Ministry for Primary Industries
Manatū Ahu Matua

Species composition and seasonal variability in commercial purse-seine catches of jack mackerel (*Trachurus declivis, T. murphyi, and T. novaezelandiae*) in JMA 1 between January 2009 and September 2011

New Zealand Fisheries Assessment Report 2012/46

C. Walsh
R. Bian
J. M. McKenzie
A. Miller
K. Spong
H. Armiger

ISSN 1179-5352 (online)
ISBN 978-0-478-40473-9 (online)
November 2012

New Zealand Government

Growing and Protecting New Zealand

Requests for further copies should be directed to:

Publications Logistics Officer
Ministry for Primary Industries
PO Box 2526
WELLINGTON 6140

Email: brand@mpi.govt.nz
Telephone: 0800 00 83 33
Facsimile: 04-894 0300

This publication is also available on the Ministry for Primary Industries websites at:
http://www.mpi.govt.nz/news-resources/publications.aspx
http://fs.fish.govt.nz go to Document library/Research reports

© Crown Copyright - Ministry for Primary Industries

EXECUTIVE SUMMARY

Walsh, C.; Bian, R.; McKenzie, J.M.; Miller, A.; Spong, K., Armiger, H. (2012). Species composition and seasonal variability in commercial purse-seine catches of jack mackerel (*Trachurus declivis, T. murphyi, and T. novaezelandiae*) in JMA 1 between January 2009 and September 2011.

***New Zealand Fisheries Assessment Report 2012/46.* 41 p.**

This report presents the results of Objectives 1–3 of the Ministry of Primary Industries project "Catch composition of jack mackerel fisheries in JMA 1" (JMA200901). The general objective was to determine the seasonality and species composition of the commercial purse-seine landings of *Trachurus declivis, T. murphyi, and T. novaezelandiae* from JMA 1 between January 2009 and September 2011 by market sampling. In addition, a characterisation was undertaken to describe the fishery catch and assess the representativeness of the sampling programme.

A total of 72 purse-seine landings from JMA 1 were sampled to determine the species composition of the catch from this fishery between January 2009 and September 2011. Between 300 and 500 ungraded jack mackerel were randomly sampled from each purse-seine landing. Species were separated, measured for length, and total species sample weights recorded.

The sample data were temporally stratified by month to estimate the proportions of the three jack mackerel species. The proportion of each species in a landing was calculated from the species weight divided by the total weight in the sample of the landing. A monthly species proportion was determined by the weighted mean of the species proportions estimated for the sampled landings within the month, with the corresponding landed catches as weightings. A species proportion for each fishing year or calendar year was calculated from the weighted mean of the monthly proportions with weightings of the corresponding month catches in the fishing year or calendar year. The uncertainty in estimating species proportions (c.v.s) were derived by bootstrapping the sampled landings and the fish within the sampled landings.

Where samples were unavailable, the species proportion for the un-sampled month was substituted from the corresponding calendar year estimate, and fishing year and calendar year species proportions were calculated from the weighted mean of all the months

An alternative seasonal stratification is proposed, which avoids estimating monthly proportions for the sampled months and substituting annual estimates for those un-sampled months. From this, species proportions were estimated for the season, fishing year and calendar year.

Purse-seine landings from JMA 1 were dominated by *T. novaezelandiae* in 70 (97%) of the 72 sampled landings. The estimated proportions for fishing and calendar year ranged from 1 to 17% for *T. declivis*, 0 to 3% for *T. murphyi*, and 81 to 99% for *T. novaezelandiae*. There was spatial and temporal heterogeneity in size and abundance of each species within JMA 1, with *T. novaezelandiae* dominating landings from the Bay of Plenty fishery throughout the year. Large *T. declivis* and *T. murphyi* were common in East Northland during winter. Precision on species proportions was high for *T. novaezelandiae* (MWCV less than 0.10), which was the most common and abundant of the jack mackerel species caught in JMA 1 during the study; well below the target estimate of 0.30. The precision of the estimates for *T. declivis and T. murphyi* were low (MWCV greater than 0.30), reflecting the highly variable occurrence for these species in recent JMA 1 purse-seine landings.

Over 54 000 jack mackerel were measured for length frequency from the JMA 1 purse-seine fishery over the study period. The length composition of the *T. novaezelandiae* catch was the narrowest of all the jack mackerels, comprised the smallest size range (98% of fish between 27 and 35 cm), and

showed little variability between years. The length composition of *T. declivis* varied considerably between landings, with low numbers of both small and large fish present at different times. Although *T. murphyi* were the least commonly caught species, they were the largest by size. Mean lengths and precision (MWCV) for the respective species sampled over the consecutive fishing years were as follows: *T. novaezelandiae* 30.8 cm (0.10) for both years; *T. declivis* 37.0 and 42.1 cm (0.30 and 0.44); *T. murphyi* 50.0 cm (0.34).

Although sampling performance was disproportionally lower in the beginning of each fishing year compared to the end, overall, it was considered to be distributed in reasonable proportion to, and representative of the fishery operation. The derived species proportions and length compositions given in this report should provide adequate and representative descriptions of the temporal and spatial spread of purse-seine catches from the JMA 1 fishery for the period January 2009 to September 2011. Data are presented by fishing year (October–September) to satisfy the reporting requirements to the New Zealand Ministry of Primary Industries (MPI), and by calendar year, as required by the South Pacific Regional Fisheries Management Organisation (SPRFMO), and the Food and Agriculture Organisation (FAO).

1. INTRODUCTION

1.1 Overview

Jack mackerel stocks support one of New Zealand's largest commercial fisheries, with a national Total Allowable Commercial Catch (TACC) of over 60 000 t. An estimated $42 million was earned from jack mackerel exports in 2011, the fourth most important finfish in New Zealand (Seafic website). Three species of jack mackerel are caught in New Zealand waters, two New Zealand species, *Trachurus declivis* (JMD; greenback horse mackerel) and *T. novaezelandiae* (JMN; yellowtail horse mackerel), and a third exotic species - *T. murphyi* (JMM; Chilean jack mackerel) which appeared in New Zealand in the mid-1980s.

The geographical distributions of all three species differ, but their ranges partially overlap. *T. novaezelandiae* predominates in waters shallower than 150 m and warmer than 13 ºC, and is uncommon south of latitude 42º S. *T. declivis* generally occurs in deeper (to 300 m) waters less than 16 ºC, and north of latitude 45º S. *T. murphyi* occurs to depths of least 500 m and has a wide geographical range extending from South America, across the South Pacific, and through much of the New Zealand EEZ, and south-eastern Australia (Ministry for Primary Industries 2011). Introduced to the Quota Management System (QMS) in 1 October 1996, all three jack mackerel species are recorded as an aggregate under the general code, JMA. Accordingly it is not possible to determine the quantity of each species caught annually from commercial catch landings data. However, reliable information on the composition of the three species in commercial catches is deemed essential for management and assessment of the stocks. Consequently estimates of species proportions have been used to apportion the aggregated catch histories into individual catch histories for each species, back to when sampling began (Taylor & Julian 2008, Penney et al. 2011).

All three species of jack mackerel occur in JMA 1 which encompasses the entire east coast of the North Island (Figure 1). Over 95% of annual landings are taken by domestic purse-seine vessels, by a target fishery operating out of Tauranga that fishes in the Bay of Plenty and along the East Northland coast. The annual TACC for JMA 1 has remained at 10 000 t for almost two decades, and was exceeded in 2007–08 (11 167 t), with landings remaining consistently high at over 90% of the TACC in subsequent years (Figure 2). Despite this, the size of the JMA 1 resource is unknown, as is the long term sustainability of current catch levels. Although substantially smaller than the commercial fishery in relative terms, the annual recreational harvest is thought to be in the order of 100 t.

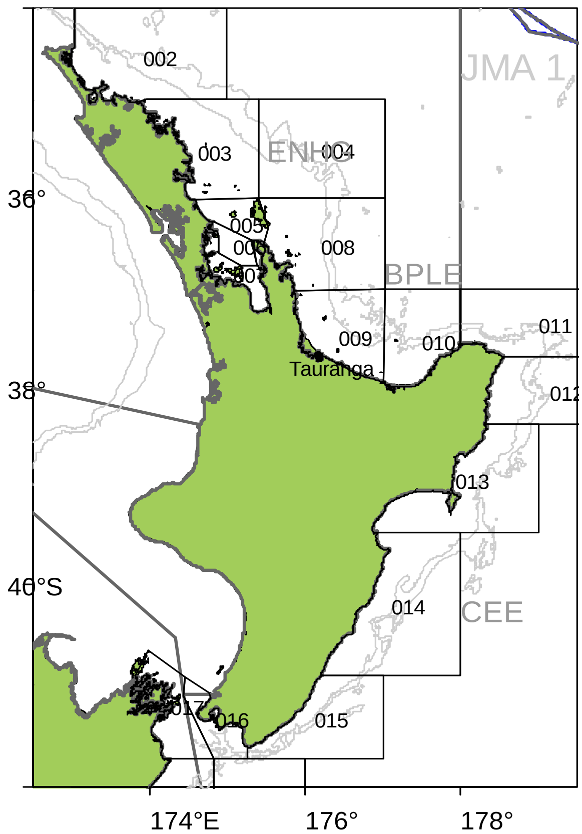

Figure 1: Quota Management Area for the east coast North Island jack mackerel stock, JMA 1 and the range of the three subareas used in this report: East Northland/Hauraki Gulf (ENHG), Bay of Plenty (BPLE), and Central East (CEE) of the North Island.

Increased availability of jack mackerels since the 1980s caused by the invading *T. murphyi* resulted in increased quotas in JMA 1 (1993–94 and 1994–95; Figure 2) under the proviso that they be accounted for by increased catches of *T. murphyi* only. The fishing industry agreed to these restrictions and voluntarily introduced monitoring programmes to provide the information necessary for them to be met. However, this information pertains to the ability to distinguish the two New Zealand species (*T. declivis* and *T. novaezelandiae*) combined from *T. murphyi* i.e., catches of the two New Zealand species are not separated.

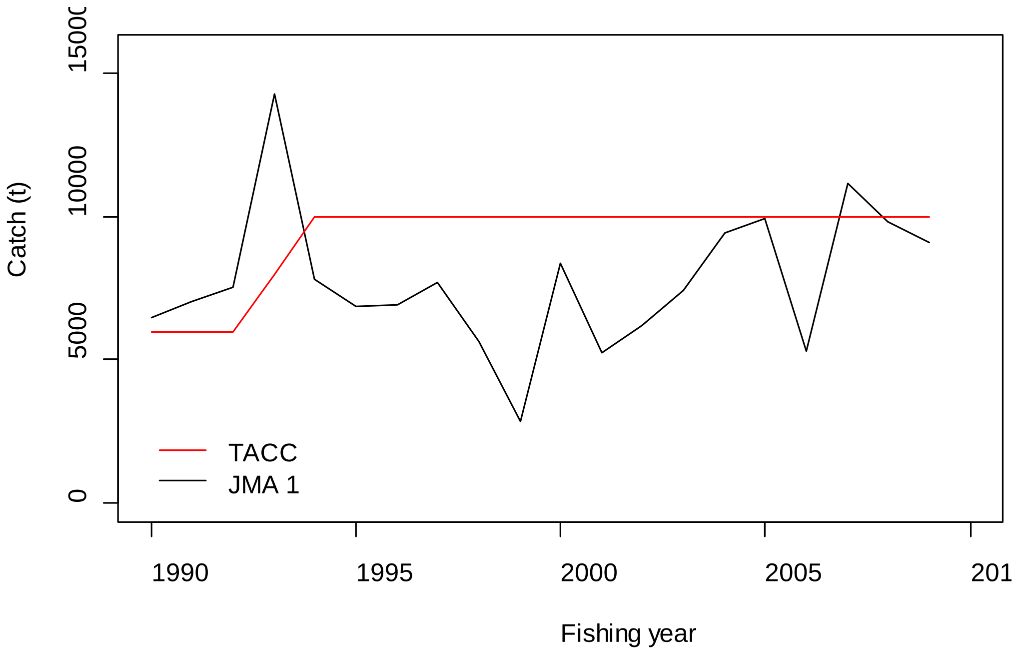

Figure 2: Reported landings of jack mackerel (t) in JMA 1 from 1990–91 to 2009–10 and gazetted and actual TACCs (t) for 1990–91 to 2009–10.

Relative proportions of the jack mackerel species in New Zealand were first estimated by Horn (1991b). The first species proportion estimates for the JMA 1 purse-seine fishery were derived from market sampling data collected between 1994 and 1996, which were used to produce catch histories for the three species for use in a stock reduction model (Taylor 1998). Since that time, an unbroken time series collection of fishing year (1 October to 30 September) species proportions data has been sampled from the JMA 1 purse-seine fishery and this information is featured in a number of reports (Taylor 1998, Taylor 1999, Taylor 2000, Taylor 2002, Taylor 2004a, 2004b, Taylor & Julian 2008, Taylor et al. unpublished FAR 2012, Penney et al. 2011). Penney et al. (2011) determined the monthly JMA 1 species proportions for the period October 1985 to December 2010 to investigate historical catch and catch composition trends, and to provide the South Pacific Regional Fisheries Management Organisation with data for the three jack mackerel species by calendar year.

1.2 Scope of the report

This report presents the results of market sampling data for three *Trachurus* species in the JMA 1 purse-seine fishery for length, species composition, and seasonality, between January 2009 and September 2011, which further extends the existing time series. Funding for this project, JMA200901, was provided by the Ministry for Primary Industries. Data are presented by fishing year (October–September) to satisfy the reporting requirements to the New Zealand Ministry for Primary Industries (MPI), and calendar year, for the South Pacific Regional Fisheries Management Organisation (SPRFMO), and the Food and Agriculture Organisation (FAO).

JMA200901 objectives
The specific objectives of this project for 2009–10 and 2010–11 were:

1. To characterise the fishery in order to inform the sampling design development.

2. To collect representative samples from fish processing sheds to determine the age, length, seasonality, and species composition of the commercial catches of *T. declivis*, *T. murphyi*, and *T. novaezelandiae* in JMA 1 in the 2009/2010 and 2010/2011 fishing years and the 2009 and 2010

calendar years (SPRFMO requirement). The target coefficient of variation (CV) for the catch-at-age will be 30% (mean weighted CV across all age classes).

3. To explore the time series of catch sampling data for the three jack mackerel species. Determine any significant changes in the species composition of commercial catches and any indications of change in stock status in JMA 1.

