by doing this.

The initial population in 1945 is assumed to be in equilibrium with average recruitment and with no fishing mortality. Each season the number of male, immature female and mature female lobsters within each size class is updated as a result of:

a) **Recruitment**. Each year, new recruits are added equally for each sex and both seasons, into the smallest size classes, beginning with the autumn-winter season. The proportion of individuals entering each size class is modelled as a normal distribution with a mean size (32 mm) and standard deviation (2 mm), and is truncated at the smallest size class (30 mm). The magnitude of recruitment in a specific year is determined by the parameter for base recruitment and (except for the early years) a parameter representing the deviation from base recruitment. The vector of recruitment deviations is assumed to be normally distributed with a mean of zero. The years for which recruitment deviations were estimated were 1960 to 2001.

b) **Mortality**. Natural, fishing and handling mortalities are applied to each sex category (male, immature female and mature female) in each size class. Natural mortality is estimated, but assumed to be constant and independent of sex category and length. Fishing mortality is determined from observed catch and model biomass, modified by legal sizes, sex-specific vulnerabilities and selectivity curves. Fisheries that respect size limits (SL fisheries − legal commercial and recreational) are differentiated from those which do not (NSL fisheries − part of the illegal fishery plus the Mäori traditional fishery). It is assumed that size limits and the prohibition of taking of berried females apply only to the SL fisheries. Otherwise, the selectivity and vulnerability functions are the same for the SL and NSL fisheries. Relative vulnerability is calculated by assuming that the males in the spring-summer season have the highest vulnerability and that the vulnerability of all other sex categories by season are equal to or less than the spring-summer males. Mature females have no legal vulnerability in the autumn-winter, when all are assumed to be ovigerous. The annual rate of SL fishing mortality is calculated as the ratio of catch to the SL biomass, where catch includes both the legal catch and the portion of NSL catch taken from the SL biomass. SL biomass is defined as the weight of males and females in the size classes above the MLS limits, adjusted for their relative vulnerability as defined above. Handling mortality rate is assumed to be proportional to legal fishing mortality at 10% of all lobsters that are released.

c) **Fishery selectivity curves**. A three-parameter fishery selectivity function is assumed, with parameters describing increasing vulnerability from the initial size class to a maximum, followed by decreasing vulnerability. The three parameters describe the shapes of the ascending and descending limbs and the size at which vulnerability is maximum. Changes in regulation over time (for instance, changes in escape gap regulations) can be modelled by estimating separate selectivity parameters appropriate to each period of the fishery (but in these assessments, only one selectivity period was estimated in the base cases).

d) **Growth and maturity**. For each size class and sex category in a season, a transition matrix specifies the probability of an individual remaining in the same size class or growing into each of the other size classes. Maturity for females is estimated as a two-parameter logistic curve from the maturity-at-size information in the size frequency data.

Model fitting

A total negative log likelihood function was minimised using AD Model Builder™. The model was fitted to standardised CPUE indices estimated by season from the 1979–80 to 2001–02 fishing years. The model was also fitted to an additional seasonal catch rate index based on daily catch and effort data for the period 1963 to 1973 (Annala & King 1983). A lognormal error structure was assumed and a catchability constant (q) was calculated analytically for each CPUE series.

The model was fitted to size data taken from commercial pots. These data were available either from research sampling conducted on commercial vessels or from voluntary logbooks maintained by rock lobster fishers in CRA 1 and CRA 2. Estimates of the seasonal size frequency were obtained by collating data that had been summarised by area/month strata and weighted by the commercial catch taken in each stratum, the number of lobsters measured and the number of days sampled. Size data from each source (research sampling or voluntary logbooks) were fitted separately. A fundamental assumption is that the size frequency data are representative of the commercial lobster catch. The size proportions within each season summed to one across all three sex categories: males, immature females, and mature females. This provides the model with seasonal estimates of the relative proportion by sex category in the catch.

Market sampling data were also used in the fitting procedure. These data are available only as carapace lengths from males and females, without maturity information. The carapace lengths were converted to tail width, and the model made predictions for the size classes beginning at one size class above the MLS.

A summary of the data used in each assessment, the data sources and the applicable years are provided in Table 20.

Table 20: Data types and sources for the 2002 assessment s for CRA 1 and CRA 2. Year codes apply to the first 9 months of each fishing year, viz. 1998–99 is called 1998. NA – not applicable or not used; MFish - NZ Ministry of Fisheries; NZRLIC – Rock Lobster Industry Council.

Data type	Data source	Begin year	End year
Historical catch rate	Annala & King (1983)	1963	1973
CPUE	FSU & CELR	1979	2002
Historical proportions-at-size	Various	1974	1978
Observer proportions-at-size	MFish	1990	2002
Logbook proportions-at-size	NZRLIC	1993	2002
Historical tag recovery data	MFish various	1975	1986
Current tag recovery data	NZRLIC & MFish	1996	2002
Historical MLS regulations	Annala (1983)	1945	2002
Escape gap regulation changes	Annala (1983)	1945	2002

The parameters estimated in each model and the priors used are provided in Table 21. Fixed parameters and their values are given in Table 22. CPUE, the historical catch rate, the priors and the tagging data were weighted directly by a relative weighting factor. For CRA 1, we varied the weights to obtain standard deviations of standardised residuals for each data set that were close to one. For CRA 2 it was necessary to further increase the weight on CPUE data to obtain a credible fit.

Table 21: Parameters estimated and priors used in basecase assessments for CRA 1 and CRA 2. Prior type abbreviations: U – uniform; N – normal; L – lognormal.

	Prior Type	Bounds	Mean	CV
Log R_0 (ln mean recruitment)	U	1–50	–	–
M (natural mortality)	L	0.01–0.35	0.12	0.4
Recruitment deviations	N [1]	-2.3–2.3	0	0.4
Increment at TW=50 (male & female)	U	1–8	–	–
Increment at TW=80 (male & female)	U	-10–3	–	–
CV of growth increment (male & female)	U	0.01–1.0	–	–
Minimum standard deviation of growth	U	0.01–5.0	–	–
TW at 50% probability female maturity	U	30–80	–	–
(TW at 95% probability female maturity) – (TW at 50% probability female maturity)	U	0–60	–	–
Relative vulnerability: males autumn-winter [2]	U	0–1	–	–
Relative vulnerability: immature females autumn-winter	U	0–1	–	–
Relative vulnerability: immature and mature females spring-summer	U	0–1	–	–
Relative vulnerability: mature females autumn-winter	U	0–1	–	–
Shape of ascending limb of vulnerability ogive	U	1–50	–	–
Size at maximum selectivity males	N	10–80	54	2.0
Size at maximum selectivity females	N	10–80	60	2.0
Variance of descending limb of vulnerability ogive (males & females)[3]	U	1–250	–	–

[1] Normal in logspace = lognormal (bounds equivalent to –10 to 10)
[2] Relative vulnerability of males in spring-summer was fixed at one
[3] Fixed at 200 in basecase assessment.

Table 22: Fixed parameter values used in base case assessment for CRA 1 and CRA 2.

	CRA 1	CRA 2
Std dev of observation error of increment	2	2
Historical catch per day CV	0.30	0.30
Maximum exploitation rate	90%	90%
Current male size limit	54	54
Current female size limit	60	60
First year for recruitment deviations	1960	1960
Last year for recruitment deviations	2001	2001
Relative weight for length frequencies	50	18
Relative weight for CPUE	1	2
Relative weight for CR	0.6	1
Relative weight for tag-recapture data	0.5	1

Model projections

Bayesian estimation procedures were used to estimate uncertainty in model estimates of current biomass, and in future projections. This procedure was conducted in the following steps:

a) Model parameters were estimated using maximum likelihood and the prior probabilities. These point estimates represent the mode of the joint posterior distributions of the parameters, and are called the MPD estimates;

b) Samples from the joint posterior distribution of parameters were generated using the Markov chain – Monte Carlo procedure (MCMC) using the Hastings-Metropolis algorithm;

c) For each sample of the posterior, 5-year projections (encompassing the 2002–03 to 2006–07 fishing years) were generated by assuming the catches indicated in Table 23. Future annual recruitment was randomly sampled with replacement from the model's estimated recruitments from the period 1989–1998;

d) A marginal posterior distribution was found for each quantity of interest by integrating the product of the likelihood and the priors over all model parameters; the posterior distribution was described by the mean, median, and 5th and 95th percentiles.

Table 23: Catches (t) used in the five-year projections. Projected catches are based on the current TACC for CRA 1 and CRA 2, and the current estimates of recreational, customary and illegal catches.

Population modelled	Commercial	Recreational	Reported Illegal	Unreported Illegal	Customary
CRA 1	129.2	47.2	0	72	10
CRA 2	225.0	122.6	5	83	10

Performance indicators

The 2001 Plenary agreed to use a number of performance indicators as measures of the stock status for CRA 1 and CRA 2. These performance indicators were calculated using the current catch levels. The RLFAWG did not consider that virgin biomass or B_{MSY} were appropriate reference points, given the difficulty of accurately estimating these quantities. Therefore the assessment used performance indicators based on biomass levels for the ten years 1979 to 1988. This is the earliest period for which we have CPUE data and base case fits for both CRA 1 and CRA 2 suggested that biomass was relatively stable during this period. The Plenary agreed that this was an appropriate reference biomass level. Biomass in both stocks increased in the mid 1990s to higher levels than this reference level.

1. $BVULN_{02}/BVULN_{79–88}$
2. $BVULN_{07}/BVULN_{02}$
3. $BVULN_{07}/BVULN_{79–88}$
4. $UNSL_{02,AW}$
5. $USL_{02,AW}$
6. $UNSL_{06,AW}$
7. $USL_{06,AW}$

The vulnerable biomass in the assessment model is determined by four factors:

- MLS for male and female lobsters
- Length-based selectivity function
- Relative seasonal vulnerability of males and mature and immature females (parameters of the model)
- Berried state for mature females

Current vulnerable biomass, $BVULN_{02}$, is defined as the beginning season vulnerable biomass on 1 April 2002, the beginning of the autumn-winter season for the 2002–03 fishing season. Similarly, projected vulnerable biomass $BVULN_{07}$ is defined as the beginning season vulnerable biomass on 1 April 2007, the beginning of the autumn-winter season for the 2007–2008 fishing season. Vulnerable biomass was also calculated for the reference period: $BVULN_{79–88}$ is defined as the mean of beginning AW vulnerable biomass from 1979 through 1988.

$USL_{02,AW}$ is the exploitation rate for catch taken from the SL vulnerable biomass in the autumn-winter season of 2002–03, and $USL_{06,AW}$ is the exploitation rate for catch taken from the SL vulnerable biomass in the autumn-winter season of 2006–07, the last year of projections. $UNSL_{02,AW}$ and $UNSL_{06,AW}$ are similarly defined except that they describe the exploitation rate for catch taken from the NSL vulnerable biomass.

Stock assessment results: Jasus edwardsii, CRA 1

The base case assessment for CRA 1 was obtained by making the standard deviations of standardised residuals from all data sets close to 1 by adjusting the relative weights for each data set. The fit to the data was acceptable, with some systematic problems in fitting the seasonal pattern of CPUE and some large residuals in the fits to proportions-at-length, perhaps caused by the poor quality of these data.

Base case results suggested that biomass decreased to a low point in 1973, increased through the early 1980s, declined again until the early 1990s (but not as low as in 1973), increased strongly in the late 1990s and then declined slightly (Figure 11). Exploitation rate peaked in the early 1970s near 30% for the spring-summer fishery, and are currently in the 7–12% range (Table 24).

A series of sensitivity trials suggested that the results were robust to these trials (based on MPD estimates), except that when the relative weight for CPUE was doubled, the model estimated a high *M* and very high biomass. A set of retrospective analyses on the MPD fits showed little effect of removing data one year at a time, beginning with the most recent year of data.

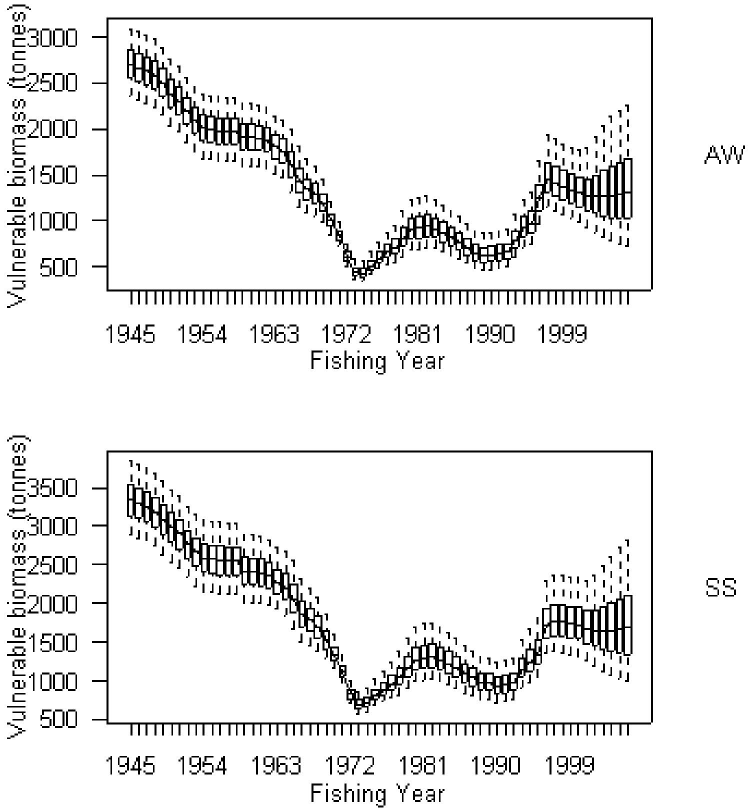


Figure 11: CRA 1: posterior trajectories of vulnerable biomass, for the AW (top) and SS (bottom) seasons, from the CRA 1 base case MCMC simulations. For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th percentiles.

Table 24: Summary statistics for performance indicators from posterior distributions from CRA 1. Biomass indicators are shown in t.

	Basecase				Estimate male SS vulnerability				Estimate descending limb variance of vulnerability ogive			
Indicator	0.05	median	mean	0.95	0.05	median	mean	0.95	0.05	median	mean	0.95
$BALL_{79-88}$	1 741	2 057	2 091	2 542	1 618	1 903	1 949	2 414	2 014	2 560	2 638	3 534
$BRECT_{79-88}$	1 029	1 278	1 304	1 652	959	1 190	1 218	1 570	1 307	1 775	1 832	2 558
$BVULN_{79-88}$	642	834	852	1 121	593	768	793	1 071	623	821	845	1 153
$BALL_{02}$	2 274	2 995	3 082	4 155	2 159	2 788	2 880	3 905	2 894	3 981	4 131	5 844
$BRECT_{02}$	1 594	2 050	2 089	2 715	1 514	1 932	1 980	2 619	2 144	2 961	3 067	4 311
$BVULN_{02}$	929	1 276	1 308	1 792	859	1 182	1 221	1 720	891	1 227	1 272	1 798
$BALL_{07}$	2 007	3 113	3 209	4 771	1 840	2 868	2 969	4 448	2 686	4 208	4 361	6 643
$BRECT_{07}$	1 268	2 087	2 170	3 355	1 172	1 944	2 025	3 171	1 877	3 099	3 231	5 040
$BVULN_{07}$	725	1 320	1 382	2 269	646	1 204	1 266	2 123	768	1 305	1 379	2 242
$UNSL_{02}$ (%)	1.7	2.5	2.5	3.3	1.8	2.6	2.7	3.5	1.7	2.4	2.4	3.3
USL_{02} (%)	7.4	10.4	10.6	14.3	7.8	11.2	11.4	15.4	7.3	10.7	10.8	14.7
$UNSL_{06}$ (%)	1.5	2.4	2.5	3.8	1.6	2.6	2.7	4.2	1.4	2.3	2.4	3.6
USL_{06} (%)	6.2	10.3	10.9	17.4	6.6	11.3	11.9	19.3	6.2	10.3	10.8	16.8
$BVULN_{02}/BVULN_{79-88}$ (%)	131	152	153	182	131	152	154	184	128	149	151	183
$BVULN_{07}/BVULN_{02}$ (%)	67	101	105	157	64	98	103	158	73	102	108	161
$BVULN_{07}/BVULN_{79-88}$ (%)	94	156	162	250	91	152	160	250	103	156	163	249

A sensitivity trial that was evaluated using the MCMC procedure involved changing the assumption that male spring-summer vulnerability is 1 and that the other sex/season vulnerabilities are less than or equal to this value. In this sensitivity trial, the assumption was changed to make the autumn-winter vulnerability for males highest and with the other vulnerabilities relatively less. These results are similar to the base case results. The exploitation rates estimated in this sensitivity trial are very similar to the exploitation rates estimated by the base case.

Stock assessment results: *Jasus edwardsii*, CRA 2

The base case assessment for CRA 2 was obtained by first making the standard deviations of standardised residuals from all data sets close to 1 by adjusting the relative weights for each data set. However, it was necessary to further increase the weight on CPUE data until a satisfactory fit to all data sets was achieved. As in the CRA 3 assessment last year the model appears to have trouble fitting the steep decline in CPUE after 1998: it expects more large lobsters to remain in the population and consequently expects CPUE to remain higher than was observed.

Base case results suggested that biomass decreased to a low point in 1977, increased to 1980, declined slowly through 1988, increased strongly to a peak in 1998 and then declined again (Figure 12). Seasonal exploitation rate peaked in the mid-1980s near 50% for the spring-summer fishery, and is currently in the 20–25% range.

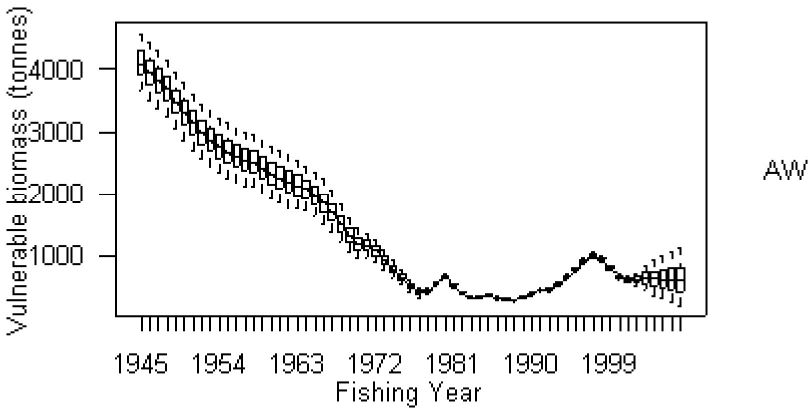
A series of sensitivity trials suggested that the results were generally robust to these trials (based on MPD estimates). A set of retrospective analyses on the MPD fits showed a strong effect to removing data from 1999, the year when CPUE began to decrease strongly. Fits to the spring-summer CPUE did not change much, indicating the problem is probably caused by the 1999 autumn-winter CPUE data point. This retrospective model estimates a much higher *M* and higher biomass than in the base case and suggests that the model has difficulty in predicting the extent of the decline between 1999 and 2001 based solely on the data available up to 1999.

The assessment results (Table 25) are based on the posterior distributions of indicators. These were obtained from MCMC simulations – for CRA 2, five chains of 600 000 simulations each were started from the likelihood profile on Ln(*R0*). Diagnostics were acceptable, and the results are based on 4950 samples remaining after the first 10 samples were discarded from each chain. Results suggest that vulnerable biomass is currently about 50% higher (0.05 and 0.95 quantiles were 30% to 70%) than in the reference period. At the current levels of catch and using recruitments sampled from 1989–98, the median expectation is that biomass will remain at current levels over five years, but with considerable uncertainty (0.05 and 0.95 quantiles were 35% to 170% of current biomass).

Table 25: Summary statistics for performance indicators from posterior distributions from CRA 2. Biomass indicators are shown in t.

	Basecase				Estimate male SS vulnerability				Alternative recreational catch trajectory			
Indicator	0.05	median	mean	0.95	0.05	median	mean	0.95	0.05	median	mean	0.95
$BALL_{79–88}$	1 592	1 656	1 657	1 723	1 443	1 499	1 499	1 561	1 625	1 699	1 699	1 773
$BRECT_{79–88}$	525	555	556	589	479	504	505	532	565	603	603	640
$BVULN_{79–88}$	391	412	413	435	362	380	381	400	414	440	440	465
$BALL_{02}$	1 807	2 170	2 176	2 571	1 578	1 997	1 997	2 428	1 886	2 292	2 296	2 723
$BRECT_{02}$	1 025	1 150	1 150	1 275	889	1 027	1 028	1 169	1 064	1 198	1 197	1 330
$BVULN_{02}$	527	619	621	716	485	588	589	696	547	647	648	750
$BALL_{07}$	1 284	2 122	2 135	3 037	1 144	2 004	2 017	2 911	1 264	2 190	2 202	3 191
$BRECT_{07}$	372	1 033	1 047	1 757	291	1 001	1 006	1 733	264	1 028	1 040	1 822
$BVULN_{07}$	199	614	631	1 117	173	612	621	1 101	153	604	621	1 142
$UNSL_{02}$ (%)	3.7	4.2	4.2	4.9	3.7	4.4	4.5	5.3	3.5	4.0	4.0	4.7
USL_{02} (%)	21.6	25.0	25.1	29.2	22.2	26.2	26.5	31.8	21.4	24.9	25.0	29.3
$UNSL_{06}$ (%)	2.8	4.4	4.8	8.4	2.8	4.4	5.1	9.9	2.7	4.3	4.9	9.3
USL_{06} (%)	15.2	25.7	30.0	59.3	15.4	26.2	31.8	73.1	15.2	26.2	31.8	72.1
$BVULN_{02}/BVULN_{79–88}$ (%)	130	150	150	171	129	154	155	181	127	146	147	169
$BVULN_{07}/BVULN_{02}$ (%)	34	99	101	170	33	104	104	176	26	93	94	167
$BVULN_{07}/BVULN_{79–88}$ (%)	48	149	153	271	46	161	163	290	35	137	141	258

A sensitivity trial that was evaluated using the MCMC procedure involved changing the assumption that male spring-summer vulnerability is 1 and that the other sex/season vulnerabilities are less than or equal to this value. In this sensitivity trial, the assumption was changed to make the autumn-winter vulnerability for males highest and with the other vulnerabilities relatively less. These results are similar to the base case results, but the indicators are slightly more optimistic. The exploitation rates estimated in this sensitivity trial are very similar to the exploitation rates estimated by the base case.



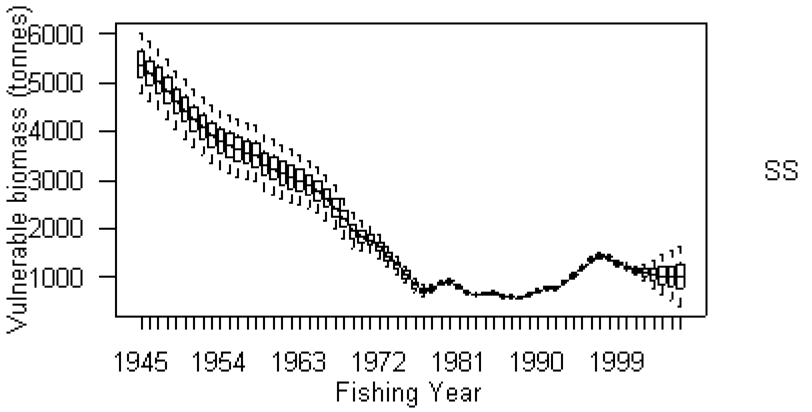


Figure 12: CRA 2: posterior trajectories of vulnerable biomass, for the AW (top) and SS (bottom) seasons, from the CRA 2 base case MCMC simulations. For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th percentiles.

6.2 CRA 3

This section reports assessments for *J. edwardsii* for CRA 3 from the NSC substock taken from the 2008 Mid-year Plenary report (Ministry of Fisheries 2008).

This assessment used a single-stock version of the multi-stock length-based model (MSLM) (Haist et al. 2009). In a simple preliminary trial, the new model was able to reasonably match the MPD results from the 2004 CRA 3 assessment when fitted to the same data.

Catch histories for CRA 3 were agreed by the RLFAWG. Other input data to the model included:

- tag-recapture data from 1975–1981 and from 1995–2006,
- standardised CPUE from 1979–2007,
- historical catch rate data from 1963–1973; and

- length frequency data from commercial catches (log book and catch sampling data) from 1989 to 2007.

Because the predicted growth rates were different for the 1975–1981 and 1995–2006 datasets, the RLFAWG agreed that it would inappropriate to fit the model to the combined tag-recapture dataset (as had been done in the 2004 CRA 3 assessment). Two approaches were used instead. First, the model was altered to permit of fitting to the two tag-recapture datasets separately. This alteration was not a formal generalised change to MSLM, but rather was a one-off change to produce a specialised CRA 3 assessment model. In this version, the growth transition matrix for years up to and including 1981 was based on the 1975–1981 tagging dataset (plus whatever contribution was made by other data sets). The growth transition matrix for years from 1995 onwards was based on the 1995–2006 tagging dataset (plus whatever contribution was made by other datasets). The growth transition matrix for the intervening years, 1982–1994, was based on an interpolation of the growth transition matrices estimated for the earlier and later periods. The sensitivity of the model predictions to the specified transition years was also examined.

In this version of the model, the size classes represented by the model were specified differently to deal with a technical problem introduced by the new growth rate handling. The midpoint of the first size bin in the model was increased from 31 mm to 45 mm, and the recruiting cohort mean size was increased to midpoint 47 mm from 33 mm. This was done to avoid growth model misspecification in the small size classes for which there are no observations.

In the second approach, the model was fitted to data from 1983 onwards, using only the 1995–2006 tag-recapture data. This approach was rejected by the RLFAWG, based on the diagnostics of the model and the value of some of the parameters in the results, and will not be described further.

The start date for the accepted model was 1945, with an annual time step through 1973 and then switching to a seasonal time step from 1974 onward: autumn/winter (AW), extending from April to September, and spring/summer (SS), extending from October to March. The last fishing year in the minimisations was 2007, and projections were made through 2012 (five years). Two selectivity epochs were modelled, with the change made in 1993 to capture regulation shifts for the pot escape gaps. Recruitment deviations were estimated from 1945 through 2004. Maximum vulnerability was assumed to be for males in the SS season. A marine reserve was modelled, beginning in 1999 and alienating 10% of the habitat. The model was fit to CPUE, the historical catch rate series, length frequency (LF) data and the two tag-recapture datasets. No pre-recruit index was fit, and the puerulus settlement index was fit in a separate randomisation trial.

A log-normal prior was specified for M, with mean 0.12 and c.v. of 0.4. A normal prior was specified for the recruitment deviations in log space, with mean 0 and standard deviation 0.4. Priors for all other parameters were specified as uniform distributions with wide bounds.

Other model options used in the reference case were:

- the dynamics option was set to instantaneous;
- selectivity was set to the double normal form used in previous assessments;
- movements were turned off;
- the relation between CPUE and biomass was fixed to linear;
- maturity parameters were fixed at values estimated outside the model;
- the growth c.v. was fixed to 0.5 to stabilise the analysis;
- the right-hand limb of the selectivity curve was fixed to 200 as in previous assessments;
- dataset weights were adjusted to attempt to obtain standard deviations of normalised residuals of 1.0 or medians of absolute residuals of 0.67.

The RLFAWG considered results from the mode of the joint posterior distribution (MPD) results and the results of 13 sets of MPD sensitivity trials:

- altering the specification of the growth transition period,
- varying the transition period between tag data sets,
- using finite dynamics instead of instantaneous,
- varying start year and initial exploitation rate,
- estimating the relation between CPUE and biomass,
- estimating the CV of predicted growth increments,
- estimating maturity parameters,
- fixing the size at maximum selectivity for females to 60,
- fixing M to 0.12 (the mean of the prior),
- removing data sets one at a time
- estimating the right-hand limb of selectivity for both sexes and epochs,
- ignoring the marine reserve,
- fitting to puerulus settlement data and
- adding uncertainty to NSL catches as requested by the WG

Most base case results showed limited sensitivity to these trials, with some notable exceptions being the removal of CPUE data or, to a lesser extent, removal of tag-recapture data. The indicator ratios were reasonably stable, but some sensitivity was observed to model starts after 1945 with different assumed values for initial exploitation rate. Overall, it was not possible to draw strong conclusions from the sensitivity trials, given that the median and mean of the assessment posterior distributions moved a considerable distance from the MPD estimates.

The assessment was based on Markov chain – Monte Carlo (McMC) simulation results. We started the simulation at the base case MPD, and made a chain of three million, with samples saved every 1000 samples, for a sample size of 3000. From the joint posterior distribution of parameter estimates, forward projections were made through 2012. In these projections, catches were assumed to remain constant at their 2007 values, except that the TACC of 190 t was used for commercial catch (which is about 20 t greater than the 2007 commercial catch). The 2007 commercial catch seasonal split was used. Recruitment was re-sampled from 1995-2004, and the estimates for 2005–2007 were overwritten. These projections are sensitive to the period chosen from which to re-sample recruitment, because recruitment trends are different over different periods. The most recent ten years' estimates are considered the best information about likely future recruitments in the short term.

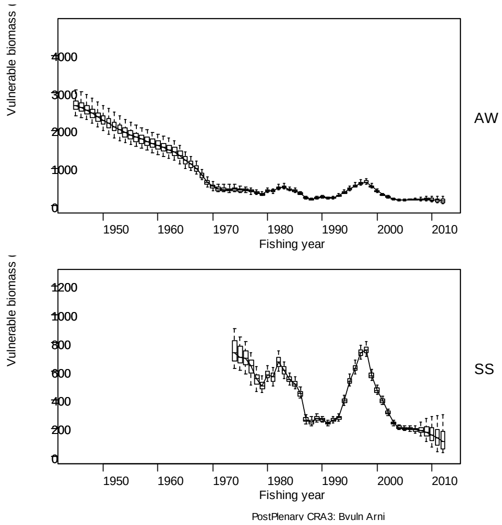


Figure 13: The posterior trajectory of vulnerable biomass, by season, from the CRA 3 base case McMC simulations, including the projections from 2008-12. For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th percentiles. Values in the AW panel before 1974 reference a complete year rather than the AW season.

The RLFAWG agreed on a set of indicators. Some of these were based on beginning of season AW vulnerable biomass: the biomass legally and functionally available to the fishery, taking MLS, female maturity, selectivity-at-size and seasonal vulnerability into account. The limit indicator *Bmin* was defined as the nadir of the vulnerable biomass trajectory (using current MLS), 1945-2007. Current biomass, *B2008*, was taken as vulnerable biomass in AW 2008, and projected biomass, *B2012*, was taken from AW 2012.

A biomass indicator associated with *MSY* or maximum yield, *Bmsy*, was calculated by doing deterministic forward projections for 50 years, using the mean of estimated recruitments from 1979-2004. This period was chosen to represent the recruitments that were estimated from adequate data, and represents the best available information about likely long-term average recruitment. These *MSY* and *Bmsy* calculations are sensitive to the period chosen to represent the mean recruitment, which varies substantially over the range of the period available, causing variation in estimated *Bmsy*. It was agreed to hold the non size-limited (NSL) catches (customary and illegal) constant at their assumed 2007 values, to vary the SL fishery mortality rate *F* to maximise the annual size-limited (SL) catch, and to record the associated AW biomass.

MSY was the maximum yield (the sum of AW and SS "size-limited" [SL] catches) found by searching across a range of multipliers (from 0.1 to 2.5) on the AW and SS *F* values that were estimated for 2007 for the SL catch for each of the 3000 samples from the joint posterior distribution. The model used a Newton-Raphson algorithm to find the NSL fishery mortality rates. The AW vulnerable biomass associated with the *MSY* was taken to be *Bmsy*. If the *MSY* were still increasing with the highest *F* multiplier, the *MSY* and *Bmsy* obtained with that multiplier were used. The multiplier, *Fmult*, was also reported as an indicator. The *MSY* and *Bmsy* calculations were based on the growth parameters estimated from the second (1996–2006) tag dataset.

We also used as indicators the exploitation rate associated with the SL catch from 2007 and 2012: *USL2007* and *USL2012* respectively. At the request of the National Rock Lobster Management Group we also compared projected CPUE with an arbitrary target of 0.75 kg/potlift.

Table 26: Quantities of interest to the assessment from the model base case McMCs. USL is the exploitation rate that produces the size-limited catch. All biomass values are in tonnes and represent the beginning of season AW vulnerable biomass.

Type	Indicator	Statistic	Value	5%	95%
biomass	*Bmin*	median	149.1	134.4	172.2
	B2008	median	167.1	135.1	218.7
	B2012	median	123.7	64.9	255.6
	Bmsy	median	330.4	301.2	378.1
CPUE	*CPUEcurr*	median	0.662	0.547	0.835
	CPUE2012	median	0.492	0.260	0.989
	CPUEmsy	median	1.314	1.178	1.476
yield	*MSY*	median	300.4	291.2	310.2
biomass ratios	*B2008/Bmin*	median	1.114	0.936	1.400
	B2008/Bmsy	median	0.505	0.406	0.643
	B2012/B2008	median	0.746	0.424	1.347
	B2012/Bmin	median	0.831	0.445	1.662
	B2012/Bmsy	median	0.372	0.195	0.759
fishing mortality	*USL2007*	median	0.550	0.461	0.621
	USL2012	median	0.811	0.392	1.546
	USL2012/USL2007	median	1.478	0.733	2.761
	Fmult	mean	0.727		
probabilities	P(*2008*>*Bmin*)	mean	82.5%		
	P(*B2008*>*Bmsy*)	mean	0.0%		
	P(*B2012*>*B2008*)	mean	24.5%		
	P(*B2012*>*Bmin*)	mean	36.5%		
	P(*B2012*>*Bmsy*)	mean	0.5%		
	P(*CPUE2012*>0.75)	mean	19.0%		
	P(*USL2012*>*USL2007*)	mean	78.9%		

The assessment was based on the medians of posterior distributions of these indicators, the posterior distributions of ratios of these indicators, and probabilities that various propositions were true in the posterior distributions.

The primary diagnostics used to evaluate the convergence of the McMC were the appearance of the traces, running quantiles and moving means. The trace for *M* was not as well mixed as one could hope to see and showed some drift throughout the run, with higher values towards the end. The running quantile plots for many estimated parameters also showed a drift through the run, suggesting poor convergence, and a trend to move well away from the MPD estimate. Diagnostic plots of the indicators, however, tended to be more acceptable than those of the parameters.

The posterior trajectory of vulnerable biomass by season from 1976 (Figure 13) shows a nadir near 1989, a strong increase in the 1990s followed by a sharp decrease, and variable projections with an decreasing median. The trajectory of biomass from 1945 to 1960 is difficult to explain as there were only low catches throughout this period; the model output shows low recruitments estimated for these years.

The assessment results are summarised in Table 26. *Bmsy* and *MSY* from the base case were calculated with growth estimates based on the later and slower growth dataset. Current biomass (2008) was above *Bmin* in 83% of runs, and the median result was 11% above *Bmin*. Current biomass was above *Bmsy* in less than 1% of runs, and the median result was half *Bmsy*. Current exploitation rate was about 55%.

Biomass increased in only 25% of projections, and the median decrease was 25%. Projected biomass had a median of 124 t, but uncertainty around this was high, with a 5% to 95% range of 65 to 256 t. *B2012* was above *Bmin* in 36% of runs, and the median result was 83% of *Bmin*. *B2012* was greater than *Bmsy* in less than 1% of runs, and the median was 37% of *Bmsy*.

Projected CPUE had a median of 0.5 kg/potlift, and only 20% of runs exceeded 0.75 kg/potlift. The mean *F* multiplier associated with *MSY* was about 75% of current *F*.

These results suggest a stock that is near *Bmin* and well below *Bmsy*. Under current catches and recent recruitments the model predicted a 75% probability of biomass decrease over four years.

Projections were made with alternative levels of SL catch (commercial plus recreational) with the NSL catch (illegal and customary) held constant (Table 27). These were 5-year projections made in the same way as the base case projections described above, and were made at the request of the Plenary for the guidance of the NRLMG, stakeholders and MPI.

Table 27: Results of 5-year projections with alternative SL catch levels.

	SL Projection Catch (t)							
Indicator	206.0	185.4	164.8	144.2	123.6	82.4	41.2	0.01
% of current catch	100%	90%	80%	70%	60%	40%	20%	0%
B2012	123.7	160.9	195.3	229.0	262.0	328.6	396.6	463.6
B2012/Bmin	0.831	1.073	1.307	1.532	1.754	2.199	2.645	3.090
B2012/B2008	0.746	0.948	1.151	1.346	1.548	1.942	2.340	2.740
B2012/Bmsy	0.372	0.481	0.586	0.688	0.788	0.989	1.191	1.394
CPUE2012	0.492	0.639	0.775	0.910	1.041	1.303	1.566	1.832
P(*B2012>Bmin*)	36.5%	57.0%	77.4%	92.4%	98.2%	100.0%	100.0%	100.0%
P(*B2012>B2008*)	24.5%	44.4%	67.6%	88.7%	97.7%	100.0%	100.0%	100.0%
P(*B2012>Bmsy*)	0.5%	1.4%	4.0%	9.0%	18.5%	47.8%	83.6%	98.3%
P(*CPUE2012>0.75*)	19.0%	34.6%	53.7%	73.5%	89.1%	99.1%	100.0%	100.0%

6.3 CRA 4

This section reports an assessment for *J. edwardsii* for CRA 4 conducted in 2011.

Model structure

A single-stock version of the multi-stock length-based model (MSLM) (Haist et al. 2009) was fitted to two series of catch rate indices from different periods, and to size frequency, puerulus settlement and tagging data. The model used an annual time step from 1945 to 1978 and then switched to a seasonal time step with AW and SS from 1979 through 2010. The model had 93 length bins, 31 for each sex group (males, immature and mature females), each 2 mm TW wide, beginning at left-hand edge 30 mm TW.

Significant catches occurred in the historical series for CRA 4. Different MLS regulations existed in the past and pots were not required to have escape gaps. The model incorporated a time series of sex-specific MLS regulations. Data and their sources are listed in Table 28.

The assessment assumed that recreational catch was equal to the mean of the 1994 and 1996 recreational surveys, was proportional to SS CPUE from 1979 through 2010, and that it increased linearly from 20% of the 1979 value in 1945 up to the 1979 value (see Section 1.3).

Table 28: Data types and sources for the 2011 assessment for CRA 4. Year codes apply to the first 9 months of each fishing year, viz 1998-99 is called 1998. NA – not applicable or not used; MFish – NZ Ministry of Fisheries; NZRLIC – NZ Rock Lobster Industry Council.

Data type	Data source	Begin year	End year
Historical catch rate CR	Annala & King (1983)	1963	1973
CPUE	FSU & CELR	1979	2010
Observer proportions-at-size	MFish and NZ RLIC	1986	2010
Logbook proportions-at-size	NZ RLIC	1997	2010
Tag recovery data	NZ RLIC & MFish	1982	2011
Historical MLS regulations	Annala (1983), MFish	1945	2010
Escape gap regulation changes	Annala (1983), MFish	1945	2010
Puerulus settlement	NIWA	1979	2010

The initial population in 1945 was assumed to be in equilibrium with average recruitment and with no fishing mortality. Each season the number of male, immature female and mature female lobsters within each size class was updated as a result of:

Recruitment. Each year, new recruits to the model were added equally for each sex for each season, as a normal distribution with a mean size (32 mm) and standard deviation (2 mm), truncated at the smallest size class (30 mm). Recruitment in a specific year was determined by the parameter for base recruitment and a parameter for the deviation from base recruitment. The vector of log recruitment deviations was assumed to be normally distributed with a mean of zero. Recruitment deviations were estimated for 1945 through 2011.

Mortality. Natural, fishing and handling mortalities were applied to each sex category (male, immature female and mature female) in each size class. Natural mortality was estimated, but was assumed to be constant and independent of sex and length. Fishing mortality was determined from observed catch and model biomass, modified by legal sizes, sex-specific vulnerabilities and selectivity curves. Handling mortality was assumed to be 10% of fish returned to the water. Two fisheries were modelled: one fishery that operated only on fish above the size limit (SL fishery – including legal commercial and recreational) and one that did not (NSL fishery – all of the illegal fishery plus the Mäori customary fishery). It was assumed that size limits and the prohibition on berried females applied only to the SL fishery. Otherwise, the selectivity and vulnerability functions were the same for the SL and NSL fisheries. Relative vulnerability was calculated by assuming (after experimentation) that females in the SS had the highest vulnerability and that the vulnerability of all other sex categories by season are equal to or less than the SS females.

Instantaneous fishing mortality rates for each fishery were calculated using Newton-Raphson iteration (four iterations after experiment) based on catch and model biomass.

Fishery selectivity: A three-parameter fishery selectivity function was assumed, with parameters describing the shapes of the ascending and descending limbs and the size at which vulnerability is at a maximum. Changes in regulations over time (for instance, changes in escape gap regulations) were modelled by estimating two separate selectivity epochs, pre–1993 and 1993–2010. As in previous assessments for the past decade, the descending limb of the selectivity curve was fixed to prevent under-estimation of vulnerability of large lobsters.

Growth and maturity. For each size class and sex category, a growth transition matrix specified the probability of an individual remaining in the same size class or growing into each of the other size classes. Maturation of females was estimated as a two-parameter logistic curve from the maturity-at-size information in the size frequency data.

Model fitting

A total negative log likelihood function was minimised using AD Model Builder™. The model was fitted to historical catch rate, standardised CPUE and puerulus settlement data using lognormal likelihood. The model was fitted to proportions-at-length with multinomial likelihood and tag-recapture data with robust normal likelihood. For the CPUE and puerulus lognormal likelihoods, CVs for each index value were initially set at the standard error from the GLM analysis. Process error was subsequently added to these CVs. A fixed CV of 0.3 was used for the historical catch rate data. The robust normal likelihood was used for the tagging data. Proportions-at-length, assumed to be representative of the commercial catch, were available from observer catch sampling for all years after 1985 and from voluntary logbooks for some years from 1997. Data were summarised by area/month strata and weighted by the commercial catch taken in each stratum, the number of lobsters measured and the number of days sampled. Size data from each source (research sampling or voluntary logbooks) were fitted separately. Seasonal proportions-at-length summed to one across males, immature and mature females. Experiments (randomisation trials) were conducted to determine whether puerulus settlement data contained a signal with respect to recruitment to the model and, if so, at what lag. Based on the results. the final base case was fit to recruitment data with an assumed lag of 1 year between settlement and recruitment to the model.

Table 29: Parameters estimated and priors used in basecase assessments for CRA 4. Prior type abbreviations: U – uniform; N – normal; L – lognormal.

Parameter	Prior Type	No. of parameters	Bounds	Mean	SD	CV
ln(*R0*) (mean recruitment)	U	1	1–25	–		–
M (natural mortality)	L	1	0.01–0.35	0.12		0.4
Recruitment deviations	N [1]	67	-2.3–2.3	0	0.4	
ln(*qCPUE*)	U	1	-25-0	–		–
ln(*qCR*)	U	1	-25-2	–		–
ln(*qpuerulus*)	U	1	-25-0	–		–
Increment at TW=50 (male & female)	U	2	0.1-20.0	–		–
difference between increment at TW=50 and increment at TW=80 (male & female)	U	2	0.001-1.000	–		–
shape of growth curve (male & female)	N	2	0.1-15.0	5.0	0.5	
TW at 50% probability female maturation	U	1	30–80	–		–
TW at 95% probability female maturation minus TW at 50% probability female maturation	N	1	5-80	14	2.8	–
Relative vulnerability (all sexes and seasons) [2]	U	3	0.01-1.0	–		–
Shape of selectivity left limb (males & females)	U	2	1–50	–		–
Size at maximum selectivity (males & females)	U	2	30-80	–		–
						–

[1] Normal in natural log space = lognormal (bounds equivalent to –10 to 10)
[2] Relative vulnerability of females in SS was fixed at 1

In the base case, it was assumed that biomass was proportional to CPUE, that growth is not density dependant, that there is no stock-recruit relationship and that there was no migration between stocks. Base case explorations involved experimentally weighting the datasets and inspecting the resulting standard deviations of normalised residuals and medians of absolute residuals, experimenting with a new procedure for weighting the LF data, experimentally fixing parts of the growth estimation, experimenting with the sex and season for maximum vulnerability, experimenting with fixing parts of the maturation ogive and exploring other model options such as density-dependence and selectivity curves. The growth C.V. was estimated and then fixed in the McMC simulations. Priors were placed on the growth shape parameters to avoid unrealistic curves and on the parameter determining the width of the maturation curve. Recruitment deviations were estimated for 1945–2011.

Parameters estimated in each model and their priors are provided in Table 29. Fixed parameters and their values are given in Table 30. CPUE, the historical catch rate, proportions-at-length and tagging data were given relative weights directly by a relative weighting factor.

Table 30: Fixed values used in base case assessment for CRA 4

Value	CRA 4
shape parameter for CPUE vs biomass	1.0
minimum std. dev. of growth increment	0.9
Std dev of observation error of increment	1.0
Std dev of historical catch per day	0.30
Handling mortality	10%
Process error for CPUE	0.25
Year of selectivity change	1993
Current male size limit	54
Current female size limit	60
First year for recruitment deviations	1945
Last year for recruitment deviations	2011
Relative weight for length frequencies	3.15
Relative weight for CPUE	4
Relative weight for CR	4
Relative weight for puerulus	1
Relative weight for tag-recapture data	0.8

Model projections

Bayesian estimation procedures were used to estimate the uncertainty in model estimates and short-term projections. This procedure was conducted in the following steps:

a) Model parameters were estimated by AD Model Builder™ using maximum likelihood and the prior probabilities. The point estimates are called MPD (mode of the joint posterior) estimates;

b) Samples from the joint posterior distribution of parameters were generated with Markov chain - Monte Carlo (McMC) simulations using the Hastings-Metropolis algorithm; two million simulations were made, starting from the base case MPD, and 1000 samples were saved. From each sample of the posterior, 4-year projections (2011–2014) were generated with an assumed current-catch scenario (Table 31);

c) Future annual recruitment was randomly sampled with replacement from the model's estimated recruitments from 2002-11 (except for the no-puerulus sensitivity trial which resampled from 1998–2007).

Table 31: Catches (t) used in the four-year projections. Projected catches are based on the current TACC for CRA 4, and the current estimates of recreational, customary and illegal catches. SL= commercial+recreational-reported illegal; NSL=reported illegal+unreported illegal+customary

Commercial	Recreational	Reported Illegal	Unreported Illegal	Customary	SL	NSL
466.9	58.6	5.3	34.7	20.0	520	60

Performance Indicators and Results

Vulnerable biomass in the assessment model was determined by the MLS, selectivity, relative sex and seasonal vulnerability and berried state for mature females. All mature females were assumed to be berried (and not vulnerable to the fishery) in AW and not berried (thus vulnerable) in SS.

Agreed indicators are summarised in Table 32. Base case results (Table 33) suggested that biomass decreased to a low point in 1991, then increased to a high in 1998 (Figure 14), decreased to 2006 and has increased again. The current vulnerable stock size (AW) is about 1.7 times the reference biomass and the spawning stock biomass is close to SSB_{msy} (Table 33). Projected biomass would decrease at the level of current catches over the next 4 years (Figure 14).

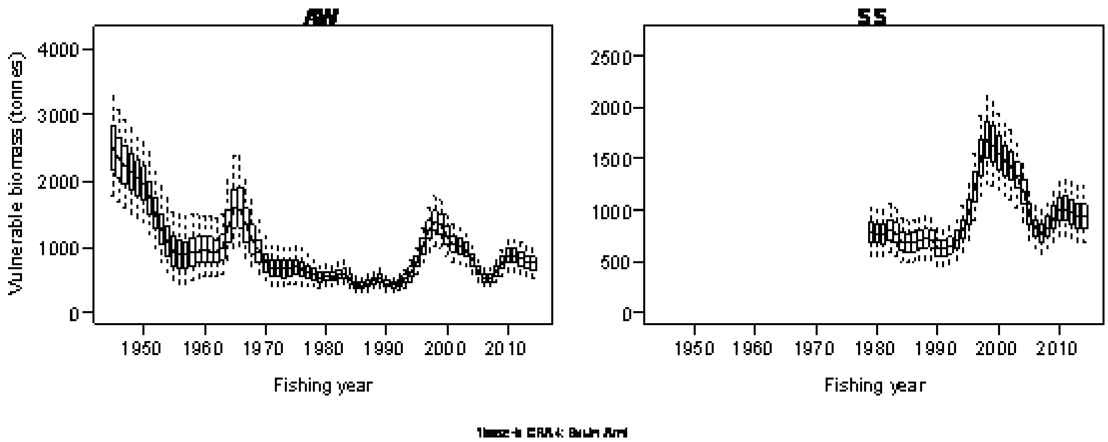


Figure 14: Posterior distributions of the CRA 4 base case McMC biomass vulnerable trajectory. Before 1979 there was a single time step, shown in AW. For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th quantiles.

Table 32: Performance indicators used in the CRA 4 stock assessment

Reference points	
Bmin	The lowest beginning AW vulnerable biomass in the series
Bcurrent	Beginning of season AW vulnerable biomass for the year the stock assessment is performed
Bref	Beginning of AW season mean vulnerable biomass for 1979–88
Bproj	Projected beginning of season AW vulnerable biomass (ie, the year of stock assessment plus 4 years)
Bmsy	Beginning of season AW vulnerable biomass associated with MSY, calculated by doing deterministic forward projections with recruitment *R0* and current fishing patterns
MSY	Maximum sustainable yield (sum of AW and SS SL catches) found by searching a across a range of multipliers on F.
Fmult	The multiplier that produced *MSY*
SSBcurr	Current spawning stock biomass at start of AW season
SSBproj	Projected spawning stock biomass at start of AW season
SSBmsy	Spawning stock biomass at start of AW season associated with *MSY*
CPUE indicators	
CPUEcurrent	CPUE at *Bcurrent*
CPUEproj	CPUE at *Bproj*
CPUEmsy	CPUE at *Bmsy*
Performance indicators	
Bcurrent / Bmin	ratio of *Bcurrent* to *Bmin*
Bcurrent / Bref	ratio of *Bcurrent* to *Bref*
Bcurrent / Bmsy	ratio of *Bcurrent* to *Bmsy*
Bproj / Bcurrent	ratio of *Bproj* to *Bcurrent*
Bproj / Bref	ratio of *Bproj* to *Bref*
Bproj / Bmsy	ratio of *Bproj* to *Bmsy*
SSBcurr/SSB0	ratio of *SSBcurrent* to *SSB0*
SSBproj/SSB0	ratio of *SSBproj* to *SSB0*
SSBcurr/SSBmsy	ratio of *SSBcurrent* to *SSBmsy*
SSBproj/SSBmsy	ratio of *SSBproj* to *SSBmsy*
SSBproj/SSBcurr	ratio of *SSBproj* to *SSBcurrent*
USLcurrent	The current exploitation rate for SL catch in AW
USLproj	Projected exploitation rate for SL catch in AW
USLproj/USLcurrent	ratio of SL projected exploitation rate to current SL exploitation rate
Probabilities	
P(Bcurrent > Bmin)	probability *Bcurrent* > *Bmin*
P(Bcurrent > Bref)	probability *Bcurrent* > *Bref*
P(Bcurrent > Bmsy)	probability *Bcurrent* > *Bmsy*
P(Bproj > Bmin)	probability *Bproj* > *Bmin*
P(Bproj > Bref)	probability *Bproj* > *Bref*
P(Bproj > Bmsy)	probability *Bproj* > *Bmsy*
P(Bproj > Bcurrent)	probability *Bproj* > *Bcurrent*
P(SSBcurr>SSBmsy)	probability *SSBcurr>SSBmsy*
P(SSBproj>SSBmsy)	probability *SSBproj>SSBmsy*
P(USLproj>USLcurr)	probability SL exploitation rate *proj* > SL exploitation rate *current*
P(SSBcurr<0.2SSB0)	soft limit: probability *SSBcurrent* < 20% *SSB0*
P(SSBproj<0.2SSB0	soft limit: probability *SSBproj* < 20% *SSB0*
P(SSBcurr<0.1SSB0)	soft limit: probability *SSBcurrent* < 10% *SSB0*
P(SSBproj<0.1SSB0)	soft limit: probability *SSBproj* < 10% *SSB0*

A series of MCMC sensitivity trials was also made, including trials with low estimated vulnerability for immature females, exclusion of puerulus data, using a different lag (3 years) for fitting the puerulus data, fixed M, using a higher weight for the LF data and using an alternative recreational catch vector. The assessment results from the base case and sensitivity trials calculated as a series of agreed indicators (Table 32) are shown in Table 33.

The sensitivity trials run were:
lovuln ; trial with low estimated vulnerability for immature females;
no poo: not fitted to puerulus data;
poolag3: fitted to puerulus data with a lag of 3 years;
fixedM: with M fixed to 0.16;
hiLFwt: fitted using a high weighting for the LF dataset, and;
hiRecCat: fitted using an historical catch vector based on doubling the recreational catch estimates.

Table 33: Assessment results for CRA 4 – medians of indicators described in Table 32 from the base case and sensitivity trials; the lower part of the table shows the probabilities that events are true; biomass in t and CPUE in kg/potlift.

Indicator	basecase	lovuln	nopoo	poolag3	fixed*M*	hiLFwt	hiRecCat
Bmin	407	398	416	355	365	321	423
Bcurr	862	844	941	742	674	805	898
Bref	514	495	521	438	477	411	536
Bproj	751	727	770	607	571	663	831
Bmsy	377	385	374	343	547	416	408
MSY	680	655	676	662	532	610	715
Fmult	4.05	3.76	4.44	3.81	1.50	2.96	3.57
SSBcurr	2 615	809	2 496	1 826	1 513	1 999	2 654
SSBproj	2 796	829	2 457	1 690	1 576	2 147	2 864
SSBmsy	2 646	652	2 387	1 757	1 739	2 143	2 675
CPUEcurrent	0.91	0.91	1.01	0.91	0.91	0.95	0.91
CPUEproj	0.77	0.75	0.78	0.69	0.74	0.73	0.83
CPUEmsy	0.29	0.31	0.29	0.30	0.68	0.38	0.31
Bcurr/Bmin	2.12	2.11	2.27	2.08	1.87	2.52	2.11
Bcurr/Bref	1.68	1.70	1.82	1.69	1.42	1.96	1.68
Bcurr/Bmsy	2.30	2.20	2.56	2.15	1.26	1.94	2.21
Bproj/Bcurr	0.87	0.86	0.82	0.82	0.85	0.83	0.93
Bproj/Bref	1.46	1.47	1.49	1.38	1.22	1.61	1.56
Bproj/Bmsy	2.01	1.90	2.08	1.78	1.08	1.60	2.04
SSBcurr/SSB0	0.65	0.43	0.67	0.62	0.46	0.58	0.63
SSBproj/SSB0	0.69	0.44	0.65	0.57	0.48	0.62	0.68
SSBcurr/SSBmsy	0.98	1.24	1.04	1.04	0.87	0.93	0.99
SSBproj/SSBmsy	1.05	1.27	1.01	0.96	0.91	1.01	1.07
SSBproj/SSBcurr	1.07	1.03	0.96	0.92	1.04	1.08	1.08
USLcurrent	0.24	0.24	0.21	0.27	0.31	0.25	0.23
USLproj	0.30	0.31	0.30	0.38	0.40	0.34	0.25
USLproj/USLcurrent	1.28	1.29	1.38	1.39	1.29	1.36	1.07
P(*Bcurr*>*Bmin*)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P(*Bcurr*>*Bref*)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P(*Bcurr*>*Bmsy*)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P(*Bproj*>*Bmin*)	1.00	1.00	0.99	1.00	1.00	1.00	1.00
P(*Bproj*>*Bref*)	1.00	1.00	0.91	1.00	0.94	1.00	1.00
P(*Bproj*>*Bmsy*)	1.00	1.00	0.99	1.00	0.69	1.00	1.00
P(*Bproj*>*Bcurr*)	0.01	0.02	0.18	0.01	0.02	0.01	0.12
P(*SSBcurr*>*SSBmsy*)	0.39	1.00	0.64	0.71	0.01	0.13	0.45
P(*SSBproj*>*SSBmsy*)	0.73	1.00	0.52	0.35	0.10	0.53	0.79
P(*USLproj*>*USLcurr*)	1.00	1.00	0.91	1.00	1.00	1.00	0.83
P(*SSBcurr*<*0.2SSB0*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P(*SSBproj*<*0.2SSB0*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P(*SSBcurr*<*0.1SSB0*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P(*SSBproj*<*0.1SSB0*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Indicators based on vulnerable biomass (AW) and *Bmsy*

In the base case and for sensitivity trials, except fixed *M* and high LF weight, the median value for *Bref* was larger than the median for *Bmsy*. In the base case and for all trials, current and projected biomass levels were larger than *Bref* and *Bmsy* reference levels by substantial factors. Projected biomass decreased in nearly all runs but remained well above the reference levels in the base case and for all trials.

Indicators based on SSBmsy

SSBmsy is biomass of mature females associated with *Bmsy*. The historical track of biomass versus fishing intensity is shown in Figure 15. The phase space in the plot shows biomass on the x-axis and fishing intensity on the y-axis. High biomass/low intensity is in the lower right-hand corner, the location of the stock when fishing first began, and low biomass/high intensity is in the upper left-hand corner, in a period when the fishery was largely uncontrolled. Note that fishing patterns include MLS, selectivity and the seasonal catch split, and note that *Fmsy* varies in each year because fishing patterns change. The reference *SSBmsy* in Figure 15 has been calculated using the 2010 fishing pattern.

Fmsy varies every year because the fishing patterns change. It was calculated with a 50-year projection for each year in each run, with the NSL catch held constant at that year's value, deterministic recruitment at *R0* and a range of multipliers on the SL catch *F*s estimated for year *y*. The *F* (actually separate *F*s for two seasons) that gives *MSY* is *Fmsy* and the multiplier is *Fmult*. Each point on the figure was plotted as the median of the posterior distributions of biomass ratio and fishing intensity ratio.

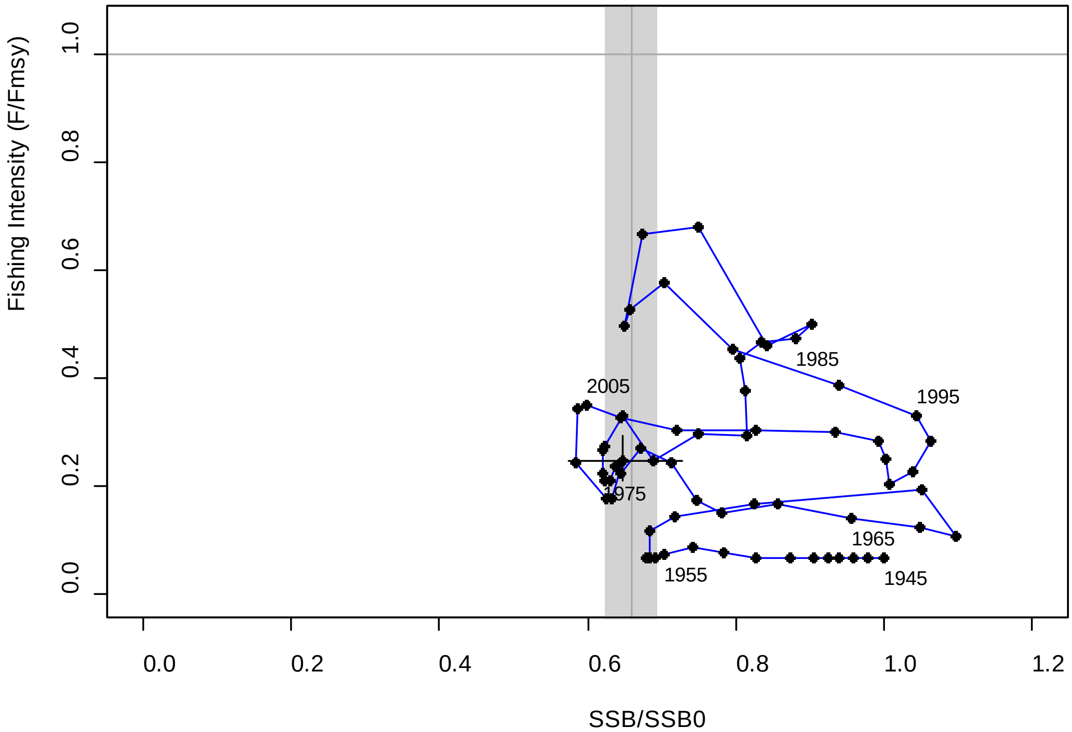


Figure 15: "Snail trail" that summarises the *SSB* history of the CRA 4 stock. The x-axis is spawning stock biomass *SSB* in year *y* as a proportion of the unfished spawning stock, *SSB0*. *SSB0* is constant for all years of a run, but varies through the 1000 runs. The y-axis is fishing intensity in year *y* as a proportion of the fishing intensity (*Fmsy*) that would have given *MSY* under the fishing patterns in year *y*; fishing patterns include MLS, selectivity, the seasonal catch split and the balance between SL and NSL catches. The vertical line in the figure is the median (line) and 90% interval (shading) of the posterior distribution of *SSBmsy* (the spawning stock biomass associated with *MSY*) as a proportion of *SSB0*; this ratio was calculated using the fishing pattern in 2010. The horizontal line in the figure is drawn at 1, the fishing intensity associated with *Fmsy*. The bars at the final year of the plot show the 90% intervals of the posterior distributions of biomass ratio and fishing intensity ratio.

6.4 CRA 5

This section reports an assessment for *J. edwardsii* for CRA 5 conducted in 2010.

Model structure

A single-stock version of the multi-stock length-based model (MSLM) (Haist et al. 2009) was fitted to two series of catch rate indices from different periods, and to size frequency, puerulus settlement and tagging data. The model used an annual time step for 1945-78 and then a seasonal time step (autumn-winter (AW): April to September, and spring-summer (SS): October to March).

Significant catches occurred in the early part of the time series for CRA 5. Different MLS regulations existed at this time and pots were not required to have escape gaps. The model incorporated a time series of sex-specific MLS regulations. Data and their sources are listed in Table 34.

The assessment assumed that recreational catch was equal to survey estimates in 1994 and 1996, proportional to area 917 AW CPUE in other years from 1979-2009, and increased linearly from 20% of the 1979 value in 1945 up to the 1979 value.

The initial population in 1945 was assumed to be in equilibrium with average recruitment and with no fishing mortality. Each season the number of male, immature female and mature female lobsters within each size class is updated as a result of:

a) **Recruitment**. Each year, new recruits were added equally for each sex season, as a normal distribution with a mean size (32 mm) and standard deviation (2 mm), truncated at the smallest size class (30 mm). Recruitment in a specific year was determined by the parameter for base recruitment and a parameter for the deviation from base recruitment. The vector of recruitment deviations was assumed to be normally distributed with a mean of zero.

b) **Mortality**. Natural, fishing and handling mortalities were applied to each sex category (male, immature female and mature female) in each size class. Natural mortality was estimated, but was assumed to be constant and independent of sex and length. Fishing mortality was determined from observed catch and model biomass, modified by legal sizes, sex-specific vulnerabilities and selectivity curves.

   Two fisheries were modelled: one fishery that operated only on fish above the size limit (SL fishery – including legal commercial and recreational) and one that did not (NSL fishery - most of the illegal fishery plus the Mäori customary fishery). It was assumed that size limits and the prohibition on berried females applied only to the SL fishery. Otherwise, the selectivity and vulnerability functions were the same for the SL and NSL fisheries. Relative vulnerability was calculated by assuming that the males in the AW had the highest vulnerability and that the vulnerability of all other sex categories by season are equal to or less than the AW males. Instantaneous fishing mortality rates for each fishery were calculated using Newton-Raphson iteration based on catch and model biomass. Handling mortality rate was assumed to be 10% of all lobsters that were released.

c) **Fishery selectivity:** A three-parameter fishery selectivity function was assumed, with parameters describing the shapes of the ascending and descending limbs and the size at which vulnerability is at a maximum. Changes in regulations over time (for instance, changes in escape gap regulations) were modelled by estimating two separate selectivity epoch, pre-1993 and 1993-2009.

d) **Growth and maturity**. For each size class and sex category, a growth transition matrix specified the probability of an individual remaining in the same size class or growing into each of the other size classes. Maturation of females was estimated as a two-parameter logistic curve from the maturity-at-size information in the size frequency data.

Model fitting

A total negative log likelihood function was minimised using AD Model Builder™. The model was fitted to historical catch rate, standardised CPUE and puerulus settlement data using lognormal likelihood. The model was fitted to proportions-at-length with multinomial likelihood and tag-recapture data with robust normal likelihood. For the CPUE and puerulus lognormal likelihoods, CVs for each index value were initially set at the standard error from the GLM analysis. Process error was subsequently added to these CVs so that the overall standard deviation of the standardised (Pearson) residuals was near 1.0. A fixed CV of 0.3 was used for the historical catch rate data. The robust normal likelihood was used for the tagging data so that data outliers (defined as observations with a standardised residual greater than 3.0) would be downweighted. Proportions-at-length, assumed to be representative of the commercial catch, were available from both observer catch sampling and voluntary logbooks; these were fitted separately.

Data were summarised by area/month strata and weighted by the commercial catch taken in each stratum, the number of lobsters measured and the number of days sampled. Size data from each source (research sampling or voluntary logbooks) were fitted separately. Seasonal proportions-at-length summed to one across males, immature and mature females. Experiments (randomisation trials) were conducted to establish that puerulus settlement data contained a signal about recruitment.

In the base case, the model's options for fitting a non-linear relation between biomass and CPUE, having density-dependent growth, having a stock-recruit relation and having movements between stocks were all turned off. The base case was obtained by weighting CR, LFs and tags so that standard deviations of normalised residuals were close to 1; CPUE data were intentionally upweighted to force an acceptable fit and puerulus data were also upweighted. It was decided to fix the value of growth c.v. to that estimated in growth-only fits to the tagging data, and to put a prior on the growth shape parameters to avoid unrealistic curves. Recruitment deviations were estimated for the whole time series.

Table 34: Data types and sources for the 2010 assessment for CRA 5. Year codes apply to the first 9 months of each fishing year, viz 1998-99 is called 1998. NA – not applicable or not used; MFish – NZ Ministry of Fisheries; NZRLIC – NZ Rock Lobster Industry Council.

Data type	Data source	Begin year	End year
Historical catch rate CR	Annala & King (1983)	1963	1973
CPUE	FSU & CELR	1979	2009
Observer proportions-at-size	MFish	1986	2009
Logbook proportions-at-size	NZRLIC	1994	2009
Tag recovery data	NZRLIC & MFish	1996	2009
Historical MLS regulations	Annala (1983), MFish	1945	2009
Escape gap regulation changes	Annala (1983), MFish	1945	2009
Puerulus settlement	NIWA	1980	2009

Parameters estimated in each model and their priors are provided in Table 35. Fixed parameters and their values are given in Table 36. CPUE, the historical catch rate, proportions-at-length and tagging data were given relative weights directly by a relative weighting factor. The weights were varied to obtain standard deviations of standardised residuals for each data set that were close to one.

Table 35: Parameters estimated and priors used in basecase assessments for CRA 5. Prior type abbreviations: U – uniform; N – normal; L – lognormal.

	Prior Type	Bounds	Mean	SD	CV
ln(*R0*) (mean recruitment)	U	1–25	–		–
M (natural mortality)	L	0.01–0.35	0.12		0.4
Recruitment deviations	N [1]	-2.3–2.3	0	0.4	
ln(*qCPUE*)	U	-25-0	–		–
ln(*qCR*)	U	-25-2	–		–
ln(*qPuerulus*)	U	-25-0	–		–
Increment at TW=50 (male & female)	U	0.1-20.0	–		–
difference between increment at TW=50 and increment at TW=80 (male & female)	U	0.001-1.000	–		–
shape of growth curve (male & female)	N	0.1-15.0	5.0	0.5	
TW at 50% probability female maturation	U	30–80	–		–
(TW at 95% probability female maturity) – (TW at 50% probability female maturity)	U	5-80	–		–
Relative vulnerability (all sexes and seasons) [2]	U	0-1	–		–
Shape of selectivity left limb (males & females)	U	1–50	–		–
Size at maxim2um selectivity (males & females)	U	30-80	–		–
Size at maximum selectivity females	U	30-80	–		–

[1] Normal in natural log space = lognormal (bounds equivalent to –10 to 10)
[2] Relative vulnerability of males in autumn-winter was fixed at one

Table 36: Fixed values used in base case assessment for CRA 5

	CRA 5
shape parameter for CPUE vs biomass	1
CV of growth increment (male & female)	0.24
minimum std. dev. of growth increment	1.5
Std dev of observation error of increment	1
Std dev of historical catch per day	0.30
Handling mortality	10%
Process error for CPUE	0.25
Year of selectivity change	1993
Current male size limit	54
Current female size limit	60
First year for recruitment deviations	1945
Last year for recruitment deviations	2009
Relative weight for length frequencies	25
Relative weight for CPUE	3
Relative weight for CR	1
Relative weight for puerulus	2
Relative weight for tag-recapture data	0.8

Model projections

Bayesian estimation procedures were used to estimate the uncertainty in model estimates and short-term projections. This procedure was conducted in the following steps:

d) Model parameters were estimated by AD Model Builder™ using maximum likelihood and the prior probabilities. These point estimates are called MPD (mode of the joint posterior) estimates;

e) Samples from the joint posterior distribution of parameters were generated with Markov chain - Monte Carlo (MCMC) simulations using the Hastings-Metropolis algorithm; two million simulations were made, starting from the base case MPD, and 1000 samples were saved. From each sample of the posterior, 5-year projections (2010–2014) were generated with two agreed catch scenarios (Table 37).

f) Future annual recruitment was randomly sampled with replacement from the model's estimated recruitments from 2000–09 (except for the no puerulus sensitivity trial which resampled from 2000–06).

Table 37: Catches (t) used in the five-year projections. Projected catches are based on the current TACC for CRA 5, and the current estimates of recreational, customary and illegal catches.

	Commercial	Recreational	Reported Illegal	Unreported Illegal	Customary
scenario 1	350	156	3	49	10
scenario 2	350	112	3	49	10

Vulnerable biomass in the assessment model was determined by the MLS, selectivity, relative sex and seasonal vulnerability and berried state for mature females. All mature females were assumed to be berried (and not vulnerable to the fishery) in AW and not berried (and vulnerable) in SS.

Base case results suggested that biomass decreased to a low point in 1991, remained low through 1995, then increased (Figure 16). The current vulnerable stock size (AW) is about 3 times the reference biomass and the spawning stock biomass is well above B_{msy} (Table 38). However, projected biomass would decrease at the level of current catches over the next 4 years (Figure 16).

Table 38: Performance indicators used in the CRA 5 stock assessment

Reference points	
Bmin	The lowest beginning AW vulnerable biomass in the series
Bcurrent	Beginning of season AW vulnerable biomass for the year the stock assessment is performed
Bref	Beginning of AW season mean vulnerable biomass for 1979–88
Bproj	Projected beginning of season AW vulnerable biomass (ie, the year of stock assessment plus 4 years)
Bmsy	Beginning of season AW vulnerable biomass associated with MSY, calculated by doing deterministic forward projections with recruitment *R0* and current fishing patterns
MSY	Maximum sustainable yield (sum of AW and SS SL catches) found by searching a across a range of multipliers on F.
Fmult	The multiplier that produced *MSY*
CPUE indicators	
CPUEcurrent	CPUE at *Bcurrent*
CPUEproj	CPUE at *Bproj*
CPUEmsy	CPUE at *Bmsy*
Performance indicators	
Bcurrent / Bmin	ratio of *Bcurrent* to *Bmin*
Bcurrent / Bref	ratio of *Bcurrent* to *Bref*
Bcurrent / Bmsy	ratio of *Bcurrent* to *Bmsy*
Bproj / Bmin	ratio of *Bproj* to *Bmin*
Bproj / Bcurrent	ratio of *Bproj* to *Bcurrent*
Bproj / Bref	ratio of *Bproj* to *Bref*
Bproj / Bmsy	ratio of *Bproj* to *Bmsy*
USLcurrent	The current exploitation rate for SL catch in AW
USLproj	Projected exploitation rate for SL catch in AW
USLproj/USLcurrent	ratio of SL projected exploitation rate to current SL exploitation rate
Probabilities	
P(Bref> Bmsy)	probability *Bref > Bmsy*
P(Bcurrent > Bmin)	probability *Bcurrent > Bmin*
P(Bcurrent > Bref)	probability *Bcurrent > Bref*
P(Bcurrent > Bmsy)	probability *Bcurrent > Bmsy*
P(Bproj > Bmin)	probability *Bproj > Bmin*
P(Bproj > Bref)	probability *Bproj > Bref*
P(Bproj > Bmsy)	probability *Bproj > Bmsy*
P(Bproj > Bcurrent)	probability *Bproj > Bcurrent*
P(USLproj > USLcurrent)	probability SL exploitation rate *proj* > SL exploitation rate *current*
P(SSBcurrent < 0.2 SSB0)	soft limit: probability *SSBcurrent* < 20% *SSB0*
P(SSBproj < 0.2 SSB0)	soft limit: probability *SSBproj* < 20% *SSB0*

A series of MCMC sensitivity trials was also made, including exclusion of puerulus data, using a flat recreational catch vector, fixed M, fast growth found in an exploratory trial, density-dependent growth and estimated shape of the CPUE/biomass relation. The assessment results from the base case and sensitivity trials calculated as a series of agreed indicators (Table 38) are shown in Table 39 for the more aggressive of the two catch scenarios (Scenario 1, Table 37). Indicators from Scenario 2, with lower projected catches, are not reported.

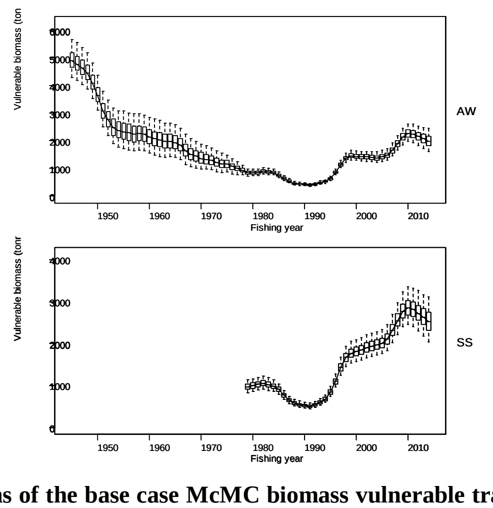


Figure 16: Posterior distributions of the base case McMC biomass vulnerable trajectory. Before 1979 there was a single time step, shown in AW. Projected catches were scenario 1 (Table 37). For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th quantiles.

Indicators based on vulnerable biomass (AW) and *Bmsy*

In the base case and for all trials, the median value for *Bref* was larger than the median for *Bmsy* and the probability of *Bref* being greater than *Bmsy* was at least 57%. In the base case and for all trials, current and projected biomass levels were larger than *Bref* and *Bmsy* reference levels by substantial factors for both catch projection scenarios. Projected biomass decreased in most runs but remained well above the reference levels in the base case and for all trials.

Table 39: Assessment results – medians of indicators described in Table 38 from the base case and sensitivity trials under Scenario 1 catches (Table 37); the lower part of the table shows the probabilities that events are true.

	base	no puerulus	flat rec. catch	fixed M	fast growth	d-d growth	non-linear CPUE
Bmin	404	401	462	338	182	263	492
Bcurr	2,266	2,279	2,633	1,943	800	1,503	1,401
Bref	763	754	867	636	345	536	754
Bproj	1,993	2,482	2,397	1,868	650	1,388	1,092
Bmsy	491	492	480	628	316	527	498
CPUEcurrent	1.61	1.63	1.63	1.66	1.39	1.58	1.50
CPUEproj	1.49	1.90	1.57	1.73	1.06	1.55	0.95
CPUEmsy	0.27	0.28	0.19	0.50	0.29	0.48	0.19
MSY	541	535	567	459	537	510	502
Bcurr/Bmin	5.59	5.68	5.72	5.74	4.41	5.67	2.85
Bcurr/Bref	2.96	3.02	3.05	3.05	2.32	2.79	1.86
Bcurr/Bmsy	4.62	4.62	5.54	3.10	2.53	2.88	2.82
Bproj/Bmin	4.91	6.15	5.15	5.51	3.60	5.23	2.23
Bproj/Bcurr	0.88	1.09	0.91	0.95	0.81	0.92	0.78
Bproj/Bref	2.60	3.27	2.75	2.92	1.89	2.57	1.45
Bproj/Bmsy	4.03	5.01	5.03	2.96	2.07	2.66	2.19
USLcurrent	0.122	0.122	0.101	0.145	0.327	0.184	0.187
USLproj	0.131	0.105	0.104	0.139	0.401	0.188	0.239
USLproj/USLcurrent	1.08	0.86	1.03	0.97	1.23	1.03	1.27
Fmult	5.47	5.41	9.51	2.73	4.05	2.97	3.14
P(Bref>Bmsy)	1.000	1.000	1.000	0.568	0.890	0.570	1.000
P(Bcurr>Bmin)	1.000	1.000	1.000	1.000	1.000	1.000	1.000
P(Bcurr>Bref)	1.000	1.000	1.000	1.000	1.000	1.000	1.000
P(Bcurr>Bmsy)	1.000	1.000	1.000	1.000	1.000	1.000	1.000
P(Bproj>Bmin)	1.000	1.000	1.000	1.000	1.000	1.000	1.000
P(Bproj>Bcurr)	0.075	0.787	0.092	0.289	0.162	0.093	0.025
P(Bproj>Bref)	1.000	1.000	1.000	1.000	0.979	1.000	0.991
P(Bproj>Bmsy)	1.000	1.000	1.000	1.000	0.986	1.000	1.000
P(USLproj>USLcurr)	0.804	0.110	0.663	0.360	0.794	0.652	0.960
P(SSBcurr<0.2SSB0)	0	0	0	0	0	0	0
P(SSBproj<0.2SSB0)	0	0	0	0	0	0	0

Indicators based on *SSBmsy*

SSBmsy is biomass of mature females associated with B_{MSY}. The historical track of biomass versus fishing intensity is shown in Figure 17. The phase space in the plot shows biomass on the x-axis and fishing intensity on the y-axis. High biomass/low intensity is in the lower right-hand corner, the location of the stock when fishing first began, and low biomass/high intensity is in the upper left-hand corner, in a period when the fishery was largely uncontrolled. Note that fishing patterns include MLS, selectivity and the seasonal catch split and that *Fmsy* varies in each year because fishing patterns change. The reference *SSBmsy* in Figure 17 has been calculated using the 2009 fishing pattern.

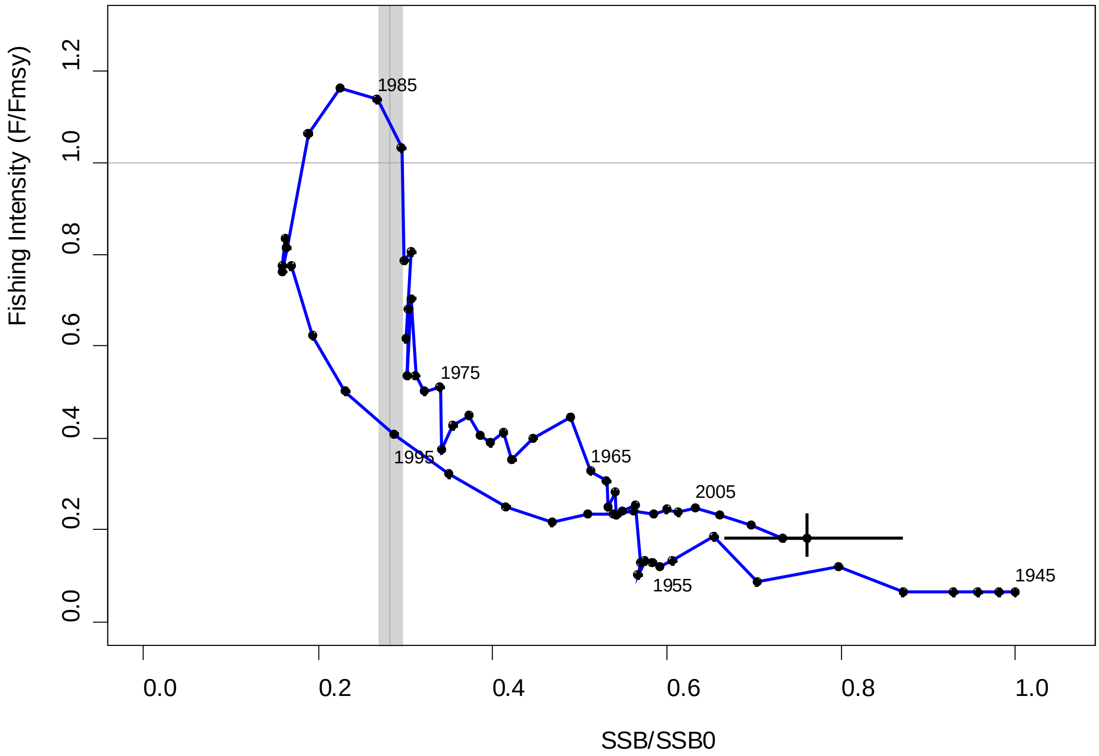


Figure 17: "Snail trail" that summarises the history of the CRA 5 fishery. The x-axis is the spawning biomass (SSB) as a proportion of B0 (SSB0); the y-axis is the ratio of the fishing intensity (F) relative to Fmsy. Each point is the median of the posterior distributions, and the bars associated with 2009 show the 90% confidence intervals. The vertical reference line shows SSBmsy as a proportion of SSB0, with the grey band indicating the 90% confidence interval. The horizontal reference line is Fmsy.

In 1945 the fishery was near the lower right-hand corner of the plot, in the high biomass/low fishing the intensity region as expected. It climbed towards the low biomass/high intensity region, reaching highest fishing intensity in 1985 and lowest biomass in 1991. After 1991, the fishery moved quite steadily back towards lower fishing intensity and higher biomass. The current biomass on this scale is near that of 1951, and current fishing intensity is near that of 1952.

6.5 CRA 6

This section reports an assessment for *J. edwardsii* for CRA 6 from the CHI stock taken from the 1996 Mid-year Plenary report (Annala & Sullivan 1996).

Alternative methods have been used to assess the CHI stock. These include a simple depletion analysis presented to the Working Group in previous years and a new production model, which appeared to fit the observed data well. Both models assume a constant level of annual productivity which is independent of the standing stock and thus will not be affected by changes to the level of the standing stock. B_0 was estimated by both models to be about 20 000 t.

6.6 CRA 7 and CRA 8

This section describes new stock assessments done for CRA 7 and CRA 8 in 2012.

Model structure

A two-stock version of the multi-stock length-based model (MSLM) (Haist et al. 2009) was fitted to data from CRA 7 and CRA 8: seasonal standardised CPUE from 1979-2011, length frequencies from observer and voluntary (logbook) catch sampling, tag-recapture data and (in preliminary explorations only) puerulus settlement data. The model used an annual time step from 1974 through 1978 and then switched to a seasonal time step with autumn-winter (AW, April through September) and spring-summer (SS) from 1979 through 2011. The model had 93 length bins, 31 for each sex group (males, immature and mature females), each 2 mm TW wide, beginning at left-hand edge 30 mm TW.

Significant catches occurred in the historical series for both CRA 7 and CRA 8 prior to the beginning of the model and the reconstruction assumed the population began from an exploited state. MLS and escape gap regulations in place at the beginning of the reconstruction differed from those currently active. To accommodate these differences, the model incorporated stock-specific time series of MLS regulations by sex and modelled escape gap regulation changes by estimating separate selectivity functions prior to 1993. For the first time, the model was modified to simulate the return of lobsters to the sea in CRA 8, where this practice had become prevalent. Smaller males are retained in preference to larger males, and the model used annual fitted retention curves from 2000 onwards to simulate this in the fishing dynamics. Data and their sources are listed in Table 40.

The assessment assumed that recreational catch was proportional to SS CPUE from 1979 through 2011, that, in 1994, 1996, 2000 and 2001, it was equal to the mean of the 1994, 1996, 2000 and 2001 recreational surveys (see Section 1.2), and that it increased linearly from 20% of the 1979 value in 1945 up to the 1979 value.

Table 40: Data types and sources for the 2012 assessment for CRA 7 and CRA 8. Year codes are from the first 9 months of each fishing year, *viz.* 1998–99 is called 1998. NA – not applicable or not used; MPI – NZ Ministry for primary Industries; NZ RLIC – NZ Rock Lobster Industry Council; FSU: Fisheries Statistics Unit; CELR: catch and effort landing returns; NIWA: National Institute of Water and Atmosphere.