A Northern Inshore Finfish Working Group meeting in December 2010 (NINSWG-2010/65) found temporal inconsistencies in length and age composition of the purse-seine catch of *T. declivis* and *T. novaezelandiae* from samples collected in the 2006–07, 2007–08 (JMA200601), and 2008–09 (PEL200803) fishing years. The fishery did not appear to be sampling the populations in a consistent fashion, and selectivity appeared highly variable, possibly as a result of fisher (due to market forces) and fish behaviour. They concluded that catch-at-age sampling was unlikely to provide an effective monitoring tool for the stock status of these species, and given the high costs, that ageing should be suspended. As a result, the age component in objective 2 above was discontinued part way through this project, and is not reported on.

2. METHODS

2.1 Characterisation of recent fishery profile data for JMA 1, 1990–91 to 2010–11

A characterisation of patterns in the JMA 1 stock and subarea fisheries (East Northland/Hauraki Gulf (ENHG), Bay of Plenty (BPLE), and Central East (CEE) of the North Island) over the period October 1990 through to September 2011 was undertaken using data extracted from the Ministry for Primary Industries' commercial catch reporting system. The basic premise of the requested extract was to provide all effort details and associated catch weights (for all jack mackerel species) from all trips landing JMA 1 catch.

Data obtained from the Ministry was groomed and checked for typical reporting errors. Information to perform the characterisation was compiled into two tables:

1. Landed catch weight: a file containing the verified green (unprocessed) landed weight of all JMA 1 trips.
2. Trip specific data: a file containing demographic information (location, method, target species, estimated catch etc) for each trip.

Although the trip effort data table has information on catch, these are only fisher estimates. Actual trip landed weight totals were prorated across the effort information (location, method, target species) on the basis of the estimated catch ratios. The link between the two data tables was the common trip number field (trip_key).

There are genuine instances where catch is reported on the Ministry for Primary Industries landing forms but is not discharged from the vessel. Retained catches get declared again when subsequently discharged, thus there is potential to double count these landings. Non-terminating catches are identifiable in Ministry for Primary Industries landing records and were excluded from the characterisation totals.

2.2 Design of JMA 1 sampling in 2009–10 and 2010–11

2.2.1 Market sampling for length and species composition

A stratified sampling approach was previously employed when sampling purse-seine landings at Sanford Ltd (Tauranga) and Pelco NZ Ltd (Mt Maunganui), with strata based on manual or mechanical grading systems. The introduction of a mechanical fish grading machine in 2003 caused uncertainty in the sampling method (Rohan et al. 2006), and an alternative random design was adopted, that sampled ungraded fish, as described by Taylor & Julian (2008). Market sampling of jack mackerels for species proportions and length frequency in 2009–10 and 2010–11 followed this design, and was carried out at Sanford Ltd by NIWA and Sanford staff, and at Pelco NZ Ltd by NIWA staff.

A random sample of about 300–500 ungraded jack mackerel was taken from each purse-seine landing selected for sampling, sorted and weighed by species and measured for length. No independent examination of species proportions was determined for either of the two fishing companies. Data were instead treated as being selected from a single stratum fishery, with the overall species proportions estimated from the data from the two companies combined, and not separately.

2.3 Data analysis for JMA 1

2.3.1 Deriving fishing-year and calendar-year species proportion estimates

The time period of sample collections taken from the JMA 1 purse-seine fishery spanned 33 months, January 2009 to September 2011. The proportions of *T. declivis*, *T. murphyi* and *T. novaezelandiae* (referred to herein section 2.3.1 as JMD, JMM and JMN) in the JMA 1 catch by fishing-year and calendar-year were estimated using three different approaches:

Approach I: Stratification by month: temporally stratify the sampled landings by month and estimate species proportions for each month. Subsequently derive species proportion estimates by fishing year (October–September) and calendar year as the catch-weighted mean of the sampled month estimates ignoring un-sampled months.

Approach II: Using substituted monthly estimates for un-sampled months: Include catch from un-sampled months in the fishing and calendar year estimates by assigning the un-sampled months with the species proportion estimates for the corresponding calendar year (obtained in Approach I) and calculate the catch-weighted mean of monthly species proportions by fishing year and calendar year.

Approach III: Stratification by season: temporally stratify samples by two seasons, early: January–September and late: October–December, and estimate the species proportions for each season. Subsequently derive fishing year (October–September) and calendar year proportional estimates as a weighted mean of the component seasons.

2.3.1.1 Approach I: Aggregate species proportions derived using sampled months only

Data from individual sampled landings were temporally stratified by month to estimate the proportions of the three jack mackerel species for a fishing year or calendar year period. Initially species proportions were calculated for each sampled landing from the weight of each species divided by the total weight in the sample of the landing. Proportion estimates from each sampled landing were then grouped by month as a weighted mean where the weights were the tonnage of each landing (for all species combined). A species proportion for a fishing year or calendar year was calculated from the weighted mean of the monthly proportions with weightings of the corresponding month catches in the fishing year or calendar year. The uncertainty (c.v.) of each species proportion was estimated by bootstrapping fish within sampled landings, from landings bootstrapped within months, for each calendar or fishing year.

Assuming $\tilde{w}_l^{(.)}$ is the sample weight of one of the species (JMD, JMM or JMN) in sampled landing *l*, $\tilde{w}_l$ is the combined sample weight of all jack mackerel species in sampled landing *l*, and w_l is the total catch weight of all jack mackerel species in sampled landing *l*, $l \in m$ meaning landing *l* was landed in month m. The proportion of one of the three species for month m, $p_m^{(.)}$, was calculated by

$$p_m^{(.)} = \frac{1}{\sum_{l \in m}(w_l)} \sum_{l \in m} \left(\frac{\tilde{w}_l^{(.)}}{\tilde{w}_l} \cdot w_l\right) \qquad (1)$$

where (.) = (JMD), (JMM), or (JMN). Given the catch of jack mackerel from landings in month m (w_m) in calendar year y ($m \in y$), the proportion of one of the three species for year y ($p_y^{(.)}$) was calculated by

$$p_y^{(.)} = \frac{1}{\sum_{m \in y}(w_m)} \sum_{m \in y} (p_m^{(.)} \cdot w_m) \qquad (2)$$

Equation (2) was also used to calculate species proportions for fishing year f, $p_f^{(.)}$, with the replacement of $m \in y$ by $m \in f$. Equation (2) can be used in calculating species proportions for any grouping of months of interest, e.g., specific seasons.

We used bootstrapping to estimate the uncertainty associated with species proportion estimates for month, season, fishing year and calendar year. We bootstrapped (randomly sampled with replacement) the sampled landings and the fish of each species within the sampled landings n times (where $n = 1000$), and estimated c.v.s.

Step 1. Estimating c.v.s for monthly species proportion estimates

a) bootstrap the original sampled landings within month m

b) bootstrap fish within the sample of each landing selected in the bootstrap and calculate weight for the bootstrapped sample of the landing.

Assuming landing l is a landing randomly selected from the bootstrap and *K*, *M* and *N* are the numbers of fish of species JMD, JMM and JMN in the sample data of landing l, we generate a string of symbols with length of the number of fish in the sample composed with *K* JMDs, *M* JMMs and *N* JMNs.

i) if fish lengths for all three species are available in the sample data, a string will be generated in the form of JMDlen_1, JMDlen_2, ..., JMDlen_K, JMMlen_1, JMMlen_2, ..., JMMlen_M, JMNlen_1, JMNlen_2,..., JMNlen_N. If length data for any of the species, say JMD, are not available, the part of the string for JMD will be JMDlen_1, JMDlen_1, …, JMDlen_1 and its length will be *K*.

ii) sample the string with replacement

iii) use each species' length-weight relationship to calculate the weight for the fish for which length data are available and use mean weight per fish for the fish for which length data are not available and calculate the bootstrapped sample weight by summing the weights of all the fish.

The species specific length-weight relationships (refer to section 2.3.2) that we used to calculate the weights of each species were:

JMD: a = 0.000023, b = 2.84 (Horn, 1991a)
JMM: a = 0.0000162, b = 2.85 (Basten 1981)
JMN: a = 0.000028, b = 2.84 (Horn, 1991a)

c) calculate species proportions for month m using Equation (1)

d) repeat steps a) through c) n times and obtain n monthly proportions, $p_{m,1}^{(.)}$, $p_{m,2}^{(.)}$, …, $p_{m,n}^{(.)}$, (.)=(JMD), (JMM), or (JMN)

e) calculate coefficient of variation (c.v.) for the monthly species proportion estimate $p_m^{(.)}$

$$\text{c.v.}\,(p_m^{(.)}) = \frac{1}{\bar{p}_m^{(.)}}\sqrt{\frac{\sum_{i=1}^{n}(p_{m,i}^{(.)}-\bar{p}_m^{(.)})^2}{n-1}} \qquad (3)$$

where $\bar{p}_m^{(.)}$ is the mean of the $p_{m,1}^{(.)}, p_{m,2}^{(.)}, \ldots, p_{m,n}^{(.)}$, i.e., $\bar{p}_m^{(.)} = \frac{1}{n}\sum_{i=1}^{n} p_{m,i}^{(.)}$.

Step 2. Estimating c.v.s for fishing year and calendar year species proportions

The methods for calculating species proportions for fishing year, calendar year are identical, so the process described below for determining c.v.s of annual species proportions is also applicable for fishing year and season.

a) bootstrap the original landings across months within calendar year y

b) bootstrap fish from each bootstrap-selected landing, see b) in Step 1 for details, and calculate weight for the bootstrapped sample of the landing

c) calculate species proportions for month ($p_{m,i}^{(.)}$) using Equation (1). Note: the months in a bootstrap are not necessarily the same as the months in the original landing sample data.

d) calculate annual species proportion ($p_{y,i}^{(.)}$) for year y using Equation (2)

e) repeat steps a) through d) for n times and obtain n proportions $p_{y,1}^{(.)}$, $p_{y,2}^{(.)}$, …, $p_{y,n}^{(.)}$, (.)=(JMD), (JMM), or (JMN)

f) calculate c.v. for the species proportion of season s

$$\text{c.v.}\,(p_y^{(.)}) = \frac{1}{\bar{p}_y^{(.)}}\sqrt{\frac{\sum_{i=1}^{n}(p_{y,i}^{(.)}-\bar{p}_y^{(.)})^2}{n-1}} \qquad (4)$$

where $\bar{p}_y^{(.)}$ is the mean of the $p_{y,1}^{(.)}, p_{y,2}^{(.)}, \ldots, p_{y,n}^{(.)}$, i.e., $\bar{p}_y^{(.)} = \frac{1}{n}\sum_{i=1}^{n} p_{y,i}^{(.)}$.

Equation (4) was also used to calculate c.v.s for fishing year f, $\text{c.v.}(p_f^{(.)})$, with the replacement of y by f for the three species, JMD, JMM and JMN.

2.3.1.2 Approach II: substituting annual monthly estimates for un-sampled months

Monthly proportions of jack mackerel species were estimated for the sampled months using Equation (1). In the time period January 2009 – September 2011, there were a number of months in which jack mackerel landings were not sampled. For the un-sampled months, the monthly proportions of the jack mackerel species were substituted with the estimated species proportions for the corresponding calendar year (Penney et al. 2011 and personal communication with Marc Griffiths). Because the sampling period for 2011 was constrained to 9 months (January to September), due to the 2010–11 fishing year period, the annual species proportion for the 2011 calendar year could not be determined and therefore monthly species proportions for the un-sampled months in 2011 cannot be substituted. As a result, proportion means have been calculated for the following time periods: seasons 2008–09 late, 2009–10 early, and 2009–10 late; fishing year 2009–10; calendar years 2009 and 2010.

Species proportion mean for calendar year y, $p_y^{(.)}$, is the weighted mean of the monthly proportions estimated or substituted for the months in the year, $p_{m\in y}^{(.)}$, and the weightings are the catches of one of the three species in the corresponding months, i.e.,

$$p_y^{(.)} = \frac{1}{\sum_{m\in y}(w_m)} \sum_{m\in y}(p_m^{(.)} \cdot w_m) \quad (5)$$

The right hand side of Equation (5) appears identical to Equation (2), but the months in Equation (5) include both sampled and un-sampled, while those in Equation (2) are only sampled months.

The species proportion means for fishing year were also calculated from Equation (5) with replacement of y by f.

2.3.1.3 Approach III: stratification by season

As sampling was not always undertaken in every month or in proportion to the operation of the fishery, this may influence the precision of the species proportions estimated with the methods outlined in section 2.3.1.1. The method discussed in section 2.3.1.2 reflects the effort that has been made to try to address the sampling hiatus issue. For the samples that have been made, we propose an alternative stratification method, which is to group months into seasons and then estimate species proportions for the seasons. Based on these seasonal proportion estimates, the species proportions for fishing year and calendar year were determined.

We considered the following factors in the seasonal stratification: 1) the species proportion in commercial catches tend to differ by seasons; 2) the seasons do not cross fishing year or calendar year; 3) there are samples from landings in all seasons. Based on these considerations, two seasons were selected: 1 January through to 30 September and 1 October through to 31 December.

The process of estimating seasonal species proportions was similar to the process of estimating monthly species proportions discussed in section 2.2.1.1 and Equation (1) was used in the estimation, with the replacement of month $\boldsymbol{m}$ by season $\boldsymbol{s}$ and $\boldsymbol{p_m^{(.)}}$ by $\boldsymbol{p_s^{(.)}}$. Equation (2) was used in estimating fishing year and calendar year species proportions, with the replacement of month $\boldsymbol{m}$ by season $\boldsymbol{s}$.

C.v.s were estimated for the species proportion estimates for season, fishing year and calendar year using bootstraps. The methods discussed in Step 1 of section 2.3.1.1 were used in estimating c.v.s of seasonal proportion estimates, with the replacement of month $\boldsymbol{m}$ by season $\boldsymbol{s}$ and methods in Step 2 for the c.v.s of the calendar and fishing year proportion estimates.

2.3.2 Estimating species length compositions

Length measurements were made from the selected species proportion samples to obtain length frequency summaries for each species by season, fishing year, and calendar year. All fish in the sample were measured to the nearest centimetre below the fork length. The sex of each measured fish was not determined, as jack mackerel do not appear to show differential growth between sexes (Horn 1993, Lyle et al. 2000).

Catch-at-length estimates were produced using NIWA's C++ software tool CALA (catch-at-length and -age, Francis & Bian 2011). The length frequency of each jack mackerel species was determined independently and in this analysis, the length frequencies were estimated for the catches in fishing years.

To estimate length frequencies for a landing, the length frequencies estimated from the sample of the landing were scaled up to the catch of the landing. Two methods can be used for the scaling: to scale by proportion or to scale to weight. To scale by proportion means that the length frequencies estimated from a sample are scaled by the proportion of the weight of the sample to the weight of the corresponding landing. The proportion for a sampled landing will be a constant and used in the scaling for the estimation of the length frequencies and in the bootstrap process of estimating the c.v.s of the frequency estimates. It is not necessary to know the weight of each bootstrap of the sample when using this method. However, the bootstraps of a sample will have different weights and by using the same proportion to scale up the scaled bootstrap weights will deviate from the original landing weight. The length frequencies for fishing year can be obtained by combining the landings' length frequencies and scaling to the weights of the landings in a month and fishing year by the corresponding proportions.

To scale to weight means that the length frequencies estimated from a sample is multiplied with a ratio so that the total weight of all the fish in the length frequencies will be equal to the weight of the corresponding landing. In the estimation of a sampled landing's length frequencies, the weights of both the landing and its sample are known and therefore a ratio can be calculated for the scaling. The weight of each bootstrap of the sample is unknown and needs to be estimated from the lengths of the bootstrapped fish and a length-weight relationship. The ratio will vary for different bootstraps in scaling the sample bootstraps, which have variable weights, to the weight of the sampled landing. Length frequency distributions for each fishing year were obtained by combining the landings' frequencies and scaling to the weights of the landings in a month and fishing year.

Although the two scaling methods were equivalent for estimating the length frequencies, the c.v.s of the estimates can be different due to the different scaling in the bootstrap process. To be consistent with the methods used in the species proportion estimates, we chose to use the second method, scaling-to-weight, in the catch-at-length analysis. The landing weights for *T. declivis* and *T. novaezelandiae*, and *T. murphyi* were calculated from the landing weights of jack mackerel and the species proportions estimated in section 2.3.1.

In New Zealand, length-weight relationships were available for *T. declivis* and *T. novaezelandiae*, but not for *T. murphyi* (Ministry for Primary Industries 2011), and was substituted with w (g) = $0.0162\ l^{2.85}$ (cm) (Basten 1981) based on *T. murphyi* samples collected in northern Chile in a study where more than 50 000 length-weight measurements were collected over four years.

The precision of each length frequency composition is measured by the mean weighted c.v. (MWCV). This was calculated as the mean of the c.v.s for the individual length classes weighted by the proportion of fish in each class. The c.v.s were calculated by bootstrapping, where fish were resampled 1000 times with replacement within each landing, and randomly resampled from the entire set.

Catch sampling data from the JMA 1 purse-seine fishery including landing information, species proportions, and length frequency data were stored on the Ministry for Primary Industries *market* database, which is maintained by NIWA.

Confirmation of the landed catch weight of jack mackerel and the statistical areas fished for each sampled landing was determined some months after sampling, based on data received from the Ministry for Primary Industries catch and effort returns.

3. RESULTS

3.1 Characterisation of JMA 1, 1990–91 to 2010–11

3.1.1 Data grooming errors

The “true” landed catch weights derived after removing non-terminating catch records from the landed catch data table are given in Table 1. Non-terminating (duplicate) catches varied from 0% to 6.2% of the annual reported JMA 1 catch. Over the last four years the non-terminating catch percentage has been in the order of 5% (Table 1).

The amount of annual catch that could be linked to (and prorated across) effort events varied between 78 and 99% (Table 1). An inspection of individual record data revealed that the inability to allocate landed JMA 1 catch to effort was due to the reported location (statistical area) of the effort being outside the JMA 1 boundaries. For example, 1000 t of the landed catch from JMA 1 was linked to trips occurring in JMA 3 and JMA 7 only. From the records it is not possible to determine whether the landed catch had been miscoded to JMA 1 or the wrong statistical area code had been entered in the effort forms. For the characterisations we have assumed the latter explanation is correct, and that the effort demographics of the proportion of unlinkable JMA 1 catch are the same as that of the catch that could be linked to effort (“Effort link” total in Table 1).

Table 1: Breakdown of total JMA 1 reported landed catch (t) by fishing year, showing total retained catch, actual landed catch, and the amount of catch that could be included in the characterisation (linked to effort).

Fishing year	Reported landed catch	Retained	% Retained	Actual landed catch	Effort link	% Effort
1990–91	7 376	0	0.0	7 376	7 286	98.8
1991–92	7 956	1	0.0	7 955	7 237	91.0
1992–93	8 918	0	0.0	8 918	8 199	91.9
1993–94	14 256	0	0.0	14 256	13 992	98.1
1994–95	10 454	0	0.0	10 454	9 927	95.0
1995–96	6 341	0	0.0	6 341	5 715	90.1
1996–97	6 994	99	1.4	6 895	6 659	96.6
1997–98	7 539	1	0.0	7 538	5 899	78.3
1998–99	5 551	0	0.0	5 551	5 466	98.5
1999–20	2 920	0	0.0	2 920	2 630	90.1
2000–01	8 243	1	0.0	8 242	8 019	97.3
2001–02	5 708	220	3.9	5 488	5 255	95.7
2002–03	6 078	6	0.1	6 072	6 018	99.1
2003–04	7 496	52	0.7	7 444	7 080	95.1
2004–05	9 509	150	1.6	9 359	9 289	99.3
2005–06	10 104	159	1.6	9 944	9 918	99.7
2006–07	5 152	4	0.1	5 148	5 100	99.1
2007–08	11 937	434	3.6	11 502	11 482	99.8
2008–09	10 418	628	6.0	9 790	9 705	99.1
2009–10	9 685	596	6.2	9 089	8 861	97.5
2010–11	8 683	289	3.3	8 395	8 236	98.1

3.1.2 Relative JMA 1 catch by subarea and method

Between 1990–91 and 2010–11, the largest proportion of the annual JMA 1 catch was taken from the Bay of Plenty (BPLE) subarea, and although significant catches were taken off East Northland and the outer Hauraki Gulf (ENHG) in 1993–94 and 1994–95, in most other years, catches were generally low (Figure 3; Appendix 1). Catches from the Central East (CEE) subarea in particular, have been consistently low for more than two decades (Figure 3; Appendix 1).

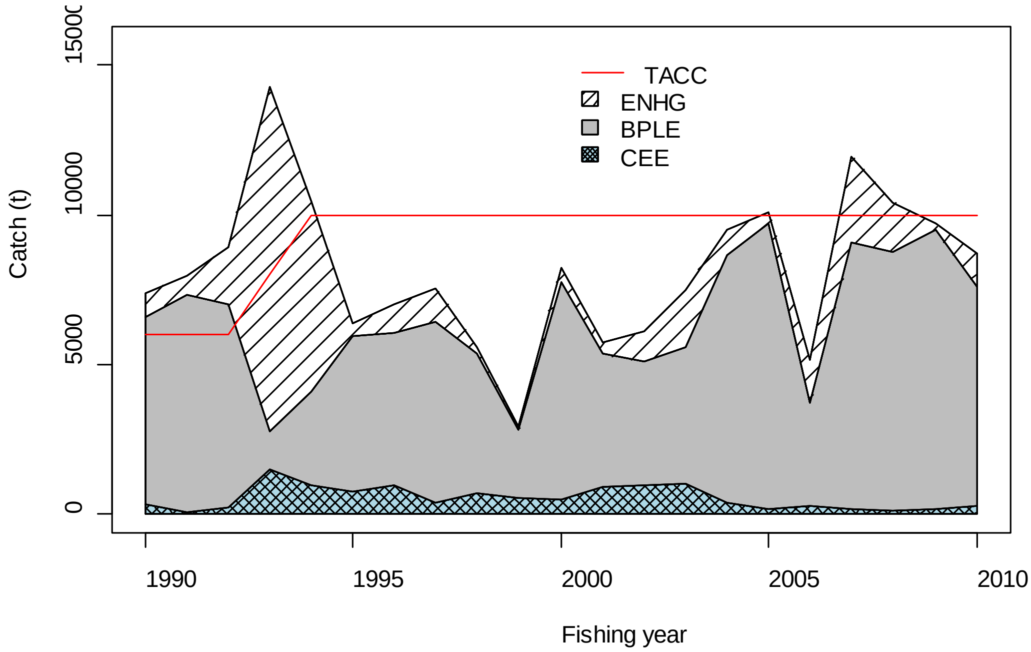

Figure 3: Annual JMA 1 catch by substock (ENHG, East Northland/Hauraki Gulf; BPLE, Bay of Plenty; CEE, Central East). Note: effort-linked ratio data has been scaled up to Allocated" LFR totals (Table 1).

Purse-seine was by far the dominant fishing method in JMA 1 and accounted for over 95% on average of the annual landed catch of jack mackerel from each subarea (Figure 4; Appendix 2).

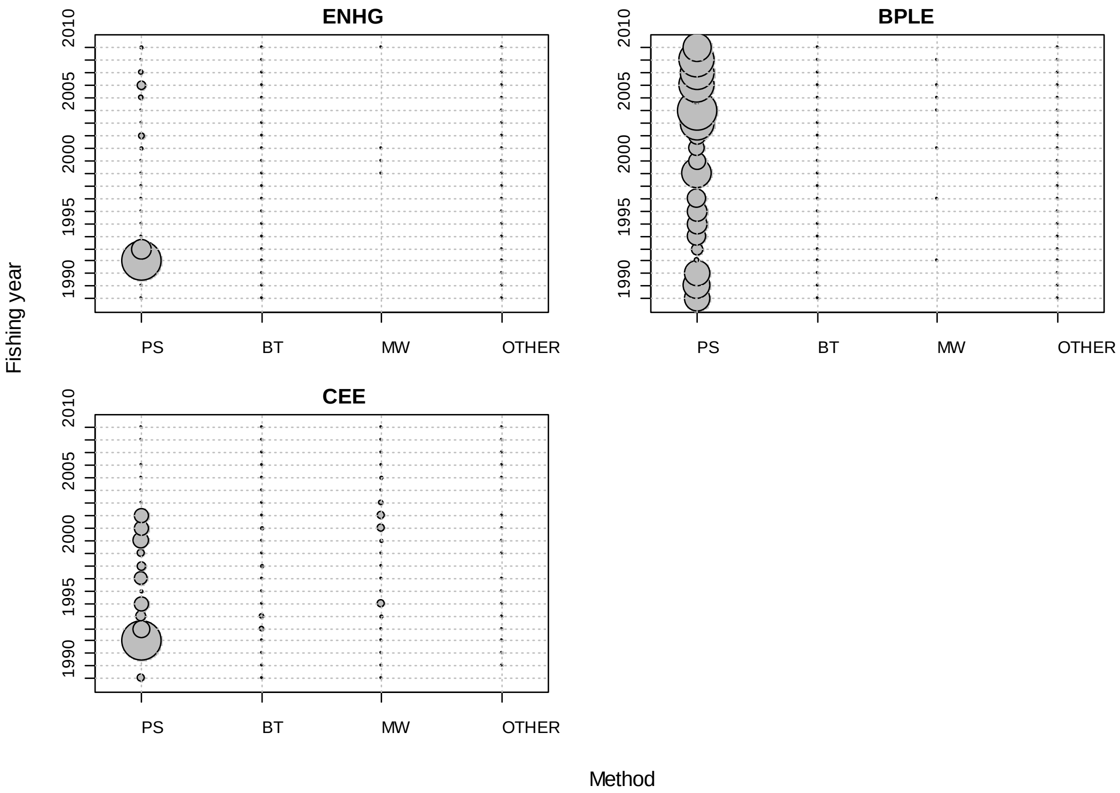

Figure 4: Relative annual catch by method in subareas in JMA 1 from 1990–91 to 2010–11 (PS, purse-seine; BT, bottom trawl; MW, mid water trawl)

3.1.3 Spatio-temporal distribution of the purse-seine commercial catch

For the past two decades, the majority of the JMA 1 purse-seine catch has been taken from statistical area 009 in the Bay of Plenty (Figure 5, Appendix 3). The main exception to this spatial catch pattern were the 1993–94 and 1994–95 fishing years when the majority of the annual JMA 1 purse-seine catch was taken from statistical areas 002 and 003 in East Northland (Figure 5, Appendix 3).

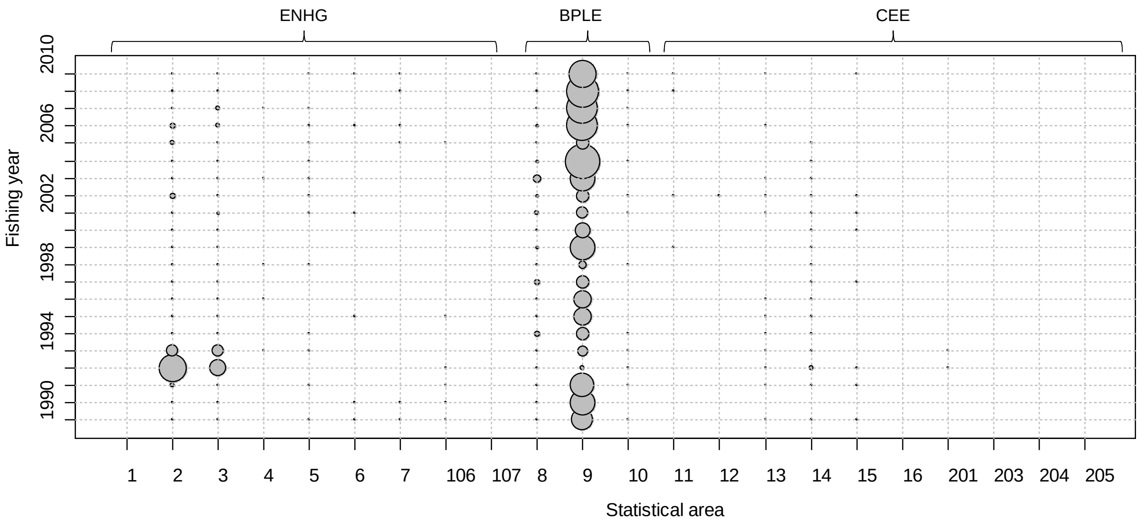

Figure 5: Annual purse-seine catch by statistical area landed in JMA 1 from 1990–91 to 2010–11.

Catches taken from East Northland in the early 1990s were predominately taken during late winter and early spring (Figure 6; Appendix 4). Most of the purse-seine catch taken from the Bay of Plenty has been taken during the months of September and October, although an increased proportion of the catch in recent years has been caught in November and December (Figure 6; Appendix 4). Consistently low purse-seine catches in the Bay of Plenty from March to May correspond to the skipjack (*Katsuwonus pelamis*) tuna season and may not reflect low jack mackerel availability (Figure 6; Appendix 4).