Data type	Data source	CRA 7 Begin year	CRA 7 End year	CRA 8 Begin year	CRA 8 End year
CPUE	FSU & CELR	1979	2011	1979	2011
Observer proportions-at-size	MPI and NZ RLIC	1988	2011	1987	2010
Logbook proportions-at-size	NZ RLIC	not used	not used	1993	2011
Tag recovery data	NZ RLIC & MFish	1965	2008	1966	2011
Historical MLS regulations	Annala (1983), MPI	1974	2011	1974	2011
Escape gap regulation changes	Annala (1983), MPI	1974	2011	1974	2011
Puerulus settlement	NIWA	1990	2011	1980	2011
Retention	NZ RLIC	NA	NA	2000	2011

The initial population in 1974 was assumed to be in equilibrium with an estimated exploitation rate in each stock. Each season, numbers of male, immature female and mature female lobsters in each size class were updated as a result of:

Recruitment: Each year, new recruits to the model were added equally for each sex for each season for each stock, as a normal distribution with a mean size (32 mm) and standard deviation (2 mm), truncated at the smallest size class (30 mm). Recruitment in a specific year was determined by the parameters for base recruitment and parameters for the deviations from base recruitment; all recruitment parameters were stock-specific. The vector of recruitment deviations in natural log space was assumed to be normally distributed with a mean of zero. Recruitment deviations were estimated for 1974 through 2009.

Mortality: Natural, fishing and handling mortalities were applied to each sex category in each size class. Natural mortality was assumed to be constant and independent of sex and length; a common estimated value was used for both stocks. Fishing mortality was determined from observed catch and model biomass in each stock, modified by legal sizes, sex-specific vulnerabilities and selectivity curves in each stock and, for CRA 8, retention curves for 2000 and later. Handling mortality was assumed to be 10% for fish returned to the water. Two fisheries were modelled for each stock: one that operated only on fish above the size limit, excluding berried females (SL fishery – including legal commercial and recreational) and one that did not respect size limits and restrictions on berried females (NSL fishery – all of the illegal fishery plus the Mäori customary fishery). Selectivity and vulnerability functions were otherwise the same for the SL and NSL fisheries. Vulnerability in each stock by sex category and season was estimated relative to males in AW, which were assumed to have the highest vulnerability. Instantaneous fishing mortality rates for each fishery were calculated using Newton-Raphson iteration (four iterations after previous experiments) based on catch and model biomass.

Fishery selectivity: A three-parameter fishery selectivity function was assumed, with parameters for each stock describing the shapes of the ascending and descending limbs and the size at which vulnerability is at a maximum. Changes in regulations over time (for instance, changes in escape gap regulations) were modelled by estimating selectivity in two separate epochs, pre–1993 and 1993–2011. As in previous assessments for the past decade, the descending limb of the selectivity curve was fixed to prevent under-estimation of vulnerability of large lobsters. Estimated selectivity parameters were stock-specific.

Growth and maturation: For each size class and sex category in each stock, a growth transition matrix specified the probability of an individual remaining in the same size class or growing into each of the other size classes. Maturation of females was estimated as a two-parameter logistic curve from the maturity-at-size information in the size frequency data. Estimated growth and maturation parameters were stock-specific.

Movements between stocks: For each year from 1985-2010, the model estimated the proportion of fish of sizes 45-60 mm TW that moved each season from CRA 7 to CRA 8. Mean movement was assumed for all other years. The estimated movement parameters were given an upper bound of 15% in the base case.

Model fitting:

A total negative log likelihood function was minimised using AD Model Builder™. The model was fitted to standardised CPUE and (in explorations only) puerulus settlement data using lognormal likelihood, to proportions-at-length with multinomial likelihood and to tag-recapture data with robust normal likelihood. For the CPUE and puerulus lognormal likelihoods, CVs for each index value were initially set at the standard error from the GLM analysis. Process error was subsequently added to these CVs.

Proportions-at-length, assumed to be representative of the commercial catch, were available (see Table 40) from observer catch sampling and voluntary logbooks: data were summarised by area/month strata and weighted by the commercial catch taken in each stratum, the number of lobsters measured and the number of days sampled. Size data from each source were fitted separately. Seasonal proportions-at-length summed to one across males, immature and mature females. These data were weighted within the model using the method of Francis (2011).

Experiments (randomisation trials) were conducted to determine whether puerulus settlement data contained a signal with respect to recruitment to the model and, if so, at what lag. These were significant for both stocks, but exploration showed there was no predictive power in the settlement data, and these data were not used further.

In the base case, it was assumed that biomass was proportional to CPUE, that growth was density-dependent, that there is no stock-recruit relationship and that there was migration between CRA 7 and CRA 8, involving fish from 45-60 mm TW. Base case explorations involved experimentally weighting the datasets and inspecting the resulting standard deviations of normalised residuals and medians of absolute residuals, exploring the effect of the start year, experimentally fixing parts of the growth estimation, experimenting with the prior for *M*, experimenting with the upper bound on annual movements and exploring other model options such as CPUE shape. The growth C.V. was fixed after early explorations.

Parameters estimated in the base case and their priors are provided in Table 41. Fixed parameters and their values are given in Table 42.

Table 41: Parameters estimated and priors used in the base case assessments for CRA 7 and CRA 8. Prior type abbreviations: U – uniform; N – normal; L – lognormal.

Parameter	Prior Type	No. of parameters	Bounds	Mean	SD	CV
ln(*R0*) (mean recruitment)	U	2	1–25	–	–	–
M (natural mortality)	L	1	0.01–0.35	0.12	–	0.15
Initial exploitation rate	U	2	0.00–0.99	–	–	–
Recruitment deviations	N [1]	72	-2.3–2.3	0	0.4	
ln(*qCPUE*)	U	2	-25–0	–	–	–
Increment at TW=50 (male & female)	U	4	1–20	–	–	–
ratio of TW=80 increment at TW=50 (male & female)	U	4	0.001–1.000	–	–	–
shape of growth curve (male & female)	U	4	0.1–15.0	–	–	–
TW at 50% probability female maturation	U	2	30–80	–	–	–
difference between TWs at 95% and 50% probability female maturation	U	2	5–60	–	–	–
Relative vulnerability (all sexes and seasons)	U	8	0.01–1.0	–	–	–
Shape of selectivity left limb (males & females)	U	6	1–50	–	–	–
Size at maximum selectivity (males & females)	U	6	30–70	–	–	–
Shape of growth density-dependence	U	2	0–1	–	–	–
Movement parameters	U	26	0.00–0.15	–	–	–

[1] Normal in natural log space = lognormal (bounds equivalent to –10 to 10)

Table 42: Fixed values used in base case assessment for CRA 7 and CRA 8

Value	CRA 7	CRA 8
Shape parameter for CPUE vs biomass	1.0	1.0
Minimum std. dev. of growth increment	0.9	0.9
Std. dev. of observation error of increment	0.5	0.5
Handling mortality	10%	10%
Process error for CPUE	0.25	0.25
Year of selectivity change	1993	1993
Current male size limit (mm TW)	47	54
Current female size limit (mm TW)	49	57
First year for recruitment deviations	1974	1974
Last year for recruitment deviations	2009	2009
Relative weight for length frequencies	1.2	1.2
Relative weight for CPUE	1.4	1.4
Relative weight for tag-recapture data*	0.5	0.5

*for CRA 7 the weight for tag-recapture data was increased by doubling the dataset

Model projections

Bayesian estimation procedures were used to estimate the uncertainty in model estimates and short-term projections. This procedure was conducted in the following steps:

1. Model parameters were estimated by AD Model Builder™ using maximum likelihood and the prior probabilities. The point estimates are called the MPD (mode of the joint posterior) estimates;
2. Samples from the joint posterior distribution of parameters were generated with Markov chain - Monte Carlo (McMC) simulations using the Hastings-Metropolis algorithm; one million simulations were made, starting from the base case MPD, and 1000 samples were saved.
3. From each sample of the posterior, 4-year projections (2012–2015) were generated using the 2011 catches, with annual recruitment randomly sampled from the model's estimated recruitments from 2000-09, and with annual movement set to its mean value.

Performance Indicators and Results

Vulnerable biomass in the assessment model was determined by the MLS, selectivity, relative sex and seasonal vulnerability and berried state for mature females. All mature females were assumed to be berried, not vulnerable to the fishery, in AW and not berried, thus vulnerable, in SS.

Agreed indicators are summarised in Table 43. The WG agreed that *Bmsy* and *SSB* indicators were not useful for CRA 7 because of the high level of out-migration estimated for this stock, and that *Bref* (mean biomass for 1979-81) should replace *Bmsy* for CRA 7. This implied that the soft and hard limits for CRA 7 should be 50% *Bref* and 25% *Bref* respectively.

For CRA 7, base case results (Figure 18 and Table 44) suggested that AW biomass decreased to a low point in 1997, increased to a high in 2009 and since then has decreased again. *Bcurrent* is just below *Bref*. Median projected biomass is 25% greater than current biomass at the level of current catches over the next 4 years. Neither current nor projected biomass is anywhere near the soft limit.

For CRA 8, base case results (Figure 19 and Table 45) suggested that AW biomass decreased to a low point in 1990, remained relatively low until 2000, then increased strongly to a high in 2009 and subsequently has decreased but remains relatively high. *Bcurrent* is well above both *Bmsy* and *Bref* (mean biomass for 1979-81). Biomass is projected to decrease by a median of 16% in four years at the current level of catches, but is projected to remain well above both *Bref* and *Bmsy*. Spawning biomass is a high proportion – more than 70% – of the unfished level. Neither current nor projected biomass is anywhere near the soft limit.

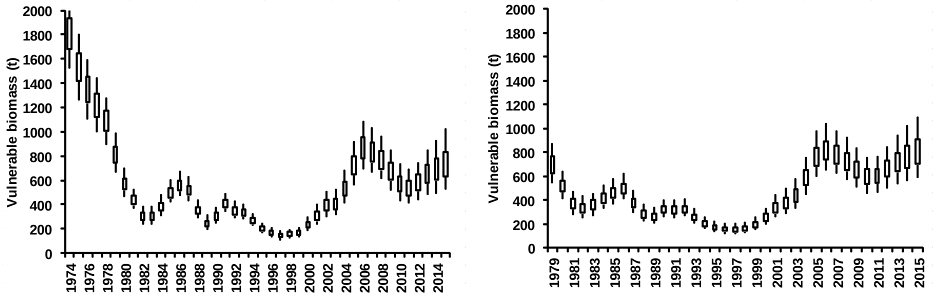


Figure 18: Posterior distributions of the CRA 7 base case McMC vulnerable biomass trajectory (left AW, right SS). Before 1979 there was a single time step, shown in AW. For each year the box spans the 25th and 75th quantiles and the whiskers span the 5th and 95th quantiles.

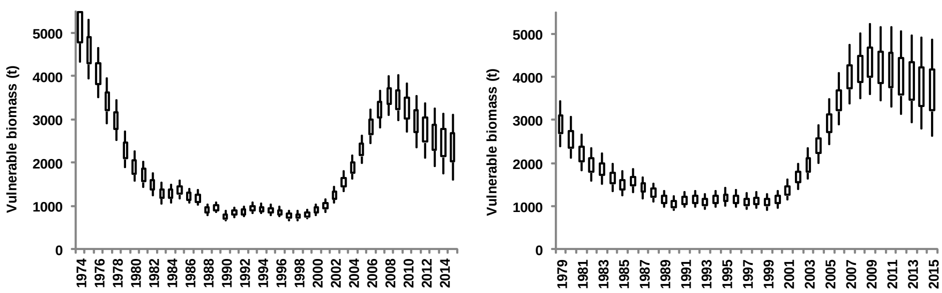


Figure 19: Posterior distributions of the CRA 8 base case McMC vulnerable biomass trajectory (left AW, right SS). Before 1979 there was a single time step, shown in AW. For each year the box spans the 25th and 75th quantiles and the whiskers span the 5th and 95th quantiles.

Table 43: Performance indicators used in the CRA 7 and CRA 8 stock assessments

Reference points	
Bmin	The lowest beginning AW vulnerable biomass in the series
Bcurrent	Beginning of season AW vulnerable biomass for the year the stock assessment is performed
Bref	Beginning of AW season mean vulnerable biomass for 1979–81
Bproj	Projected beginning of season AW vulnerable biomass (ie, the year of stock assessment plus 4 years)
Bmsy	Beginning of season AW vulnerable biomass associated with MSY, calculated by doing deterministic forward projections with recruitment *R0* and current fishing patterns
MSY	Maximum sustainable yield (sum of AW and SS SL catches) found by searching a across a range of multipliers on *F*.
Fmult	The multiplier that produced *MSY*
SSBcurr	Current spawning stock biomass at start of AW season
SSBproj	Projected spawning stock biomass at start of AW season
SSBmsy	Spawning stock biomass at start of AW season associated with *MSY*
CPUE indicators	
CPUEcurrent	CPUE at *Bcurrent*
CPUEproj	CPUE at *Bproj*
CPUEmsy	CPUE at *Bmsy*
Performance indicators	
Bcurrent / Bmin	ratio of *Bcurrent* to *Bmin*
Bcurrent / Bref	ratio of *Bcurrent* to *Bref*
Bcurrent / Bmsy	ratio of *Bcurrent* to *Bmsy*
Bproj / Bcurrent	ratio of *Bproj* to *Bcurrent*
Bproj / Bref	ratio of *Bproj* to *Bref*
Bproj / Bmsy	ratio of *Bproj* to *Bmsy*
SSBcurr/SSB0	ratio of *SSBcurrent* to *SSB0*
SSBproj/SSB0	ratio of *SSBproj* to *SSB0*
SSBcurr/SSBmsy	ratio of *SSBcurrent* to *SSBmsy*
SSBproj/SSBmsy	ratio of *SSBproj* to *SSBmsy*
SSBproj/SSBcurr	ratio of *SSBproj* to *SSBcurrent*
USLcurrent	The current exploitation rate for SL catch in AW
USLproj	Projected exploitation rate for SL catch in AW
USLproj/USLcurrent	ratio of SL projected exploitation rate to current SL exploitation rate
Probabilities	
P*(Bcurrent > Bmin)*	probability *Bcurrent* > *Bmin*
P*(Bcurrent > Bref)*	probability *Bcurrent* > *Bref*
P*(Bcurrent > Bmsy)*	probability *Bcurrent* > *Bmsy*
P*(Bproj > Bmin)*	probability *Bproj* > *Bmin*
P*(Bproj > Bref)*	probability *Bproj* > *Bref*
P*(Bproj > Bmsy)*	probability *Bproj* > *Bmsy*
P*(Bproj > Bcurrent)*	probability *Bproj* > *Bcurrent*
P*(SSBcurr>SSBmsy)*	probability *SSBcurr>SSBmsy*
P*(SSBproj>SSBmsy)*	probability *SSBproj>SSBmsy*
P*(USLproj>USLcurr)*	probability SL exploitation rate *proj* > SL exploitation rate *current*
P*(SSBcurr<0.2SSB0)*	soft limit CRA 8: probability *SSBcurrent* < 20% *SSB0*
P*(SSBproj<0.2SSB0)*	soft limit CRA 8: probability *SSBproj* < 20% *SSB0*
P*(SSBcurr<0.1SSB0)*	hard limit CRA 8: probability *SSBcurrent* < 10% *SSB0*
P*(SSBproj<0.1SSB0)*	hard limit CRA 8: probability *SSBproj* < 10% *SSB0*
P(*Bcurr*<50%*Bref*)	soft limit CRA 7: probability *Bcurr* < 50% *Bref*
P(*Bcurr*<25%*Bref*)	hard limit CRA 7: probability *Bcurr* < 25% *Bref*
P(*Bproj*<50%*Bref*)	soft limit (CRA 7): probability *Bproj* < 50% *Bref*
P(*Bproj*<25%*Bref*)	hard limit (CRA 7):probability *Bproj*< 25% *Bref*

MCMC sensitivity trials were also made:
TwoMs: estimating separate natural mortality for CRA 7 and CRA 8
Moves5% and *Moves25%*: capping seasonal movements at 5% and 25%
FlatRec: using an alternative constant recreational catch vector, not proportional to abundance
FixShape: with growth shape fixed at 2
noDD: with no growth density-dependence

Results from the base case and sensitivity trials are compared in Table 44 for CRA 7 and Table 45 for CRA 8.

Table 44: Assessment results: median and probability indicators for CRA 7 from the base case McMC and sensitivity trials; biomass in tonnes and CPUE in kg/pot. Probabilities involving the *Bref* hard and soft limits were not calculated when the sensitivity trials were done, but are shown for the base case (last four rows).

indicator	base	TwoMs	Moves5%	Moves25%	FlatRec	FixShape	NoDD
Bmin	147.8	155.5	2815.9	127.0	170.7	160.6	151.8
Bcurr	599.5	599.6	8147.0	504.1	659.9	612.4	573.4
Bref	616.3	633.1	7047.3	447.4	669.6	n.a.	613.1
Bproj	754.8	727.2	8456.1	659.8	796.8	744.5	717.9
Bmsy	217.4	203.5	5187.6	172.7	215.6	202.5	206.1
MSY	154.1	165.0	461.0	177.9	177.7	174.4	175.1
Fmult	10.1	12.7	15.2	15.2	15.2	15.2	13.2
SSBcurr	99.5	128.1	2373.7	120.3	161.4	166.1	174.4
SSBproj	138.1	155.9	1863.0	142.0	186.6	188.3	192.2
CPUEcurrent	1.0	0.9	0.9	0.8	0.9	0.9	0.9
CPUEproj	1.294	1.183	0.839	1.220	1.178	1.166	1.174
CPUEmsy	0.275	0.225	0.501	0.191	0.223	0.215	0.232
Bcurr/Bmin	4.057	3.863	2.880	3.972	3.874	3.822	3.788
Bcurr/Bref	0.972	0.944	1.159	1.123	0.982	n.a.	0.929
Bproj/Bcurr	1.251	1.200	1.028	1.295	1.198	1.200	1.233
Bproj/Bref	1.225	1.145	1.209	1.475	1.193	n.a.	1.160
USLcurrent	0.067	0.066	0.004	0.081	0.059	0.064	0.069
USLproj	0.077	0.080	0.007	0.089	0.076	0.078	0.081
USLproj/USLcurrent	1.155	1.227	1.654	1.084	1.301	1.244	1.198
P(*Bcurr*>*Bmin*)	1.000	1.000	1.000	1.000	1.000	1.000	1.000
P(*Bcurr*>*Bref*)	0.382	0.299	0.912	0.124	0.438	n.a.	0.276
P(*Bproj*>*Bmin*)	1.000	1.000	1.000	1.000	1.000	1.000	1.000
P(*Bproj*>*Bref*)	0.866	0.782	0.799	0.776	0.830	n.a.	0.783
P(*Bproj*>*Bcurr*)	0.975	0.926	0.549	0.966	0.894	0.900	0.947
P(*USLproj*>*USLcurr*)	0.811	0.891	0.951	0.686	0.944	0.885	0.830
P(*Bcurr*<*0.5Bref*)	0.000	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
P(*Bproj*<*0.5Bref*)	0.000	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
P(*Bcurr*<*0.25Bref*)	0.000	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
P(*Bproj*<*0.25Bref*)	0.000	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Table 45: Assessment results: median and probability indicators for CRA 8 from base case McMC and sensitivity trials; biomass in tonnes and CPUE in kg/pot.

indicator	base	TwoMs	Moves5%	Moves25%	FlatRec	FixShape	NoDD
Bmin	734.2	721.7	775.0	722.5	731.0	704.1	964.8
Bcurr	2758.2	2767.3	3013.0	2837.2	2875.1	2761.4	4378.0
Bref	1970.1	1922.8	2033.7	1566.6	1905.9	n.a.	2432.2
Bproj	2303.7	2360.5	2580.1	2482.2	2452.6	2378.2	4176.3
Bmsy	1221.2	1361.4	1203.4	1297.8	1320.8	1328.2	2180.6
MSY	1136.1	1151.2	1146.2	1127.2	1128.7	1122.8	1224.1
Fmult	2.0	1.7	2.3	1.8	2.0	1.7	1.6
SSBcurr	4532.0	4828.0	5458.7	4945.1	4799.6	4512.6	5498.4
SSBproj	4526.0	4994.2	5467.0	5166.1	5024.2	4668.1	5725.7
SSBmsy	2130.4	2723.0	2373.8	2651.3	2604.9	2578.5	3459.1
CPUEcurrent	2.7	2.8	2.9	2.8	2.8	2.8	3.1
CPUEproj	2.004	2.115	2.188	2.230	2.142	2.155	2.817
CPUEmsy	0.896	1.082	0.845	1.024	1.000	1.069	1.353
Bcurr/Bmin	3.712	3.838	3.900	3.924	3.912	3.924	4.519
Bcurr/Bref	1.385	1.445	1.488	1.806	1.498	n.a.	1.797
Bcurr/Bmsy	2.247	2.027	2.505	2.175	2.192	2.055	2.000
Bproj/Bcurr	0.843	0.850	0.854	0.865	0.851	0.856	0.942
Bproj/Bref	1.165	1.233	1.270	1.570	1.266	n.a.	1.698
Bproj/Bmsy	1.885	1.728	2.144	1.896	1.865	1.763	1.914
SSBcurr/SSB0	0.713	0.660	0.900	0.688	0.688	0.725	0.452
SSBproj/SSB0	0.712	0.685	0.900	0.717	0.721	0.752	0.476
SSBcurr/SSBmsy	2.13	1.77	2.31	1.87	1.84	1.75	1.56
SSBproj/SSBmsy	2.12	1.84	2.32	1.95	1.92	1.81	1.64
SSBproj/SSBcurr	1.000	1.039	1.001	1.046	1.046	1.040	1.045
USLcurrent	0.218	0.218	0.198	0.214	0.211	0.220	0.143
USLproj	0.280	0.274	0.250	0.260	0.276	0.272	0.155
USLproj/USLcurrent	1.282	1.255	1.266	1.228	1.315	1.244	1.095
P(*Bcurr*>*Bmin*)	1.000	1.000	1.000	1.000	1.000	1.000	1.000
P(*Bcurr*>*Bref*)	0.991	0.998	1.000	1.000	1.000	1.000	1.000
P(*Bcurr*>*Bmsy*)	1.000	1.000	1.000	1.000	1.000	1.000	0.998
P(*Bproj*>*Bmin*)	1.000	1.000	1.000	1.000	1.000	1.000	1.000
P(*Bproj*>*Bref*)	0.765	0.857	0.931	0.910	0.910	n.a.	0.999
P(*Bproj*>*Bmsy*)	0.999	0.994	1.000	1.000	0.999	0.998	0.989
P(*Bproj*>*Bcurr*)	0.063	0.100	0.061	0.096	0.082	0.076	0.293
P(*SSBcurr*>*SSBmsy*)	1.000	1.000	1.000	1.000	1.000	1.000	0.970
P(*SSBproj*>*SSBmsy*)	1.000	1.000	1.000	1.000	1.000	1.000	0.985
P(*USLproj*>*USLcurr*)	0.981	0.946	0.982	0.955	0.973	0.950	0.750
P(*SSBcurr*<*0.2SSB0*)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
P(*SSBproj*<*0.2SSB0*)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
P(*SSBcurr*<*0.1SSB0*)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
P(*SSBproj*<*0.1SSB0*)	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Indicators based on vulnerable biomass (AW) and *Bmsy*

In all cases, the median *Bref* was larger than the median *Bmsy*. For CRA 8, in all trials, current and projected biomass was larger than *Bref* and *Bmsy* by substantial factors. In CRA 7, current biomass was near *Bref*, above in some trials and below in others, but in all trials projected biomass was greater than *Bref*. Projected biomass increased in nearly all runs for CRA 7; it decreased in most runs for CRA 8 but remained well above the reference levels.

Indicators based on *SSBmsy*

The historical track of biomass versus fishing intensity is shown in Figure 20 for the CRA 8 stock. The phase space in the plot shows biomass on the x-axis and fishing intensity on the y-axis. High biomass/low intensity is in the lower right-hand corner, the location of the stock when fishing first began, and low biomass/high intensity is in the upper left-hand corner, in a period when the fishery was largely uncontrolled. *Fmsy* varies among runs because of parameter variations and among years because of variation in fishing patterns, which include MLS, selectivity and the seasonal catch split. The reference *SSBmsy* in Figure 20 was calculated using the 2011 fishing pattern.

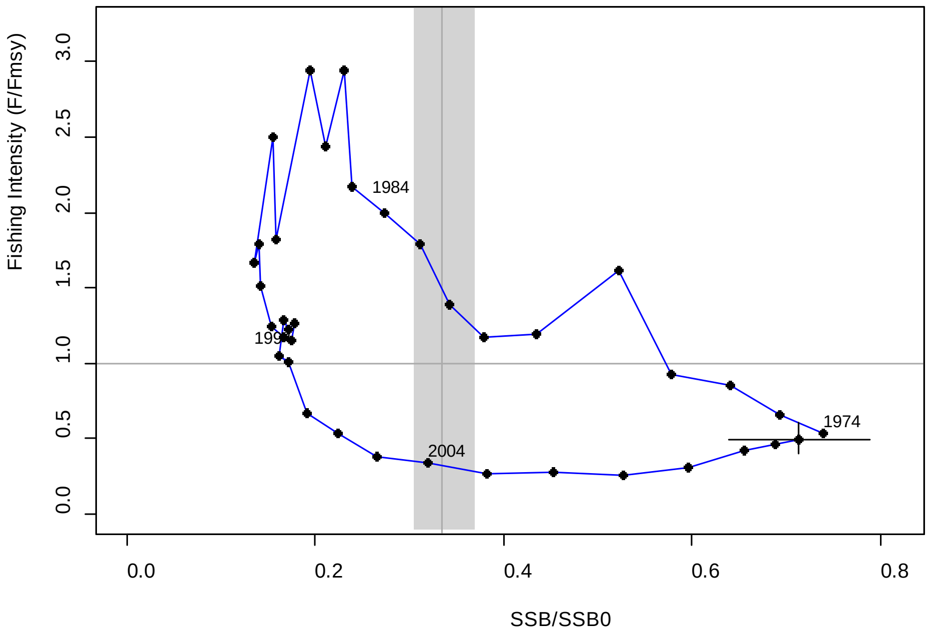


Figure 20: "Snail trail" that summarises the *SSB* history of the CRA 8 stock. The phase space in the plot is defined by biomass on the abscissa and fishing intensity on the ordinate. High biomass/low intensity is in the lower right-hand corner, the location of the stock in 1974, and low biomass/high intensity is in the upper left-hand corner, in a period when the fishery was loosely controlled. The x-axis is spawning stock biomass *SSB* in each year as a proportion of the unfished spawning stock, *SSB0*. *SSB0* is constant for all years of a run, but varies through the 1000 runs. The y-axis is fishing intensity in each year as a proportion of the fishing intensity (*Fmsy*) that would have given *MSY* under the fishing patterns in that year. *Fmsy* between years because fishing patterns change: fishing patterns include MLS, selectivity, the seasonal catch split and the balance between SL and NSL catches; and varies between runs within a year because the parameter vectors vary. *Fmsy* was calculated with a 50-year projection for each year in each run, with the NSL catch held constant at that year's value, deterministic recruitment at *R0* and a range of multipliers on the SL catch *F*s estimated for that year. Each point on the figure shows the median of the posterior distributions of biomass ratio and fishing intensity ratio for one year. The vertical line in the figure is the median (line) and 90% interval (shading) of the posterior distribution of *SSBmsy* ; this ratio was calculated using the fishing pattern in 2011. The horizontal line in the figure is drawn at 1, the fishing intensity associated with *Fmsy*. The bars at the final year of the plot (2011) show the 90% intervals of the posterior distributions of biomass ratio and fishing intensity ratio.

Fmsy was calculated with a 50-year projection for each year in each run, with the NSL catch held constant at that year's value, deterministic recruitment at *R0* and a range of multipliers on the SL catch *F*s estimated for year *y*. The *F* (actually separate *F*s for two seasons) that gives *MSY* is

Fmsy and the multiplier is *Fmult*. Each point on the figure was plotted as the median of the posterior distributions of biomass ratio and fishing intensity ratio.

The silvery trail suggests that the CRA 8 stock was above *Bmsy* and was fished at below *Fmsy* in 1974; that fishing intensity increased and biomass decreased to overfishing and overfished levels; and that biomass has been above *Bmsy* since 2004 and fishing intensity below *Fmsy* since 2000.

No corresponding figure is available for CRA 7 because of the WG's determination that *Bmsy* and *SSB* indicators are not useful for that stock.

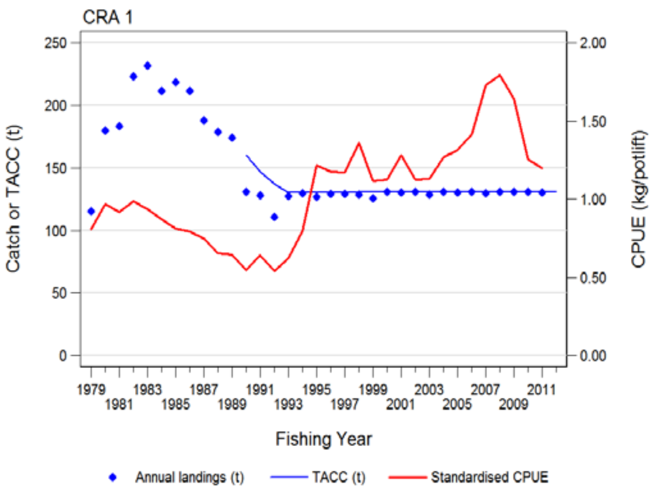
7. STATUS OF THE STOCKS

For the purposes of stock assessment and management, rock lobsters are assumed to constitute separate Fishstocks within each CRA QMA area. There is likely to be some degree of relationship and/or exchange between Fishstocks in these CRA areas, either as a result of migration, larval dispersal or both.

7.1 *Jasus edwardsii*, Northland (CRA 1) and Bay of Plenty (CRA 2)

CRA 1 Northland

Stock Status	
Year of Most Recent Assessment	2002
Assessment Runs Presented	Base case and 2 sensitivity runs
Reference Points	Target: Not established (reported against *Bref*) *Bref*: mean of beginning AW vulnerable biomass for the period 1979-88 Soft limit: 20% SSB_0 (default) Hard limit: 10% SSB_0 (default)
Status in relation to Target	Biomass in 2002 was 150% of *Bref*
Status in relation to Limits	Unknown
Historical Stock Status Trajectory and Current Status	



Annual landings, TACC and standardised CPUE for CRA1 from 1979 to 2011

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Standardised CPUE increased steadily from 2003 to 2008, but dropped between 2008 and 2010, with the 2011 index very similar to the 2010 index
Recent Trend in Fishing	Unknown

Mortality or Proxy	
Other Abundance Indices	
Trends in Other Relevant Indicators or Variables	
Projections and Prognosis	
Stock Projections or Prognosis	5 year forward projections conducted in 2002 using 2002 levels of commercial, customary, non-commercial and illegal catches showed that the stock would remain at a similar level.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology		
Assessment Type	Level 1 Quantitative Assessment model	
Assessment Method	Bayesian length based model	
Main data inputs	CPUE, length frequency data, tagging data	
Period of Assessment	Latest assessment: 2002	Next assessment: Unknown
Changes to Model Structure and Assumptions		
Major Sources of Uncertainty	Non-commercial catch	

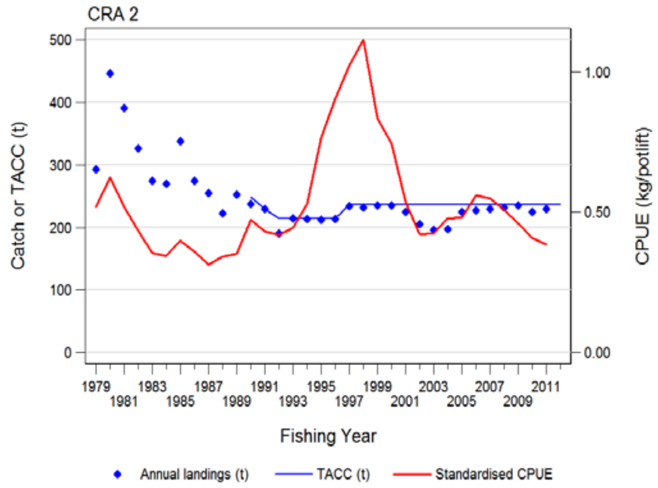
Qualifying Comments
CPUE rose nearly 50% after the 2002 assessment to the highest in the series in 2008, but has since dropped about 20% from that peak.

Fishery Interactions

CRA 2 Bay of Plenty

Stock Status	
Year of Most Recent Assessment	2002
Assessment Runs Presented	Base case and 2 sensitivity runs
Reference Points	Target: Not established (reported against *Bref*) *Bref*: mean of beginning AW vulnerable biomass for the period 1979-88 Soft limit: 20% SSB_0 (default) Hard limit: 10% SSB_0 (default)
Status in relation to Target	Biomass in 2002 was 150% of *Bref*
Status in relation to Limits	Unknown

Historical Stock Status Trajectory and Current Status



Annual landings, TACC and standardised CPUE for CRA2 from 1979 to 2011

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	After peaking at more than 1.0 kg/potlift in 1998, standardised CPUE has declined and dropped to below 0.5 kg/potlift from 2009.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	
Trends in Other Relevant Indicators or Variables	

Projections and Prognosis		
Stock Projections or Prognosis	5 year forward projections conducted in 2002 using 2002 levels of commercial, customary, non-commercial and illegal catches showed that the stock would remain at a similar level.	
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown	
Assessment Methodology		
Assessment Type	Level 1 Quantitative Assessment model	
Assessment Method	Bayesian length based model	
Main data inputs	CPUE, length frequency data, tagging data	
Period of Assessment	Latest assessment: 2002	Next assessment: Unknown
Changes to Model Structure and Assumptions		
Major Sources of Uncertainty	Non-commercial catch	

Qualifying Comments
CPUE in the last 3 years has been below 0.5 kg/potlift and CPUE in 2010 and 2011 are the lowest since the escape gap regulations changed in 1993.

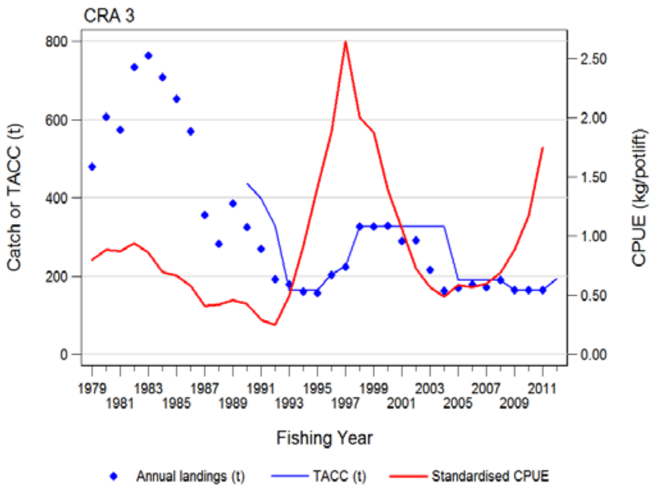
Fishery Interactions

7.2 *Jasus edwardsii*, Gisborne (CRA 3), Wairarapa – Hawkes Bay (CRA 4) and Marlborough - Kaikoura (CRA 5)

CRA 3 Gisborne

Stock Status	
Year of Most Recent Assessment	2008
Assessment Runs Presented	Base case and 13 MPD sensitivity runs
Reference Points	Target: reported against B_{MSY} B_{MSY}: AW vulnerable biomass associated with MSY (maximum SL catch summed across AW and SS) Limit: reported against B_{MIN} B_{MIN}: minimum AW vulnerable biomass, 1945–2007 Soft limit: 20% SSB_0 (default) Hard limit: 10% SSB_0 (default)
Status in relation to Target	Biomass in 2008 was about half B_{MSY}, with a 0% probability of being above B_{MSY}. Virtually certain (>99%) to be below B_{MSY}
Status in relation to Limits	Biomass in 2008 was 11% above B_{MIN}, with an 82% probability of being above B_{MIN}. Likely (60–90%) to be above B_{MIN}. Status relative to hard and soft limits is unknown.

Historical Stock Status Trajectory and Current Status



Annual landings, TACC and standardised CPUE for CRA3 from 1979 to 2011

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass declined steadily from 1997 to 2003 and is increasing after several years of little change; CPUE has increased steadily in the three years since 2008 and is now about 25% below the 1997 peak.
Recent Trend in Fishing Mortality or Proxy	
Other Abundance Indices	
Trends in Other Relevant Indicators or Variables	

Projections and Prognosis	
Stock Projections or Prognosis	5 year forward projections in 2009 under 2008 levels of commercial, customary, non-commercial and illegal catches showed that the stock would decrease by 25%.
Probability of Current Catch or	Status relative to hard and soft limits at the end of the projection

TACC causing decline below Limits	period is unknown.

Assessment Methodology		
Assessment Type	Level 1 Quantitative Assessment model	
Assessment Method	Multi-stock length based model (Haist et al 2009)	
Main data inputs	CPUE, length frequency, tagging data	
Period of Assessment	Latest assessment: 2008	Next assessment: Unknown
Changes to Model Structure and Assumptions		
Major Sources of Uncertainty	Future recruitment and growth rate	

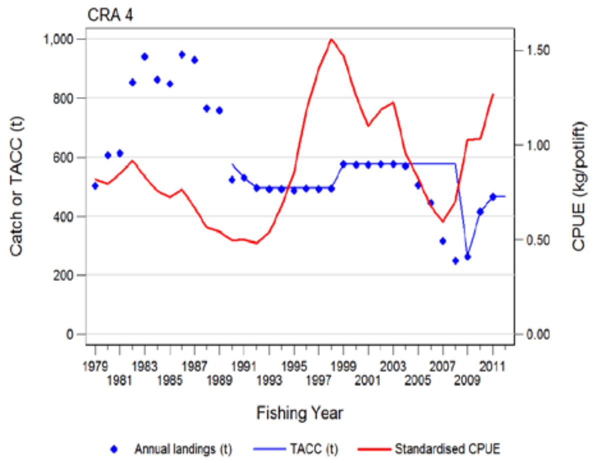
Qualifying Comments
The quality of the 2008 Markov chain–Monte Carlo simulations was poor. The running quantile plots for many estimated parameters showed a drift through the run, suggesting poor convergence, and a trend to move well away from the MPD estimate.

Recent developments in stock status
CPUE has been increasing since 2004, particularly since 2008. In 2012, the management procedure for CRA 3 proposed that the TAC be increased to 354.5 t because the standardised offset year CPUE was 2.314 kg/potlift, which is above the upper 1.08 kg/potlift threshold.
Fishery Interactions

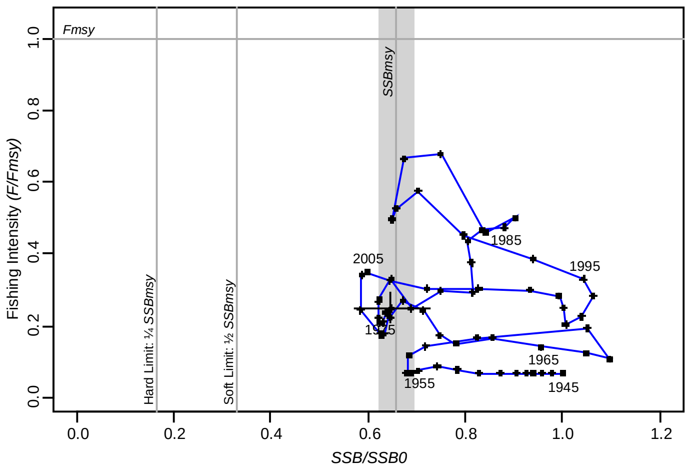
CRA 4 Wairarapa – Hawkes Bay

Stock Status	
Year of Most Recent Assessment	2011
Assessment Runs Presented	Base case and 6 MCMC sensitivity runs
Reference Point	Target: Not established (reported against *Bref* and SSB_{MSY}) *Bref*: mean of beginning AW vulnerable biomass for the period 1979-88 SSB_{MSY}: mature female biomass associated with B_{MSY} Soft limit: 20% SSB_0 (default) Hard limit: 10% SSB_0 (default)
Status in relation to Target	Biomass in 2010 was about 1.7 times *Bref*. Virtually certain (>99%) to be above *Bref* SSB_{2010} = 0.98 SSB_{MSY}. About as Likely as Not (40-60%) to be above SSB_{MSY}
Status in relation to Limits	Exceptionally Unlikely (<1%) to be below the soft and hard limits

Historical Stock Status Trajectory and Current Status



Annual landings, TACC and standardised CPUE for CRA4 from 1979 to 2011



"Snail trail" that summarises the history of the CRA 4 fishery. The x-axis is the spawning biomass (*SSB*) as a proportion of SSB_0; the y-axis is the ratio of the fishing intensity (*F*) relative to F_{MSY}. Each point is the median of the posterior distributions, and the bars associated with 2010 show the 90% confidence intervals. The vertical reference lines shows SSB_{MSY} as a proportion of SSB_0 (with the grey band indicating the 90% confidence interval), the default soft limit: ½ SSB_{MSY} and the default hard limit: ¼ SSB_{MSY}. The horizontal reference line is F_{MSY}

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass decreased in two steps from a peak in 1997 to a low in 2007, but increased between 2008 and 2010 to a level similar to that observed in 2004; the 2011 CPUE increased again to a level similar to 2001 to 2003.
Recent Trend in Fishing Mortality or Proxy	Fishing intensity increased from a low observed in 2007 but was well below F_{MSY} in 2010
Other Abundance Indices	None
Trends in Other Relevant Indicators or Variables	Recent average 14-year puerulus settlement index is low relative to the long-term (32-year) mean index.

Projections and Prognosis	
Stock Projections or Prognosis	4-year forward projections conducted in 2011 using 2010 levels of commercial, customary, non-commercial and illegal catches showed that the stock would decrease, but remain well above *Bref*. Virtually certain (>99%) to remain above *Bref*.
Probability of Current Catch or	Exceptionally unlikely (<1%) to fall below the soft and hard limits

TACC causing decline below Limits	at the end of the projection period.

Assessment Methodology		
Assessment Type	Level 1 Quantitative Assessment model	
Assessment Method	Bayesian length based model	
Main data inputs	CPUE, length frequency, tagging data, puerulus settlement indices	
Period of Assessment	Latest assessment: 2011	Next assessment: Unknown
Changes to Model Structure and Assumptions	Addition of fitting to puerulus settlement indices	
Major Sources of Uncertainty	Level of non-commercial catches, illegal catches, modelling of growth, estimation of productivity , vulnerability of immature females.	

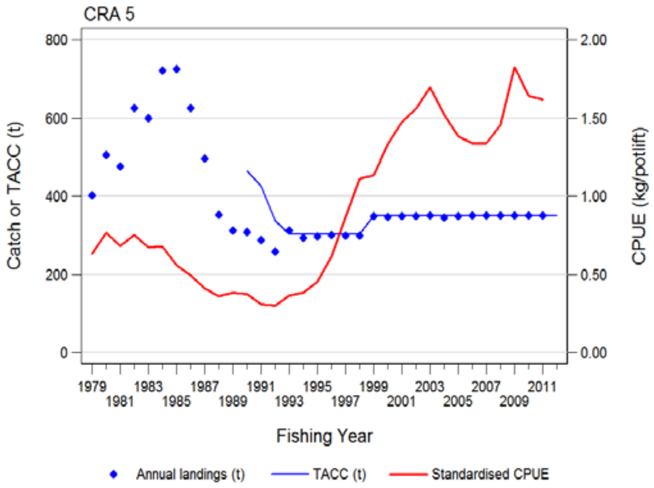
Qualifying Comments
A new management procedure has been developed, based on the 2011 assessment

Fishery Interactions
Potting is the main method of targeting rock lobster and is thought to have little direct effect on non-target species. For all QMAs, the most frequently reported incidental species caught are, in decreasing order of catch across all stocks: octopus, conger eel, blue cod, trumpeter, sea perch, red cod, butterfish and leatherjackets. However, these comprise less than 10% of the rock lobster catch.

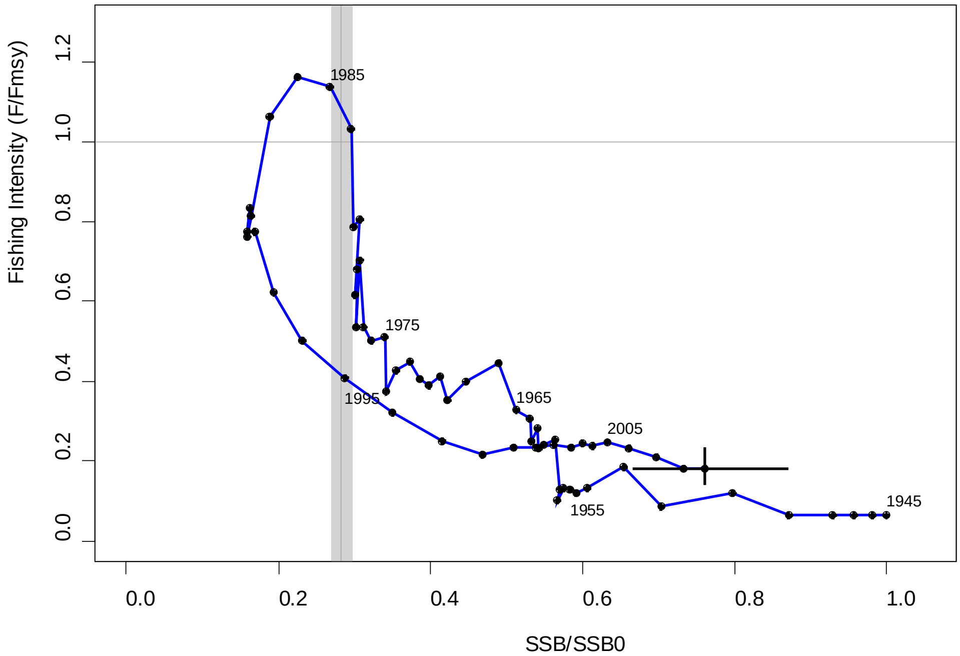
CRA 5 Marlborough - Kaikoura

Stock Status	
Year of Most Recent Assessment	2010
Assessment Runs Presented	Base case
Reference Points	Target: Not established (reported against *Bref* and SSB_{MSY}) *Bref*: mean of beginning AW vulnerable biomass for the period 1979-88 SSB_{MSY}: mature female biomass associated with B_{MSY} Soft limit: 20% SSB_0 (default) Hard limit: 10% SSB_0 (default)
Status in relation to Target	B_{2009} = 3.0 *Bref*. Virtually certain (>99%) to be above *Bref* SSB_{2009} = 4.6 SSB_{MSY}. Virtually certain (>99%) to be above SSB_{MSY}
Status in relation to Limits	Exceptionally unlikely (<1%) to fall below the soft and hard limits.

Historical Stock Status Trajectory and Current Status



Annual landings, TACC and standardised CPUE for CRA5 from 1979 to 2011



"Snail trail" that summarises the history of the CRA 5 fishery. The x-axis is the spawning biomass (*SSB*) as a proportion of B_0 (SSB_0); the y-axis is the ratio of the fishing intensity (*F*) relative to F_{MSY}. Each point is the median of the posterior distributions, and the bars associated with 2009 show the 90% confidence intervals. The vertical reference line shows SSB_{MSY} as a proportion of *SSB0*, with the grey band indicating the 90% confidence interval. The horizontal reference line is F_{MSY}

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE dropped in 2010 and 2011 from 2009, the highest level observed in the 33 year series, after a short period of decline in the mid-2000s.
Recent Trend in Fishing Mortality or Proxy	Fishing mortality declined substantially after CRA 5 entered the QMS, and was at its lowest level in 2009 since that introduction. Fishing intensity in 2009 is equivalent to the level observed in 1952.
Other Abundance Indices	None
Trends in Other Relevant Indicators or Variables	The 2009 puerulus (settlement) index is about 1/3 average. However, average settlement over the past 10 years has been near

	the long-term average.

Projections and Prognosis		
Stock Projections or Prognosis	5 year forward projections from 2010 under 2009 levels of commercial, customary, illegal catches and 2 alternative recreational catches catch levels (155 t and 112 t) showed that the biomass would decrease, but remain well above *Bref* and B_{MSY}.	
Probability of Current Catch or TACC causing decline below Limits	Exceptionally unlikely (<1%) to fall below the soft and hard limits at the end of the projection period.	
Assessment Methodology		
Assessment Type	Level 1 Quantitative Assessment model	
Assessment Method	Bayesian length based model	
Main data inputs	CPUE, length frequency, tagging data, puerulus data	
Period of Assessment	Latest assessment: 2010	Next assessment: Unknown
Changes to Model Structure and Assumptions	Revised growth model, addition of puerulus data.	
Major Sources of Uncertainty	Level of non-commercial catches, illegal catches, modelling of growth, estimation of productivity .	

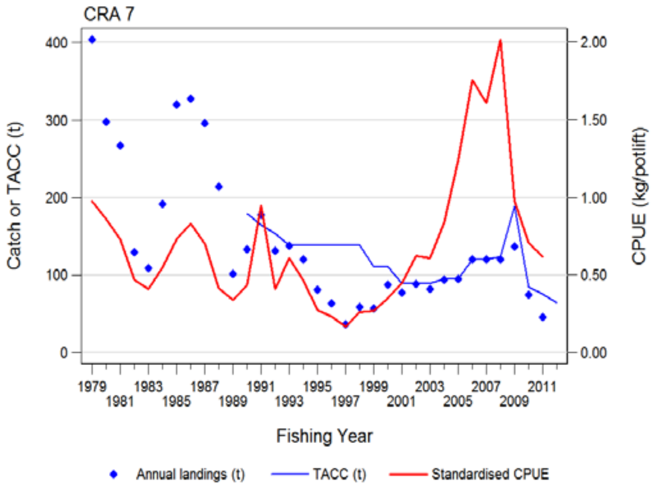
Qualifying Comments
A management procedure has been developed that may be used to manage the fishery in the future.

Recent developments in stock status
CPUE dropped in 2010 and 2011 from 2009, the highest point in the series.

Fishery Interactions
Potting is the main method of targeting rock lobster and is thought to have very little direct effect on non-target species. For all QMAs, the most frequently reported incidental species caught are, in decreasing order of catch across all stocks: octopus, conger eel, blue cod, trumpeter, sea perch, red cod, butterfish and leatherjackets. However, these generally comprise less than 10% of the rock lobster catch.

CRA 7 Otago

Stock Status	
Year of Most Recent Assessment	2012
Assessment Runs Presented	Base case and 6 MCMC sensitivity runs
Reference Point	Target: Not established (reported against *Bref*) *Bref*: mean of beginning AW vulnerable biomass for the period 1979-81 SSB_{MSY}: the RLFAWG considered this reference level meaningless, given the high level of estimated out-migration from CRA 7 Soft limit: ½**Bref* (default) Hard limit: ¼**Bref* (default)
Status in relation to Target	Biomass in 2011 was near *Bref*. About as Likely as Not (40-60%) to be above *Bref*
Status in relation to Limits	Unlikely (<40%) to be below the hard limit

Historical Stock Status Trajectory and Current Status

Annual landings, TACC and standardised CPUE for CRA 7 from 1979 to 2011

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass decreased to a low point in 1997, after which it increased to a level nearly 10 times greater than the 1997 low in 2006 and again in 2008; biomass levels have since decreased to a level 3 to 4 times the 1997 minimum
Recent Trend in Fishing Mortality or Proxy	Fishing mortality trended downward from the mid-1990s, except for a short period of increase in the late 2000s, caused by higher TACCs raised in response to increased abundance
Other Abundance Indices	None
Trends in Other Relevant Indicators or Variables	Recent puerulus settlement indices near long-term (22-year) mean index

Projections and Prognosis	
Stock Projections or Prognosis	4-year forward projections beginning in 2012 using 2011 levels of commercial, customary, non-commercial and illegal catches showed that the stock would remain stable and above *Bref*. Likely (>60%) to remain above *Bref*.
Probability of Current Catch or TACC causing decline below Limits	Unlikely (<40%) to fall below the hard limit during the projection period.

Assessment Methodology		
Assessment Type	Level 1 Quantitative Assessment model	
Assessment Method	Bayesian length based model	
Main data inputs	CPUE, length frequency, tagging data	
Period of Assessment	Latest assessment: 2012	Next assessment: Unknown
Changes to Model Structure and Assumptions	Average movement used for years without movement estimated; Francis (2011) weights for composition data; change in tag recapture likelihood; density-dependent growth;	
Major Sources of Uncertainty	Level of non-commercial catches, illegal catches, modelling of growth, estimation of productivity , vulnerability of immature females.	

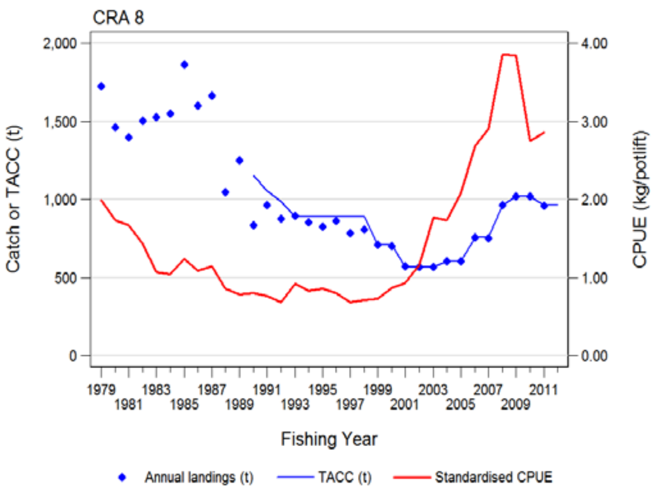
Qualifying Comments
A new management procedure has been developed, based on the 2012 assessment

Fishery Interactions
Potting is the main method of targeting rock lobster and is thought to have little direct effect on non-target species. For all QMAs, the most frequently reported incidental species caught are, in decreasing order of catch across all stocks: octopus, conger eel, blue cod, trumpeter, sea perch, red cod, butterfish and leatherjackets. However, these comprise less than 10% of the rock lobster catch.

CRA 8 Stewart Island – Fiordland

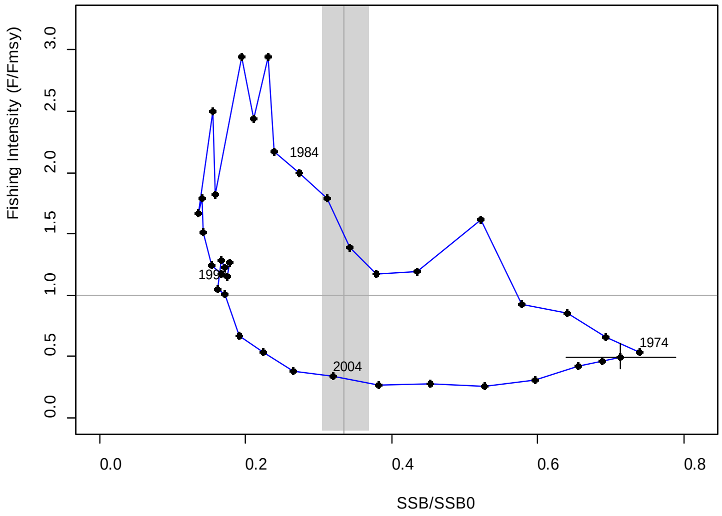
Stock Status	
Year of Most Recent Assessment	2012
Assessment Runs Presented	Base case and 6 MCMC sensitivity runs
Reference Point	Target: Not established (reported against *Bref* and SSB_{MSY}) *Bref*: mean of beginning AW vulnerable biomass for the period 1979-85 SSB_{MSY}: mature female biomass associated with B_{MSY} Soft limit: 20% SSB_0 (default) Hard limit: 10% SSB_0 (default)
Status in relation to Target	Biomass in 2011 was about 1.4 times *Bref*. Very Likely (>90%) to be above *Bref*
Status in relation to Limits	Exceptionally Unlikely (<1%) to be below the soft and hard limits

Historical Stock Status Trajectory and Current Status



Annual landings, TACC and standardised CPUE for CRA 8 from 1979 to 2011

Historical Stock Status Trajectory and Current Status (continued)



"Snail trail" that summarises the history of the CRA 8 fishery. The x-axis is the spawning biomass (*SSB*) as a proportion of SSB_0; the y-axis is the ratio of the fishing intensity (*F*) relative to F_{MSY}. Each point is the median of the posterior distributions, and the bars associated with 2010 show the 90% confidence intervals. The vertical reference lines shows SSB_{MSY} as a proportion of SSB_0 (with the grey band indicating the 90% confidence interval), the default soft limit: ½ SSB_{MSY} and the default hard limit: ¼ SSB_{MSY}. The horizontal reference line is F_{MSY}

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass decreased to several low points in the 1990s, after which it increased to a level about 6 times greater than the lowest observed value in 2008 and 2009; since then, biomass levels have decreased to levels near to 5 times the minimum
Recent Trend in Fishing Mortality or Proxy	Fishing mortality trended downward from the mid-1990s to the mid-2000s, in response to reduced TACCs; since then, fishing mortality has remained stable, with higher TACCs implemented in response to increased abundance
Other Abundance Indices	None
Trends in Other Relevant Indicators or Variables	Recent puerulus settlement indices above long-term (32-year) mean index

Projections and Prognosis	
Stock Projections or Prognosis	4-year forward projections beginning in 2012 using 2011 levels of commercial, customary, non-commercial and illegal catches showed that the stock would decline, but remain well above *Bref* and *Bmsy*. Likely (>60%) to remain above *Bref*.
Probability of Current Catch or TACC causing decline below Limits	Exceptionally unlikely (<1%) to fall below the soft and hard limits at the end of the projection period.

Assessment Methodology		
Assessment Type	Level 1 Quantitative Assessment model	
Assessment Method	Bayesian length based model	
Main data inputs	CPUE, length frequency, tagging data	
Period of Assessment	Latest assessment: 2012	Next assessment: Unknown
Changes to Model Structure and Assumptions	Francis (2011) weights for composition data; change in tag recapture likelihood; density-dependent growth;	

Major Sources of Uncertainty	Level of non-commercial catches, illegal catches, modelling of growth, estimation of productivity , vulnerability of immature females.

Qualifying Comments
A new management procedure has been developed, based on the 2012 assessment

Fishery Interactions
Potting is the main method of targeting rock lobster and is thought to have little direct effect on non-target species. For all QMAs, the most frequently reported incidental species caught are, in decreasing order of catch across all stocks: octopus, conger eel, blue cod, trumpeter, sea perch, red cod, butterfish and leatherjackets. However, these comprise less than 10% of the rock lobster catch.

7.4 *Jasus edwardsii,* Chatham Islands (CRA 6)

The most recent stock assessment for CRA 6 was done in 1996, using catches and abundance indices current up to the 1995–96 fishing year. The status of this stock is uncertain. Catches were less than the TACC 1990–91 to 2004–05, but have been within 10 t of the TACC since then. CPUE showed a declining trend from 1979–80 to 1997–98, but has then increased in two stages to levels higher than seen in the early 1990s. These observations suggest a stable or increasing standing stock after an initial fishing down period. However, size frequency distributions in the lobster catch had not changed when they were examined in the mid 1990s, with a continuing high frequency of large lobsters. Large lobsters would have been expected to disappear from a stock declining under fishing pressure. This apparent discrepancy could be caused by immigration of large lobsters into the area being fished. The models investigated assume a constant level of annual productivity which is independent of the standing stock.

Commercial removals in the 2009–10 fishing year (345 t) were within the range of estimates for MCY (300–380 t), and close to the current TACC (360 t). The current TAC (370 t) lies within the range of the estimated MCY.

7.5 *Sagmariasus verreauxi***, PHC stock**

The status of this stock is unknown.

8. FOR FURTHER INFORMATION

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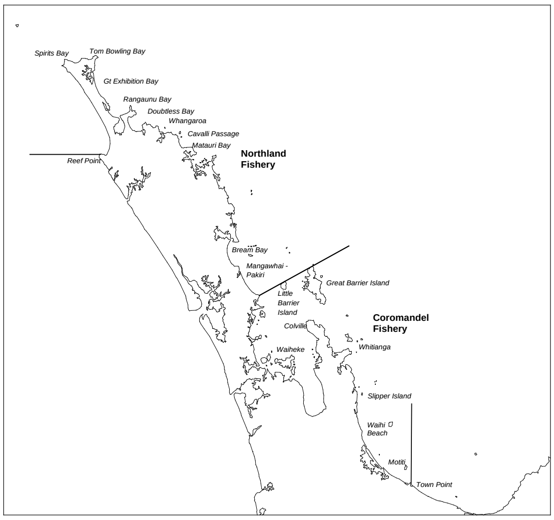
SCALLOPS NORTHLAND (SCA 1)

(*Pecten novaezelandiae*)
Kuakua, Tipa



1. FISHERY SUMMARY

Northland scallops were introduced into the QMS on 1 April 1997. The Northland TAC is 75 t, comprised of a TACC of 40 t, allowances of 7.5 t for recreational and customary fisheries, and an allowance of 20 t for other sources of mortality (Table 1; values all in meatweight).

Table 1: Total Allowable Commercial Catch (TACC, t) declared for SCA 1 since introduction into the QMS.

Year	TAC	Customary	Recreational	Other Mortality	TACC
1996 - present	75	7.5	7.5	20	40

1.1 Commercial fisheries

Scallops support regionally important commercial fisheries off the north-east coast of the North Island between Reef Point (Ahipara) and Cape Rodney, the limits of the Northland fishery. Fishing is conducted within discrete beds in Spirits Bay, Tom Bowling Bay, Great Exhibition Bay, Rangaunu Bay, Doubtless Bay, Stevenson’s Island, the Cavalli Passage, Bream Bay, and the coast between Mangawhai and Pakiri Beach. All commercial fishing is by dredge, with fishers preferring self-tipping “box” dredges to the “ring bag” designs used in Challenger and Chatham Island fisheries.

The fishing year for SCA 1 is from 1 April to 31 March. The Northland commercial scallop season runs from 15 July to 14 February. The minimum legal size (MLS) is 100 mm. Since 1980, landings have varied more than 10-fold from 80 t to over 1600 t (greenweight). The lowest recorded landings were over the last three fishing years, 2009–10 to 2011-12 (the lowest on record).

Northern scallop fisheries are managed under the QMS using individual transferable quotas (ITQ) that are proportions of the Total Allowable Commercial Catch (TACC). Catch limits and landings from the Northland fishery are shown in Table 2. Both northern scallop fisheries have been gazetted on the Second Schedule of the Fisheries Act 1996 which specifies that, for certain "highly variable" stocks, the Annual Catch Entitlement (ACE) can be increased within a fishing season. The TACC is not changed by this process and the ACE reverts to the "base" level of the TACC at the end of each season.

Table 2: Catch limits and landings (t meatweight or greenweight) from the Northland fishery since 1980. Data before 1986 are from Fisheries Statistics Unit (FSU) forms. Landed catch figures come from Quota Management Returns (QMRs), Monthly Harvest Returns (MHRs) forms, and from the landed section of Catch Effort and Landing Returns (CELRs), whereas estimated catch figures come from the effort section of CELRs and are pro-rated to sum to the total CELR landed greenweight. Catch limits for 1996 were specified on permits as meatweights, and, since 1997, were specified as a formal TACC in meatweight (Green1 assumes the gazetted meatweight recovery conversion factor of 12.5% and probably overestimates the actual greenweight taken in most years). In seasons starting in 1999 and 2000, voluntary catch limits were set at 40 and 30 t, respectively. *, split by area not available; –, no catch limits set, or no reported catch (Spirits).

								Landings (t)
	Catch limits (t)		QMR/ MHR	CELR & FSU		Scaled estimated catch (t green)		
Fishing year	Meat	Green[1]	Meat	Meat	Green	Whangarei	Far North	Spirits
1980–81	–	–	–	–	238	*	*	*
1981–82	–	–	–	–	560	*	*	*
1982–83	–	–	–	–	790	*	*	*
1983–84	–	–	–	–	1 171	78	1 093	–
1984–85	–	–	–	–	541	183	358	–
1985–86	–	–	–	–	343	214	129	–
1986–87	–	–	–	–	675	583	92	–
1987–88	–	–	–	–	1 625	985	640	–
1988–89	–	–	–	–	1 121	1 071	50	–
1989–90	–	–	–	–	781	131	650	–
1990–91	–	–	–	–	519	341	178	–
1991–92	–	–	–	168	854	599	255	–
1992–93	–	–	–	166	741	447	294	–
1993–94	–	–	–	110	862	75	787	1
1994–95	–	–	–	186	1 634	429	1 064	142
1995–96	–	–	–	209	1 469	160	810	499
1996–97	188	1 504	–	152	954	55	387	512
1997–98	188	1 504	–	144	877	22	378	477
1998–99	106	848	28	29	233	0	102	130
1999–00	106	785	22	20	132	0	109	23
2000–01	60	444	15	16	128	0	88	40
2001–02	40	320	38	37	291	14	143	134
2002–03	40	320	40	42	296	42	145	109
2003–04	40	320	38	38	309	11	228	70
2004–05	40	320	40	37	319	206	77	37
2005–06	70	560	69	68	560	559	1	0
2006–07	70	560	53	50	405	404	1	0
2007–08	40	320	33	32	242	9	197	35
2008–09	40	320	25	25	197	0	171	26
2009–10	40	320	10	10	80	0	80	0
2010–11	40	320	1	1	8	0	8	0
2011–12	40	320	2	2	16	0	16	0

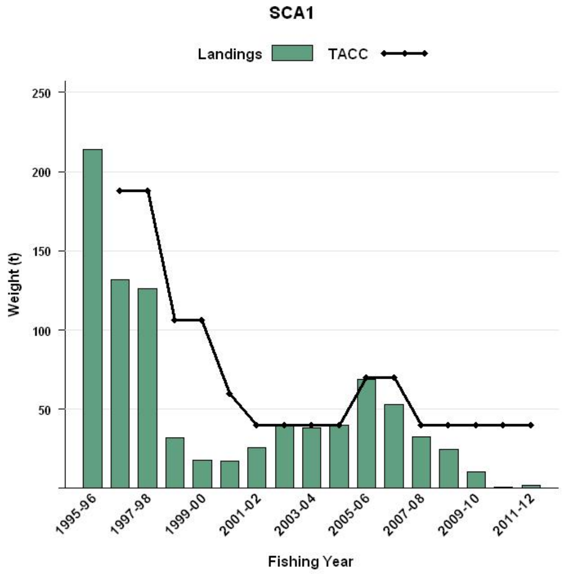


Figure 1: Landings and catch limits for SCA 1 (Northland) from 1997–98 to 2009–10. TACC refers to catch limits and 'Weight' refers to mean weight.

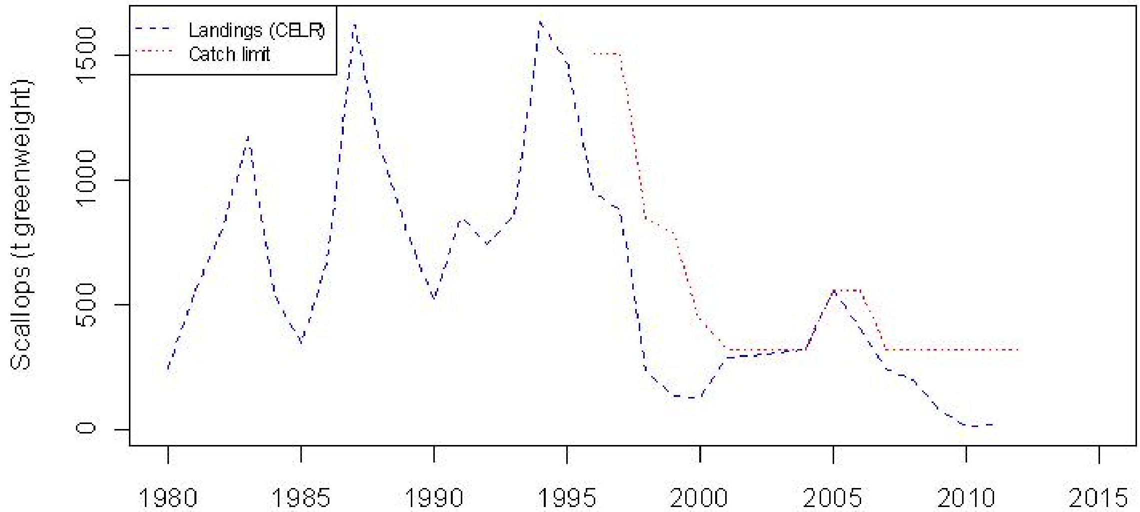


Figure 2: Catch limits and reported landings (from CELRs) in t greenweight for the SCA 1 fishery since 1980.

1.2 Recreational fisheries

There is a strong non-commercial (recreational and Maori customary) interest in scallops in suitable areas throughout the Northland fishery, mostly in enclosed bays and harbours. Scallops are usually taken by diving using snorkel or scuba, although considerable amounts are also taken using small dredges. In some areas, especially in harbours, scallops can be taken by hand from the shallow subtidal and even the low intertidal zones (on spring tides), and, in storm events, scallops can be cast onto lee beaches in large numbers. One management tool for northern scallop fisheries is the general spatial separation of commercial and amateur fisheries through the closure of harbours and enclosed waters to commercial dredging. There remain, however, areas of contention and conflict, some of which have been addressed using additional voluntary or regulated closures. Regulations governing the recreational harvest of scallops from SCA 1 include a minimum legal size of 100 mm shell length and a restricted daily harvest (bag limit) of 20 per person. A change to the recreational fishing regulations in 2005, allows divers operating from a vessel to take scallops for up to two nominated safety people on board the vessel, in addition to the catch limits for the divers. Until 2006, the recreational scallop season ran from 15 July to 14 February, but in 2007 the season was changed to run from 1 September to 31 March.

Currently, there are no reliable estimates of non-commercial harvest of scallops from the Northland fishery. Estimates of catch by recreational fishers from the two northern scallop fisheries have been made on four occasions as part of recreational fishing (telephone and diary) surveys (3). A Marine Recreational Fisheries Technical Working Group (FTWG) reviewed these surveys and recommended “that the telephone-diary estimates be used only with the following qualifications: 1) they may be very inaccurate; 2) the 1996 and earlier surveys contain a methodological error; and 3) the 1999–2000 and 2000–01 estimates are implausibly high for many important fisheries.”

Given the above concerns about the reliability of non-commercial harvest estimates, it is difficult to make comparisons between the levels of commercial and non-commercial harvest. However, recreational catch in 1993–94 from the area shared with the Northland commercial fishery was estimated at 40–60 t (Bradford 1997). Commercial landings from the Northland fishery in the most comparable period (July 1994 to February 1995 scallop season) were 1634 t, suggesting that, in that year, the recreational catch of scallops was probably 2–4% of total removals (Table 3).

Table 3: Harvest estimates (numbers, and equivalent greenweight) of scallops taken by recreational fishers in Northland (QMA 1) from the telephone-diary surveys conducted in 1993–94, 1996, 1999–2000, and 2000–01. A Marine Recreational Fisheries Technical Working Group considered that these estimates may be very inaccurate.

	QMA 1 (Northland)			
Year	No. of scallops	CV	Weight (t, green)	Reference
1993–94	374 000	0.17	40.0–60.0	Bradford (1997)
1996	272 000	0.18	32.0	Bradford (1998)
1999–00	634 000	0.34	69.8	Boyd & Reilly (2002)
2000–01	820 000	0.31	90.3	Boyd *et al.* (2004)

1.3 Customary fisheries

Limited quantitative information on the level of customary take is available from the Ministry for Primary Industries (MPI) (Table 4).

Table 4: MPI records of customary harvest of scallops (reported as numbers or greenweight, or units unspecified) taken from the Northland scallop fishery, 2003–04 to 2008–09. –, no data.

SCA1	Quantity approved, by unit type			Actual quantity harvested, by unit type		
Fishing year	Weight (kg)	Number	Unspecified	Weight (kg)	Number	Unspecified
2006–07	–	1650	–	–	1650	–
2007–08	–	1780	–	–	1780	–
2008–09	120	–	300	120	–	300

1.4 Illegal catch

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

1.5 Other sources of mortality

There is no quantitative information on other sources of mortality for Northland scallops. The box dredges in use in the Northland commercial fishery have been found to be considerably more efficient than ring-bag or Keta-Ami dredges. However, scallops encountered by box dredges in the Coromandel scallop fishery showed modest reductions in growth rate, compared with scallops collected by divers, and quite high mortality (about 20–30% mortality but potentially as high as 50% for scallops that are returned to the water. I.e. those just under the MLS of 100 mm). Stochastic modelling suggested that, of the three dredge designs tested, box dredges would generate the greatest yield-per-recruit and catch rates. The incidental mortality caused by dredging substantially changed the shape of yield-per-recruit curves for Coromandel scallops, causing generally asymptotic curves to become domed, and decreasing estimates of F_{max} and $F_{0.1}$. More recent field experiments and modelling suggest that dredging reduces habitat heterogeneity, increases juvenile mortality, makes yield-per-recruit curves even more domed, and decreases estimates of F_{max} and $F_{0.1}$ even further.

2. BIOLOGY

Pecten novaezelandiae is one of several species of “fan shell” bivalve molluscs found in New Zealand waters. Others include queen scallops and some smaller species of the genus *Chlamys*. *P. novaezelandiae* is endemic to New Zealand, but is very closely related to the Australian species *P. fumatus* and *P. modestus*. Scallops of various taxonomic groups are found in all oceans and support many fisheries world-wide; most scallop populations undergo large fluctuations.

Scallops are found in a variety of coastal habitats, but particularly in semi-enclosed areas where circulating currents are thought to retain larvae. After the planktonic larval phase and a relatively mobile phase as very small juveniles, scallops are largely sessile and move actively mainly in response to predators. They may, however, be moved considerable distances by currents and storms and are sometimes thrown up in large numbers on beaches.

Scallops are functional hermaphrodites, and become sexually mature at a size of about 70 mm shell length. They are extremely fecund and may spawn several times each year. Fertilisation is external and larval development lasts for about 3 weeks. Initial settlement occurs when the larva attaches via a byssus thread to filamentous material or dead shells on or close to the seabed. The major settlement of spat in northern fisheries usually takes place in early January. After growth to about 5 mm, the byssus is detached and, after a highly mobile phase as a small juvenile, the young scallop takes up the relatively sedentary adult mode of life.

The very high fecundity of this species, and likely variability in the mortality of larvae and pre-recruits leads to great variability in annual recruitment. This, combined with variable mortality and growth of adults, leads to scallop populations being highly variable from one year to the next, especially in areas of rapid growth where the fishery may be supported by only one or two year classes. This variability is characteristic of scallop populations world-wide, and often occurs independently of fishing pressure.

Little detailed information is available on the growth and natural mortality of Northland scallops, although the few tag returns from Northland indicate that growth rates in Bream Bay are similar to those in the nearby Coromandel fishery (see the report for SCA CS). The large average size of scallops in the northern parts of the Northland fishery and the consistent lack of small animals there suggests that growth rates may be very fast in the far north.

3. STOCKS AND AREAS

Scallops inhabit waters of up to about 60 m deep (apparently up to 85 m at the Chatham Islands), but are more common in depths of 10 to 50 m on substrates of shell gravel, sand or, in some cases, silt. Scallops are typically patchily distributed at a range of spatial scales; some of the beds are persistent and others are ephemeral. The extent to which the various beds or populations are reproductively or functionally seperate is not known. It is currently assumed for management that the Northland stock is separate from the adjacent Coromandel stock and from the various west coast harbours, Golden Bay, Tasman Bay, Marlborough Sounds, Stewart Island and Chatham Island areas.

4. STOCK ASSESSMENT

Northland scallops are managed using a TACC of 40 t meatweight which can be augmented with additional ACE based on a Current Annual Yield (CAY) calculation using $F_{0.1}$ as a reference point. Pre-season research (dredge) surveys are used to estimate recruited biomass. The last biomass survey conducted in SCA 1 was in 2007.

4.1 Estimates of fishery parameters and abundance

At the fishery-wide level, estimated fishing mortality on scallops 100 mm or more in the Northland fishery was in the range F_{est} = 0.33–0.78 y^{-1} (mean F_{est} = 0.572 y^{-1}) between 1997–98 and 2003–04, but was lower in the period 2005–07 (mean F_{est} = 0.203 y^{-1}) (Table 5). The level of fishing mortality in more recent years is unknown because of the lack of surveys to estimate biomass. There is no known stock-recruit relationship for Northland scallops.

CPUE is not usually presented for this fishery because it is not a reliable index of abundance (Cryer 2001b). However, recent simulation studies in the Coromandel scallop fishery have shown that CPUE could be used as a basis for some management strategies (Haist & Middleton 2010). This may or may not apply to the Northland scallop fishery.

In the absence of survey estimates of abundance in recent years, CPUE indices in 2011 were generated for SCA 1 based on the available data for the period 1991–2011 (Hartill & Williams 2012). Almost all commercial fishing during this period has taken place in three statistical reporting areas, but none of these areas has been fished continuously; in any given year, fishers tend to select the most productive area(s). A stock-wide CPUE index, produced by combining data from the different areas, suggests that the abundance of scallops throughout SCA 1 declined in the late 1990's, and then steadily increased substantially until 2005–06, after which there has been a steady decline; such an index, however, must be regarded with caution. The limitations of CPUE as an index of abundance are well understood, but are particularly severe for sedentary species like scallops. The nature of the relationship between CPUE and abundance is unclear, but is likely to be hyperstable.

4.2 Biomass estimates

Virgin biomass, B_0, and the biomass that will support the maximum sustainable yield, B_{MSY}, have not been estimated and are probably not appropriate reference points for a stock with highly variable recruitment and growth such as scallops.

Table 5: Estimated start of season abundance and biomass of scallops of 100 mm or more shell length in the Northland fishery from 1997 to 2007 using historical average dredge efficiency; for each year, the catch (reported on the 'Landed' section of CELRs), exploitation rate (catch to biomass ratio), and the estimated fishing mortality (F_{est}) are also given. F_{est} was estimated by iteration using the Baranov catch equation where t = 7/12 and M = 0.50 spread evenly through the year. Abundance and biomass estimates are mean values up to and including 2003, and median values from 2005, when the analytical methodology for producing the estimates was modified. This, together with changes to survey coverage each year, make direct comparisons among years difficult. –, no data. There were no surveys in 1999, 2000, 2004, or 2008–11.

Year	Abundance		Biomass				Exploitation rate	F_{est}
	(millions)	C.V.	(t green)	C.V.	(t meat)	C.V.	(catch/biomass)	≥100 mm
1997	34.9	0.22	3520	0.22	475	0.22	0.27	0.62
1998	13.9	0.13	1547	0.13	209	0.13	0.15	0.33
1999	–	–	–	–	–	–	–	–
2000	–	–	–	–	–	–	–	–
2001	8.9	0.27	871	0.27	118	0.27	0.32	0.78
2002	13.2	0.19	1426	0.19	193	0.19	0.21	0.46
2003	9.3	0.19	1031	0.19	139	0.19	0.28	0.66
2004	–	–	–	–	–	–	–	–
2005	51.3	0.72	5565	0.70	753	0.71	0.09	0.19
2006	66.6	0.45	7280	0.43	984	0.44	0.05	0.11
2007	15.1	0.47	1637	0.45	208	0.46	0.14	0.31

There have been reasonably regular assessments of Northland scallops between 1992 and 2007 (Table 5 and Table 6), in support of a CAY management strategy. Assessments are based on pre-season biomass surveys conducted by diving and/or dredging. Composite dive-dredge surveys were conducted annually from 1992 to 1997, except in 1993 when only divers were used. From 1998, surveys were conducted using dredges only. The Northland fishery was not surveyed in 1999, 2000, 2004, or 2008–12. Where dredges have been used, absolute biomass must be estimated by correcting for the efficiency of the particular dredges used. Previously, estimates were corrected for dredge efficiency using scalars (multipliers) which were estimated by directly comparing dredge counts with diver counts in experimental areas (e.g., Cryer & Parkinson 1999). However, different vessels were used in the most recent surveys and no trials were conducted on the efficiency of the particular dredges used. Estimating start-of-season biomass and yield is, therefore, difficult and contains unmeasurable as well as measurable uncertainty. For some years, the highest recorded estimate of dredge efficiency has been used, but more recent surveys have had a range of corrections applied from no correction (the most conservative) to the historical average across all studies (the least conservative). A new model of scallop dredge efficiency (Bian *et al.* 2012) is now available, but has not yet been used to re-analyse the historical survey time series for SCA 1 (or SCA CS).

Estimates for the Northland fishery calculated using historical average dredge efficiency are shown for scallops 95 mm or more in Table 6. Estimates of current biomass for the Northland fishery are not available (the last biomass survey of the Northland fishery was in 2007), and there are no estimates of reference biomass with which to compare historical estimates of biomass. A substantial increase in biomass was observed between 2003 and 2006, which resulted in the 2006 biomass estimate being the highest recorded for Northland. In 2005 and 2006, estimates of biomass were considerably higher than those in 2003 for some beds (notably Bream Bay), but similar or lower in others. There appeared to have been a "shift" in biomass away from the Far North and towards Bream Bay and Mangawhai/Pakiri Beach. This was the "reverse" of the shift towards the Far North that occurred in the early 1990s. However, the 2007 survey results suggested that the biomass in Bream Bay and Mangawhai/Pakiri had declined markedly since 2006, and, consequently, the overall fishery biomass was far lower in 2007 than in previous years. The beds in Rangaunu Bay seem more consistent between years, although the 2007 biomass estimate was the highest on record. The biomass in Spirits/Tom Bowling Bays was higher in 2007 than 2006 but was low compared with historical levels.

Table 6: Estimated recruited biomass (t greenweight) of scallops of 95 mm or more shell length at the time of the surveys in various component beds of the Northland scallop fishery from 1992 to 2007, assuming historical average dredge efficiency. – indicates no survey in a given year; there have been no surveys of SCA 1 since 2007. Estimates of biomass given for 1993 are probably negatively biased, especially for Rangaunu Bay (*), by the restriction of diving to depths under 30 m, and all estimates before 1996 are negatively biased by the lack of surveys in Spirits Bay (†). Totals also include biomass from less important beds at Mangawhai, Pakiri, around the Cavalli Passage, in Great Exhibition Bay, and Tom Bowling Bay when these were surveyed. Commercial landings in each year for comparison can be seen in Table 1, wherein "Far North" landings come from beds described here as "Whangaroa", "Doubtless", and "Rangaunu".

						Biomass (t)
	Bream Bay	Whangaroa	Doubtless	Rangaunu	Spirits Bay	Total
1992	1 733	–	78	766	–	3 092 †
1993	569	172	77	170 *	–	1 094 *
1994	428	66	133	871	–	1 611 †
1995	363	239	103	941	–	1 984 †
1996	239	128	32	870	3 361	5 098
1997	580	117	50	1 038	1 513	3 974
1998	18	45	37	852	608	1 654
1999	–	–	–	–	–	–
2000	–	–	–	–	–	–
2001	110	8	0	721	604	1 451
2002	553	10	–	1 027	1 094	2 900
2003	86	33	3	667	836	1 554
2004	–	–	–	–	–	–
2005	2 945	–	–	719	861	4 676
2006	5 315	–	–	1 275	261	7 539
2007	795	–	–	1 391	432	2 694

Substantial uncertainty stemming from assumptions about dredge efficiency during the surveys, rates of growth and natural mortality between survey and season, and predicting the average recovery of meatweight from greenweight remain in these stock assessments. A new model of scallop dredge efficiency (Bian *et al.* 2012) has helped to reduce this uncertainty, as should future research projects aimed at collecting more data on scallop growth and mortality. Managing the fisheries based on the number of recruited scallops at the start of the season as opposed to recruited biomass (the current approach) could remove the uncertainty associated with converting estimated numbers of scallops to estimated meatweight.

Diver surveys of scallops were conducted in June 2006 and June–July 2007 at selected scallop beds in Northland recreational fishing areas (Williams *et al.* 2008, Williams 2009). For the four small beds (total area of 4.35 km^2) surveyed, start-of-season biomass of scallops over 100 mm shell length was estimated to be 49.7 t greenweight (CV of 23%) or 6.2 t meatweight in 2006, and 42 t greenweight (CV of 25%) or 5 t meatweight (CV of 29%) in 2007.

4.3 Estimation of Maximum Constant Yield (MCY)

MCY has not been estimated for Northland scallops and would probably be close to zero.