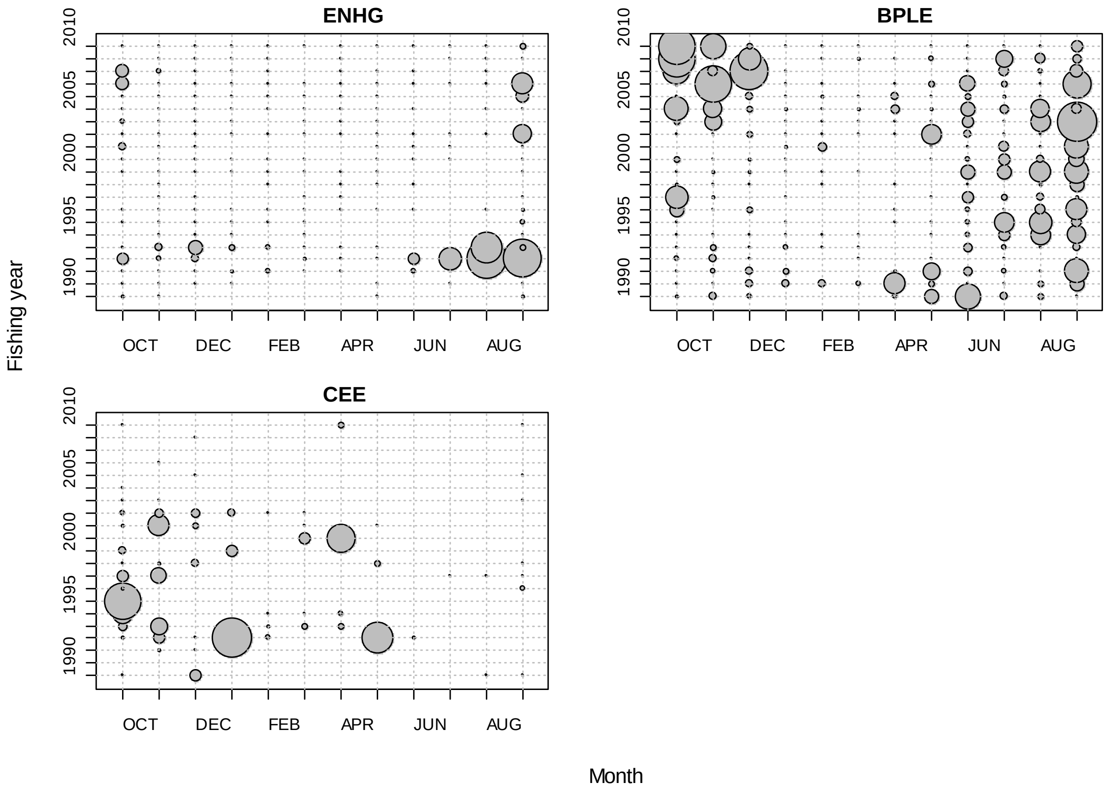

Figure 6: Relative annual purse-seine catch by month and subarea in JMA 1 from 1990–91 to 2010–11.

The JMA 1 purse-seine fishery is almost exclusively a target fishery in all three subareas (Figure 7; Appendix 5), with relatively small amounts of jack mackerel taken when targeting blue mackerel (*Scomber australasicus*, EMA) and kahawai (*Arripis trutta*, KAH).

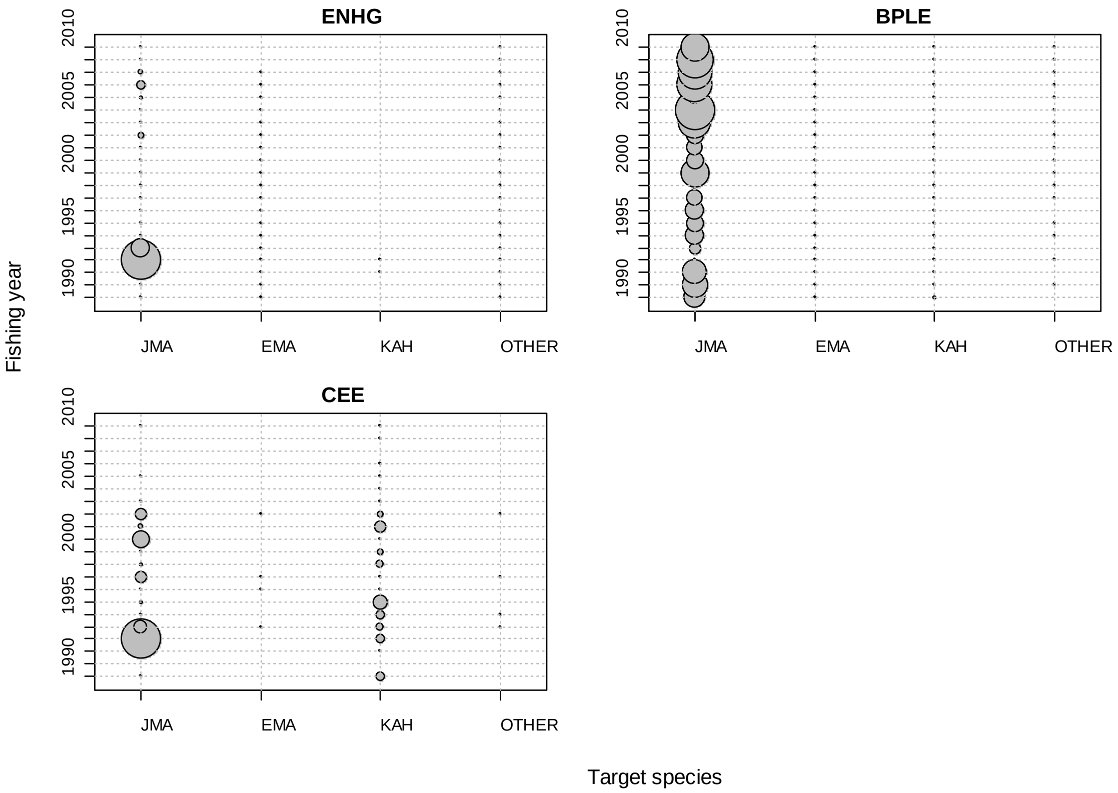

Figure 7: Relative annual purse-seine catch by target species and subarea in JMA 1 from 1990–91 to 2010–11.

3.1.4 Comparison of annual Monthly Harvest Return and Catch-Effort reported catches

Since 1986 the official published annual catch totals for each of the jack mackerel Quota Management Areas (QMAs) have been derived from monthly reporting data provided by quota holders reporting on Quota Management Returns (QMRs) and Monthly Harvest Returns (MHRs) (see Penney et al. 2011). Catch and effort data supplied by fishers to the Ministry (effectively since the 1990–91 fishing year) represents a second source of official catch reporting in which the landed green-weight of fish caught against quota is recorded. Ideally, annual catch totals derived from the two independent reporting systems should match, but for stocks where comparisons have been made, exact matches are rare, although the two totals are usually close (Jeremy McKenzie, pers. obs.). Differences in the two reporting systems can occur because the landed catches are reported by different individuals (e.g. the quota holder and the fisher) at different times. Alternatively, the differences could be due to random accounting errors or miscommunication between quota owners and fishers. Variations between the two reporting systems in the order of plus or minus 2% or less are not generally a cause for concern, whereas differences greater than 5–10% warrant further investigation or explanation.

Large discrepancies in the JMA 1 annual catch totals from the two reporting systems are evident prior to 1995–96 (Figure 8), which appear to need explanation (see section 3.3)

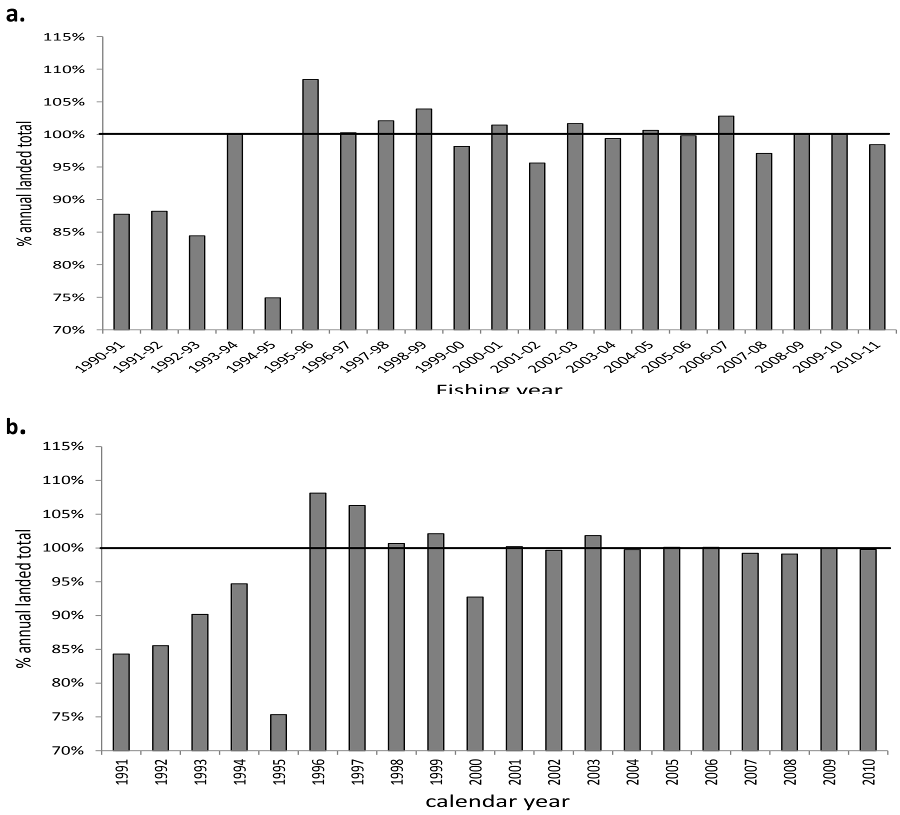

Figure 8: Annual JMA 1 catch from MHR reporting (official Plenary figures) expressed as a percentage of reported landed catch totals by fishing year (top panel) and calendar year (bottom panel).

3.2 Species composition of the JMA 1 purse-seine fishery

3.2.1 Sample collections

A total of 72 landings were sampled for species proportions between January 2009 and September 2011, and accounted for 41% by weight and 37% by number of the total purse-seine landings in JMA 1 (Figure 9, Appendix 6). A monthly summary of the percentage sample size of the number of landings and weight of jack mackerel sampled in the JMA 1 purse-seine fishery, including the number of fish used to calculate species proportions and measured for length frequency, is given in Appendix 6.

Of the 72 sampled landings, 69 were comprised of jack mackerel caught in the Bay of Plenty subarea only, two in East Northland, and one of mixed subarea origin. The mean weight of the sampled landings was 108 t, with a broad range spanning 7 to 315 t. Jack mackerel was a target species in 71 of the 72 sampled landings, with kahawai the only other main target species reported. Jack mackerel were taken as a bycatch to multi-species targets on a few trips (i.e., where jack mackerel and blue mackerel were targeted on the same trip).

During this study, a total of five moderate sized purse-seine vessels operated in JMA 1 fishery and accounted for almost the entire JMA 1 purse-seine catch, all of which was landed into Tauranga. Small inshore purse-seine vessels, that primarily target pilchard (*Sardinops sagax*), and itinerant super-seiners that mainly target seasonal skipjack tuna in New Zealand waters, caught only small quantities of jack mackerel and were not included in the catch sampling programme. Similarly, landings comprising less than 10 t of jack mackerel were excluded from the analysis as they were usually bycatch to other targeted species.

3.2.2 Fishing year analysis, 2009–10 and 2010–11

Sampling representativeness of the monthly purse-seine catch

Although jack mackerel may be caught year-round, the greatest proportion of the purse-seine catch over the consecutive fishing years was over the spring and winter months (Figure 9). Despite substantial catches, no samples were collected in December in either year, and sampling was proportionally low in November 2010 relative to the landed catch of jack mackerel (Figure 9). Catch sampling mostly occurred during months when substantial tonnages of jack mackerel were landed, but there were a greater number of months during which low tonnages were landed and catches were not sampled.

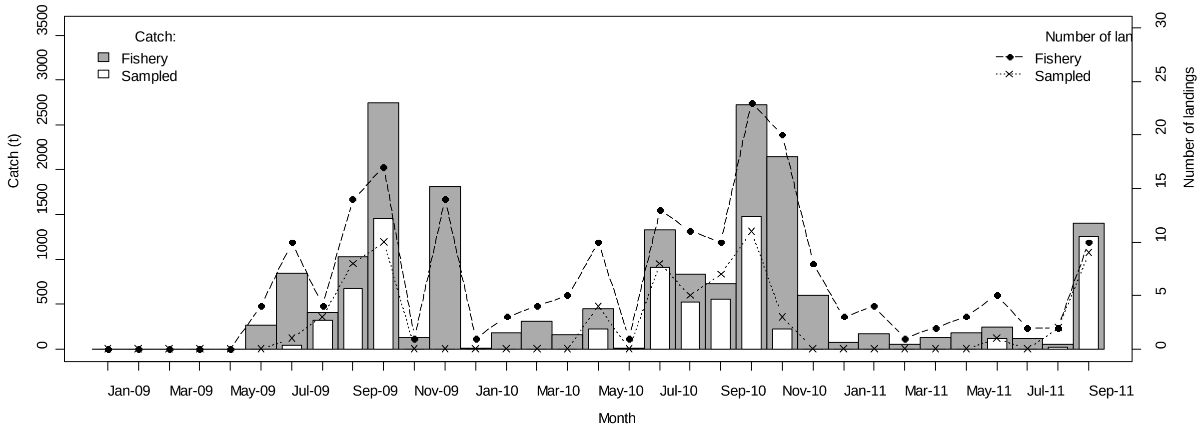

Figure 9: Comparison of the monthly distribution of landed weight (grey bars) and numbers of landings (dashed line) of jack mackerel in the JMA 1 purse-seine fishery for all landings over 10 t where jack mackerel was caught between January 2009 and September 2011. Included are corresponding estimates for all sampled landings (white bars and dotted line) to show representativeness of collections.

The sampling performance relative to the cumulative catch of the fishery throughout each fishing year illustrates that sampling was disproportionately lower in the beginning of each year compared to the end and generally associated with large volumes of jack mackerel being landed (Figure 10).

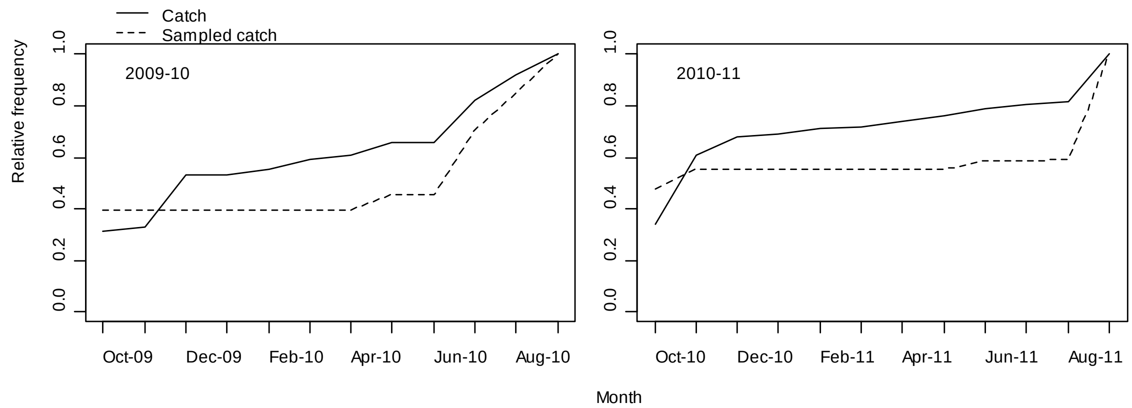

Figure 10: The cumulative proportion of the number of landings and samples taken from the JMA 1 purse-seine fishery in 2009–10 and 2010–11.

Spatial catch, statistical area, and target species comparisons

Fine scale comparisons (0.1 degree blocks) of the proportional distribution of the purse-seine fishery and sampled catch of jack mackerel for 2009–10 and 2010–11 are presented in Figures 11 and 12. Almost the entire JMA 1 catch over the consecutive fishing years was taken in the northern half of the stock. Approximately 90% of the catch was taken from the Bay of Plenty subarea; mostly from statistical area 009 (Figures 11 and 12). Moderate catches of jack mackerel were also taken from the East Northland subarea, mainly from statistical area 002 (Figures 12 and 13), in the latter part of 2010–11. The sampled component is spread throughout most areas where the commercial purse-seine fishery operated and suggests that sampled landings are spatially representative of the fishery (Figures 11–13). The vast majority (96%) of the landed purse-seine catch of jack mackerel over the consecutive years was taken in jack mackerel targeted shots, far outweighing the catch for the other target species used (Figure 14). The proportionality of the sampled component to that of the fishery suggests that sampled landings were representative of the operation of the JMA 1 purse-seine fleet as a whole.

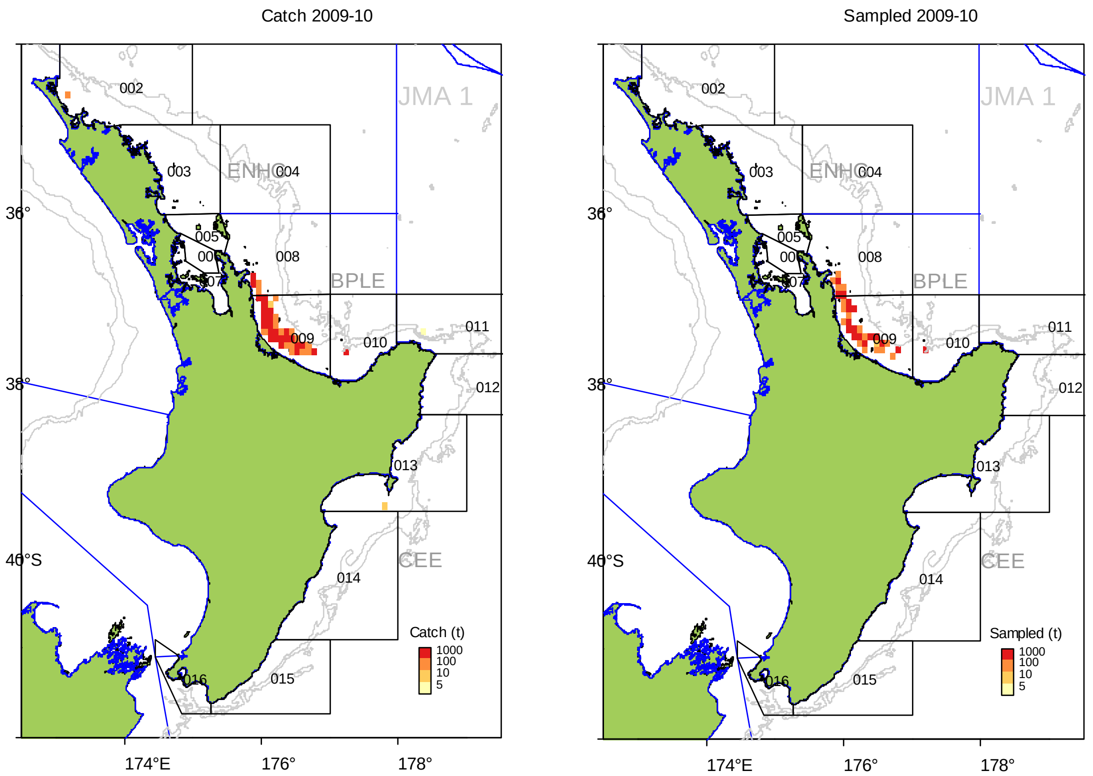

Figure 11: Comparison of the spatial distribution of the purse-seine catch and the sampled component for the JMA 1 stock in 2009–10.

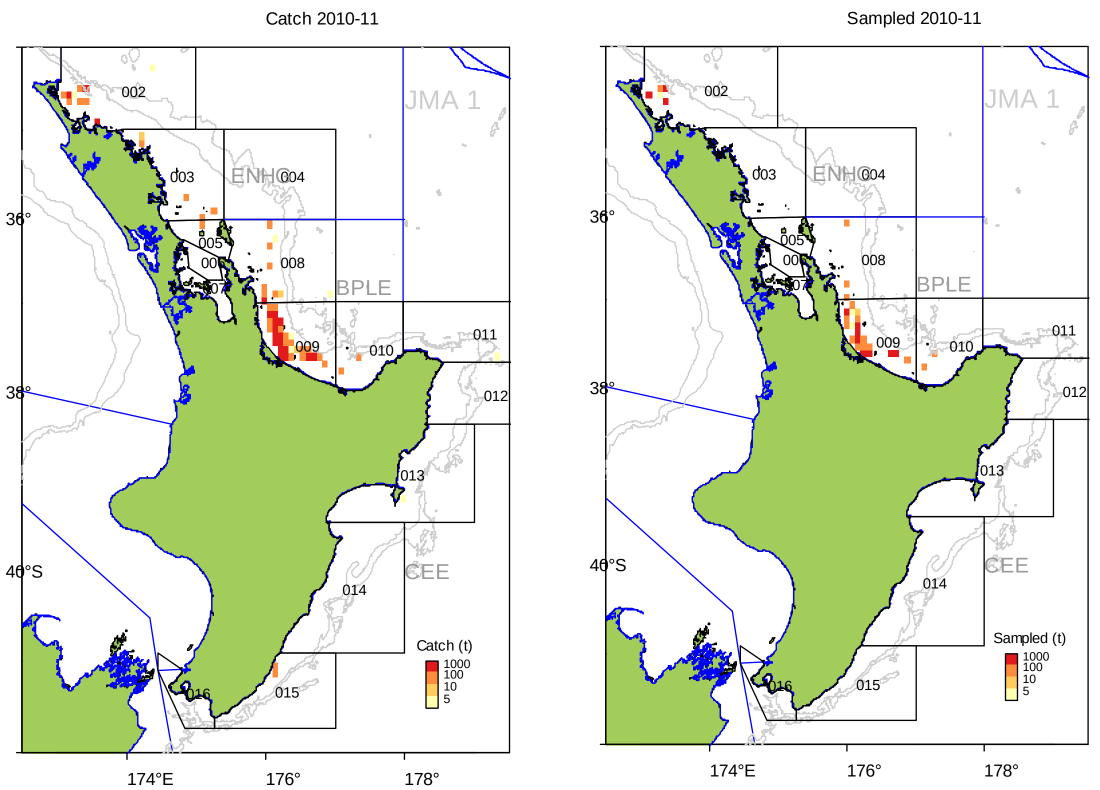

Figure 12: Comparison of the spatial distribution of the purse-seine catch and the sampled component for the JMA 1 stock in 2010–11.

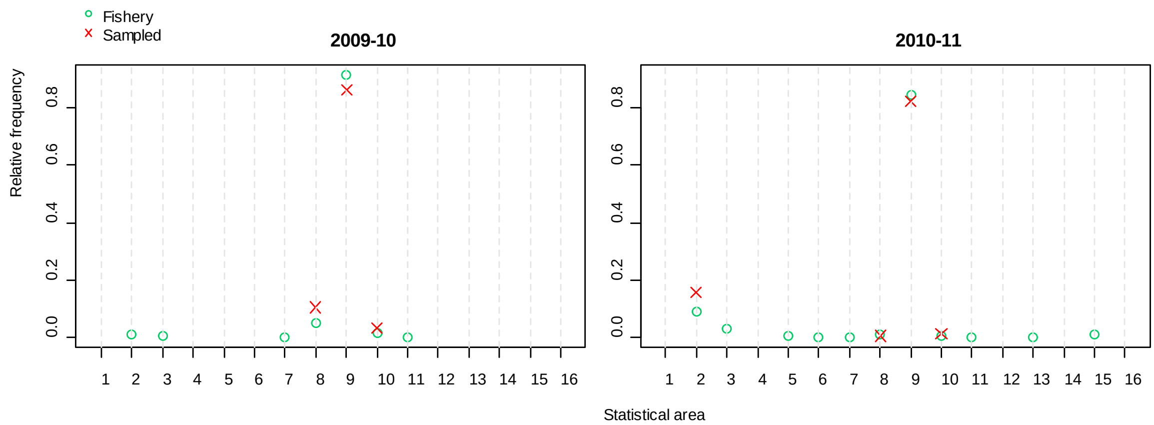

Figure 13: Comparison of the proportional distribution of the purse-seine catch and the sampled component by statistical area over the sampling period for the JMA 1 stock in 2009–10 and 2010–11.

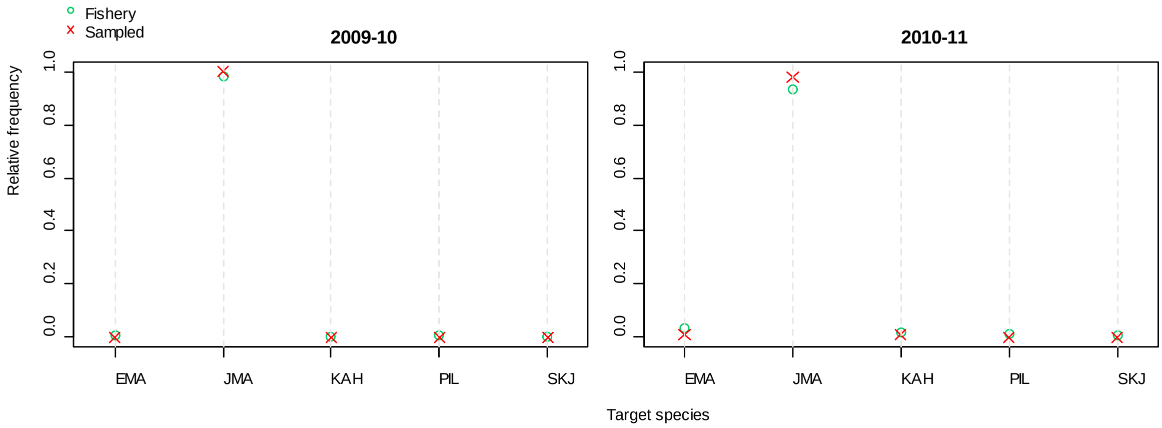

Figure 14: Comparison of the proportional distribution of the purse-seine catch and the sampled component by target species over the sampling period for the JMA 1 stock in 2009–10 and 2010–11.

3.2.3 JMA 1 species proportions – January 2009 to September 2011

3.2.3.1 Approach I: Aggregate species proportions derived using sampled months only

The estimated monthly species proportions for the three jack mackerel species landed in the JMA 1 purse-seine fishery for the period January 2009 to September 2011 for those months in which samples were collected are presented in Figure 15 and Appendix 7. Over this period, *T. novaezelandiae* represented the most common jack mackerel species in 70 of the 72 sampled landings (97%), and in all sampled months (Figure 15). The lowest monthly species proportion for *T. novaezelandiae* was 61% in September 2011, substantially influenced by two East Northland landings that were dominated by *T. declivis* (91–98%) and a small proportion of *T. murphyi* (2–9%).

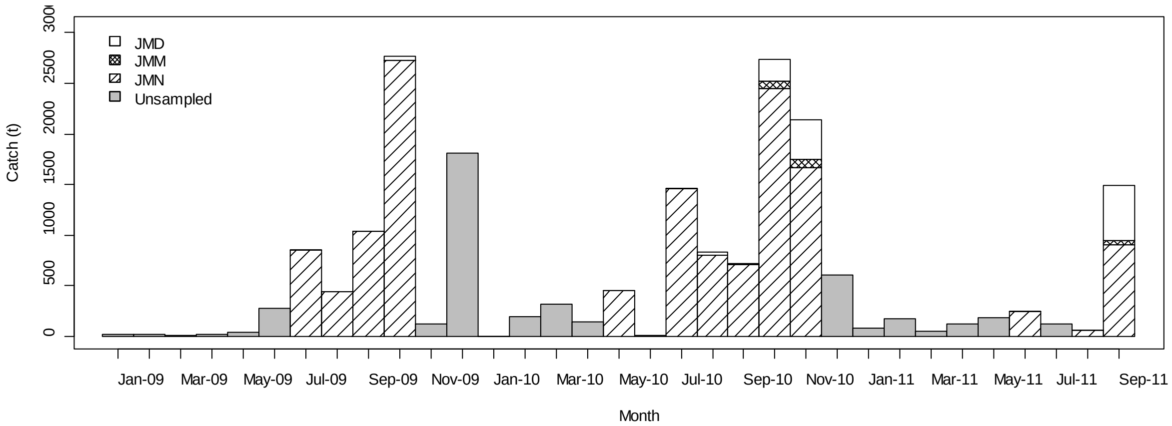

Figure 15: Estimated monthly total catch of the jack mackerel species in the JMA 1 purse-seine fishery from October 2009 to September 2011: JMD is *T. declivis*, JMM is *T. murphyi*, JMN is *T. novaezelandiae*; individual species catches were generated as scaled proportions of the sampled catch using estimated species proportions. Shaded bars indicate months in which no species proportion data were collected.

As a consequence of its dominance in the monthly samples, *T. novaezelandiae*, made up 90–98% of overall purse-seine jack mackerel catch by fishing and calendar year (Table 2; Appendix 8). Precision on species proportion estimates was high for *T. novaezelandiae* (MWCV less than 0.10), but low

(MWCV greater than 0.30) for the other two jack mackerels in the catch, *T. declivis* and *T. murphyi* (Table 2).

Table 2: Estimated proportions and c.v.s of the three jack mackerel species (JMD, *Trachurus declivis*; JMM, *T. murphyi*; JMN, *T. novaezelandiae*) landed by calendar year and fishing year in the JMA 1 purse-seine fishery from January 2009 to December 2011.