4.4 Estimation of Current Annual Yield (CAY)

Yield estimates are generally calculated using reference rates of fishing mortality applied in some way to an estimate of current or reference biomass. Cryer & Parkinson (2006) reviewed reference rates of fishing mortality and summarised modelling studies by Cryer & Parkinson (1997) and Cryer *et al.* (2004). The Ministry for Primary Industries' Shellfish Working Group recommend $F_{0.1}$ as the most appropriate reference rate (target) of fishing mortality for scallops.

Management of Northland scallops is based on a CAY approach. Since 1998, in years when biomass surveys have been conducted, catch limits have been adjusted in line with estimated start-of-season recruited biomass and an estimate of CAY made using the Baranov catch equation:

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

where t = 7/12 years, F_{ref} is a reference fishing mortality ($F_{0.1}$) and B_{beg} is the estimated start-of-season (15 July) recruited biomass (scallops of 90 mm or more shell length). Natural mortality is assumed to act in tandem with fishing mortality for the first 7 months of the fishing season, the length of the current Northland commercial scallop season. B_{beg} is estimated assuming historical average dredge efficiency at length, average growth (from previous tagging studies), M = 0.5 spread evenly through the year, and historical average recovery of meatweight from greenweight. Because of the uncertainty over biomass estimates, growth, and mortality in a given year, and appropriate reference rates of fishing mortality, yield estimates must be treated with caution.

Modelling studies for Coromandel scallops (Cryer & Morrison 1997, Cryer *et al.* 2004) indicate that $F_{0.1}$ is sensitive not only to the direct incidental effects of fishing (reduced growth and increased mortality on essentially adult scallops), but also to indirect incidental effects (such as additional juvenile mortality related to reduced habitat heterogeneity in dredged areas). Cryer & Morrison's (1997) yield-per-recruit model for the Coromandel fishery was modified to incorporate growth parameters more suited to the Northland fishery and estimate reference fishing mortality rates. Including direct incidental effects of fishing only, and for an assumed rate of natural mortality of M = 0.50, $F_{0.1}$ was estimated as $F_{0.1}$ = 0.943 y^{-1} (reported by Cryer *et al.*, 2004, as 7/12 * $F_{0.1}$ = 0.550) for SCA 1, but estimates of $F_{0.1}$ including direct and indirect incidental effects of fishing were not estimated.

Consequently, the most recent CAY estimates were derived in 2007 (the year of the last biomass survey) for one scenario only:

CAY including direct effects on adults

By including only the direct incidental effects of fishing on scallops, Cryer *et al.* (2004) derived an estimate of $F_{0.1}$ = 0.943 y^{-1} (reported by Cryer *et al.*, 2004, as 7/12 * $F_{0.1}$ = 0.550). Using this value and the 2007 start of season biomass estimates (median projected values), CAY for 2007–08 was estimated to be 609 t greenweight or 77 t meatweight.

These estimates of CAY would have a CV at least as large as that of the estimate of start-of-season recruited biomass (50–51%), are sensitive to assumptions about dredge efficiency, growth, and expected recovery of meatweight from greenweight, and relate to the surveyed beds only. The sensitivity of these yield estimates to excluding areas of low density has not been calculated, but excluding stations with scallop density less than 0.02 m^{-2} and 0.04 m^{-2} reduced the fishery-wide time of survey biomass estimate by 95 and 100%, respectively. It should be noted that these low-density exclusions were calculated before correcting for average historical dredge efficiency, so these estimates are conservative. However, even if corrections for dredge efficiency were applied and no exclusions were made, the density of scallops 100 mm or more was low in all areas of the fishery surveyed in 2007. There is also additional uncertainty associated with using a point estimate of $F_{0.1}$ (i.e., variance associated with the point estimate of $F_{0.1}$ was not incorporated in the analysis).

4.5 Other yield estimates and stock assessment results

The estimation of Provisional Yield (PY) is no longer accepted as appropriate, and assessments since 1998 have used a CAY approach.

5. STOCK STATUS

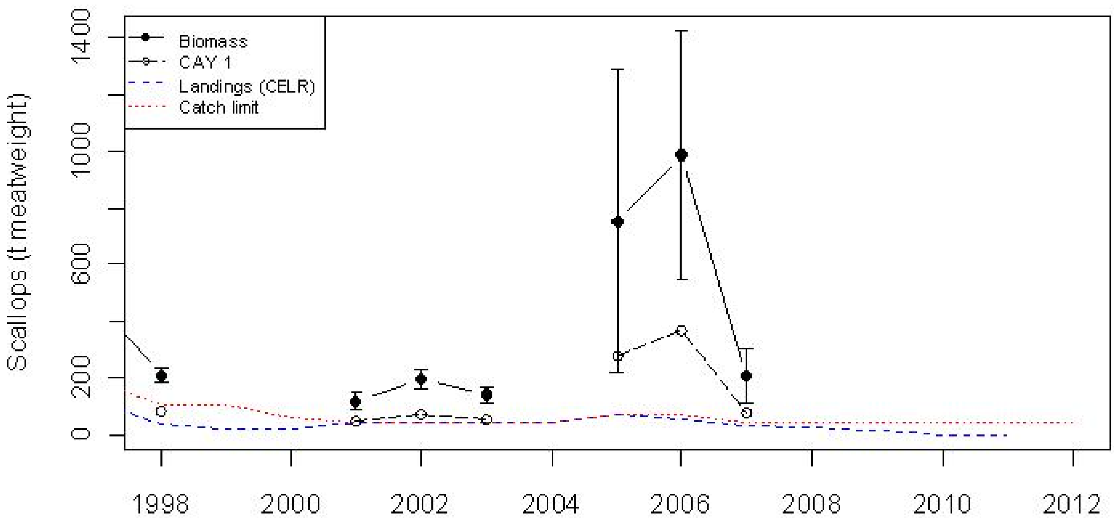
Stock Structure Assumptions

The stock structure of scallops in New Zealand waters is uncertain. For the purposes of this assessment, SCA 1 is assumed to be a single biological stock, although the extent to which the various beds or populations are separate reproductively or functionally is not known.

- **Northland scallops, SCA 1**

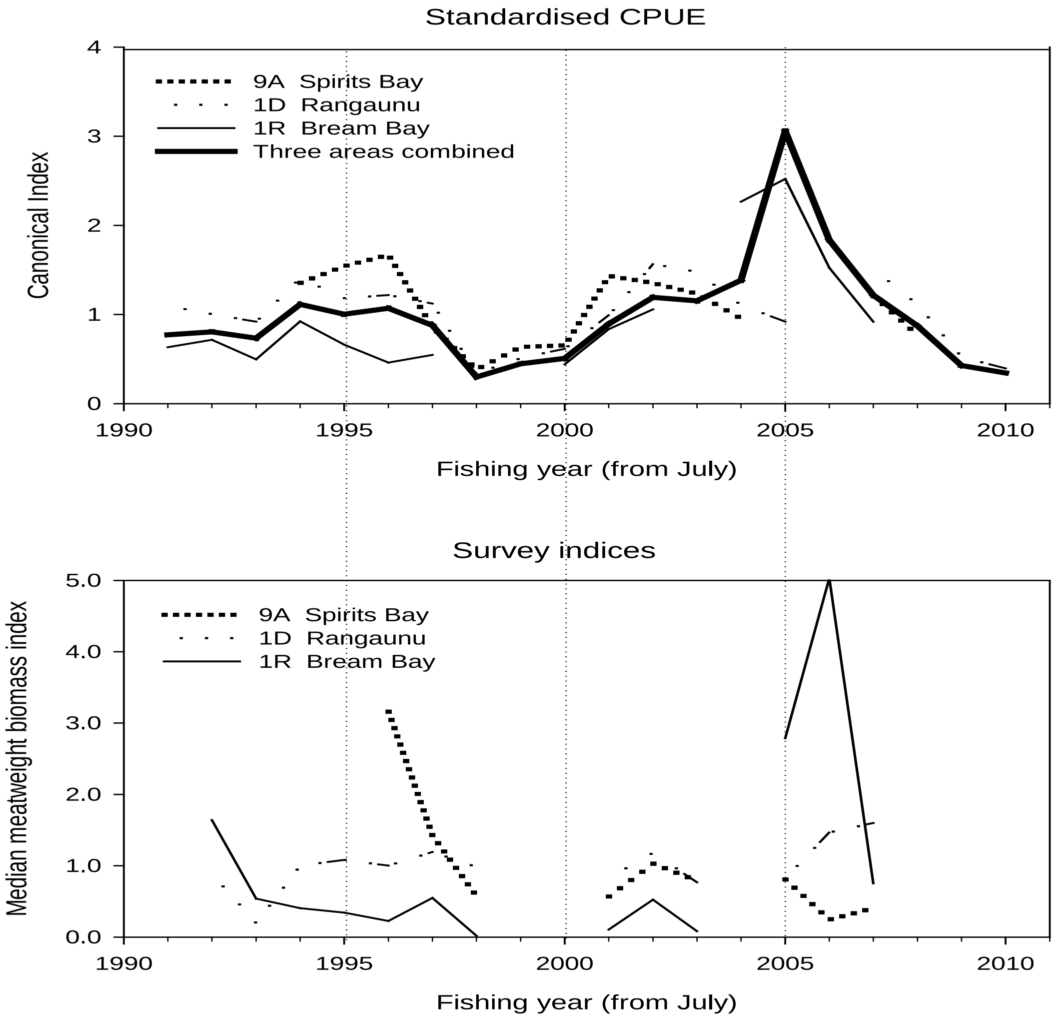
Stock Status	
Year of Most Recent Assessment	2007
Assessment Runs Presented	Estimate of CAY for 2007
Reference Points	Target: Fishing mortality at or below $F_{0.1}$ ($F_{0.1}$ = 0.943 y^{-1} including direct incidental effects of fishing only) Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Unlikely (< 40%) to be at or above the target
Status in relation to Limits	Unknown

Historical Stock Status Trajectory and Current Status



Recruited biomass (scallops 100 mm or more shell length), CAY 1 (includes direct effects of fishing on adult scallops), catch limits, and reported landings (from CELRs) in t meatweight for the SCA 1 fishery since 1998.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The recent (2008 to present) trend in biomass is unknown.
Recent Trend in Fishing Mortality or Proxy	F_{est} in recent years cannot be estimated for this fishery. Catches in 2010–11 and 2011–12 were the lowest on record.
Other Abundance Indices	CPUE is not a reliable index of abundance (Cryer 2001b).
Other Abundance Indices	



Standardised (lognormal) scallop catch rate indices for the three most commonly fished areas of SCA 1 and for all three areas combined (upper panel), compared with indices based on biomass survey estimates (lower panel).

Trends in Other Relevant Indicator or Variables	None

Projections and Prognosis	
Stock Projections or Prognosis	Stock projections are not available.
Probability of Current Catch causing decline below Limits Probability of TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown The TACC is very likely to cause the stock to fall or remain below both the soft and hard limits

Assessment Methodology		
Assessment Type	Level 2: Partial quantitative stock assessment	
Assessment Method	Biomass surveys and CAY management strategy	
Assessment Dates	Latest assessment: 2007	Next assessment:unknown
Overall Assessment Quality Rank	1 – High Quality	

Main data inputs (rank)	Biomass survey: 2007	1 – High Quality
Data not used (rank)	Not applicable	
Changes to Model Structure and Assumptions	Current model has been in use since 2005	
Major Sources of Uncertainty	These include assumptions about: dredge efficiency during the survey, growth rates and natural mortality between the survey and the start of the season, predicting the average recovery of meatweight from greenweight and the extent to which dredging causes incidental mortality and affects recruitment.	

Qualifying Comments
In the Northland fishery some scallop beds are persistent and others are ephemeral. The extent to which the various beds or populations are reproductively or functionally separate is not known. This fishery is managed with a CAY management strategy with a base TACC. However, the management strategy currently resembles a constant catch strategy because there have been no surveys since 2007.

Fishery Interactions

A bycatch survey was conducted in the Coromandel fishery in 2009 under project SCA2007-01B. The results are summarised below and may or may not be relevant to the Northland scallop fishery.

Bycatch composition
Live components

- Scallops 26%
- Seaweed 11%
- Starfish 4%
- Other bivalves 4%
- Coralline turf 1%

Dead components

- Dead shell 45%
- Rock and gravel 8%

Bycatch data were also collected during the 2010 and 2012 surveys of SCA CS; the data were loaded to the MPI database "*scallop*" for use in future work.

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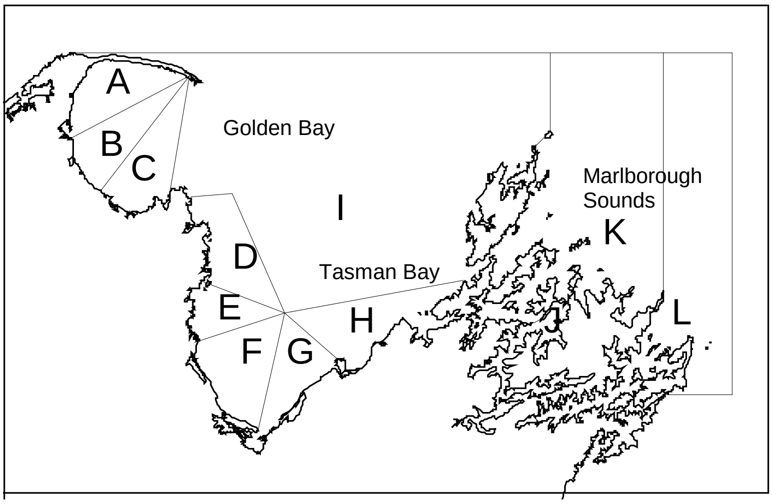
SCALLOPS Nelson/Marlborough (SCA 7)

(*Pecten novaezelandiae*)
Kuakua



1. FISHERY SUMMARY

The SCA 7 fishery was introduced into a modified form of the Quota Management system (QMS) in 1992 and in 1995 an annual TACC was set at 720 t. In 2002 the TACC was increased and a TAC set with allowances made for customary and recreational fishing (Table 1).

Table 1: Total Allowable Commercial Catch (TACC, t) declared for SCA 7 since introduction into the QMS in 1992.

Year	TAC	Customary	Recreational	Other Mortality	TACC
1995-2002	–	–	–	–	720
2002-present	827	40	40	0	747

1.1 Commercial fisheries

The Nelson/Marlborough scallop fishery (SCA 7), often also referred to as the ‘Southern’ or ‘Challenger’ fishery, is comprised of 12 sectors (see A–L in the map above) spread across three regions: Golden Bay, Tasman Bay, and the Marlborough Sounds. Up to 1980, the fishery was managed with a combination of gear restrictions, closed areas and seasons, and a 100 mm size limit, together with limitations on the number of entrants (from 1977). Landings reached an all time peak of 1244 tonnes in 1975, when there were 216 licensed vessels involved in the fishery. The fishery then rapidly declined, and in 1981 and 1982 the fishery was closed. Only 48 licences were issued when it re-opened in 1983, with each vessel being allocated a defined, and equal, catch limit on an annual basis. A scallop enhancement programme was initiated in the same year. By 1989 the success of the enhancement programme enabled rotational fishing in Golden and Tasman Bays (Sectors A–I). Initially, several sectors were opened to fishing each year, and were re-seeded following fishing down. Rotational fishing was accompanied by a reduction in the minimum legal size to 90 mm.

The SCA 7 fishery was introduced into a modified form of the Quota Management system (QMS) in 1992. An annual harvest limit of 640 t (12 t to each of the 48 licence holders, plus 64 t to Maori) was initially allocated as ITQ. Provision was also made for any additional quota in excess of the 640 t to be allocated to the Crown for lease, with preference being given to existing quota holders. The catch limit was set at the level that enabled the fishery to produce the Maximum Economic Yield.

In October 1995, legislation was passed in which annual quotas were fixed proportionally rather than as a fixed tonnage, which provided for greater flexibility in changing the TACC. A statutory Enhancement Plan was also introduced at this time, to provide for ongoing enhancement of the fishery. The legislation also provided for a transition enabling the enhancement programme to be implemented by the Challenger Scallop Enhancement Company (CSEC) under contract to MFish (it had previously been implemented and managed by government).

With the passage of the Fisheries Act 1996, the fishery was able to be managed using an approach that represented an improvement on achieving the Maximum Sustainable Yield, rather than focus on Maximum Economic Yield. In addition, a levy was established which created an ability for the CSEC to collect their own funds from quota owners. This led to the termination of the contract with MFish, and for CSEC to implement the enhancement programme in accordance with conditions set down by the Minister of Fisheries. In 1998, an amended Enhancement Plan was approved by the Minister of Fisheries to better reflect the new arrangements. Because of the rotationally enhanced nature of the fishery, the fishery was placed on the Third Schedule to the Fisheries Act 1996, and is, therefore, able to have an alternative TAC set under section 14 of the Fisheries Act 1996.

There has been relatively little change in the process used to manage this fishery in recent years. An annual dredge survey helps define biomass levels and population size structures by sector, before each season begins. This approach enables the fishery to concentrate in areas where scallops are predominantly above the minimum legal size, and reduces disturbance in areas where most of the population is sub-legal. The intended strategy has then been to open sectors on a rotational basis, with reseeding at the end of the season. This has not always occurred however, particularly in recent years when reseeding activity has been reduced. In 2000–01 and 2001–02, for example, high levels of natural recruitment in Golden Bay, led to fishing in all three sectors (A, B & C), with the fishery targeting patches of recruited scallops. Further, Sector B has been fished almost every year, with the harvest from this sector accounting for the majority of that taken from Golden Bay. This practise of sub-sector ‘rotation’ is not consistent with that of three yearly sector rotational fishing regime as recommended by Breen & Kendrick (1997).

Separate catch limits are set each year (by CSEC in consultation with MFish) for the Tasman/Golden Bays and the Marlborough Sounds regions of the fishery. Actual commercial catch is subject to:

- the biomass in areas open to fishing in that year,
- any adverse effects of fishing on the marine environment being avoided, remedied or mitigated,
- providing for an allowance for non-commercial fishing,
- a biotoxin monitoring programme being maintained, and
- the ratio of legal to non-legal sized fish in the areas open to fishing being above pre-set levels.

Reported landings (in meatweight i.e., processed weight, being the adductor muscle plus attached roe) from the Challenger scallop fishery are listed in Tables 2 and 3. The fishing year applicable to this fishery is from 1 April to 31 March. Commercial fishing usually occurs from August to December, although opening and closing dates are defined each year, and may differ between years.

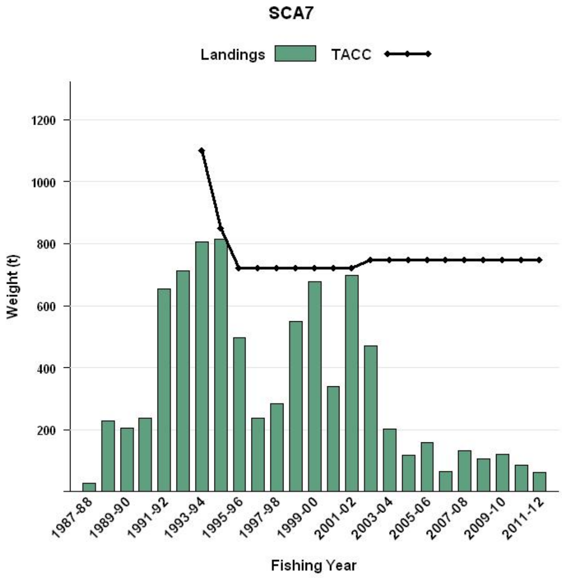


Figure 1: Historical landings and TACC for SCA7 (Nelson Marlborough).

Table 2: Reported landings (t, meatweight) of scallops from SCA 7 from 1959–60 to 1982–83. The fishery was closed for the 1981–82 and 1982–83 scallop fishing years. Landings are presented by region (GB, Golden Bay; TB, Tasman Bay; MS, Marlborough Sounds) and total, except before 1977 when landings were reported by the Golden Bay and Tasman Bay combined area (Gold/Tas). Data source: King & McKoy (1984).

Year	Gold/Tas	GB	TB	MS	Total
1959–60	1	–	–	0	1
1960–61	4	–	–	2	7
1961–62	19	–	–	0	19
1962–63	24	–	–	< 0.01	24
1963–64	105	–	–	2	107
1964–65	108	–	–	2	110
1965–66	44	–	–	< 0.5	44
1966–67	23	–	–	8	32
1967–68	16	–	–	7	23
1968–69	1	–	–	8	9
1969–70	72	–	–	6	78
1970–71	73	–	–	7	80
1971–72	206	–	–	10	215
1972–73	190	–	–	46	236
1973–74	193	–	–	127	320
1974–75	597	–	–	36	632
1975–76	1172	–	–	73	1244
1976–77	589	–	–	79	668
1977–78	–	342	168	63	574
1978–79	–	86	4	76	166
1979–80	–	32	30	40	101
1980–81	–	0	14	27	41
1981–82	–	–	–	–	–
1982–83	–	–	–	–	–

Table 3: Catch limits and reported landings (t, meatweight) of scallops from SCA 7 since 1983–84. The fishery was closed for the 1981–82 and 1982–83 scallop fishing years, and was subsequently managed under a rotationally enhanced regime. Two catch limits are presented: TACC, Total Allowable Commercial Catch; MSCL, Marlborough Sounds catch limit (a subset of the TACC, or a subset of the Annual Allowable Catch in 1994–95). Landings data come from the following sources: FSU, Fisheries Statistics Unit; MHR, Monthly Harvest Returns (Quota Harvest Returns before October 2001); CELR, Catch Effort Landing Returns; CSEC, Challenger Scallop Enhancement Company. Landings are also presented by region (GB, Golden Bay; TB, Tasman Bay; MS, Marlborough Sounds) and best total (believed to be the most accurate record) for the SCA 7 fishstock. –, no data.

	Catch limits		Landings				Landings by region and best total				
Year	TACC	MSCL	FSU	MHR	CELR	CSEC	GB	TB	MS	Best total	Source
1983–84	–	–	225	–	–	–	< 0.5	164	61	225	FSU
1984–85	–	–	367	–	–	–	45	184	138	367	FSU
1985–86	–	–	245	–	–	–	43	102	100	245	FSU
1986–87	–	–	355	–	–	–	208	30	117	355	FSU
1987–88	–	–	219	29	–	–	113	1	105	219	FSU
1988–89	–	–	222	228	–	–	127	23	72	222	FSU
1989–90	–	–	–	205	125	–	68	42	95	205	Shumway & Parsons (2006)
1990–91	–	–	–	237	228	–	154	8	66	228	CELR
1991–92	–	–	–	655	659	–	629	9	20	659	CELR
1992–93	–	–	–	712	674	–	269	247	157	674	CELR
1993–94	*1 100	–	–	805	798	–	208	461	129	798	CELR
1994–95	*850	70	–	815	825	–	415	394	16	825	CELR
1995–96	720	73	–	496	479	–	319	92	67	479	CELR
1996–97	#720	61	–	238	224	231	123	47	61	231	CSEC
1997–98	#720	58	–	284	265	299	239	2	58	299	CSEC
1998–99	#720	120	–	549	511	548	353	78	117	548	CSEC
1999–00	720	50	–	678	644	676	514	155	7	676	CSEC
2000–01	720	50	–	338	343	338	303	19	16	338	CSEC
2001–02	720	76	–	697	715	717	660	32	25	717	CSEC
2002–03	747	–	–	469	469	471	370	39	62	471	CSEC
2003–04	747	–	–	202	209	206	28	107	71	206	CSEC
2004–05	747	–	–	117	112	118	20	47	51	118	CSEC
2005–06	747	–	–	158	156	156	35	5	116	157	CSEC
2006–07	747	–	–	67	66	68	26	0	43	68	CSEC
2007–08	747	–	–	134	183	134	128	0	6	134	CSEC
2008–09	747	–	–	103	137	104	76	0	28	104	CSEC
2009–10	747	–	–	120	120	–	19	0	101	120	CELR
2010–11	747	–	–	85	85	–	10	0	74	85	CELR
2011–12	747	–	–	62	61	–	1	0	60	61	CELR

*Annual Allowable Catch (AAC); TACCs came into force 1 October 1995.
#Initial industry controlled catch limit was 350 t in 1996-97, 310 t in 1997-98, and 450 t in 1998-99.

1.2 Recreational fisheries

Scallops are taken by recreational fishers, throughout SCA 7, generally by dredge or diving. The recreational fishing season runs from 15 July to 14 February.

Each year the commercial and recreational sectors jointly review the prospects for the recreational fishery based on pre-season abundance and yield surveys. Following those discussions a number of non-commercial areas are routinely established to supplement the various regulatory closures, which apply to the commercial fishery only. Levels of recreational harvest probably vary significantly through time.

The first recreational harvest estimates available were derived from telephone diary programmes in 1992–93 (Tierney *et al*. 1997), 1996 (Bradford 1998), 1999-00 (Boyd & Reilly 2004), and 2000–01 (Boyd *et al*. 2004), but these estimates are of dubious reliability (Table 4). In 2004, the

Marine Recreational Fisheries Technical Working Group reviewed the harvest estimates of these surveys and concluded that the 1992/93 and 1996 estimates were unreliable due to a methodological error. While the same error did not apply to the 1999/2000 and 2000/01 surveys, it was considered the estimates may still be very inaccurate.

The most recent harvest estimates come from a targeted creel survey of the Golden Bay and Tasman Bay fisheries (Table 4), which was conducted in 2003–04 (Cole *et al*. 2006). This later estimate may be more accurate, as it is based upon direct, independent, and structured observations of the fishery, but there are no estimates available for the Marlborough Sounds. The scale of these estimates suggests, however, that recreational fishers only account for a small proportion of annual removals.

Table 4: Estimated numbers of scallops harvested by recreational fishers in QMA 7, and a corresponding estimate of meatweight (Mwt, t) based on an assumed mean scallop meat weight of 13 g. The Marine Recreational Fisheries Technical Working Group reviewed the telephone/diary harvest estimates and concluded that the 1993/94 and 1996 estimates were unreliable due to a methodological error, and while the same error did not apply to the 1999/2000 and 2000/01 surveys, it was considered the estimates may still be very inaccurate.

Year	Area	Method	Number	CV	Mwt	% of SCA 7 landings	Source
1992–93	SCA 7	Telephone/diary	1 680 00	15	21.8	3.0	Tierney *et al*. (1997)
1996	SCA 7	Telephone/diary	1 456 00	21	18.9	7.6	Bradford (1998)
1999–00	SCA 7	Telephone/diary	3 391	20	44.1	6.1	Boyd & Reilly (2004)
2000–01	SCA 7	Telephone/diary	2 867	14	37.3	10.0	Boyd *et al*. (2004)
2003–04	Golden & Tasman	Creel survey	860 000	5%	9.4	6.5	Cole *et al*. (2006)

1.3 Customary fisheries
Scallops were undoubtedly used traditionally as food by Maori, although quantitative information on the level of customary take is not available.

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

1.5 Other sources of fishing mortality
The extent of other sources of fishing mortality is unknown. Incidental mortality of scallops caused by ring-bag dredging is unknown for the Challenger fishery, although studies conducted in the Coromandel fishery showed that mortality was quite high (about 20–30% mortality for scallops that are returned to the water. i.e. just under the MLS of 90 mm) for scallops encountered by box dredges. Stochastic modelling suggested that the incidental mortality caused by dredging substantially changed the shape of yield-per-recruit curves for Coromandel scallops, causing generally asymptotic curves to become domed, and decreasing estimates of F_{MAX} and $F_{0.1}$. Other field experiments and modelling suggest that dredging reduces habitat heterogeneity, increases juvenile mortality, makes yield-per-recruit curves even more domed, and decreases estimates of F_{MAX} and $F_{0.1}$ even further.

2. BIOLOGY

Pecten novaezelandiae is a functional hermaphrodite that breeds generally in early summer (although partial spawning can occur from at least August to February). Most scallops mature by the end of their first year, but they contribute little to the spawning pool until the end of their second year. Year 1 scallops contain about 500 000 eggs, whereas year 4 and 5 scallops can contain over 40 million. Scallop veliger larvae spend about three weeks in the plankton. They then attach to algae or some other filamentous material with fine byssus threads. When the spat reach about 5 mm they detach and take up the free-living habit of adults, usually lying in depressions on the seabed and often covered by a layer of silt. Although adult scallops can swim, they appear to move very little (based on underwater observations, the recovery of tagged scallops, and the persistence of morphological differences between adjacent sub-populations).

The relatively high fecundity, and likely variability in the mortality of larvae and pre-recruits, could lead to high variability in natural annual recruitment. This variability is a characteristic of scallop populations worldwide.

All references to “shell length” in this report refer to the maximum linear dimension of the shell, in an anterior-posterior axis. Scallops in the outer Pelorus Sound grew to a shell length of about 60 mm in one year, and can reach 100 mm in two years. This is typical of the pattern of growth that occurs under the rotational fishing strategy in Tasman and Golden Bays as well. Growth slows during the winter, and was found to vary between years (it is probably influenced by water temperature, food availability, and scallop density). Growth rings form on the shell during winter, but also at other times, precluding the use of ring counts as accurate indicators of age. Experience with enhanced stocks in Tasman and Golden Bay has indicated that scallops generally attain a shell length of 90 mm in just under two years, although, in conditions where food is limiting, almost three years may be required to reach this size.

Bull (1976) estimated the annual natural mortality rate for two populations of adult scallops in Pelorus Sound to be 23% and 39%. Bull & Drummond (1994) estimated the mortality of 0+ and 1+ scallops to be about 38% per year, with mortality of 2+ scallops increasing to 66%. These studies suggest that average natural mortality in the Challenger fishery is quite high (Table 5), and most previous stock assessments have assumed $M = 0.46\ y^{-1}$ (instantaneous rate). Incidences of large-scale die-off in localised areas have been observed (e.g., mortality associated with storms in 1998).

Table 5: Estimates of biological parameters

		Estimates	Source
1. Natural mortality, M			
Pelorus Sound		0.26, 0.49	Bull (1976)
Golden & Tasman Bays		0+ & 1+, 0.21	Bull & Drummond (1994)
Golden & Tasman Bays		2+, 0.46	Bull & Drummond (1994)
2. Growth			
Age-length relationship	Age (y)	SL (mm)	
Pelorus Sound	1	60	Bull (1976)
Pelorus Sound	2	97	Bull (1976)
Pelorus Sound	3	105	Bull (1976)
Pelorus Sound	4	111	Bull (1976)
von Bertalanffy parameters	L_∞	K	
	144	0.40	Data of Bull (1976), analysed by Breen (1995)

3. STOCKS AND AREAS

Scallops inhabit waters of up to about 60 m deep (apparently up to 85 m at the Chatham Islands), but are more common in depths of 10 to 50 m on substrates of shell gravel, sand or, in some cases, silt. Scallops are typically patchily distributed at a range of spatial scales; some of the beds are persistent and others are ephemeral. The extent to which the various beds or populations are reproductively or functionally separate is not known. Whether or not scallops in Tasman Bay and Golden Bay constituted a single genetic stock before enhancement began, is unknown. Enhancement in the Marlborough Sounds has been limited, but could have contributed towards homogenising stocks. Water movements eastward through Cook Strait could have enabled a degree of genetic mixing between Tasman/Golden Bay and Marlborough Sounds stocks before any enhancement began. It is currently assumed for management that the SCA 7 stock is made up of three individual substocks (Golden Bay, Tasman Bay, Marlborough Sounds) that are separate from the Northland and Coromandel stocks and from the various west coast harbours, Stewart Island and Chatham Island areas.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

Scallop abundance and biomass in the main commercial scallop beds in the Challenger fishery have been estimated annually since 1994 using a two-phase stratified random dredge survey (Table 6), although no second-phase sampling was conducted in the 2009–12 surveys. Surveys since 1998 are essentially comparable, in that they used the same fishing gear and covered quite similar areas. Earlier surveys covered smaller areas, although these would generally have included the areas of main recruited scallop densities. Surveys up to 1995 used the "MAF" dredge, while from 1997 the "CSEC" dredge was used. In 1996, both dredges were used, with data from the CSEC dredge being used for the biomass analysis. The efficiencies of the two dredges at a single site in each of Golden Bay, Tasman Bay, and the Marlborough Sounds were not significantly different. The mean efficiency at these sites (based on a comparison of diver and dredge transects) were 0.58, 0.66, and 0.85, respectively, giving an overall mean efficiency of 0.70. The values in Table 6 are absolute estimates, produced by reanalysing the historical survey data using a revised analytical procedure described by Tuck & Brown (2008) to better account for uncertainty in the biomass estimates (Table 6).

Estimates in Table 6 use a recruit size of ≥ 90 mm (the commercial size limit) up to 1995. A yield per recruit analysis in 1995 indicated that 89 mm was the optimal harvest size, so from 1996 to 2000, recruit estimates were calculated using this value (although harvesters and processors continued to take only scallops ≥ 90 mm, the minimum legal size). In 2001, a recruit size of ≥ 90 mm was again used.

Table 6: Absolute estimates and CVs of recruited numbers of scallops 90 mm or more shell length (RecN, millions), recruited greenweight (RecG, t), and recruited meatweight (MtWt, t) in Golden Bay, Tasman Bay, the Marlborough Sounds, and for the SCA 7 fishery total, from dredge surveys in May-June of each year. Values in this table were derived by reanalysing the historical survey data using a revised analytical procedure described by Tuck & Brown (2008) to better account for uncertainty in the time of survey biomass estimates. These estimates do not include Croisilles Harbour in Tasman Bay. – value not estimated.

Year						Golden Bay
	RecN	RecN CV	RecG	RecG CV	MtWt	MtWt CV
1997	40.1	0.24	3 471	0.25	437	0.29
1998	55.7	0.18	4 605	0.19	584	0.24
1999	60.4	0.20	5 323	0.20	673	0.25
2000	87.8	0.18	6 896	0.18	872	0.24
2001	151.5	0.22	11 510	0.21	1 456	0.26
2002	106.6	0.18	8 326	0.18	1 053	0.24
2003	28.9	0.18	2 269	0.17	287	0.23
2004	5.6	0.20	432	0.20	55	0.25
2005	10.9	0.20	871	0.20	110	0.25
2006	10.3	0.20	858	0.20	109	0.25
2007	55.6	0.20	4 411	0.20	557	0.24
2008	27.0	0.20	2 198	0.20	278	0.25
2009	13.6	0.23	1061	0.23	146	0.23
2010	6.5	0.25	510	0.24	–	–
2011	1.5	0.35	120	0.36	–	–
2012	0.8	0.42	64	0.42	–	–

Table 6 [cont.]: Absolute estimates and CVs of recruited numbers of scallops 90 mm or more shell length (RecN, millions), recruited greenweight (RecG, t), and recruited meatweight (MtWt, t) in Golden Bay, Tasman Bay, the Marlborough Sounds, and for the SCA 7 fishery total, from dredge surveys in May-June of each year. Values in this table were derived by reanalysing the historical survey data using a revised analytical procedure described by Tuck & Brown (2008) to better account for uncertainty in the time of survey biomass estimates. These estimates do not include Croisilles Harbour in Tasman Bay. – value not estimated.

Year						Tasman Bay
	RecN	RecN CV	RecG	RecG CV	MtWt	MtWt CV
1997	3.1	0.25	245	0.25	31	0.29
1998	66.2	0.19	5 108	0.18	645	0.23
1999	55.3	0.21	4 724	0.21	602	0.27
2000	36.3	0.18	3 027	0.18	386	0.23
2001	37.8	0.18	2 977	0.18	378	0.23
2002	55.3	0.18	4 272	0.18	544	0.23
2003	67.9	0.18	5 192	0.18	661	0.23
2004	31.8	0.18	2 386	0.18	304	0.24
2005	13.1	0.19	1 012	0.19	129	0.23
2006	2.4	0.19	186	0.19	24	0.23
2007	1.6	0.22	131	0.22	17	0.27
2008	0.8	0.32	58	0.32	7	0.35
2009	1.1	0.32	88	0.31	11	0.31
2010	1.6	0.26	125	0.26	–	–
2011	0.7	0.36	63	0.36	–	–
2012	0.5	0.39	42	0.40	–	–

Year						Marlborough Sounds
	RecN	RecN CV	RecG	RecG CV	MtWt	MtWt CV
1997	9.0	0.23	781	0.24	99	0.29
1998	20.8	0.25	1 731	0.25	220	0.29
1999	11.6	0.18	969	0.19	123	0.23
2000	11.4	0.19	962	0.19	122	0.24
2001	14.0	0.20	1 124	0.20	143	0.24
2002	24.8	0.21	2 048	0.22	260	0.26
2003	16.6	0.21	1 325	0.21	168	0.26
2004	14.5	0.19	1 120	0.19	142	0.24
2005	21.6	0.20	1 690	0.20	214	0.25
2006	13.6	0.22	1 041	0.22	132	0.27
2007	16.7	0.23	1 326	0.23	169	0.28
2008	19.8	0.21	1 611	0.21	205	0.26
2009	28.6	0.23	2 321	0.24	281	0.24
2010	19.8	0.19	1 606	0.19	–	–
2011	19.1	0.20	1 615	0.21	–	–
2012	10.1	0.21	885	0.22	–	–

For comparability with previous years, these 2012 estimates do not include the 2012 survey strata 8 or 19 in the previously unsurveyed outer (deeper) region of Golden and Tasman Bays.

Year						SCA 7 fishery total
	RecN	RecN CV	RecG	RecG CV	MtWt	MtWt CV
1997	52.1	0.22	4 497	0.23	568	0.26
1998	142.7	0.17	11 444	0.18	1 450	0.20
1999	127.2	0.18	11 016	0.19	1 399	0.21
2000	135.5	0.17	10 885	0.17	1 380	0.20
2001	203.3	0.20	15 611	0.19	1 977	0.22
2002	186.7	0.17	14 646	0.18	1 857	0.20
2003	113.3	0.17	8 786	0.17	1 116	0.19
2004	51.9	0.17	3 937	0.17	501	0.20
2005	45.7	0.18	3 574	0.18	453	0.20
2006	26.3	0.19	2 085	0.19	264	0.22
2007	74.0	0.19	5 868	0.19	742	0.22
2008	47.6	0.19	3 867	0.19	490	0.22
2009	43.4	0.19	3 489	0.19	444	0.19
2010	27.9	0.18	2 254	0.18	–	–
2011	21.3	0.20	1 796	0.20	–	–
2012	11.5	0.20	1 006	0.21	–	–

For comparability with previous years, these 2012 estimates do not include the 2012 survey strata 8 or 19 in the previously unsurveyed outer (deeper) region of Golden and Tasman Bays.

This fishery operates with a feedback loop that checks the reliability of the biomass survey. At the end of each commercial season, landings from each sector fished are compared with the survey biomass estimates for the sector.

4.2 Biomass estimates

Virgin biomass, B_0, and the biomass that will support the maximum sustainable yield, B_{MSY}, have not been estimated and are probably not appropriate reference points for a stock with highly variable recruitment and growth such as scallops.

Start of season (nominally 1 September) absolute recruited biomass is estimated each year from a pre-season dredge survey, which is usually conducted in May. Estimates were derived by reanalysing the historical survey data using a revised analytical procedure described by Tuck & Brown (2008) to better account for uncertainty in the start of season biomass estimates (Table 7).

Table 7: Projected recruited biomass (and c.v.) of scallops (90 mm or longer shell length) at the nominal start of season (1 September) in the survey years, 1997 to present. Estimates were derived using the revised analytical procedure described by Tuck & Brown (2008). For each year, the catch (reported on the 'Landed' section of CELRs) and exploitation rate (catch to biomass ratio) are also given. Biomass and catch are in t meatweight.

Year	Golden Bay				Tasman Bay			
	Biomass	c.v.	Catch	Catch/Biomass	Biomass	c.v.	Catch	Catch/Biomass
1997	432	0.26	239	0.55	38	0.27	2	0.05
1998	659	0.22	353	0.54	847	0.25	78	0.09
1999	642	0.24	514	0.80	626	0.25	155	0.25
2000	1236	0.21	303	0.25	606	0.23	19	0.03
2001	1640	0.24	660	0.40	945	0.25	32	0.03
2002	1186	0.22	370	0.31	1225	0.25	39	0.03
2003	354	0.22	28	0.08	1110	0.24	107	0.10
2004	79	0.23	20	0.25	468	0.22	47	0.10
2005	132	0.21	35	0.27	169	0.21	5	0.03
2006	265	0.25	26	0.10	43	0.24	0	0.00
2007	636	0.23	128	0.20	32	0.28	0	0.00
2008	313	0.22	76	0.24	15	0.31	0	0.00
2009	278	0.21	19	0.07	14	0.31	0	0.00
2010	78	0.27	10	0.13	15	0.27	0	0.00
2011	20	0.3	1	0.05	8	0.36	0	0.00
2012	9	0.39	–	–	5	0.42	–	–

Year	Marl. Sounds				SCA 7 Total			
	Biomass	c.v.	Catch	Catch/Biomass	Biomass	c.v.	Catch	Catch/Biomass
1997	98	0.26	58	0.59	572	0.2	299	0.52
1998	228	0.29	117	0.51	1737	0.17	548	0.32
1999	132	0.24	7	0.05	1404	0.19	676	0.48
2000	143	0.22	16	0.11	1969	0.17	338	0.17
2001	185	0.23	25	0.14	2798	0.18	717	0.26
2002	378	0.24	62	0.16	2787	0.18	471	0.17
2003	232	0.24	71	0.31	1692	0.18	206	0.12
2004	246	0.24	51	0.21	797	0.17	118	0.15
2005	370	0.25	116	0.31	675	0.18	157	0.23
2006	272	0.26	43	0.16	580	0.21	68	0.12
2007	273	0.27	6	0.02	940	0.19	134	0.14
2008	270	0.23	28	0.10	597	0.18	104	0.17
2009	396	0.22	101	0.26	690	0.18	120	0.17
2010	228	0.19	74	0.32	321	0.19	85	0.26
2011	221	0.19	60	0.27	248	0.18	61	0.25
2012	120	0.22	–	–	131	0.21	–	–

For comparability with previous years, the 2012 estimates do not include the 2012 survey strata 8 or 19 in the previously unsurveyed outer (deeper) region of Golden and Tasman Bays, nor stratum 16 (Croisilles Harbour)

In addition to estimates of absolute biomass, the biomass at different commercial threshold ('critical') densities (in the range 0–0.2 scallops m^{-2}) is also estimated each year.

4.3 Estimation of Maximum Constant Yield (MCY)

MCY has not been estimated for SCA 7 scallops because it is not thought to be a reasonable management approach for highly fluctuating stocks such as scallops.

4.4 Estimation of Current Annual Yield (CAY)

Historically, CAY has not been estimated for Golden and Tasman Bays because those areas operate under a fishing plan that involves enhancement and rotational fishing. Under legislation (section 14 of the Fisheries Act 1996), the catch limit for those parts of the fishery can be set at a level other than at the Maximum Sustainable Yield.

There is no enhancement or rotational fishing plan for the Marlborough Sounds, so harvest levels need to be set there each year. For the Marlborough Sounds, CAY was calculated using Method 1(Ministry for Primary Industries 2012):

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

where B_{beg} is the projected (i.e., 1 September) recruited meatweight biomass estimate and F_{ref} is $F_{0.1}$. This equation is appropriate where fishing occurs over a short period of the year.

The projected absolute recruited biomass estimate for the Marlborough Sounds at the start of the 2012 season (nominally 1 September) was an estimated 120 t meatweight with a CV of 22% (Williams & Bian 2012). Using this value and the range in $F_{0.1}$ of 0.553 (assumed M = 0.4) to 0.63 (assumed M = 0.5) gives CAY estimates (in tonnes meatweight) as follows:

		$F_{0.1}$ = 0.55	$F_{0.1}$ = 0.63
B_{beg} =	120 t	51 t	56 t

These estimates of CAY would have a CV at least as large as that of the estimate of start-of-season recruited biomass, are sensitive to assumptions about dredge efficiency, growth, expected recovery of meatweight from greenweight, and relate to the surveyed beds only. The level of risk to the putative Marlborough Sounds scallop substock of fishing at the estimated CAY level has not been determined.

The actual catch limit (MSCL in Table 3) is usually set at, or close to, the level of recruited relative meatweight biomass as determined in the pre-season abundance survey. This approach usually produces a value in the middle of the CAY range.

4.5 Other yield estimates and stock assessment results

A simulation modelling study of the Challenger scallop fishery examined the effects of catch limits, exploitation rate limits, rotational fishing, and enhancement (Breen & Kendrick 1997). The results suggested that constant catch strategies are not safe, but constant exploitation rate strategies are safe, if the maximum rate is appropriate. Rotational fishing appears to be highly stabilising, even without enhancement; collapses occurred only when the short rotational periods are combined with high intensity. Three-year rotation appears to be safer than two-year rotation. Enhancement appears to improve safety, catch, and biomass, and slightly reduces the population variability. The conclusions from this study underpinned the agreed rotational and enhancement management framework for the fishery. However, the theory of rotational fishing assumes that scallops, and habitats important for scallops, are distributed approximately evenly among the areas (sectors) to be fished rotationally; this is probably an invalid assumption for the SCA 7 fishery sectors.

$F_{0.1}$ was estimated for the Challenger fishery from a yield per recruit analysis using a size at recruitment of 90 mm and assumed values of M of 0.40 and 0.50 (Breen & Kendrick 1999). $F_{0.1}$

was 0.553 and 0.631, respectively[1]. For similar values of minimum size and natural mortality, Cryer (1999) estimated $F_{0.1}$ to be 0.469 and 0.508 in the northern scallop fishery. Consequently, $F_{0.1}$ for the Challenger fishery is assumed to be in the range 0.47 to 0.63[2].

Scallop meatweight recovery (meatweight divided by greenweight) is variable among areas, years, and weeks within the fishing season but in general appears to be highest from scallops in parts of Golden Bay (e.g., sector A) and lowest from those in Tasman Bay (e.g., sector D). Using data on the commercial landings of recruited scallops in the period 1996–2008, the mean annual meatweight recovery was 13.8% for Golden Bay, 11.8% for Tasman Bay, and 13.2% for the Marlborough Sounds. An analysis of meatweight recovery data at the time of the survey and during the fishing season for the years 1996–2007 showed meatweight recovery measured at the time of the survey could not be used to predict meatweight recovery during the fishing season.

5. STATUS OF THE STOCKS

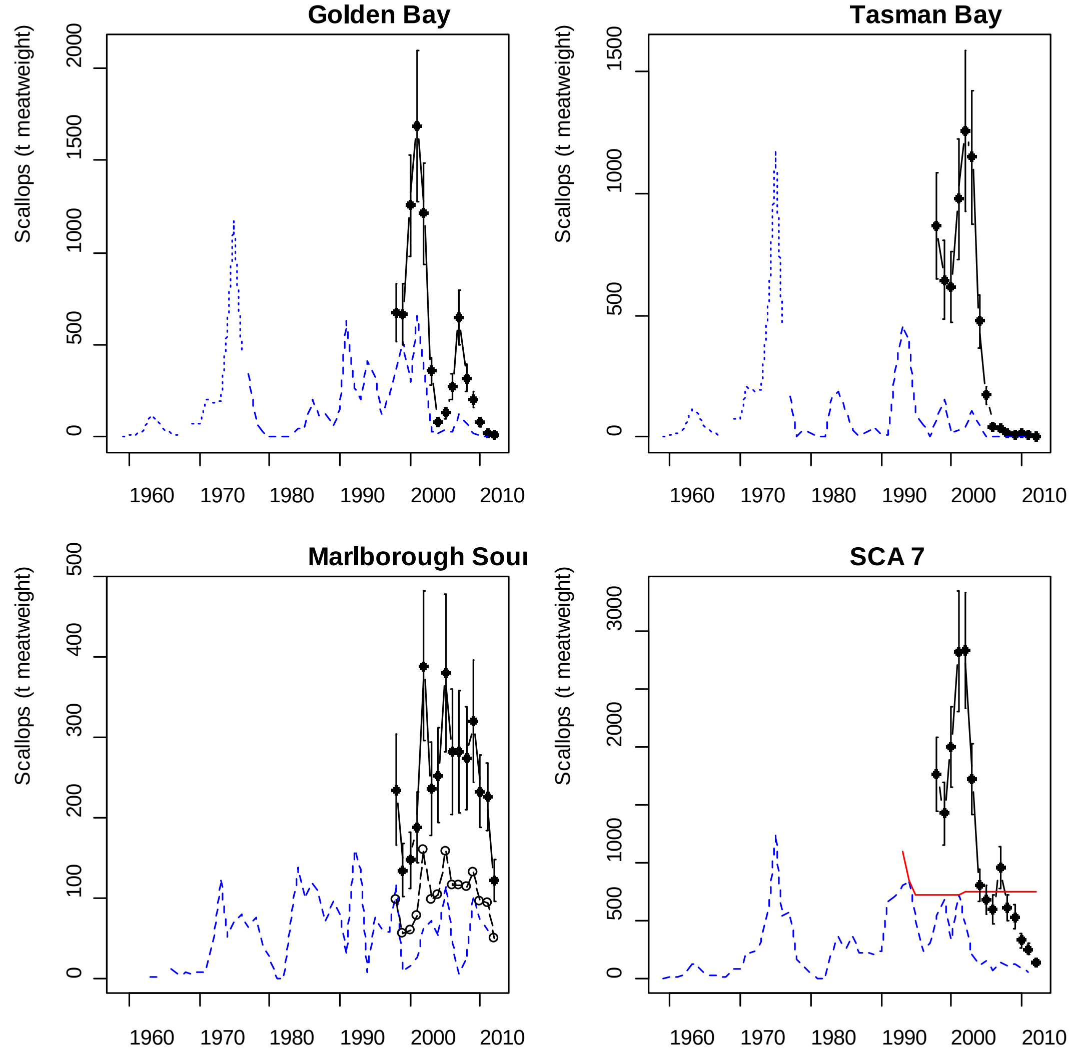
Stock Structure Assumptions
The stock structure of scallops in New Zealand waters is uncertain. For the purposes of this assessment and due to the different management regimes, Golden Bay, Tasman Bay and Marlborough Sounds are assumed to be individual and separate substocks of SCA 7.

- **Challenger scallops, SCA 7**

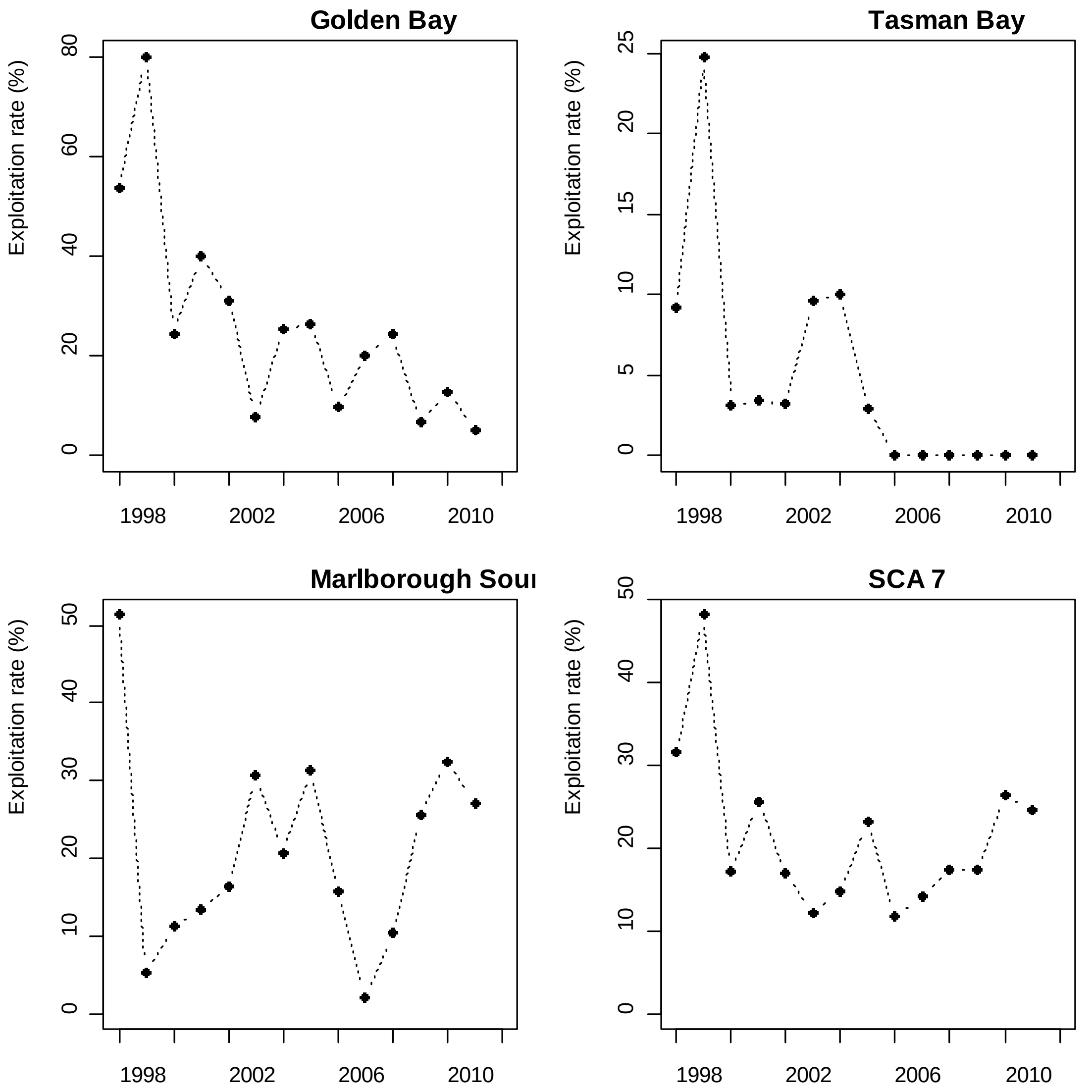
Stock Status	
Year of Most Recent Assessment	2012
Assessment Runs Presented	Estimates of biomass for Golden Bay and Tasman Bay. Two approaches to estimating CAY for Marlborough Sounds.
Reference Points	Target: Fishing mortality at or below $F_{0.1}$ for Marlborough Sounds ($F_{0.1}$ = 0.553 y^{-1} or 0.631 y^{-1} if M = 0.4 and 0.5, respectively) No targets have been set for Golden Bay or Tasman Bay; B_{MSY} assumed. Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Likely (> 60%) below F_{target} for Marlborough Sounds. Very Unlikely (< 10%) to be at or above the biomass target for Golden Bay or Tasman Bay.
Status in relation to Limits	Unlikely (< 40%) to be below the soft and hard limits for Marlborough Sounds. Very Likely (> 90%) to be below the soft limit for Golden Bay and Tasman Bay. Likely (> 60%) to be below the hard limit for Golden Bay and Tasman Bay.

[1] The F values reported by Breen & Kendrick (1999) are instantaneous Fs
[2] The F values reported by Cryer (1999) are not instantaneous Fs

Historical Stock Status Trajectory and Current Status



Recruited (scallops 90 mm or more shell length) mean (and C.V. of) biomass estimates (closed symbols with error bars joined by solid black line), TACC (solid red line), and reported landings (dashed blue line; dotted blue line for combined landings in Golden Bay/Tasman Bay before 1977) in t meatweight for the three regions of the fishery and the overall SCA 7 stock since 1959. CAY (using $F_{0.1} = 0.553$) for the Marlborough Sounds is also shown (open symbols with dashed line). Estimates of biomass from surveys before 1998 are not presented because the surveys did not cover the full extent of the SCA 7 fishery. Scale differs between plots. Note the fishery was closed for the 1981–82 and 1982–83 scallop fishing years, and was subsequently managed under a rotationally enhanced regime.



Exploitation rate (catch to biomass ratio, expressed as a percentage) for recruited scallops (90 mm or more shell length) in the three regions of the fishery and the overall SCA 7 stock since 1998.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The current status of the SCA 7 stock is the lowest recorded since extensive (fishery-wide) surveys began in 1998. In all three substocks of SCA 7, estimated recruited scallop biomass generally increased from the late 1990s to reach peak levels around 2001–02. Since then there has been a substantial biomass decline in both Golden Bay and Tasman Bay, and current biomass in both regions is at historically low levels. In contrast, biomass in the Marlborough Sounds has remained relatively stable over the same period, although there is increasing evidence of a decline there since 2009.
Recent Trend in Fishing Mortality or Proxy	In Golden Bay, the exploitation rate (catch to biomass ratio) on scallops 90 mm or more was high in in the period 1998–99 (54–80%), followed by a decreasing trend with fluctuation from 2000, and was very low (5%) in 2011–12. In Tasman Bay, the peak exploitation rate in the time series was 25% in 1999, but otherwise has been relatively low. No fishing has occurred in Tasman Bay since 2005.

	In the Marlborough Sounds, the exploitation rate decreased from 51% in 1998 to 5% in 1999, and has since ranged from 2% to 38% (mean of 20% in the period 2000–11; mean of 28% in the period 2009–11).
Other Abundance Indices	None
Trends in Other Relevant Indicator or Variables	None

Projections and Prognosis	
Stock Projections or Prognosis	Stock projections beyond the start of the 2012 season are not available, but the low numbers of pre-recruit scallops (89 mm or smaller) in Golden Bay and Tasman Bay at the time of the 2012 survey suggests recruitment to the fishable biomass in those areas over the next two years is likely to be minimal. High densities of scallop spat were observed in mesh spatbags in Golden Bay in March 2012, suggesting larval abundance was high, but the success of natural settlement and survivorship on the seabed is unknown.
Probability of Current Catch / TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology		
Assessment Type	Level 2 - Partial quantitative stock assessment	
Assessment Method	Biomass surveys and CAY management strategy	
Assessment Dates	Latest assessment: 2012	Next assessment: 2013
Overall Assessment Quality Rank	1 – High Quality	
Main data inputs (rank)	Biomass survey: 2012	1 – High Quality
Data not used (rank)	Not applicable	
Changes to Model Structure and Assumptions	None since the 2008 assessment when the survey workup methodology was revised. CAY model for Marlborough Sounds has been in use since 1997.	
Major Sources of Uncertainty	These include assumptions about: dredge efficiency during the survey, growth rates and natural mortality between the survey and the start of the season, predicting the average recovery of meatweight from greenweight and the extent to which dredging causes incidental mortality and affects recruitment.	

Qualifying Comments
The extent to which the various beds or populations are reproductively or functionally separate is not known. The Golden Bay and Tasman Bay regions of SCA 7 operate under a fishing plan that involves enhancement and rotational fishing, although these activities have been minimal in recent years. MPI projects SCA200704 and SAP200914 (Williams *et al*. in prep) are reviewing factors that may have affected the performance of the SCA 7 scallop fishery; the work includes a characterisation of the fishery, a comparison of historical landings with CAY calculated retrospectively, and an investigation of the effects of historical enhancement activities. The cause of the declines in these shellfish is unknown, but is probably associated with factors other than simply the magnitude of direct removals by fishing. It may be a combination of natural

(e.g., oceanographic) and anthropogenic (e.g., indirect effects of fishing, land-based) factors.
Fishery Interactions
Bycatch data are collected routinely during the annual surveys. Bycatch can include dredge oysters, green-lipped mussels, and a range of other benthic invertebrates. The bycatch of the fishery is likely to be similar to that of the survey.

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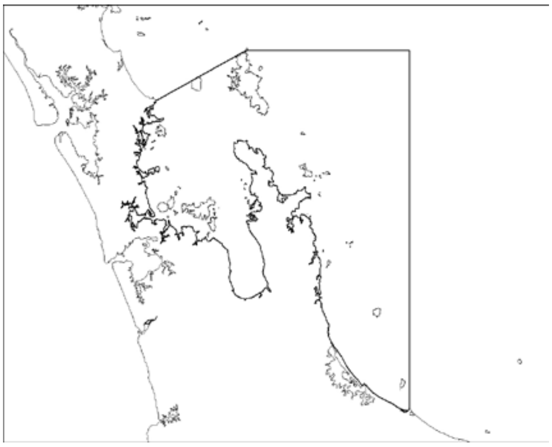
SCALLOPS COROMANDEL (SCA CS)

(*Pecten novaezelandiae*)
Kuakua, Tipa



1. FISHERY SUMMARY

Coromandel scallops were introduced into the QMS on 1 April 2002, with a TAC of 48 t, a TACC of 22 t, allowances of 7.5 t for recreational and customary fisheries, and an allowance of 11 t for other sources of mortality (Table 1; values all in meatweight).

Table 1: Total Allowable Commercial Catch (TACC, t) declared for SCA CS since introduction into the QMS.

Year	TAC	Customary	Recreational	Other Mortality	TACC
2002 - present	48	7.5	7.5	11	22

1.1 Commercial fisheries

The Coromandel scallop fishery is a regionally important commercial fishery and runs between Tauranga and Cape Rodney. Fishing is conducted within a number of discrete beds around Little Barrier Island, east of Waiheke Island (though not in recent years), at Colville, north of Whitianga (to the west and south of the Mercury Islands), and in the Bay of Plenty (principally off Waihi, and around Motiti and Slipper Islands). In 2011, fishers discovered that a large area of the Hauraki Gulf contained good densities of large scallops, which supported a large proportion of the fishing during the 2011 and 2012 seasons. That new, deeper (45–50 m water depth) region of the fishery lies mainly within statistical reporting area 2W and a smaller portion in 2S, and was surveyed for the first time in 2012. All commercial fishing is by dredge, with fishers preferring self-tipping “box” dredges to the “ring bag” designs used in the Challenger and Chatham Island fisheries. The fishing year applicable to this fishery is from 1 April to 31 March. The Coromandel commercial scallop fishing season runs from 15 July to 21 December each year.

A wide variety of effort controls and daily catch limits have been imposed in the past, but, since 1992the fishery has been limited by explicit seasonal catch limits specified in meatweight (adductor muscle with roe attached), together with some additional controls on dredge size, fishing hours and non-fishing days. Catch and catch rates from the Coromandel fishery are variable both within and among years, a characteristic typical of scallop fisheries worldwide. Catch rates typically decline as each season progresses, but such declines are highly variable and depletion analysis cannot be used to assess start-of-season biomass.

Until the 1994 season, the minimum legal size for scallops taken commercially in northern (Coromandel and Northland) scallop fisheries was 100 mm shell length. From 1995 onwards, a new limit of 90 mm shell length was applied in the Coromandel (but not the Northland) fishery as part of a management plan comprising several new measures. Since 1980 when the fishery was considered to be fully-developed, landings have varied more than 30-fold from less than 50 t to over 1500 t (greenweight). The two lowest recorded landings were in 1999 and 2000.

Northern scallop fisheries are managed under the QMS using individual transferable quotas (ITQ) that are proportions of the Total Allowable Commercial Catch (TACC). Catch limits and landings from the Coromandel fishery are shown in Table 2. Both northern scallop fisheries have been gazetted on the Second Schedule of the Fisheries Act 1996 which specifies that, for certain "highly variable" stocks, the Annual Catch Entitlement (ACE) can be increased within a fishing season. The TACC is not changed by this process and the ACE reverts to the "base" level of the TACC at the end of each season.

Table 2: Catch limits and landings (t meatweight or greenweight) from the Coromandel fishery since 1974. Data before 1986 are from Fisheries Statistics Unit (FSU) forms. Landed catch figures come from Monthly Harvest Return (MHR) forms, Licensed Fish Receiver Return (LFRR) forms, and from the landed section of Catch Effort and Landing Return (CELR) forms, whereas estimated catch figures come from the effort section of CELRs and are pro-rated to sum to the total CELR greenweight. "Hauraki" = 2X and 2W, "Mercury" = 2L and 2K, "Barrier" = 2R, 2S, and 2Q, "Plenty" = 2A–2I. Seasonal catch limits (since 1992) have been specified as ACE or on permits in meatweight (Green[1] assumes the gazetted meatweight recovery conversion factor of 12.5% and probably overestimates the actual greenweight taken in most years). * 1991 landings include about 400 t from Colville; #2011 landings were from a relatively deep (45–50 m) area of 2W fished for the first time in 2011; –, no catch limits set, or no reported catch.

	Catch limits (t)		Landings (t)			Scaled estimated catch (t green)			
			MHR	CELR					
Season	Meat	Green[1]	Meat	Meat	Green	Hauraki	Mercury	Barrier	Plenty
1974	–	–	–	–	26	0	26	0	0
1975	–	–	–	–	76	0	76	0	0
1976	–	–	–	–	112	0	98	0	14
1977	–	–	–	–	710	0	574	0	136
1978	–	–	–	–	961	164	729	3	65
1979	–	–	–	–	790	282	362	51	91
1980	–	–	–	–	1 005	249	690	23	77
1981	–	–	–	–	1 170	332	743	41	72
1982	–	–	–	–	1 050	687	385	49	80
1983	–	–	–	–	1 553	687	715	120	31
1984	–	–	–	–	1 123	524	525	62	12
1985	–	–	–	–	877	518	277	82	0
1986	–	–	–	–	1 035	135	576	305	19
1987	–	–	–	–	1 431	676	556	136	62
1988	–	–	–	–	1 167	19	911	234	3
1989	–	–	–	–	360	24	253	95	1
1990	–	–	–	–	903	98	691	114	0
1991	–	–	–	–	1 392	*472	822	98	0
1992-93	154	1 232	–	–	901	67	686	68	76
1993-94	132	1 056	–	–	455	11	229	60	149
1994-95	66	528	–	–	323	17	139	48	119
1995-96	86	686	–	79	574	25	323	176	50
1996-97	88	704	–	80	594	25	359	193	18
1997-98	105	840	–	89	679	26	473	165	15
1998-99	110	880	–	37	204	1	199	2	1
1999-00	31	248	–	7	47	0	12	17	18
2000-01	15	123	–	10	70	0	24	2	44
2001-02	22	176	–	20	161	1	63	85	12
2002-03	35	280	32	31	204	0	79	12	112
2003-04	58	464	58	56	451	63	153	13	223
2004-05	78	624	78	78	624	27	333	27	237
2005-06	118	944	119	121	968	21	872	75	0
2006-07	118	944	118	117	934	28	846	60	0
2007-08	108	864	59	59	471	51	373	45	2
2008-09	95	760	71	72	541	12	509	15	5
2009-10	100	800	33	33	267	12	184	71	0
2010-11	100	800	35	35	281	11	110	160	1
2011-12	50	400	50	50	402	#220	160	20	0

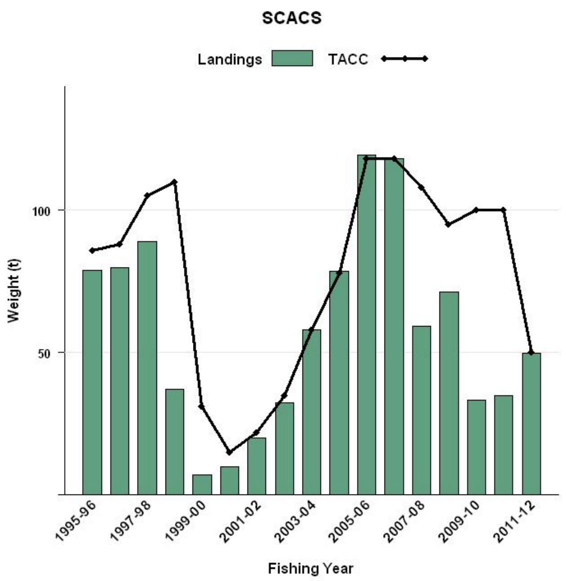


Figure 1: Landings and catch limits for SCACS (Coromandel) from 2002–03 to 2009–10. TACC refers to catch limit, and Weight refers to Meatweight.

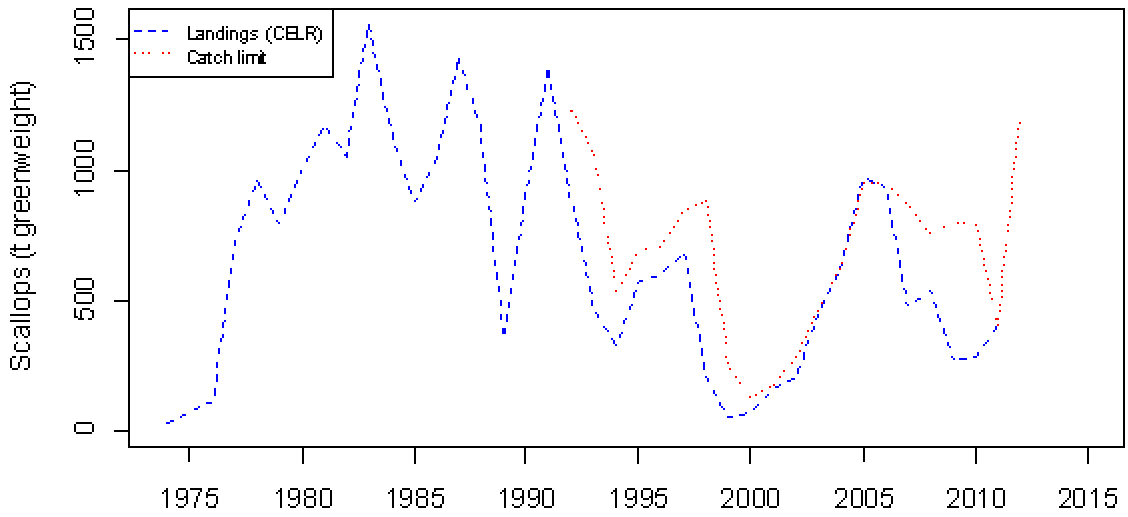


Figure 2: Catch limits and reported landings (from CELRs) in t greenweight for the SCA CS fishery since 1974.

1.2 Recreational fisheries

There is a strong non-commercial (recreational and Maori customary) interest in scallops in suitable areas throughout the Coromandel fishery, mostly in enclosed bays and harbours. Scallops are usually taken by diving using snorkel or scuba, although considerable amounts are also taken using small dredges. In some areas, especially in harbours, scallops can be taken by hand from the shallow subtidal and even the low intertidal zones (on spring tides), and, in storm events, scallops can be cast onto lee beaches in large numbers. One management tool for northern scallop fisheries is the general spatial separation of commercial and amateur fisheries through the closure of harbours and enclosed waters to commercial dredging. There remain, however, areas of contention and conflict, some of which have been addressed using additional regulated closures. Regulations governing the recreational harvest of scallops from SCA CS include a minimum legal size of 100 mm shell length and a restricted daily harvest (bag limit) of 20 per person. A change to the recreational fishing regulations in 2005 allowed divers operating from a vessel to take scallops for up to two nominated safety people on board the vessel, in addition to the catch limits for the divers. Until 2006, the recreational scallop season ran from 15 July to 14 February, but in 2007 the season was changed to run from 1 September to 31 March.

A pilot study was conducted in 2007–08 to assess the feasibility of estimating the recreational catch in that part of the Coromandel scallop fishery from Cape Colville to Hot Water Beach (Holdsworth & Walshe 2009). The study was based on an access point (boat ramp) survey using interviewers to collect catch and effort information from returning fishers, and was conducted from 1 December 2007 to 28 February 2008 (90 days) during the peak of the scallop season. The total estimated harvest during the survey period was 205,400 scallops (c.v. = 8.6%), with an estimated 23.9 t greenweight harvested (about 3 t meatweight).

Currently, there are no reliable fishery-wide estimates of non-commercial harvest of scallops from the Coromandel fishery. Estimates of catch by recreational fishers have been made on four occasions as part of recreational fishing (telephone and diary) surveys (Table 3). A Marine Recreational Fisheries Technical Working Group (FTWG) reviewed these surveys and recommended “that the telephone-diary estimates be used only with the following qualifications: 1) they may be very inaccurate; 2) the 1996 and earlier surveys contain a methodological error; and 3) the 1999–2000 and 2000–01 estimates are implausibly high for many important fisheries.”

Given the above concerns about the reliability of fishery-wide non-commercial harvest estimates, it is difficult to make comparisons between the levels of commercial and non-commercial harvest. However, in 1993–94 the recreational harvest estimate was 60–70 t (greenweight) from the area shared with the Coromandel commercial fishery (Bradford 1997). These estimates may include some Maori customary catch. Commercial landings from the Coromandel controlled fishery in the most comparable period (July to December 1994 scallop season) were 323 t, suggesting that, in that year, the recreational catch of scallops was about 16–18% of total removals. It is not known if these estimates are typical of the recreational catch, but the commercial catch was very low and 1993–94 may not have been a typical year.

Table 3: Harvest estimates (numbers, and equivalent greenweight) of scallops taken by recreational fishers in the area shared with the Coromandel scallop fishery from the telephone-diary surveys conducted in 1993–94, 1996, 1999–00, and 2000–01. A Marine Recreational Fisheries Technical Working Group considered that these estimates may be very inaccurate.

	Coromandel			
Year	No. of scallops	CV	Weight (t, green)	Reference
1993–94	626 000	0.14	60.0–70.0	Bradford (1997)
1996	614 000	0.12	62.0	Bradford (1998)
1999–00	257 000	1.01	30.1	Boyd & Reilly (2002)
2000–01	472 000	0.47	55.3	Boyd *et al.* (2004)

1.3 Customary fisheries

Scallops were undoubtedly used traditionally as food by Maori, and some limited quantitative information on recent levels of customary take is available from MFish (Table 4).

Table 4: MFish records of customary harvest of scallops (reported on customary permits as numbers or greenweight, or units unspecified) taken from the Coromandel scallop fishery, 2003–04 to 2008–09. –, no data.

SCACS	Quantity approved, by unit type			Actual quantity harvested, by unit type		
Fishing year	Weight (kg)	Number	Unspecified	Weight (kg)	Number	Unspecified
2003–04	600	200	–	600	200	–
2004–05	360	50	150	360	–	–
2005–06	3	700	50	0	–	–
2006–07	–	290	–	–	180	–
2007–08	330	630	–	285	280	–
2008–09	–	440	–	–	440	–

1.4 Illegal catch

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

1.5 Other sources of mortality

The box dredges in use in the Coromandel commercial fishery have been found to be considerably more efficient, in the generally sandy conditions prevalent in the fishery, than ring-bag or Keta-Ami dredges. However, scallops encountered by box dredges showed modest reductions in growth rate, compared with scallops collected by divers, and quite high mortality (about 20–30% mortality for scallops that are returned to the water. I.e. just under the MLS of 90 mm). Stochastic modelling suggested that, of the three dredge designs tested, box dredges would generate the greatest yield-per-recruit and catch rates. The incidental mortality caused by dredging substantially changed the shape of yield-per-recruit curves for Coromandel scallops, causing generally asymptotic curves to become domed, and decreasing estimates of F_{max} and $F_{0.1}$. More recent field experiments and modelling suggest that dredging reduces habitat heterogeneity, increases juvenile mortality, makes yield-per-recruit curves even more domed, and decreases estimates of F_{max} and $F_{0.1}$ even further.

2. BIOLOGY

Pecten novaezelandiae is one of several species of “fan shell” bivalve molluscs found in New Zealand waters. Others include queen scallops and some smaller species of the genus *Chlamys*. *P. novaezelandiae* is endemic to New Zealand, but is very closely related to the Australian species *P. fumatus* and *P. modestus*. Scallops of various taxonomic groups are found in all oceans and support many fisheries world-wide; most scallop populations undergo large fluctuations.

Scallops are found in a variety of coastal habitats, but particularly in semi-enclosed areas where circulating currents are thought to retain larvae. After the planktonic larval phase and a relatively mobile phase as very small juveniles, scallops are largely sessile and move actively mainly in response to predators. They may, however, be moved considerable distances by currents and storms and are sometimes thrown up in large numbers on beaches.

Scallops are functional hermaphrodites, and become sexually mature at a size of about 70 mm shell length. They are extremely fecund and may spawn several times each year. Fertilisation is external and larval development lasts for about 3 weeks. Initial settlement occurs when the larva attaches via a byssus thread to filamentous material or dead shells on or close to the seabed. The major settlement of spat in northern fisheries usually takes place in early January. After growth to about 5 mm, the byssus is detached and, after a highly mobile phase as a small juvenile, the young scallop takes up the relatively sedentary adult mode of life.

The very high fecundity of this species, and likely variability in the mortality of larvae and pre-recruits, leads to great variability in annual recruitment. This, combined with variable mortality and growth rate of adults, leads to scallop populations being highly variable from one year to the next, especially in areas of rapid growth where the fishery may be supported by only one or two year classes. This variability is characteristic of scallop populations world-wide, and often occurs independently of fishing pressure.

The growth of scallops within the Coromandel fishery is variable among areas, years, seasons and depths, and probably among substrates. In the Hauraki Gulf scallops have been estimated to grow to 100 mm shell length in 18 months or less, whereas this can take three or more years elsewhere (Table 5). In some years, growth is very slow, whereas in others it is very rapid. There is a steep relationship with depth and scallops in shallow water grow much faster than those in deeper water. This is not a simple relationship, however, as scallops in some very deep beds (e.g., Rangaunu Bay and Spirits Bay in the far north, both deeper than 40 m) appear to grow at least as fast as those in favourable parts of the Coromandel fishery. Food supply undoubtedly plays a role.

A variety of studies suggest that average natural mortality in the Coromandel fishery is quite high at $M = 0.50\ y^{-1}$ (instantaneous rate), and maximum age in unexploited populations is thought to be about 6 or 7 years.

Table 5: Estimates of biological parameters.

Stock	Estimates		Source
1. Natural mortality, *M*			
Motiti Island	0.4–0.5		Walshe 1984
Coromandel Fishery	Mean 0.5		Cryer 2001a
2. Weight = a(length)^b			
	a	b	
Coromandel fishery	0.00042	2.662	Cryer & Parkinson 1999
3. von Bertalanffy parameters			
	L_∞	K	
Motiti Island (1981–82)	140.6	0.378	Walshe 1984
Hauraki Gulf (1982–83)	115.9	1.200	Walshe 1984
Whitianga (1982)	114.7	1.210	Data of L.G. Allen, analysed by Cryer & Parkinson 1999
Whitianga (1983)	108.1	1.197	Data of L.G. Allen, analysed by Cryer & Parkinson 1999
Whitianga (1984)	108.4	0.586	Data of L.G. Allen, analysed by Cryer & Parkinson 1999
Coromandel fishery (1992–97)	108.8	1.366	Cryer & Parkinson 1999
Whitianga mean depth 10.6 m	113.5	1.700	Cryer & Parkinson 1999
Whitianga mean depth 21.1 m	109.0	0.669	Cryer & Parkinson 1999
Whitianga mean depth 29.7 m	110.3	0.588	Cryer & Parkinson 1999

3. STOCKS AND AREAS

Scallops inhabit waters of up to about 60 m deep (apparently up to 85 m at the Chatham Islands), but are more common in depths of 10 to 50 m on substrates of shell gravel, sand or, in some cases, silt. Scallops are typically patchily distributed at a range of spatial scales; some of the beds are persistent and others are ephemeral. The extent to which the various beds or populations are reproductively or functionally separate is not known. It is currently assumed for management that the Northland stock is separate from the adjacent Coromandel stock and from the various west coast harbours, Golden Bay, Tasman Bay, Marlborough Sounds, Stewart Island and Chatham Island areas.

4. STOCK ASSESSMENT

Coromandel scallops are managed using a TACC of 22 t meatweight which can be augmented with additional ACE based on a Current Annual Yield (CAY) calculation using $F_{0.1}$ as a reference point. Surveys of selected scallop beds in the fishery have been conducted on an almost annual basis, as a means of estimating stock size, calculating CAY, and informing potential increases in ACE.

In 2011, however, no survey was conducted; instead, CAY for the 2011 season was calculated using estimates of projected biomass generated by projecting the 2010 survey data forward to the start of the 2011 fishing season. The projection approach used a length-based growth transition matrix (based on tag return data) to grow the scallops from the time of the survey (May 2010) to the start of the fishing season the following year (July 2011), correcting for dredge efficiency, and allowing for natural mortality and fishing mortality (catch and incidental mortality). Uncertainty was incorporated during the projection process by bootstrapping (resampling with replacement) from the various data sources (Tuck 2011).

In 2012, a comprehensive survey was conducted that aimed to provide an index of abundance representative of the status of the overall SCA CS stock. The survey coverage was more extensive than used previously, with the stratification comprising ‘core’ strata (those surveyed and fished consistently in the past), ‘background’ strata (areas of lower densities outside the core strata that formed part of the survey coverage in the past), and ‘new’ strata (those in Hauraki Gulf that had never been surveyed before).

4.1 Estimates of fishery parameters and abundance

Fishing mortality has sometimes been quite high in the Coromandel fishery (Table 6).

CPUE is not presented for this fishery because it is not a reliable index of abundance (Cryer 2001b). However, recent simulation studies have examined the use of CPUE as a basis for some management strategies (Haist & Middleton 2010).

4.2 Biomass estimates

Virgin biomass, B_0, and the biomass that will support the maximum sustainable yield, B_{MSY}, have not been estimated and are probably not appropriate reference points for a stock with highly variable recruitment and growth such as scallops.

There have been annual surveys and assessments of Coromandel scallops since 1992 (except for 2000 and 2011), in support of a CAY management strategy. Assessments are based on pre-season biomass surveys done by diving and/or dredging (Tables 6–8). Bian *et al*. (2012) modelled the efficiency of box dredges used in northern New Zealand scallop fisheries, and the results suggest the efficiency of these dredges was underestimated previously (2004 to 2010), resulting in overestimation of biomass and yield. The 2012 estimates of abundance and biomass were made using the new parametric model of dredge efficiency (Bian et al. 2012) that estimates efficiency with respect to scallop length, water depth, substrate type, and tow termination.

Table 6: Estimated start of season abundance and biomass of scallops of 90 mm or more shell length in the Coromandel fishery since 1998 using historical average dredge efficiency; for each year, the catch (reported on the ‘Landed’ section of CELRs), exploitation rate (catch to biomass ratio), and the estimated fishing mortality (F_{est}) are also given. F_{est} was estimated by iteration using the Baranov catch equation where t = 5/12 and M = 0.50 spread evenly through the year. Abundance and biomass estimates are mean values up to and including 2003, and median values from 2004, when the analytical methodology for producing the estimates was modified. Note the estimates for 1998–2010 were produced by correcting for dredge efficiency using the method of Cryer & Parkinson (2006), which was replaced by the method of Bian et al (2012) in 2012 (a preliminary version of that method was used in 2011). This, together with changes to survey coverage each year, makes direct comparisons among years difficult. –, no data. There was no survey in 2000 or 2011. The 2011 values are projected estimates generated by projecting forward the 2010 survey data to the start of the 2011 fishing season. Estimates of abundance in numbers (millions) of scallops were not reported in 2011.

Year	Abundance		Biomass				Catch	Exploitation rate	F_{est}
	(millions)	c.v.	(t green)	c.v.	(t meat)	c.v.	(t meat)	(catch/biomass)	≥90 mm
1998	35.4	0.16	2702	0.16	365	0.16	31	0.08	0.237
1999	10.3	0.18	752	0.18	102	0.18	7	0.07	0.189
2000	–	–	–	–	–	–	10	–	–
2001	8.3	0.26	577	0.27	78	0.27	20	0.26	0.796
2002	10.3	0.20	768	0.20	104	0.20	31	0.30	0.954
2003	16.0	0.18	1224	0.18	165	0.18	56	0.34	1.131
2004	111.5	0.22	9024	0.21	1131	0.26	78	0.07	0.191
2005	169.3	0.24	14374	0.23	1795	0.27	121	0.07	0.185
2006	143.1	0.21	12302	0.21	1531	0.25	117	0.08	0.212
2007	101.6	0.20	8428	0.20	1061	0.23	59	0.06	0.152
2008	94.0	0.29	6900	0.28	868	0.31	72	0.08	0.232
2009	64.5	0.23	4676	0.22	595	0.24	33	0.06	0.154
2010	58.8	0.20	4442	0.19	540	0.21	35	0.07	0.180
2011	–	–	5426	0.85	658	0.87	50	0.08	0.211
2012	140.0	0.15	11423	0.15	1380	0.18	–	–	–

The 2012 estimates were produced from a comprehensive survey coverage that included previously unsurveyed areas of the SCA CS stock (e.g., the 40–50 m deep region of Hauraki Gulf, which contained a considerable biomass in 2012).

Discerning trends in the abundance and biomass of recruited scallops is complicated by changes to survey coverage, the establishment of closed areas, and uncertainty about dredge efficiency in any particular year. However, some changes have been so large as to transcend this combined uncertainty. Time series of abundance and biomass estimates of scallops 90 mm or more shell length are shown in Table 7. It is important to note that these time series were produced by correcting for dredge efficiency using the method of Cryer & Parkinson (2006), so the 2012 values were generated using that same method so that all years are comparable. In future, the data should be re-worked using the new method of Bian et al (2012). For 2012, the estimates were generated using data from the 'core' strata only (i.e., the 'background' strata, and 'new' strata in the Hauraki Gulf region, were excluded, the latter because there was no survey from the past; it was surveyed for the first time in 2012).