	Estimated proportion			Coefficient of variation			
Year	JMD	JMM	JMN	JMD	JMM	JMN	Catch (t)
Calendar year							
2009	0.007	0.001	0.992	0.330	0.952	0.002	7 416
2010	0.078	0.019	0.903	0.483	0.466	0.058	9 612
Fishing year							
2009–10	0.017	0.002	0.981	0.374	0.947	0.004	8 837
2010–11	0.172	0.029	0.799	0.361	0.379	0.101	8 027

3.2.3.2 Approach II: substituting annual monthly estimates for un-sampled months

Calendar year proportion means were calculated for 2009 and 2010, based on the species proportion estimates observed in sampled months and imputed estimates for un-sampled months during the same season (Table 3). Compared to estimated proportions (Table 2), the derived proportion means were identical for the calendar year proportions and differed slightly for the 2009–10 fishing year estimate (Table 3).

Table 3: Calculated proportion means of the three jack mackerel species (JMD, *Trachurus declivis*; JMM, *T. murphyi*; JMN, *T. novaezelandiae*) landed by calendar year and fishing year in the JMA 1 purse-seine fishery from January 2009 to December 2011.

	Proportion mean			
Year	JMD	JMM	JMN	Catch (t)
Calendar year				
2009	0.007	0.001	0.992	7 224
2010	0.078	0.019	0.903	9 612
Fishing year				
2009–10	0.013	0.001	0.986	8 837

3.2.3.3 Approach III: stratification by season

The species proportions estimated with seasonal stratification were not dissimilar to the results attained for stratification by month (section 3.2.3.1) or where substituted calendar year values were used (section 3.2.3.2) (Table 4). Species proportions in early 2011 were considerably different to all other seasons with a higher proportion (33%) of *T. declivis* caught during two trips in September (section 3.2.3.1). Consequently, precision was low for all species proportion estimates in this last season, reflecting high between landing variability in the catch of the jack mackerel species for this period (Table 4).

Table 4: Estimated proportions and c.v.s of the three jack mackerel species (JMD, *Trachurus declivis*; JMM, *T. murphyi*; JMN, *T. novaezelandiae*) landed by calendar year and fishing year in the JMA 1 purse-seine fishery from January 2009 to December 2011.

	Estimated proportion			Coefficient of variation			
Season/year	JMD	JMM	JMN	JMD	JMM	JMN	Catch (t)
Season							
2009 early	0.002	0.000	0.998	0.676	–	0.001	2 541
2009 late	0.012	0.001	0.987	0.325	0.930	0.004	4 683
2010 early	0.015	0.000	0.985	0.595	–	0.007	3 997
2010 late	0.091	0.028	0.881	0.362	0.519	0.053	5 468
2011 early	0.331	0.022	0.647	0.573	0.737	0.297	2 420
Calendar year							
2009	0.008	0.001	0.991	0.324	0.893	0.002	7 416
2010	0.058	0.016	0.926	0.330	0.510	0.029	9 612
Fishing year							
2009–10	0.014	0.001	0.986	0.342	0.923	0.004	8 837
2010–11	0.167	0.026	0.806	0.373	0.433	0.085	8 027

The stratification used in previous reports used different definitions for seasonal strata (early: October to March and late: April to September) which were based on a descriptive analysis of the JMA 1 fishery which suggested that landings peaked during two periods in each fishing year, (October–December and June–September). For comparison we estimated species proportions and c.v.s for Taylor's season using the methods described in section 2.3.1.1 and 2.3.1.2 (Appendix 8).

3.2.4 JMA 1 species length compositions for the 2009–10 and 2010–11 fishing years

Fishing year and seasonal length distributions and coefficients of variations (c.v.) for the three jack mackerel species in the JMA 1 purse-seine fishery in 2009–10 and 2010–11 are presented as a series of histograms (Figures 16). A proportional comparison of the size distributions of *T. novaezelandiae* and *T. declivis* over the consecutive fishing years is also given in cumulative plots (Figures 17 and 18).

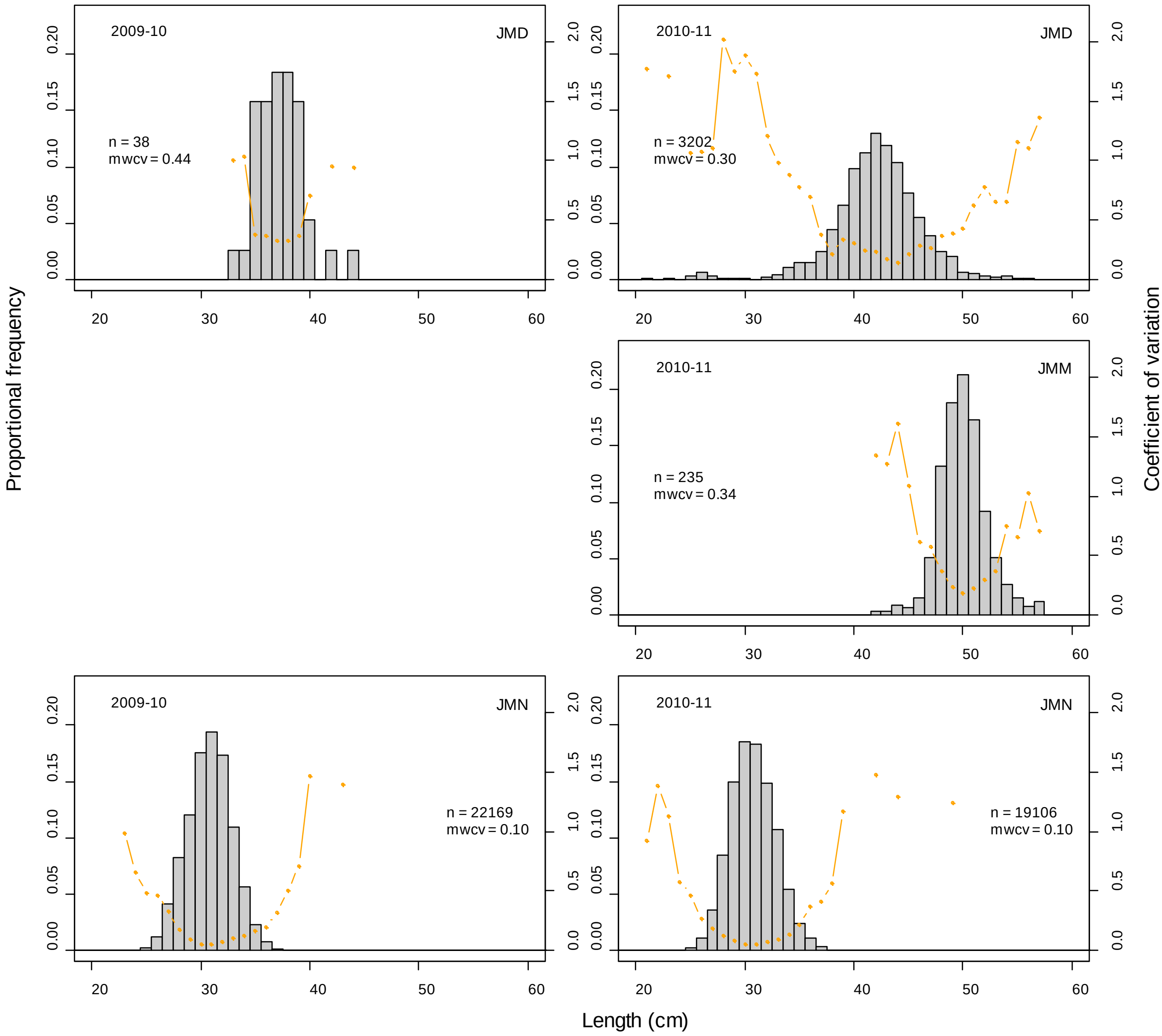

Figure 16: Proportional frequency distributions (histograms) and c.v.s (lines) of *T. declivis* (top), *T. murphyi* (middle) and *T. novaezelandiae* (bottom) by fishing year sampled from JMA 1 purse-seine fishery in 2009–10 and 2010–11.

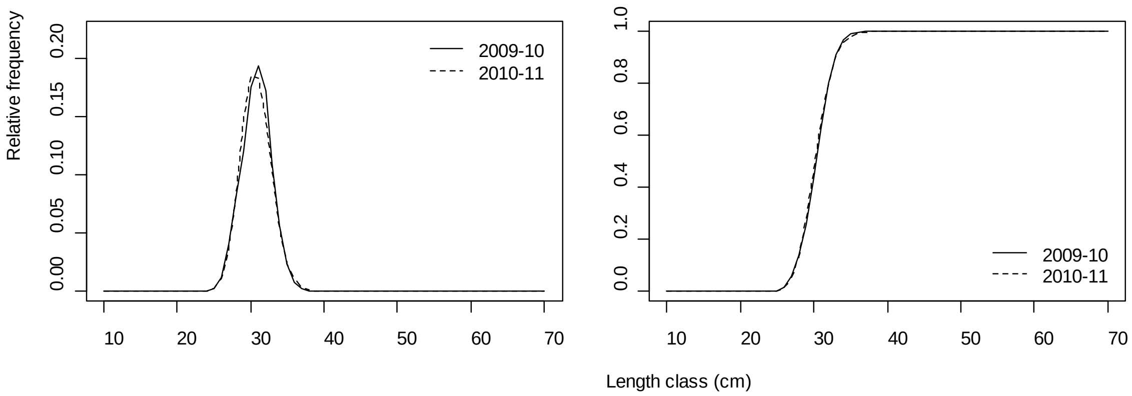

Figure 17: Comparison of the proportion and cumulative proportion at length distributions of *T. novaezelandiae* sampled from JMA 1 purse-seine fishery in 2009–10 and 2010–11.

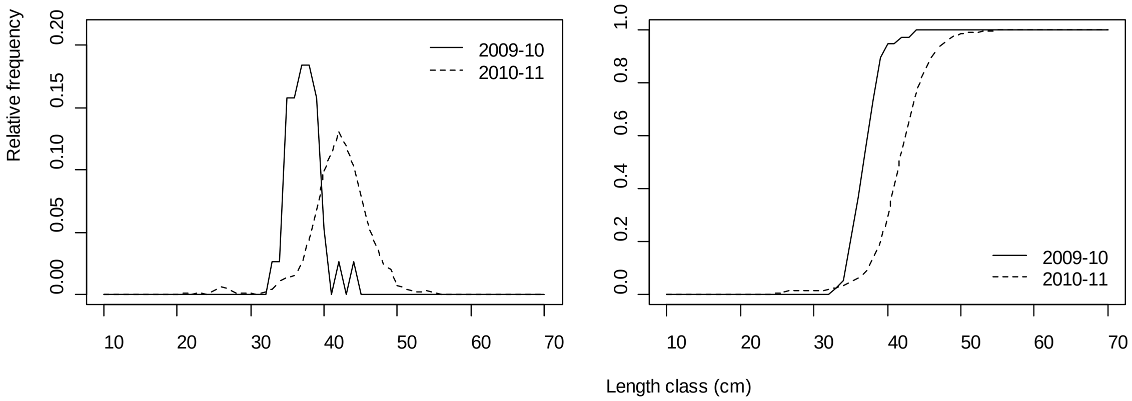

Figure 18: Comparison of the proportion and cumulative proportion at length distributions of *T. declivis* sampled from JMA 1 purse-seine fishery in 2009–10 and 2010–11.

The length compositions of *T. novaezelandiae* (the smallest of the three species) illustrates that a consistent size structure pattern exists temporally within the fishery, occupying a single mode, where 98% of the landed catch is between 27 and 35 cm (0.325–0.680 g) (Figures 16 and 17). The size range for *T. declivis* varied between years with low numbers (*n* = 38) of moderate sized individuals (33–44 cm) sampled in 2009–10, compared to moderate numbers (*n* = 3 202) of predominantly larger individuals (70% over 40 cm) more prevalent in 2010–11 collections (Figure 16). A low number of large *T. murphyi* (*n* = 235) were sampled in 2010–11, with sizes ranging from 42 to 57 cm, comprising a single mode at 50 cm (Figure 16). The mean lengths and proportion-at-length MWCVs of three jack mackerel species sampled from JMA 1 over the consecutive fishing years were as follows: *T. novaezelandiae* 30.8 cm (0.10), equivalent for both years; *T. declivis* 37.0–42.1 cm (0.30–0.44); *T. murphyi* 50.0 cm (0.34) (Figure 16).

3.3 Time series analysis

Species composition estimates for annual JMA 1 catches going back to the mid-1980s are given in Penney et al. (2011). Catch sampling results from the current study update the Penney et al. (2011) JMA 1 compositional time series to include the 2009 and 2010 calendar years and the 2009–10 fishing year (Tables 5 and 6).

Table 5: Species proportion estimates (JMD, *T. declivis*; JMM, *T. murphyi*; JMN, *T. novaezelandiae*) of JMA 1 catches (t) by calendar year, reproduced from Penney et al. (2011). Shaded years represent data from this report.

Calendar year	JMD	JMM	JMN	Plenary	Landed	% annual landed total
1985	0.680	0.000	0.320			
1986	0.160	0.000	0.840	2 691		
1987	0.160	0.000	0.840	2 973		
1988	0.160	0.000	0.840	3 214		
1989	0.140	0.100	0.760	3 737		
1990	0.160	0.000	0.840	4 573		
1991	0.140	0.140	0.720	5 808	6 890	84%
1992	0.100	0.360	0.540	6 928	8 098	86%
1993	0.110	0.320	0.570	9 677	10 730	90%
1994	0.190	0.760	0.050	12 994	13 723	95%
1995	0.130	0.390	0.480	6 392	8 484	75%
1996	0.020	0.120	0.860	7 103	6 570	108%
1997	0.050	0.370	0.580	8 868	8 343	106%
1998	0.090	0.360	0.550	7 608	7 557	101%
1999	0.120	0.150	0.730	3 634	3 559	102%
2000	0.040	0.020	0.940	3 220	3 472	93%
2001	0.040	0.010	0.950	8 350	8 334	100%
2002	0.300	0.010	0.690	5 635	5 654	100%
2003	0.150	0.020	0.830	6 147	6 037	102%
2004	0.380	0.120	0.500	8 595	8 617	100%
2005	0.000	0.000	1.000	10 663	10 652	100%
2006	0.250	0.000	0.750	7 410	7 403	100%
2007	0.170	0.060	0.770	8 609	8 676	99%
2008	0.400	0.130	0.470	13 588	13 710	99%
2009	0.007	0.001	0.992	7 476	7 478	100%
2010	0.078	0.019	0.903	9 862	9 883	100%

Table 6: Species proportion estimates (JMD, *T. declivis*; JMM, *T. murphyi*; JMN, *T. novaezelandiae*) of JMA 1 catches (t) by fishing year, reproduced from Penney et al. (2011). Shaded years represent this report.