Estimates around the turn of the century (2000) were consistently at or near the lowest on record and it seems reasonable to conclude that the population was, for unknown reasons, at a very low ebb. In contrast, following reasonable increases in 2003 and, especially, 2004, the abundance and biomass in 2005 were the highest on record and probably higher than in the mid 1980s when not all of the beds were surveyed. This remarkable resurgence was strongest in the Mercury region to the north of Whitianga (the mainstay of the fishery), but most beds showed some increase in density. There has been a gradual decline in the overall recruited population since the peak in 2005, but in 2010 this downward trend appeared to have stalled. For the regions usually fished (i.e. for the core strata only, excluding the 'new' area in Hauraki Gulf and the 'background' strata) the status of the recruited population in 2012 appears to be fairly similar to that in 2010 (Appendix 8; estimated using Cryer & Parkinson (2006) dredge efficiency method), and again most of the fishable biomass is held in the Mercury beds, but with high densities of recruits in beds at Little Barrier. For the new Hauraki Gulf region of the fishery (2W/2S), it is unknown whether the large biomass of scallops found in 2012 is a consistent part of the population, or a product of successful recruitment in recent years.

Table 7: Estimated abundance and biomass of scallops 90 mm or more shell length at the time of surveys in the five main regions of the Coromandel fishery since 1998. Excludes the "new", deep fishery region in Hauraki Gulf, which was fished for the first time in 2011, and surveyed for the first time in 2012 (estimated 148.5 million scallops or 13278 t greenweight biomass). Survey data were analysed using a non-parametric re-sampling with replacement approach to estimation (1000 bootstraps). Note these estimates were produced by correcting for dredge efficiency using the method of Cryer & Parkinson (2006), which has now been replaced by the method of Bian et al (2012). Figures are not necessarily directly comparable among years because of changes to survey coverage. –, no survey in a region or year. The 2001 survey totals include scallops surveyed in 7 km^2 strata at both Kawau (0.5 million, 3 t) and Great Barrier Island (0.8 million, 62 t).

Year					Abundance (millions)		Area surveyed
	Barrier	Waiheke	Colville	Mercury	Plenty	Total	(km^2)
1998	2.0	9.0	0.4	21.3	2.2	36.1	341
1999	0.5	0.5	0.0	7.3	2.7	11.2	341
2000	–	–	–	–	–	–	–
2001	7.4	0.4	–	6.9	2.1	18.1	125
2002	1.8	4.0	–	6.6	2.0	14.7	119
2003	2.5	4.0	4.3	12.3	4.9	28.6	130
2004	4.5	9.8	0.4	58.5	8.2	82.6	149
2005	6.2	3.3	3.0	118.8	12.6	145.3	174
2006	5.6	–	10.3	101.6	6.5	125.3	160
2007	4.2	1.3	4.4	59.9	14.3	84.6	175
2008	2.0	–	1.7	56.3	4.8	65.0	144
2009	10.4	–	3.1	31.8	1.3	46.9	144
2010	9.6	0.8	2.6	28.0	3.9	45.6	149
2011	–	–	–	–	–	–	–
2012	7.7	0.4	2.4	22.8	2.9	36.8	180

Year					Biomass (t green)		Area
	Barrier	Waiheke	Colville	Mercury	Plenty	Total	(km^2)
1998	173	731	30	1 674	205	2 912	341
1999	42	34	1	559	224	873	341
2000	–	–	–	–	–	–	–
2001	554	32	–	525	165	1 362	125
2002	150	289	–	538	163	1 156	119
2003	225	302	387	995	406	2 355	130
2004	348	737	30	4 923	676	6 794	149

2005	544	274	316	10 118	1 058	12 404	174
2006	519	–	1 041	8 731	534	10 902	160
2007	376	96	409	5 498	1 110	7 539	175
2008	166	–	150	4 575	367	5 265	144
2009	823	–	257	2 512	102	3 725	144
2010	764	59	219	2 299	291	3 671	149
2011	–	–	–	–	–	–	–
2012	629	32	250	1 855	225	3 027	180

Uncertainty stemming from assumptions about dredge efficiency during the surveys, rates of growth and natural mortality between survey and season, and predicting the average recovery of meatweight from greenweight remain in these biomass estimates.A new model of scallop dredge efficiency (Bian et al. 2012) has helped to reduce this uncertainty, as should future research projects aimed at collecting more data on scallop growth and mortality. Managing the fisheries based on the number of recruited scallops at the start of the season as opposed to recruited biomass (the current approach) could remove the uncertainty associated with converting estimated numbers of scallops to estimated meatweight.

Until 1997, assessments for the Coromandel fishery were based on Provisional Yield (PY, estimated as the lower bound of a 95% confidence distribution for the estimated start-of-season biomass of scallops 100 mm or more shell length). Experiments and modelling showed this method to be sub-
optimal however. New estimates of the reference fishing mortality rates $F_{0.1}$, $F_{40\%}$ and F_{max} were therefore made, taking into account experimental estimates of incidental fishing mortality. For assessments since 1998, CAY was estimated using these reference fishing mortality rates, and CAY supplanted PY as a yield estimator. Recent experimentation and modelling of juvenile mortality in relation to habitat heterogeneity suggest that even these more conservative reference fishing mortality rates may be too high.

Diver surveys of scallops were conducted annually in June–July from 2006 to 2010 at selected scallop beds in the Coromandel recreational fishing areas (Williams *et al*. 2008, Williams 2009a, b, 2012). For the four small beds (total area of 4.64 km^2) surveyed each year, the projected (15 July) biomass of scallops over 100 mm shell length was estimated to be 128 t greenweight (CV of 26%) or 16 t meatweight in 2006, 82 t greenweight (CV of 13%) or 10 t meatweight (CV of 20%) in 2007, and 79 t greenweight (CV of 14%) or 10 t meatweight (CV of 21%) in 2008. Survey stratum boundaries were revised in 2009 to better reflect the extent of the scallop bed at each site, resulting in a slightly reduced total area (3.6 km^2) surveyed; the total projected biomass was estimated to be 50 t greenweight or 6 t meatweight (CVs of 13%) in 2009, and 48 t greenweight or 6 t meatweight (CVs of 13 and 16%) in 2010 (Williams 2012).

4.3 Estimation of Maximum Constant Yield (MCY)

MCY has not been estimated for Coromandel scallops and would probably be close to zero.

4.4 Estimation of Current Annual Yield (CAY)

Yield estimates are generally calculated using reference rates of fishing mortality applied to an estimate of current or reference biomass. Cryer & Parkinson (2006) reviewed reference rates of fishing mortality and summarised modelling studies by Cryer & Parkinson (1997) and Cryer *et al.* (2004). $F_{0.1}$ is used as the target reference rate of fishing mortality for scallops.

Management of Coromandel scallops is based on a CAY approach. Since 1998, catch limits have been adjusted in line with estimated start-of-season recruited biomass and an estimate of CAY made using the Baranov catch equation:

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

where t = 5/12 years, F_{ref} is a reference fishing mortality ($F_{0.1}$) and B_{beg} is the estimated start-of-season (15 July) recruited biomass (scallops of 90 mm or more shell length). Natural mortality is assumed to act in tandem with fishing mortality for the first 5 months of the fishing season, the length of the current Coromandel commercial scallop season. B_{beg} is estimated assuming historical average dredge efficiency at length, average growth (from previous tagging studies), M = 0.5 spread evenly through the year, and historical average recovery of meatweight from greenweight. Because of the uncertainty over biomass estimates, growth, and mortality in a given year, and appropriate reference rates of fishing mortality, yield estimates must be treated with caution.

Modelling studies for Coromandel scallops (Cryer & Morrison 1997, Cryer *et al*. 2004) indicate that $F_{0.1}$ is sensitive not only to the direct incidental effects of fishing (reduced growth and increased mortality on essentially adult scallops), but also to indirect incidental effects (such as additional juvenile mortality related to reduced habitat heterogeneity in dredged areas).

Consequently, the most recent CAY estimates were derived in 2012 for two scenarios:

1) CAY including direct effects on adults

By including only the direct incidental effects of fishing on scallops, Cryer *et al*. (2004) derived an estimate of $F_{0.1}$ = 1.034 y^{-1} (reported by Cryer *et al*., 2004, as 5/12 * $F_{0.1}$ = 0.431). Using this value and the 2012 start of season biomass estimate of 1380 t meatweight (median projected value), the CAY for 2012–13 was estimated to be 439 t meatweight (Williams et al. 2012).

2) CAY including direct and indirect effects on adults and juveniles

Cryer *et al*. (2004) modelled the “feedback” effects of habitat modification by the dredge method on juvenile mortality in scallops. They developed estimates of F_{ref} that incorporated such effects, but had to make assumptions about the duration of what they called the “critical phase” of juvenile growth during which scallops were susceptible to increased mortality. To give some guidance on the possible outcome of including “indirect” (as well as direct) effects on yield estimates, Cryer *et al*.s (2004) estimate of $F_{0.1}$ = 0.658 y^{-1} (reported as 5/12 * $F_{0.1}$ = 0.274) was applied here. Using this value and the 2012 start of season biomass estimate of 1380 t (median projected value), the CAY for 2012–13 was estimated to be 300 t meatweight (Williams et al. 2012).

For both scenarios, the estimates of CAY would have C.V.s at least as large as those of the estimate of start-of-season recruited biomass (18%), are sensitive to assumptions about dredge efficiency, growth, and expected recovery of meatweight from greenweight, and relate to the surveyed beds only. Further, the second approach which includes indirect incidental effects (putative “habitat effects”) is sensitive to the duration of any habitat-mediated increase in juvenile mortality. There is also additional uncertainty associated with using a point estimate of $F_{0.1}$ (i.e., variance associated with the point estimate of $F_{0.1}$ was not incorporated in the analysis), and the fact that the estimates of $F_{0.1}$ were generated using estimates of dredge efficiency that are different to those used to estimate current biomass; the latter may have resulted in underestimates of yield.

Regardless of the approach used to estimate CAY, the production of a single ‘best estimate’ of CAY should be treated with caution; it is better to work with a range of estimates. For the projections to the 2012 start of season, the 1000 combined greenweight estimates were converted to meatweight (resampling from the meatweight greenweight conversion ratio data).. The median of this meatweight distribution was 1380 tonnes. Using the existing target reference $F_{0.1}$ values for Coromandel scallops, this meatweight distribution was converted into a distribution of CAY estimates and a range of catch limit options were compared with this distribution to provide a decision table (Table 9).

Table 9: Decision table showing probability that a particular catch limit (t meatweight) would exceed reference fishing mortality values, for the Coromandel scallop (SCA CS) 2012–13 fishing year. $F_{0.1}$ (direct effects) represents the probability that the estimate of $F_{0.1}$ = 1.034 incorporating direct incidental mortality effects is exceeded. $F_{0.1}$ (direct & indirect effects) represents the probability that the estimate of $F_{0.1}$ = 0.658 incorporating direct and indirect incidental mortality effects is exceeded. These probabilities were generated from an analysis using estimates of absolute biomass within the surveyed area (i.e., a critical density of 0.00 scallops m^{-2}).

Catch limit (t)	F0.1 (direct effects)	F0.1 (direct & indirect effects)
150	0.000	0.000
160	0.000	0.000
170	0.000	0.001
180	0.000	0.002
190	0.000	0.005
200	0.000	0.011
210	0.000	0.018
220	0.000	0.036
230	0.000	0.063
240	0.001	0.109
250	0.001	0.162
260	0.002	0.217
270	0.002	0.285
280	0.007	0.351
290	0.010	0.429
300	0.016	0.510
310	0.020	0.577
320	0.033	0.645
330	0.050	0.706
340	0.070	0.772
350	0.104	0.817
360	0.138	0.850
370	0.179	0.886
380	0.213	0.914
390	0.259	0.933
400	0.306	0.950
410	0.353	0.960
420	0.402	0.974
430	0.460	0.985
440	0.513	0.988

4.5 Other yield estimates and stock assessment results

The estimation of Provisional Yield (PY) is no longer accepted as appropriate, and assessments since 1998 have used a CAY approach.

Stochastic yield-per-recruit (YPR) and spawning-stock-biomass-per-recruit (SSBPR) modelling has been conducted for the Coromandel scallop fishery, including the incidental effects on growth and mortality of the dredge method in use throughout the fishery. Estimates of reference rates of fishing mortality from this study have been used to estimate CAY since 1998. More recent experimental and modelling studies indicate that even these reference rates of fishing mortality may be too high if habitat effects and juvenile scallop mortality are taken into account, causing a positive bias in CAY. CAY may also be over-estimated when either the efficiency of the dredge used during the survey is greater than that assumed in calculations (i.e., the multiplier used to account for dredge efficiency is optimistic), or the density of scallops is low and part of the biomass occurs at a density not viable for commercial fishing.

5. STOCK STATUS

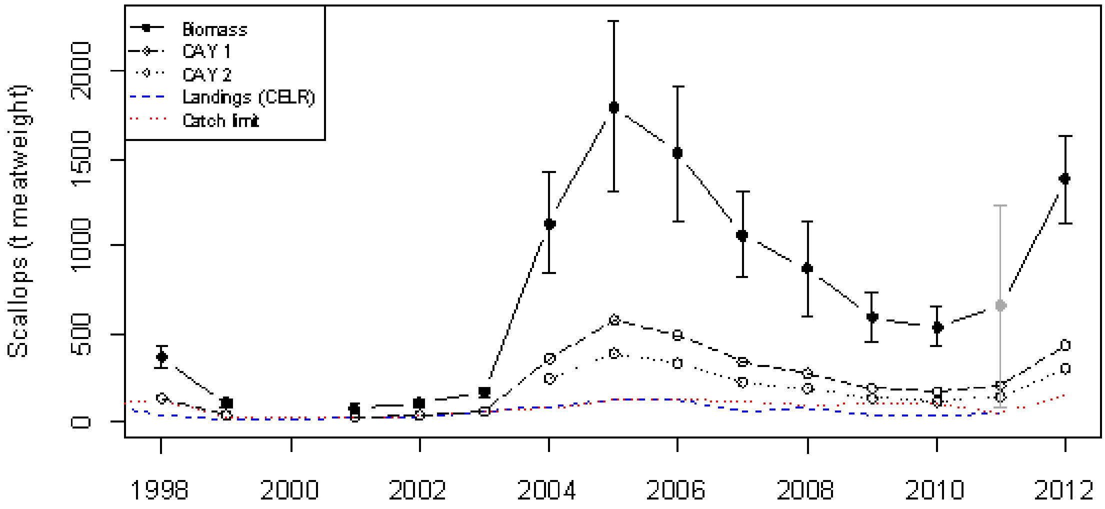
Stock Structure Assumptions

The stock structure of scallops in New Zealand waters is uncertain. For the purposes of this assessment, SCA CS is assumed to be a single biological stock, although the extent to which the various beds or populations are reproductively or functionally separate is not known.

- **Coromandel scallops, SCA CS**

Stock Status	
Year of Most Recent Assessment	2012
Assessment Runs Presented	Two approaches to estimating CAY
Reference Points	Target: Fishing mortality at or below $F_{0.1}$ ($F_{0.1}$ = 1.034 y^{-1} including direct incidental effects of fishing only, or $F_{0.1}$ = 0.658 y^{-1} including direct and indirect effects of fishing) Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Very Likely (> 90%) to be below F_{target} (in 2011–12, F_{est} = 0.211 y^{-1}) CAY for 2012–13 was estimated at 439 t (using $F_{0.1}$ = 1.034 y^{-1}) or 300 t (using $F_{0.1}$ = 0.658 y^{-1}) meatweight
Status in relation to Limits	Unlikely (< 40%) to be below the soft and hard limits.

Historical Stock Status Trajectory and Current Status



Estimated recruited biomass (scallops 90 mm or more shell length), CAY 1 (includes direct effects of fishing on adult scallops), CAY 2 (includes direct and indirect effects of fishing on adults and juveniles), catch limits, and reported landings (from CELRs) in t meatweight for the SCA CS fishery since 1998. In 2011, no survey was conducted; instead, biomass was estimated by projecting forward from the 2010 survey (shown in grey).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Estimated recruited biomass (t meatweight of scallops ≥ 90 mm shell length) in the core areas of the fishery between 1999–2003 was consistently at or near the lowest on record (78 t meatweight in 2001), but increased dramatically to record high levels in 2005 (1795 t) and 2006 (1531 t). There has been a recent trend of decreasing biomass from the peak in 2005 to the 2009 estimate of 595 t, but this downward trend appears to have abated in 2010 (540 t). In addition to the core areas, the comprehensive 2012 survey coverage included a large new area of the fishery in Hauraki Gulf, and showed that it held a considerable biomass. It is unknown whether the large biomass of scallops found in 2012 is a consistent part of the population, or a product of successful recruitment in recent years. Including that 'new' area, projected biomass in 2012 was an estimated 1380 t.
Recent Trend in Fishing Mortality or Proxy	At the fishery-wide level, estimated fishing mortality on scallops 90 mm or more was relatively low in the periods 1998–99 and 2004–11 (mean F_{est} = 0.19 y^{-1}), but much higher between 2001 and 2003 (mean F_{est} = 0.96 y^{-1}).
Other Abundance Indices	None.
Trends in Other Relevant Indicator or Variables	None

Projections and Prognosis	
Stock Projections or Prognosis	Stock projections beyond the start of the 2012 season are not available. Catch, catch rates and growth are highly variable both within and among years. Recruitment is also highly variable between years.
Probability of Current Catch / TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology		
Assessment Type	Level 2 - Partial quantitative stock assessment	
Assessment Method	Biomass surveys and CAY management strategy	
Assessment Dates	Latest assessment: 2012	Next assessment: 2013
Overall Assessment Quality Rank	1 – High Quality	
Main data inputs (rank)	Biomass survey: 2012	1 – High Quality
Data not used (rank)	Not applicable	
Changes to Model Structure and Assumptions	None since the 2009 assessment. Current model has been in use since 1998. In 2011, however, no survey was conducted; instead, CAY was calculated using estimates of projected biomass generated by projecting forward the 2010 survey data to the 2011 season.	
Major Sources of Uncertainty	These include assumptions about: dredge efficiency during the survey, growth rates and natural mortality between the survey and the start of the season, predicting the average recovery of meatweight from greenweight and the extent to which dredging causes incidental mortality and affects recruitment.	

Qualifying Comments
In the Coromandel fishery some scallop beds are persistent and others are ephemeral. The

extent to which the various beds or populations are reproductively or functionally separate is not known. At the Shellfish Fishery Assessment Working Group held on 21–22 January 2010, concerns were raised about the large discrepancy that has been observed over recent years between the CAY estimates for the commercial Coromandel scallop fishery and the actual catch taken by the fishers. Fishers that attended the SFWG meeting believe that it is not possible to catch the CAY. MFish project SAP2009-10 (Williams *et al*. 2011) investigated a number of factors which could affect the difference between CAY and the actual commercial catch, and found that the calculated dredge efficiency was the major factor contributing to the difference. Project SAP200913 (Bian *et al*. 2012) modelled the efficiency of box dredges used in northern New Zealand scallop fisheries; results suggest the efficiency of these dredges was underestimated previously (2004 to 2010), resulting in overestimation of biomass and yield. The new model of dredge efficiency (Bian et al. 2012) was used in the 2012 assessment.
Fishery Interactions
A bycatch survey was conducted in the Coromandel fishery in 2009 under project SCA2007-01B. The results are summarised below. The bycatch of the fishery is likely to be similar to that of the survey. Bycatch composition Live components • Scallops 26% • Seaweed 11% • Starfish 4% • Other bivalves 4% • Coralline turf 1% Dead components • Dead shell 45% • Rock and gravel 8% Bycatch data were also collected during the 2010 and 2012 surveys of SCA CS; the data were loaded to the MPI database "*scallop*" for use in future work.

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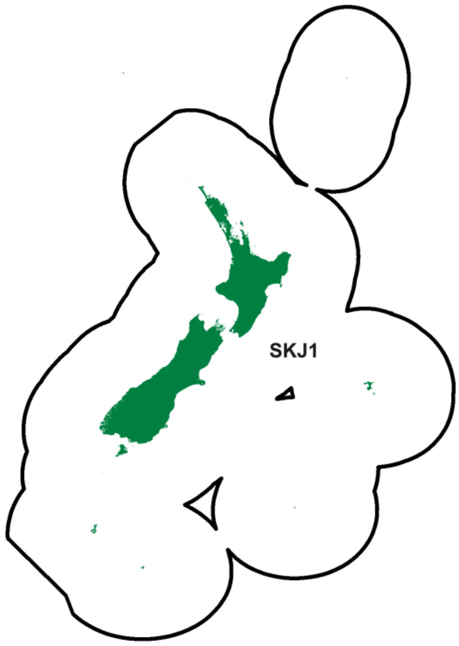
SKIPJACK TUNA (SKJ)

(Katsuwonus pelamis)
Aku



1. FISHERY SUMMARY

Management of skipjack tuna throughout the Western and Central Pacific Ocean (WCPO) is the responsibility of the Western and Central Pacific Fisheries Commission (WCPFC). Under this regional convention New Zealand is responsible for ensuring that the management measures applied within New Zealand fisheries waters are compatible with those adopted by the Commission.

1.1 Commercial fisheries

Skipjack was the first commercially exploited tuna in New Zealand waters, with landings beginning in the 1960s in the Taranaki Bight and quickly extending to the Bay of Plenty. The fishery in New Zealand waters has been almost exclusively a purse seine fishery, although minor catches (< 1%) are taken by other gear types (especially troll). The purse seine fishery for from 2006-2010 has been based on a few (5-7 medium sized vessels < 500 GRT) operating on short fishing trips assisted by fixed wing aircraft, acting as spotter planes, in FMA 1, FMA 2 and occasionally FMA 9 during summer months. In addition, during the late 1970s and early 1980s a fleet of US purse seiners seasonally operated in New Zealand waters. During this period total annual catches were about 9000 t.

Since 2001, however, New Zealand companies have operated four large ex-US super seiners which fish for skipjack in the EEZ, on the high seas, and in the EEZs of various Pacific Island countries in equatorial waters. Domestic landings within the EEZ have averaged at 10 389 t annually between 2006-07 and 2010-11. Catches in the New Zealand EEZ are variable and can approximate 10 000 t in a good season such as 1999-00, 2003-04, 2004-05, 2006-07, 2007-08 and 2010-11.

Table 1 compares New Zealand landings with total catches from the WCPO stock, while Table 2 shows the catches reported on commercial logsheets and Monthly Harvest Returns. Figure 1 shows historical landings and longline fishing effort for SKJ fisheries.

Catches from within New Zealand fisheries waters are very small (0.5% average for 2007-2009) compared to those from the greater stock in the WCPO. Catches by New Zealand flagged vessels in the WCPO are larger (1.2% average for 2007-2009).

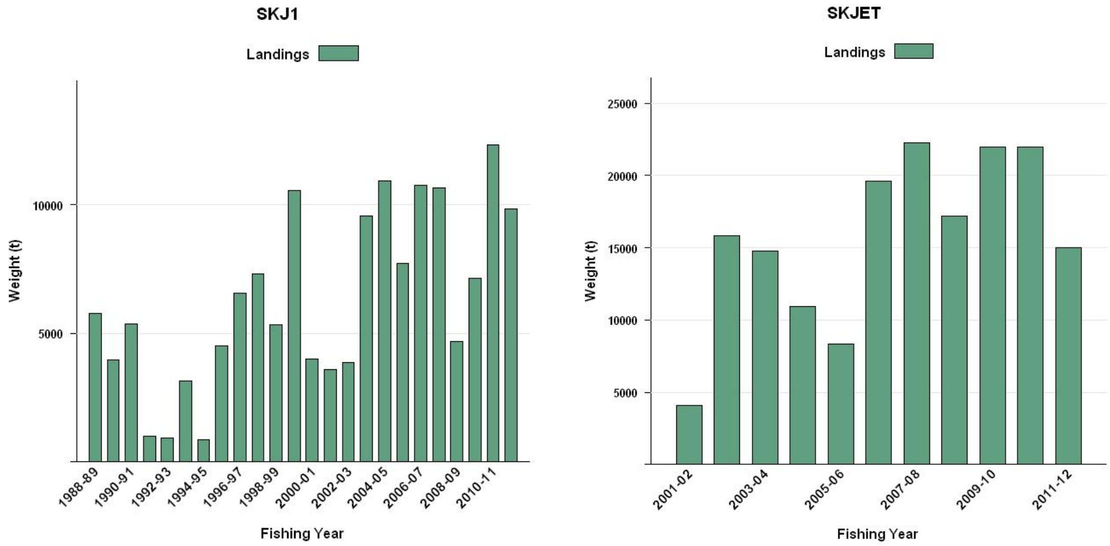


Figure 1: Skipjack purse seine catch from 1988-89 to 2011-12 within NZ waters (SKJ1), and 2001-02 to 2011-12 in the equatorial Pacific by New Zealand vessels.

Table 1: Total New Zealand landings (t) both within and outside the New Zealand EEZ, and total landings from the Western and Central Pacific Ocean (t) of skipjack tuna by calendar year from 2001 to 2011.

	NZ landings (t)			All WCPO Landings
Year	Within NZ fisheries waters	Outside NZ fisheries waters*	Total	Total landings (t)
2001	4 261	4 069	8 330	1 141 466
2002	3 555	15 827	19 382	1 222 323
2003	3 828	14 769	18 597	1 223 454
2004	9 704	10 932	20 636	1 308 800
2005	10 819	8 335	19 154	1 378 374
2006	7 247	19 588	26 835	1 484 948
2007	11 392	22 266	33 659	1 650 123
2008	10 033	17 204	27 237	1 647 371
2009	4 685	21 991	26 676	1 799 991
2010	8 629	21 991	30 620	1 688 473
2011	10 839	14 994	25 833	1 557 588

*Includes some catches taken in the EEZs of other countries under access agreements.
Source: Ministry of Fisheries Catch, Effort, Landing Returns, High Seas reporting system; OFP (2010); and Anon (2012).

Table 2: Reported commercial catches (t) within New Zealand fishing waters of skipjack by fishing year from catch effort data (mainly purse seine fisheries), and estimated landings from LFRRs (processor records) and Monthly Harvest Returns (MHRs).

Year	Total catches from catch/effort	Total catches from catch/effort	LFRR	MHR
1988-89	0		5 769	
1989-90	6 627		3 972	
1990-91	7 408		5 371	
1991-92	1 000		988	
1992-93	1 189		946	
1993-94	3 216		3136	
1994-95	1 113		861	
1995-96	4 214		4 520	
1996-97	6 303		6 571	
1997-98	7 325		7 308	
1998-99	5 690		5 347	
1999-00		10 306	10 561	
2000-01		4 342	4 020	
2001-02		3 840	3 487	3 581
2002-03		3 664	2 826	3 868
2003-04		9 892	9 225	9 606
2004-05		10 311	8 301	10 928
2005-06		7 220	7 702	7702
2006-07		10 115	10 761	10 762
2007-08		10 116	10 665	10 665
2008-09		4 384	4 737	4 685
2009-10			8 020	7 141
2010-11			17 764	12 326
2011-12			11 814	9 829

Skipjack tuna account for the majority of purse seine target sets in New Zealand fishery waters (Figure 2). However, jack mackerel make up the bulk of the catch and skipjack tuna account for 25% of the landed mass of the domestic purse seine fleet (Figure 3). The skipjack tuna catch occurs on both the east and west coasts of the North Island (Figure 4).

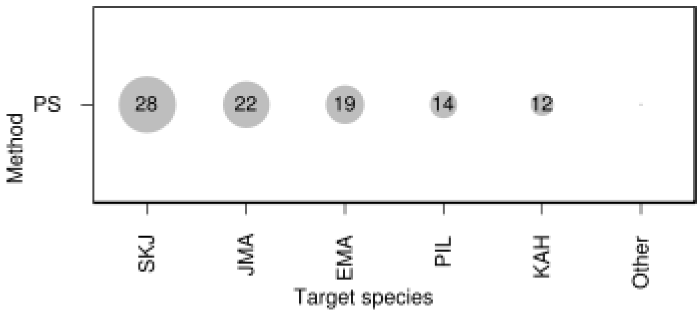


Figure 2: A summary of the proportion of lnadings target sets in the domestic purse seine fishery. The area of each circle represents the percentage of the vessel days targeting each species PS = purse seine (Bentley *et al.* 2012).

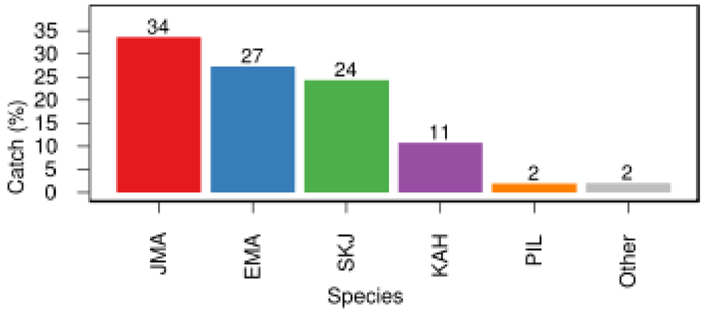


Figure 3: A summary of species composition of the reported purse seine catch. The percentage by weight of each species is calculated for all domestic trips (Bentley *et al.* 2012).

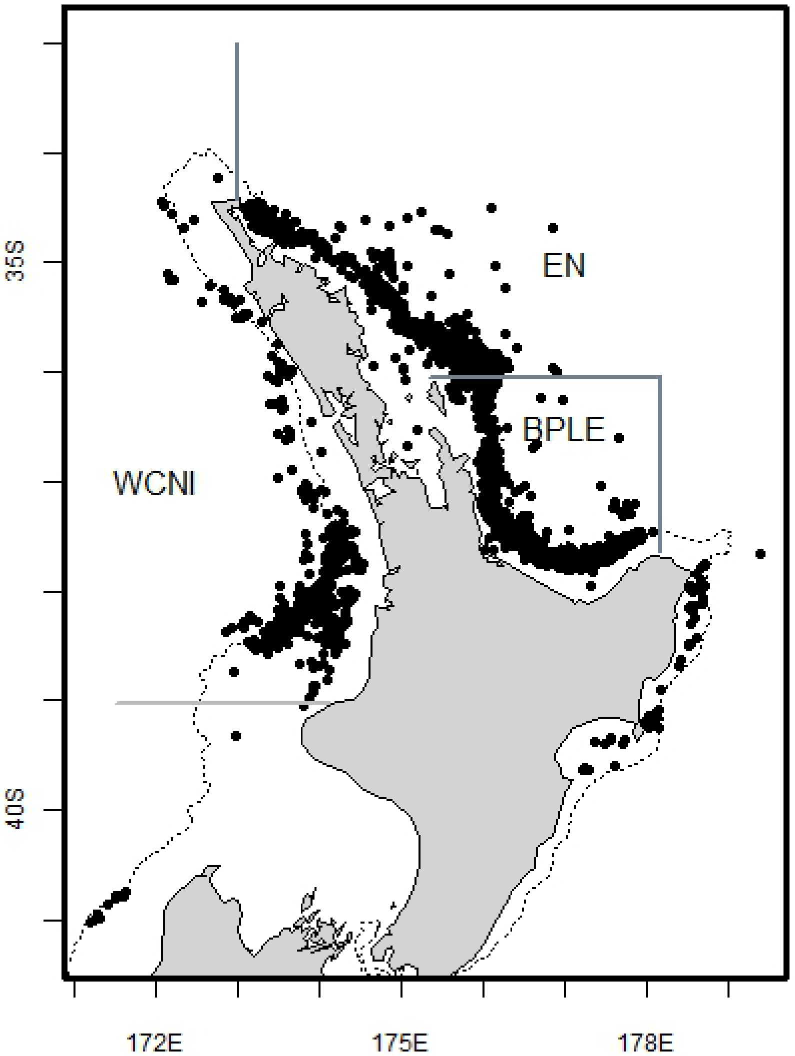


Figure 4: Location of purse-seine sets targeting skipjack tuna from 1999–2000 to 2008–09. The solid grey lines denote the boundaries of the main fishery areas (EN, east Northland, BPLE, Bay of Plenty; WCNI, west coast North Island). The dashed line represents the 200 m depth contour (Langley 2011).

Fishing activity for skipjack tuna by New Zealand flagged vessels outside of New Zealand fishery waters is generally limited to within the 10° S to 5° N latitudinal range (Figure 5). The distribution of fishing activity is largely constrained to areas of international waters ("high seas") and the national waters of those countries for which the fleet has established access arrangements, most notably the EEZs of Tuvalu and Kiribati (Table 3). A limited amount of fishing has also occurred in the waters of Nauru, Solomon Islands, Tokelau, Federal States of Micronesia (FSM) and Marshall Islands although the activity in these areas has either been intermittent or maintained at a low level. Fishing access to a country's national waters is generally negotiated collectively under the auspices of the New Zealand Far Seas Tuna Fishers Association. However, the individual members of the association may decide not to purchase a licence in a specific year (Langley 2011).

There are four main areas of international waters within the western equatorial Pacific. Of these areas, most of the fishing by the New Zealand fleet has been within the area of international waters surrounded by the national waters of Nauru, Kiribati (Gilbert Islands), Tuvalu, Solomon Islands, Papua New Guinea and FSM (the so called "high seas pockets", denoted A2 in Figure 5). The fleet also operates in the narrow strip of international waters between Tuvalu and the Phoenix Islands (Kiribati) (area A3) and intermittently in the eastern area of international waters between the Phoenix Islands and Line Islands (Kiribati) (area A4). Limited fishing has occurred in the international waters between Papua New Guinea and FSM (area A1). Overall, the areas of international waters account for about 30% of the annual level of fishing activity and skipjack tuna catch of the New Zealand fleet operating in the equatorial fishery (Table 3) (Langley 2011).

Total fishing effort (number of sets) was highest in 2002 and was dominated by fishing within Kiribati waters. In the subsequent years, the fishing effort tended to fluctuate about the average level, with higher levels of effort in 2006 and 2009 and lower effort in 2005 and 2007 (Table 3) (Langley 2011).

In the initial years (2002–2005), there was considerable variability in the distribution of fishing effort among the main fishing areas. Fishing effort in Kiribati waters was high in 2002 and 2005 and fishing effort in Tuvalu waters was low in 2003 when a considerable amount of fishing occurred in the waters of FSM. During 2006–2009, the distribution of fishing effort was relatively stable with international waters and the EEZs of Tuvalu and Kiribati each accounting for about 25–35% of the annual fishing effort and 5–15% of the total effort occurring in other areas (Table 3) (Langley 2011).

Table 3: Number of sets conducted New Zealand flagged purse-seine vessels operating within areas of international waters (IW) and countries EEZ's in the western equatorial Pacific fishery by calendar year. KI denotes Kiribati. Areas of international waters (A1-4) are defined in Figure 5 (Langley 2011).

Area	**Year**								
	2001	2002	2003	2004	2005	2006	2007	2008	2009
IW A1	0	0	50	0	0	0	0	0	0
IW A2	7	58	114	73	52	189	125	163	110
IW A3	7	15	74	37	16	39	43	19	30
IW A4	0	126	3	5	39	29	1	0	48
FSM	0	1	143	0	0	0	0	0	0
Gilbert Is (KI)	43	92	130	122	111	133	90	112	37
Line Is (KI)	0	149	0	0	3	0	27	0	0
Pheonix Is (KI)	12	126	31	44	144	49	62	9	164
Marshall Islands	0	0	4	6	10	0	0	0	0
Nauru	0	0	0	44	30	17	17	21	0
Solomon Islands	0	0	65	77	4	71	2	89	25
Tokelau	0	12	1	0	1	0	0	0	32
Tuvalu	94	187	29	136	81	138	141	169	211
Other	0	5	14	3	1	6	3	1	1
Total	163	771	658	547	492	671	511	583	658
% IW	9	26	37	21	22	38	33	31	29

1.2 Recreational fisheries

Recreational fishers using rod and reel regularly catch skipjack tuna particularly in FMA 1, FMA 2 and FMA 9. They do not comprise part of the voluntary recreational tag and release programme and there is limited information on the size of the recreational catch. Much of the recreational skipjack catch is used as bait.

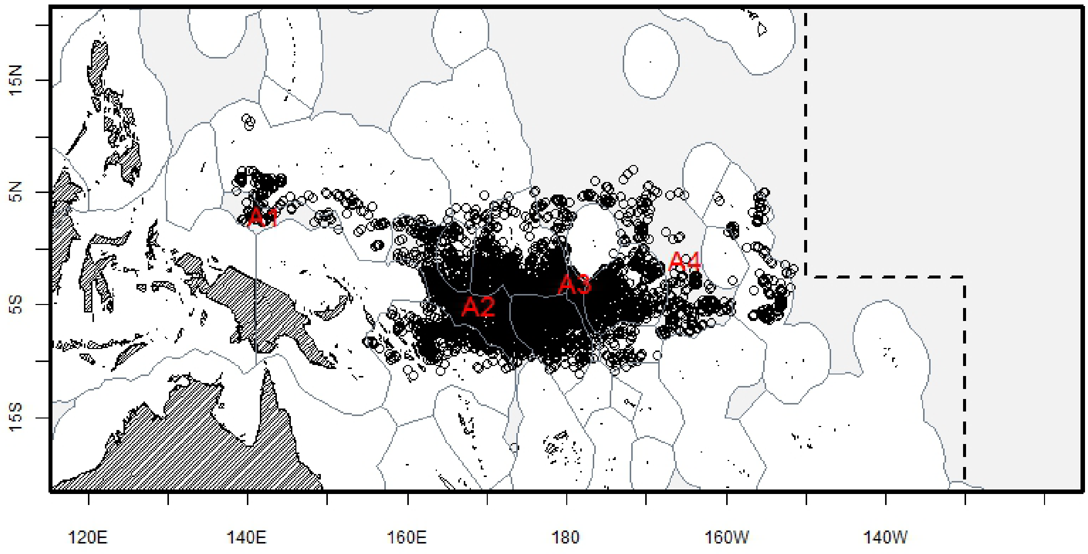


Figure 1: Distribution of purse-seine set locations for the New Zealand flagged vessels operating in the equatorial region of the western Pacific Ocean from 2001 to 2009. The red labels (A 1–4) denote the four areas of international waters referred to in the text.

1.3 Customary non-commercial fisheries

There is no information on the customary take, but it is considered to be low.

1.4 Illegal catch

There is no known illegal catch of skipjack tuna.

1.5 Other sources of mortality

Skipjack tuna are occasionally caught as bycatch in the tuna longline fishery in small quantities, because of their low commercial value this bycatch are often discarded.

2. BIOLOGY

Skipjack tuna are epi-pelagic opportunistic predators of fish, crustaceans and cephalopods found within the upper few hundred meters of the surface. Individual tagged skipjack tuna are capable of movements of over several thousand nautical miles but also exhibit periods of residency around islands in the central and western Pacific, resulting in some degree of regional fidelity. Skipjack are typically a schooling species with juveniles and adults forming large schools at or near the surface in tropical and warm-temperate waters to at least 40ºS in New Zealand waters. Individuals found in New Zealand waters are mostly juveniles that also occur more broadly across the Pacific Ocean, in both the northern and southern hemisphere. Adult skipjack reach a maximum size of 34.5 kg and lengths of 108 cm. The maximum reported age is 12 years old although the maximum time at liberty for a tagged skipjack of 4.5 years indicates that skipjack grow rapidly (reach 80 cm by age 4) and probably few fish live beyond 5 years old. Spawning takes place in equatorial waters across the entire Pacific Ocean throughout the year, in tropical waters spawning is almost daily. Recruitment shows a strong positive correlation with periods of El Niño.

Natural mortality is estimated to vary with age with maximum values for age 1 skipjack and M declining for older fish. A range of von Bertalanffy growth parameters has been estimated for skipjack in the western and central Pacific Ocean depending on area and size of skipjack studied (Table 3). For skipjack tuna in the Pacific Ocean, the intrinsic rate of increase (k) is inversely related to asymptotic length (L_∞) by a power relationship, both parameters are also weakly correlated with sea surface temperature over the range 12º to 29º C.

Length frequency data were available from the MPI observer programme. In most years, the sampled component of the skipjack tuna purse-seine catch from the main fishery areas was dominated by fish in the 40–50 cm (FL) length range (Figure 6). Considerably larger fish were caught in the Bay of Plenty and East Northland fisheries in 2004/05 and in the North Taranaki Bight fishery in 2005/06 and 2006/07. The modal structure in the length composition data indicates the fishery is principally catching fish of 1–2 years of age (Tanabe *et al.* 2003 estimated that skipjack tuna in the western Pacific reach 45 cm at 1 year and 65 cm at 2 years old) (Langley 2011).

Table 4: The range in L_∞ and k by country or area.

L_∞ (cm)	k	Country/Area
84.6 to 102.0	1.16 to 0.55	Hawaii
79.0 to 80.0	1.10 to 0.95	Indonesia
144.0	0.185	Japan
65.0 to 74.8	0.92 to 0.52	Papua New Guinea
72.0 to 84.5	0.70 to 0.51	Philippines
104.0	0.30 to 0.43	Taiwan
62.0	1.10	Vanuatu
61.3	1.25	Western Pacific
65.1	1.30	Western tropical Pacific

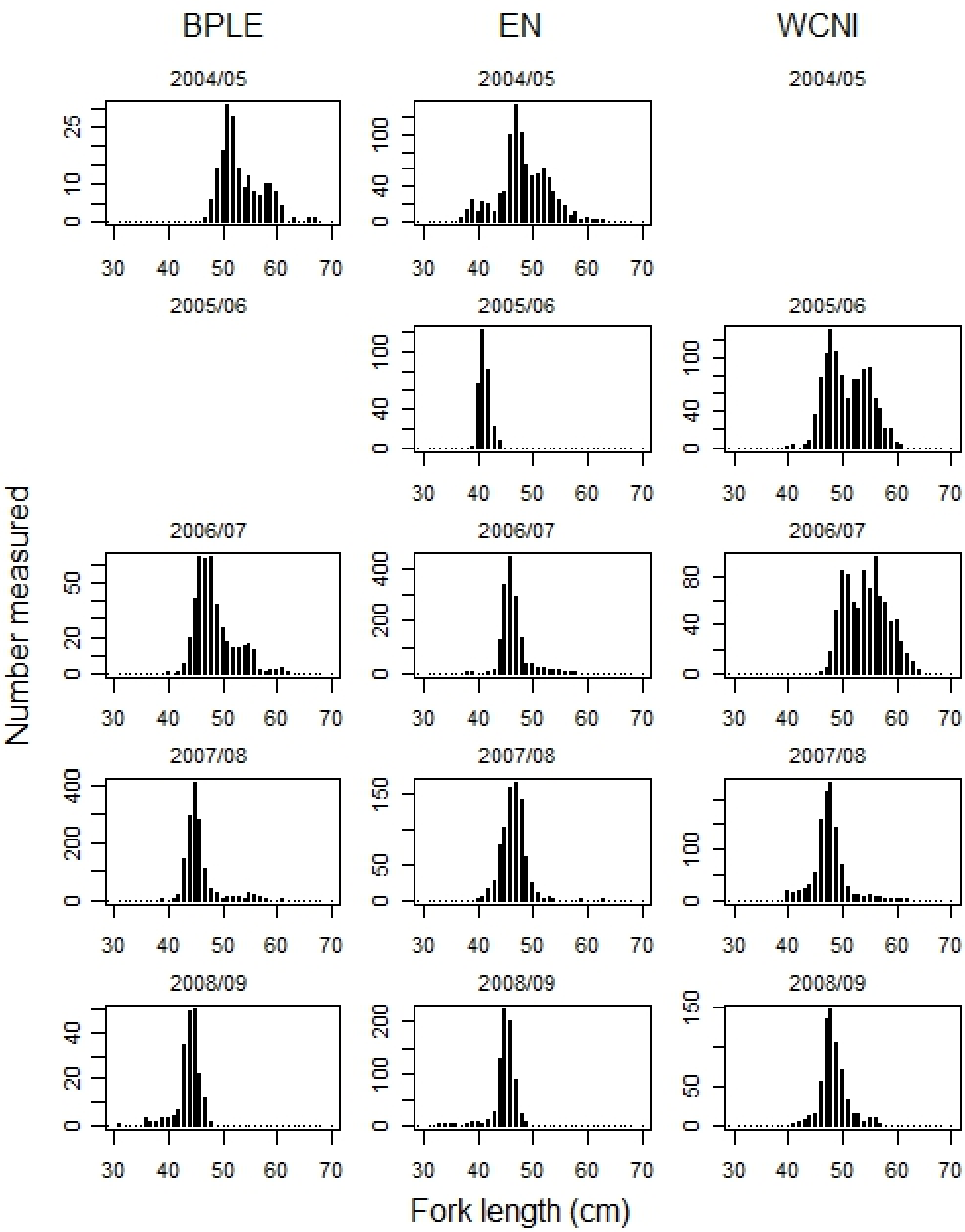


Figure 6: Length (FL) composition of the skipjack tuna catch sampled by the MIP observers from the domestic target purse-seine fishery by fishery area (columns) and fishing year (rows) (fishery areas: BPLE, Bay of Plenty; EN, east Northland; WCNI, west coast North Island) (Langley 2011).

3. STOCKS AND AREAS

Surface-schooling, adult skipjack tuna (> 40 cm fork length, FL) are commonly found in tropical and subtropical waters of the Pacific Ocean.

Skipjack in the western and central Pacific Ocean (WCPO) are considered a single stock for assessment purposes. A substantial amount of information on skipjack movement is available from tagging programmes. In general, skipjack movement is highly variable but is thought to be influenced by large-scale oceanographic variability. In the western Pacific, warm, poleward-flowing currents near northern Japan and southern Australia extend their distribution to 40°N and 40°S. These limits roughly correspond to the 20°C surface isotherm.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the November 2012 Fishery Assessment Plenary after review by the Aquatic Environment Working Group. This summary is from the perspective of skipjack tuna fishery; a more detailed summary from an issue-by-issue perspective is, or will shortly be, available in the Aquatic Environment & Biodiversity Annual Review where the consequences are also discussed (http://fs.fish.govt.nz/Page.aspx?pk=113&dk=22982).

4.1 Role in the ecosystem

Skipjack tuna (*Katsuwonus pelamis*) average 45-60 cm length in New Zealand, reaching an upper maxim of around 70cm (Paul 2000). Skipjack are prey of larger tuna, HMS sharks and billfish.

4.2 Incidental bycatch

4.2.1 Purse seine fishery

4.2.1.1 Protected species bycatch

In the domestic skipjack purse seine fishery observer rates are relatively high. Relative to the skipjack catch, observed bycatch is minor and consists mostly of teleosts (Table 5). Manta rays (*Mobula japanica*) are the only protected species that have been observed captured by purse seine vessels in New Zealand. Work is underway to develop safe release methods for manta rays. Overall Jack mackerel and blue mackerel are the most common teleost bycatch by weight but small numbers of large individuals such as striped marlin and mako sharks are also landed (Table 6).

Table 5: Domestic purse seine sets targeting skipjack tuna observed as a percentage of sets made for 2010 and 2011.

Calendar year	No. sets observed	% sets observed	% SKJ catch
2010	109	8.8	15.3
2011	116	8.9	22.3

Table 6: Catch composition from eight observed purse seine trips targeting skipjack tuna operating within New Zealand fisheries waters in 2010 and 2011.

Common name	Scientific name	Observed catch weight (kg)	% Catch
Skipjack tuna	*Katsuwonus pelamis*	3 600 988	98.92
Jack mackerel	*Trachurus* spp.	22 090	0.61
Jellyfish	Scyphozoa	6 740	0.19
Blue mackerel	*Scomber australasicus*	4 040	0.11
Manta ray	*Mobula japanica*	2 122	0.06
Sunfish	*Mola mola*	1 456	0.04
Striped marlin	*Tetrapturus audax*	820	0.02
Mako shark	*Isurus oxyrinchus*	517	0.01
Albacore tuna	*Thunnus alalunga*	422	0.01
Porcupine fish	*Tragulichthys jaculiferus*	343	0.01
Flying fish	Exocoetidae	174	<0.01
Frigate tuna	*Auxis thazard*	100	<0.01
Hammerhead shark	*Sphyrna zygaena*	80	<0.01
Frostfish	*Lepidopus caudatus*	79	<0.01
Thresher shark	*Alopias vulpinus*	75	<0.01
Salps	Thaliacea	57	<0.01
Barracouta	*Thyrsites atun*	42	<0.01
Moonfish	*Lampris guttatus*	40	<0.01
Discfish	*Diretmus argenteus*	25	<0.01
Electric ray	*Torpedo fairchildi*	21	<0.01
Slender tuna	*Allothunnus fallai*	20	<0.01
Blue shark	*Prionace glauca*	10	<0.01
Garfish	*Hyporhamphus ihi*	5	<0.01
Pilot fish	*Naucrates ductor*	5	<0.01
Porbeagle shark	*Lamna nasus*	5	<0.01
Smooth skate	*Dipturus innominatus*	5	<0.01
Pilchard	*Sardinops neopilchardus*	3	<0.01
Starfish	Asteroidea & ophiuroidea	3	<0.01
Dealfish	*Trachipterus trachypterus*	2	<0.01
Arrow Squid	*Nototodarus sloanii & n gouldi*	2	<0.01
Dolphinfish	*Coryphaena hippurus*	1	<0.01
Gurnard	*Chelidonichthys kumu*	1	<0.01
John dory	*Zeus faber*	1	<0.01
Decapod	Crustacea	1	<0.01

5. STOCK ASSESSMENT

Recent stock assessments of the western and central Pacific Ocean stock of skipjack tuna have been undertaken by the Oceanic Fisheries Programme (OFP) of Secretariat of the Pacific Community (SPC) under contract to WCPFC.

No assessment is possible for skipjack tuna within the New Zealand EEZ as the proportion of the greater stock found within New Zealand fisheries waters is unknown and is likely to vary from year to year.

The most recent stock assessment of the WCPO stock of skipjack tuna was done in 2011 and reviewed by the WCPFC Scientific Committee in August 2011. The executive summary of the stock assessment report is provided below (from Hoyle *et al.* 2011) and in Figures 7-12 and Tables 5 and 6.

"The assessment uses the stock assessment model and computer software known as MULTIFAN-CL. The skipjack tuna model is age (16 quarterly age-classes) and spatially structured. The catch, effort, size composition, and tagging data used in the model are grouped into 18 fisheries (a change from the 17 fisheries used in the 2010 assessment) and quarterly time periods from 1972 through 2010.

The current assessment incorporates a number of changes from the 2010 assessment, including:

a. Updated catch, effort, and size data;
b. A revised standardised effort series for each region based on a new GLM analysis of catch and effort data from the Japanese distant-water pole-and-line fishery.
c. Adjustment of size frequency data based on observer sampling of skipjack, bigeye, and yellowfin size and species compositions, and adjustment for grab-sampling bias.
d. Changes to the modelling of the Philippines and Indonesia purse seine fisheries. These fisheries are separated into fishing activity in archipelagic waters, and fishing outside archipelagic waters to the east of longitude 125°E. Purse seine effort to the east of 125°E is included in the main associated purse seine fishery, apart from domestically-based vessels which are included in a new PI-ID domestic purse seine fishery.
e. Inclusion of tag releases and recoveries from the recent SPC-PTTP tagging programmes, which increases tagging data in the assessment by 50%.
f. Steepness, a parameter defining the shape of the stock recruitment relationship, was changed from 0.75 to 0.8 in the reference case, with alternative values of 0.65 and 0.95 included in sensitivity analyses.
g. Growth parameters were fixed at their values estimated in 2010.

In addition to these changes, a large suite of additional models were run to aid the development of the final "reference case" model. This reference case model is used as an example for presenting model diagnostics, but the most appropriate model run(s) upon which to base management advice will be determined by the Scientific Committee. The sensitivity of the reference model to key assumptions (i.e., regarding the stock recruitment relationship, the catch per unit effort time series, the purse seine catch and size data, the growth model, and the PTTP tagging data) were explored via sensitivity analyses. The results of these analyses should also be considered when developing management advice.

A number of trends in key data inputs were noted as particularly influential for the assessment results. The large tagging data set, and associated information on tag reporting rates, is relatively informative regarding stock size. The relative sizes of fish caught in different regions are also indicative of trends in total mortality, mediated though growth, catch, and movement rates. The assessment is therefore very dependent on the growth model.

For the northern region, there was little contrast in the Japanese pole and line CPUE time-series. However, both the southern region Japanese pole and line CPUE time series showed increases early in the time series and declines at the end, with greater decline in region 2.

Overall, the main assessment results and conclusions are as follows.

a. Estimates of natural mortality are strongly age-specific, with higher rates estimated for younger skipjack.

b. The model estimates significant seasonal movements between the western and eastern equatorial regions. The performance of the fishery in the eastern region has been shown to be strongly influenced by the prevailing environmental conditions with higher stock abundance and/or availability associated with El Niño conditions (Lehodey *et al.* 1997). This is likely to be at least partly attributable to an eastward displacement of the skipjack biomass due to the prevailing oceanographic conditions, although this dynamic cannot be captured by the parameterisation of movement in the current model.

c. Recruitment showed an upward shift in the mid-1980s and is estimated to have remained at a higher level since that time. This change in estimated recruitment is driven in the model by the CPUE data, and also by the tagging data, given the relative tag return rates from the SSAP and the RTTP tagging programmes. Recruitment in the eastern equatorial region is more variable with recent peaks in recruitment occurring in 1998 and 2004–2005 following strong El Niño events around those times. Conversely, the lower recruitment in 2001–2003 followed a period of sustained La Nina conditions. Recent recruitment is estimated to be at a high level, but is poorly determined due to limited observations from the fishery.

d. The biomass trends are driven largely by recruitment and fishing mortality. The highest biomass estimates for the model period occurred in 1998–2001 and in 2005–2007, immediately following periods of sustained high recruitment within the eastern equatorial region (region 3).

e. The biomass trajectory is influenced by the underlying assumptions regarding the treatment of the various fishery-specific catch and effort data sets within the model. The Japanese pole-and-line fisheries are all assumed to have constant catchability, with any temporal trend in efficiency assumed to have been accounted for by the standardization of the effort series. The CPUE trends are influential regarding the general trend in both recruitment and total biomass over the model period. In all regions there is a relatively good fit to the observed CPUE data, with some deterioration when PTTP tagging data are introduced.

f. The model also incorporates a considerable amount of tagging data that provides information concerning absolute stock size during the main tag recovery periods. Including the PTTP tagging data in the model resulted in higher estimates of recent biomass and MSY. Initial analyses of the data suggest some conflict with inferences from the CPUE time series about trends in abundance. Further work on both data sources is recommended.

g. Within the equatorial region, fishing mortality increased throughout the model period and is estimated to be highest in the western region in the most recent years. The impact of fishing is predicted to have reduced recent biomass by about 47% in the western equatorial region and 21% in the eastern region. For the entire stock, the depletion is estimated to be approximately 35%.

h. The principal conclusions are that skipjack is currently exploited at a moderate level relative to its biological potential. Furthermore, the estimates of $F_{current}/\tilde{F}_{MSY}$ and $B_{current}/\tilde{B}_{MSY}$ indicate that overfishing of skipjack is not occurring in the WCPO, nor is the stock in an overfished state. These conclusions appear relatively robust, at least within the statistical uncertainty of the current assessment. Fishing pressure and recruitment variability, influenced by environmental conditions, will continue to be the primary influences on stock size and fishery performance.

i. For the model assumptions investigated, there was only moderate variation in the estimates of stock status. The most influential assumptions involved steepness and growth. There are insufficient data to estimate steepness reliably within the assessment model and many of the key management quantities are strongly influenced by the values assumed. Growth and its variation in space, through time, and among individuals is not well understood. However, only a limited range of assumptions was investigated in this assessment, and as a result the true level of uncertainty is likely to be under-estimated. A range of other assumptions in the model should be investigated either internally or through directed research. Further studies are required to refine our estimates of growth and reproductive potential, including spatio-temporal variation; to examine in detail the time-series of size frequency data from the fisheries, which may lead to refinement in the structure of the fisheries included in the model; to consider size-based selectivity processes in the assessment model; to continue to improve the accuracy of the catch estimates from a number of key fisheries; to refine the methods used to adjust catch and size data in the purse seine fisheries; to refine the methodology and data sets used to derive CPUE abundance indices from the pole and line fishery; to refine approaches to integrate the recent tag release/recapture data into the assessment model; and to develop more formal and rigorous methods for prioritizing the many available research options.

j. ***Based on estimates of*** $F_{current}/\tilde{F}_{MSY}$ ***and*** $B_{current}/\tilde{B}_{MSY}$ ***from the reference model and associated sensitivity grid, it is concluded that overfishing of skipjack is not occurring in the WCPO, nor is the stock in an overfished state.*** These conclusions appear relatively robust, at least within the statistical uncertainty of the current assessment. Although the current (2006-2009) level of exploitation is below that which would provide the maximum sustainable yield, recent catches have increased strongly and the mean catch for 2006-2009 of 1.5 million tonnes is equivalent to the estimated MSY at an assumed steepness of 0.8, but below the grid median estimate of 1.9 million tonnes. Maintenance of this level of catch would be expected to decrease the spawning stock size towards MSY levels if recruitment remains near its long-term average level. Fishing mortality and recruitment variability, influenced by environmental conditions, will both continue to affect stock size and fishery performance."

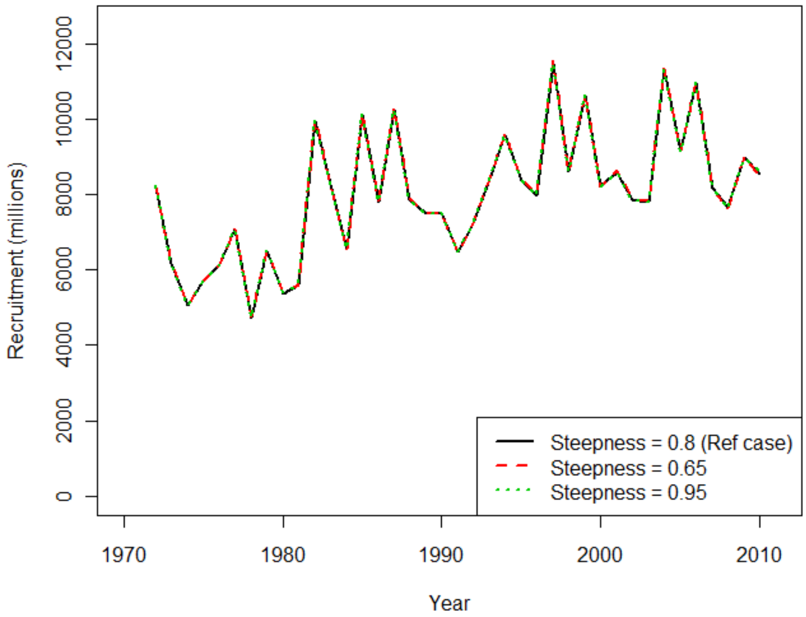


Figure 7: Estimated annual recruitment (millions of fish) for the WCPO obtained from the reference model (steepness = 0.8 - black line) and the two alternative steepness values.

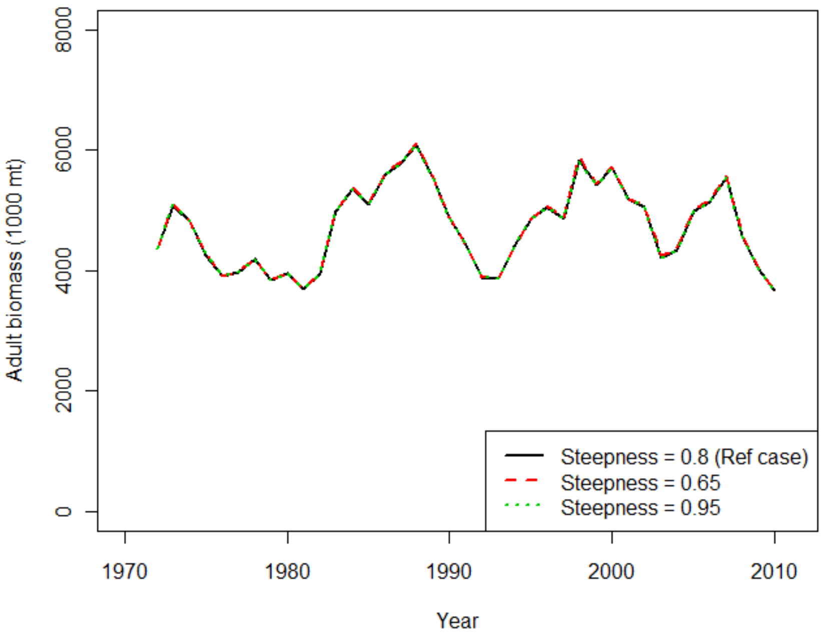


Figure 8: Estimated average annual average spawning biomass for the WCPO obtained from the reference model and the two alternative steepness values.

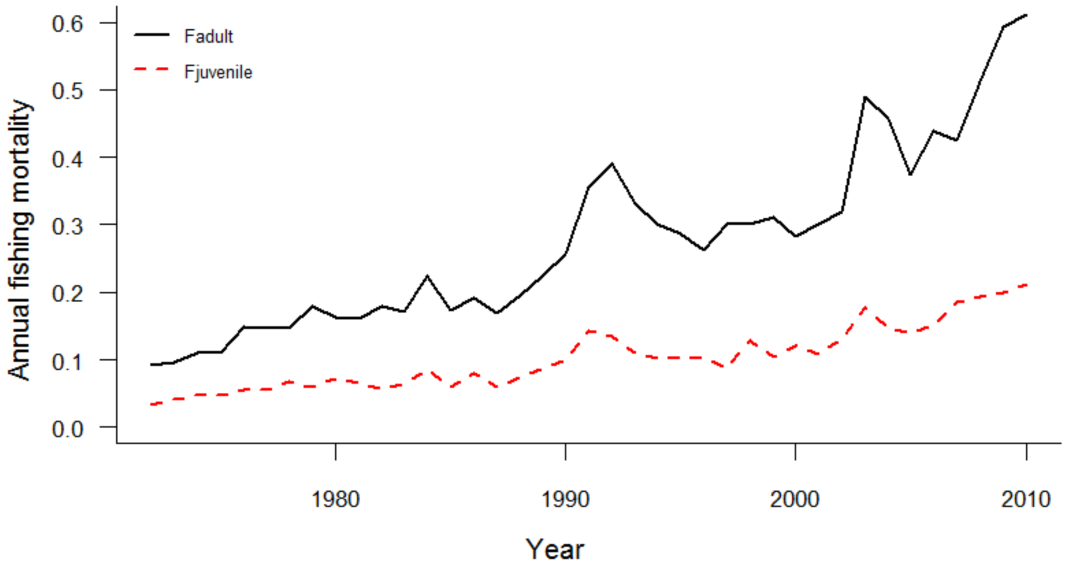


Figure 9: Estimated annual average juvenile and adult fishing mortality for the WCPO obtained from the reference case model.

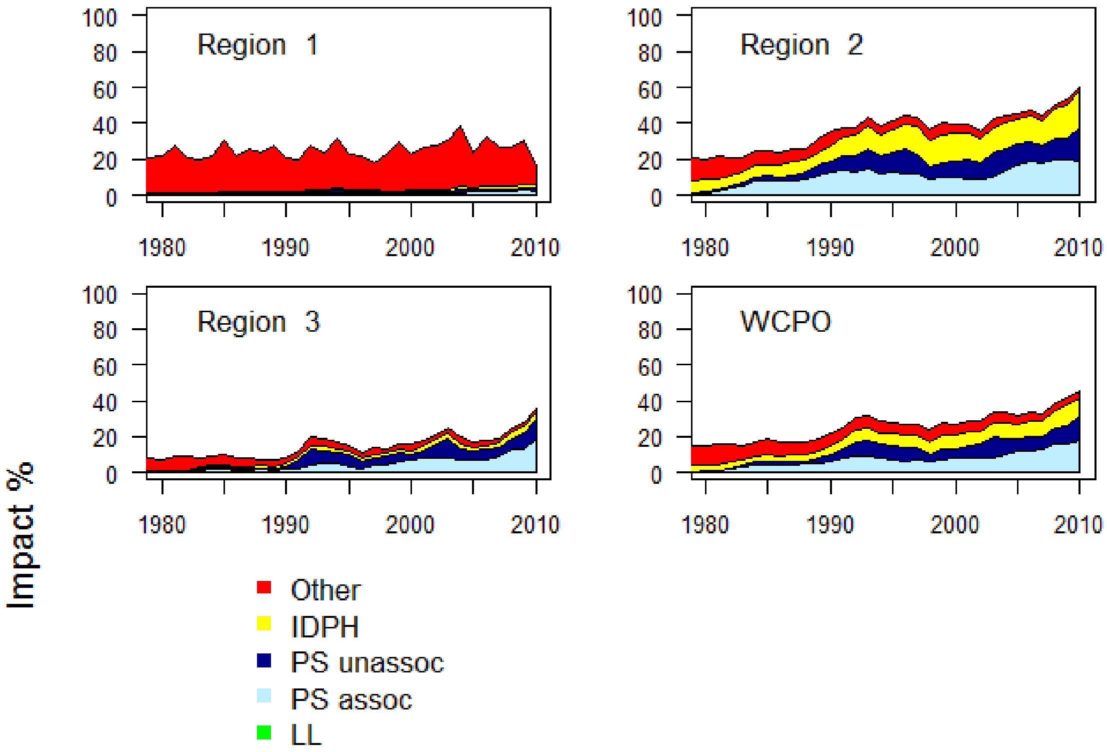
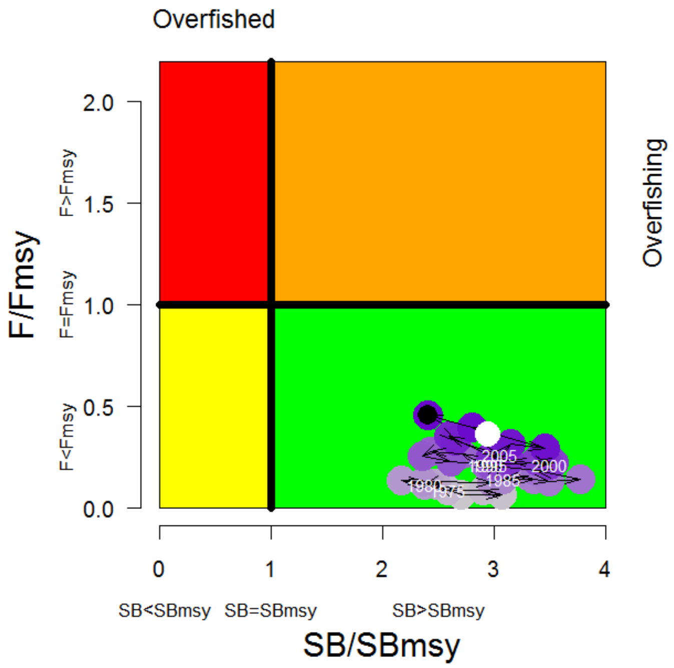


Figure 10: Estimates of reduction in spawning potential due to fishing (fishery impact = 1-$SB_t/SB_{tF=0}$) by region and for the WCPO attributed to various fishery groups (reference case model). L = all longline fisheries; IDPH = Philippines and Indonesian domestic fisheries; PS assoc = purse-seine log and FAD sets; PS unassoc = purse-seine school sets; Other = pole-and-line fisheries and coastal Japan purse-seine.



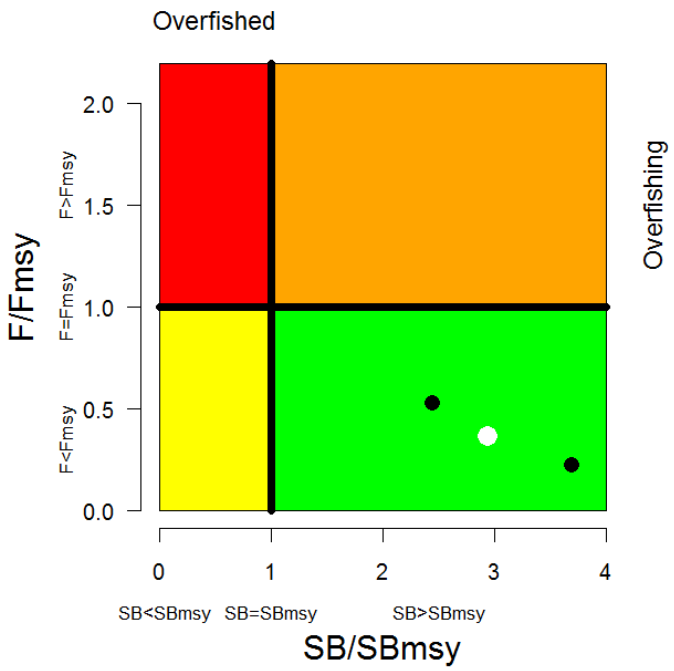


Figure 11: Temporal trend in annual stock status, relative to SB_{MSY} (x-axis) and F_{MSY} (y-axis) reference points for the reference case model the colour of the points is graduated from mauve (1972) to dark purple (2010) (top) and $F_{current}/F_{MSY}$ and $SB_{current}/SB_{MSY}$ for the reference case (white circle) and the two alternative steepness values. See Table 4 to determine the individual model runs.

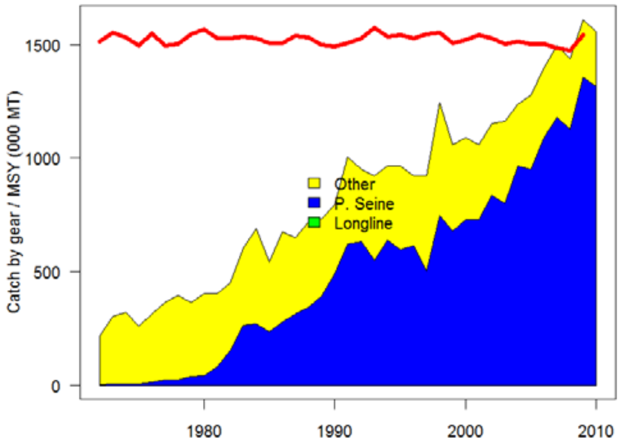


Figure 12: History of annual estimates of MSY [red line] compared with catches of three major fisheries sectors. [other mostly Indonesia and the Philippines catch, longline catch is to low to be shown on the scale]

Table 7. Estimates of management quantities for selected stock assessment models from the 2011 reference case model and the two alternative steepness values. For the purpose of this assessment, "current" is the average over the period 2006–2009 and "latest" is 2010 [*C* = catch].

	H80 (Base case)	H65	H95
1.0	1 484 702	1 484 729	1 484 894
	1 556 643	1 556 596	1 556 924
	1 503 600	1 274 000	1 818 000
	0.99	1.17	0.82
	1.04	1.22	0.86
1.1	2.71	1.9	4.46
	0.37	0.53	0.22
	5 787 000	5 940 000	5 888 000
	0.27	0.32	0.22
	0.79	0.77	0.82
	0.60	0.58	0.62
	2.94	2.45	3.69
	2.21	1.84	2.80
	0.63	0.63	0.65
	0.54	0.54	0.56
Steepness (*h*)	0.80	0.65	0.95

Table 8. Estimates of reference points from the 2011 (with uncertainty based on the range of models in Table 4), 2010, and 2008 skipjack tuna stock assessments. The spatial domain of the 2008 assessment was limited to the equatorial region of the WCPO.

Management quantity	2011 Assessment (uncertainty)	2010 Assessment	2008 Assessment
Most recent catch	1 556 643	1 575 287 mt (catch based on spill sampling)[a]	1 546 436 mt (2007[b]) 1 726 702 mt (2007[c]) 1 410 389 (WCPO catch based on spill sampling)
MSY	1 503 600 (1 274 000 – 1 818 000)	1 375 600 mt	1 280 000 mt
$Y_{Fcurrent}/MSY$	0.76 (0.65-0.86)	0.80	0.70
$B_{current}/B_{current,\ F=0}$	0.65 (0.65-0.67)	0.63	0.66
$F_{current}/F_{MSY}$	0.37 (0.22-0.53)	0.34	0.26
$B_{current}/B_{MSY}$	2.68 (2.32-3.17)	2.24	2.99
$SB_{current}/SB_{MSY}$	2.94 (2.45-3.69)	2.67	3.82

5.1 Estimates of fishery parameters and abundance

There are no fishery-independent indices of abundance for the skipjack tuna. Unlike other pelagic tunas, the low selectivity of skipjack tuna to longline gear means that no relative abundance information is available from longline catch per unit effort data. Regional CPUE indices derived from Japanese pole-and-line logsheet data are the principal indices of stock abundance incorporated in the WCPO stock assessment. However, the pole-and-line fleet has declined considerably over the last 20 years and there has been a contraction of the spatial distribution of the fishery in the equatorial region. Purse seine catch per unit effort data is difficult to interpret. Returns from a large scale tagging programme undertaken in the early 1990s also provides information on rates of fishing mortality which in turn leads to improved estimates of abundance.

Fishing mortality for the juvenile skipjack is very low in all regions, although it has tended to increase slightly over time within the western component of the equatorial WCPO. This is mainly due to the steady increase in catch from the Philippines fishery. For adult skipjack, fishing mortality rates vary considerably between regions. Fishing mortality rates are highest in the western equatorial region and are estimated to have increased considerably over the last five years. For the eastern component of the equatorial WCPO, fishing mortality rates for adult skipjack remained relatively low until recent years. Since 2007, fishing mortality rates in the eastern region are estimated to have increased in line with the higher catches taken from the area.

5.2 Biomass estimates

The biomass trajectories are largely driven by the trends in the pole-and-line CPUE indices. The indices have remained relatively stable and to account for the increasing total catch the stock assessment model estimated an upward shift in recruitment during the mid-1980s. Recruitment is estimated to have remained at a higher level since that time.

5.3 Estimation of Maximum Constant Yield (MCY)

No estimates of MCY are available.

5.4 Estimation of Current Annual Yield (CAY)

No estimates of CAY are available.

5.5 Other yield estimates and stock assessment results

Though no reference points have yet been agreed by the WCPFC, stock status conclusions are generally presented in relation to two criteria. The first relates to “overfished” which compares the current biomass level to that necessary to produce the maximum sustainable yield. The second relates to “over-fishing” which compares the current fishing mortality rate to that which would move the stock towards a biomass level necessary to produce the maximum sustainable yield. The first criteria is similar to that required under our own Fisheries Act while the second has no equivalent in our legislation and relates to how hard a stock can be fished.

Because recent catch data are often unavailable, these measures are calculated based on the average fishing mortality/biomass levels in the ‘recent past’, e.g., 2006-2010 for the 2012 assessment. The assessment included a wide range of sensitivities to key assumptions. Some key reference points for the range of model sensitivities are presented in Table 5.

Recent catches were comparable to the upper limit of the range of estimates of MSY and were considerably higher than the lower range of plausible MSY estimates. The estimates of MSY are sensitive to the assumptions regarding the steepness of the stock-recruitment relationship and current yields are consistent with recent (above average) levels of recruitment. Spawning biomass (SB) was estimated to be about 2-3 times the level necessary to produce MSY and, by definition, well above the overfished threshold. The ratio of $F_{current}$ compared with F_{MSY} (the fishing mortality level that would produce the MSY under equilibrium conditions) is below 1 indicating that recent fishing mortality rates were below F_{MSY}. Fishing mortality rates were estimated to have increased considerably in the last few years but still remain well below the F_{MSY} level.

5.6 Other factors

One area of concern with fisheries for skipjack tuna relates to the potential for significant bycatch of juvenile bigeye and yellowfin tunas in the purse seine fishery in equatorial waters. Juveniles of these species occur in mixed schools with skipjack tuna broadly through the equatorial Pacific Ocean, and are vulnerable to the large-scale purse seine fishing when floating objects (FAD’s) are set on. The fishery in New Zealand fisheries waters is done on single species free schools.

While the skipjack resource within New Zealand waters is considered to represent a component of the wider WCPO stock, the extent of the interaction between the domestic fishery and the fisheries in the equatorial region is unclear. Catches within New Zealand waters vary inter-annually due to prevailing oceanographic conditions. Nonetheless, recent domestic catches have been at or about the highest level recorded from the fishery while the recent total catches from the WCPO have also been the highest on record. A recent review of domestic purse-seine catch and effort data and associated aerial sightings data from the skipjack tuna fishery did not reveal any temporal trend in the availability of skipjack to the domestic fishery (Langley 2011).

6. STATUS OF THE STOCKS

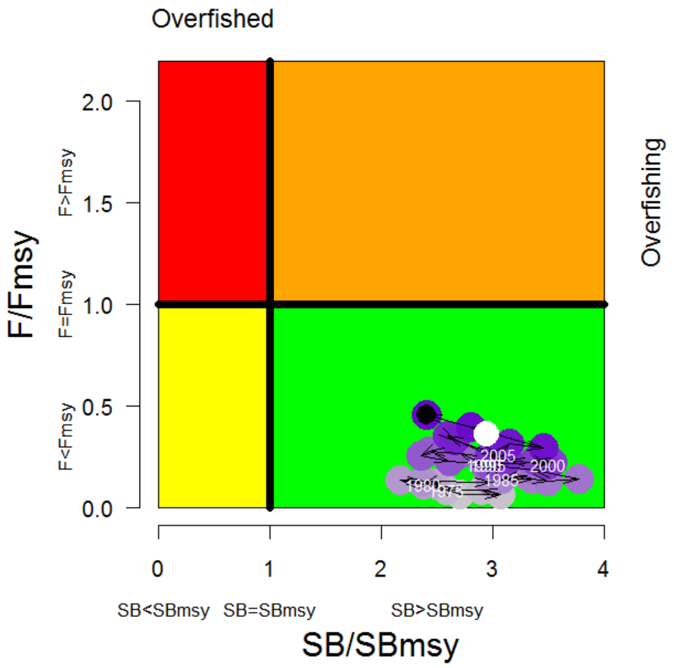
Stock structure assumptions

Skipjack tuna are considered to be a single stock in the WCPO but the assessment presented below is limited to the area north of 20°S and, hence, does not include the component of the fishery within New Zealand waters.

Stock Status	
Year of Most Recent Assessment	A full stock assessment was completed in 2011.
Assessment Runs Presented	Base case model only
Reference Points	Target: $B > B_{MSY}$ and $F < F_{MSY}$

	Soft Limit: Not established by WCPFC; but evaluated using HSS default of 20% B_0. Hard Limit: Not established by WCPFC; but evaluated using HSS default of 10% B_0.
Status in relation to Target	Very Likely to be above B_{MSY} and Very Likely that $F < F_{MSY}$
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below Hard Limit: Very Unlikely (< 10%) to be below

Historical Stock Status Trajectory and Current Status



Temporal trend in annual stock status, relative to SB_{MSY} (x-axis) and F_{MSY} (y-axis) reference points for the reference case model. The colour of the points is graduated from mauve (1972) to dark purple (2010). The black circle represents the B_{2010}/B_{MSY} and the F_{2010} / F_{MSY} the white circle represents the $B_{2006-2009}$ / B_{MSY} and $F_{2006-2009}$ / F_{MSY}.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass increased in the mid 1980s and fluctuated about the higher level over the subsequent period, before declining in the three most recent years (2008, 2009 and 2010). Recent depletion levels are estimated at 0.35 (i.e., 0.65 of the unfished level).
Recent Trend in Fishing Mortality or Proxy	F is estimated to have remained well below F_{MSY} over the history of the fishery, although the level of fishing mortality has increased considerably over the last 5 years.
Other Abundance Indices	
Trends in Other Relevant Indicator or Variables	Recruitment showed an upward shift in the mid-1980s and is estimated to have fluctuated about the higher level since that time. Recruitment in the eastern equatorial region is considerably more variable with recent peaks in recruitment occurring in 1998 and 2004−2005 following strong El Niño events around that time. Conversely, the lower recruitment in 2001−2003 followed a period of sustained La Niña conditions.

Projections and Prognosis	
Stock Projections or Prognosis	Recent catches are above the MSY level but have been supported by above average recruitment. If recruitment

	returned to long-term average levels then the current level of catches would reduce the biomass to below B_{MSY}. Conversely, biomass is likely to remain above B_{MSY} if recruitment remains at the recent average level.	
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Unlikely (< 40%)	
Assessment Methodology and Evaluation		
Assessment Type	Level 1: Quantitative Stock assessment	
Assessment Method	The assessment uses the stock assessment model and computer software known as MULTIFAN-CL.	
Assessment Dates	Latest assessment: 2011	Next assessment: 2014
Overall assessment quality rank	1 - High Quality	
Main data inputs (rank)	The skipjack tuna model is age (16 quarterly age-classes, i.e. 4 years) and spatially structured, and the catch, effort, size composition and tagging data used in the model are classified by 24 fisheries and quarterly time periods from 1972–2009.	1 - High Quality
Data not used (rank)		
Changes to Model Structure and Assumptions	a. Updated catch, effort, and size data. b. A revised standardised effort series for each region based on a new GLM analysis of catch and effort data from the Japanese distant-water pole-and-line fishery. c. Adjustment of size frequency data based on observer sampling of skipjack, bigeye, and yellowfin size and species compositions, and adjustment for grab-sampling bias. d. Changes to the modelling of the Philippines and Indonesia purse seine fisheries. These fisheries are separated into fishing activity in archipelagic waters, and fishing outside archipelagic waters to the east of longitude 125°E. Purse seine effort to the east of 125°E is included in the main associated purse seine fishery, apart from domestically-based vessels which are included in a new PI-ID domestic purse seine fishery. e. Inclusion of tag releases and recoveries from the recent SPC-PTTP tagging programmes, which increases tagging data in the assessment by 50%. f. Steepness, a parameter defining the shape of the stock recruitment relationship, was changed from 0.75 to 0.8 in the reference case, with alternative values of 0.65 and 0.95 included in sensitivity analyses. g. Growth parameters were fixed at their values estimated in 2010.	
Major Sources of Uncertainty	A range of sensitivity analyses were undertaken to investigate key sources of uncertainty in the model, including steepness, natural mortality, and catch history. The key conclusions of the stock assessment, in particularly the current stock status, are robust to the range of assumptions investigated. However, there remains considerable	

	uncertainty regarding the utility of the Japanese pole-and-line CPUE indices as an index of stock abundance.

Qualifying Comments
-

Fishery Interactions
There is a high level of bycatch of small bigeye and yellowfin tuna in the tropical skipjack purse seine fishery when using Fish Aggregating Devices (FADs). This has substantially increased the catch of bigeye and yellowfin and has contributed to the biomass decline of these two species. Sea turtles also get incidentally captured in purse seine nets and FAD's; the WCPFC is attempting to reduce sea turtle interactions through Conservation and Management Measure (CMM2008-03). Mortality of whale sharks, basking sharks and whales, that act as FADs and are caught in purse seine nets, is known to occur, but the extent of this is currently unknown.

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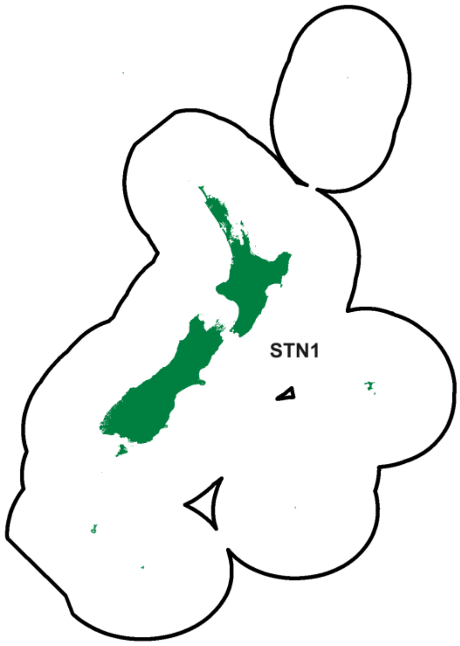
SOUTHERN BLUEFIN TUNA (STN)

(*Thunnus maccoyii)*



1. FISHERY SUMMARY

Southern bluefin tuna were introduced into the QMS on 1 October 2004 under a single QMA, STN 1, with allowances, TACC, and TAC as outlined in Table 1.

Table 1: Recreational and Customary non-commercial allowances, TACCS and TAC (all in tonnes) for southern bluefin tuna.

Fishstock	Recreational Allowance (t)	Customary non-commercial Allowance (t)	Other mortality (t)	TACC (t)	TAC (t)
STN 1	4	1	2	413	420

Southern bluefin tuna were added to the Third Schedule of the Fisheries Act 1996 with a TAC set under s14 because a national allocation of southern bluefin tuna for New Zealand has been determined as part of an international agreement. The TAC applies to all New Zealand fisheries waters, and all waters beyond the outer boundary of the exclusive economic zone.

Southern bluefin tuna were also added to the Sixth Schedule of the Fisheries Act 1996 with the provision that:

> "A person who is a New Zealand national fishing against New Zealand's national allocation of southern bluefin tuna may return any southern bluefin tuna to the waters from which it was taken from if –
> (a) that southern bluefin tuna is likely to survive on return; and
> (b) the return takes place as soon as practicable after the southern bluefin tuna is taken".

Management of southern bluefin tuna throughout its range is the responsibility of the Commission for Conservation of Southern Bluefin Tuna (CCSBT) of which New Zealand is a founding member. Current members of the CCSBT also include Australia, Japan, the Republic of Korea, the Fishing Entity of Taiwan and Indonesia. The Republic of South Africa, the European

Community, and the Philippines have Cooperating Non-member status. Determination of the global TAC and provision of a national allocation to New Zealand is carried out by the CCSBT.

The allocation for New Zealand for 2010 and 2011 agreed at the 16th meeting of CCSBT in October 2009 was 709 t. However, additional agreements reached by New Zealand reduced the available catch limit to 570 t for 2010 and 2011. At the 19th meeting of CCSBT in October 2012 the global TACC was increased to 10 449 t (Table 2) and the New Zealand catch limit increased to 800 t.

Table 2: Allocated catches for Members and Cooperating Non-members for 2012.

Member	Effective catch limit (t)
Australia	4528
Fishing Entity of Taiwan	911
Japan	2519
New Zealand	800
Republic of Korea	911
Indonesia	685
Cooperating Non-Member	
European Community	10
Philippines	45
South Africa	40
TOTAL	10449

Management procedure 2011

In 2011, the Commission adopted a management procedure (MP) to set quotas for 3 year periods based on the latest fisheries indicators from the stock. The MP is designed to rebuild the spawning stock to 20% of the unfished level by 2035 (with 70% certainty). However, the Commission decided not to fully implement the first increase indicated by the operation of the MP in 2011 as there was concern that the TAC may have to be reduced again at the end of the 3 years. Instead the Commission opted for a limited increase in the first 3 year period. Quotas set for the next 3 years allow a 1000 t increase in 2012 to 10 449, a further increase in 2013 to 10 949 t and subject to the MP output an increase to 12 449 in 2014.

Market and farming reviews

In July 2006, the CCSBT Commission reviewed the results of two joint Australia / Japan reviews: the first was an assessment of the amount of southern bluefin tuna being sold through Japanese markets (referred to as the Market Review), and the second was an assessment of the potential for overcatch from the Australian surface fishery and associated farming operations (referred to as the Farming Review).

The Market Review reported that quantities of southern bluefin tuna sold through the Japanese markets (back to the mid-1980s) were well in excess of the amount reported by Japan as domestic catch or imported from other countries (measured through the Trade Documentation Scheme), i.e., there were large volumes of unreported catch. The Market Review could not determine where the catch came from.

The Farming Review reported that while the catch in numbers from the surface fishery were probably well reported there was scope for biases in reported catch in weight due to two factors: (1) changes in the weight of fish between the time of capture and when the weight sample is taken; and (2) the sample of fish taken to estimate the mean weight of fish in the catch may not be representative (causing either negative or positive biases in the mean weight estimate).

The Farming Review was inconclusive. To remove doubt Australia has agreed to undertake a research program to address some of the issues raised in the Farming Review.

While Japan does not accept the findings of the Market review they have acknowledged some illegal catch during the 2005 fishing season and recently changed how they manage their fishery and in 2006 accepted a cut in their allocated catch to 3000 t down from 6065 t for a minimum of 5 years. Current allocations for all countries are provided in Table 2 above.

The findings of the two reviews have resulted in considerable uncertainty in the southern bluefin tuna science process as even the most fundamental data (e.g., catch history) are not reliable and may be very different from reported catches. Further, many of the indicators of stock status previously relied upon are now under question as they may be biased due to illegal activity.
This working group report has not been updated to reflect the findings of these two reviews in relation to total removals from the stock, but in some places the possible impact of the reviews are noted.

1.1 Commercial fisheries

The Japanese distant water longline fleet began fishing for southern bluefin tuna in the New Zealand region in the late 1950s and continued after the declaration of New Zealand's EEZ in 1979 under a series of bilateral access agreements until 1995 (Table 4).

The domestic southern bluefin tuna fishery began with exploratory fishing by Watties in 1966 and Ferons Seafoods in 1969. Most of the catch was used for crayfish bait (reported landings began in 1972). During the 1980s the fishery developed further when substantial quantities of southern bluefin tuna were air freighted to Japan. Throughout the 1980s, small vessels handlining and trolling for southern bluefin tuna dominated the domestic fishery. Southern bluefin tuna were landed to a dedicated freezer vessel serving as a mother ship, or, ashore for the fresh chilled market in Japan.

Longlining for southern bluefin tuna was introduced to the domestic fishery in the late 1980s under government encouragement and began in 1988 with the establishment of the New Zealand Japan Tuna Company Ltd. New Zealand owned and operated longliners, mostly smaller than 50 GRT, began fishing in 1991 for southern bluefin tuna (1 vessel). The number of domestic vessels targeting STN expanded throughout the 1990s and early 2000s prior to the introduction of STN into the QMS. Table 3 summarises southern bluefin landings in New Zealand waters since 1972. Figure 1 shows historical landings and TACC values for domestic southern bluefin tuna.

Since 1991 surface longlines have been the predominant gear used to target southern bluefin tuna in the domestic fishery with 96% of all days fished using this method and only 4% using hand line (< 1% used trolling). This represents a major change from the 1980s when most fishing was by hand line.

In the few instances when the New Zealand allocation has been exceeded, the domestic catch limit has been reduced in the following year by an equivalent amount. Table 3 contrasts New Zealand STN catches with those from the entire stock. The low catches relative to other participants in the global fishery are due to New Zealand's limited involvement historically rather than to local availability. Table 4 indicates that throughout most of the 1980s catches of STN up to two thousand tonnes were taken within the New Zealand EEZ.

Data on reported catch of southern bluefin tuna are available from the early 1950s. By 1960 catches had peaked at nearly 80 000 t, most taken on longline by Japan. From the 1960s through the mid 1970s, when Australia was expanding their domestic surface fisheries for southern bluefin tuna, total catches were in the range 40 000 to 60 000 t. From the mid 1970s through the mid 1980s catches were in the range 35 000 to 45 000 t. Catches declined from 33 325 t in 1985 to 13 869 t in 1990 and fluctuated about 15 000 t per year until 2005. However, since 2006 catches have been less than 12 000 t (see Table 4). However, it should be noted that reported total catches are likely to be underestimates, at least after 1989, as they do not incorporate the findings from the

Market and Farming Reviews. Despite this uncertainty the catches reported in 2009 (10 941 t) are the lowest estimated global catch for over 50 years.

From 1960 to the 1990s catches by longline declined while surface fishery catches in Australian waters increased to reach its maximum level of 21 512 t in 1982 (equal to the longline catches of Japan). During the 1980s catches by both surface and longline fisheries declined but following dramatic TAC reductions in the late 1980s, catches stabilised. The main difference between gear types is that surface fisheries target juveniles (age-1 to age-3 year olds) while longline fisheries catch older juveniles and adults (age-4 year old up to age-40+). The surface fishery has comprised purse seine and pole-&-line vessels supported by aerial spotter planes that search out surface schools. The Australian surface fisheries prior to 1990 were a mix of pole-&-line and purse seine vessels, and have since the mid-1990s become almost exclusively a purse seine fishery. Whereas prior to 1990, surface fishery catches supplied canneries, since the mid-1990s these vessels catch juveniles for southern bluefin tuna farms where they are “on-grown” for the Japanese fresh fish market. The fisheries of all other members, (including New Zealand) are based on longline. Historically New Zealand also supported handline and troll fisheries for STN, although these were small scale and targeted large adults.

Analysis of New Zealand catch data shows that most southern bluefin tuna are caught in FMA1, FMA2, FMA5 and FMA7. The northern FMAs (FMA1 and FMA2) that accounted for a small proportion of southern bluefin tuna before 1998 have in recent years accounted for about the same amount of southern bluefin tuna as the southern FMAs (FMA5 and FMA7). This change in spatial distribution of catches can be attributed to the increase in domestic longline effort in the northern waters. Table 5 shows the longline effort targeted at southern bluefin in New Zealand waters by the charter and domestic fleets since 1989. Some of the charter fleet effort in region 5 was directed at other fish species than southern bluefin but most of the effort was targeting STN.

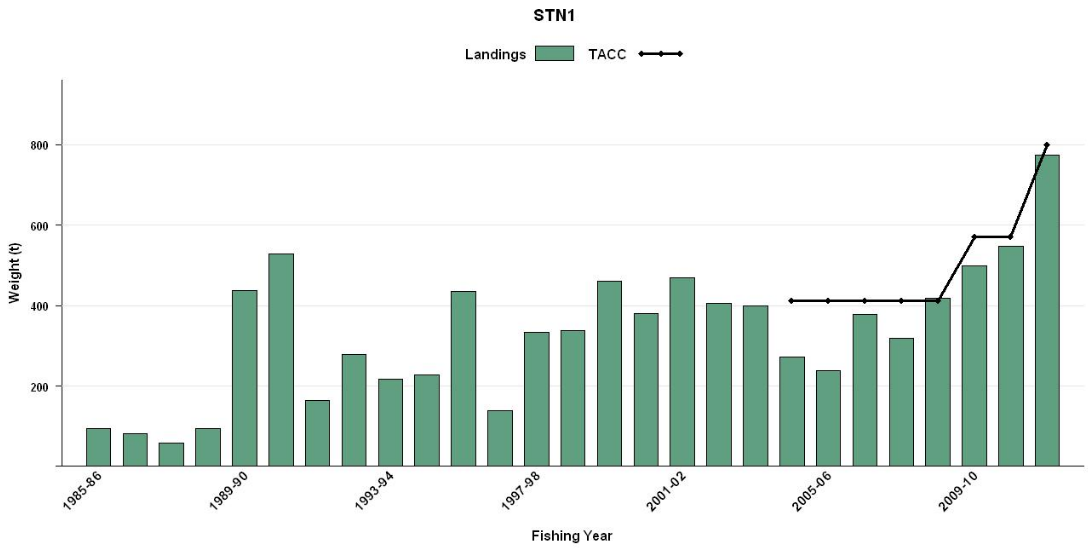


Figure 1: Commercial catch of southern bluefin tuna from 1985-86 to 2010-11 within NZ fishery waters (STN1).

Table 3: Reported domestic[1] and total[2] southern bluefin tuna landings (t) from 1972 to 2011 (calendar year).

Year	NZ Landings (t)	Total stock (t)	Year	NZ Landings (t)	Total stock (t)
1972	1	51 925	1993	217	14 344
1973	6	41 205	1994	277	13 154
1974	4	46 777	1995	436	13 637
1975	0	32 982	1996	139	16 356
1976	0	42 509	1997	334	16 076
1977	5	42 178	1998	337	17 776
1978	10	35 908	1999	461	19 529
1979	5	38 673	2000	380	15 475
1980	130	45 054	2001	358	16 032
1981	173	45 104	2002	450	15 258
1982	305	42 788	2003	390	14 077
1983	132	42 881	2004	393	13 504
1984	93	37 090	2005	264	16 150
1985	94	33 325	2006	238	11 741
1986	82	28 319	2007	379	10 583
1987	59	25 575	2008	319	11 396
1988	94	23 145	2009	419	10 946
1989	437	17 843	2010	501	9 558
1990	529	13 870	2011	547	9 310
1991	164	13 691	2012	775	-
1992	279	14 217			

[1] Domestic here includes catches from domestic vessels and Japanese vessels operating under charter agreement, i.e. all catch against the New Zealand allocation; [2] These figures are likely underestimates as they do not incorporate the findings from the Market and Farming Reviews

Source: NZ data from Annual Reports on Fisheries, MPI data, NZ Fishing Industry Board Export data and LFRR data; Total stock from www.ccsbt.org.

Table 4 Reported catches or landings (t) of southern bluefin tuna by fleet and Fishing Year. NZ: New Zealand domestic and charter fleet, ET: catches by New Zealand flagged vessels outside these areas, JPNFL: Japanese foreign licensed vessels, LFRR: Estimated landings from Licensed Fish Receiver Returns, and MHR: Monthly Harvest Return Data.

Fish Yr	JPNFL	NZ	Total	LFRR/MHR	NZ ET
1979/80	7 374.7		7 374.7		
1980/81	5 910.8		5 910.8		
1981/82	3 146.6		3 146.6		
1982/83	1 854.7		1 854.7		
1983/84	1 734.7		1 734.7		
1984/85	1 974.9		1 974.9		
1985/86	1 535.7		1 535.7		
1986/87	1 863.1		1 863.1	59.9	
1987/88	1 059.0		1 059.0	94.0	
1988/89	751.1	284.3	1 035.5	437.0	
1989/90	812.4	379.1	1 191.5	529.3	
1990/91	780.5	93.4	873.9	164.6	
1991/92	549.1	248.9	798.1	279.1	
1992/93	232.9	126.6	359.5	216.4	
1993/94	0.0	287.3	287.3	277.0	
1994/95	37.3	358.0	395.2	435.3	
1995/96		141.8	141.8	140.5	
1996/97		331.8	331.8	333.5	
1997/98		330.8	330.8	331.5	
1998/99		438.1	438.1	457.9	
1999/00		378.3	378.3	381.3	
2000/01		366.0	366.0	366.4	
2001/02		468.3	468.3	465.4	
2002/03		405.7	405.7	391.7	0.0
2003/04		399.6	399.6	394.6	0.0
2004/05		272.1	272.1	264.1	0.0
2005/06		237.7	237.7	238.0	0.1
2006/07*		379.1	379.1	379.1	-
2007/08*		318.2	318.2	318.2	-
2008/09*		417.3	417.3	417.5	-
2009/10*		499.5	499.5	499.5	-
2010/11*		547.3	547.3	547.3	-
2011/12*		775.2	775.2	775.2	-

* - Southern bluefin tuna landings are not separated into within zone and ET since 2006/07

Table 5: Effort (thousands of hooks) for the charter and domestic fleet by year and CCSBT Region.

	Charter			Domestic[#]		
Calendar Year	**Region 5**	**Region 6**	**Other***	**Region 5**	**Region 6**	**Other***
1989		1596	3.5			
1990	259	1490.6		41.7		
1991	306	1056.5		31.5	49.2	
1992	47.6	1386.8	3	71.7	12.1	
1993	174.1	1125.7	101.4	644.0	108.1	7.7
1994		799.1		122.6	143.3	5.8
1995	27.1	1198.7	13.5	221.5	760.4	26.7
1996				417.9	564.3	11.5
1997	135.2	1098.7		736.4	8.9	17.3
1998	225	616		633.6	314.5	1.2
1999	57.2	955.1		1221.4	382.9	5.5
2000	30.3	757.9		1164.0	454.4	8.5
2001		639.4		1027.6	751.5	1.9
2002		726.4		1358.6	1246.8	13.5
2003	3	866.6		1868.7	1569.1	4.3
2004		1113.5		1154.1	1431.9	1.2
2005	137	498.9		1133.0	153.6	2.4
2006	39.4	562.5		1036.4	122.4	0.9
2007	271.6	1136.1		681.2	19.0	
2008		568.3		527.8	94.0	
2009	66.8	731.0		733.9	165.4	1.3
2010		484.9		1114.9	294.2	1.3
2011		495.9		965.0	196.5	

* Includes erroneous position data and data without position data

[#] Effort for sets that either targeted or caught southern bluefin tuna

The majority of southern bluefin tuna (86%) are caught in the southern bluefin tuna fishery (Figure 2). However, albacore comprise an equal proportion of the catch (27%) as southern bluefin tuna (Figure 3). Longline fishing effort is distributed along the east coast of the North Island and the south west coast of the South Island. The west coast South Island fishery predominantly targets southern bluefin tuna, whereas the east coast of the North Island targets a range of species including bigeye, swordfish, and southern bluefin tuna (Figure 4).

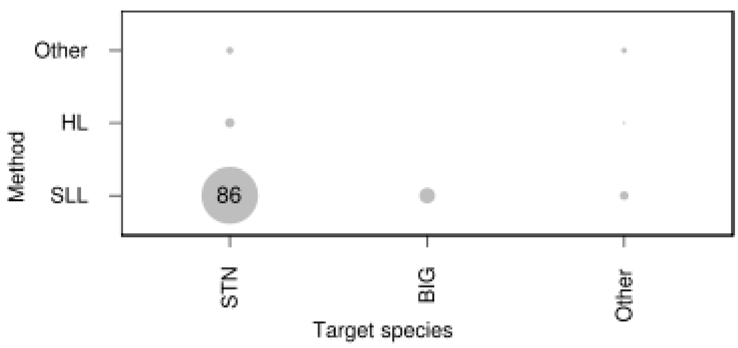


Figure 2: A summary of the proportion of landings of southern bluefin tuna taken by each target fishery and fishing method. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the bobble is the percentage. SLL = surface longline, HL = hook and line (Bentley *et al.* 2012).

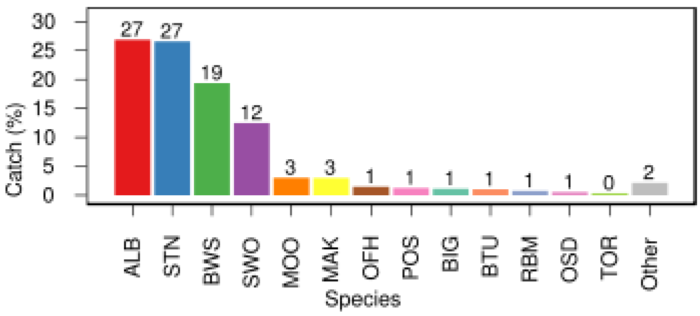


Figure 3: A summary of species composition of the reported southern bluefin tuna target surface longline catch. The percentage by weight of each species is calculated for all surface longline trips targeting southern bluefin tuna (Bentley *et al.* 2012).

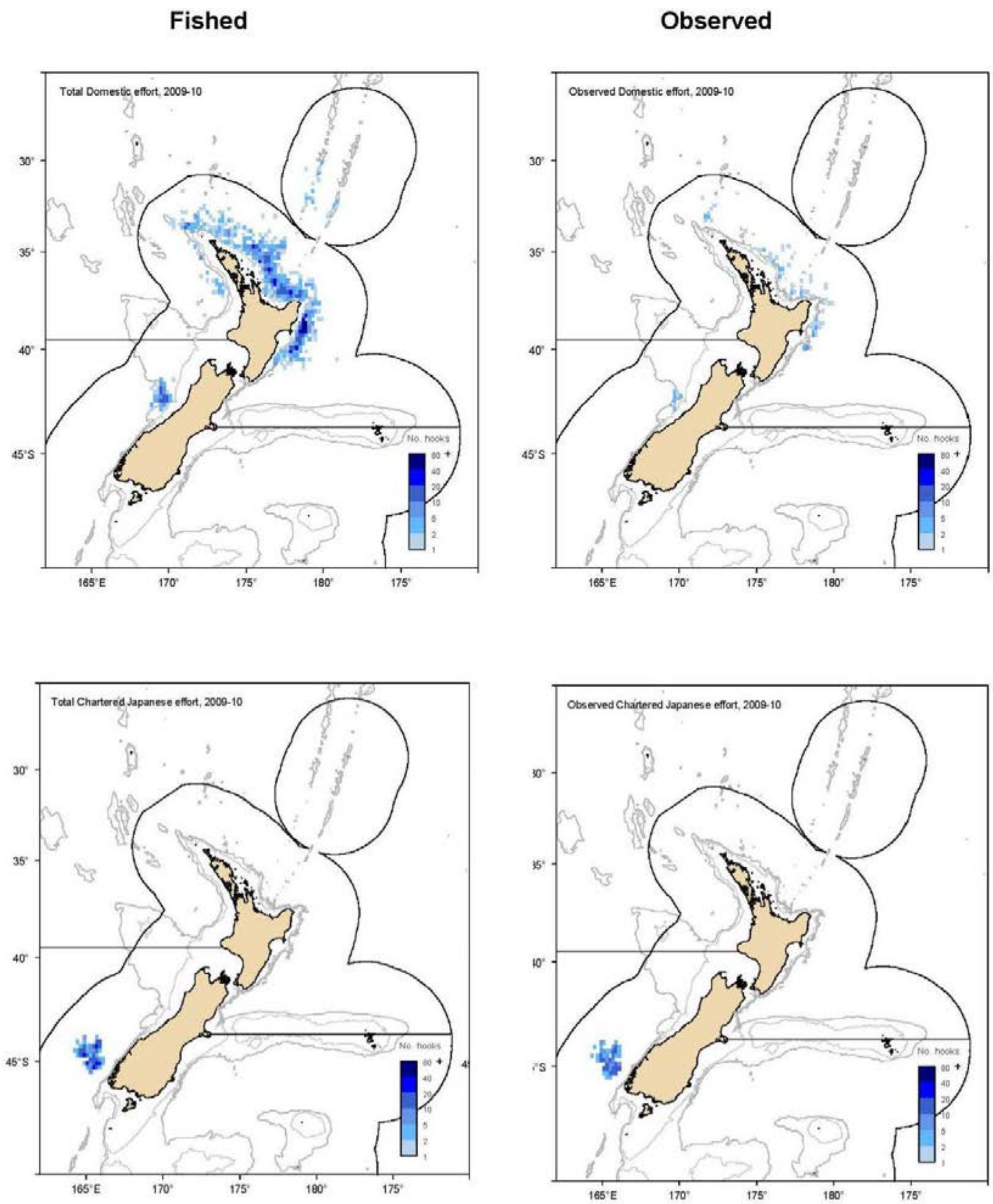


Figure 4: Distribution of fishing positions for domestic (top two panels) and charter (bottom two panels) vessels, for the 2009-10 fishing year, displaying both fishing effort (left) and observer effort (right).

1.2 Recreational fisheries
Charter vessels based in Milford Sound are known to have targeted southern bluefin tuna historically. Gamefish charter vessels fishing from Greymouth and Westport now take STN as bycatch in the newly developed Pacific bluefin tuna fishery. Estimates of catch based on voluntary charter boat reporting range from 4 025 kg (35 fish) in 2007 to 400 kg (3 fish) in 2008. A further 20 fish (2 171 kg) were released alive, probably after tagging.

The estimate of non-commercial SBT catch as bycatch from the Pacific bluefin tuna game fishery was less than one tonne in 2010. Only one fish was reported as non-commercial SBT catch from recreational charter vessels in 2011.

1.3 Customary non-commercial fisheries
An estimate of the current customary catch is not available**.** Given that Maori knew of several oceanic fish species and missionaries reported that Maori regularly fished several miles from shore, it is possible that southern bluefin tuna were part of the catch of Maori prior to European settlement. It is clear that Maori trolled lures (for kahawai) that are very similar to those still used by Tahitian fishermen for small tunas and also used large baited hooks capable of catching large southern bluefin tuna. However, there is no Maori name for southern bluefin tuna, therefore it is uncertain if Maori caught southern bluefin tuna.

1.4 Illegal catch
There is no known illegal catch of southern bluefin tuna by New Zealand vessels in the EEZ or from the high seas. The review of the Japanese Market suggests very large illegal catch from the broader stock historically.

CCSBT has operated a catch documentation scheme since 1 January 2010, with documentation and tagging requirements for all STN, coupled with market-based controls and reporting obligations. Recent actions by individual CCSBT members to improve monitoring, control, and surveillance measures for southern bluefin tuna fisheries are also intended to halt the occurrence of unreported catch.

1.5 Other sources of mortality
Incidental catches of southern bluefin tuna appear to be limited to occasional small catches in trawl and troll fisheries. Small catches of southern bluefin tuna have been reported as non-target catch (< 0.5 t and 2 t respectively), in trawl fisheries for hoki (*Macruronus novaezelandiae*) and arrow squid (*Notodarus* spp.). In addition there have been occasional anecdotal reports of southern bluefin being caught in trawl fisheries for southern blue whiting (*Micromesistius australis*) and jack mackerel (*Trachurus* spp.) in sub-Antarctic waters.

In addition to the limited trawl bycatch there is some discarding and loss (usually as a result of shark damage) before fish are landed that occurs in the longline fishery. The estimated overall incidental mortality rate from observed longline effort is 0.54% of the catch. Discard rates are 0.86% on average from observer data of which approximately 50% are discarded dead. Fish are also lost at the surface in the longline fishery during hauling, 1.47% on average from observer data, of which 95% are thought to escape alive. An allowance of 2 t has been made for other sources of mortality.

2. BIOLOGY

The age at which 50% of southern bluefin are mature is uncertain because of limited sampling of fish on the spawning ground off Java. Recent sampling of the Indonesian catch suggests that 50% age-at-maturity may be as high as 12 years, while interpretations of available data since 1994 have used 8 years and older fish as representing the adult portion of the stock in the population models.

As the growth rate has changed over the course of the fishery (see following section & Table 7) the size-at-maturity depends on when the fish was alive (prior to the 1970s, during the 1970s, or in the period since 1980), as well as which maturity ogive is used. A simple linear interpolation is assumed for the 1970s. Table 6 shows the range of sizes (cm) for southern bluefin tuna aged 8 to 12 years for the two von Bertalanffy growth models used.

Table 6: Differences in southern bluefin tuna size at ages 8 – 12 between the 1960s and 1980s (lengths in cm).

Age	1960s	1980s
8	138.2	147.0
9	144.6	152.7
10	150.2	157.6
11	155.1	161.6
12	159.4	165.0

Radiocarbon dating of otoliths has been used to determine that southern bluefin tuna live beyond 30 years of age and that individuals reaching asymptotic length may be 20 years or older.

The sex ratio of southern bluefin caught by longline in the EEZ has been monitored since 1987. The ratio of males to females is 1.2:1.0, and is statistically significantly different than 1:1.

The parameters of length:weight relationships for southern bluefin tuna based on linear regressions of greenweight versus fork length are in Table 7.

Table 7: Parameters of length/ weight relationship for southern bluefin tuna. *l*n (Weight) = b_1 *l*n(length) – b_0 (Weight in kg, length in cm).

	b_0	B_1
Male	-10.94	3.02
Female	-10.91	3.01
All	-10.93	3.02

The data used include all longline observer data for the period 1987 to 2000 from all vessels in the EEZ (n = 18 994).

CCSBT scientists have used two stanza Von Bertalanffy growth models since 1994:

$$l_t = L_\infty(1 - e^{-k2(t-t0)})(1 + e^{-\beta(t-t0-\alpha)}) / (1 + e^{\beta\alpha})^{-(k2-k1)}, \text{ where t is age in years.}$$

Table 8: von Bertalanffy growth parameters for southern bluefin tuna.

	L_∞	k_1	k_2	α	β	t_0
1960 von Bertalanffy	187.6	0.47	0.14	0.75	30	0.243
1980 von Bertalanffy	182	0.23	0.18	2.9	30	-0.35

While change in growth in the two periods (pre-1970 and post 1980) is significant and the impact of the change in growth on the results of population models substantial, the differences between the growth curves seem slight. The change in growth rate for juveniles and young adults has been attributed to a density dependent effect of over fishing.

No estimates of F and Z are presented because they are model dependent and because a range of models and modelling approaches are used. Prior to 1995 natural mortality rates were assumed to be constant and M = 0.2 was used. However, the results indicating that asymptotic size was reached at about 20 years and fish older than 30 years were still in the population, suggested that values of M ≥ 0.2 were likely to be too high. Tagging results of juvenile's ages 1 to 3 years also suggests that M for these fish is high (possibly as high as M = 0.4), while M for fish of intermediate years is unknown. For these reasons M has been considered to be age-specific and represented by various M vectors. In the CCSBT stock assessments, a range of natural mortality vectors are now used.

A conversion factor of 1.15 is used for gilled and gutted southern bluefin tuna.

3. STOCKS AND AREAS

Southern bluefin tuna consist of a single stock primarily distributed between 30ºS and 45ºS, which is only known to spawn in the Indian Ocean south of Java.
Adults are broadly distributed in the South Atlantic, Indian and western South Pacific Oceans, especially in temperate latitudes while juveniles occur along the continental shelf of Western and South Australia and in high seas areas of the Indian Ocean. Southern bluefin tuna caught in the New Zealand EEZ appear to represent the easternmost extent of a stock whose centre is in the Indian Ocean.

A large-scale electronic tagging programme, involving most members of the Commission, has been undertaken to provide better information on stock structure. The goal has been to tag smaller fish across the range of the stock. New Zealand has participated in this programme, having deployed 19 implantable tags in small fish in 2007. Fifteen larger STN were tagged with pop-off tags as well, with 12 tags having reported data thus far. Of note, one of the tagged fish moved to the spawning ground south of Indonesia.

Electronic tagging of juvenile STN in the Great Australian Bight showed that for a number of years tagged juveniles were not moving into the Tasman Sea. It was not known whether this was due to unfavourable environmental conditions or range contraction following the decline in the stock. However, in the last couple of years more of these tagged juveniles have been reported in New Zealand catches.

Two sources of information suggest that there may be 'sub-structure' within the broader STN stock, in particular the Tasman Sea. Tagging of adult STN within the Australian east coast tuna and billfish fishery suggests that STN may spend most of the years within the broader Tasman Sea region. An analysis of the length and age composition of catches from the New Zealand JV fleet showed that cohorts that were initially strong or weak did not change over time, e.g., if a particular year class was weak (or strong) when it initially recruited to the New Zealand fishery it remained so over time.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the November 2012 Fishery Assessment Plenary after review by the Aquatic Environment Working Group. This summary is from the perspective of the southern bluefin tuna longline fishery; a more detailed summary from an issue-by-issue perspective is, or will shortly be, available in the Aquatic Environment & Biodiversity Annual Review where the consequences are also discussed (http://www.mpi.govt.nz/news-resources/publications.aspx).

4.1 Role in the ecosystem

Southern bluefin tuna (*Thunnus maccoyii*) are apex predators, feeding opportunistically on a mixture of fish, crustaceans, squid and juveniles also feed on a variety of zooplankton and micronecton species (Young *et al.* 1997). The Southern bluefin tuna are large pelagic predators, so they are likely to have a 'top down' effect on the fish, crustaceans and squid they feed on.

4.2 Incidental catch of seabirds, sea turtles and mammals

These capture estimates relate to the southern bluefin target longline fishery only, from the New Zealand EEZ. The capture estimates presented here include all animals recovered onto the deck (alive, injured or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds caught on a hook but not brought onboard the vessel).

4.2.1 Seabird bycatch

Between 2002-03 and 2010-11, there were 511 observed captures of birds in southern bluefin longline fisheries. Seabird capture rates since 2003 are presented in Figure 5. The seabird bycatch is most noticeable off the Fiordland and around East Cape (see Table 9 and Figure 6). The analytical methods used to estimate capture numbers across the commercial fisheries have depended on the quantity and quality of the data, in terms of the numbers observed captured and the representativeness of the observer coverage. Ratio estimation was historically used to calculate total captures in longline fisheries by target fishery fleet and area (Baird 2008) and by all fishing methods but recent estimates are either ratio or model based as specified in the tables below (Abraham *et al.* 2010a).

Through the 1990s the minimum seabird mitigation requirement for surface longline vessels was the use of a bird scaring device (tori line) but common practice was that vessels set surface longlines primarily at night. In 2007 a notice was implemented under s 11 of the Fisheries Act 1996 to formalise the requirement that surface longline vessels only set during the hours of darkness and use a tori line when setting. This notice was amended in 2008 to add the option of line weighting and tori line use if setting during the day. In 2011 notices were combined and repromulgated under a new regulation (Regulation 58A of the Fisheries (Commercial Fishing) Regulations 2001) which provides a more flexible regulatory environment under which to set seabird mitigation requirements.

Table 9: Number of observed seabird captures in southern bluefin tuna longline fisheries, 2002-03 to 2010-11, by species and area (Thompson & Abraham (2012) from http://data.dragonfly.co.nz/psc/). See glossary above for areas used for summarising the fishing effort and protected species captures. 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 southern bluefin tuna using longline gear but rather the total risk for each seabird species.

Species	Risk ratio	Northland and Hauraki	Bay of Plenty	East Coast North Island	Stewart Snares Shelf	Fiordland	West Coast South Island	Total
Salvin's albatross	2.49	0	0	3	0	0	0	3
Light-mantled sooty albatross	2.18	0	0	0	0	0	1	1
Campbell albatross	1.84	1	0	12	0	3	2	18
Southern Buller's albatross	1.28	0	1	13	0	251	31	296
Gibson's albatross	1.25	0	0	4	0	3	1	8
Antipodean albatross	1.11	0	0	4	0	0	0	4
White capped albatross	0.83	0	0	3	10	54	24	91
Southern royal albatross	0.74	0	0	0	0	4	0	4
Black-browed albatrosses	-	0	0	2	0	0	0	2
Pacific albatross	-	0	0	1	0	0	0	1
Wandering albatross	-	0	0	5	0	3	0	8
Unknown albatross	N/A	0	0	1	0	0	0	1
Total albatrosses	**N/A**	**1**	**1**	**48**	**10**	**318**	**59**	**437**
Westland petrel	3.31	0	0	0	0	1	5	6
White chinned petrel	0.79	0	0	1	1	19	0	21
Cape petrel	0.76	0	0	2	0	0	0	2
Grey petrel	0.39	1	2	35	0	0	0	38
Sooty shearwater	0.02	0	0	0	3	1	0	4
Southern giant petrel	-	0	0	2	0	0	0	2
Unknown seabird*	N/A	0	0	0	0	1	0	1
Total other birds	**N/A**	**1**	**2**	**40**	**4**	**22**	**5**	**74**

Table 10: Effort, observed and estimated seabird captures in southern bluefin tuna fisheries by fishing year within the EEZ. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); the capture rate (captures per thousand hooks); and the mean number of estimated total captures (with 95% confidence interval). The estimation method used was a Bayesian model with 100% of hooks included in the estimate. For more information on the methods used to prepare the data see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures		Estimated captures	
	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002-2003	3 514 361	1 133 740	32.3	43	0.038	439	313-616
2003-2004	3 195 316	1 471 964	46.1	70	0.048	437	327-579
2004-2005	1 661 979	734 026	44.2	36	0.049	161	119-221
2005-2006	1 493 418	655 445	43.9	29	0.044	141	101-198
2006-2007	1 938 111	916 660	47.3	111	0.121	212	176-260
2007-2008	1 104 825	376 675	34.1	30	0.08	140	106-185
2008-2009	1 484 438	840 048	56.6	48	0.057	183	141-235
2009-2010	1 559 858	580 395	37.2	112	0.193	319	255-401
2010-2011	1 307 645	567 154	43.4	32	0.056	176	130-241

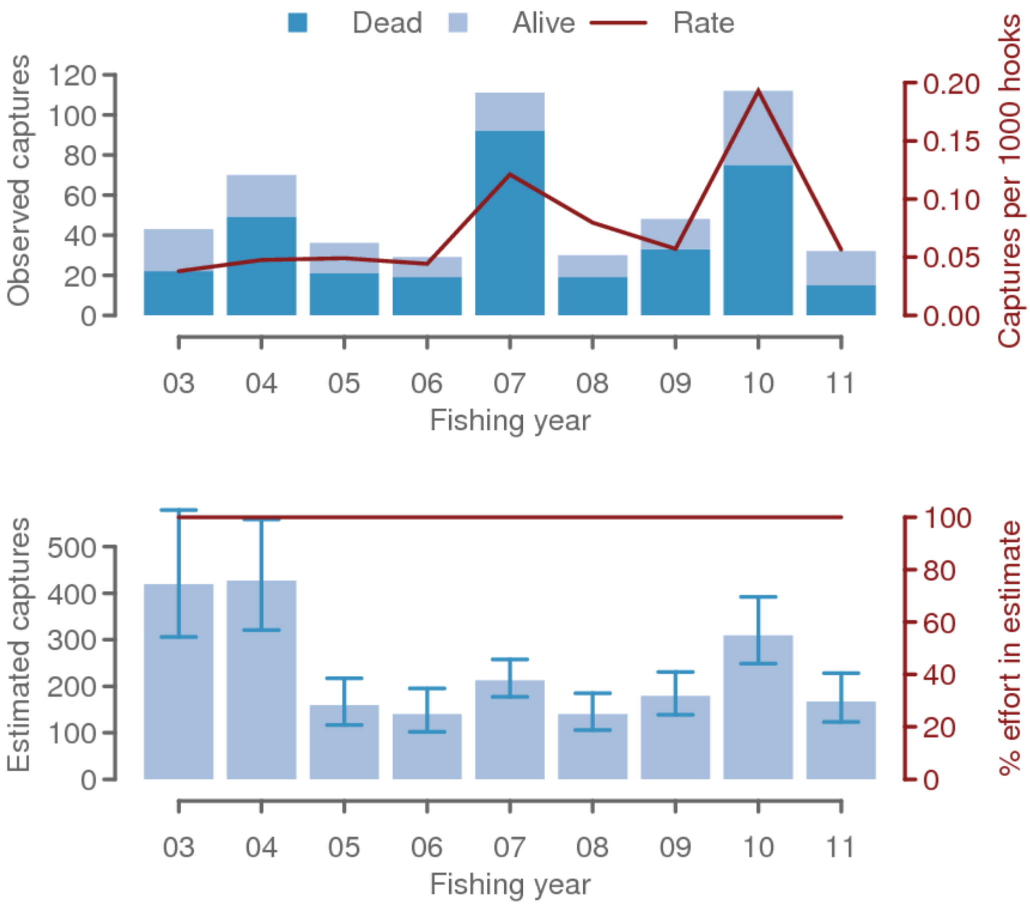


Figure 5: Observed and estimated captures of seabirds in southern bluefin tuna longline fisheries from 2003 to 2011.

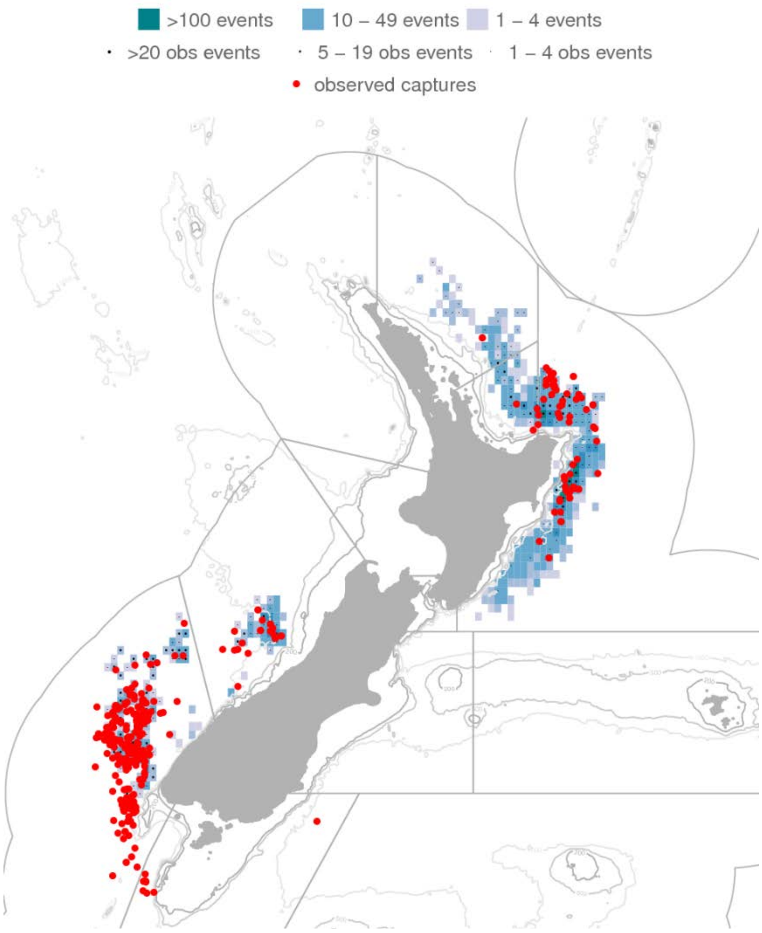


Figure 6: Distribution of fishing effort targeting southern bluefin tuna and observed seabird captures, 2002-03 to 2010-11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 66.2% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.2 Sea turtle bycatch

Between 2002-03 and 2010-11, there were three observed captures of sea turtles in southern bluefin longline fisheries (Tables 11 and 12, Figure 7). Observer recordings documented all sea turtles as captured and released alive. Sea turtle captures for this fishery have only been observed off the east coast of the North Island (Figure 8).

Table 11: Number of observed sea turtle captures in southern bluefin tuna longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson & Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/.

Species	Bay of Plenty	East Coast North Island	Total
Leatherback turtle	1	1	2
Olive ridley turtle	0	1	1
Total	**1**	**2**	**3**

Table 12: Fishing effort and sea turtle captures in southern bluefin tuna longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	3 510 061	1 133 740	32.3	0	0
2003-2004	3 193 871	1 471 964	46.1	0	0
2004-2005	1 661 979	734 026	44.2	0	0
2005-2006	1 493 418	655 445	43.9	0	0
2006-2007	1 938 111	916 660	47.3	0	0
2007-2008	1 104 825	376 675	34.1	0	0
2008-2009	1 484 438	840 048	56.6	0	0
2009-2010	1 559 858	580 395	37.2	0	0
2010-2011	1 307 645	567 154	43.4	3	0.005

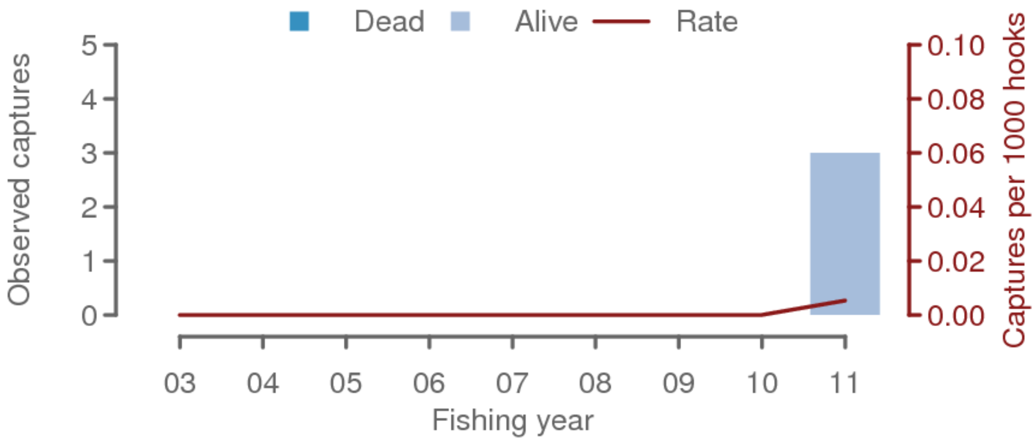


Figure 7: Observed captures of sea turtles in southern bluefin tuna longline fisheries from 2003 to 2011.

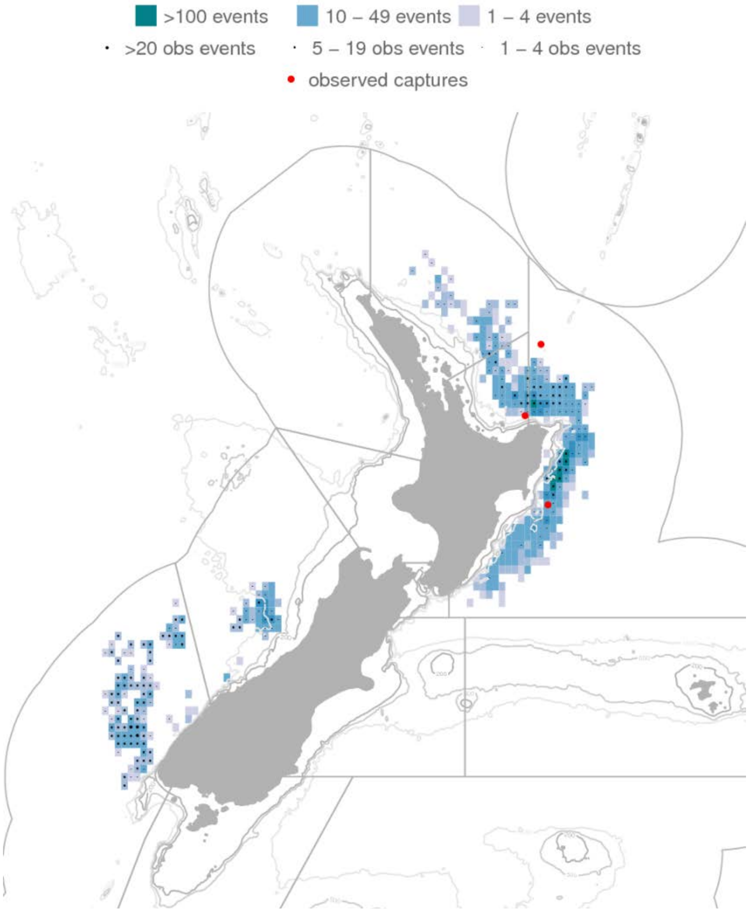


Figure 8: Distribution of fishing effort targeting southern bluefin tuna and observed sea turtle captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 66.1% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3 Marine Mammals

4.2.3.1 Cetaceans

Cetaceans are dispersed throughout New Zealand waters (Perrin *et al.* 2008). The spatial and temporal overlap of commercial fishing grounds and cetacean foraging areas has resulted in cetacean captures in fishing gear (Abraham and Thompson 2009, 2011).

Between 2002–03 and 2010–11, there were five observed captures of whales and dolphins in southern bluefin longline fisheries (Tables 13 and 14, Figure 9). Observed captures included two long-finned pilot whales and three unidentified cetaceans (Abraham and Thompson 2011). All captured animals recorded were documented as being caught and released alive (Thompson and Abraham 2010), with catches occurring in the east coast of the North Island, west coast of the South Island, Fjordland, and Bay of Plenty (Figure 9). Cetacean capture distributions do not coincide with fishing effort and are more common on the north east coast of the North Island (Figure 10).

Table 13: Number of observed cetacean captures in southern bluefin tuna longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson & Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/

Species	Bay of Plenty	East Coast North Island	Fiordland	West Coast South Island	Total
Long-finned pilot whale	0	1	0	1	2
Unidentified cetacean	1	1	1	0	3
Total	**1**	**2**	**1**	**1**	**5**

Table 14: Effort and cetacean captures in southern bluefin tuna longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	3 510 061	1 133 740	32.3	0	0
2003-2004	3 193 871	1 471 964	46.1	3	0.002
2004-2005	1 661 979	734 026	44.2	1	0.001
2005-2006	1 493 418	655 445	43.9	0	0
2006-2007	1 938 111	916 660	47.3	0	0
2007-2008	1 104 825	376 675	34.1	1	0.003
2008-2009	1 484 438	840 048	56.6	0	0
2009-2010	1 559 858	580 395	37.2	0	0
2010-2011	1 307 645	567 154	43.4	0	0

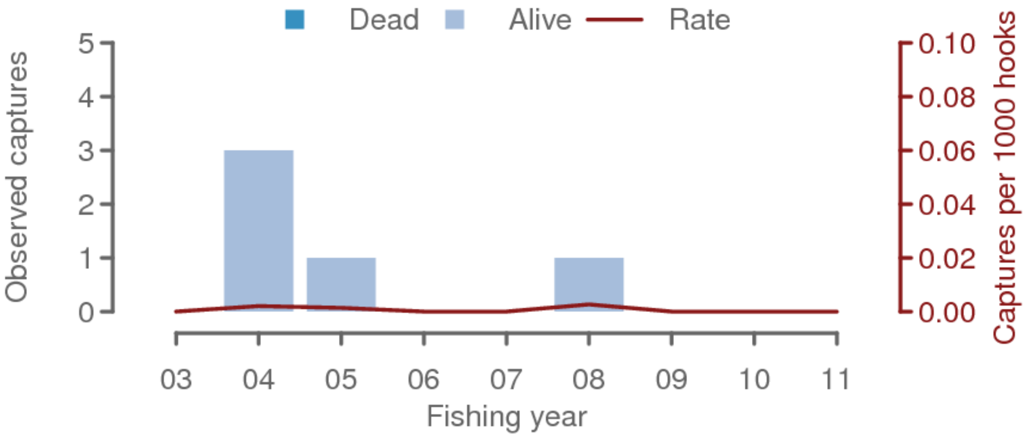


Figure 9: Observed captures of cetaceans in southern bluefin longline fisheries from 2003 to 2011.

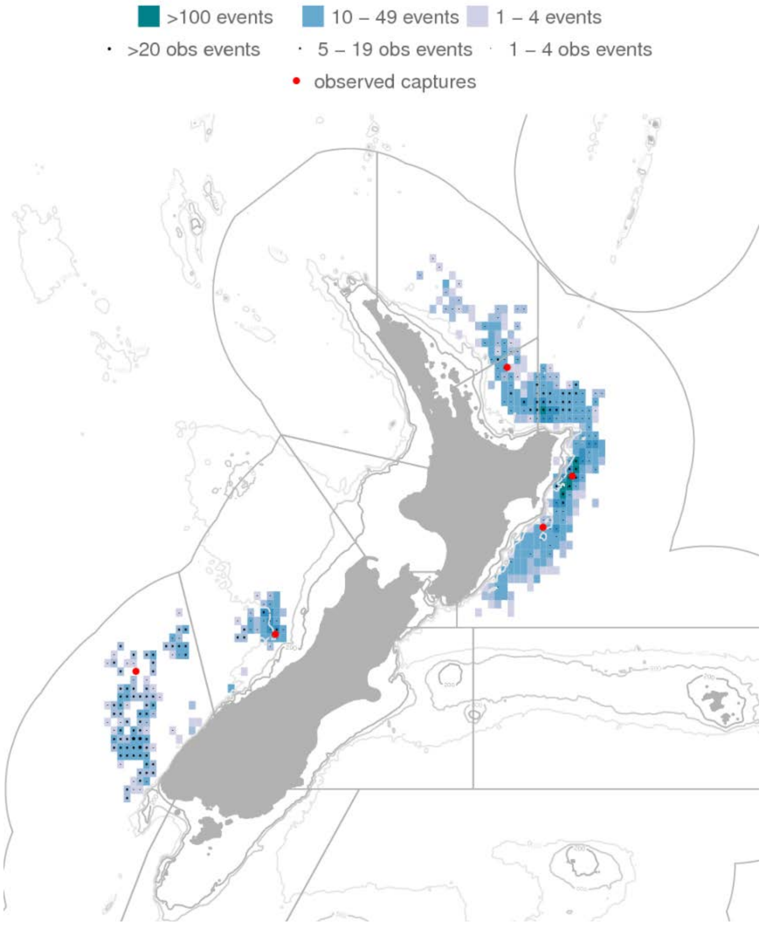


Figure 10: Distribution of fishing effort targeting southern bluefin tuna and observed cetacean captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 66.1% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3.2 New Zealand fur seal bycatch

Currently, New Zealand fur seals are dispersed throughout New Zealand waters, but are more common in waters south of about 40º S to Macquarie Island. The spatial and temporal overlap of commercial fishing grounds and New Zealand fur seal foraging areas has resulted in New Zealand fur seal captures in fishing gear (Mattlin 1987, Rowe 2009). Most fisheries with observed captures occur in waters over or close to the continental shelf. Captures on longlines occur when the seals attempt to feed on the fish catch and bait during hauling. Most New Zealand fur seals captured in the southern bluefin tuna longline fishery are released alive, typically with a hook and short snood or trace still attached.

New Zealand fur seal captures in surface longline fisheries have been generally observed in waters south and west of Fiordland, but also in the Bay of Plenty-East Cape area. Estimated numbers range from 127 (95% CI 121–133) in 1998–99 to 25 (14–39) in 2007-08 during southern bluefin tuna fishing by chartered and domestic vessels (Abraham *et al.* 2010) (Table 16). These capture rates include animals that are released alive (100% of observed surface longline capture in 2008-09; Thompson and Abraham 2010). Capture rates in 2010-11 were low, and lower than they were in the early 2000s (Figure 11). While the fur seal captures have occurred throughout the range of this fishery most New Zealand fur seal captures have occurred off the Southwest coast of the South Island (Figure 12).

Table 15: Number of observed New Zealand fur seal captures in southern bluefin tuna longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson & Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/.

	Bay of Plenty	East Coast North Island	Fiordland	Northland and Hauraki	Stewart Snares Shelf	West Coast South Island	Total
New Zealand fur seal	9	15	139	3	4	32	202

Table 16: Effort and captures of New Zealand fur seal by fishing year in southern bluefin tuna longline fisheries. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	3 510 061	1 133 740	32.3	56	0.049
2003-2004	3 193 871	1 471 964	46.1	40	0.027
2004-2005	1 661 979	734 026	44.2	18	0.025
2005-2006	1 493 418	655 445	43.9	12	0.018
2006-2007	1 938 111	916 660	47.3	10	0.011
2007-2008	1 104 825	376 675	34.1	8	0.021
2008-2009	1 484 438	840 048	56.6	22	0.026
2009-2010	1 559 858	580 395	37.2	19	0.033
2010-2011	1 307 645	567 154	43.4	17	0.030

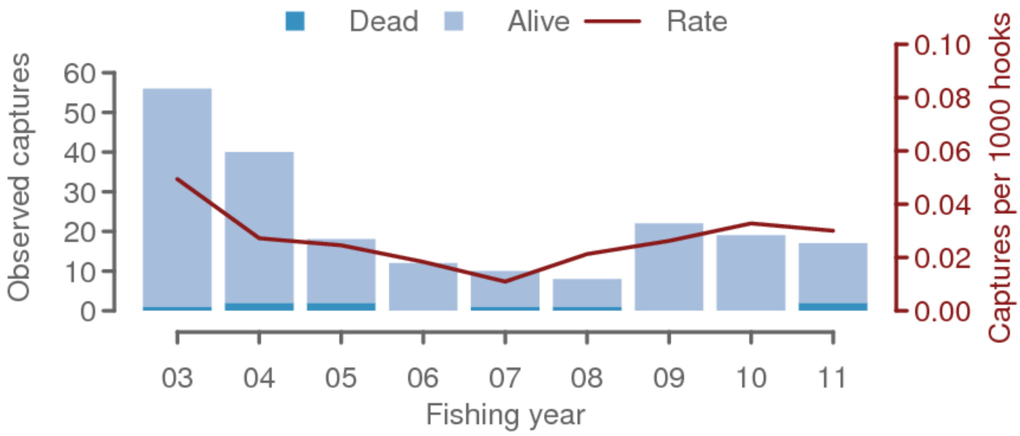


Figure 11: Observed captures of New Zealand fur seal in southern bluefin longline fisheries from 2003 to 2011.

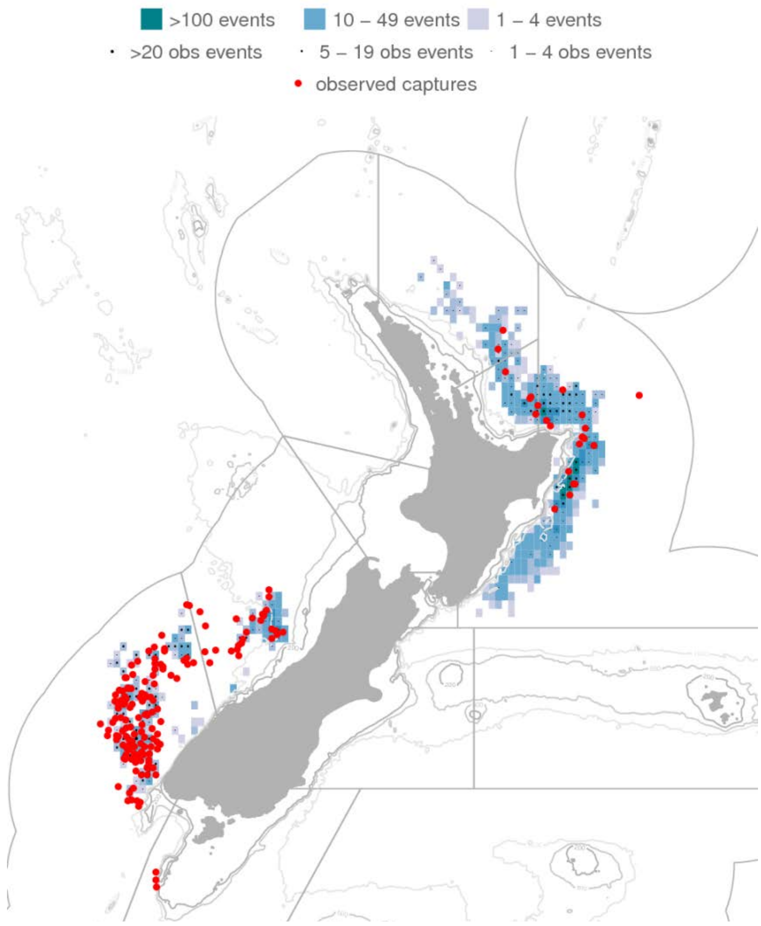


Figure 12: Distribution of fishing effort targeting southern bluefin tuna and observed New Zealand fur seal captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 66.1% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.3 Incidental fish bycatch

This section summarises fish catches taken in tuna longline sets that either targeted or caught southern bluefin tuna. Numbers of fish observed, and estimated numbers scaled from observer to the commercial fishing effort during the 2009 and 2010 calendar years are shown in Table 17. Catch per unit effort is also shown in Table 17. The scaled estimates provided for the domestic fleet can be considered less reliable than those of the charter fleet as they are based on lower observer coverage.

The species most commonly caught were blue shark (*Prionace glauca*), Ray's bream (*Brama brama*), and albacore (*Thunnus alalunga*). Other non-target fish caught in relatively large numbers were dealfish (*Trachipterus trachypterus*), bigscale pomfret (*Taractichthys longipinnis*), porbeagle shark (*Lamna nasus*), deepwater dogfish (Squaliformes of various species, mostly Owstons dogfish), swordfish (*Xiphias gladius*), lancetfish (*Alepisaurus ferox* & *A. brevirostris*), mako shark (*Isurus oxyrinchus*), moonfish (*Lampris guttatus*), swordfish (*Xiphias gladius*), and butterfly tuna (*Gasterochisma melampus*).

The next most abundant non-target fish species were oilfish (*Ruvettus pretiosus*), school shark (*Galeorhinus galeus*), rudderfish (*Centrolophus niger*), hoki (*Macruronus novaezelandiae*), escolar (*Lepidocybium flavobrunneum*), and thresher shark (*Alopias vulpinus*). In 2009 and 2010, sunfish (*Mola mola*), flathead pomfret (*Taractes asper*), and Pelagic stingray (*Pteroplatytrygon violacea*) were also amongst the 25 most abundant species. Some other non-target tunas and billfish were caught, including Pacific bluefin tuna (*Thunnus orientalis*), skipjack tuna (*Katsuwonus pelamis*), yellowfin tuna (*Thunnus albacares*) and striped marlin (*Tetrapturus audax*).

Bycatch composition from the charter fleet and the domestic fleet is different. This is likely to be due to differences in waters fished, with the charter fleet mostly operating in southern waters, and the domestic vessels fishing primarily in waters north of about 40oS. Charter vessels fished north of East Cape late in the 2009 season but only fished off the West Coast of the South Island in 2010 and this resulted in a different catch composition in the two years. In both 2009 and 2010, blue shark, Ray's bream, and albacore were predominant in the catches overall, with these three species making up nearly 70% of the catch. Charter vessels caught mostly blue sharks and Ray's bream, with blue sharks the most abundant species in the catch in 2009 and Ray's bream higher in 2010. Blue sharks dominated the catches of the domestic vessels, followed by albacore.

Dealfish, bigscale pomfret, and deepwater dogfish were caught in the south by charter vessels, while domestic vessels caught lancetfish, swordfish, and mako sharks in the north. Both caught porbeagle sharks, moonfish and butterfly tuna. Oilfish and escolar were caught in the north, with oilfish recorded by both fleets and escolar by domestic vessels only. Bigscale pomfret and escolar have been more important components of the catch in recent years than in earlier years, possibly because of improved identification.

Observers onboard both the charter and domestic fleets reported on fish that were caught and subsequently discarded, and fish that were lost before they could be brought aboard the vessel. Observers also recorded whether fish were landed alive or dead.

Since their introduction into the QMS, most Ray's bream and moonfish have been retained. Blue, porbeagle and mako sharks have also been discarded less frequently since their introduction into the QMS. There were some differences between the domestic and charter fleet, with the domestic fleet more likely to discard sharks.

Tunas (other than butterfly tuna) and swordfish were seldom discarded. The charter vessels kept most of the butterfly tuna they caught while domestic vessels discarded more than half of it in 2009 and kept the majority of it in 2010. Almost all of the lancetfish, deepwater dogfish, and dealfish caught were discarded. Charter vessels discarded oilfish and rudderfish and while domestic vessels retained the majority of oilfish, rudderfish, and escolar. Charter vessels kept the majority of their bigscale pomfret in 2009 and discarded the majority of it in 2010.

Tunas that were discarded were usually dead (and typically damaged). Most of the sharks that were discarded were alive when they were landed, although some dead sharks were discarded by domestic vessels. Porbeagle sharks did not survive as well on longlines as the other sharks. Most butterfly tuna discarded by the domestic vessels were dead when landed. The majority of the other fish bycatch species that were commonly discarded were landed alive.

Observers record life status on landing but they do not record if live fish are still alive at time of discard. Fish that are landed alive and subsequently discarded are not necessarily returned to the sea alive. Many fishers retrieve their hooks prior to discarding fish and this often damages the fish and reduces its ability to survive. Some species such as dealfish do not survive the dehooking process.

Table 17: Numbers of fish caught reported on commercial catch effort returns (reported), observed, estimated from observer reports and total fishing effort (scaled), and catch per unit effort (CPUE) for fish species caught on longline sets where southern bluefin tuna was either targeted or caught during the 2010 calendar year.

	Charter			New Zealand Domestic		
	Observed	Scaled	CPUE	Observed	Scaled	CPUE
Blue shark	2 024	2 501	5.226	5 062	57 834	46.406
Rays bream	3 295	4 072	8.508	362	4 136	3.319
Albacore tuna	90	111	0.232	1 219	13 927	11.175
Dealfish	882	1 090	2.277	7	80	0.064
Big scale pomfret	349	431	0.901	3	34	0.028
Porbeagle shark	72	89	0.186	279	3 188	2.558
Deepwater dogfish	305	377	0.788	0	0	0.000
Swordfish	3	4	0.008	269	3 073	2.466
Lancetfish	3	4	0.008	337	3 850	3.089
Mako shark	11	14	0.028	211	2 411	1.934
Moonfish	76	94	0.196	143	1 634	1.311
Butterfly tuna	15	19	0.039	103	1 177	0.944
Oilfish	2	2	0.005	44	503	0.403
School shark	34	42	0.088	2	23	0.018
Sunfish	7	9	0.018	65	743	0.596
Rudderfish	39	48	0.101	18	206	0.165
Flathead pomfret	56	69	0.145	0	0	0.000
Escolar	0	0	0.000	58	663	0.532
Pelagic stingray	0	0	0.000	8	91	0.073
Thresher shark	7	9	0.018	9	103	0.083
Hoki	0	0	0.000	1	11	0.009
Pacific bluefin tuna	0	0	0.000	2	23	0.018
Skipjack tuna	0	0	0.000	1	11	0.009
Striped marlin	0	0	0.000	1	11	0.009
Yellowfin tuna	0	0	0.000	0	0	0.000

4.4 Benthic interactions
N/A

4.5 Key environmental and ecosystem information gaps
Cryptic mortality is unknown at present but developing a better understanding of this in future may be useful for reducing uncertainty of the seabird risk assessment and could be a useful input into risk assessments for other species groups.

The survival rates of released target and bycatch species is currently unknown.

Observer coverage in the New Zealand fleet is not spatially and temporally representative of the fishing effort.

5. STOCK ASSESSMENT

Determination of the status of the southern bluefin tuna stock is undertaken by the CCSBT Scientific Committee (CCSBT-SC). In recent years the stock assessment has been based on the results from the reconditioned CCSBT Operating Model. The Scientific Committee made further changes in 2011 to the final grid used for the assessment (Anon. 2011). There is no single agreed stock assessment base case, but an agreed range of values for key input parameters is run and the results averaged over the whole grid. In addition, in 2011 a set of four alternative models considered to be highly plausible were run to test the robustness of the results from the base grid.

5.1 Estimates of fishery parameters and abundance

As part of the stock assessment, a range of fishery indicators that were independent of any stock assessment model were considered to provide support and/or additional information important to aspects of current stock status. Indicators considered included those relating to recent recruitment, spawning biomass, and vulnerable biomass and were based on catch at age data, CPUE data, and information from various surveys (e.g., aerial sightings and troll surveys).

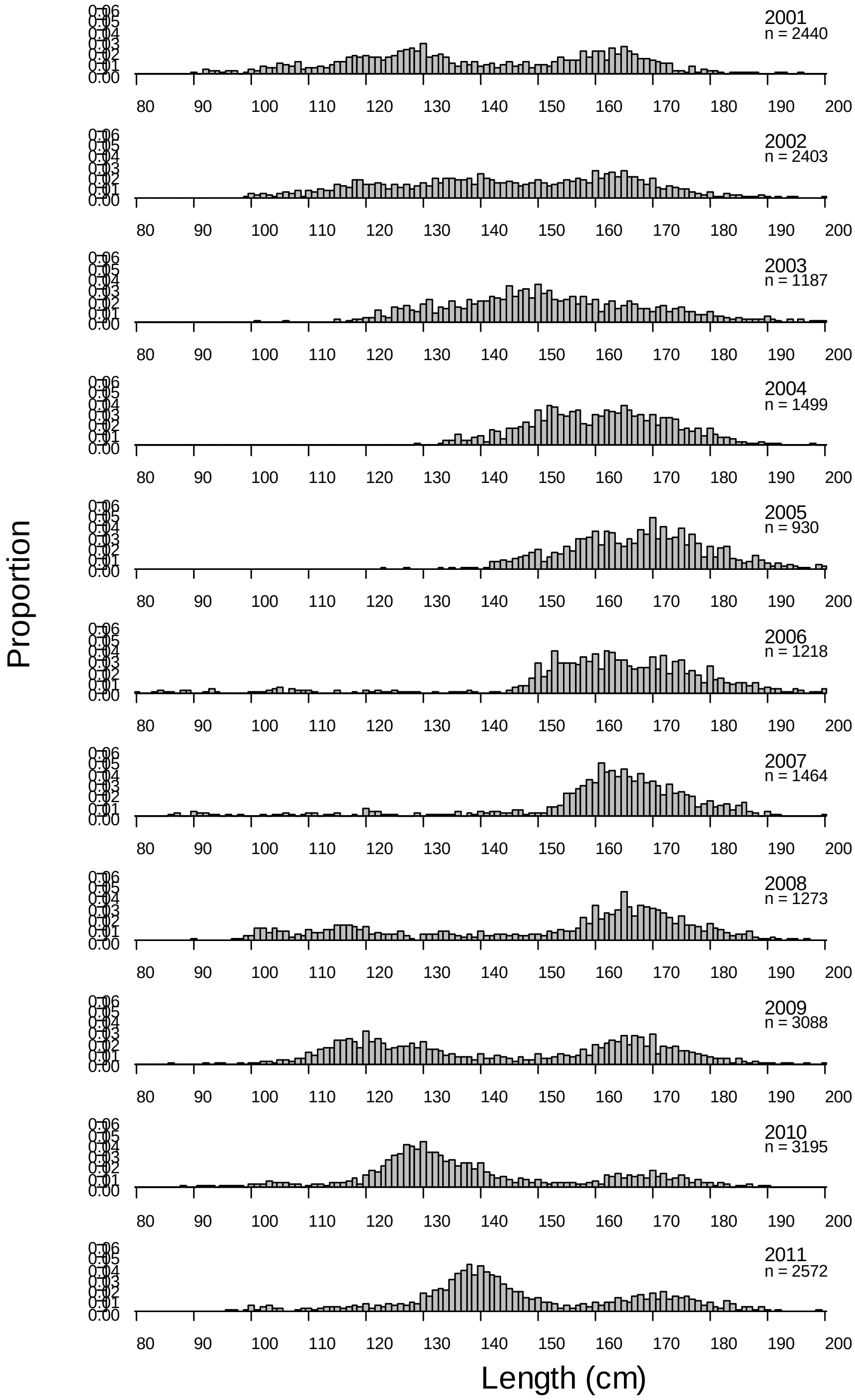


Figure 13: Proportion at length for the Japanese charter fleet operating in New Zealand Fishery waters for 2001 to 2011. Source: CCSBT-ESC/1208/SBT Fisheries New Zealand (2012).

Trends in juvenile abundance

The latest scientific aerial survey index showed a large decrease from the previous year. This was also seen in the surface abundance per unit effort (SAPUE) index for age 2 to 4 in the Great Australian Bight (GAB). These observations are surprising as in the previous year the highest values in the time series were reported. There is a possibility that the fish were in a different area in 2012 and not measured by the survey. For this reason the Scientific Committee could not determine the strength of recent recruitment, but agreed that more detailed analysis of the environmental data was warranted,

CPUE in New Zealand waters

Nominal CPUE by fleet across all Regions based on targeted longline effort is provided in Figure 6. Charter CPUE averaged around three STN per 1000 hooks over 1997-2002. Associated with the lack of new recruitment, CPUE declined dramatically in 2003 and stayed at about these historically low levels for five consecutive years until a marked increase from 2008 to 2010 for the Charter fleet (followed by a slight drop in 2011). This increase occurred in the core area of their fishery (e.g., Region 6) and was likely due to the appearance of the smaller fish seen in Figure 5. The domestic fleet mainly operating in area 5 has also experienced increased CPUE since 2006, with a furher increase in 2011.

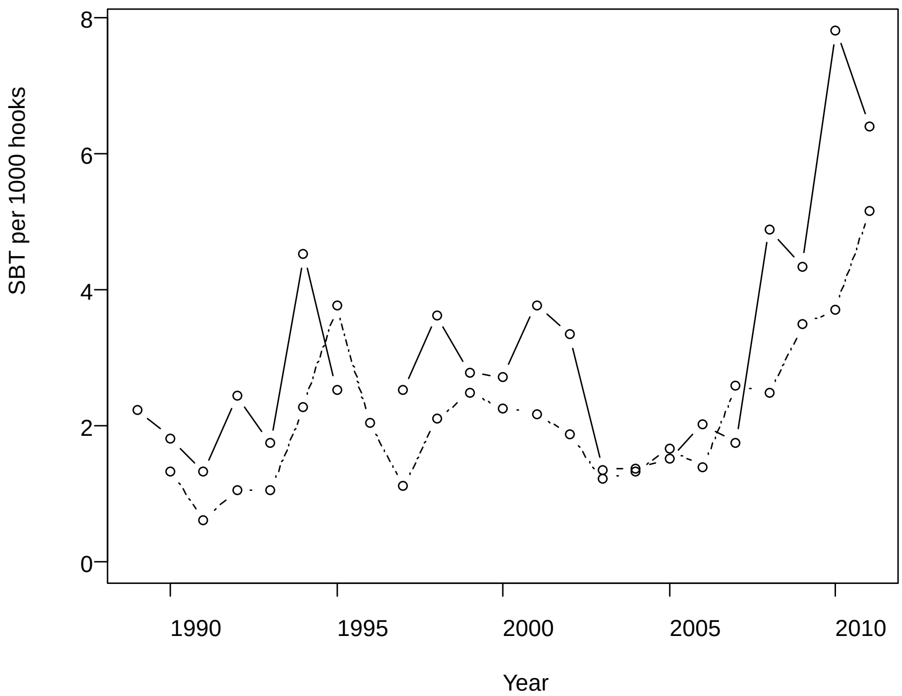


Figure 14: Nominal catch per unit effort (number of STN per thousand hooks) by calendar year for the New Zealand Charter (solid line) and domestic (dashed line) longline fleets operating in New Zealand based only on effort from sets that either targeted or caught southern bluefin tuna. Source: CCSBT-ESC/1208/SBT Fisheries New Zealand (2012).

5.2 Biomass estimates

5.2.1 Spawning biomass

The stock assessment was updated by the Scientific Committee in 2011. The results from the reconditioned Operating Model (OM) indicate that the spawning stock biomass is at a very low level. For the base case, the spawning biomass is estimated to be at 5% of the unfished level (SB_0), with a 90% probability interval of 3% to 7%. This very low spawning stock biomass is consistent across all the plausible alternative scenarios (median range: 4 -5%) and is a little more than 15% of the level at which MSY could be obtained.

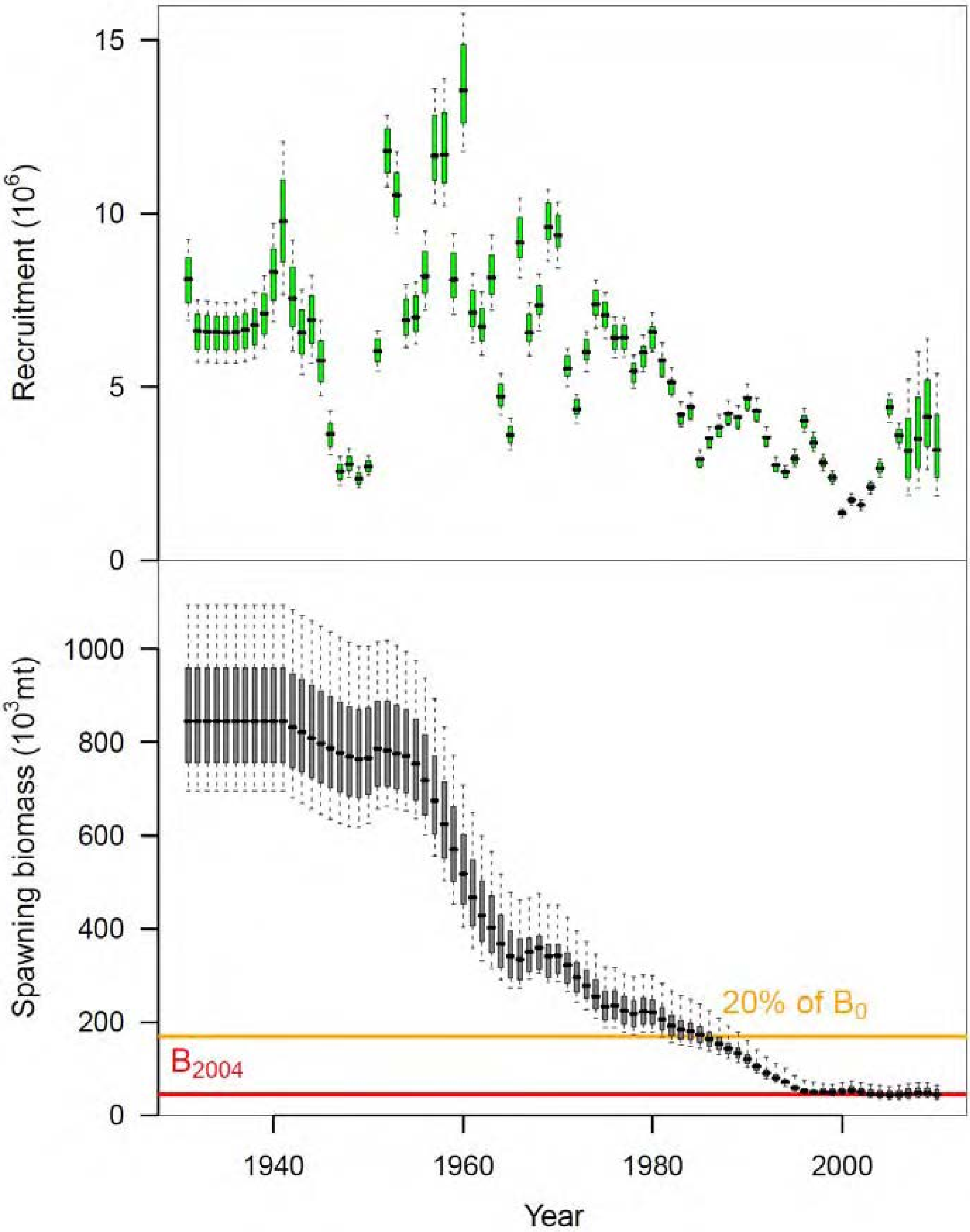


Figure 15: Recruitment and spawning stock biomass for the base case, showing the medians, quartiles and 90th percentiles, together with reference points of 20% of pre-exploitation spawning stock biomass and the spawning stock biomass in 2004 (B_{2004}). Source: Report of the Scientific Committee 2011.

The estimated trajectories of spawning stock biomass integrated over the grid for the base case over the full time series for the fishery are given in Figure 7. This shows a continuous decline from the late 1950s to the late 1970s, then a short period of stabilisation followed by a further decline from the early 1980s to mid 1990s to a very low level. The spawning stock biomass is estimated to have remained at this low level with relatively small annual variation until the early 2000s. For the more recent period, a decline in the median spawning stock biomass is evident from 2002. There is no current evidence of the spawning stock rebuilding, but it is projected to start rebuilding after 2012

There are several positive signs for the spawning stock:

- Total reported catches have dropped as a result of reduced quota limits
- Current fishing mortality is now below F_{MSY}
- The stock is expected to increase under catch levels determined by the Management Procedure

However, there were mixed signals from the indicators in 2012:

- Longline CPUE shows increases since 2007
- A decrease in the scientific aerial survey and SAPUE indices to low levels in 2012. (Note: the Scientific Committee of CCSBT has identified the need to examine the factors that may have impacted on the 2012 survey indices).

5.2.2 Stock projections

The median catch projection under the current TAC (9449 t) for the base case suggests that the stock would reach the interim rebuilding target of $0.2SB_0$ in 2024. The faster than predicted recovery of the SB is driven by the higher estimates of recruitment and CPUE. Note that the future, catch levels will be set by the Commission based on the output from the Management Procedure.

5.3 Estimation of Maximum Constant Yield (MCY)

MCY has not been estimated.

5.4 Estimation of Current Annual Yield (CAY)

CAY has not been estimated.

5.5 Other yield estimates and stock assessment results

In 2012 the preliminary results from the close-kin genetics study were reported at the Scientific Committee of CCSBT (CCSBT-ESC/1208/19). Over 13,000 bluefin caught in the GAB (juveniles) and off Indonesia (mature adults) from 2006 to 2010 were genotyped and 45 Parent-Offspring Pairs (POPs) were detected. When these data were analysed in an independent assessment model the result was that adult abundance was estimated to be higher than the current estimates from the Operating Model used by the Scientific Committee in 2011. The data from the close-kin study will be incorporated into the Operating Model in 2013.

5.6 Other factors

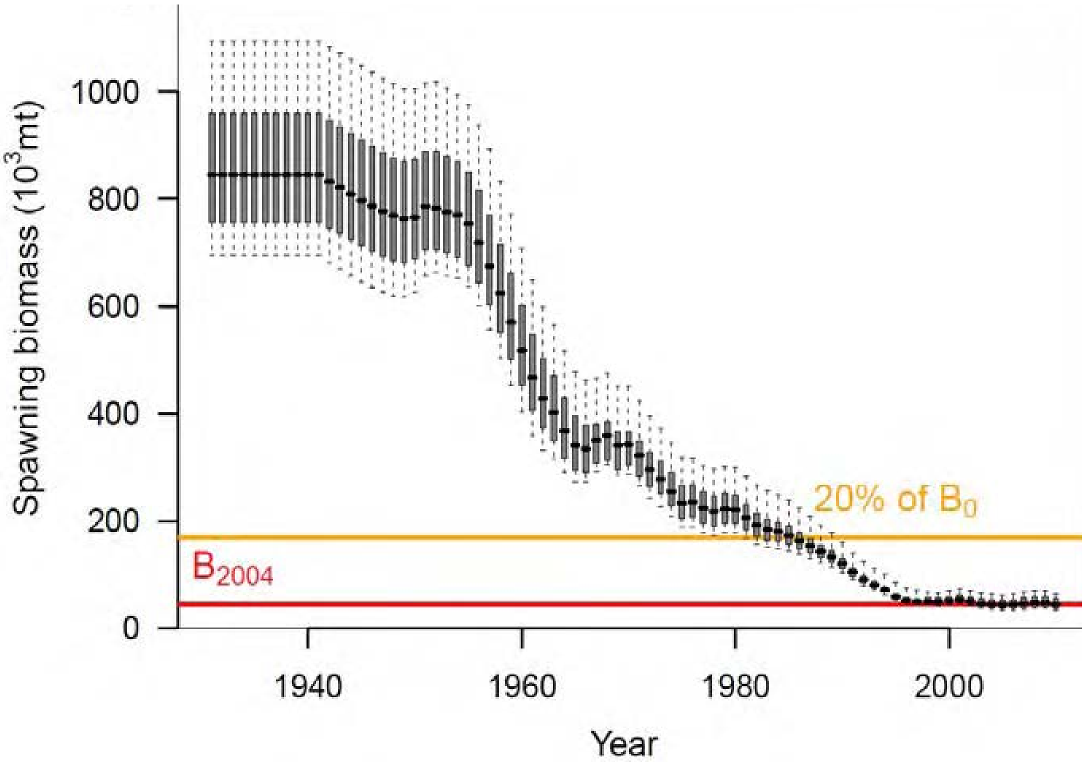
6. STATUS OF THE STOCK

The results from the reconditioned OM indicate that the spawning stock biomass is at a very low level. For the base case, the spawning biomass is estimated to be at 5% of the unfished level (SB0), with a 90% probability interval of 3% to 7%. This very low spawning stock biomass is consistent across all the plausible alternative scenarios (median range: 4-5%) and is a little more than 15% of the level at which MSY could be obtained.

The estimated trajectories of spawning stock biomass integrated over the grid for the base case over the full time series for the fishery are given in Figure 4. This shows a continuous decline from the late 1950s to the late 1970s, then a short period of stabilisation followed by a further decline from the early 1980s to mid 1990s to a very low level. The spawning stock biomass is estimated to have remained at this low level with relatively small annual variation until the early 2000s. For the more recent period, a decline in the median spawning stock biomass is evident from 2002. There is no current evidence of the spawning stock rebuilding, but it is projected to start rebuilding after 2012.

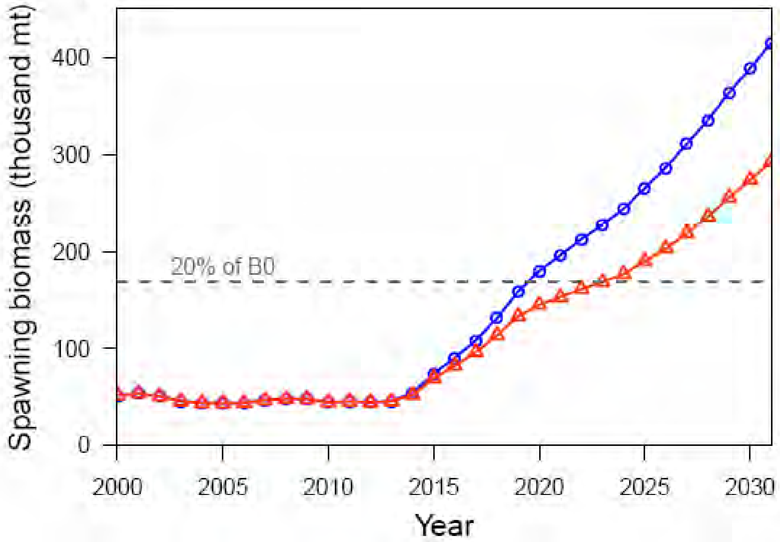
Stock Status	
Year of Most Recent Assessment	2011
Assessment Runs Presented	Basecase grid plus 4 plausible scenarios
Reference Points	B_{MSY}
Status in relation to Target	Well below B_{MSY}. Spawning stock biomass estimated to be about 5% B_0. Very Unlikely to be above B_{MSY}.
Status in relation to Limits	Very Likely (> 90%) to be below the soft limit Likely (> 60%) to be below the hard limit

Historical Stock Status Trajectory and Current Status



Spawning stock biomass for the base case, showing the medians, quartiles and 90th percentiles, together with reference points of 20% of pre-exploitation spawning stock biomass and the spawning stock biomass in 2004 (B_{2004}). Source: Report of the Scientific Committee 2011.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Flat trajectory of SB.
Recent Trend in Fishing Mortality or Proxy	Reduced in last 3 years. Current fishing mortality is below F_{MSY}.
Other Abundance Indices	CPUE has been increasing since 2007, juvenile abundance is improved in recent years.
Trends in Other Relevant Indicators or Variables	Recent recruitments are estimated to be well below the levels from 1950-1980, but have improved since the poor recruitments of 199-2002.