Fishing year	JMD	JMM	JMN	Plenary	Landed	% annual landed total
1985–86	0.160	0.000	0.840	1 268		
1986–87	0.160	0.000	0.840	4 056		
1987–88	0.160	0.000	0.840	3 108		
1988–89	0.146	0.068	0.785	2 986		
1989–90	0.152	0.040	0.808	4 226		
1990–91	0.146	0.096	0.758	6 472	7 376	88%
1991–92	0.108	0.317	0.575	7 017	7 955	88%
1992–93	0.108	0.327	0.565	7 529	8 918	84%
1993–94	0.171	0.654	0.176	14 256	14 256	100%
1994–95	0.143	0.500	0.357	7 832	10 454	75%
1995–96	0.026	0.101	0.874	6 874	6 341	108%
1996–97	0.050	0.265	0.685	6 912	6 895	100%
1997–98	0.048	0.430	0.522	7 695	7 538	102%
1998–99	0.121	0.294	0.585	5 767	5 551	104%
1999–00	0.065	0.081	0.854	2 866	2 920	98%
2000–01	0.022	0.011	0.967	8 360	8 242	101%
2001–02	0.182	0.007	0.811	5 247	5 488	96%
2002–03	0.213	0.014	0.773	6 172	6 072	102%
2003–04	0.397	0.077	0.526	7 396	7 444	99%
2004–05	0.104	0.061	0.835	9 418	9 359	101%
2005–06	0.151	0.002	0.847	9 924	9 944	100%
2006–07	0.338	0.095	0.567	5 293	5 148	103%
2007–08	0.300	0.043	0.657	11 167	11 502	97%
2008–09	0.219	0.132	0.649	9 791	9 790	100%
2009–10	0.013	0.001	0.986	9 086	9 089	100%

Purse-seine catches of jack mackerel throughout the 1990s were dominated by *T. murphyi*, with the highest proportions of this species occurring in 1993–94 when it accounted for two-thirds of the overall landed tonnage (Figure 19). By 2000–01 however, the catch of *T. murphyi* had diminished to just 1%, with catch levels remaining low relative to the two New Zealand species (Figure 19).

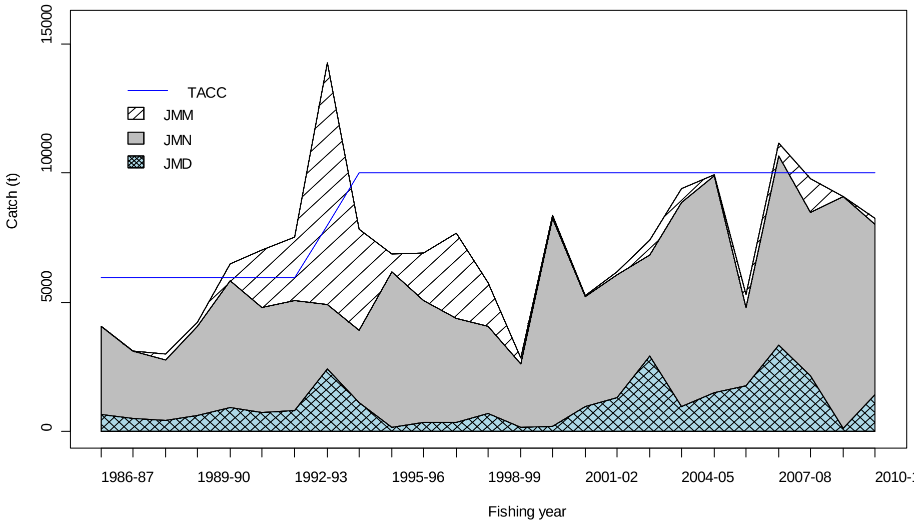

Figure 19: Species proportion estimates (JMD, *T. declivis* ; JMM, *T. murphyi*; JMN, *T. novaezelandiae*) of JMA 1 catches by fishing year scaled to the Plenary (QMR/MHR) annual reported catch.

The years of *T. murphyi* dominance in the JMA 1 fishery correspond with the period of highest discrepancy in the QMR/MHR and landed catch totals (Figure 20). A possible explanation is that some quota owners did not deem the newly invasive *T. murphyi* as a quota species and hence did not account for it on their QMR/MHR forms, whereas the actual fishers were more inclined to report *T. murphyi* along with the other species as JMA 1 on their landed catch forms. In our opinion the landed catch totals are likely to be a more accurate reflection of the JMA 1 catch during the 1990s than the QMR/MHR totals (Figure 20).

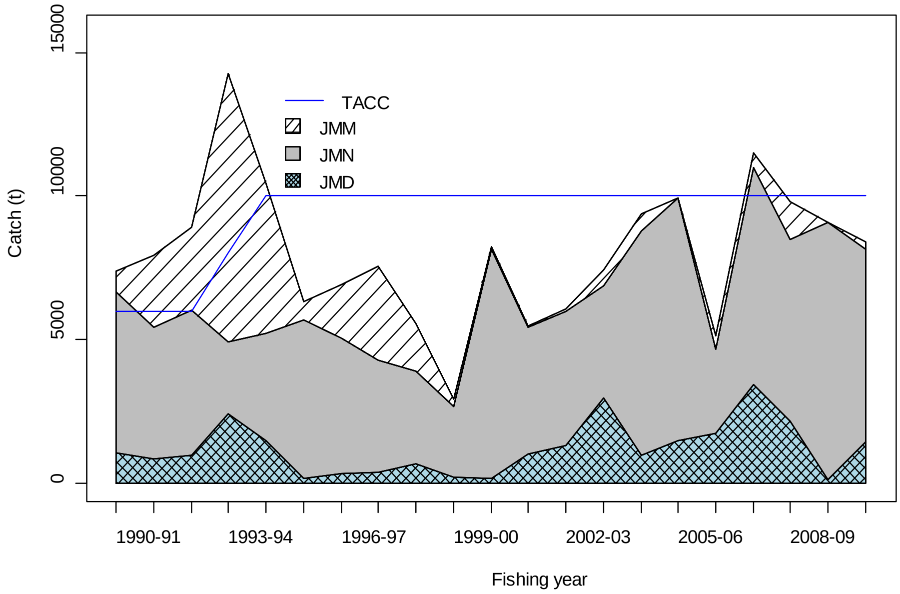

Figure 20: Species proportion estimates (JMD, *T. declivis*; JMM, *T. murphyi*; JMN, *T. novaezelandiae*) of JMA 1 catches by fishing year scaled to the landed annual reported catch.

4. DISCUSSION

This is the tenth report to summarise the species composition of the three jack mackerels from purse-seine landings in JMA 1, and continues an unbroken time series of collections dating back to 1994–95 (Taylor 1998, Taylor 1999, Taylor 2000, Taylor 2002, Taylor 2004a,b, Taylor & Julian 2008, Taylor et al. in press, Penney et al. 2011). Despite considerable developments within the commercial fishing industry in recent years, the domestic purse-seine fleet operating from Tauranga, has remained comparatively stable with a core group of five vessels taking approximately 95% of the annual landed JMA 1 catch (approximately 8500 t) in 2009–10 and 2010–11.

Sampling landings and representativeness

The cooperation of the fishing companies involved in the JMA 1 fishery, Sanford Ltd and Pelco NZ Ltd, has been pivotal to this catch sampling programme in terms of minimising the potential bias normally associated with sample collections (i.e., spatial, temporal, size selective). Comprehensive totals of 72 JMA 1 purse-seine landings and 54 000 jack mackerel were successfully sampled for species composition data between January 2009 and September 2011. Despite few samples being made over the summer and autumn months when the landing size and/or volume of jack mackerel were low, the temporal and spatial fishing and sampling effort overall generally suggests a good level of representativeness.

Factors affecting fish size and landed volume of jack mackerel

Aside from environmental and operational variables that may influence the catch of a particular species, target variables relating to preference of fish size and the timing of targeting particular species have also been found to influence landings, especially in a mixed species purse-seine fishery (Taylor 2008). It is entirely possible that catch proportions presented within this report may be affected by a number of such factors where the market value, preferred fish size, availability of other important species (i.e., skipjack, blue mackerel), bycatch issues (i.e., kahawai), market demands, and the amount of available ACE (annual catch entitlement) have all influenced the landed catch composition of jack mackerel in JMA 1 over the sampling period. In the large volume mixed species purse-seine fishery, the difficulty of selectively catching the intended target species cannot be understated. In the past, when fishing restrictions were less rigorous, purse-seine vessels would often jig a few samples using handlines to determine the species of the school below, but they now regularly use sonar detection and drop cameras to confirm the species and size composition prior to initiating fishing (Peter Reid, Pelco NZ Ltd).

With jack mackerel the third most preferred species in the fishery behind skipjack and blue mackerel, Taylor et al. (in press) concluded that this hierarchy would remain the most important consideration in dictating target choice at any time unless there were further changes to catch limits or the market price of a species. As a result, the operation of the jack mackerel fishery in this study period has generally remained the same as recent years, constrained to the end-beginning of the consecutive fishing years. A steady global increase and stabilisation of jack mackerel prices, may provide a cost-effective alternative target to the traditional hierarchy (Taylor et al. 2012), in what has been a high-volume low-value fishery (Taylor 2008). With export sale prices for jack mackerel (frozen green product) increasing to @$NZ1.40 per kilo (SeaFIC stats), coupled with well-developed overseas markets (particularly eastern Europe, Asia, and Africa) that have a preference for small fish (400–600 g) (Taylor & Julian 2008), the economic status of the JMA 1 purse-seine fishery is probably the most buoyant it has ever been. In the past, large jack mackerels (greater than 600 g), and in particular *T. declivis,* were highly valued returning the highest export margin of the three species (pers comm. factory managers), but now attain a much lower market value than before. Similarly, *T. murphyi*, in high demand in the early to mid-1990s when purse-seine catches were also high in JMA 1 (Taylor & Julian 2008) is now much less marketable and the least preferred option in targeted jack mackerel fishing, where greater emphasis is now focused on exporting a smaller product, (i.e., *T. novaezelandiae*).

Species proportions and size composition

T. novaezelandiae, the smallest of the three species landed under the JMA code, continues to be the preferential target for domestic purse-seine fleet, estimated to make up between 81% and 99% of the JMA 1 catch over the study period. The overwhelming predominance of *T. novaezelandiae* in 97% of sampled landings, caught solely in the Bay of Plenty, suggests *T. novaezelandiae* is readily abundant year-round, easy to catch in large volumes, and accessible in close proximity to the home port. These factors are likely to be the main reason for the steady increase in landings of *T. novaezelandiae* in recent years.

Catches of *T. declivis* within JMA 1 were generally low and the data suggest that that spatial and temporal variation in fish size and relative abundance may exist for this species. The presence of large jack mackerels (i.e., *T. declivis* and *T. murphyi*) in JMA 1 landings was postulated by Taylor et al. (in press) as being the result of a less preferred option in the absence of small fish, or the result of size mixing within schools. We suggest that a spatial or temporal component may also be present within the fishery where an alternative targeting of larger fish (i.e., *T. declivis*) occurs on occasions when prevalence is high, particularly in East Northland and possibly over winter. Two such significant East Northland landings in 2010–11 were found to be highly influential in determining species proportion estimates. Notably absent of *T. novaezelandiae*, but where *T. declivis* made up over 90% of the catch composition, and *T. murphyi* the remainder, both landings were in early spring (September) when water temperature was low, which is preferred by both larger species. Given the enormous demand for a small product, we believe these landings most likely reflect an opportunistic catch when vessels were some distance from the home port and looking to fill their holds. Although not investigated, it is unknown if any apparent depth related effect exists between the catch of the three jack mackerel species over the consecutive fishing years. Ideally, a comprehensive review of the time series sample collections would be required to test this theory and investigate possible spatial and temporal patterns in species compositions within JMA 1, given they have overlapping but different geographical distributions. The insignificant proportion (less than 3%) of *T. murphyi* in JMA 1 purse-seine landings during this study appears to support the overall reduction in the New Zealand wide catch of *T. murphyi*, observed since the mid to late 1990s (Taylor et al. 2008, Taylor & Julian 2008, Taylor et al. unpublished FAR 2012, Penney & Taylor 2008, Penney et al. 2011).

Precision on species proportions was usually high for *T. novaezelandiae* (MWCV less than 0.10), being the most common and abundant jack mackerel species caught, and well below the target estimate of 0.30. Precision was low (MWCV more than 0.30) for both *T. declivis and T. murphyi,* reflecting the highly variable occurrence of these species in JMA 1 purse-seine landings during the study period.

Although annual length compositions varied considerably between the jack mackerel species sampled from the JMA 1 purse-seine fishery over the consecutive fishing years, they were generally reflective of the inherent size differences that exist between the three species, and similar to previous findings (Taylor 2002, Taylor et al. unpublished FAR 2012). The size composition of the *T. novaezelandiae* catch varied little, being temporally consistent between seasons and years, while *T. declivis* illustrated inter-annual variability in size, which may be spatially or temporally influenced, or possibly linked to ontogeny as only small *T. declivis* were caught with *T. novaezelandiae*. The size range (42 to 57 cm) and mean length (50 cm) for *T. murphyi* from JMA 1 sample collections in 2010–11 were closely aligned with the most recent New Zealand estimates (Penney & Taylor 2008), indicative of a single New Zealand wide population showing little evidence of inter-annual size variability due to recruitment. The presence of only a small population of large *T. murphyi* adults remaining in JMA 1 further supports the hypothesis of a diminishing New Zealand population (Taylor et al. 2008, Taylor & Julian 2008, Taylor et al. unpublished FAR 2012, Penney & Taylor 2008, Penney et al. 2011) associated with the Pacific-wide decline of the Chilean mackerel stock (SPRFMO 2010). However, it has been suggested that the New Zealand population may continue to be periodically supplemented by further migrations from the east (Penney & Taylor 2008), and although successful spawning and recruitment of *T. murphyi* in New Zealand waters has been documented (Taylor 2002) the numbers of recovered juveniles have been small. The current status of the New Zealand *T. murphyi* stock is unknown, as is the sustainability of current commercial harvest levels. The catch limit for JMA 1 was increased in the early 1990s, to account for an increase in the abundance of *T. murphyi*, but this species now makes up a small proportion of the catch, and the current catch of the New Zealand species, *T. novaezelandiae* and *T. declivis*, has exceeded the original quota of 5970 t set in 1992–93, for a period of more than two decades.

Revised temporal sampling stratification

From this study, it has become apparent that current sampling and analytical strategies may introduce subtle bias in fishing year and seasonal species proportion estimates. This is primarily due to the overlap of the fishing and calendar year periods, and the use of substituted catch-weighted calendar year monthly means for un-sampled months, and only when a full calendar year has been sampled. Furthermore, this bias is expected to be more obvious if fishing operations and the species proportion catch changes considerably between fishing years. We propose that a revised sampling strategy be adopted, encompassing the two seasons outlined in this report (Oct–Dec; Jan–Sep) as the temporal stratification, as opposed to individual months, given that fewer months were sampled than not sampled within this study. This design may also ensure that adequate sample sizes are collected than would normally be possible in individual months, and form a better representative temporal description of the overall purse-seine catch of jack mackerel. Similarly, from this, an optimised and cost-effective sampling design may be determined.