Projections and Prognosis		
Stock Projections or Prognosis	The Management Procedure adopted by the Commission in 2011 should rebuild the SB to 20%SB_0 by 2035 with a 70% probability.  **Spawning stock biomass projections under a constant catch equal to the current catch limit (9449 t) and zero catch.**	
Probability of Current Catch or TACC causing decline below Limits	The stock is already below both the soft and hard limits.	

Assessment Methodology		
Assessment Type	Level 1: Quantitative stock assessment	
Assessment Method	Basecase grid of reconditioned CCSBT Operating Model	
Main data inputs	CPUE, catch at age and length frequency data, tag recoveries, scientific aerial survey indices, commercial spotting indices, trolling indices	
Period of Assessment	Latest assessment: 2011	Next assessment: 2013
Changes to Model Structure and Assumptions	Values of steepness and M10 (natural mortality at age 10) were changed in 2011.	
Major Sources of Uncertainty	CPUE indices: • Historical indices have an unknown bias from misreporting • Fisheries management and operational changes since 2006 mean that recent CPUE series may not be comparable with earlier years.	

Qualifying Comments
Note the comments in section 4.5 on the preliminary results of the close-kin genetics study to determine the size of the SBT spawning stock.

Fishery Interactions
The ERS working group noted interactions reported by observers on seabirds, turtles and sharks but total mortalities of these groups were not estimated.

7. FOR FURTHER INFORMATION

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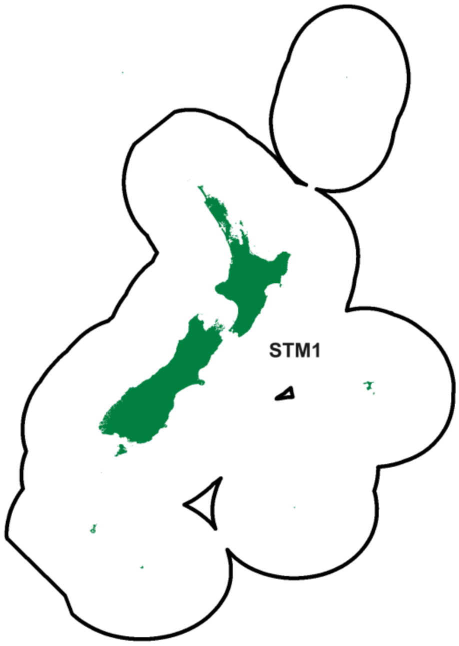
STRIPED MARLIN (STM)

(*Kajikia audax*)



1. FISHERY SUMMARY

All marlin species are currently managed outside the Quota Management System.

Management of the striped marlin and other highly migratory pelagic species throughout the western and central Pacific Ocean (WCPO) is the responsibility of the Western and Central Pacific Fisheries Commission (WCPFC). Under this regional convention, New Zealand is responsible for ensuring that the fisheries management measures applied within New Zealand fisheries waters are compatible with those of the Commission.

At its third annual meeting (2006) the WCPFC passed a Conservation and Management Measure (CMM) (this is a binding measure that all parties must abide by) relating to conservation and management of striped marlin in the southwest Pacific Ocean (www.wcpfc.int). This measure restricts the number of vessels a state can have targeting striped marlin on the high seas. However, this does not do not apply to those coastal states south of 15 degrees south in the Convention Area who have already taken, and continue to take, significant steps to address concerns over the status of striped marlin in the Southwestern Pacific region, through the establishment of a commercial moratorium on the landing of striped marlin caught within waters under their national jurisdiction.

1.1 Commercial fisheries

Most of the commercial striped marlin catch in the southwest Pacific is caught in the tuna surface longline fishery, which started in 1952 and in the New Zealand region in 1956. Since 1980 foreign fishing vessels had to obtain a license to fish in New Zealand's EEZ and were required to provide records of catch and effort. New Zealand domestic vessels commenced fishing with surface longlines in 1989 and the number of vessels and fishing effort expanded rapidly during the 1990s. Also in 1989, licences were issued to charter up to five surface longline vessels (Japanese) to fish on behalf of New Zealand companies. Very few striped marlin are caught by other commercial methods, although there are occasional reports of striped marlin caught in purse seine nets, these fish are seldom seen in catch records.

A three-year billfish moratorium was introduced in October 1987 in response to concerns over the decline in availability of striped marlin to recreational fishers. The moratorium prohibited access to the Auckland Fisheries Management Area (AFMA - Tirua Point to Cape Runaway) by foreign licensed and chartered tuna longline vessels between 1 October and 31 May each year. Licence restrictions required that all billfish, including broadbill swordfish, caught in the AFMA be released. In 1990 the moratorium was renewed for a further 3 years with some amended conditions and it was reviewed and extended in 1993 for a further year.

Regulations prohibited domestic commercial fishing vessels from retaining billfish caught within the AFMA since 1988. In 1991 these regulations were amended to allow the retention of broadbill swordfish and prohibited the retention of marlin species (striped, blue and black marlin) by commercial fishers in the New Zealand fishery waters. These regulations and government policy changes on the access rights of foreign licensed surface longline vessels have replaced the billfish moratorium. A billfish memorandum of understanding (MOU) between representatives of commercial fishers and recreational interests provided a framework for discussion and agreement on billfish management measures. This MOU was reviewed annually between 1990 and 1997 and was last signed in 1996.

Estimates of total landings (commercial and recreational) for New Zealand are given in Table 1. Commercial catch of striped marlin reported on Catch Effort Landing Returns (CELRs) and Tuna Longline Catch and Effort Reports (TLCERs) and recreational catches from New Zealand Big Game Fishing Council records are given in Table 1. Figure 1 shows historic landings and longline fishing effort for the STM stocks.

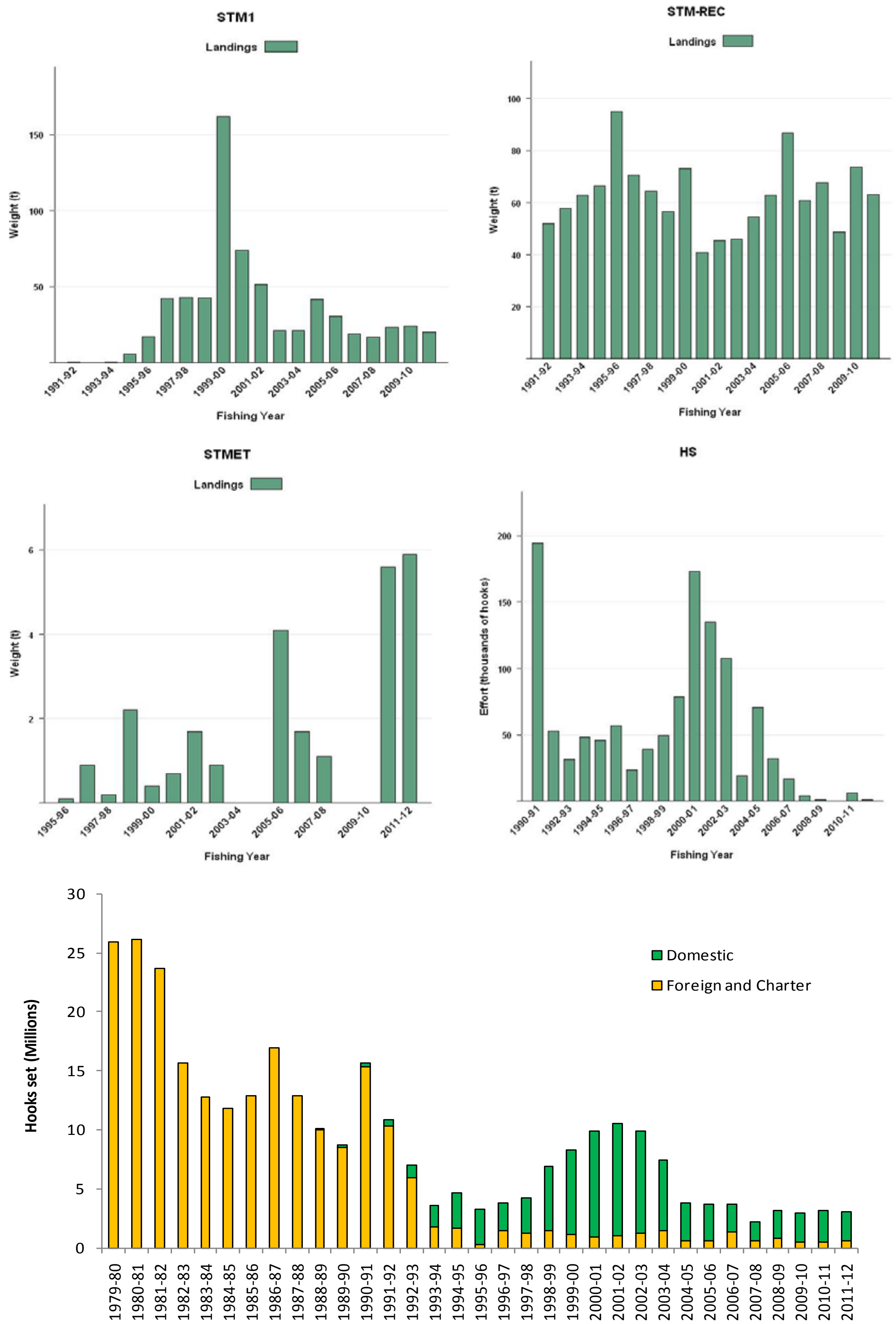


Figure 1: [Top and middle left] Striped marlin catch from 1991-92 to 2010-11 within NZ waters of commercial discards (STM1) and recreational catch (STM-REC), and 1995-96 to 2011-12 on the high seas (STMET). [Middle right] Fishing effort (number of hooks set) for all high seas New Zealand flagged surface longline vessels, and [Bottom] domestic vessels (including effort by foreign vessels chartered by NZ fishing companies), from 1990-91 to 2011-12 and 1979-80 to 2011-12, respectively.

Table 1: Commercial landings and discards (number of fish) of striped marlin in the New Zealand EEZ reported by fishing nation (CELRs and TLCERs), and recreational landings and number of fish tagged, by fishing year.

Fishing	Japan	Japan	Korea	Philippine	Australia	Domestic	NZ Recreational		Total
Year	Landed	Discarded	Landed	Discarded	Discarded	Discarded	Landed	Tagged	
1979-80	659						692	17	1 368
1980-81	1 663		46				792	2	2 503
1981-82	2 796		44				704	11	3 555
1982-83	973		32				702	6	1 713
1983-84	1 172		199				543	9	1 923
1984-85	548		160				262		970
1985-86	1 503		19				395	2	1 919
1986-87	1 925		26				226	2	2 179
1987-88	197		100				281	136	714
1988-89	23		30			5	647	408	1 113
1989-90	138					1	463	367	969
1990-91		1				6	532	232	771
1991-92		17				1	519	242	779
1992-93						7	608	386	1 001
1993-94						59	663	929	1 651
1994-95						182	910	1 206	2 298
1995-96						456	705	1 104	2 265
1996-97						441	619	1 302	2 362
1997-98						445	543	898	1 886
1998-99						1 642	823	1 541	4 006
1999-00		2				798	398	791	1 989
2000-01						527	422	851	1 800
2001-02						225	430	771	1 426
2002-03		3		7		205	495	671	1 381
2003-04		1				423	592	1 051	2 067
2004-05						307	834	1 348	2 489
2005-06						203	630	923	1 756
2006-07					9	152	688	964	1 813
2007-08		1				231	485	806	1 523
2008-09						242	731	1 058	2 030
2009-10						197	597	809	1 603
2010-11						269	529	698	1 496

Total recorded commercial catch was highest in 1981–82 at 2 843 fish and 198 t. Following the introduction of the billfish regulations, striped marlin caught on commercial vessels were required to be returned to the sea and few of these fish were recorded on catch/effort returns. In 1995 the Ministry of Fisheries (now MPI) instructed that commercially caught marlin be recorded on TLCERs. However, compliance with this requirement was inconsistent and estimated catches in the tuna longline fishery (calculated by scaling-up observed catches to the entire fleet) are considerably higher in fishing years for which these estimates are available. However, these estimates are probably imprecise as the MPI observer coverage of the domestic fleet has been low (just below 10% for the years 2007-2010) and has not adequately covered the spatial and temporal distribution of the fishery over summer.

Very few striped marlin in the TLCER database were reported south of 42°S and most striped marlin reported by commercial fishers were caught north of 38°S. Historically, Japanese and Korean vessels caught most striped marlin between 31°S and 35°S with a peak at 33°S. The New Zealand domestic fleet caught the majority of their striped marlin in the Bay of Plenty, East Cape area, between 36°S and 37°S.

A significant number of records from domestic commercial vessels provide the number of fish caught but not estimated catch weight. The total weight of striped marlin caught per season was calculated using fisher estimates from TLCER and CELR records plus an estimate from the number of fish with blank weights multiplied by the mean recreational striped marlin weight for that season. Catch has been split by landed fish and discarded or tagged for inside the New Zealand EEZ and outside the EEZ (Table 2).

Combined landings from within New Zealand fisheries waters are relatively small compared to commercial landings from the greater stock in the southwest Pacific Ocean (8% average for 2002-2006). In New Zealand, striped marlin are landed almost exclusively by the recreational sector, but there are no current estimates of recreational catch from elsewhere in the southwest Pacific.

Table 2: Reported total New Zealand landings and discards (commercial and recreational) (t) and commercial landings from the western and Central Pacific Ocean (WCPO) (t) of striped marlin from 1991 to 2011.

	Commercial Landed	Commercial Discarded	Recreational Landed	Recreational Tagged	EEZ Total	NZ Commercial Outside the EEZ	WCPO all gears *
1991	0.1	0.5	52	21	73		7 076
1992	0.8	0.1	57.8	21.9	81		6 878
1993	0	0.8	62.8	34.4	99		11 867
1994		5.7	66.3	81.2	153		8 013
1995		17.2	95	100	214	0.1	8 437
1996		42.3	70.6	91.6	204	0.9	6 746
1997		42.9	64.4	127.8	230	0.2	6 027
1998		42.7	56.5	80.9	182	2.2	8 501
1999		161.9	73.2	130.9	345	0.4	7 222
2000		74.1	40.9	72.1	179	0.7	5 644
2001		51.6	45.5	78.7	177	1.7	6 149
2002		21.2	45.8	76.9	144	0.9	5 962
2003		21.1	54.6	65.4	142		6 625
2004		41.7	62.7	105.6	208		6 551
2005		30.7	86.6	131.3	249	3.5	5 611
2006	0.4	19.0	60.8	85.8	166	3.2	5 534
2007	1.2	16.9	67.5	93.4	179	1.9	4 486
2008		23.5	48.6	79.7	152	1.1	5 057
2009		24.1	73.7	104.4	202		3 930
2010		20.5	63.1	79.5	163		3 530
2011		25.8	51.1	66.6	144	5.5	4 174

Source: TLCER and CELRs; NZSFC and Holdsworth (2008a);* Oceanic Fisheries Programme (2012).

The majority of striped marlin (66%) are caught in the New Zealand commercial fisheries are caught as bycatch in the bigeye tuna target surface longline fishery (Figure 2). Striped marlin are not allowed to be retained by commercial fishers in the New Zealand fishery waters and as a result do not show up in the reported catch (Figure 3). Longline fishing effort is distributed along the east coast of the North Island and the south west coast of the South Island. The west coast South Island fishery predominantly targets southern bluefin tuna, whereas the east coast of the North Island targets a range of species including bigeye, swordfish, and southern bluefin tuna (Figure 4).

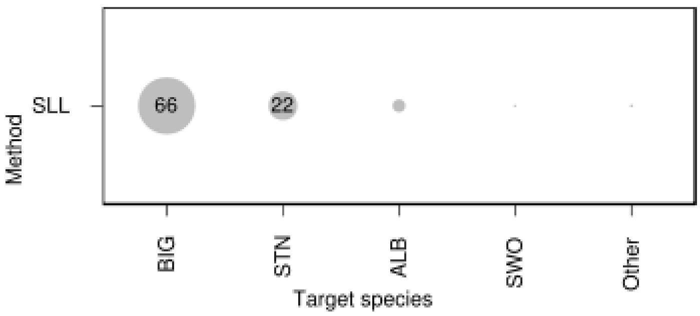


Figure 2: A summary of the proportion of striped marlin taken by each target fishery and fishing method. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the bobble is the percentage. SLL = surface longline (Bentley *et al.* 2012).

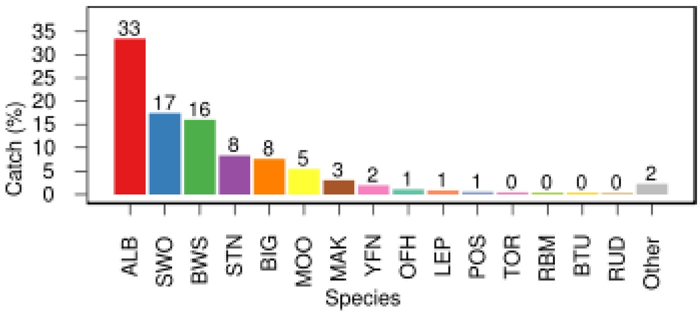


Figure 3: A summary of species composition of the reported surface longline catch. The percentage by weight of each species is calculated for all surface longline trips (Bentley *et al.* 2012).

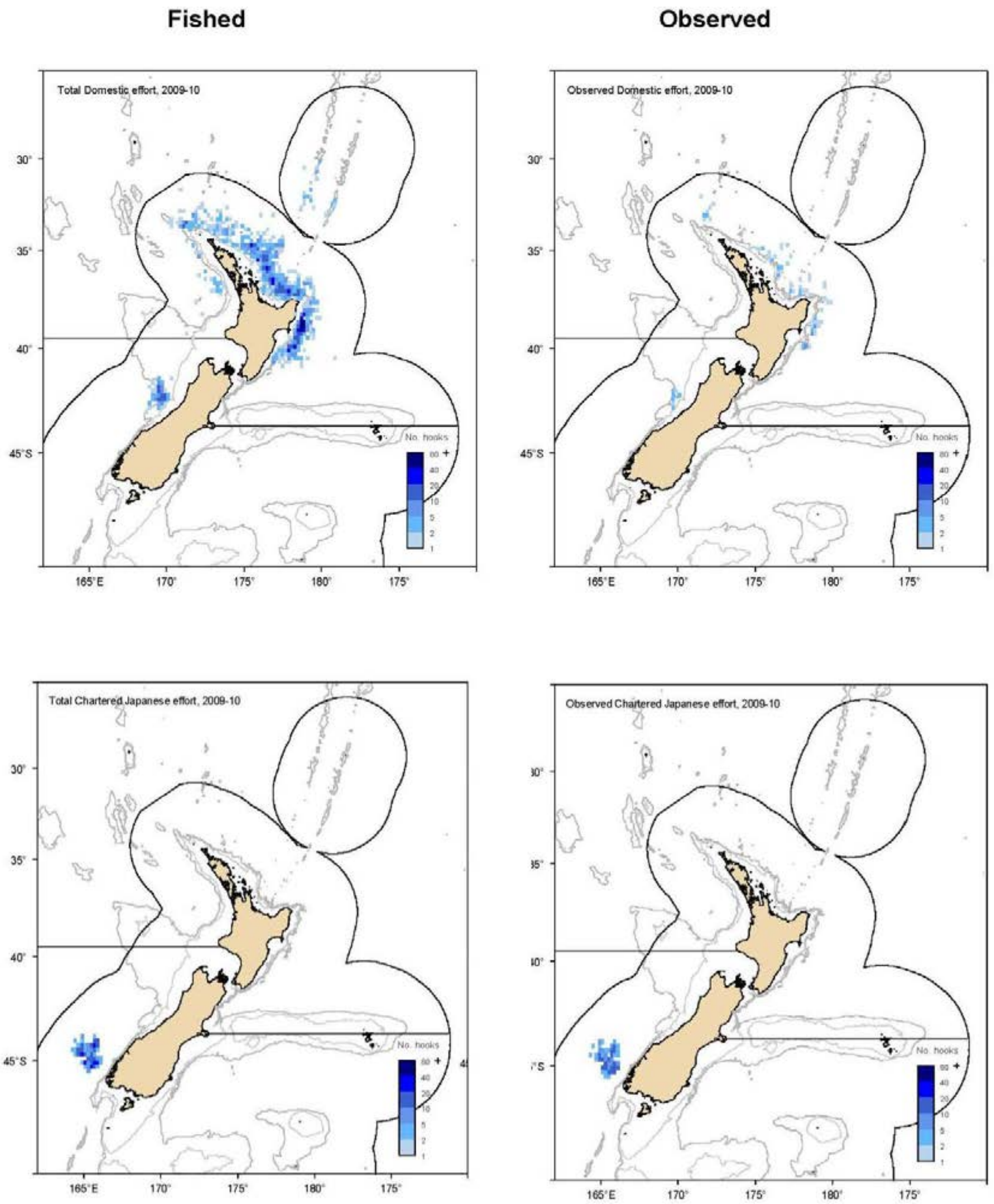


Figure 4: Distribution of fishing positions for domestic (top two panels) and charter (bottom two panels) vessels, for the 2009-10 fishing year, displaying both fishing effort (left) and observer effort (right).

In the longline fishery 73% of the striped marlin were alive when brought to the side of the vessel for all fleets (Table 3), and almost all were discarded (Table 4) as required by New Zealand legislation.

Table 3: Percentage of striped marlin (including discards) that were alive or dead when arriving at the longline vessel and observed during 2006–07 to 2009–10, by fishing year, fleet and region. Small sample sizes (number observed < 20) were omitted Griggs and Baird (in press).

Year	Fleet	Area	% alive	% dead	Number
2006-07	Total		65.0	35.0	20
2007-08	Total		100.0	0.0	6
2008-09	Total		50.0	50.0	8
2009-10	Domestic	North	72.7	27.3	22
	Total		72.7	27.3	22
Total all strata			69.6	30.4	56

Table 4: Percentage striped marlin that were retained, or discarded or lost, when observed on a longline vessel during 2006–07 to 2009–10, by fishing year and fleet. Small sample sizes (number observed < 20) omitted Griggs and Baird (in press).

Year	Fleet	% retained	% discarded or lost	Number
2006-07	Total	10.0	90.0	20
2007-08	Total	0.0	100.0	6
2008-09	Total	0.0	100.0	9
2009-10	Domestic	4.3	95.7	23
	Total	4.3	95.7	23

1.2 Recreational fisheries

The striped marlin fishery is an important component of the recreational fishery and tourist industry from late December to May in northern New Zealand. There are approximately 100 recreational charter boats that derive part of their income from marlin fishing and a growing number of private vessels participating in the fishery. Many of the largest fishing clubs in New Zealand target gamefish and are affiliated to the national body, the New Zealand Sport Fishing Council (NZSFC). Clubs provide facilities to weigh fish and keep catch records. The sport fishing season runs from 1 July to 30 June the following year. Almost all striped marlin are caught between January and June in the later half of the season.

In 1988 the NZSFC proposed a voluntary minimum size of 90 kg for striped marlin in order to encourage tag and release. Fish under this size do not count for club or national contests or trophies but most are included in the catch records each fishing season. In 2009–10 the 59 recreational fishing clubs affiliated to NZSFC reported landing 2708 billfish, sharks, kingfish, mahimahi, and tuna, and tagged and released a further 1996 gamefish. In 2009-10, 607 striped marlin were landed and weighed at a club (22% of landed fish in NZSFC records) and 764 were tagged and released (38% of tagged fish in NZSFC records). There is a fairly complete historical database of recreational catch records for each striped marlin caught by the Bay of Islands Swordfish Club and the Whangaroa Big Game Fishing Club going back to the 1920s, when this fishery started.

1.3 Customary non-commercial fisheries

Maori traditionally ate a wide variety of seafood, however, no record of specific marlin fishing methods has been found to date. An estimate of the current customary catch is not available.

1.4 Illegal catch

There is no known illegal catch of striped marlin.

1.5 Other sources of mortality

Some fish that break free from commercial or recreational fishing gear may die due to hook damage or entanglement in trailing line. A high proportion of fish that are caught are released alive by both commercial and recreational fishers. Data collected by the Ministry of Fisheries Observer Services from the tuna longline fishery suggest that most striped marlin are alive on retrieval (72% of the observed catch). The proportion of striped marlin brought to the boat alive was similar on domestic longliners and foreign and charter vessels. However, post release survival rates are unknown.

Recreational anglers tag and release 65% of their striped marlin catch (mean of the last ten years). Most of these fish are caught on lures. Reported results from 66 pop-up satellite archival tags (PSATs) deployed on lure caught striped marlin in New Zealand showed a high survival rate following catch and release. The pop-up archival tags are programmed to release from the fish following death. No fish died and sank to the seafloor. One fish was eaten (tag and all) by a lamnid shark about 15 hours after it was tagged and released. A small proportion of other PSAT tags failed to report so the fate of these fish is unknown.

Striped marlin caught on baits in Mexico showed a 26% mortality rate within 5 days of release. Injury was a clear predictor of mortality; 100% of fish that were bleeding from the gill cavity died, 63% of fish hooked deep died, and 9% of those released in good condition died.

2. BIOLOGY

Striped marlin is one of eight species of billfish in the family Istiophoridae. They are epi-pelagic predators in the tropical, subtropical and temperate pelagic ecosystem of the Pacific and Indian Oceans. Juveniles generally stay in warmer waters, while adults move into higher latitudes and temperate water feeding grounds in summer (southern hemisphere 1st quarter of the calendar year; 3rd quarter in the northern hemisphere). The latitudinal range estimated from longline data extends from 45°N to 40°S in the Pacific and from continental Asia to 45°S in the Indian Ocean. Striped marlin are not uniformly distributed, having a number of areas of high abundance. Fish tagged in New Zealand have undergone extensive seasonal migrations in the southwest Pacific but not beyond.

Samples from recreationally caught striped marlin in New Zealand indicate the most frequent prey items are saury and arrow squid, followed by jack mackerel. However, 28 fish species and 4 cephalopod species have been identified from stomach contents indicating that they are opportunistic predators.

The highest striped marlin catch for the surface longline method is recorded in January-February but striped marlin have been caught in New Zealand fisheries waters in every month, with lowest catches in November and December.

Striped marlin are oviparous and are known to spawn in the Coral Sea between Australia and New Caledonia. Their ovaries start to mature in this region during late September or early October. Spawning peaks in November and December and 60-70% of fish captured at this time are in spawning condition. The minimum size of mature fish in the Coral Sea is recorded at approximately 170 cm lower jaw-fork length (LJFL) and 36 kg. Striped marlin captured in New Zealand are rarely less than 200 cm (LJFL) suggesting that these fish are all mature. Female striped marlin on average, are larger than males but sexual dimorphism is not as marked as that seen in blue and black marlin. The sex ratio of striped marlin sampled from the recreational fishery in Northland (n = 61) was 1:1 prior to the introduction of the voluntary minimum size restriction (90 kg). There is no clear evidence of striped marlin reproductive activity in New Zealand waters. The northern edge of the EEZ around the Kermadec Islands extends into subtropical waters. According to historical longline records, in some years, there are moderate numbers of striped marlin in this area from October to December. Therefore, striped marlin spawning could occur in this area.

Estimated growth and validated age estimates of striped marlin were derived from fin spine and otolith age estimates from 425 striped marlin collected between 2006 and 2009. Samples came from the Australian commercial longline and recreational fisheries, longline fisheries in Pacific Island countries and 133 samples from the New Zealand recreational fishery. Ages ranged from 130 days to 8 years, in striped marlin ranging in length from 990 mm (~4 kg) to 2871 mm (~168 kg) LJFL (Kopf *et al*. 2009). Ages of striped marlin from New Zealand estimated ranged from 2 to 8 years in fish ranging in length from 2000 mm to 2871 mm LJFL. The median age of striped marlin landed in the New Zealand recreational fishery was 4.4 years for females and 3.8 years for males.

Growth for striped marlin in the southwest Pacific is broadly comparable with overseas studies. Melo-Barrera *et al.* (2003) identified between 2 and 11 growth bands from fish sampled in Mexico, and Skillman and Yong (1976) classified up to 12 age groups from length frequency analysis of striped marlin in Hawaii. Recreational catch records kept by the International Game Fish Association (IGFA) list the heaviest striped marlin as 224.1 kg caught in New Zealand in 1975.

Estimates of biological parameters for striped marlin in New Zealand waters are given in Table 5.

Table 5: Estimates of biological parameters.

Fishstock	Estimate				Source
1. Natural mortality (M)					
STM	0.49–1.33				Boggs (1989)
STM	0.389–0.818				Hinton & Bayliff (2002)
2. Weight = a (length)^b (Weight in kg, length in mm lower jaw fork length)					
	a	b			
STM	1.012×10^{-10}	3.55		South West Pacific	Kopf *et al.* (2010)
STM males	4.171×10^{-11}	3.67		South West Pacific	
STM females	1.902×10^{-9}	3.16		South West Pacific	
STM males	2.0×10^{-8}	2.88		New Zealand	Kopf *et al.* (2005)
STM females	2.0×10^{-8}	2.90			
3. Von Bertalanffy model parameter estimates					
	k	t_0	L_∞		
STM	0.44	-1.07	2636	South West Pacific	Kopf *et al.* (2009)
STM	0.22	-0.04	3010	New Zealand	Kopf *et al.* (2005)
STM	0.23	-1.6	2210	Mexico	Melo-Barrera *et al.* (2003)
STM male	0.315–0.417	-0.521	2774-3144	Hawaii	Skillman & Yong (1976)
STM female	0.686–0.709	0.136	2887-3262	Hawaii	Skillman & Yong (1976)

3. STOCKS AND AREAS

Striped marlin are a highly migratory species, and fish caught in the New Zealand fisheries waters are part of a wider stock. The stock structure of striped marlin in the Pacific Ocean is not well understood, but resolving stock structure uncertainties is the focus of current research activities. The two most frequently considered hypotheses are: (1) a single-unit stock in the Pacific, which is supported by the continuous "horseshoe-shaped" distribution of striped marlin; and (2) a two-stock structure, with the stocks separated roughly at the Equator, albeit with some intermixing in the eastern Pacific.

Spawning occurs in water warmer than 24°C, mainly in November and December, in the southern hemisphere. Known spawning areas in the southwest Pacific are in the Coral Sea in the west and French Polynesia in the east of the region. The southern hemisphere spawning season is out of phase with the north Pacific. Very warm equatorial water in the western Pacific, where striped marlin are seldom caught, may be acting as a natural barrier to stock mixing. However, in the eastern Pacific striped marlin may be found in equatorial waters and 3 fish tagged in the northern hemisphere have been recaptured in the southern hemisphere. The results of mitochondrial DNA analysis are consistent with shallow population structuring within striped marlin in the Pacific.

The New Zealand Gamefish Tagging Programme has tagged and released 20 627 striped marlin between 1 July 1975 and 30 June 2012. Of the 83 recaptures reported 31 have been made outside the EEZ spread across the region from French Polynesia (142°W) to eastern Australia (154°E) and from 2°S to 38°S latitude. There have been no reports of striped marlin tagged in the southwestern Pacific being recaptured elsewhere in the Pacific Ocean. Projects by New Zealand and US researchers using electronic tags have described the movement and habitat preferences of Pacific striped marlin.

Striped marlin are believed to have a preference for sea surface temperatures of 20 to 25°C. Generally striped marlin arrive in New Zealand fisheries waters in January and February, and tag recaptures indicate that they leave the New Zealand EEZ between March and June; although they have been caught by surface longliners in the EEZ in every month. Within the EEZ most striped marlin are caught in FMA 1 and FMA 9.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the November 2012 Fishery Assessment Plenary after review by the Aquatic Environment Working Group. This summary is from the perspective of striped marlin but there is no directed fishery for them and the incidental catch sections below reflect the New Zealand longline fishery as a whole and are not specific to this species; a more detailed summary from an issue-by-issue perspective is, or will shortly be, available in the Aquatic Environment & Biodiversity Annual Review where the consequences are also discussed. (http://www.mpi.govt.nz/news-resources/publications.aspx).

4.1 Role in the ecosystem

Striped marlin (*Kajikia audax*) are large pelagic predators, so they are likely to have a 'top down' effect on the squid, fish and crustaceans they feed on.

4.2 Incidental catch (seabirds, sea turtles and mammals)

The protected species, capture estimates presented here include all animals recovered onto the deck (alive, injured or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds caught on a hook but not brought onboard the vessel).

4.2.1 Seabird bycatch

Between 2002–03 and 2010–11, there were 731 observed captures of birds across all surface longline fisheries. Seabird capture rates since 2003 are presented in Figure 5. While the seabird capture distributions largely coincide with fishing effort that are more frequent off the south west coast of the South Island (Figure 6). The analytical methods used to estimate capture numbers across the commercial fisheries have depended on the quantity and quality of the data, in terms of the numbers observed captured and the representativeness of the observer coverage. Ratio estimation was historically used to calculate total captures in longline fisheries by target fishery fleet and area (Baird 2008) and by all fishing methods but recent estimates are either ratio or model based as specified in the tables below (Abraham *et al.* 2010a).

Through the 1990s the minimum seabird mitigation requirement for surface longline vessels was the use of a bird scaring device (tori line) but common practice was that vessels set surface longlines primarily at night. In 2007 a notice was implemented under s 11 of the Fisheries Act 1996 to formalise the requirement that surface longline vessels only set during the hours of darkness and use a tori line when setting. This notice was amended in 2008 to add the option of line weighting and tori line use if setting during the day. In 2011 notices were combined and repromulgated under a new regulation (Regulation 58A of the Fisheries (Commercial Fishing) Regulations 2001) which provides a more flexible regulatory environment under which to set seabird mitigation requirements.

Table 6: Number of observed seabird captures in the New Zealand surface longline fisheries, 2002-03 to 2010-11, by species and area (Thompson & Abraham (2012) from http://data.dragonfly.co.nz/psc/). See glossary above for a description of the areas used for summarising the fishing effort and protected species captures. 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 striped marlin using longline gear but rather the total risk for each seabird species.

Species	Risk ratio	Kermadec Islands	Northland and Hauraki	Bay of Plenty	East Coast North Island	Stewart Snares Shelf	Fiordland	West Coast South Island	West Coast North Island	Total
Salvin's albatross	2.49	0	1	1	6	0	0	0	0	8
Northern royal albatross	2.21	0	0	1	0	0	0	0	0	1
Light-mantled sooty albatross	2.18	0	0	0	0	0	0	1	0	1
Campbell albatross	1.84	0	8	0	26	0	3	3	0	40
Southern Buller's albatross	1.28	0	3	1	26	0	251	31	0	312
Gibson's albatross	1.25	4	10	0	11	0	3	1	1	30
Antipodean albatross	1.11	12	9	1	7	0	0	0	1	30
White capped albatross	0.83	0	1	0	3	10	54	25	0	93
Southern royal albatross	0.74	0	0	0	0	0	4	0	0	4
Black browed albatrosses	-	2	1	0	0	0	0	0	1	4
Pacific albatross	-	0	0	0	1	0	0	0	0	1
Southern black-browed albatross	-	0	0	0	2	0	0	0	0	2
Wandering albatross	-	0	2	0	6	0	3	0	0	11
Antipodean and Gibson's albatrosses	N/A	5	2	0	0	0	0	0	0	7
Unidentified albatross	N/A	33	0	0	1	0	0	0	1	35
Total albatrosses	**N/A**	**56**	**37**	**4**	**89**	**10**	**318**	**61**	**4**	**579**
Black petrel	11.15	1	9	1	0	0	0	0	1	12
Westland petrel	3.31	0	0	0	2	0	1	5	0	8
Flesh footed shearwater	2.51	0	0	0	10	0	0	0	2	12
Cape petrels	0.76	0	0	0	2	0	0	0	0	2
White chinned petrel	0.79	2	2	3	3	1	19	0	3	33
Grey petrel	0.39	3	3	2	38	0	0	0	0	46
Sooty shearwater	0.02	1	0	0	8	3	1	0	0	13
Great winged petrel	0.01	12	5	1	2	0	0	0	0	20
White headed petrel	0.01	2	0	0	0	0	0	0	0	2
Pterodroma petrels	-	0	1	0	0	0	0	0	0	1
Southern giant petrel	-	0	0	0	2	0	0	0	0	2
Unidentified seabird	N/A	0	0	0	0	0	1	0	0	1
Total other birds	**N/A**	**21**	**20**	**7**	**67**	**4**	**22**	**5**	**6**	**152**

Table 7: Effort, observed and estimated seabird captures by fishing year for the New Zealand surface longline fishery within the EEZ. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); the capture rate (captures per thousand hooks); and the mean number of estimated total captures (with 95% confidence interval). The estimation method used was a Bayesian model with 100% of hooks included in the estimate. For more information on the methods used to prepare the data see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures		Estimated captures	
	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002-2003	10 764 588	2 195 152	20.4	115	0.052	2490	1817-3461
2003-2004	7 380 779	1 607 304	21.8	71	0.044	1665	1259-2220
2004-2005	3 676 365	783 812	21.3	41	0.052	687	507-936
2005-2006	3 687 339	705 945	19.1	37	0.052	816	607-1120
2006-2007	3 738 362	1 040 948	27.8	187	0.18	949	725-1304
2007-2008	2 244 339	426 310	19	41	0.096	521	408-681
2008-2009	3 115 633	937 233	30.1	57	0.061	721	562-934
2009-2010	2 992 285	665 883	22.3	149	0.224	1014	777-1345
2010-2011	3 164 159	674 522	21.3	47	0.07	824	607-1152

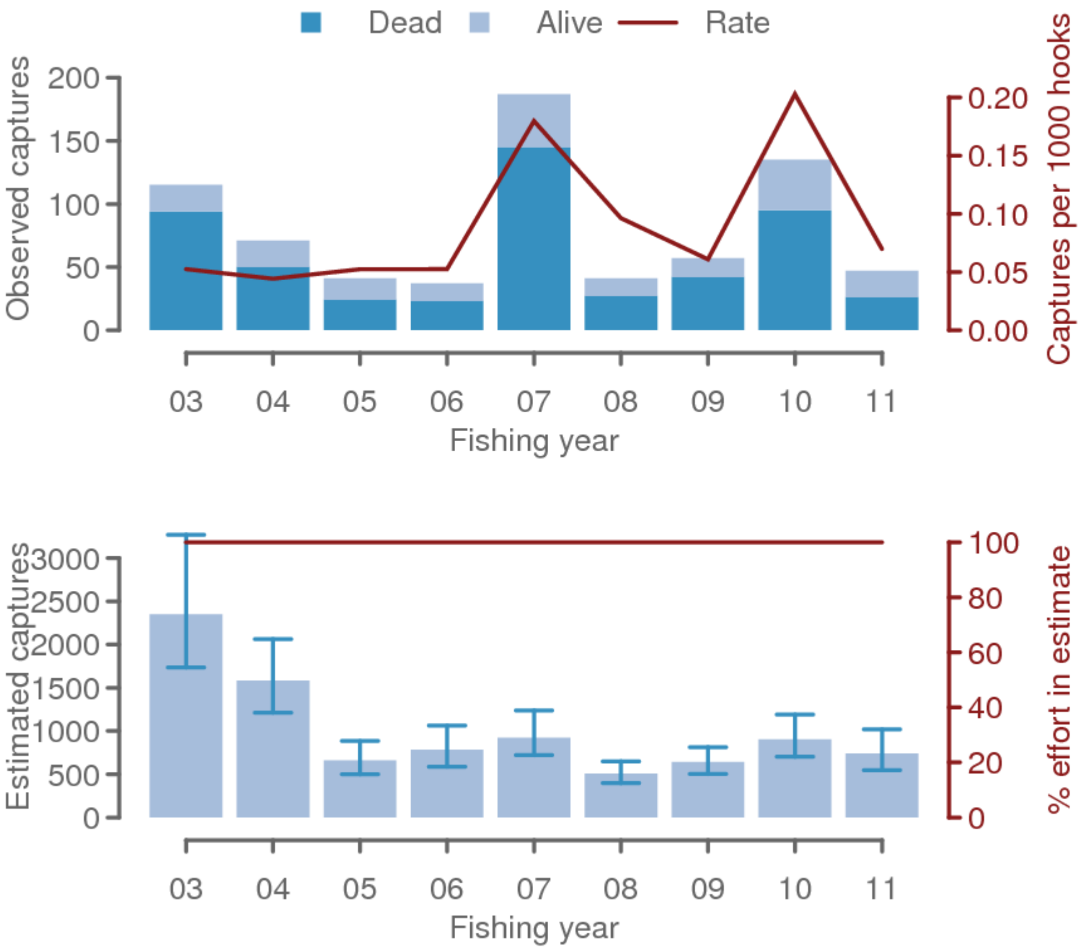


Figure 5: Observed and estimated captures of seabirds birds in the New Zealand surface longline fisheries from 2003 to 2011.

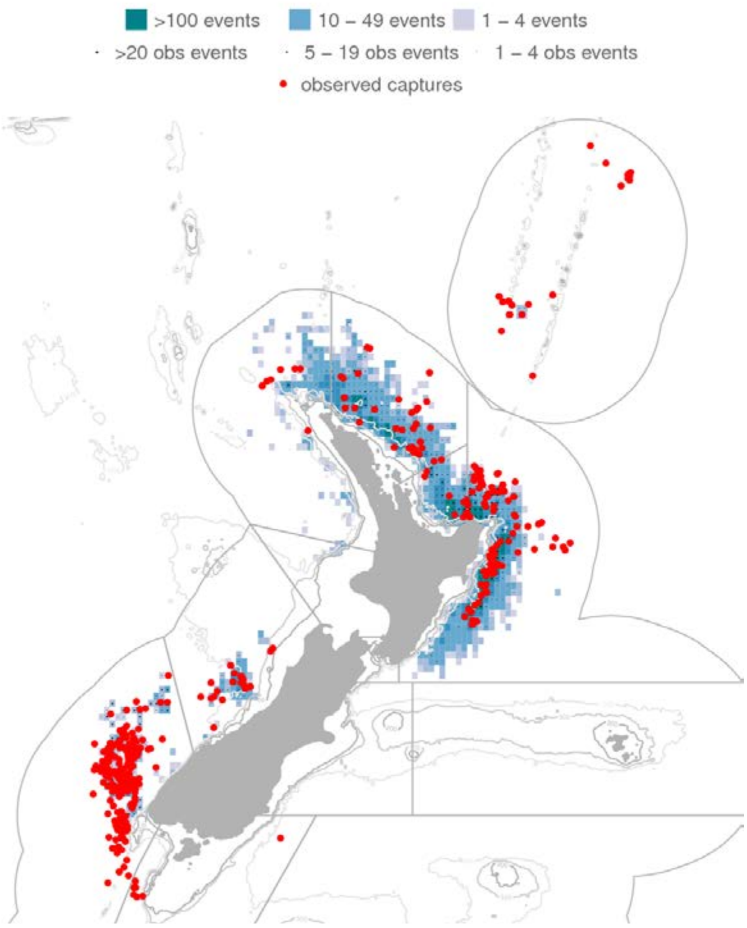


Figure 6: Distribution of fishing effort in the New Zealand surface longline fisheries and observed seabird captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.2 Sea turtle bycatch

Between 2002–03 and 2010–11, there were 13 observed captures of sea turtles across all surface longline fisheries (Tables 8 and 9, Figure 7). Observer records documented all but one sea turtle as captured and released alive. Sea turtle capture distributions predominantly occur throughout the east coast of the North Island and Kermadec Island fisheries (Figure 8).

Table 8: Number of observed sea turtle captures in the New Zealand surface longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson and Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

Species	Bay of Plenty	East Coast North Island	Kermadec Islands	West Coast North Island	Total
Leatherback turtle	1	4	3	3	11
Olive ridley turtle	0	1	0	0	1
Unknown turtle	0	1	0	0	1
Total	**1**	**6**	**3**	**3**	**13**

Table 9: Effort and sea turtle captures in surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	10 764 588	2 195 152	20.4	0	0
2003-2004	7 380 779	1 607 304	21.8	1	0.001
2004-2005	3 676 365	783 812	21.3	2	0.003
2005-2006	3 687 339	705 945	19.1	1	0.001
2006-2007	3 738 362	1 040 948	27.8	2	0.002
2007-2008	2 244 339	426 310	19.0	1	0.002
2008-2009	3 115 633	937 233	30.1	2	0.002
2009-2010	2 992 285	665 883	22.3	0	0
2010-2011	3 164 159	674 522	21.3	4	0.006

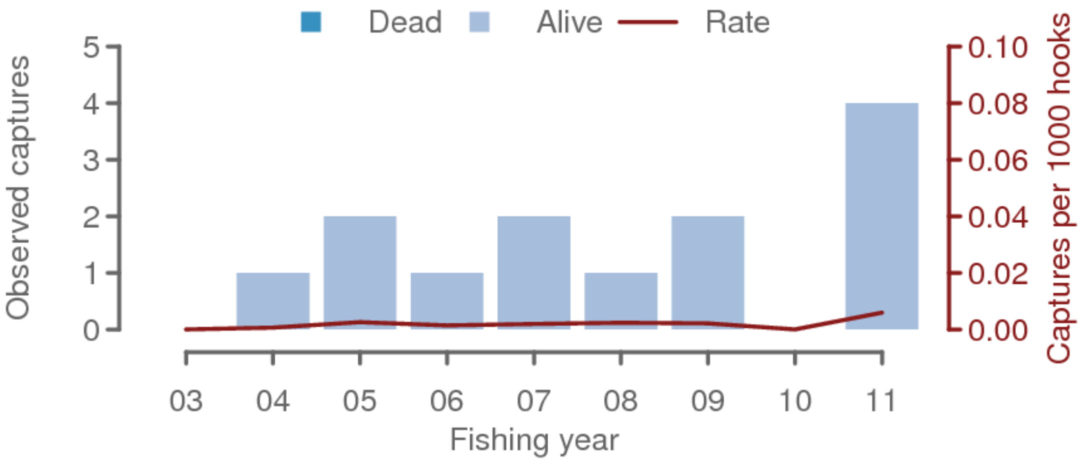


Figure 7: Observed captures of sea turtles in the New Zealand surface longline fisheries from 2003 to 2011.

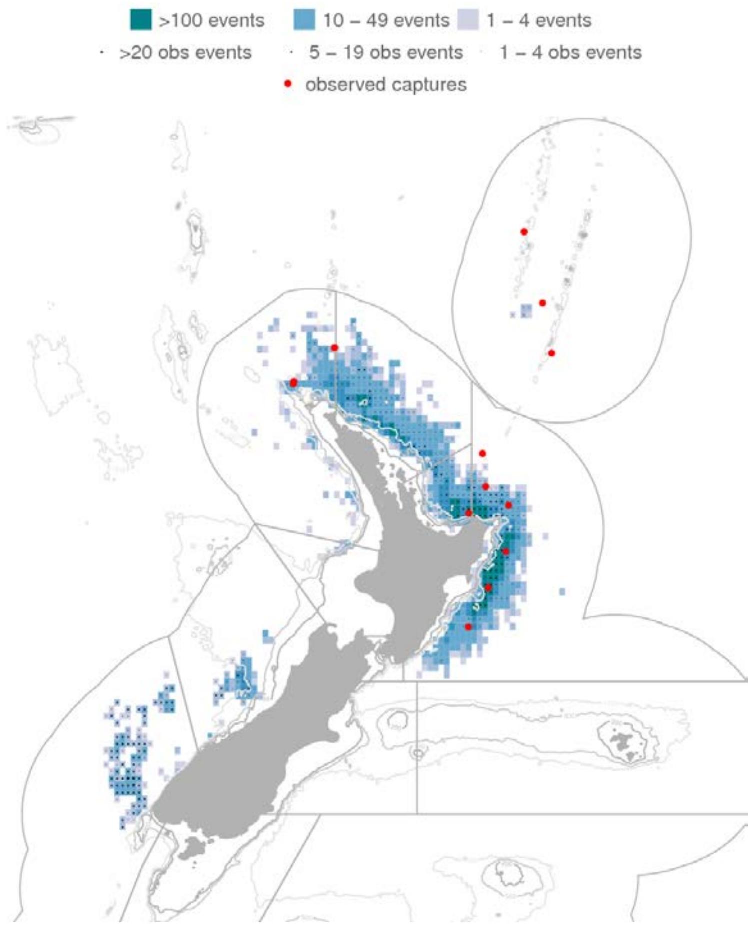


Figure 8: Distribution of fishing effort in the New Zealand surface longline fisheries and observed sea turtle captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3 Marine Mammals

4.2.3.1 Cetaceans

Cetaceans are dispersed throughout New Zealand waters (Perrin *et al.* 2008). The spatial and temporal overlap of commercial fishing grounds and cetacean foraging areas has resulted in cetacean captures in fishing gear (Abraham and Thompson 2009, 2011).

Between 2002–03 and 2010–11, there were seven observed captures of whales and dolphins in surface longline fisheries. Observed captures included 5 unidentified cetaceans and 2 long-finned Pilot whales (Tables 10 and 11, Figure 9) (Abraham and Thompson 2011). All captured animals recorded were documented as being caught and released alive (Thompson and Abraham 2010). Cetacean capture distributions are more frequent off the east coast of the North Island (Figure 10)

Table 10: Number of observed cetacean captures in the New Zealand surface longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson and Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

Species	Bay of Plenty	East Coast North Island	Fiordland	Northland and Hauraki	West Coast North Island	West Coast South Island	Total
Long-finned pilot whale	0	1	0	0	0	1	2
Unidentified cetacean	1	1	1	1	1	0	5
Total	**1**	**2**	**1**	**1**	**1**	**1**	**7**

Table 11: Effort and captures of cetaceans in surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	10 764 588	2 195 152	20.4	1	0.0005
2003-2004	7 380 779	1 607 304	21.8	4	0.002
2004-2005	3 676 365	783 812	21.3	1	0.001
2005-2006	3 687 339	705 945	19.1	0	0
2006-2007	3 738 362	1 040 948	27.8	0	0
2007-2008	2 244 339	426 310	19.0	1	0.002
2008-2009	3 115 633	937 233	30.1	0	0
2009-2010	2 992 285	665 883	22.3	0	0
2010-2011	3 164 159	674 522	21.3	0	0

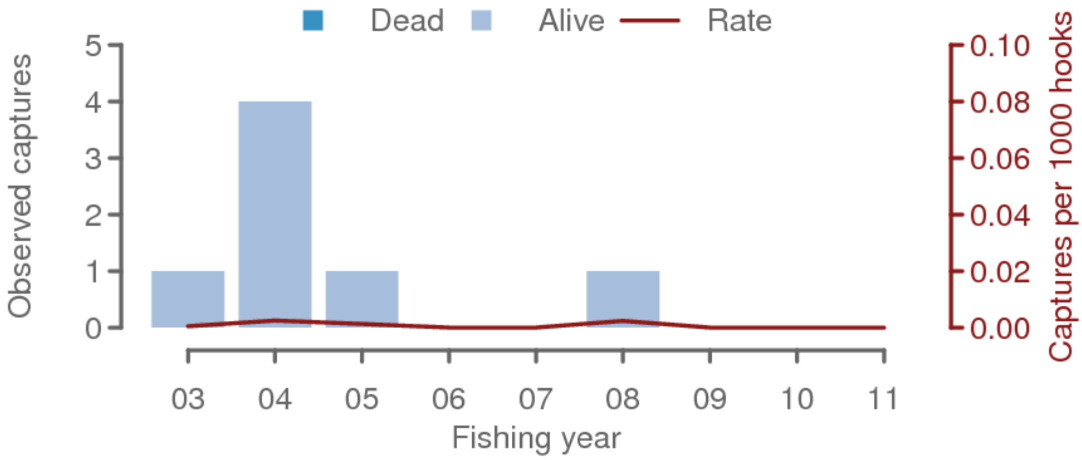


Figure 9: Observed captures of cetaceans in the New Zealand surface longline fisheries from 2003 to 2011.

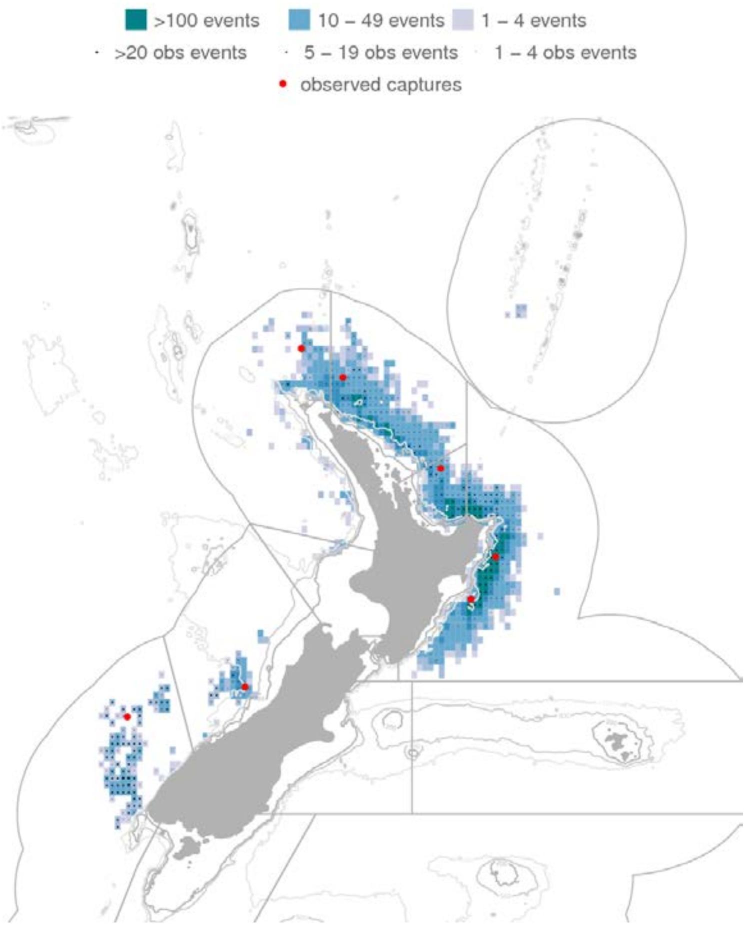


Figure 10: Distribution of fishing effort in the New Zealand surface longline fisheries and observed cetacean captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3.2 New Zealand fur seal bycatch

Currently, New Zealand fur seals are dispersed throughout New Zealand waters, especially in waters south of about 40º S to Macquarie Island. The spatial and temporal overlap of commercial fishing grounds and New Zealand fur seal foraging areas has resulted in New Zealand fur seal captures in fishing gear (Mattlin 1987, Rowe 2009). Most fisheries with observed captures occur in waters over or close to the continental shelf, which around much of the South Island and offshore islands slopes steeply to deeper waters relatively close to shore, and thus rookeries and haulouts. Captures on longlines occur when the seals attempt to feed on the fish and bait catch during hauling. Most New Zealand fur seals are released alive, typically with a hook and short snood or trace still attached.

New Zealand fur seal captures in surface longline fisheries have been generally observed in waters south and west of Fiordland, but also in the Bay of Plenty-East Cape area when the animals have attempted to take bait or fish from the line as it is hauled. These capture rates include animals that are released alive (100% of observed surface longline capture in 2008-09; Thompson and Abraham 2010). Bycatch rates in 2010-11 are low and lower than they were in the early 2000s (Figure 11). While fur seal captures have occurred throughout the range of this fishery most New Zealand captures have occurred off the Southwest coast of the South Island

(Figure 12). Between 2002–03 and 2010–11, there were 206 observed captures of New Zealand fur seal in surface longline fisheries (Tables 12 and 13).

Table 12: Number of observed New Zealand fur seal captures in the New Zealand surface longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson and Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

	Bay of Plenty	East Coast North Island	Fiordland	Northland and Hauraki	Stewart Snares Shelf	West Coast North Island	West Coast South Island	Total
New Zealand fur seal	10	16	139	3	4	2	32	206

Table 13: Effort and captures of New Zealand fur seal in the New Zealand surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	10 764 588	2 195 152	20.4	56	0.026
2003-2004	7 380 779	1 607 304	21.8	40	0.025
2004-2005	3 676 365	783 812	21.3	20	0.026
2005-2006	3 687 339	705 945	19.1	12	0.017
2006-2007	3 738 362	1 040 948	27.8	10	0.010
2007-2008	2 244 339	426 310	19.0	10	0.023
2008-2009	3 115 633	937 233	30.1	22	0.023
2009-2010	2 992 285	665 883	22.3	19	0.029
2010-2011	3 164 159	674 522	21.3	17	0.025

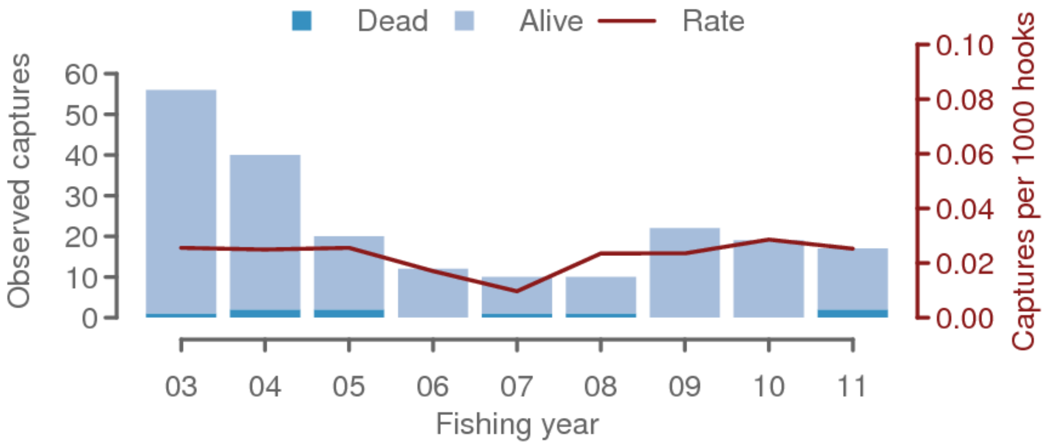


Figure 11: Observed captures of New Zealand fur seal in the New Zealand surface longline fisheries from 2003 to 2011.

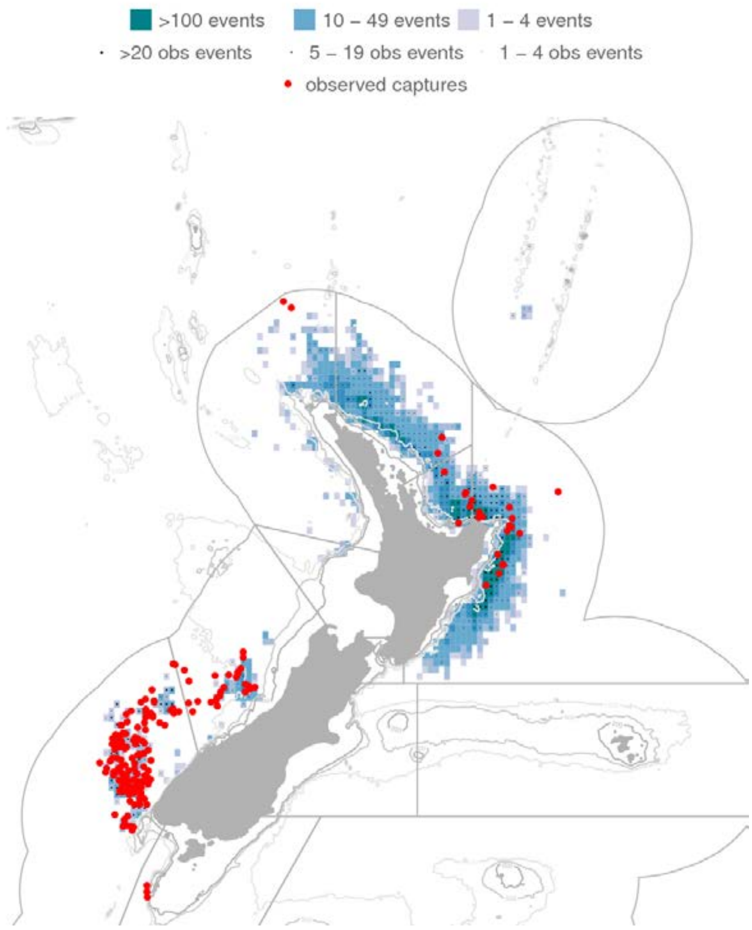


Figure 12: Distribution of fishing effort in the New Zealand surface longline fisheries and observed New Zealand fur seal captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.3 Incidental fish bycatch

Observer records indicate that a wide range of species are landed by the longline fleets in New Zealand fishery waters. Blue sharks are the most commonly landed species (by number), followed by Ray's bream (Table 14). Southern bluefin tuna and albacore tuna are the only target species that occur in the top five of the frequency of occurrence.

Table 14: Numbers of the most common fish species observed in the New Zealand longline fisheries during 2009-10 by fleet and area. Species are shown in descending order of total abundance (Griggs and Baird in press).

	Charter	Domestic		Total
Species	South	North	South	number
Blue shark	2 024	4 650	882	7 556
Rays bream	3 295	326	88	3 709
Southern bluefin tuna	3 244	211	179	3 634
Lancetfish	3	2 139	1	2 143
Albacore tuna	90	1 772	42	1 904
Dealfish	882	0	7	889
Swordfish	3	452	2	457
Moonfish	76	339	6	421
Porbeagle shark	72	328	20	420
Mako shark	11	343	7	361
Big scale pomfret	349	4	0	353
Deepwater dogfish	305	0	0	305
Sunfish	7	283	5	295
Bigeye tuna	0	191	0	191
Escolar	0	129	0	129
Butterfly tuna	15	100	3	118
Pelagic stingray	0	96	0	96
Oilfish	2	75	0	77
Rudderfish	39	20	2	61
Flathead pomfret	56	0	0	56
Dolphinfish	0	47	0	47
School shark	34	0	2	36
Striped marlin	0	24	0	24
Thresher shark	7	17	0	24
Cubehead	13	0	1	14
Kingfish	0	10	0	10
Yellowfin tuna	0	9	0	9
Hake	8	0	0	8
Hapuku bass	1	6	0	7
Pacific bluefin tuna	0	5	0	5
Black barracouta	0	4	0	4
Skipjack tuna	0	4	0	4
Shortbill spearfish	0	4	0	4
Gemfish	0	3	0	3
Bigeye thresher shark	0	2	0	2
Snipe eel	2	0	0	2
Slender tuna	2	0	0	2
Wingfish	2	0	0	2
Bronze whaler shark	0	1	0	1
Hammerhead shark	0	1	0	1
Hoki	0	0	1	1
Louvar	0	1	0	1
Marlin, unspecified	0	1	0	1
Scissortail	0	1	0	1
Broadnose seven gill shark	1	0	0	1
Shark, unspecified	0	1	0	1
Unidentified fish	2	30	8	40
Total	10 545	11 629	1 256	23 430

4.4 Benthic interactions

N/A

4.5 Key environmental and ecosystem information gaps

Cryptic mortality is unknown at present but developing a better understanding of this in future may be useful for reducing uncertainty of the seabird risk assessment and could be a useful input into risk assessments for other species groups.

The survival rates of released target and bycatch species is currently unknown.

Observer coverage in the New Zealand fleet is not spatially and temporally representative of the fishing effort.

5. STOCK ASSESSMENT

With the establishment of WCPFC in 2004, the Scientific Committee of the Western and Central Pacific Fisheries Commission (WCPFC) will review stock assessments of striped marlin in the western and central Pacific Ocean stock.

In 2012, scientists from Australia and the Secretariat of the Pacific Community (SPC) collaborated on an assessment for striped marlin in the southwest Pacific Ocean (further details can be found in Davies *et al.* (2012). This was the second attempt to carry out an assessment for this stock and contained many improvements from the previous assessment.

"Excerpts from the stock assessment are provided below, as are several figures and tables regarding stock status that reflect the model runs selected by SC for the determination of current stock status and the provision of management advice. This assessment is supported by several other analyses which are documented separately, but should be considered when reviewing this assessment as they underpin many of the fundamental inputs to the models. These include standardised CPUE analyses of aggregate Japanese and Taiwanese longline catch and effort data (Hoyle & Davies 2012); standardised CPUE analyses of operational catch and effort data for Australian longline fishery (Robert Campbell 2012); standardized CPUE for the recreational fisheries in Australia (Ghosn *et al.* 2012) and New Zealand (Holdsworth and Kendrick, 2012), and new biological estimates for growth, the length-weight relationship, and maturity at age (Kopf, 2009, 2011). The assessment includes a series of model runs describing stepwise changes from the 2006 assessment model (bcase06) to develop a new "reference case" model (Ref.case), and then a series of "one-off" sensitivity models that represent a single change from the Ref.case model run. A sub-set of key model runs was taken from the sensitivities that represent a set of plausible model runs, and these were included in a structural uncertainty analysis (grid) for consideration in developing management advice.

Besides updating the input data to December 2011, the main developments to the inputs compared to the 2006 assessment included:

a) Japanese longline catches for 1952-2011 revised downwards by approximately 50%;
b) Nine revised and new standardised CPUE time series (with temporal CVs) derived from:
    - aggregate catch-effort data for Japanese and Taiwanese longline fisheries;
    - operational catch-effort data for the Australian longline fishery;
    - operational catch-effort data for the Australian and New Zealand recreational fisheries, and
c) Size composition data for the Australian recreational fishery.

The main developments to model structural assumptions were to: fix steepness at 0.8; fix growth at the published estimates; estimate spline selectivities for the main longline fisheries; estimate logistic selectivity for the Australian recreational fishery; include time-variant precision in fitting the model to standardized CPUE indices; and remove conflict among the CPUE indices by taking only the Japanese longline index in model area 2 as being representative for the Ref.case.

The primary factors causing the differences between the 2006 and 2012 assessments are:

- The approximately 50% reduction in Japanese longline catches over the entire model time period;
- The faster growth rates;
- Steepness fixed at 0.8 rather than estimated (0.546);
- Selectivities for the major longline fisheries use cubic splines, and are not constrained to be asymptotic;

- Removing conflict among the CPUE indices by separating conflicting indices into different models.

Together these changes produce an estimated absolute biomass that is around 30% lower than the 2006 base case and MSY is estimated to be 20% lower. Current biomass levels are higher relative to the MSY reference point levels.

The main conclusions of the 2012 assessment undertaken by SPC (Davies *et al.* 2012) and reviewed by the WCPFC Scientific Committee in August 2012 are as follows:

a) "The decreasing trend in recruitment estimated in the 2006 assessment remains a feature of the current assessment, particularly during the first 20 years. It is concurrent with large declines in catch and CPUE in the Japanese longline fishery in area 2. Recruitment over the latter 40 years of the model period declines slightly.
b) Estimates of absolute biomass were sensitive to assumptions about selectivity and to conflicts among the standardized CPUE time series. The reference case model (Ref.case) estimated selectivity functions that decrease with age for the main longline fisheries that achieved the best fit to the size data. The CPUE time series for the Japanese longline fishery in area 2 was selected for fitting the Ref.case model because this time series was considered to be the most representative of changes in overall population relative abundance. Alternative options for selectivity assumptions and the CPUE time series included in the model fit were explored in sensitivity and structural uncertainty analyses, and are presented as the key model runs.
c) Estimates of equilibrium yield and the associated reference points are highly sensitive to the assumed values of natural mortality and, to a lesser extent, steepness in the stock-recruitment relationship. Estimates of stock status are therefore uncertain with respect to these assumptions.
d) If one considers the recruitment estimates since 1970 to be more plausible and representative of the overall productivity of the striped marlin stock than estimates of earlier recruitments, the results of the 'msy_recent' analysis could be used for formulating management advice. Under this productivity assumption *MSY* was 16% lower than the grid median value, but the general conclusions regarding stock status were similar.
e) Total and spawning biomass are estimated to have declined to at least 50% of their initial levels by 1970, with more gradual declines since then in both total biomass ($B_{current}/B_0$ = 36%) and spawning biomass ($SB_{current}/SB_0$ = 29%).
f) When the non-equilibrium nature of recent recruitment is taken into account, we can estimate the level of depletion that has occurred. It is estimated that, for the period 2007-2010, spawning potential is at 43% of the level predicted to exist in the absence of fishing, and for 2011 is at 46%.
g) The attribution of depletion to various fisheries or groups of fisheries indicates that the Japanese longline fisheries have impacted the population for the longest period, but this has declined to low levels since 1990. Most of the recent impacts are attributed to the 'Other' group of longline fisheries in areas 1 and 4, and to a lesser extent the 'Other' and Australian fisheries in areas 2 and 3.
h) Recent catches are 20% below the *MSY* level of 2182 mt. In contrast, the 'msy-recent' analysis calculates *MSY* to be 1839 mt, which places current catches 5% below this alternative *MSY* level. Based on these results, we conclude that current levels of catch are below MSY but are approaching MSY at the recent [low] levels of recruitment estimated for the last four decades.
i) Fishing mortality for adult and juvenile striped marlin is estimated to have increased continuously since the beginning of industrial tuna fishing. Apart from those model runs that assumed lower natural mortality or steepness, $F_{current}/F_{MSY}$ was estimated to be lower than 1. For the grid median, this ratio is estimated at 0.58. Based on these results, we conclude that overfishing is not occurring in the striped marlin stock.

j) The reference points that predict the status of the stock under equilibrium conditions at current F are $B_{Fcurrent}/B_{MSY}$ and $SB_{Fcurrent}/SB_{MSY}$. The model predicts that at equilibrium the biomass and spawning biomass would increase to 129% and 144%, respectively, of the level that supports *MSY*. This is equivalent to 39% of virgin spawning biomass. Current stock status compared to these reference points indicates that the current total and spawning biomass are close to the associated MSY levels ($B_{current}/B_{MSY}$ = 0.96 and $SB_{current}/SB_{MSY}$ = 1.09) based on the medians from the structural uncertainty grid. The structural uncertainty analysis indicates a 50% probability that $SB_{current}<SB_{MSY}$, and 6 of the 10 key model runs indicate the ratio to be < 1. Based on these results above, and the recent trend in spawning biomass, we conclude that striped marlin is approaching an overfished state."

The Scientific Committee selected the reference case model from the assessment to characterize stock status and selected several key sensitivity runs to characterize uncertainty in trends in abundance and stock status (Figures 13-17 and Tables 15 and 16). It was noted that the use of the reference case and key sensitivities selected by the Scientific Committee in 2012 (Table 3) leads to slightly different conclusions in terms of stock status compared to that based on the uncertainty grid used in the assessment. The reference case and five of the six other key sensitivity runs estimated $F_{current}/F_{MSY}$ to be less than one indicating that overfishing is unlikely to be occurring. However, when considering $SB_{current}/SB_{MSY}$, the reference case and four of the six other key sensitivity runs are estimated to be less than one, indicating evidence that the stock may be overfished.

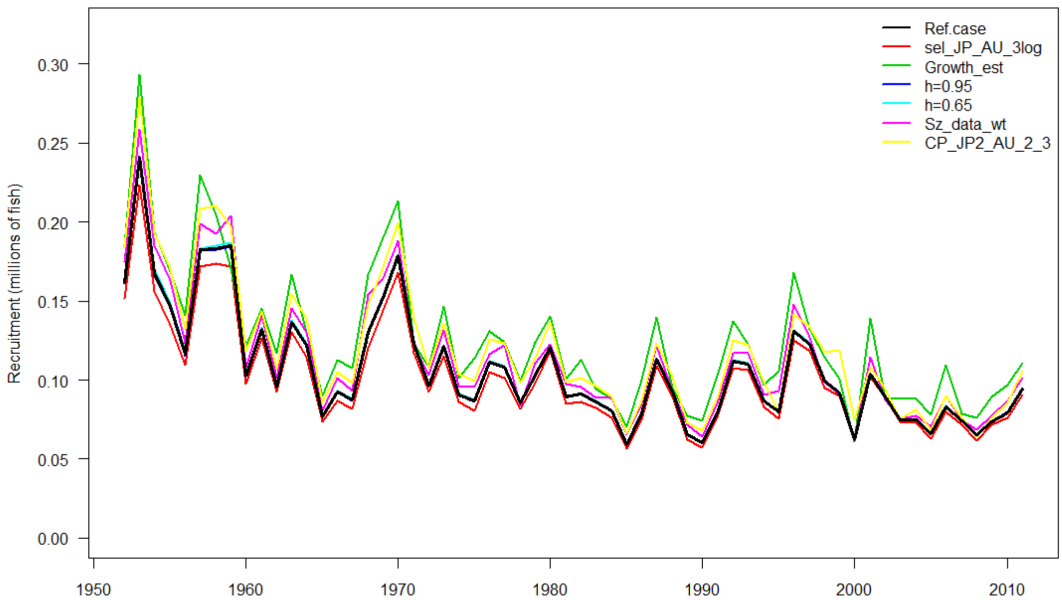


Figure 13: Estimated annual recruitment (millions of fish) for the southwest Pacific Ocean striped marlin obtained from the Ref.case model (black line) and the six plausible key model runs.

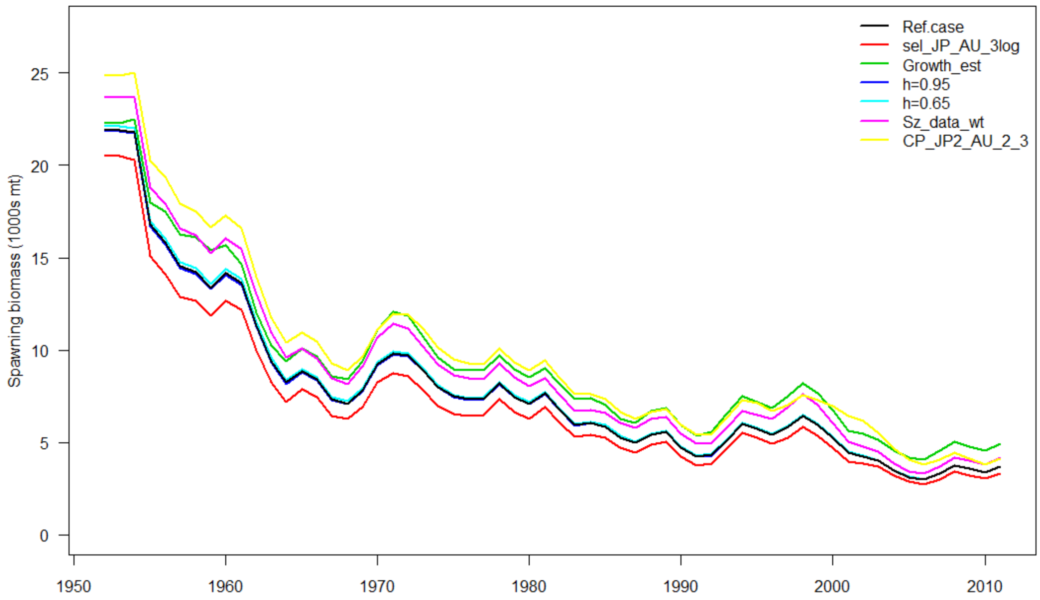


Figure 14: Estimated average annual average spawning potential for the southwest Pacific Ocean striped marlin obtained from the Ref.case model (black line) and the six plausible key model runs.

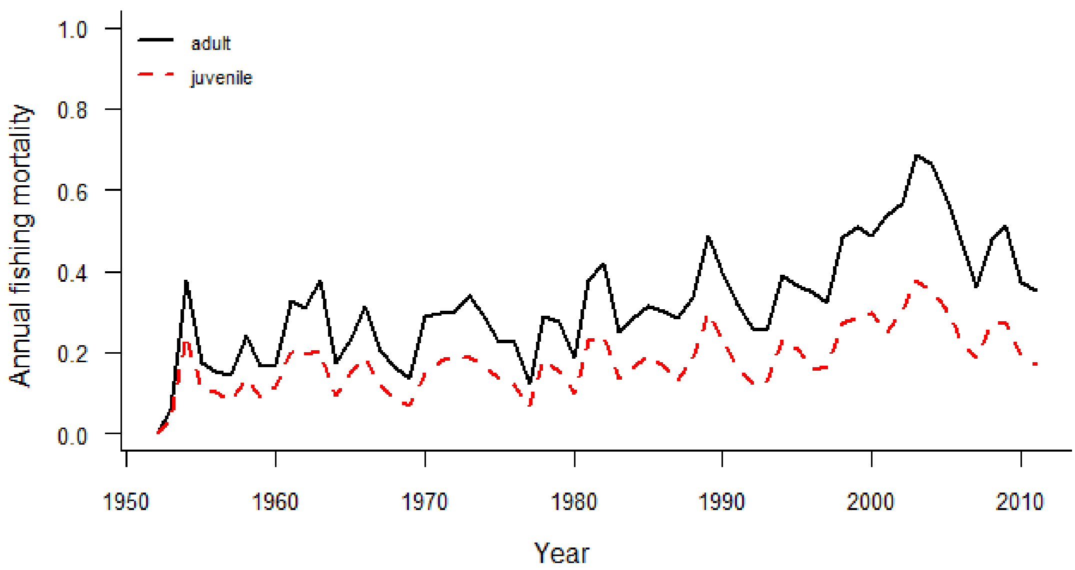


Figure 15: Estimated annual average juvenile and adult fishing mortality for the southwest Pacific Ocean striped marlin obtained from the Ref.case model.

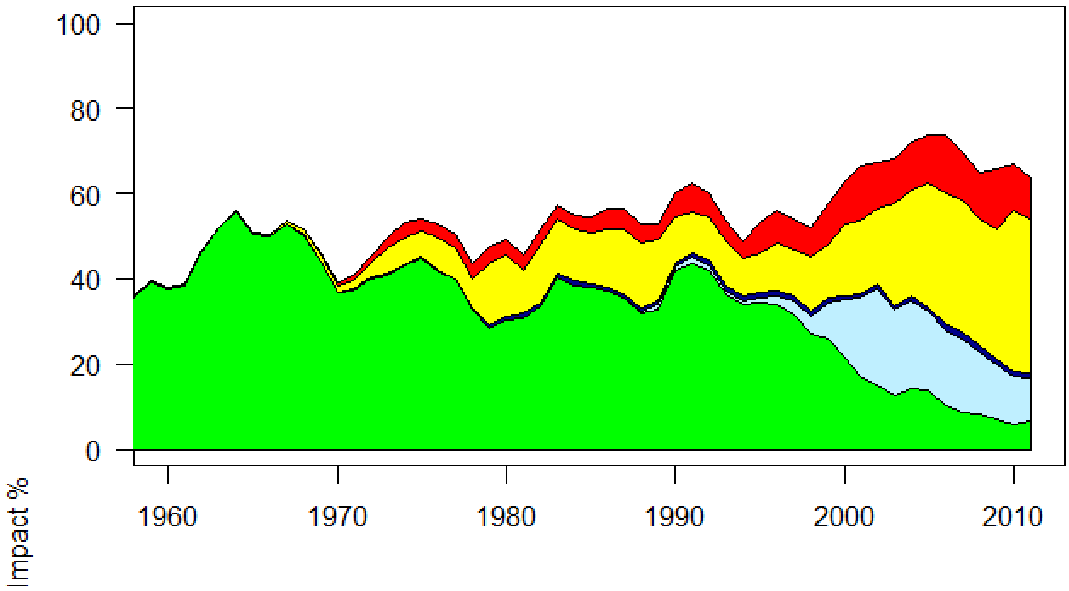
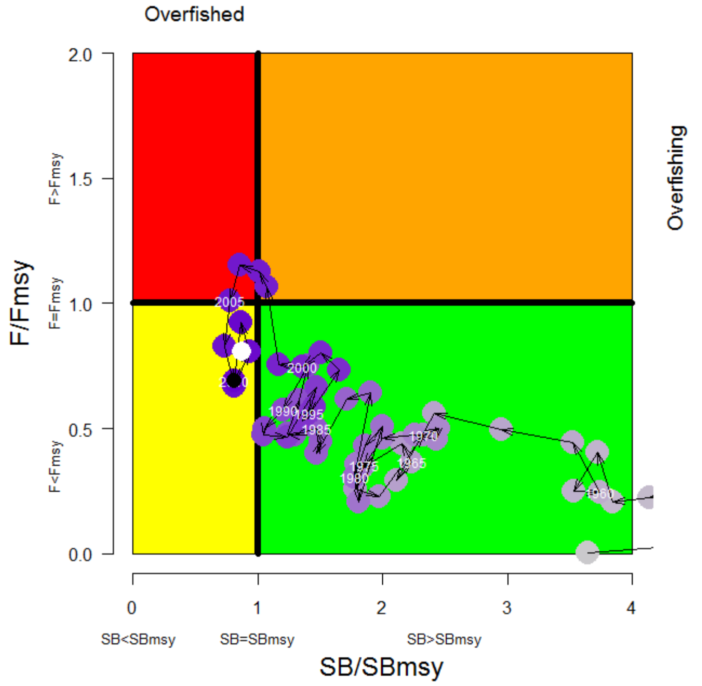


Figure 16: Estimates of reduction in spawning potential due to fishing (fishery impact = 1-SBt/SB$_{tF=0}$) for the southwest Pacific Ocean striped marlin attributed to various fishery groups (Ref.case model). Green = Japanese longline fisheries in sub-areas 1 to 4 and Taiwanese longline fishery in sub-area 4; Light blue = Australian and New Zealand longline fisheries; Dark blue = Australian and New Zealand recreational fisheries; Yellow = all longline fisheries in sub-areas 1 and 4 excluding Taiwanese in sub-area 4 and excluding Japanese; Red = all longline fisheries in sub-areas 2 and 3 excluding Japanese, Australian and New Zealand.



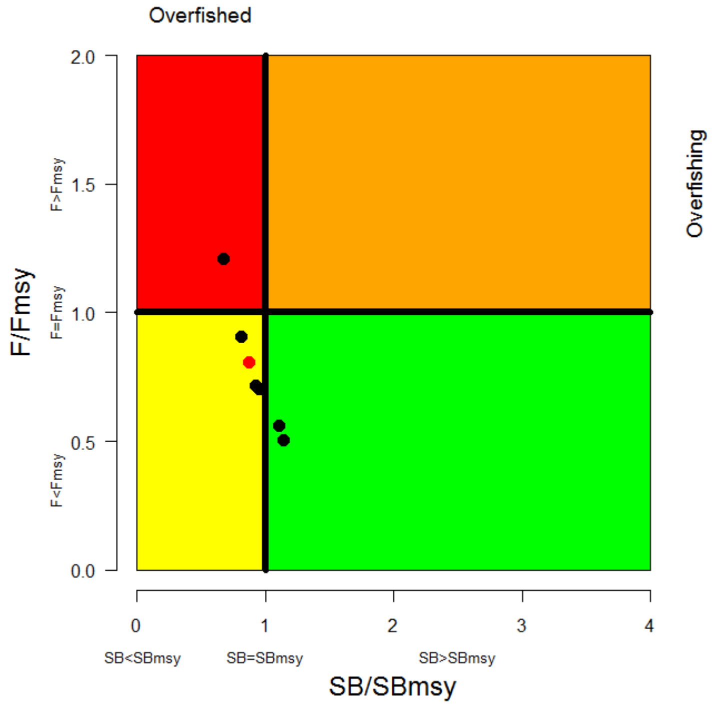


Figure 17: Temporal trend in annual stock status, relative to SB_{MSY} (x-axis) and F_{MSY} (y-axis) reference points for the Ref.case (top) and $F_{current}/F_{MSY}$ and $SB_{current}/SB_{MSY}$ for the Ref.case (red circle) and the six plausible key model runs. See Table 3 to determine the individual model runs.

Table 15. Estimates of management quantities for selected stock assessment models from the 2012 Ref.case model and the six plausible key model runs. For the purpose of this assessment, "current" is the average over the period 2007–2010 and "latest" is 2011.

	Ref.case	sel_JP_AU_3log	CP_JP2_AU_2_3	h=0.65	h=0.95	Growth_est	Sz_data_wt
	1758	1753	1785	1759	1759	1707	1764
	1522	1523	1512	1522	1522	1476	1521
	2081	2017	2256	1914	2276	2182	2179
	0.85	0.87	0.79	0.92	0.77	0.78	0.81
	0.73	0.76	0.67	0.80	0.67	0.68	0.70
	1.24	1.10	1.39	0.83	1.98	1.79	1.42
	0.81	0.91	0.72	1.21	0.51	0.56	0.71
	15,130	14,530	16,590	16,790	14,220	15,360	16,000
	0.27	0.27	0.27	0.32	0.22	0.28	0.26
	0.24	0.22	0.25	0.21	0.25	0.31	0.25
	0.24	0.23	0.25	0.22	0.26	0.32	0.26
	0.87	0.81	0.92	0.67	1.14	1.11	0.95
	0.90	0.84	0.92	0.70	1.19	1.14	1.00
	0.34	0.32	0.37	0.34	0.34	0.44	0.37
	0.37	0.34	0.39	0.37	0.37	0.46	0.40
Steepness (*h*)	0.80	0.80	0.80	0.65	0.95	0.80	0.80

Table 16: Comparison of southwest Pacific Ocean striped marlin reference points from the 2012 reference case model and the range of the seven models in Table 3; the 2006 base case model (steepness estimated as 0.51). *NA* = not available.

Management quantity	**2012 assessment Ref.case (uncertainty)**	**2006 assessment Base case**
Most recent catch	1758 mt (2011)	1412 mt (2004)
MSY	2081 mt (1914 – 2276)	2610 mt
$F_{current}/F_{MSY}$	0.81 (0.51-1.21)	1.25
$B_{current}/B_{MSY}$	0.83 (0.70-0.99)	0.70
$SB_{current}/SB_{MSY}$	0.87 (0.67-1.14)	0.68
$Y_{Fcurrent}/MSY$	0.99 (0.93-1.00)	0.99
$B_{current}/B_{current, F=0}$	0.46 (0.44-0.53)	0.53
$SB_{current}/SB_{current, F=0}$	0.34 (0.32-0.44)	*NA*

Commercial catch and effort returns in New Zealand

The commercial TLCER data are compromised by the failure of many vessels to report their catch of striped marlin which they are required to release. Since 2000 the standardised series of positive catches shows some promise as an index of relative abundance.

The final non-zero model explained almost 25% of the variance in log catch, largely by standardising for changes in the core fleet and in the month fished, both of which are predicted to have improved observed catches over the study period. No measure of effort entered the model.

Log(number STM per set) = fishing year + vessel + month

Positive catches usually comprise a single fish and rarely more than two fish per set. There is thus little contrast in catch rate in positive sets, but the standardised series suggests an overall decline in abundance (Figure 18). The fit of positive catches to the lognormal assumption is poor and is improved slightly by assuming an inverse Gaussian error distribution. The effect of the alternative error distribution on the annual indices is to steepen the decline slightly in recent years. The series is based on recorded catches and has large error bars around each point due to the small number of records.

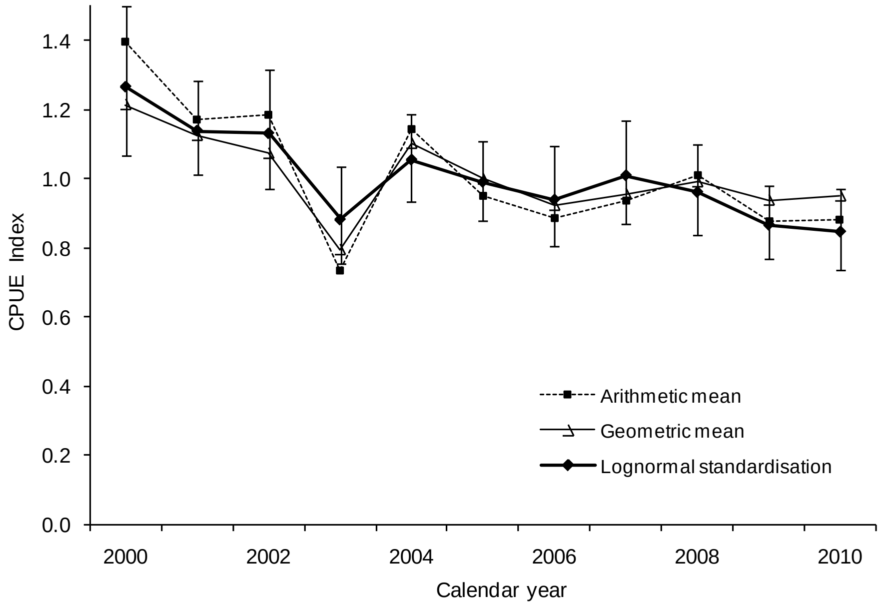


Figure 18: Unstandardised CPUE (annual geometric mean number of STM per set), the year effects from the model of non-zero catches from commercial logbooks (± 2 s.e.).

These CPUE analyses are done on the data that were groomed and submitted to WCPFC. In respect of some potential explanatory variables these datasets are not complete, and there is some potential to improve the analyses in future with dedicated data extracts. The shortened time series of commercial data used reflects the period for which we have confidence that striped marlin were being reported, however, there is some potential to extend that series back a little further in time for the positive catches only.

Observer logbook data

The observer database is limited in its coverage of the striped marlin which is largely a bycatch of bigeye tuna and swordfish target fisheries from the northern part of the EEZ, because observer effort is focused on the charter fleet that fishes further south for southern bluefin tuna.

The final non-zero model of observer logbook data explained 30% of the variance in catch rate. Fishing year was forced as the first variable and explained most of the variance in catch (16%). Sea surface temperature entered the model as the second most important variable explaining an additional 5% of the variance and it was followed by longitude, buoy-line length and longline length, each adding little additional explanatory power.

The final model form was as follows:

Log(number STM per set) = fishing year + temperature + longitude + buoy-line length + longline length

The effect of standardisation is marked because of the unbalanced nature of the dataset that the model attempts to account for. The standardised series is smoother than the unstandardised with most of the anomalous peaks being removed. The first two years in the series was comprise entirely of sets in cool water which the model accounts for by lifting the standardised CPUE in those years relative to the unstandardised model, but the error around each point are nevertheless large and the overall trend is essentially flat (Figure 19).

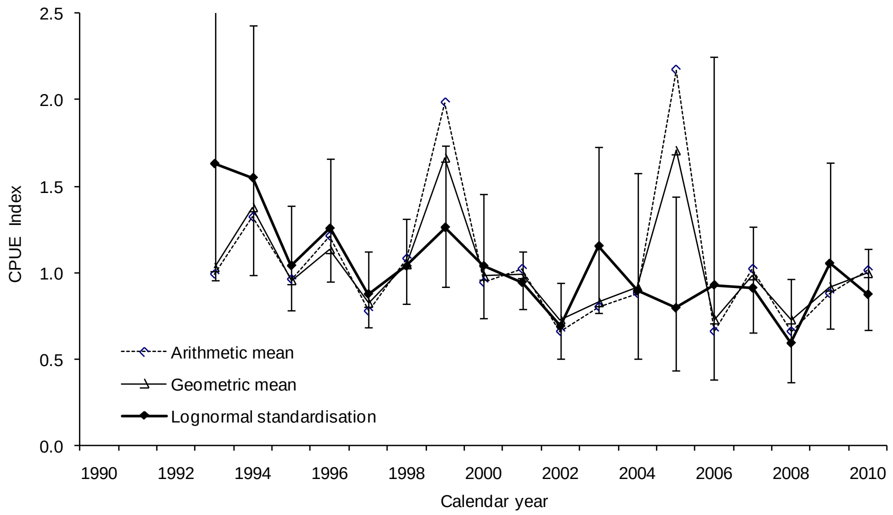


Figure 19: Unstandardised CPUE (arithmetic and geometric mean numbers of STM per set) and the year effects from the lognormal model of catch rates in successful sets (± 2 s.e.).

Recreational charter boat data

A longer time series of data was collected using annual postal surveys of East Northland gamefish charter skippers. They provided striped marlin catch and effort information giving an average catch per vessel day fished over the whole season. Since 2006–07 more detailed daily catch and effort information has been collected from all regions with the billfish logbook programme. A subset of these data from east northland charter vessels extends the existing data series. Survey responses were trimmed to include vessels with 6 or more years data and a range of factors were investigated using GLMs. Fine scale spatial and environmental variables are not available for most earlier years and were not offered to the model.

The final model form was as follows:

Log(number STM per season) = fishing year + log(days fished) + vessel

Club catch tallies and charter catch rates had been low in the 1960s and early 1970s (Holdsworth *et al.* 2003). Higher charter CPUE in the late 1970s and early 1980s were followed by three very poor years (Figure 20). Since then there has been an increasing trend in charter CPUE. While these data are informative on recreational fishing success in east Northland care should be taken making more general assumptions because of the relatively small area where this fishery operates.

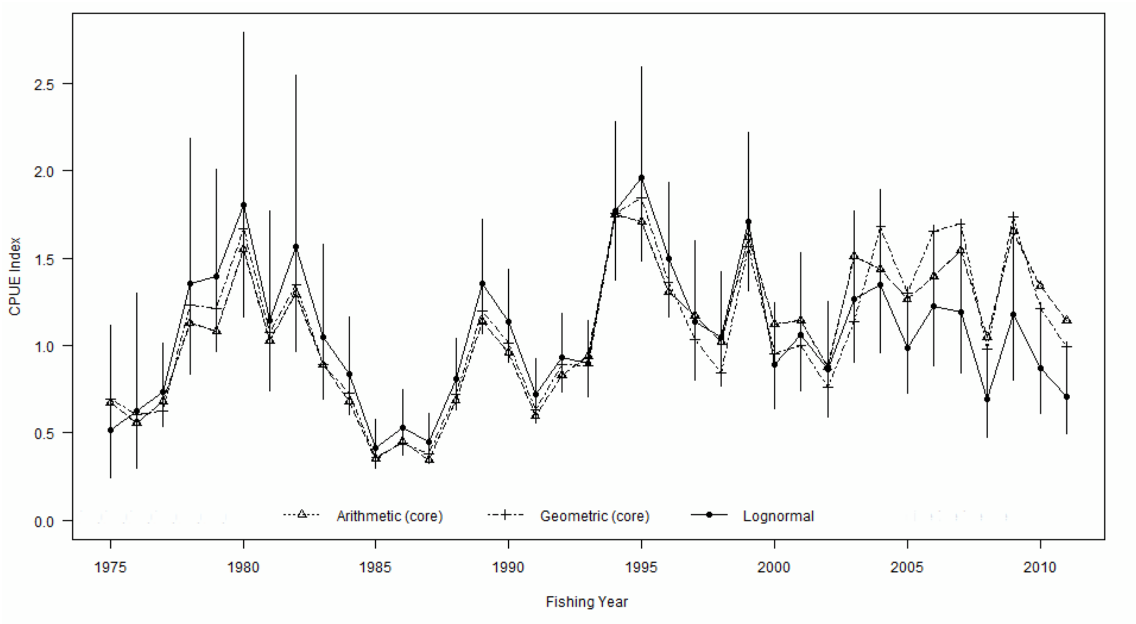


Figure 20: Unstandardised recreational charter boat CPUE (arithmetic and geometric mean number of striped marlin per vessel season) and the year effects from the model of non-zero catches (± 2 s.e.).

Comparison of models

The standardised series of observed non-zero commercial catches shows considerable interannual variance due to the small number of records, but does not disagree with the better estimated series for the core longline vessels reporting in commercial catch reporting, in describing a flat or maybe slightly declining trajectory over the last decade (Figure 21). There is also considerable interannual variability in the standardised series from the recreational charter fishery but trends are similar to the non-zero commercial and observer time series with high CPUE in the mid-1990s, a peak in 1999 and a declining trend over the last decade (Figure 21).

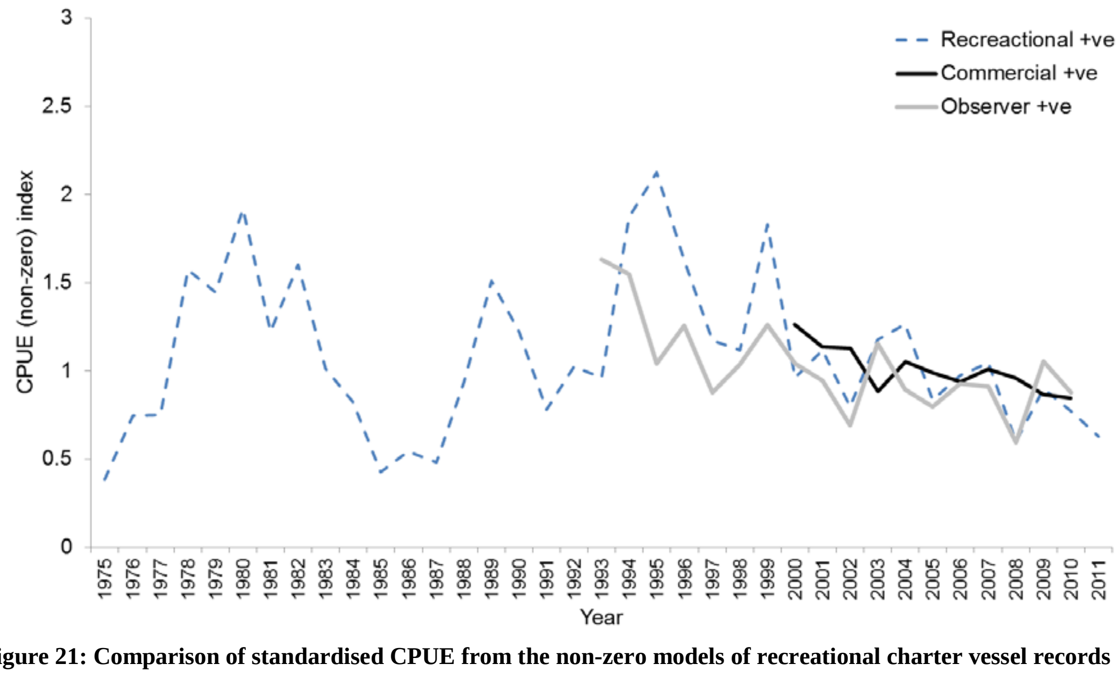


Figure 21: Comparison of standardised CPUE from the non-zero models of recreational charter vessel records with non-zero models of commercial and observer logbook records.

All the New Zealand CPUE data sets suffer from a limited spatial scale and limited number of records. There are some quite large changes in availability from year to year which appear in all indices. These may be indicative of changes in abundance or recruitment in some part of the south western Pacific stock but the scale may be amplified by annual variability in oceanographic conditions.

5.1 Biomass and yield estimates

No estimates of biomass or yield are available for New Zealand. A southwestern Pacific stock assessment is planned for 2012.

5.2 Other factors

Given that New Zealand fishers encounter some of the largest striped marlin in the Pacific, the abundance of fish found within New Zealand fisheries waters will be very sensitive to the status of the stock. In addition environmental factors may also influence availability. The average size of striped marlin in the recreational fishery has declined over the last 80 years. Individual weights were averaged from publish catch records in sport fishing club year books (Figure 22).

A commercial marlin fishery was started in waters north of New Zealand in 1956 by Japanese surface longline vessels. Mean fish weight has declined since then and there is more inter annual variability. There have been changes to recreational fishing methods the area fished over this time. The most significant change was in the late 1980s when a switch from trolled baits to artificial lures. Over the last 15 years more than half the weights have been estimated following tag and release.

In 2006–07 the Ministry of Fisheries instigated a billfish logbook programme to capture fine scale temporal and spatial information along with marlin catch and effort. Data collection expanded to include private vessels in all areas, including Bay of Plenty, West Coast North Island and the Three Kings.

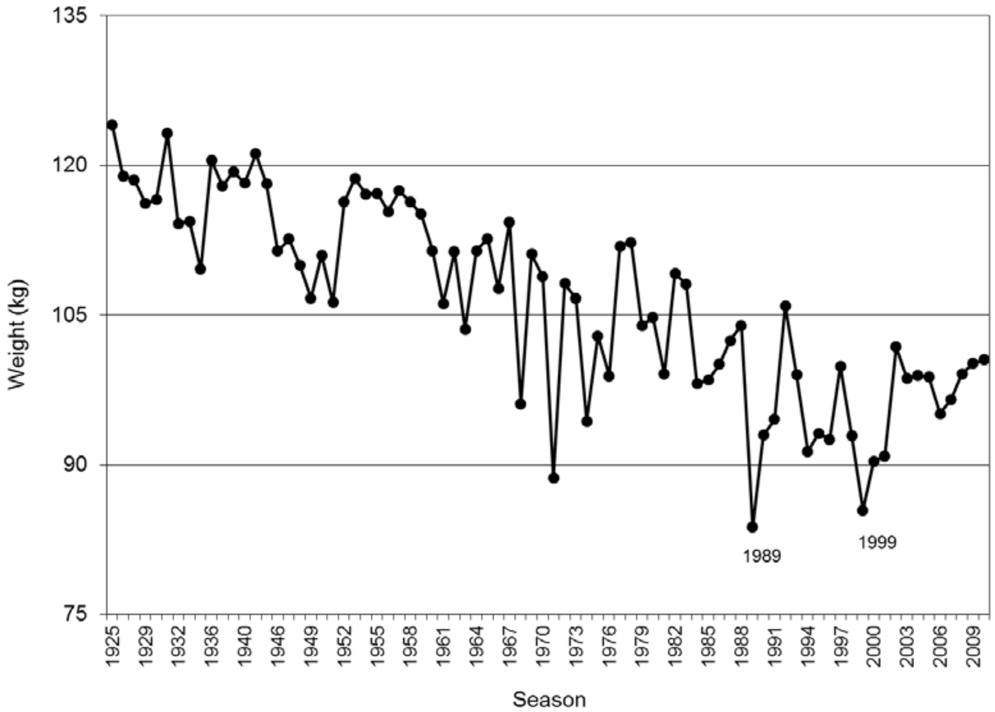


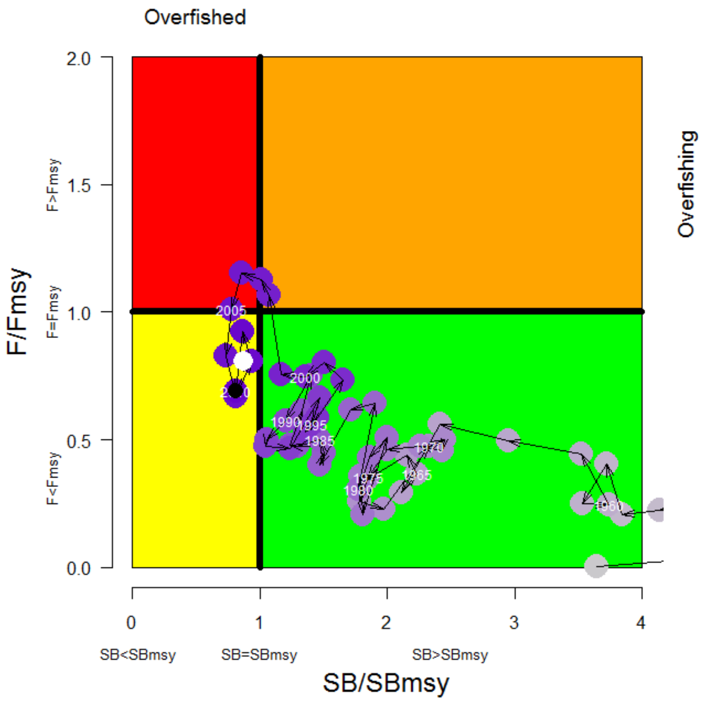
Figure 22: The mean annual weight of striped marlin (landed and tagged) caught in New Zealand fishery waters by recreational fishers by season from club records.

6. STATUS OF THE STOCK

Stock structure assumptions
Western and Central Pacific Ocean
All biomass in this Table refer to spawning biomass (SB)

Stock Status	
Year of Most Recent Assessment	2012
Assessment Runs Presented	Reference case (ref.case) and five sensitivity runs
Reference Points	Target: SB > SB_{MSY} and F < F_{MSY} Soft Limit: Not established by WCPFC; but evaluated using HSS default of 20% SB_0. Hard Limit: Not established by WCPFC; but evaluated using HSS default of 10% SB_0.
Status in relation to Target	About as Likely as Not that SB = SB_{MSY} and Unlikely that F> F_{MSY}
Status in relation to Limits	Soft Limit: Unlikely to be below Hard Limit: Unlikely to be below

Historical Stock Status Trajectory and Current Status



Temporal trend in annual stock status, relative to SB_{MSY} (x-axis) and F_{MSY} (y-axis) reference points for the Ref.case

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Stock biomass declined rapidly through the 1960s, the stock decline das more gradual from 1970 through to 2011.
Recent Trend in Fishing Mortality or Proxy	Overall fishing mortality has shown a slow but continuous increase from the 1950s through to 2011.
Other Abundance Indices	Recruitment is variable but has declined by 50% since the 1950s.
Trends in Other Relevant Indicator or Variables	

Projections and Prognosis		
Stock Projections or Prognosis	The stock is Likely to decline without management intervention.	
Probability of Current Catch causing decline below limits	Soft Limit: Unknown Hard Limit: Unknown	
Assessment Methodology and Evaluation		
Assessment Type	Level 1: Quantitative Stock assessment	
Assessment Method	MULTIFAN-CL	
Assessment Dates	Latest assessment: 2012	Next assessment: 2017
Overall assessment quality rank	1 - High Quality	
Main data inputs (rank)	**a)** Japanese longline catches for 1952-2011 revised downwards by approximately 50%; **b)** Nine revised and new standardised CPUE time series (with temporal CVs) derived from: • aggregate catch-effort data for Japanese and Taiwanese longline fisheries; • operational catch-effort data for the Australian longline fishery; • operational catch-effort data for the Australian and New Zealand recreational fisheries, and c) Size composition data for the Australian recreational fishery.	1 - High Quality
Data not used (rank)		
Changes to Model Structure and Assumptions		
Major Sources of Uncertainty	Catch estimated from the most recent years is uncertain as some catch has still not been reported. There are high levels of uncertainty regarding recruitment estimates and the resulting estimates of steepness.	

Qualifying Comments
At a 2012 ISC Billfish Working Group a meta-analysis was presented that included a) a review of all known estimates of striped marlin steepness including the 2006 WCPFC assessment of southwest Pacific striped marlin; b) a description of the analytical methods used; and c) a description of the data. The point estimate of steepness from the meta-analysis was M = 0.38 with a credible range of 0.3 to 0.5. Based on the results of this meta-analysis, SPC considered that the southwest Pacific striped marlin model runs where M was set to be 0.2 and 0.6 should have a low weight as they are probably outside the plausible range of natural mortality rates.
Fishery Interactions
Interactions with protected species are known to occur in the longline fisheries of the South Pacific, particularly south of 25°S. Seabird bycatch mitigation measures are required in the New Zealand, Australian EEZ's and through the WCPFC Conservation and Management Measure (CMM2007-04). Sea turtles also get incidentally captured in longline gear; the WCPFC is attempting to reduce sea turtle interactions through Conservation and Management Measure (CMM2008-03). Shark bycatch is common in longline fisheries and largely unavoidable; this is being managed through New Zealand domestic legislation and to a limited extent through Conservation and Management Measure (CMM2010-07).

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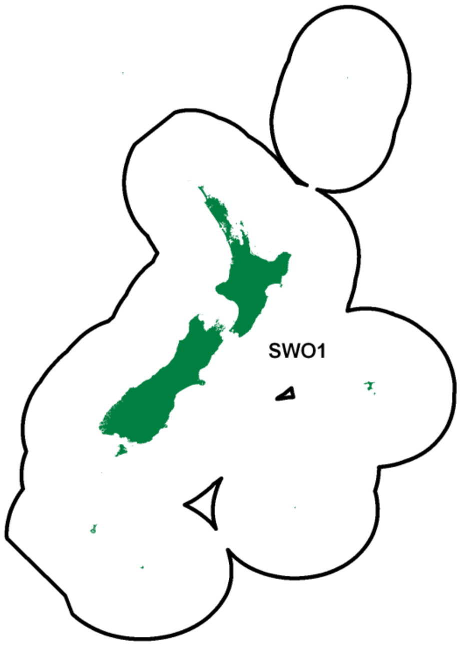
SWORDFISH (SWO)

(*Xiphias gladius*)



1. FISHERY SUMMARY

Swordfish were introduced into the QMS on 1 October 2004 under a single QMA, SWO 1, with allowances, TACC, and TAC in Table 1.

Table 1: Recreational and Customary non-commercial allowances, TACC and TAC (all in tonnes) for swordfish.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other mortality	TACC	TAC
SWO 1	20	10	4	885	919

Swordfish were added to the Third Schedule of the 1996 Fisheries Act with a TAC set under s14 because swordfish is a highly migratory species and it is not possible to estimate MSY for the part of the stock that is found within New Zealand fisheries waters.

Swordfish were also added to the Sixth Schedule of the 1996 Fisheries Act with the provision that:

> "A commercial fisher may return any swordfish to the waters from which it was taken from if –
> (a) that swordfish is likely to survive on return; and
> (b) the return takes place as soon as practicable after the swordfish is taken; and
> (c) that swordfish has a lower jaw to fork length of less than 1.25m."

Management of swordfish throughout the western and central Pacific Ocean (WCPO) is the responsibility of the Western and Central Pacific Fisheries Commission (WCPFC). At its sixth annual meeting (2009) the WCPFC passed a Conservation and Management Measure (CMM) (this is a binding measure that all parties must abide by) relating to conservation and management of swordfish in the southwest Pacific Ocean (www.wcpfc.int/). This measure restricts the number of vessels fishing for swordfish and sets catch limits in the convention area south of 20 degrees south.

1.1 Commercial fisheries

Annual swordfish catches throughout the Pacific have been increasing with catches increasing to 18 000 t in 2009 and 2010, in the western and Central Pacific. The swordfish catch from the southwest Pacific has averaged about 12% of the Pacific Ocean total in recent years. In New Zealand, swordfish are caught throughout the year in oceanic waters, primarily by pelagic longlines in areas where the bottom depth exceeds 1000 m.

Swordfish are either targeted or caught in the tuna longline fishery as a bycatch when targeting bigeye and to a lesser extent when targeting southern bluefin tunas. Swordfish can be caught in most FMAs and adjacent high seas areas although most catches are from waters north of 40ºS. Swordfish catch by domestic vessels increased rapidly from 1994-95 to peak at 1100 t in 2000-01. Since 2000-01 swordfish catches declined in each year coinciding with the decline in effort in the surface longline fishery, until 2005-06 when they increased again (Table 2). This increase is attributed to the development of a target fishery, which was, in part, initiated by the arrival of several surface longline vessels from Australia. Most of the catch is from FMA 1, FMA 2 and FMA 9. Figure 1 shows historical landings and TACCs and longline effort for SWO stocks.

Swordfish are processed at sea and the processed weight of the catch is converted to a greenweight using approved conversion factors. TLCER, CELR and LFRR data are provided for comparative purposes in Table 2 for the domestic fleet (NZ owned and operated vessels and chartered longline vessels).

Before the start of the domestic longline fishery in 1990-91, distant water longline fleets were granted foreign license access to fish for southern bluefin and bigeye tuna (Japan) and albacore (Korea). Swordfish catches for the Japanese fleet is given in Table 2 (Japan). Korean catches were only small (0 to 7 t per year) and was mostly (79%) from FMA 9 and FMA 10.

The swordfish bycatch by the Japanese foreign licensed fishery averaged 388 t per year between 1979-80 and 1992-93 with a maximum catch of 761 t in 1980-81. Most of the Japanese swordfish catch (85%) was from FMA 2 and FMA 9.

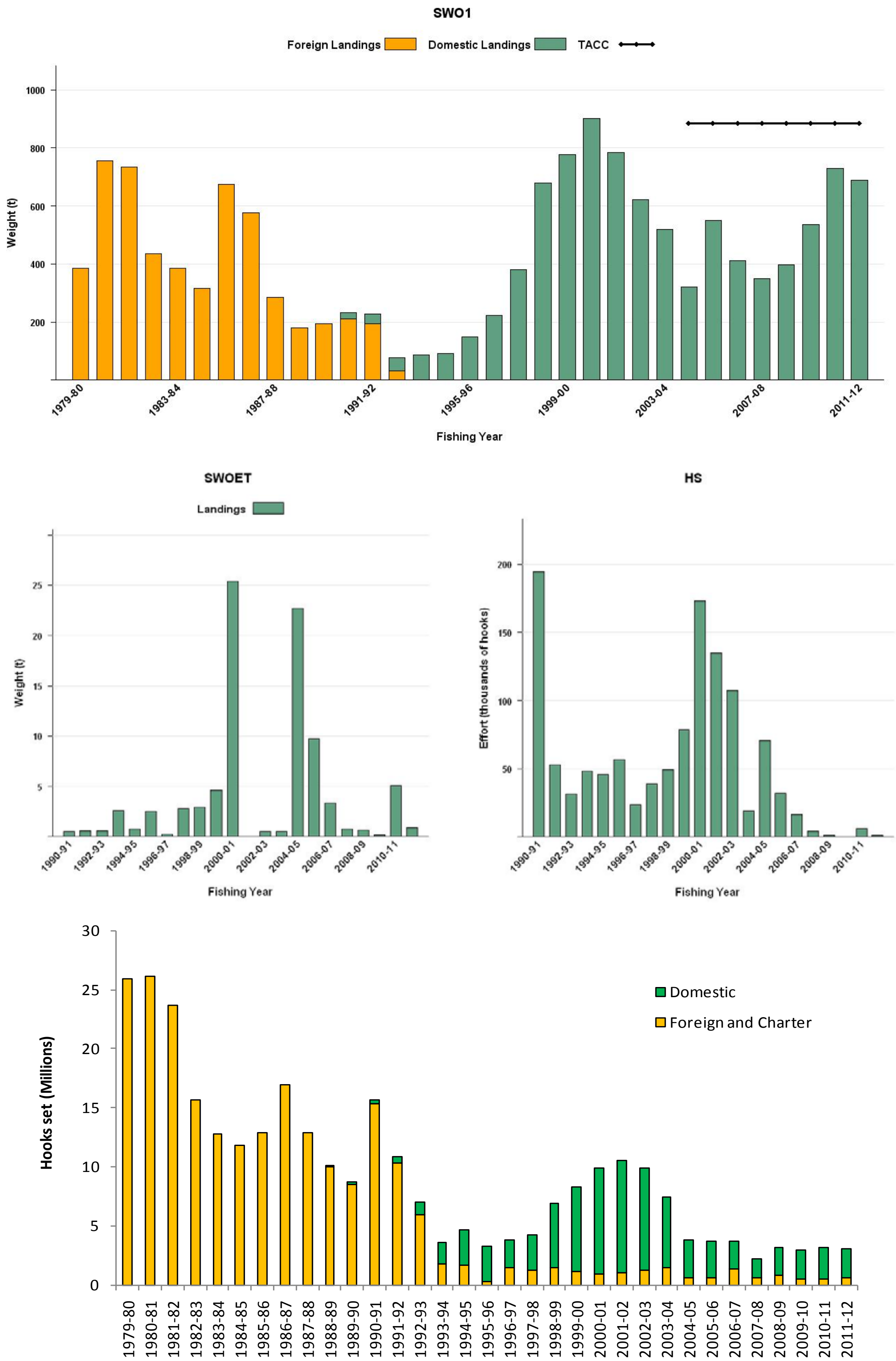


Figure 1: [Top and middle left] Swordfish catch by foreign licensed and New Zealand vessels from 1979-80 to 2011-12 within NZ waters (SWO1) and 1990-91 to 2011-12 on the high seas (SWOET). [Middle right] Fishing effort (number of hooks set) for all high seas New Zealand flagged surface longline vessels, and [Bottom] domestic vessels (including effort by foreign vessels chartered by NZ fishing companies), from 1990-91 to 2011-12 and 1979-80 to 2011-12, respectively.

Table 2: Reported catches (t) of *X. gladius* by fishing year (from TLCER and CELR data) for the New Zealand domestic and chartered vessel fleet and Japanese foreign licensed fleet 1979-80 to 2011-12; with annual totals from LFRR and MHR (from 2001-02) data.

	SWO 1 (all FMAs)				
Year	JPNFL	NZ/MHR	Total	LFRR	NZ ET
1979-80	386		386		
1980-81	756.1		756.1		
1981-82	734.6		734.6		
1982-83	436.1		436.1		
1983-84	384.8		384.8		
1984-85	316.1		316.1		
1985-86	673.6		673.6		
1986-87	575.5		575.5		
1987-88	286.2		286.2		
1988-89	181.1		181.1		
1989-90	194.3		194.3		
1990-91	211.9	21.9	233.8	41	0.5
1991-92	194.5	33.5	228	32	0.6
1992-93	31.1	46.8	77.9	79	0.6
1993-94		88.2	88.2	102	2.6
1994-95		91.4	91.4	102	0.8
1995-96		148.6	148.6	187	2.5
1996-97		223.3	223.3	283	0.2
1997-98		379.7	379.7	534	2.8
1998-99		679.1	679.1	965	2.9
1999-00		778	778	976	4.6
2000-01		901.4	901.4	1 022	25.4
2001-02		945	783.9	958.8	
2002-03		673	622.0	670.1	0.5
2003-04		545	519.4	555.2	0.5
2004-05		344	320.7	344.7	22.7
2005-06		560.9	548.3	558.9	9.7
2006-07		412.7	412.7	425.8	3.3
2007-08		350.1	350.1	351.4	0.7
2008-09		398.7	398.7	393.9	0.6
2009-10		536.5	536.5	533.4	0.1
2010-11		729.6	729.6	739	5.1
2011-12		688.1	688.1	686.7	0

The majority of swordfish are caught in the bigeye target surface longline fishery (64%) (Figure 2), however, across all longline fisheries swordfish make up 17% of the catch by weight (Figure 3). Longline fishing effort is distributed along the east coast of the North Island and the south west coast of the South Island. The west coast South Island fishery predominantly targets southern bluefin tuna, whereas the east coast of the North Island targets a range of species including bigeye, swordfish, and southern bluefin tuna (Figure 4).

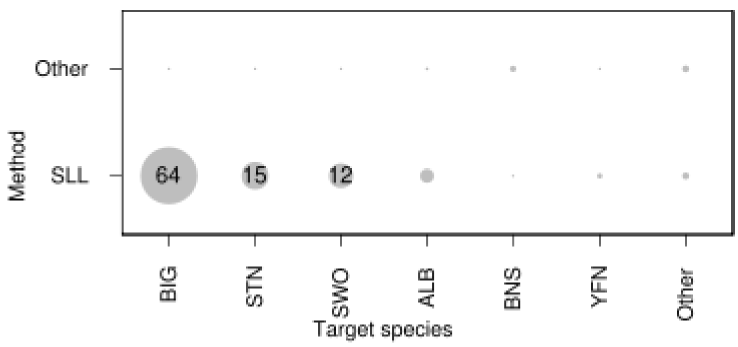


Figure 2: A summary of the proportion of landings of swordfish taken by each target fishery and fishing method. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the bobble is the percentage. SLL = surface longline (Bentley *et al.* 2012).

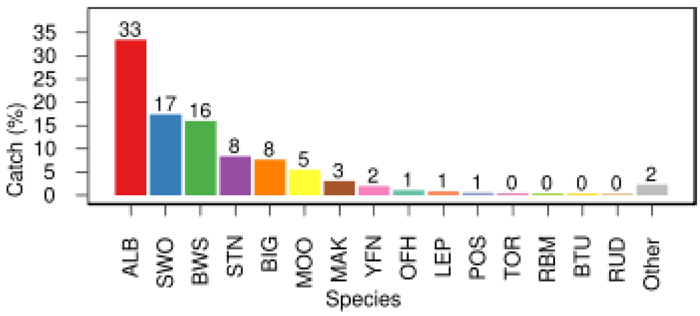


Figure 3: A summary of species composition of the reported surface longline catch. The percentage by weight of each species is calculated for all surface longline trips (Bentley *et al.* 2012).

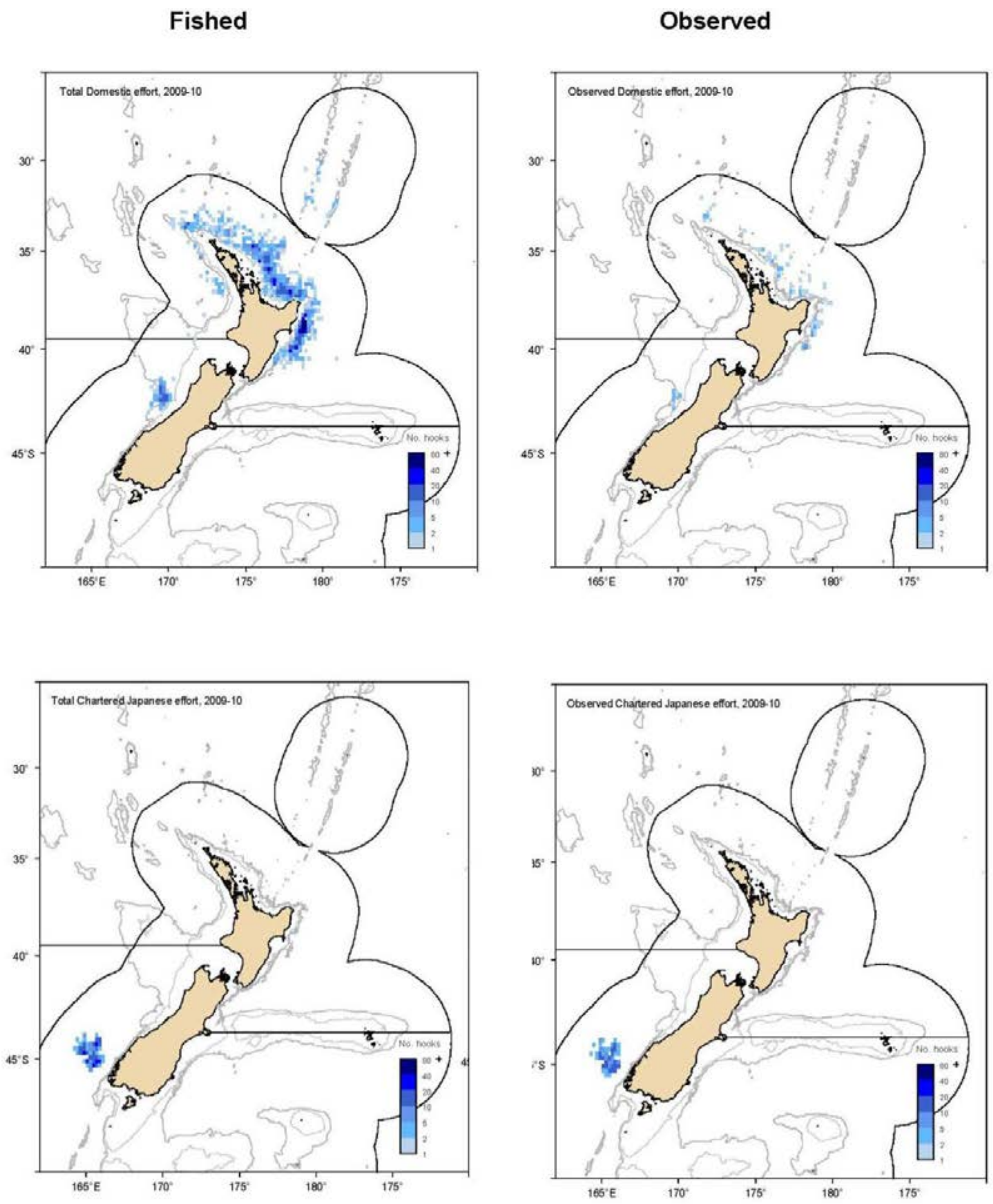


Figure 4: Distribution of fishing positions for domestic (top two panels) and charter (bottom two panels) vessels, for the 2009-10 fishing year, displaying both fishing effort (left) and observer effort (right).

In the longline fishery 30.9% of the swordfish were alive when brought to the side of the vessel for all fleets (Table 3). The domestic fleets retain around 90-99% of their swordfish catch, while the foreign charter fleet retain 99-100% of the swordfish catch, the Australian fleet that fished in New Zealand waters in 2006-07 retained most (94.8%) of their swordfish (Table 4).

Table 3: Percentage of swordfish (including discards) that were alive or dead when arriving at the longline vessel and observed during 2006–07 to 2009–10, by fishing year, fleet and region. Small sample sizes (number observed < 20) were omitted Griggs and Baird (in press).

Year	Fleet	Area	% alive	% dead	Number
2006-07	Australia	North	42.8	57.2	325
	Charter	North	58.9	41.1	90
		South	61.9	38.1	21
	Domestic	North	27.3	72.7	355
	Total		**38.2**	**61.8**	**791**
2007-08	Domestic	North	25.1	74.9	495
	Total		**25.3**	**74.7**	**498**
2008-09	Charter	North	97.0	3.0	33
	Domestic	North	26.0	74.0	416
	Total		**31.6**	**68.4**	**455**
2009-10	Domestic	North	23.2	76.8	448
	Total		**23.7**	**76.3**	**452**
Total all strata			**30.9**	**69.1**	**2 196**

Table 4: Percentage swordfish that were retained, or discarded or lost, when observed on a longline vessel during 2006–07 to 2009–10, by fishing year and fleet. Small sample sizes (number observed < 20) omitted Griggs and Baird (in press).

Year	Fleet	% retained	% discarded or lost	Number
2006-07	Australia	94.8	5.2	326
	Charter	99.1	0.9	115
	Domestic	93.2	6.8	355
	Total	**94.7**	**5.3**	**796**
2007-08	Charter	100.0	0.0	3
	Domestic	91.5	8.5	496
	Total	**91.6**	**8.4**	**499**
2008-09	Charter	100.0	0.0	43
	Domestic	97.1	2.9	418
	Total	**97.4**	**2.6**	**461**
2009-10	Charter	100.0	0.0	3
	Domestic	94.3	5.7	454
	Total	**94.3**	**5.7**	**457**
Total all strata		**94.5**	**5.5**	**2 213**

1.2 Recreational fisheries

Swordfish are targeted by some recreational big gamefishers with annual the annual recreational catch averaging 60 swordfish per annum over the last 3 years. Despite variable and low recreational catch there is considerable recreational interest in swordfish and targeting methods have developed significantly in recent years. Most catch has been from vessels drifting or slow trolling baits at night with more fishers successfully using deep drifted baits during the day since 2011.

1.3 Customary non-commercial fisheries

An estimate of the current customary catch is not available, but it is considered to be low.

1.4 Illegal catch

Prior to QMS introduction in 2004 it was illegal to target swordfish but analyses of CPUE data suggest targeting did occur. These catches were generally still reported (although as bycatch), so estimates of total annual catch were not affected.

1.5 Other sources of mortality

The estimated overall incidental mortality rate from observed longline effort is 0.44% of the catch. Discard rates are 0.7% on average from observer data of which approximately 60% are discarded dead (usually small fish, or as a result of shark damage). Fish are also lost at the surface in the longline fishery, 0.21% on average from observer data. Approximately 20% of those fish are also dead. Swordfish have occasionally been observed as a bycatch in the skipjack tuna purse seine fishery and in trawl fisheries for jack mackerel and hoki.

2. BIOLOGY

Swordfish (*Xiphias gladius* Linnaeus, 1758) are an epi- and mesopelagic highly migratory species found in all tropical and temperate oceans and large seas. Based on longline catches, swordfish range from 50ºN to 45ºS in the western Pacific Ocean and from 45ºN to 35ºS in the eastern Pacific Ocean.

Growth rates have been estimated for Pacific Ocean swordfish caught off Taiwan. Estimates of growth rate indicate rapid growth with fish reaching about 1 m in lower jaw to fork length during the first year. Growth rate slows progressively with age. Females grow significantly faster than males. Asymptotic length for males is 213 cm while asymptotic length for females is about 300 cm. The maximum age observed in Taiwanese samples was 10 years for males and 12 years for females. The maximum size reported for a swordfish is 445 cm total length (includes the bill and furthest extension of the tail) and about 540 kg.

A recent study of swordfish growth has been undertaken in Australia and New Zealand. The results are generally consistent within the two areas with maximum ages of 18 and 15 years, respectively. It is likely that swordfish attain a maximum age of 20 years. Given the lack of observations of swordfish in New Zealand with ripe or running ripe gonad condition, age-at-maturity was defined on the basis of the Australian estimates of length-at-50% maturity for males and females of 101 and 221 cm, respectively. Using the growth curves estimated for New Zealand swordfish, this corresponds to ages at 50% maturity for males and females of 1 and 10 years, respectively.

In the New Zealand EEZ swordfish size varies markedly with latitude, with larger swordfish (and hence fewer males) caught south of 40ºS. Average size of both males and females is larger in the southern region compared to the north: 228 and 158.4 cm for males, and 231.9 and 175 cm for females, respectively. Average length (lower jaw to fork length) of swordfish caught in the EEZ has been relatively stable since 1991, averaging 196.6 cm for the Japanese charter fleet and 163.9 cm for the domestic owned and operated fleet based on limited observer data. Overall the average size over all fleets since 1991 is 178.3 cm, however, this will be largely representative of the charter fleet. Males are substantially smaller than females with most males smaller than 189 cm (77%) and most females (51%) are larger than 189 cm for all fleets.

A relationship between lower jaw-fork length and weight has been estimated for swordfish from observer records (n = 2 835): weight (kg) = (3.8787×10^{-6}) length$^{3.24}$.

Spawning takes place in the tropical waters of the western Pacific Ocean and to a lesser extent the equatorial waters of the central Pacific Ocean.

Swordfish are serial batch spawners, perhaps spawning as frequently as every few days over several months. Eggs are spawned in the upper layers of the tropical ocean and, like the protracted larval phase, are pelagic. Depending on fish size, swordfish egg production is estimated to range from 1 to 29 million eggs per year (68 – 272 kg females respectively).

From 1987 to 2005 the average sex ratio of longline-caught swordfish in the EEZ was 1:3.15 (male:female).

Little information on mortality rate is available, but M has been estimated elsewhere in the Pacific to be 0.22 yr^{-1}. This value is consistent with the maximum estimated ages for swordfish in Australia and New Zealand.

3. STOCKS AND AREAS

Swordfish found in the New Zealand EEZ are part of a much larger stock that spawns in the tropical central to western Pacific Ocean. They are highly migratory and their residence time in the EEZ and adjacent waters is unknown. In the Pacific Ocean swordfish occur from 50ºN to 45ºS in the western Pacific Ocean and from 45ºN to 35ºS in the eastern Pacific Ocean. Swordfish are visual predators with a wide temperature tolerance. Extensive diel vertical migrations have been observed for swordfish in the Atlantic and Pacific Oceans from waters deeper than 600 m to the surface and across large temperature gradients (e.g., from 8º to 27ºC) in a few hours. Swordfish are found at or near the surface, at night. Within the EEZ most swordfish are caught in FMA 1, FMA 2, and FMA 9 when sea surface temperatures are 17º to 19ºC.

Stock structure is uncertain and recent genetic studies have indicated that there may be multiple Pacific Ocean stocks. There is limited information on swordfish movement from conventional tagging studies. From a release sample of 124 swordfish tagged in the New Zealand EEZ as part of the New Zealand gamefish tagging programme, to date two have been recaptured. The release locations were 120 nm north of New Zealand and 80 nm north east of East Cape. Both fish were of small size at release and following extended periods at liberty, 8 and 10 years respectively, had grown to sizes consistent with being sexually mature. Despite the long liberty period the recapture positions were not a large distance (< 130 nm) from the release locations. Although the apparent net movement is limited, little can be inferred from this information in relation to swordfish stock structure or migration in, and around, New Zealand waters. From a release sample of 672 fish tagged in the Australian EEZ, eight recaptures have been reported. Although some fish tagged in east Australian waters have moved large distances (e.g., 893 nm), none were recaptured outside of the Australian EEZ, or have crossed the Tasman Sea into the New Zealand EEZ. Nineteen pop-off satellite archival tags have been deployed on swordfish in New Zealand with the aim of tracking fish over the spring spawning period. The eight longer term tracks (4 to 8 months) show fish moving into sub-tropical waters in spring and returning to the New Zealand EEZ or adjacent waters in summer. Data from satellite tagged swordfish in New Zealand and Australia was used to describe the stock structure, in the south-west Pacific region in a stock assessment model.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the November 2012 Fishery Assessment Plenary after review by the Aquatic Environment Working Group. This summary is from the perspective of the swordfish longline fishery; a more detailed summary from an issue-by-issue perspective is, or will shortly be, available in the Aquatic Environment & Biodiversity Annual Review where the consequences are also discussed (http://www.mpi.govt.nz/news-resources/publications.aspx).

4.1 Role in the ecosystem

Swordfish (*Xiphias gladius*) are large pelagic predators, so they are likely to have a 'top down' effect on the squid, fish and crustaceans they feed on.

4.2 Incidental catch of seabirds, sea turtles and mammals

These capture estimates relate to the swordfish target longline fishery only, from the New Zealand EEZ. The capture estimates presented here include all animals recovered onto the deck (alive, injured or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds caught on a hook but not brought onboard the vessel).

4.2.1 Seabird bycatch

Between 2002–03 and 2010–11, there were 79 observed captures of seabirds in swordfish longline fisheries. Seabird capture rates since 2003 are presented in Figure 5. The seabird bycatch distributions are predominantly within the northern area of New Zealand's EEZ (see Table 5 and Figure 6). The high number of captures in 2007 (Figure 5) are anomalous and are the result an Australian vessel fishing in the EEZ with inappropriate mitigation gear, this issue has since been resolved. The analytical methods used to estimate capture numbers across the commercial fisheries have depended on the quantity and quality of the data, in terms of the numbers observed captured and the representativeness of the observer coverage. Ratio estimation was historically used to calculate total captures in longline fisheries by target fishery fleet and area (Baird 2008) and by all fishing methods but recent estimates are either ratio or model based as specified in the tables below (Abraham *et al.* 2010).

Through the 1990s the minimum seabird mitigation requirement for surface longline vessels was the use of a bird scaring device (tori line) but common practice was that vessels set surface longlines primarily at night. In 2007 a notice was implemented under s 11 of the Fisheries Act 1996 to formalise the requirement that surface longline vessels only set during the hours of darkness and use a tori line when setting. This notice was amended in 2008 to add the option of line weighting and tori line use if setting during the day. In 2011 notices were combined and repromulgated under a new regulation (Regulation 58A of the Fisheries (Commercial Fishing) Regulations 2001) which provides a more flexible regulatory environment under which to set seabird mitigation requirements.

Table 5: Number of observed seabird captures in swordfish longline fisheries, 2002-03 to 2010-11, by species and area (Thompson & Abraham (2012) from http://data.dragonfly.co.nz/psc/). See glossary above for areas used for summarising the fishing effort and protected species captures. 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 swordfish using longline gear but rather the total risk for each seabird species.

Species	**Risk Ratio**	**Kermadec Islands**	**Northland and Hauraki**	**East Coast North Island**	**West Coast South Island**	**West Coast North Island**	**Total**
Campbell albatross	1.84	0	1	0	1	0	2
Southern Buller's albatross	1.28	0	0	1	0	0	1
Gibson's albatross	1.25	4	5	0	0	0	9
Antipodean albatross	1.11	12	3	0	0	0	15
White capped albatross	0.83	0	0	0	1	0	1
Black browed albatross	-	2	0	0	0	0	2
Antipodean and Gibson's albatross	N/A	5	0	0	0	0	5
Unidentified albatrosses	N/A	33	0	0	0	0	33
Total albatrosses	**N/A**	**56**	**9**	**1**	**2**	**0**	**68**
Black petrel	11.15	0	1	0	0	1	2
Flesh footed shearwater	2.51	0	0	1	0	0	1
White chinned petrel	0.79	2	0	0	0	0	2
Grey petrel	0.39	3	0	0	0	0	3
Sooty shearwater	0.02	1	0	0	0	0	1
Great winged petrel	0.01	1	1	0	0	0	2
Total other birds	**N/A**	**63**	**11**	**2**	**2**	**1**	**79**

Table 6: Effort, observed and estimated seabird captures by fishing year for the swordfish fishery within the EEZ. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); the capture rate (captures per thousand hooks); and the mean number of estimated total captures (with 95% confidence interval). The estimation method used was a Bayesian model with 100% of hooks included in the estimate. For more information on the methods used to prepare the data see [Abraham and Thompson (2011)](#).

Fishing year	Fishing effort			Observed captures		Estimated captures	
	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002-2003	0	0	N/A	0	N/A	N/A	N/A
2003-2004	0	0	N/A	0	N/A	N/A	N/A
2004-2005	132 503	11 553	8.7	2	0.173	46	24-83
2005-2006	228 305	4 800	2.1	2	0.417	90	46-174
2006-2007	210 175	40 138	19.1	71	1.769	206	128-368
2007-2008	125 330	23 180	18.5	1	0.043	51	26-91
2008-2009	41 700	3 990	9.6	0	0	12	4-25.
2009-2010	137 840	500	0.4	3	6	61	34-103
2010-2011	177 248	18 638	10.5	0	0	45	25-76

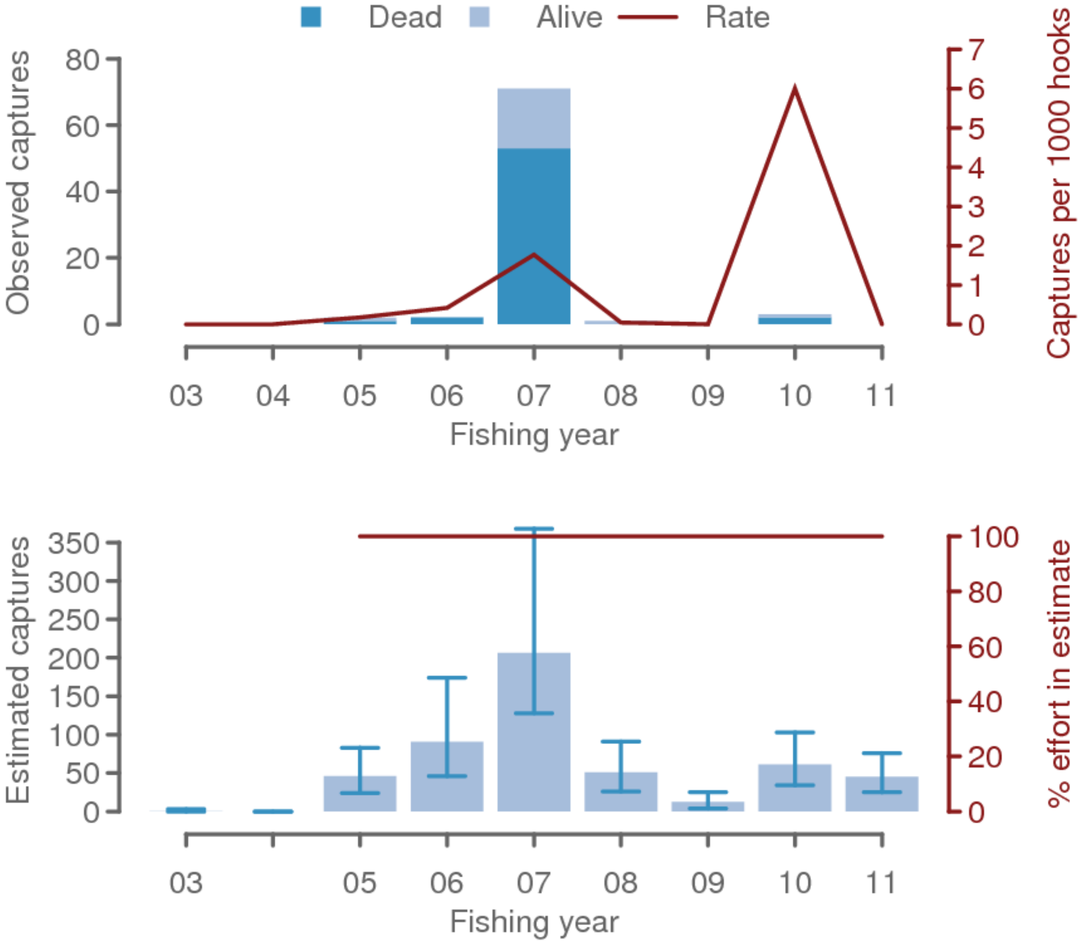


Figure 5: Observed and estimated captures of seabirds in swordfish longline fisheries from 2003 to 2011.

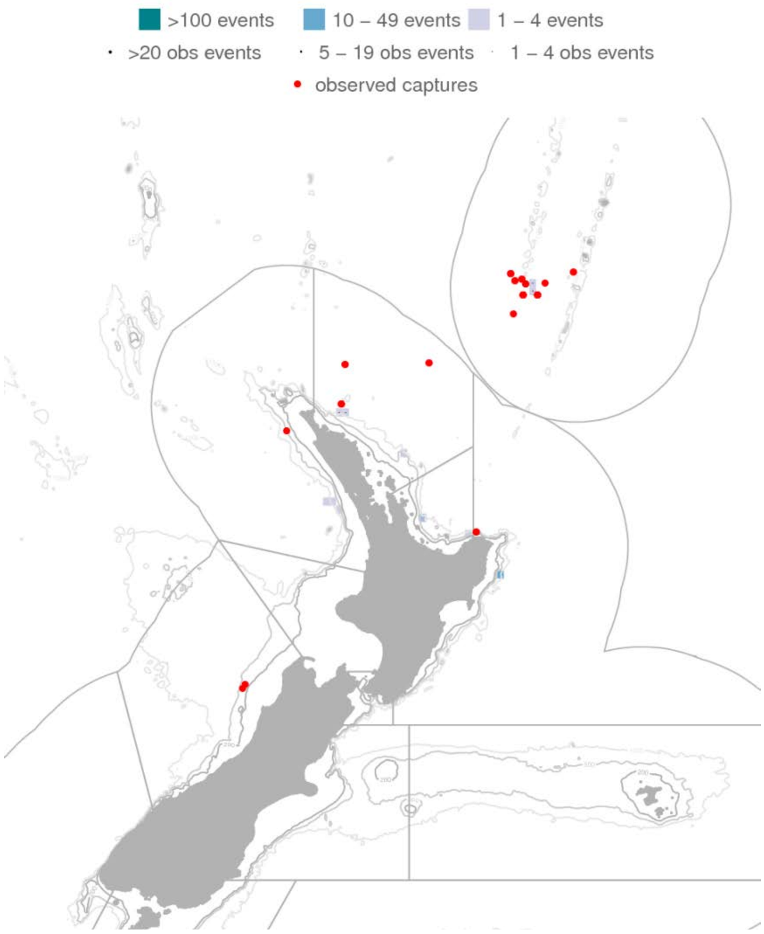


Figure 6: Distribution of fishing effort targeting swordfish and observed seabird captures, 2002-03 to 2010-11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 4.7% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.2 Sea turtle bycatch

Between 2002-03 and 2010-11, there were two observed captures of sea turtles in swordfish longline fisheries (Figure X). Observer recordings documented all sea turtles as captured and released alive. Sea turtle captures for this fishery have only been observed in the Kermadec Islands fishing area (Figure y).

Table 7: Number of observed sea turtle captures in swordfish longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson & Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/.

Species	Kermadec Islands	Total
Leatherback turtle	2	2

Table 8: Fishing effort and sea turtle captures in swordfish longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	0	0	N/A	0	N/A
2003-2004	0	0	N/A	0	N/A
2004-2005	132 503	11 553	8.7	0	0
2005-2006	228 305	4 800	2.1	0	0
2006-2007	210 175	40 138	19.1	1	0.025
2007-2008	125 330	23 180	18.5	1	0.043
2008-2009	41 700	3 990	9.6	0	0
2009-2010	137 840	500	0.4	0	0
2010-2011	177 248	18 638	10.5	0	0

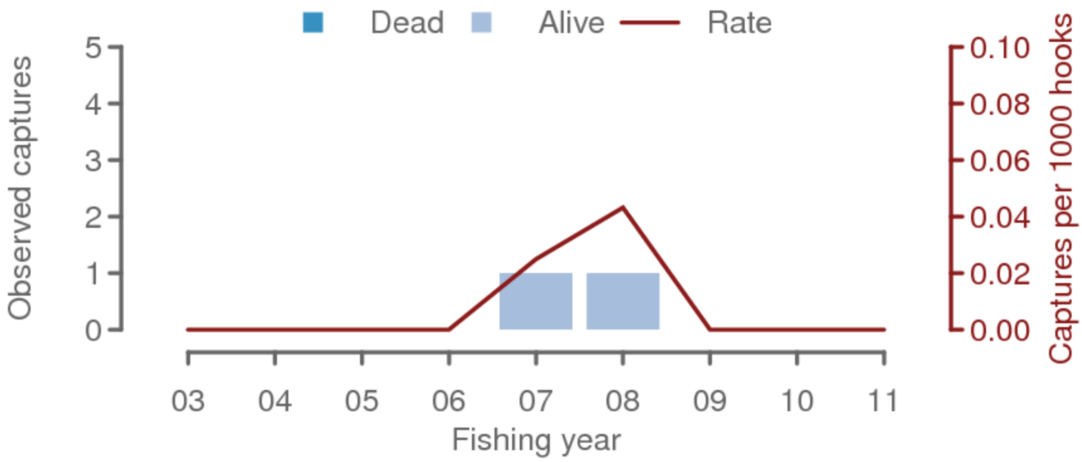


Figure 7: Observed captures of sea turtles in swordfish longline fisheries from 2003 to 2011.

Figure 8: Distribution of fishing effort targeting swordfish and observed sea turtle captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 4.7% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3 Marine Mammals

4.2.3.1 Cetaceans

Between 2002–03 and 2010–11, there were no observed captures of whales or dolphins in swordfish longline fisheries (Table 9 and Figure 9).

Table 9: Effort and cetacean captures in swordfish longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	0	0	N/A	0	N/A
2003-2004	0	0	N/A	0	N/A
2004-2005	132503	11553	8.7	0	0
2005-2006	228305	4800	2.1	0	0
2006-2007	210175	40138	19.1	0	0
2007-2008	125330	23180	18.5	0	0
2008-2009	41700	3990	9.6	0	0
2009-2010	137840	500	0.4	0	0
2010-2011	177248	18638	10.5	0	0

Figure 9: Distribution of fishing effort targeting swordfish, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 4.7% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3.2 New Zealand fur seal bycatch

Currently, New Zealand fur seals are dispersed throughout New Zealand waters, but are more common in waters south of about 40º S to Macquarie Island. The spatial and temporal overlap of commercial fishing grounds and New Zealand fur seal foraging areas has resulted in New Zealand fur seal captures in fishing gear (Mattlin 1987, Rowe 2009). Most fisheries with observed captures occur in waters over or close to the continental shelf. Captures on longlines occur when the seals attempt to feed on the fish catch and bait during hauling. Most New Zealand fur seals captured in the SBT lll fishery are released alive, typically with a hook and short snood or trace still attached.

Between 2002–03 and 2010–11, there were two observed captures of New Zealand fur seals in swordfish longline fisheries (Table 10 and 11, Figures 10 and 11). These captures include animals that are released alive (Thompson and Abraham 2010).

Table 10: Number of observed New Zealand fur seal captures in swordfish longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson & Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/.

	Bay of Plenty	East Coast North Island	Total
New Zealand fur seal	1	1	2

Table 11: Effort and captures of New Zealand fur seal in swordfish longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	0	0	N/A	0	N/A
2003-2004	0	0	N/A	0	N/A
2004-2005	132503	11553	8.7	2	0.173
2005-2006	228305	4800	2.1	0	0
2006-2007	210175	40138	19.1	0	0
2007-2008	125330	23180	18.5	0	0
2008-2009	41700	3990	9.6	0	0
2009-2010	137840	500	0.4	0	0
2010-2011	177248	18638	10.5	0	0

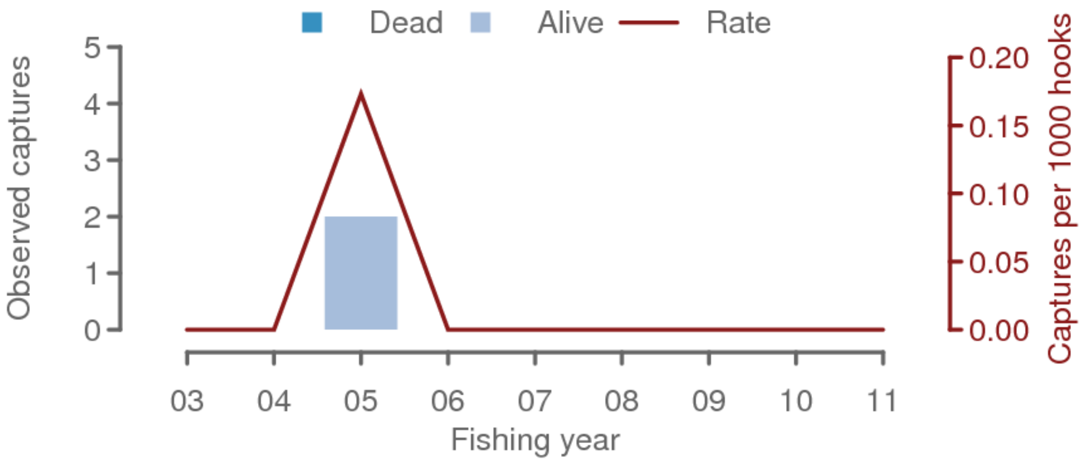


Figure 10: Observed captures of New Zealand fur seal in swordfish longline fisheries from 2003 to 2011.

Figure 11: Distribution of fishing effort targeting swordfish and observed New Zealand fur seal captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 4.7% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.3 Incidental fish bycatch

Observer records indicate that a wide range of species are landed by the longline fleets in New Zealand fishery waters. Blue sharks are the most commonly landed species (by number), followed by Ray's bream (Table 12). Southern bluefin tuna and albacore tuna are the only target species that occur in the top five of the frequency of occurrence.

Table 12: Numbers of the most common fish species observed in the New Zealand longline fisheries during 2009-10 by fleet and area. Species are shown in descending order of total abundance (Griggs and Baird in press).

	Charter	Domestic		Total
Species	South	North	South	number
Blue shark	2 024	4 650	882	7 556
Rays bream	3 295	326	88	3 709
Southern bluefin tuna	3 244	211	179	3 634
Lancetfish	3	2 139	1	2 143
Albacore tuna	90	1 772	42	1 904
Dealfish	882	0	7	889
Swordfish	3	452	2	457
Moonfish	76	339	6	421
Porbeagle shark	72	328	20	420
Mako shark	11	343	7	361
Big scale pomfret	349	4	0	353
Deepwater dogfish	305	0	0	305
Sunfish	7	283	5	295
Bigeye tuna	0	191	0	191
Escolar	0	129	0	129
Butterfly tuna	15	100	3	118
Pelagic stingray	0	96	0	96
Oilfish	2	75	0	77
Rudderfish	39	20	2	61
Flathead pomfret	56	0	0	56
Dolphinfish	0	47	0	47
School shark	34	0	2	36
Striped marlin	0	24	0	24
Thresher shark	7	17	0	24
Cubehead	13	0	1	14
Kingfish	0	10	0	10
Yellowfin tuna	0	9	0	9
Hake	8	0	0	8
Hapuku bass	1	6	0	7
Pacific bluefin tuna	0	5	0	5
Black barracouta	0	4	0	4
Skipjack tuna	0	4	0	4
Shortbill spearfish	0	4	0	4
Gemfish	0	3	0	3
Bigeye thresher shark	0	2	0	2
Snipe eel	2	0	0	2
Slender tuna	2	0	0	2
Wingfish	2	0	0	2
Bronze whaler shark	0	1	0	1
Hammerhead shark	0	1	0	1
Hoki	0	0	1	1
Louvar	0	1	0	1
Marlin, unspecified	0	1	0	1
Scissortail	0	1	0	1
Broadnose seven gill shark	1	0	0	1
Shark, unspecified	0	1	0	1
Unidentified fish	2	30	8	40
Total	10 545	11 629	1 256	23 430

4.4 Benthic interactions
N/A

4.5 Key environmental and ecosystem information gaps
Cryptic mortality is unknown at present but developing a better understanding of this in future may be useful for reducing uncertainty of the seabird risk assessment and could be a useful input into risk assessments for other species groups.

The survival rates of released target and bycatch species is currently unknown.

Observer coverage in the New Zealand fleet is not spatially and temporally representative of the fishing effort.

5. STOCK ASSESSMENT

With the establishment of WCPFC in 2004, stock assessments of the western and central Pacific Ocean stock of swordfish are reviewed by the WCPFC. Unlike the major tuna stocks, in the short-term, development of a regional assessment for swordfish is to be undertaken by collaboration among interested members. The first stock assessment for swordfish in the southwest Pacific was a collaborative effort between scientists from Australian and New Zealand. This assessment was reviewed by the Scientific Committee of the WCPFC in August 2006. All models were age-structured (ages 0-19+), sex-aggregated, iterated on a quarterly timestep (1952-2007), spatially-disaggregated into two roughly equal longitudinal units, with 11 fisheries and 4 informative effort series. The varying model assumptions in the uncertainty 'grid' were explored in a balanced factorial design with:

• 2 stock recruitment curve steepness priors (0.65, 0.9)
• 2 diffusive mixing assumptions (0.05, 0.1 per quarter)
• 8 growth rate / maturity / mortality options
• 2 recruitment deviation options (SD of log-normal deviates = 0.1, 0.5)
• 2 sample size down-weighting options for catch-at-size likelihoods (1/5, 1/20)
• 3 relative weighting options for CPUE indices (fleets weighted differently)
• 2 selectivity constraint options

The Maximum Posterior Density results from the plausible model ensemble indicate:
• $B_{(2007)}/B_{(1997)}$: median = 0.69, range = (0.55 – 0.83).
• $SB_{(2007)}/SB_{(1997)}$ = 0.58 (0.42 – 0.71).

The assessment was updated the conclusions are briefly described below. Full details of the assessment can be found in Davies *et al.* (2006, 2008), and Kolody *et al.* (2006a; 2006b, 2008). "Stock assessments were undertaken for two areas: the south-west Pacific (SWP, 140°Ẽ-175°W) and the south-central Pacific (SCP, 175°W̃-130°W), both separately and combined.

The subset of models represents the most extreme (highest and lowest) of the models in terms of a set of reference points. The 2008 estimates appear to be much more certain than 2006, and near the centre of the distribution of estimates provided in 2006. This reduction in uncertainty is what might have been predicted given that the recent reduction in fishing effort seems to have been sufficient to break the "one-way-trip" nature of the fishery that was observed up to 2003-2004, and hence appears to now provide informative contrast with which to improve the estimation of stock productivity. The model predicts that following a period of continued decline the southwest Pacific swordfish biomass has recently increased.

The key conclusions of the models presented indicate that in the southwest Pacific overfishing is not occurring and the stock is not in an overfished state (Figure 12). Reference point levels estimated in the 2008 assessment where more optimistic than the 2006 assessment, $F_{current}/\tilde{F}_{MSY}$ was 0.44 compared to 0.71 in 2006, although $B_{current}/\tilde{B}_{MSY}$ was 1.57 compared to 1.70 in 2006 and the range estimated in the 2006 assessment included more pessimistic estimates.

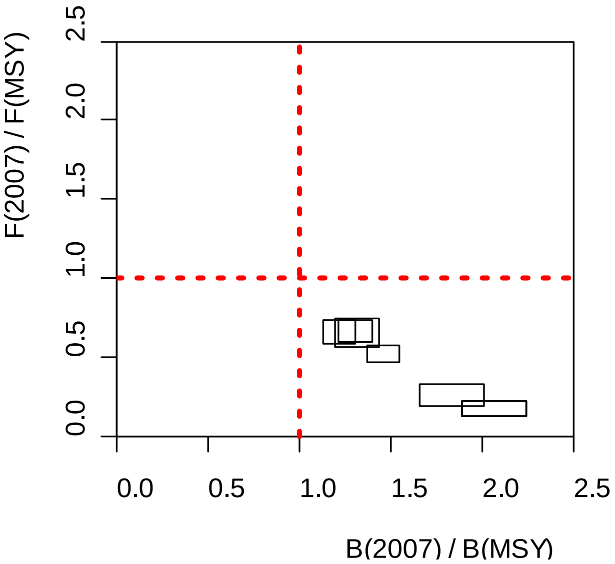


Figure 12: Summary plot comparing South-West Pacific fishing mortality, $F_{(2007)}/F_{(MSY)}$, and total stock biomass, $B_{(2007)}/B_{(MSY)}$, for Southwest Pacific swordfish from a subset of plausible MULTIFAN-CL models. Boxes indicate the upper and lower 95% confidence limits (but not the covariance) for each individual model.

The stock assessment attempted for swordfish in the south-central Pacific was unable to determine the current stock status. It was also noted that the available data do not indicate evidence of significant fishery impacts in the South Central Pacific, but catches have increased in recent years to levels exceeding those in the South West Pacific."

5.1 Catch per unit effort indices (CPUE)

The following section describes the New Zealand abundance indices used in the regional assessment.

Nominal and standardised CPUE indices for the longline fishery have been calculated with fishing operational variables and environmental effects examined as potentially significant factors in explaining the variance in CPUE models. Catch and effort data collected using the detailed TLCER forms for the tuna longline fishery from 1993 to 2004 has been groomed. A total of 51 004 data records were available with detailed effort information for individual fishing operations. This data has been linked to a range of environmental variables including remotely sensed observations for sea surface temperature (SST) and ocean colour (chlorophyll) at a spatial resolution closely related to individual operations. These variables have been expressed in relation to oceanic fronts, climatology and oceanographic indices of meso-scale dynamics on both a seasonal and monthly temporal scale. Other potential explanatory variables include moon brightness (phase), day length, fraction of longline set during night hours, depth and depth variation.

The significant factors affecting NZ swordfish CPUE were year and quarter; and important predictors were location (particularly longitude); depth, and depth variation (especially areas of high bathymetric gradient, e.g., continental slope and over local seamounts); local fishing effort; night fraction; moon phase (CPUE was highest during the hours of darkness and increased around the time of the full moon); mean SST (positively correlated); and, SST anomaly (negatively correlated with CPUE). Although light sticks and bait type have been identified as significantly affecting swordfish catch rates, this predictor was excluded from the standardised CPUE analysis because of the lack of available data before 2003.

A strong seasonal (quarter) factor in both nominal and standardised CPUE was estimated. This is potentially of high utility for the development of a regional stock assessment model in that seasonality in catch rates may be indicative of annual cycles in fish abundance caused by movements between NZ waters and, most likely, the tropics or north-east Australia where swordfish are believed to spawn.

The nominal and standardised annual CPUE indices from 1993 to 2004 are broadly similar with an increasing trend in catch rates from 1995 to 1998, followed by a stable phase, and then a decrease to 2003, followed by a slight increase in 2004. The substantial increase by around 200% from 1995 to 1998 requires careful consideration before this time series is of utility for a stock assessment model. It has been suggested that a number of fishing operational factors have most likely contributed to the increase in catch rates. These include: increased targeting for swordfish in the domestic longline fishery; changes in operations such as the time of setting, setting on or near full moon, number of hooks set, and the increased use of light sticks. The latter has been identified as the most significant factor affecting catch rates. It is therefore highly unlikely that the time series through this period is an accurate index of relative abundance. For this part of the time series to be of utility in to the regional stock assessment, a process that produces a trend in catchability must be defined and estimated.

The CPUE decline from 2000 to 2004 in NZ is consistent with a corresponding decline observed for the east Australian swordfish fishery, where in central parts of the fishery catch rates declined from over 6 fish per 1000 hooks in 2000 to around 3 fish per 1000 hooks in 2003.

5.2 Other factors

Other fleets also fish the stock fished in the New Zealand EEZ and the impact of current regional catches on the stock are unknown. It is often assumed that swordfish, particularly large swordfish, may have long residence times which may make them vulnerable to over fishing. Recent Australian research suggests that swordfish CPUE has declined in areas that have been fished the longest and that vessels have maintained high catch rates by travelling further each season, suggesting that serial depletion may be occurring.

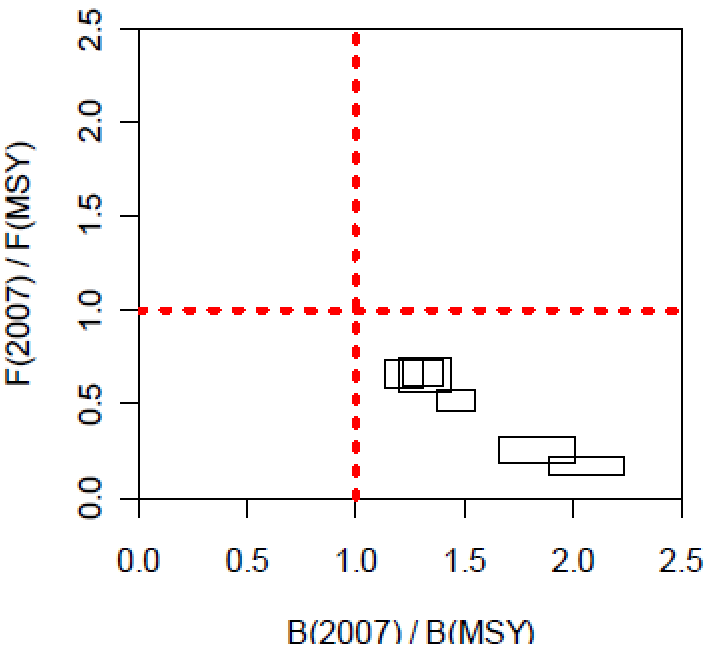
6. STATUS OF THE STOCKS

Stock structure assumptions

Swordfish taken in New Zealand are part of a larger southwest and south-central Pacific stocks the evaluation below refers to the assessment of the southwest portion of that stock.

Stock Status	
Year of Most Recent Assessment	A full stock assessment was conducted in 2008.
Assessment Runs Presented	Base case model only
Reference Points	Target: $B > B_{MSY}$ and $F < F_{MSY}$ Soft Limit: Not established by WCPFC; but evaluated using HSS default of 20% SB_0. Hard Limit: Not established by WCPFC; but evaluated using HSS default of 10% SB_0.
Status in relation to Target	Very Likely (> 90%) that $B > B_{MSY}$ and Very Unlikely (< 10%) that $F > F_{MSY}$
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below Hard Limit: Very Unlikely (< 10%) to be below

Historical Stock Status Trajectory and Current Status



Summary plot comparing southwest Pacific fishing mortality, $F_{(2007)}/F_{(MSY)}$, and total stock biomass, $B_{(2007)}/B_{(MSY)}$, for southwest Pacific swordfish from a subset of plausible MULTIFAN-CL models. Boxes indicate the upper and lower 95% confidence limits (but not the covariance) for each individual model.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Following a period of continuous decline, the southwest Pacific swordfish biomass has recently increased.
Recent Trend in Fishing Mortality or Proxy	
Other Abundance Indices	Annual CPUE trends for the southwest Pacific has shown that the Australian and New Zealand fleets declined from 1997-2003, and increased from 2003-2007. In contrast, the Japanese fleets show a continuous (though noisy) decline from 1997-2006. It is not clear which of the trends is closer to actual abundance.
Trends in Other Relevant Indicator or Variables	
Projections and Prognosis	
Stock Projections or Prognosis	Projections predict further increases in stock size at current fishing mortality levels.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1: Quantitative Stock assessment	
Assessment Method	The assessment uses the stock assessment model and computer software known as MULTIFAN-CL. A parallel assessment in CASAL was also undertaken, but is not reported here.	
Assessment Dates	Latest assessment: 2008	Next assessment: 2013
Overall assessment quality rank	1 - High Quality	
Main data inputs (rank)	Commercial catch and effort data, CPUE, catch-at-age	1 - High Quality
Data not used (rank)		
Changes to Model Structure and Assumptions	Major changes from the 2006 assessment include: • Two-three years of additional data, which includes informative contrast in catch levels and CPUE in the SWP • Simplification of the spatial structure within the SWP • Quantification of swordfish mixing rates on the basis of recent Pop-up Satellite Archival Tags (PSAT) and conventional tagging studies • Correction of catch data from NZ (~25% of landings were omitted in 2006) • Additional size composition data (NZ port sampling from 2006-7, Spanish observer data from 2004) • Exploration of alternative growth curves and maturity schedules, in light of evidence of methodological variability among laboratories • Exploration of models that include the SCP population	
Major Sources of Uncertainty	Conflicts between CPUE data from Japan compared to that of Australia and New Zealand.	

Qualifying Comments
Limiting data and lack of an abundance index from the South Central portion of the stock resulted in no reliable assessment results for that portion of the stock.

Fishery Interactions
Interactions with protected species are known to occur in the longline fisheries of the South Pacific, particularly south of 25^{o}S. Seabird bycatch mitigation measures are required in the New Zealand, Australian EEZ's and through the WCPFC Conservation and Management Measure (CMM2007-04). Sea turtles also get incidentally captured in longline gear; the WCPFC is attempting to reduce sea turtle interactions through Conservation and Management Measure (CMM2008-03). Shark bycatch is common in longline fisheries and largely unavoidable; this is being managed through New Zealand domestic legislation and to a limited extent through Conservation and Management Measure (CMM2010-07).

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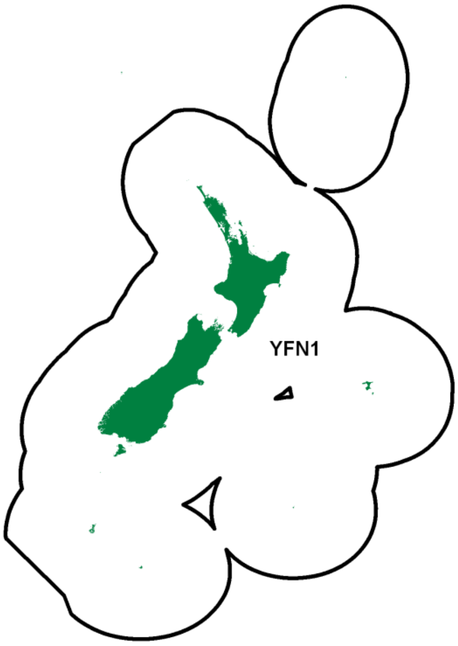
YELLOWFIN TUNA (YFN)

(Thunnus albacares)



1. FISHERY SUMMARY

Yellowfin tuna were introduced into the QMS on 1 October 2004 under a single QMA, YFN 1, with allowances, TACC, and TAC in Table 1.

Table 1: Recreational and Customary non-commercial allowances, TACCs and TACs (all in tonnes) for yellowfin tuna.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other mortality	TACC	TAC
YFN 1	60	30	5	263	358

Yellowfin tuna were added to the Third Schedule of the 1996 Fisheries Act with a TAC set under s14 because yellowfin tuna is a highly migratory species and it is not possible to estimate MSY for the part of the stock that is found within New Zealand fisheries waters.

Management of the yellowfin stock throughout the Western and Central Pacific Ocean (WCPO) is the responsibility of the Western and Central Pacific Fisheries Commission (WCPFC). Under this regional convention New Zealand is responsible for ensuring that the management measures applied within New Zealand fisheries waters are compatible with those of the Commission.

At its second annual meeting (2005) the WCPFC passed a Conservation and Management Measure (CMM) (this is a binding measure that all parties must abide by throughout the convention area including EEZ's) relating to conservation and management of tunas. Key aspects of this resolution were presented in the 2006 Plenary document. That measure was reviewed by the Scientific Committee (SC) and further recommendations were made such that at its third annual meeting (2006) the WCPFC passed an additional CMM relating to conservation and management if yellowfin tuna (http://www.wcpfc.int/). A further measure CMM2008-01 was agreed to in December 2009, the aim of which was to:

- "Ensure through the implementation of compatible measures for the high seas and EEZs that bigeye and yellowfin tuna stocks are maintained at levels capable of producing their maximum sustainable yield; as qualified by relevant environmental and economic factors including the special requirements of developing States in the Convention area as expressed by Article 5 of the Convention.
- Achieve, through the implementation of a package of measures, over a three-year period commencing in 2009, a minimum of 30% reduction in bigeye tuna fishing mortality from the annual average during the period 2001-2004 or 2004;
- Ensure that there is no increase in fishing mortality for yellowfin tuna beyond the annual average during the period 2001-2004 average or 2004; and
- Adopt a package of measures that shall be reviewed annually and adjusted as necessary by the Commission taking account of the scientific advice available at the time as well as the implementation of the measures. In addition, this review shall include any adjustments required by Commission decisions regarding management objectives and reference points."

This measure is large and detailed with numerous exemptions and provisions. Despite this effort reductions are being attempted through seasonal FAD closures, and high seas area closures (in high seas pockets) for the purse seine fleets, longline effort reductions as well as other methods. At the 2009 meeting the Scientific Committee recommended that this measure would need to be strengthened if it was to achieve its objectives.

1.1 Commercial fisheries

Most of the commercial catch of yellowfin takes place in the equatorial Western Pacific Ocean (WPO) where they are taken primarily by purse seine and longline. Commercial catches by distant water Asian longliners of yellowfin tuna, in New Zealand waters, began in 1962. Catches through the 1960s averaged 283 t. Yellowfin were not a target species for these fleets and catches remained small and seasonal. Domestic tuna longline vessels began targeting bigeye tuna in 1990/91 in northern waters of FMA 1, FMA 2 and FMA 9 (Table 2). Catches of yellowfin have increased with increasing longline effort, but as yellowfin availability fluctuates dramatically between years, catches have been variable. In addition, small catches of yellowfin are made by pole-and-line fishing (about 4 t per year) and also by trolling (about 14 t per year). Figure 1 shows historic landings and longline fishing effort for YFN stocks.

Catches from within New Zealand fisheries waters are very small (0.07% average for 2000-2011) compared to those from the greater stock in the WCPO (Table 3). In contrast to New Zealand, where yellowfin are taken almost exclusively by longline, 50% of the WCPO catches of yellowfin tuna are taken by purse seine and other surface gears (e.g., ring-nets and pole-and-line).

Table 2: Reported catches or landings (t) of yellowfin tuna by fleet and Fishing Year. NZ: New Zealand domestic and charter fleet, ET: catches outside these areas from New Zealand flagged longline vessels, JPNFL: Japanese foreign licensed vessels, KORFL: foreign licensed vessels from the Republic of Korea. LFRR: Estimated landings from Licensed Fish Receiver Returns and MHR: Monthly Harvest Return Data from 2001/02.

	YFN 1 (all FMAs)					
Fish Yr	JPNFL	KORFL	NZ/MHR	Total	LFRR	NZ ET
1979-80	10.1			10.1		
1980-81	79.1	29.9		109		
1981-82	89.4	6.7		96.1		
1982-83	22.4	6.6		29		
1983-84	46.1	12.8		58.9		
1984-85	21.3	64.5		85.8		
1985-86	92.5	3.3		95.8		
1986-87	124.8	29		153.8		
1987-88	35.2	37.3		72.5		
1988-89	11.5	1.8		13.3	19	
1989-90	29.1		4.3	33.4	6.3	
1990-91	7.4		10.7	18.1	19.9	
1991-92	0.2		16.1	16.3	11.8	
1992-93			10.1	10.1	69.7	0.2
1993-94			50.5	50.5	114.4	1.5
1994-95			122.2	122.2	193.4	0.3
1995-96			251.6	251.6	156.7	7.4
1996-97			144.1	144.1	105.3	0.2
1997-98			93.6	93.6	174.7	2.3
1998-99			136.1	136.1	100.6	0.3
1999-00			77.8	77.8	168	2.1
2000-01			123.5	123.5	62.5	3.1
2001-02			64.5	56.7	61.9	1.9
2002-03			41.8	39.7	42.1	2.1
2003-04			57.7	21.1	21.4	36.6
2004-05			42.0	36.1	41.4	6.0
2005-06			9.3	9.2	8.8	0.1
2006-07			18.8	17.3	19.7	1.0
2007-08			22.2	22.4	22.3	0.2
2008-09			5.4	43.6	43.3	38.2
2009-10			6.2	6.2	48.2	42.6
2010-11			2.8	2.8	234.8	232.2
2011-12			2.2	2.2	767	765

Table 3: Reported total New Zealand within EEZ landings, catch made by New Zealand vessels outside New Zealand fishery waters (NZ ET)* and WCPO landings (t) of yellowfin tuna from 1991 to 2010.

Year	NZ landings (t)	WCPO landings (t)	Year	NZ landings (t)	NZ ET landings (t)	WCPO landings (t)
1991	6	359 826	2001	138	955	513 336
1992	20	380 413	2002	25	3 531	476 380
1993	34	367 942	2003	38	3 646	516 280
1994	53	299 711	2004	20	2 658	506 057
1995	141	370 049	2005	36	2 486	565 635
1996	198	354 915	2006	14	2 679	491 216
1997	143	460 638	2007	25	2 329	511 550
1998	127	557 066	2008	12	3 200	574 825
1999	154	477 400	2009	3	1 264	510 200
2000	107	524 341	2010	6	1 264	546 084
			2011	2	765	479 403

Source: Ministry of Fisheries Licensed Fish Receiver Reports, Solander Fisheries Ltd, Anon. 2006, Williams & Terawasi 2011; WCPO landings sourced from WCPFC Yearbook 2012 (Anon 2012).

*New Zealand purse seine vessels operating in tropical regions catch moderate levels of yellowfin tuna when fishing around Fish Aggregating Devices (FADs) and on free schools. These catches are only estimates of catch based on analysis of observer data across all fleets rather than specific data for NZ vessels. In addition, catches of juvenile bigeye and yellowfin tuna are often combined on catch effort returns due to difficulties in differentiating the catch.

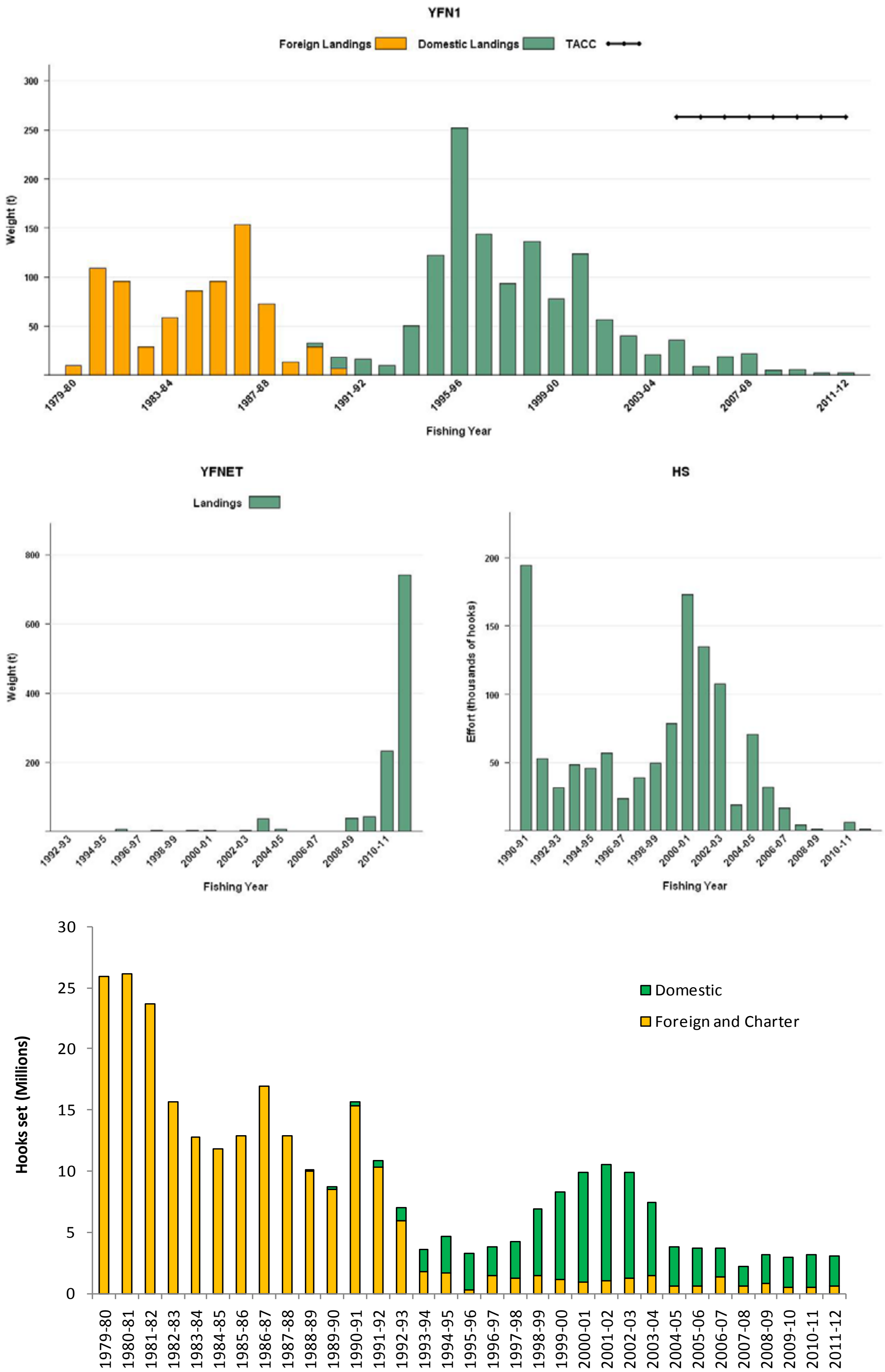


Figure 1: [Top and middle left] Yellowfin catch by foreign licensed and New Zealand vessels from 1979-80 to 2011-12 within NZ waters (YFN1), and 1992-93 to 2011-12 on the high seas (YFNET). [Middle right] Fishing effort (number of hooks set) for all high seas New Zealand flagged surface longline vessels, and [Bottom] domestic vessels (including effort by foreign vessels chartered by NZ fishing companies), from 1990-91 to 2011-12 and 1979-80 to 2011-12, respectively.

The majority of yellowfin tuna are caught in the bigeye tuna surface longline fishery (67%) (Figure 2), however, across all longline fisheries albacore make up the bulk of the catch (33%) and yellowfin tuna make up only 2% of the catch (Figure 3). Longline fishing effort is distributed along the east coast of the North Island and the south west coast of the South Island. The west coast South Island fishery predominantly targets southern bluefin tuna, whereas the east coast of the North Island targets a range of species including bigeye, swordfish, and southern bluefin tuna (Figure 4).

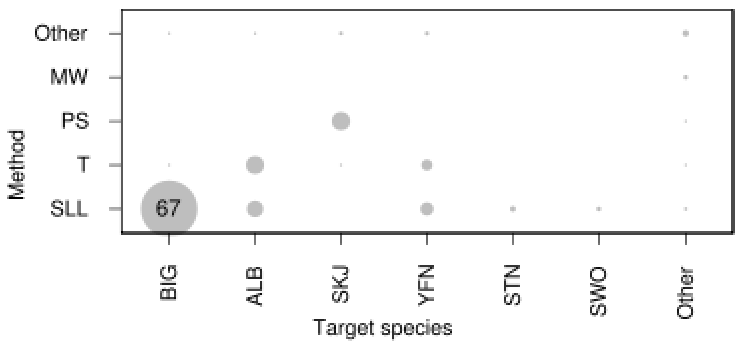


Figure 2: A summary of the proportion of landings of yellowfin tuna taken by each target fishery and fishing method. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the bobble is the percentage. SLL = surface longline, T = trawl, PS = purse seine, MW = mid-water trawl (Bentley *et al.* 2012).

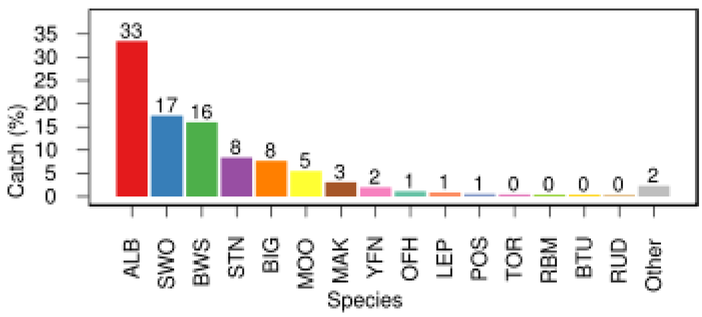


Figure 3: A summary of species composition of the reported surface longline catch. The percentage by weight of each species is calculated for all surface longline trips (Bentley *et al.* 2012).

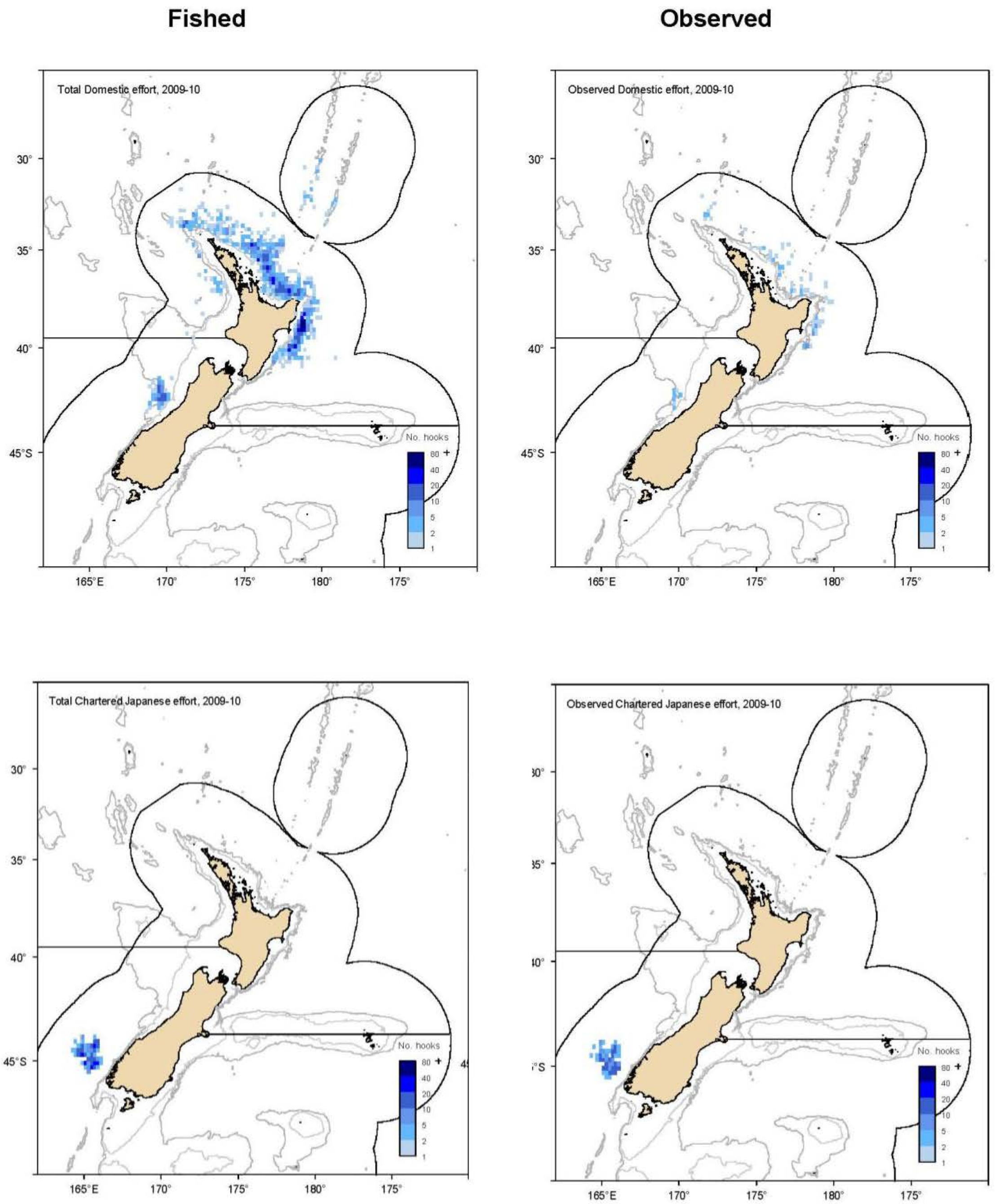


Figure 4: Distribution of fishing positions for domestic (top two panels) and charter (bottom two panels) vessels, for the 2009-10 fishing year, displaying both fishing effort (left) and observer effort (right).

In the longline fishery 79.4% of the yellowfin tuna were alive when brought to the side of the vessel for all fleets (Table 4). The domestic fleets retain between 78-100% of their yellowfin tuna catch (Table 5).

Table 4: Percentage of yellowfin tuna (including discards) that were alive or dead when arriving at the longline vessel and observed during 2006–07 to 2009–10, by fishing year, fleet and region. Small sample sizes (number observed < 20) were omitted Griggs and Baird (in press).

Year	Fleet	Area	% alive	% dead	Number
2006-07	Domestic	North	75.0	25.0	28
	Total		**78.3**	**21.7**	**46**
2007-08	Domestic	North	75.8	24.2	33
	Total		**75.8**	**24.2**	**33**
2008-09	**Total**		**88.9**	**11.1**	**9**
2009-10	**Total**		**88.9**	**11.1**	**9**
Total all strata			**79.4**	**20.6**	**97**

Table 5: Percentage yellowfin that were retained, or discarded or lost, when observed on a longline vessel during 2006–07 to 2009–10, by fishing year and fleet. Small sample sizes (number observed < 20) omitted Griggs and Baird (in press).

Year	Fleet	% retained	% discarded or lost	Number
Total all strata		**71.0**	**29.0**	**617**
2006-07	Domestic	78.6	21.4	28
	Total	**80.4**	**19.6**	**46**
2007-08	Domestic	90.9	9.1	33
	Total	**90.9**	**9.1**	**33**
2008-09	**Total**	**100.0**	**0.0**	**9**
2009-10	**Total**	**100.0**	**0.0**	**9**
Total all strata		**87.6**	**12.4**	**97**

1.2 Recreational fisheries

Recreational fishers used to make regular catches of yellowfin tuna particularly during summer months and especially in FMA 1 and FMA 2 where the recreational fishery targeted yellowfin as far south as the Wairarapa coast.

While the magnitude of the recreational catch is unknown catches weighed at sport fishing clubs have dropped from over 1000 fish per year in the 1990s to an average of 30 per year in the last 3 years.

1.3 Customary non-commercial fisheries

An estimate of the current customary catch is not available.

1.4 Illegal catch

There is no known illegal catch of yellowfin tuna in the EEZ. Estimates of illegal catch are not available, but are probably insignificant.

1.5 Other sources of mortality

The estimated overall incidental mortality rate from observed longline effort is 0.22% of the catch. Discard rates are 0.92% on average from observer data of which approximately 25% are discarded dead (usually because of shark damage). Fish are also lost at the surface in the longline fishery, 0.16% on average from observer data, of which 95% are reported as escaping alive.

2. BIOLOGY

Yellowfin tuna are epi-pelagic opportunistic predators of fish, crustaceans and cephalopods. Yellowfin tuna are found from the surface to depths where low oxygen levels are limiting (about 250 m in the tropics but probably deeper in temperate waters). Individuals found in New Zealand waters are mostly adults that are distributed in the tropical and temperate waters of the western and central Pacific Ocean. Adults reach a maximum size of 200 kg and lengths of 239 cm. First maturity is reached at 60 to 80 cm (1 to 2 years old), and the size at 50% maturity is estimated to be 105 cm. The maximum reported age is 8 years. Spawning takes place at the surface at night mostly within 10º of the equator when temperatures exceed 24ºC. Spawning takes place throughout the year but the main spawning season is November to April. Yellowfin are serial spawners, spawning every few days throughout the peak of the season.

Natural mortality is assumed to vary with age. A range of von Bertalanffy growth parameters has been estimated for yellowfin in the Pacific Ocean depending on area (Table 6).

Table 6: von Bertalanffy growth parameters for yellowfin tuna by country or area.

L_∞ (cm)	K	t_0	Country/Area
148.0	0.420		Philippines
162.0	0.660		Mexico
166.0	0.250		Western tropical Pacific
169.0	0.564		Japan
173.0	0.660		Mexico
190.0	0.454		Hawaii
191.0	0.327	-1.02	Japan

Females predominate in the longline catch of yellowfin tuna in the in the New Zealand EEZ (0.75 males:females).

3. STOCKS AND AREAS

Yellowfin tuna in New Zealand waters are part of the western and central Pacific Ocean stock that is distributed throughout the North and South Pacific Ocean west of about 150ºW.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the November 2012 Fishery Assessment Plenary after review by the Aquatic Environment Working Group. This summary is from the perspective of yellowfin tuna but there is no directed fishery for them and the incidental catch sections below reflect the New Zealand longline fishery as a whole and are not specific to this species; a more detailed summary from an issue-by-issue perspective is, or will shortly be, available in the Aquatic Environment & Biodiversity Annual Review where the consequences are also discussed. (http://www.mpi.govt.nz/news-resources/publications.aspx).

4.1 Role in the ecosystem
Yellowfin tuna (*Thunnus albacares*) are epi-pelagic opportunistic predators of fish, crustaceans and cephalopods generally found within the upper few hundred meters of the ocean. Yellowfin tuna are large pelagic predators, so they are likely to have a ‘top down’ effect on the fish, crustaceans and squid they feed on.

4.2 Incidental catch (seabirds, sea turtles and mammals)
The protected species, capture estimates presented here include all animals recovered onto the deck (alive, injured or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds caught on a hook but not brought onboard the vessel).

4.2.1 Seabird bycatch
Between 2002–03 and 2010–11, there were 731 observed captures of birds across all surface longline fisheries. Seabird capture rates since 2003 are presented in Figure 5. While the seabird capture distributions largely coincide with fishing effort that are more frequent off the south west coast of the South Island (Figure 6). The analytical methods used to estimate capture numbers across the commercial fisheries have depended on the quantity and quality of the data, in terms of the numbers observed captured and the representativeness of the observer coverage. Ratio estimation was historically used to calculate total captures in longline fisheries by target fishery fleet and area (Baird 2008) and by all fishing methods but recent estimates are either ratio or model based as specified in the tables below (Abraham *et al.* 2010a).

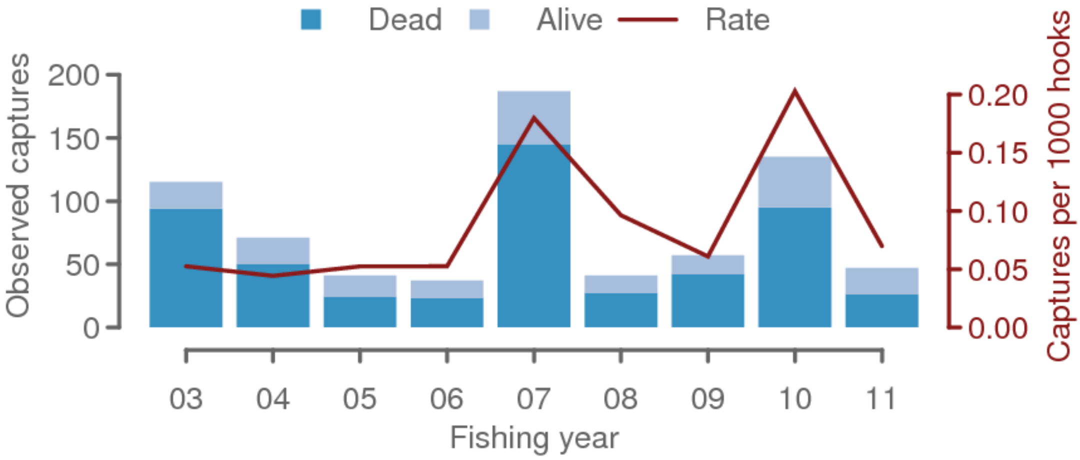
Through the 1990s the minimum seabird mitigation requirement for surface longline vessels was the use of a bird scaring device (tori line) but common practice was that vessels set surface longlines primarily at night. In 2007 a notice was implemented under s 11 of the Fisheries Act 1996 to formalise the requirement that surface longline vessels only set during the hours of darkness and use a tori line when setting. This notice was amended in 2008 to add the option of line weighting and tori line use if setting during the day. In 2011 notices were combined and repromulgated under a new regulation (Regulation 58A of the Fisheries (Commercial Fishing) Regulations 2001) which provides a more flexible regulatory environment under which to set seabird mitigation requirements.

Table 7: Number of observed seabird captures in the New Zealand surface longline fisheries, 2002-03 to 2010-11, by species and area (Thompson & Abraham (2012) from http://data.dragonfly.co.nz/psc/). See glossary above for a description of the areas used for summarising the fishing effort and protected species captures. 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 yellowfin tuna using longline gear but rather the total risk for each seabird species.

Species	Risk ratio	Kermadec Islands	Northland and Hauraki	Bay of Plenty	East Coast North Island	Stewart Snares Shelf	Fiordland	West Coast South Island	West Coast North Island	Total
Salvin's albatross	2.49	0	1	1	6	0	0	0	0	8
Northern royal albatross	2.21	0	0	1	0	0	0	0	0	1
Light-mantled sooty albatross	2.18	0	0	0	0	0	0	1	0	1
Campbell albatross	1.84	0	8	0	26	0	3	3	0	40
Southern Buller's albatross	1.28	0	3	1	26	0	251	31	0	312
Gibson's albatross	1.25	4	10	0	11	0	3	1	1	30
Antipodean albatross	1.11	12	9	1	7	0	0	0	1	30
White capped albatross	0.83	0	1	0	3	10	54	25	0	93
Southern royal albatross	0.74	0	0	0	0	0	4	0	0	4
Black browed albatrosses	-	2	1	0	0	0	0	0	1	4
Pacific albatross	-	0	0	0	1	0	0	0	0	1
Southern black-browed albatross	-	0	0	0	2	0	0	0	0	2
Wandering albatross	-	0	2	0	6	0	3	0	0	11
Antipodean and Gibson's albatrosses	N/A	5	2	0	0	0	0	0	0	7
Unidentified albatross	N/A	33	0	0	1	0	0	0	1	35
Total albatrosses	**N/A**	**56**	**37**	**4**	**89**	**10**	**318**	**61**	**4**	**579**
Black petrel	11.15	1	9	1	0	0	0	0	1	12
Westland petrel	3.31	0	0	0	2	0	1	5	0	8
Flesh footed shearwater	2.51	0	0	0	10	0	0	0	2	12
Cape petrels	0.76	0	0	0	2	0	0	0	0	2
White chinned petrel	0.79	2	2	3	3	1	19	0	3	33
Grey petrel	0.39	3	3	2	38	0	0	0	0	46
Sooty shearwater	0.02	1	0	0	8	3	1	0	0	13
Great winged petrel	0.01	12	5	1	2	0	0	0	0	20
White headed petrel	0.01	2	0	0	0	0	0	0	0	2
Pterodroma petrels	-	0	1	0	0	0	0	0	0	1
Southern giant petrel	-	0	0	0	2	0	0	0	0	2
Unidentified seabird	N/A	0	0	0	0	0	1	0	0	1
Total other birds	**N/A**	**21**	**20**	**7**	**67**	**4**	**22**	**5**	**6**	**152**

Table 8: Effort, observed and estimated seabird captures by fishing year for the New Zealand surface longline fishery within the EEZ. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); the capture rate (captures per thousand hooks); and the mean number of estimated total captures (with 95% confidence interval). The estimation method used was a Bayesian model with 100% of hooks included in the estimate. For more information on the methods used to prepare the data see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures		Estimated captures	
	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002-2003	10 764 588	2 195 152	20.4	115	0.052	2490	1817-3461
2003-2004	7 380 779	1 607 304	21.8	71	0.044	1665	1259-2220
2004-2005	3 676 365	783 812	21.3	41	0.052	687	507-936
2005-2006	3 687 339	705 945	19.1	37	0.052	816	607-1120
2006-2007	3 738 362	1 040 948	27.8	187	0.18	949	725-1304
2007-2008	2 244 339	426 310	19	41	0.096	521	408-681
2008-2009	3 115 633	937 233	30.1	57	0.061	721	562-934
2009-2010	2 992 285	665 883	22.3	149	0.224	1014	777-1345
2010-2011	3 164 159	674 522	21.3	47	0.07	824	607-1152



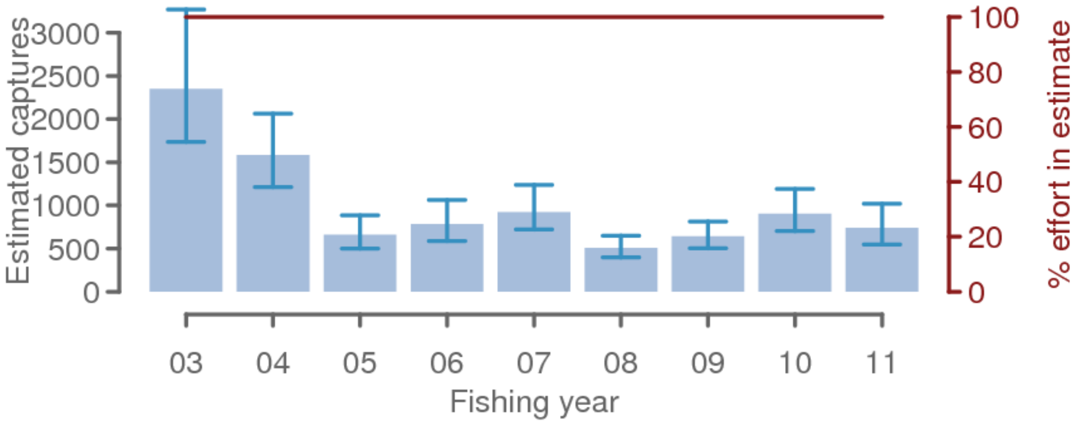


Figure 5: Observed and estimated captures of seabirds birds in the New Zealand surface longline fisheries from 2003 to 2011

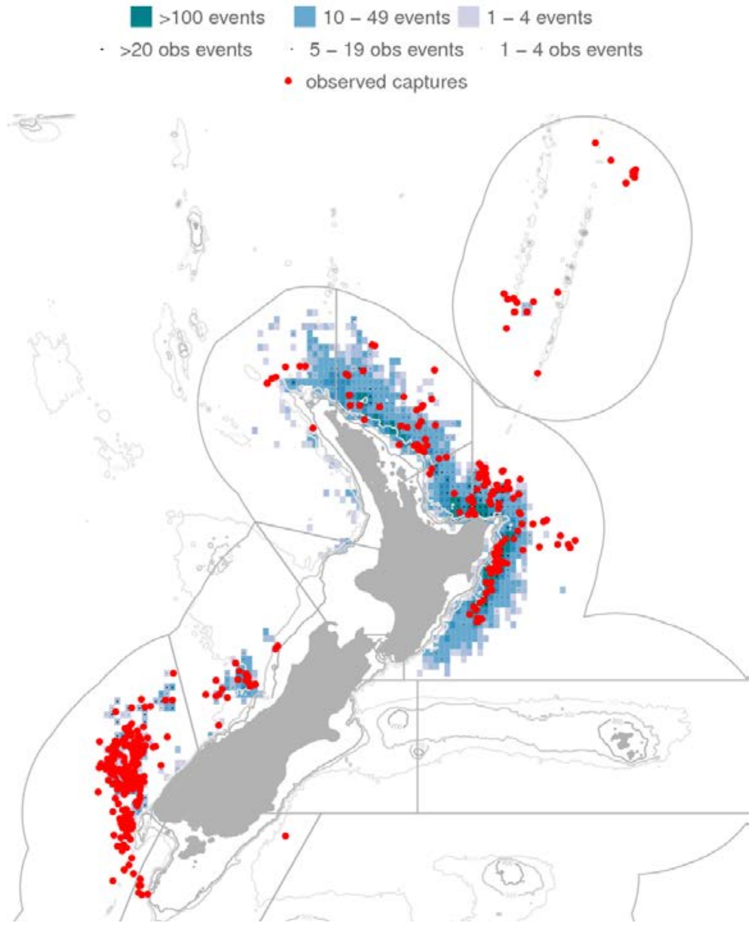


Figure 6: Distribution of fishing effort in the New Zealand surface longline fisheries and observed seabird captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.2 Sea turtle bycatch

Between 2002–03 and 2010–11, there were 13 observed captures of sea turtles across all surface longline fisheries (Tables 9 and 10, Figure 7). Observer records documented all but one sea turtle as captured and released alive. Sea turtle capture distributions predominantly occur throughout the east coast of the North Island and Kermadec Island fisheries (Figure 8).

Table 9: Number of observed sea turtle captures in the New Zealand surface longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson and Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

Species	Bay of Plenty	East Coast North Island	Kermadec Islands	West Coast North Island	Total
Leatherback turtle	1	4	3	3	11
Olive ridley turtle	0	1	0	0	1
Unknown turtle	0	1	0	0	1
Total	**1**	**6**	**3**	**3**	**13**

Table 10: Effort and sea turtle captures in surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	10 764 588	2 195 152	20.4	0	0
2003-2004	7 380 779	1 607 304	21.8	1	0.001
2004-2005	3 676 365	783 812	21.3	2	0.003
2005-2006	3 687 339	705 945	19.1	1	0.001
2006-2007	3 738 362	1 040 948	27.8	2	0.002
2007-2008	2 244 339	426 310	19.0	1	0.002
2008-2009	3 115 633	937 233	30.1	2	0.002
2009-2010	2 992 285	665 883	22.3	0	0
2010-2011	3 164 159	674 522	21.3	4	0.006

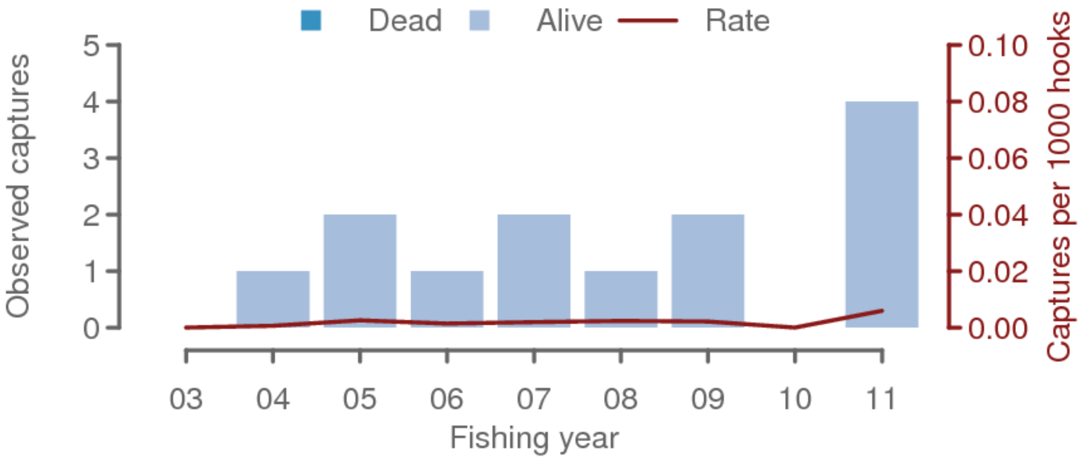


Figure 7: Observed captures of sea turtles in the New Zealand surface longline fisheries from 2003 to 2011.

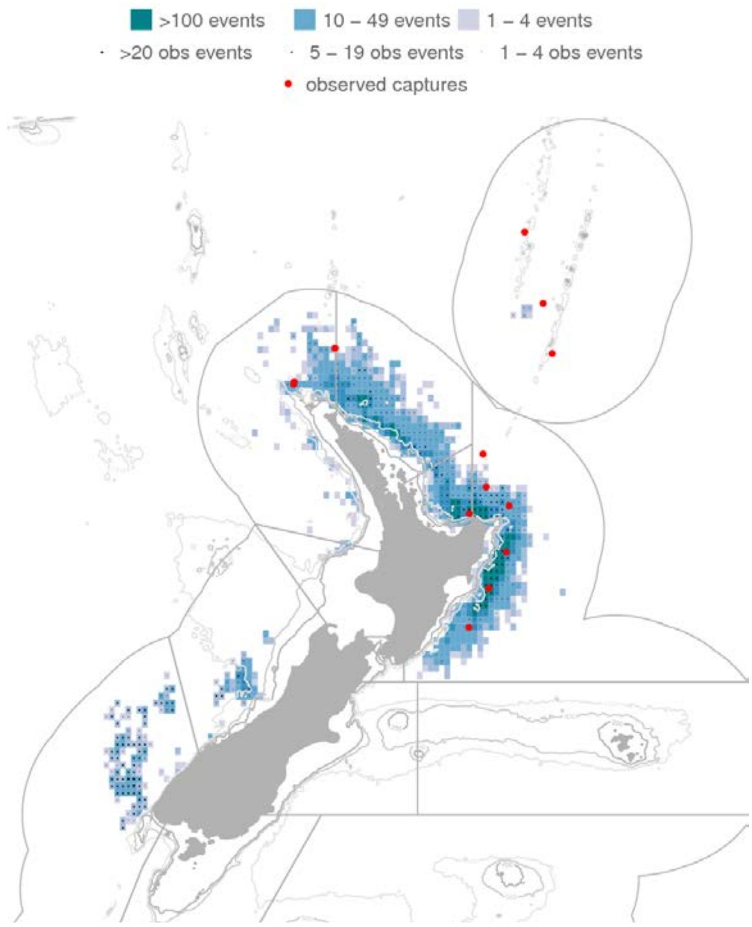


Figure 8: Distribution of fishing effort in the New Zealand surface longline fisheries and observed sea turtle captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3 Marine Mammals

4.2.3.1 Cetaceans

Cetaceans are dispersed throughout New Zealand waters (Perrin *et al.* 2008). The spatial and temporal overlap of commercial fishing grounds and cetacean foraging areas has resulted in cetacean captures in fishing gear (Abraham and Thompson 2009, 2011).

Between 2002–03 and 2010–11, there were seven observed captures of whales and dolphins in surface longline fisheries. Observed captures included 5 unidentified cetaceans and 2 long-finned Pilot whales (Tables 11 and 12, Figure 9) (Abraham and Thompson 2011). All captured animals recorded were documented as being caught and released alive (Thompson and Abraham 2010). Cetacean capture distributions are more frequent off the east coast of the North Island (Figure 10)

Table 11: Number of observed cetacean captures in the New Zealand surface longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson and Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

Species	Bay of Plenty	East Coast North Island	Fiordland	Northland and Hauraki	West Coast North Island	West Coast South Island	Total
Long-finned pilot whale	0	1	0	0	0	1	2
Unidentified cetacean	1	1	1	1	1	0	5
Total	**1**	**2**	**1**	**1**	**1**	**1**	**7**

Table 12: Effort and captures of cetaceans in surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	10 764 588	2 195 152	20.4	1	0.0005
2003-2004	7 380 779	1 607 304	21.8	4	0.002
2004-2005	3 676 365	783 812	21.3	1	0.001
2005-2006	3 687 339	705 945	19.1	0	0
2006-2007	3 738 362	1 040 948	27.8	0	0
2007-2008	2 244 339	426 310	19.0	1	0.002
2008-2009	3 115 633	937 233	30.1	0	0
2009-2010	2 992 285	665 883	22.3	0	0
2010-2011	3 164 159	674 522	21.3	0	0

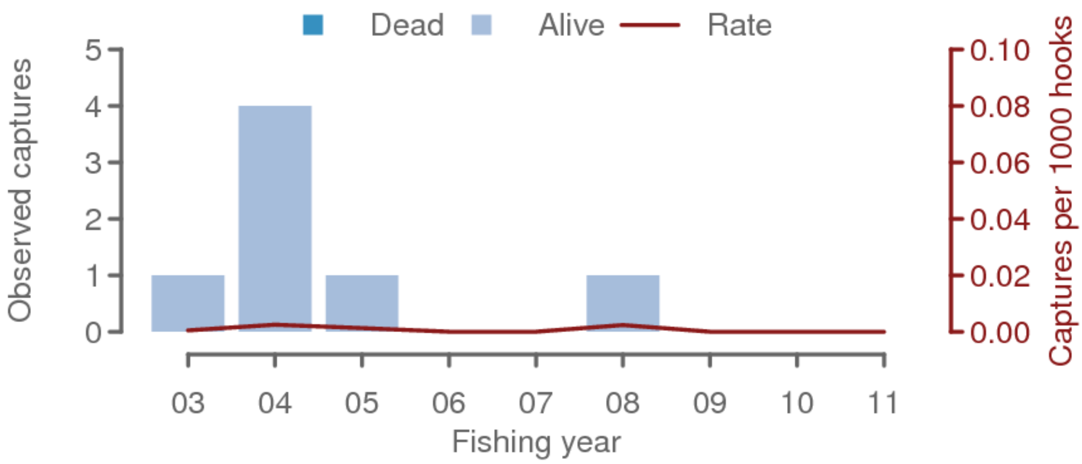


Figure 9: Observed captures of cetaceans in the New Zealand surface longline fisheries from 2003 to 2011.

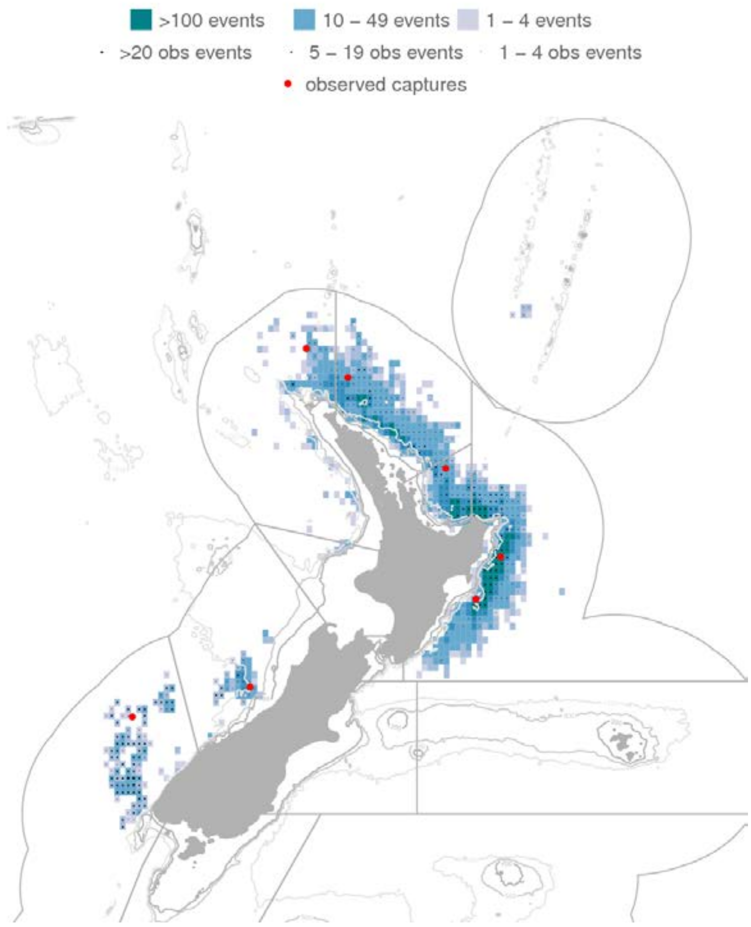


Figure 10: Distribution of fishing effort in the New Zealand surface longline fisheries and observed cetacean captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3.2 New Zealand fur seal bycatch

Currently, New Zealand fur seals are dispersed throughout New Zealand waters, especially in waters south of about 40º S to Macquarie Island. The spatial and temporal overlap of commercial fishing grounds and New Zealand fur seal foraging areas has resulted in New Zealand fur seal captures in fishing gear (Mattlin 1987, Rowe 2009). Most fisheries with observed captures occur in waters over or close to the continental shelf, which around much of the South Island and offshore islands slopes steeply to deeper waters relatively close to shore, and thus rookeries and haulouts. Captures on longlines occur when the seals attempt to feed on the fish and bait catch during hauling. Most New Zealand fur seals are released alive, typically with a hook and short snood or trace still attached.

New Zealand fur seal captures in surface longline fisheries have been generally observed in waters south and west of Fiordland, but also in the Bay of Plenty-East Cape area when the animals have attempted to take bait or fish from the line as it is hauled. These capture rates include animals that are released alive (100% of observed surface longline capture in 2008-09; Thompson and Abraham 2010). Bycatch rates in 2010-11 are low and lower than they were in the early 2000s (Figure 11). While fur seal captures have occurred throughout the range of this fishery most New Zealand captures have occurred off the Southwest coast of the South Island

(Figure 12). Between 2002–03 and 2010–11, there were 206 observed captures of New Zealand fur seal in surface longline fisheries (Tables 13 and 14).

Table 13: Number of observed New Zealand fur seal captures in the New Zealand surface longline fisheries, 2002-03 to 2010-11, by species and area. Data from Thompson and Abraham (2012), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

	Bay of Plenty	East Coast North Island	Fiordland	Northland and Hauraki	Stewart Snares Shelf	West Coast North Island	West Coast South Island	Total
New Zealand fur seal	10	16	139	3	4	2	32	206

Table 14: Effort and captures of New Zealand fur seal in the New Zealand surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Abraham and Thompson (2011).

Fishing year	Fishing effort			Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002-2003	10 764 588	2 195 152	20.4	56	0.026
2003-2004	7 380 779	1 607 304	21.8	40	0.025
2004-2005	3 676 365	783 812	21.3	20	0.026
2005-2006	3 687 339	705 945	19.1	12	0.017
2006-2007	3 738 362	1 040 948	27.8	10	0.010
2007-2008	2 244 339	426 310	19.0	10	0.023
2008-2009	3 115 633	937 233	30.1	22	0.023
2009-2010	2 992 285	665 883	22.3	19	0.029
2010-2011	3 164 159	674 522	21.3	17	0.025

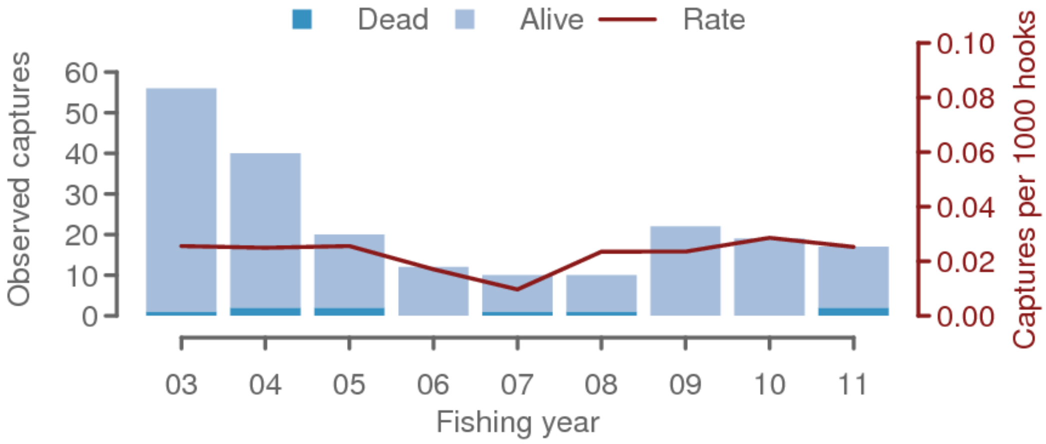


Figure 11: Observed captures of New Zealand fur seal in the New Zealand surface longline fisheries from 2003 to 2011.

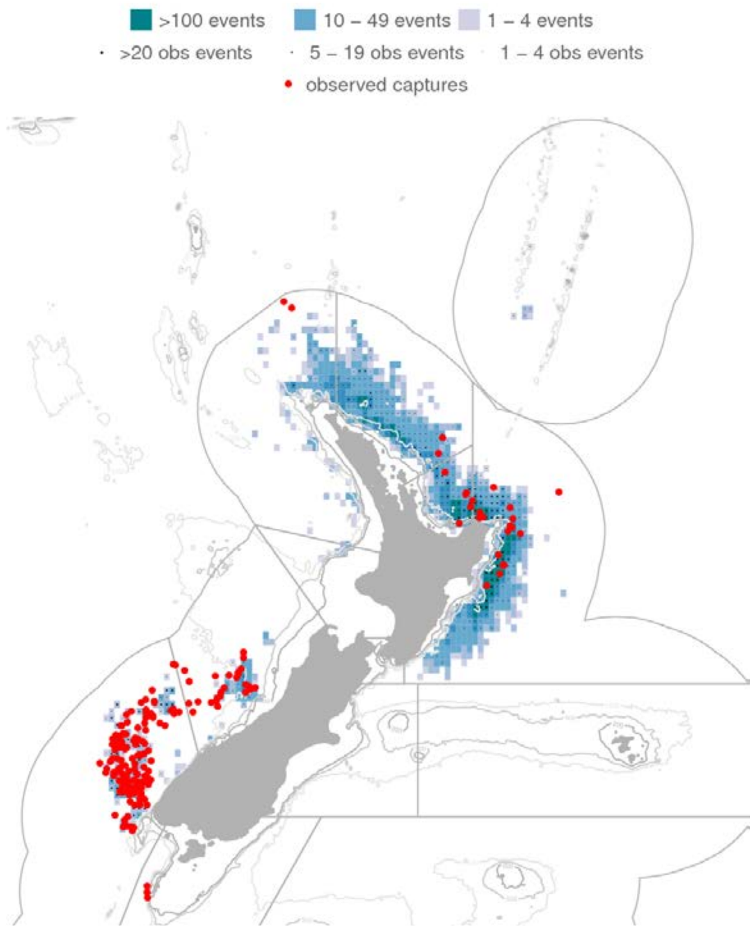


Figure 12: Distribution of fishing effort in the New Zealand surface longline fisheries and observed New Zealand fur seal captures, 2002–03 to 2010–11. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 75.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.3 Incidental fish bycatch

Observer records indicate that a wide range of species are landed by the longline fleets in New Zealand fishery waters. Blue sharks are the most commonly landed species (by number), followed by Ray's bream (Table 15). Southern bluefin tuna and albacore tuna are the only target species that occur in the top five of the frequency of occurrence.

Table 15: Numbers of the most common fish species observed in the New Zealand longline fisheries during 2009-10 by fleet and area. Species are shown in descending order of total abundance (Griggs and Baird in press).

	Charter	Domestic		Total
Species	South	North	South	number
Blue shark	2 024	4 650	882	7 556
Rays bream	3 295	326	88	3 709
Southern bluefin tuna	3 244	211	179	3 634
Lancetfish	3	2 139	1	2 143
Albacore tuna	90	1 772	42	1 904
Dealfish	882	0	7	889
Swordfish	3	452	2	457
Moonfish	76	339	6	421
Porbeagle shark	72	328	20	420
Mako shark	11	343	7	361
Big scale pomfret	349	4	0	353
Deepwater dogfish	305	0	0	305
Sunfish	7	283	5	295
Bigeye tuna	0	191	0	191
Escolar	0	129	0	129
Butterfly tuna	15	100	3	118
Pelagic stingray	0	96	0	96
Oilfish	2	75	0	77
Rudderfish	39	20	2	61
Flathead pomfret	56	0	0	56
Dolphinfish	0	47	0	47
School shark	34	0	2	36
Striped marlin	0	24	0	24
Thresher shark	7	17	0	24
Cubehead	13	0	1	14
Kingfish	0	10	0	10
Yellowfin tuna	0	9	0	9
Hake	8	0	0	8
Hapuku bass	1	6	0	7
Pacific bluefin tuna	0	5	0	5
Black barracouta	0	4	0	4
Skipjack tuna	0	4	0	4
Shortbill spearfish	0	4	0	4
Gemfish	0	3	0	3
Bigeye thresher shark	0	2	0	2
Snipe eel	2	0	0	2
Slender tuna	2	0	0	2
Wingfish	2	0	0	2
Bronze whaler shark	0	1	0	1
Hammerhead shark	0	1	0	1
Hoki	0	0	1	1
Louvar	0	1	0	1
Marlin, unspecified	0	1	0	1
Scissortail	0	1	0	1
Broadnose seven gill shark	1	0	0	1
Shark, unspecified	0	1	0	1
Unidentified fish	2	30	8	40
Total	10 545	11 629	1 256	23 430

4.4 Benthic interactions
N/A

4.5 Key environmental and ecosystem information gaps
Cryptic mortality is unknown at present but developing a better understanding of this in future may be useful for reducing uncertainty of the seabird risk assessment and could be a useful input into risk assessments for other species groups.

The survival rates of released target and bycatch species is currently unknown.

Observer coverage in the New Zealand fleet is not spatially and temporally representative of the fishing effort.

5. STOCK ASSESSMENT

With the establishment of WCPFC in 2004, stock assessments of the WCPO stock of yellowfin tuna are undertaken by the Oceanic Fisheries Programme (OFP) of Secretariat of the Pacific Community (SPC) under contract to WCPFC.

No assessment is possible for yellowfin within the New Zealand EEZ as the proportion of the stock found within New Zealand fisheries waters is unknown and likely varies from year to year.

A summary of the 2011 assessment undertaken by OFP (Langley *et al.* 2011) and reviewed by the WCPFC Scientific Committee in August 2011 is provided below.

"The assessment uses the stock assessment model and computer software known as MULTIFAN-CL. The yellowfin tuna model is age (28 age-classes) and spatially structured (6 regions) and the catch, effort, size composition and tagging data used in the model are classified by 24 fisheries and quarterly time periods from 1952 through 2010. The assessment included a range of model options and sensitivities that were applied to investigate key structural assumptions and sources of uncertainty in the assessment.

While the structure of the assessment model(s) was similar to the previous (2009) assessment, there were some substantial revisions to a number of key data sets, specifically the longline CPUE indices, catch and size data, purse-seine catch and size data, and the configuration of the Indonesian and Philippines domestic fisheries. Cumulatively, these changes resulted in a substantial change in the key results from the 2009 assessment, reducing the overall level of biomass and the estimates of *MSY*, $B_{current}/\tilde{B}_{MSY}$ and $SB_{current}/\tilde{SB}_{MSY}$, while increasing the estimate of $F_{current}/\tilde{F}_{MSY}$ Overall, the current models represent a considerable improvement to the fit to the key data sets compared to 2009 indicating an improvement in the consistency among the main data sources, principally the longline CPUE indices and the associated length and weight frequency data.

The current assessment represents the first attempt to integrate the tagging data from the recent PTTP. The model diagnostics indicate a relatively poor fit to these data compared to the data from earlier tagging programmes, particularly for fish of the older age classes and/or longer periods at liberty. For all model options, there was a positive bias in the model's prediction of the number of tags recovered from older fish, indicating that estimated exploitation rates for recent years were higher than observed directly from the tag recoveries. This indicates a degree of conflict between the tagging data and the other key data sources, specifically the longline CPUE indices and, to a lesser extent, the longline size data. Consequently, the inclusion of PTTP data set in the model yields a rather more optimistic assessment (when contrasted with models that exclude these data).

The main conclusions of the current assessment are as follows.

For all analyses, there are strong temporal trends in the estimated recruitment series. Initial recruitment was relatively high but declined during the 1950s and 1960s. Recruitment remained relatively constant during the 1970s and 1980s, declined steadily from the early 1990s and then recovered somewhat over the last decade. Recent recruitment is estimated to be lower than the long-term average (approximately 85%).

Trends in biomass are generally consistent with the underlying trends in recruitment. Biomass is estimated to have declined throughout the model period. The biomass trends in the model are principally driven by the time-series of catch and GLM standardised effort from the principal longline fisheries. Over recent years, there has been considerable refinement of the longline CPUE indices, largely as a result of the utilisation of the operational level data from the longline fishery, principally from the Japanese fleet. This data enables a number of factors to be incorporated within the analysis to account for temporal trends in the catchability of the fleet.

Refinement in the approach applied to process the longline size frequency data (length and weight data) has resulted in a more coherent trend in these data over the model period. As a result, there has been a substantial improvement in the fit to both the size frequency data and the CPUE indices compared to recent assessments.

There is considerable conflict between the tagging data (principally from the PTTP) and the other key sources of data included in the model, primarily the CPUE indices. The inclusion of the PTTP tagging data results in a the estimation of a substantially lower level of fishing mortality, particularly for the both the younger age classes vulnerable to the purse-seine associated fishery (age classes 3-4) and the older age classes (age classes > 9) vulnerable to the unassociated purse-seine fishery. The resulting assessment is more optimistic when the PTTP tags are incorporated in the model. Further auxiliary analysis of the PTTP tagging data are required to resolve the conflict between these key sources of data.

Fishing mortality for adult and juvenile yellowfin tuna is estimated to have increased continuously since the beginning of industrial tuna fishing. A significant component of the increase in juvenile fishing mortality is attributable to the Philippines and Indonesian surface fisheries, which have the weakest catch, effort and size data. There has been recent progress made in the acquisition of a large amount of historical length frequency data from the Philippines and these data were incorporated in the assessment. However, there is an ongoing need to improve estimates of recent and historical catch from these fisheries and maintain the current fishery monitoring programme within the Philippines. Previous analyses have shown that the current stock status is relatively insensitive to the assumed level of catch from these fisheries, although yield estimates from the fishery vary in accordance to the assumed levels of historical catch. Therefore, improved estimates of historical and current catch from these fisheries are important in the determination of the underlying productivity of the stock.

The ratios $B_t / B_{t,F=0}$ provide a time-series index of population depletion by the fisheries. Depletion has increased steadily over time, reaching a level of about 50-55% of unexploited biomass (a fishery impact of 45-50%) in 2006–2009. This represents a moderate level of stock-wide depletion although the stock remains considerably higher than the equivalent equilibrium-based reference point ($\tilde{B}_{MSY} / \tilde{B}_0$ of approximately 0.35–0.40). However, depletion is considerably higher in the equatorial region 3 where recent depletion levels are approximately 0.30 for total biomass (a 70% reduction from the unexploited level). Impacts are moderate in region 4 (37%), lower (about 15–25%) in regions 1, 5, and 6 and minimal (9%) in region 2. If stock-wide over-fishing criteria were applied at the level of our model regions, we would conclude that region 3 is fully exploited and the remaining regions are under-exploited.

The attribution of depletion to various fisheries or groups of fisheries indicates that the associated purse-seine fishery and Philippines/Indonesian domestic fisheries have the highest impact, particularly in region 3, while the unassociated purse seine fishery has a moderate impact. These fisheries are also contributing to the fishery impacts in all other regions. Historically, the coastal Japanese pole-and-line and purse-seine fisheries have had a significant impact on biomass levels in their home region (1). In all regions, the longline fishery has a relatively small impact, less than 5%.

For the most plausible range of models, the fishing mortality based reference point $F_{current} / \tilde{F}_{MSY}$ is estimated to be 0.56–0.90 and on that basis conclude that **overfishing is not occurring**. The corresponding biomass based reference points $B_{current} / \tilde{B}_{MSY}$ and $SB_{current} / S\tilde{B}_{MSY}$ are estimated to be above 1.0 (1.25–1.60 and 1.34–1.83, respectively) and, therefore, the stock is **not in an overfished state**. The stock status indicators are sensitive to the assumed value of steepness for the stock-recruitment relationship. A value of steepness greater than the default value (0.95) yields a more optimistic stock status and estimates considerably higher potential yields from the stock. Conversely, for a lower (0.65) value of steepness, the stock is estimated to be approaching the *MSY* based fishing mortality and biomass thresholds**.**

The western equatorial region accounts for the most of the WCPO yellowfin catch. In previous assessments, there have been concerns that the stock status in this region (region 3) might differ from the stock status estimated for the entire WCPO. A comparison between the results from the WCPO models and a model encompassing only region 3 yielded very similar results, particularly with respect to stock status. Nonetheless, there appear to be differences in the biological characteristics of yellowfin tuna in this region that warrant further investigation**.**

The estimates of *MSY* for the principal model options (480,000–580,000 mt) are comparable to the recent level of (estimated) catch from the fishery (550,000 mt). Further, under equilibrium conditions, the predicted yield estimates ($Y_{Fcurrent}$) are very close to the estimates of *MSY* indicating that current yields are at or above the long-term yields available from the stock. Further, while estimates of current fishing mortality are generally below F_{MSY} , any increase in fishing mortality would most likely occur within region 3 — the region that accounts for most of the catch. This would further increase the levels of depletion that is occurring within that region.

The current assessment investigated the impact of a range of sources of uncertainty in the current model and the interaction between these assumptions. Nonetheless, there remains a range of other assumptions in the model that should be investigated either internally or through directed research. Further studies are required to refine our estimates of growth, natural mortality and reproductive potential, incorporating consideration of spatio-temporal variation and sexual dimorphism; to examine in detail the time-series of size frequency data from the fisheries, which may lead to refinement in the structure of the fisheries included in the model; to consider size-based selectivity processes in the assessment model; to collect age frequency data from the commercial catch in order to improve current estimates of the population age structure; to continue to improve the accuracy of the catch estimates from a number of key fisheries, particularly those catching large quantities of small yellowfin; to refine the methodology and data sets used to derive CPUE abundance indices from the longline fishery; and to refine approaches to integrate the recent tag release/recapture data into the assessment model.”

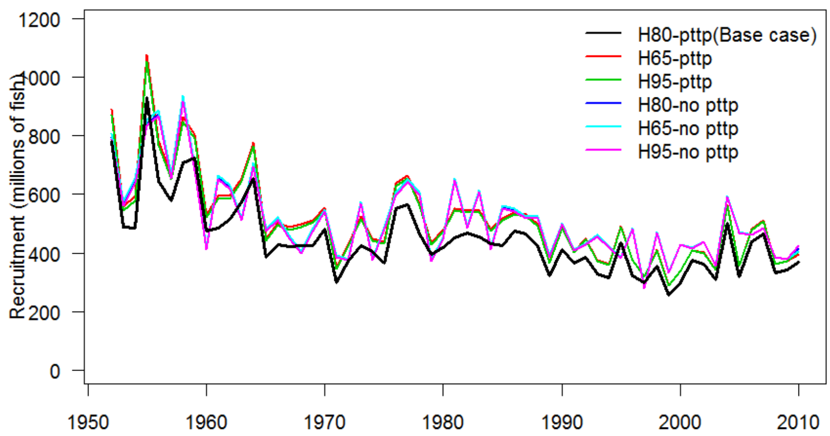


Figure 13: Estimated annual recruitment (millions of fish) for the WCPO obtained for the base case (LLcpueOP_TWcpueR6_PTTP – H80pttp) and the five combinations of steepness and tagging data sets included.

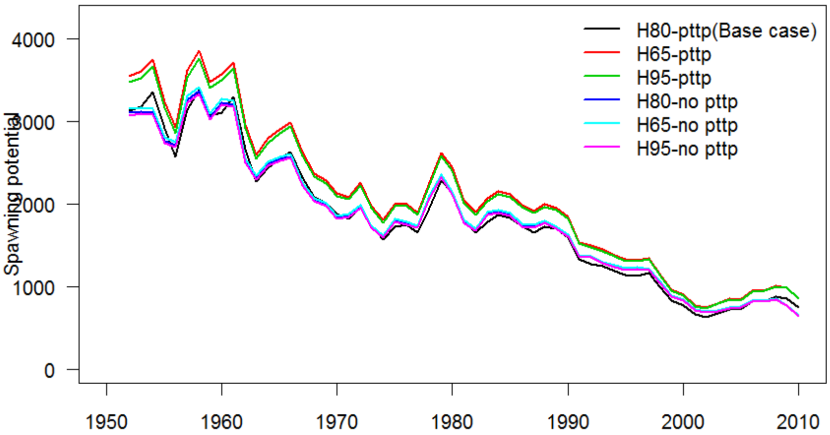


Figure 14: Estimated average annual spawning potential for the WCPO obtained from for the base case (LLcpueOP_TWcpueR6_PTTP – H80pttp) and the five combinations of steepness and tagging data sets included.

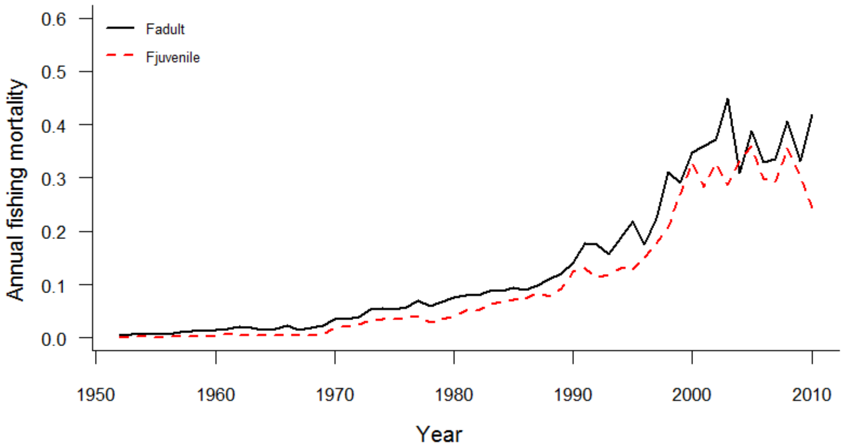


Figure 15: Estimated annual average juvenile and adult fishing mortality for the WCPO obtained from the base case model (LLcpueOP_TWcpueR6_PTTP – H80pttp).

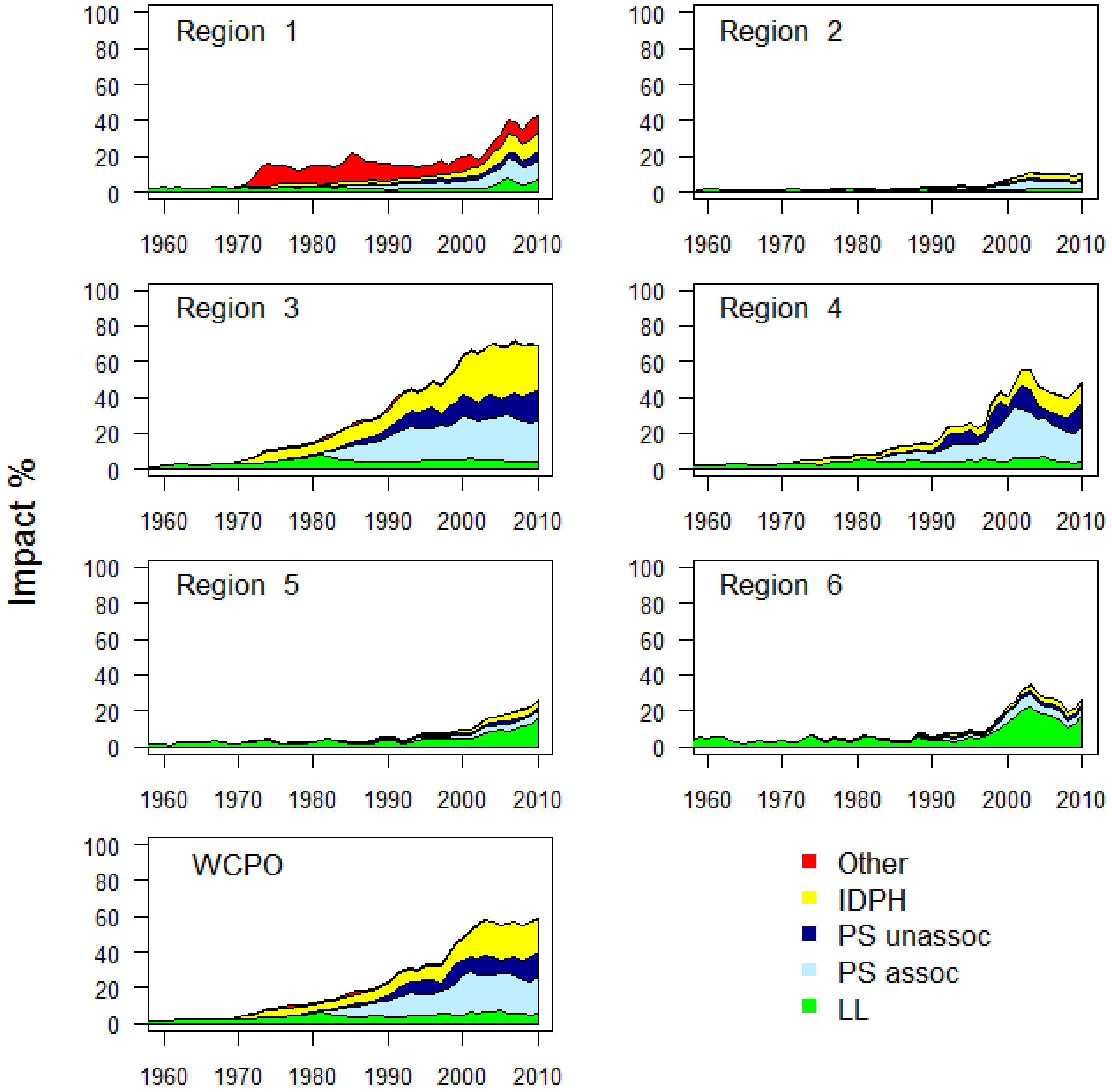


Figure 16: Estimates of reduction in spawning potential due to fishing (fishery impact = 1- $SB_t/SBt_{F=0}$) by region and for the WCPO attributed to various fishery groups (base case model (LLcpueOP_TWcpueR6_PTTP – H80pttp)). L = all longline fisheries; IDPHIDPH = Philippines and Indonesian domestic fisheries; PS assoc = purse-seine log and FAD sets; PS unassoc = purse-seine school sets; Other = pole-and-line fisheries and coastal Japan purse-seine.

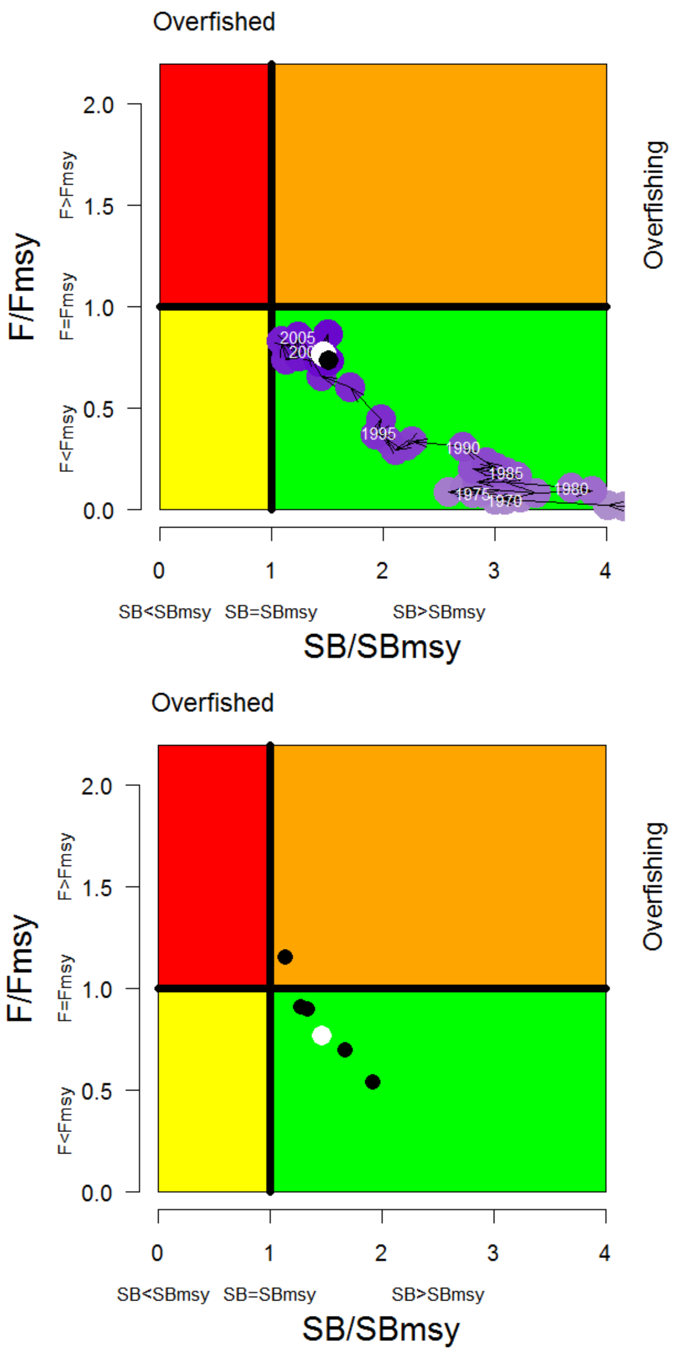


Figure 17: Temporal trend in annual stock status, relative to SB_{MSY} (x-axis) and F_{MSY} (y-axis) reference points for the base case model (LLcpueOP_TWcpueR6_PTTP – H80pttp, the colour of the points is graduated from mauve (1972) to dark purple (2010) top) and $F_{current}/F_{MSY}$ and $SB_{current}/SB_{MSY}$ for the base case (white circle) and the five combinations of steepness and tagging data sets included. See Table 5 to determine the individual model runs.

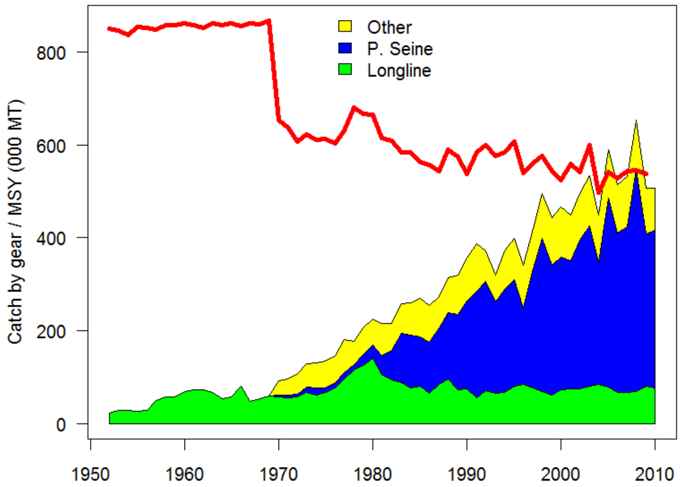


Figure 18: History of annual estimates of MSY compared with catches of three major fisheries sectors. Declining MSY results from the change in selectivity of fishing gear and increases in catches of small yellowfin.

Table 16. Estimates of management quantities for selected stock assessment models from the 2011 base case model LLcpueOP_TWcpueR6_PTTP (H80-pttp) and the five combinations of steepness and tagging data sets included. For the purpose of this assessment, "current" is the average over the period 2006–2009 and "latest" is 2010.

	H80-pttp (Base case)	H65-pttp	H95-pttp	H80-no pttp	H65- no pttp	H95- no pttp
	551,120	551,300	551,283	551,488	551,508	551,480
	507,100	507,443	507,358	508,329	508,398	508,286
	538,800	498,000	644,800	493,600	432,000	551,200
	1.02	1.11	0.85	1.12	1.28	1.00
	0.94	1.02	0.79	1.03	1.18	0.92
	1.30	1.10	1.84	1.11	0.87	1.44
	0.77	0.91	0.54	0.90	1.15	0.70
	2,001,000	2,272,000	2,145,000	2,035,000	2,108,000	1,984,000
	0.29	0.34	0.24	0.30	0.34	0.25
	0.42	0.43	0.45	0.40	0.39	0.41
	0.37	0.38	0.40	0.32	0.31	0.32
	1.47	1.28	1.92	1.34	1.14	1.67
	1.30	1.12	1.69	1.06	0.90	1.32
	0.44	0.47	0.47	0.40	0.40	0.40
	0.41	0.44	0.44	0.35	0.35	0.35
Steepness (*h*)	0.80	0.65	0.95	0.80	0.65	0.95

Table 17. Comparison of WCPO yellowfin tuna reference points from the 2011 reference case model (with uncertainty based on the six models in Table 5); the 2009 and 2007 assessments (across a range of models).

Management quantity	2011 assessment	2009 Assessment	2007 Assessment
Most recent catch	507 100	539 481 mt (2008)	426 726 mt (2006)
MSY	538 800 (432 000-644 800)	Range: 493 600 ~ 767 200 mt	Base case: 400 000 mt Range: 344 520 ~ 549 200 mt
$F_{current}/F_{MSY}$	0.77 (0.54-1.15)	Range: 0.41 ~ 0.85	Base case: 0.95 Range: 0.56 ~ 1.0
$B_{current}/B_{MSY}$	1.33 (1.12-1.54)	Range: 1.38 ~ 1.88	Base case: 1.17 Range: 1.13 ~ 1.42
$SB_{current}/SB_{MSY}$	1.47 (1.14-1.92)	Range: 1.44 ~ 2.43	Base case: 1.25 Range: 1.12 ~ 1.74
$Y_{Fcurrent}/MSY$	0.97 (0.88-0.99)	Range: 0.76 ~ 0.98	Base case: 1.0 Range: 0.88 ~ 1.0
$B_{current}/B_{current,\ F=0}$	0.53 (0.48-0.55)	Range: 0.53 ~ 0.63	Base case: 0.51 Range: 0.51 ~ 0.58
$SB_{current}/SB_{current,\ F=0}$	0.44 (0.40-0.47)		

5.1 Estimates of fishery parameters and abundance

There are no fishery-independent indices of abundance for the yellowfin tuna stock. Relative abundance information is available from longline catch per unit effort data, though there is no agreement on the best method to standardise these. Returns from a large scale tagging programmes undertaken in the early 1990s and 2000s also provide information on rates of fishing mortality which in turn leads to improved estimates of abundance.

5.2 Biomass estimates

These estimates apply to the WCPO portion of the stock or an area that is approximately equivalent to the waters west of 150°W. The trend in biomass for the WCPO is largely driven by the biomass trend from the tropics i.e. region 3 (Langley *et al.*, 2011) (http://www.wcpfc.int/). The ratios $B_{current}/B_{current\ F=0}$ provide a time-series index of population depletion by the fisheries. Depletion has increased steadily over time, reaching a level of about 53% of unexploited biomass (a fishery impact of 47%) in 2010. This represents a moderate level of stock-wide depletion. Overall, the impact of fishing has reduced the current total biomass in region 3 to about 42% of the unexploited level, while the current total WCPO biomass is sustained by the lower impacts outside of the equatorial regions. If stock-wide over-fishing criteria were applied at the level of the model regions, we would conclude that region 3 is fully exploited and the remaining regions are under-exploited.

The attribution of depletion to various fisheries or groups of fisheries indicates that the Philippines/Indonesian domestic fisheries and associated purse-seine fishery have the highest impact, particularly in region 3, while the unassociated purse seine fishery has a moderate impact. These fisheries are also contributing significantly to the fishery impact in all other regions. Historically, the coastal Japanese pole-and-line and purse-seine fisheries have had a significant impact on biomass levels in their home region (1). Overall, the longline fishery has a relatively small impact, less than 5%.

5.3 Estimation of Maximum Constant Yield (MCY)

No estimates of MCY are available.

5.4 Estimation of Current Annual Yield (CAY)

No estimates of CAY are available.

5.5 Other yield estimates and stock assessment results

Though no reference points have yet been agreed by the WCPFC, stock status conclusions are generally presented in relation to two criteria. The first reference point relates to "overfished" which compares the current biomass level to that necessary to produce the maximum sustainable yield (MSY). The second relates to "over-fishing" which compares the current fishing mortality rate to that which would move the stock towards a biomass level necessary to produce the MSY. The first criteria is similar to that required under the New Zealand Fisheries Act while the second has no equivalent in our legislation and relates to how hard a stock can be fished.

Because recent catch data are often unavailable, these measures are calculated based on the average fishing mortality/biomass levels in the 'recent past', e.g., 2006-2009 for the 2011 assessment.

The estimate of MSY is lower than recent catches in some model runs. This is due to high fishing mortality and fishing down the stock towards B_{MSY}-levels. The SB ratio larger than 1.0 indicates that the stock is not in an overfished state. The ratio of $F_{current}$ compared with F_{MSY} (the fishing mortality level that would keep the stock at MSY) is less than 1.0 indicating that overfishing is not occurring.

5.6 Other factors

It is thought that large numbers of small yellowfin tuna are taken in surface fisheries in Indonesia and the Philippines. There are considerable uncertainties in the exact catches and these lead to uncertainties in the assessment. Programmes are in place to improve the collection of catch statistics in these fisheries.

6. STATUS OF THE STOCKS

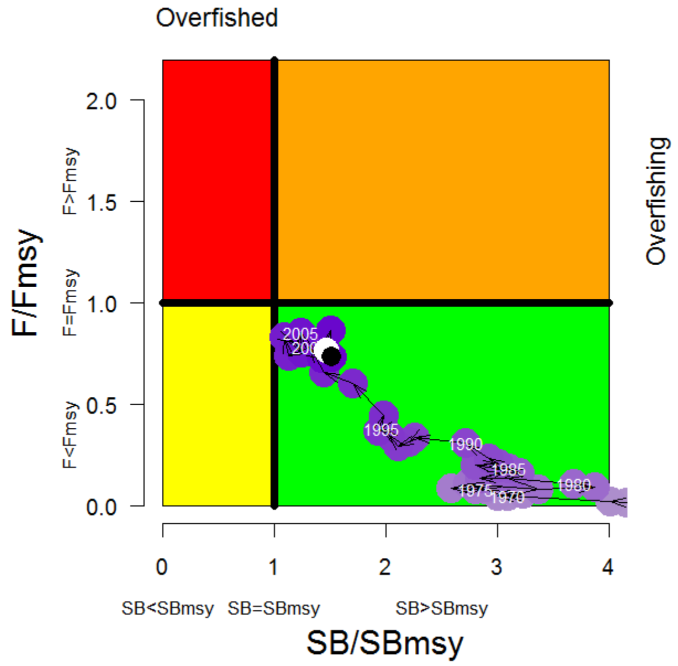
Stock structure assumptions

Western and Central Pacific Ocean

All biomass in this Table refer to spawning biomass (SB)

Stock Status	
Year of Most Recent Assessment	2011
Assessment Runs Presented	Base case model only
Reference Points	Target: SB > SB_{MSY} and F < F_{MSY} Soft Limit: Not established by WCPFC; but evaluated using HSS default of 20% SB_0. Hard Limit: Not established by WCPFC; but evaluated using HSS default of 10% SB_0.
Status in relation to Target	Likely (> 60%) that SB > SB_{MSY} and Unlikely (< 40%) that F > F_{MSY}
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Unlikely (< 40%) to be below

Historical Stock Status Trajectory and Current Status



Temporal trend in annual stock status, relative to SB_{MSY} (x-axis) and F_{MSY} (y-axis) reference points. The colour of the points is graduated from mauve (1972) to dark purple (2010). The black circle represents the B_{2010}/B_{MSY} and the F_{2010} / F_{MSY} the white circle represents the $B_{2006\text{-}2009}$ / B_{MSY} and $_{F2006\text{-}2009}$ / F_{MSY} (Langley *et al.* 2011).

Fishery and Stock Trends	
Recent trend in Biomass or Proxy	Biomass has been reduced steadily over time reaching a level of about 53% of unexploited biomass in 2005-2009. However, depletion is considerably higher in the equatorial regions 3 and 4 where biomass is estimated to have declined to about 17% of the level that is estimated to occur in the absence of fishing.
Recent Trend in Fishing Mortality or Proxy	Fishing mortality has increased over time but is estimated to be lower than F_{MSY} in all cases but for lower values of steepness is approaching F_{MSY}.
Other Abundance Indices	
Trends in Other Relevant Indicator or Variables	Recent (1998-2009) levels of estimated recruitment are considerably lower (80%) than the long-term average level of recruitment used to calculate the estimates of MSY. If recruitment remains at recent levels, then the overall yield from the fishery will be lower than the current MSY estimates.

Projections and Prognosis	
Stock Projections or Prognosis	Region 3 (the tropical WPO) is fully exploited and the remaining regions are under-exploited. Future stock trends are uncertain due to exploitation patterns and recruitment autocorrelation.
Probability of Current Catch causing decline below limits	Soft Limit: Unlikely (< 40%) Hard Limit: Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1: Quantitative Stock assessment	
Assessment Method	The assessment uses the stock assessment model and computer software known as MULTIFAN-CL.	
Assessment Dates	Latest assessment: 2011	Next assessment: 2014
Overall assessment quality rank	1 - High Quality	
Main data inputs (rank)	The yellowfin tuna model is age (28 age-classes) and spatially structured (6 regions) and the catch, effort, size composition and tagging data used in the model are classified by 24 fisheries and quarterly time periods from 1952 through 2009.	1 - High Quality
Data not used (rank)		
Changes to Model Structure and Assumptions	While the structure of the assessment model was similar to the previous (2009) assessment, there were some substantial revisions to a number of key data sets, specifically the longline CPUE indices, catch and size data, purse-seine catch and size data, and the configuration of the Indonesian and Philippines domestic fisheries.	
Major Sources of Uncertainty		

Qualifying Comments
The biomass trends in the model are principally driven by the time-series of catch and GLM standardised effort from the principal longline fisheries. The current assessment incorporated a revised set of longline CPUE indices and, for some model options, the indices were modified to account for an estimate increase in longline catchability. Further research is required to explore the relationship between longline CPUE and yellowfin abundance and the methodology applied to standardise the longline CPUE data. The spawning biomass in region 3 is estimated to have been reduced to approximately 30% of the unexploited level; however, due to the lower overall depletion of the entire WCPO stock, the model assumes that there has been no significant reduction in the spawning capacity of the stock.

Fishery Interactions
Interactions with protected species are known to occur in the longline fisheries of the South Pacific, particularly south of 25°S. Seabird bycatch mitigation measures are required in the New Zealand, Australian EEZ's and through the WCPFC Conservation and Management Measure (CMM2007-04). Sea turtles also get incidentally captured in longline gear; the WCPFC is attempting to reduce sea turtle interactions through Conservation and Management Measure (CMM2008-03). Shark bycatch is common in longline fisheries and largely unavoidable; this is being managed through New Zealand domestic legislation and to a limited extent through Conservation and Management Measure (CMM2010-07).

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