Despite considerable discussion, the Northern Inshore Finfish Working Group meeting in August 2012 (NINSWG-2012/52b) could not reach a consensus as to which of the three proposed methods was best for deriving species proportions. The NINSWG recommended that a review of methods used for calculating species proportions be undertaken, by people with appropriate statistical expertise.

5. ACKNOWLEDGMENTS

We thank members of the staff and management at Sanford Ltd (Tauranga) and Pelco NZ Ltd (Mt Maunganui) for their assistance in sampling the purse-seine landings; Paul Taylor for advice on the JMA 1 fishery and species proportions data; also Shane Grayling and Bruce Davison (previously NIWA), for coordinating and contributing to the sampling. We also thank Bruce Hartill, NIWA, for reviewing the report and providing some helpful comments.

This work was funded by the Ministry for Primary Industries under project JMA200901.

6. REFERENCES

Basten, J.C. (1981). The fishery for jack mackerel (*Trachurus murphyi*) off Northern Chile. Theses, Dissertations and Student Research Papers (College of Earth, Ocean and Atmospheric Sciences), School of Oceanography, Oregon State University, June 1981. 65 p.

Francis, R.I.C.C; Bian, R. (2011). Catch-at-length and -age User Manual, CALA v1.0 National Institute of Water & Atmospheric Research Ltd. (Unpublished report held by NIWA library, Wellington). 83 p.

Horn, P.L. (1991a). Assessment of jack mackerel stocks off the central west coast, New Zealand, for the 1990–91 fishing year. New Zealand Fisheries Assessment Research Document 1991/6. 14 p. (Unpublished report held by NIWA library, Wellington).

Horn, P.L. (1991b). Trawl survey of jack mackerels (*Trachurus* spp.) off the central west coast, New Zealand, February–March 1990. *New Zealand Fisheries Technical Report 28*, 39 p.

Horn, P.L. (1993). Growth, age structure, and productivity of jack mackerels (*Trachurus* spp.) in New Zealand waters. *New Zealand Journal of Marine and Freshwater Research 27*: 145–155.

Lyle, J.M.; Krusic-Golub, K.; Morison, A.K. (2000). Age and growth of jack mackerel and the age structure of the jack mackerel purse-seine catch. FRDC Final Report on Project 1995/034. Tasmanian Aquaculture and Fisheries Institute, Marine Research Laboratories, Taroona, Tasmania 7053, Australia. 49 p.

Ministry for Primary Industries (2011). Report from the Fisheries Assessment Plenary, 2011: stock assessments and yield estimates. Compiled by the Ministry of Primary Industries Science Group. (Unpublished report held by Ministry for Primary Industries, Wellington).

Penney, A.J.; Loveridge, C.J.; Moriarty, J.A.; George, K. (2011). Estimation of New Zealand monthly purse-seine and midwater trawl catches of *Trachurus declivis*, *T. murphyi*, *T. novaezelandiae* by fisheries management area from October 1985 to December 2010. *New Zealand Fisheries Assessment Report 2011/41*.

Penney, A.J.; Taylor, P. (2008). An overview of the New Zealand jack mackerel fishery: catch composition, catch trends, seasonality and length-frequency composition. Information Paper CHJMWS#19 to the SPRFMO Chilean Jack Mackerel Workshop, June/July 2008. 19 p.

Rohan, V.M.; Mittinty, M.; Taylor, P.R. (2006). Aspects of estimating species proportions in the jack mackerel fishery: JMA 7 estimates using a Bayesian approach and examination of sampling bias in JMA 1 resulting from automated grading. Final Research Report for Specific Objective 7 of project JMA2004/01: Stock monitoring of jack mackerels. PELWG06/09. 26 p. (Unpublished report held by Ministry for Primary Industries, Wellington).

SPRFMO (2010). Report of the Jack Mackerel Subgroup. *In*: Report of the 9th Science Working Group, Viña del Mar, Chile: 21-29 October 2010. 66 p.

Taylor, P.R. (1998). Estimates of biological parameters, total mortality, and maximum constant yield for jack mackerel, *Trachurus declivis* and *T. novaezelandiae,* in JMA 1. New Zealand Fisheries Assessment Research Document 98/11. 38 p. (Unpublished report held in NIWA library, Wellington.).

Taylor, P.R. (1999). Species composition and seasonal variability of jack mackerel, *Trachurus declivis*, *T. murphyi*, *T. novaezelandiae* in JMA 1, 3, and 7. New Zealand Fisheries Assessment Research Document 99/49. 21 p. (Unpublished report held in NIWA library, Wellington.).

Taylor, P.R. (2000). Species composition and seasonal variability in commercial catches and aerial sightings of jack mackerel, *Trachurus declivis*, *T. murphyi*, and *T. novaezelandiae* in JMA 1, JMA 3, and JMA 7. *New Zealand Fisheries Assessment Report 2000/45*. 25 p.

Taylor, P.R. (2002). Species composition and seasonality of jack mackerel (*Trachurus declivis*, *T. murphyi*, *T. novaezelandiae*) in commercial catches from JMA 1, 3, and 7 during 1998–99 and 1999–2000, with a summary of biological information from 1990–91 to 1999–2000. *New Zealand Fisheries Assessment Report 2002/51*. 72 p.

Taylor, P.R. (2004a). Species composition and seasonal variability in commercial catches of jack mackerel (*Trachurus declivis*, *T. murphyi*, *T. novaezelandiae*) in JMA 1, 3, and 7 during 2000–01. *New Zealand Fisheries Assessment Report 2004/28*. 22 p.

Taylor, P.R. (2004b). Species composition and seasonal variability in commercial catches of jack mackerel (*Trachurus declivis*, *T. symmetricus murphyi*, and *T. novaezelandiae*) in JMA 1, JMA 3, and JMA 7 during 2001–02 and 2002–03. Final Research Report for MFish Project JMA2001/01. 20 p. (Unpublished report held by Ministry for Primary Industries,Wellington).

Taylor, P.R. (2008). Factors affecting fish size and landed volumes in the purse-seine and TCEPR charter-boat fisheries in 2004–05 and 2005–06. *New Zealand Fisheries Assessment Report 2008/32*. 17 p.

Taylor, P.R.; Beentjes, M.P.; McKenzie, A. (2008). The status of Murphy's mackerel (*Trachurus murphyi*) in New Zealand waters. Unpublished presentation to the Pelagic Fisheries Assessment Working Group, Ministry for Primary Industries, New Zealand. (Unpublished presentation held by Ministry for Primary Industries, Wellington).

Taylor, P.R.; Julian, K.A. (2008). Species composition and seasonal variability in commercial catches of jack mackerel (*Trachurus declivis*, *T. murphyi*, *T. novaezelandiae*) in JMA 1, 3, and 7 during 2004–05. *New Zealand Fisheries Assessment Report 2008/25*. 24 p.

Taylor, P.R.; Horn, P.L.; O'Maolagain, C. (In press). Commercial catch sampling for species proportion, sex, length, and age of jack mackerels in JMA 1 in the 2006–07, 2007–08 and 2008–09 fishing years. *New Zealand Fisheries Assessment Report*. 33 p.

Appendix 1: Total reported JMA 1 catch (t) by fishing year and subarea.

Fishing year	East Northland/ Hauraki Gulf	Bay of Plenty	Central East	Total JMA1	TACC
1990–91	804	6 275	297	7 376	5 970
1991–92	614	7 313	29	7 955	5 970
1992–93	1898	6 827	193	8 918	5 970
1993–94	11 500	1 289	1 467	14 256	8 000
1994–95	6 365	3 158	931	10 454	10 000
1995–96	414	5 164	763	6 341	10 000
1996-97	934	5 006	955	6 895	10 000
1997–98	1 110	6 041	387	7 538	10 000
1998–99	213	4 641	697	5 551	10 000
1999–20	87	2 305	528	2 920	10 000
2000–01	484	7 301	457	8 242	10 000
2001–02	348	4 294	847	5 488	10 000
2002–03	1 011	4 131	930	6 072	10 000
2003–04	1 913	4 555	976	7 444	10 000
2004–05	871	8 135	353	9 359	10 000
2005–06	393	9 392	160	9 944	10 000
2006–07	1 446	3 440	262	5 148	10 000
2007–08	2 753	8 607	142	11 502	10 000
2008–09	1 545	8 147	98	9 790	10 000
2009–10	197	8 769	123	9 089	10 000
2010–11	1 039	7 123	233	8 395	10 000

Appendix 2: Landed JMA 1 catch (t) by fishing year, subarea and method.

Fishing	East Northland/Hauraki Gulf				Bay of Plenty				Central East			
year	PS	BT	MW	Other	PS	BT	MW	Other	PS	BT	MW	Other
1990–91	767	11	0	25	6 180	23	0	72	280	15	2	0
1991–92	564	18	0	32	7 264	45	0	5	0	27	1	0
1992–93	1 841	30	0	26	6 770	54	0	3	99	70	23	0
1993–94	11 446	33	0	21	1 241	44	0	4	1 381	48	38	0
1994–95	6 315	36	0	14	3 095	60	0	2	658	203	70	0
1995–96	365	36	0	13	5 109	50	0	4	417	187	158	2
1996–97	913	24	0	10	4 951	50	0	76	542	120	307	0
1997–98	1 062	35	0	13	6 004	35	0	3	168	118	102	0
1998–99	186	21	0	6	4 535	105	0	1	497	119	82	0
1999–20	66	13	0	8	2 267	37	0	0	362	131	35	0
2000–01	470	10	0	3	7 265	36	0	0	301	107	49	0
2001–02	346	12	0	4	4 418	48	0	0	619	101	161	0
2002–03	1 004	6	0	2	4 067	67	0	1	504	139	287	0
2003–04	1 920	5	0	2	4 560	26	0	1	552	113	318	0
2004–05	878	5	0	2	8 248	17	0	1	44	115	200	0
2005–06	367	31	0	2	9 502	39	1	0	23	76	63	0
2006–07	1 427	17	0	3	3 416	24	0	2	53	60	148	0
2007–08	2 838	14	0	5	8 909	22	0	1	47	66	34	0
2008–09	1 629	12	0	3	8 652	16	0	2	0	77	27	0
2009–10	187	14	0	9	9 306	37	0	1	11	105	15	0
2010–11	1 055	16	0	4	7 334	33	0	0	96	117	27	0

Appendix 3: Landed purse-seine catch (t) from JMA 1 by fishing year, subarea and statistical reporting area.

Fishing									East Northland/Hauraki Gulf			Bay of Plenty
year	001	002	003	004	005	006	007	106	107	008	009	010
1990–91	0	468	145	0	0	1	71	82	0	113	5 474	593
1991–92	0	143	200	0	0	160	40	19	0	567	6 696	0
1992–93	0	1 141	631	0	10	0	0	60	0	69	6 443	258
1993–94	0	6 956	4 198	0	0	0	0	292	0	4	1 081	156
1994–95	0	3 133	3 018	164	0	0	0	0	0	452	2 643	1
1995–96	0	40	325	0	0	0	0	0	0	1 547	3 561	2
1996-97	0	497	366	0	0	13	0	24	0	282	4 599	0
1997–98	0	622	42	398	0	0	0	0	0	468	5 535	0
1998–99	0	140	47	0	0	0	0	0	0	1 360	3 174	0
1999–20	0	62	1	1	3	0	0	0	0	77	2 159	30
2000–01	0	192	278	0	0	0	0	0	0	914	6 350	0
2001–02	0	156	176	0	0	0	0	0	0	365	3 883	0
2002–03	0	180	780	0	0	43	0	0	0	1 223	2 824	16
2003–04	0	1 617	283	0	6	0	0	0	0	1 012	3 491	26
2004–05	0	414	366	79	5	0	0	0	0	1 960	6 157	0
2005–06	0	237	119	0	4	0	0	0	0	810	8 468	73
2006–07	0	1 101	266	0	11	0	0	48	0	50	3 363	0
2007–08	0	1 564	1 167	0	3	0	0	0	0	999	7 582	4
2008–09	0	221	1 278	31	1	0	0	0	0	451	7 671	8
2009–10	0	103	72	0	0	0	0	0	0	453	8 160	121
2010–11	0	728	255	0	28	1	9	0	0	104	6 946	40

Fishing										Central East
year	011	012	013	014	015	016	201	203	204	205
1990–91	0	0	179	101	0	0	0	0	0	0
1991–92	0	0	0	0	0	0	0	0	0	0
1992–93	0	0	37	29	33	0	0	0	0	0
1993–94	0	0	40	1 269	22	0	50	0	0	0
1994–95	0	0	24	622	0	0	12	0	0	0
1995–96	0	0	43	374	0	0	0	0	0	0
1996-97	0	0	257	277	0	0	0	0	0	0
1997–98	0	0	0	168	0	0	0	0	0	0
1998–99	0	0	0	478	18	0	0	0	0	0
1999–20	0	0	0	362	0	0	0	0	0	0
2000–01	154	0	0	147	0	0	0	0	0	0
2001–02	0	0	0	236	359	0	0	0	0	0
2002–03	0	0	86	397	21	0	0	0	0	0
2003–04	129	3	5	363	48	0	0	0	0	0
2004–05	0	0	21	22	0	0	0	0	0	0
2005–06	0	0	0	23	0	0	0	0	0	0
2006–07	0	0	0	53	0	0	0	0	0	0
2007–08	0	0	45	0	0	0	0	0	0	0
2008–09	0	0	0	0	0	0	0	0	0	0
2009–10	10	0	0	0	0	0	0	0	0	0
2010–11	0	0	1	0	92	0	0	0	0	0

Appendix 4: Landed purse-seine catch (t) from JMA 1 by fishing year, subarea and month.

East Northland/Hauraki Gulf

Fishing year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1990–91	301	23	0	0	0	0	0	71	0	0	0	372
1991–92	155	27	69	3	0	0	0	197	0	19	0	93
1992–93	87	61	39	345	455	3	182	0	410	42	0	216
1993–94	956	420	639	0	0	346	232	18	967	1 767	3 081	3 021
1994–95	101	661	1 235	518	458	71	6	194	0	0	2 574	499
1995–96	0	42	98	1	0	0	0	0	0	0	0	224
1996-97	203	172	81	0	1	0	0	0	0	0	0	443
1997–98	284	266	74	6	2	8	9	15	0	0	1	398
1998–99	0	79	79	0	0	3	1	0	0	0	0	25
1999–20	0	62	0	0	1	0	1	1	2	0	0	0
2000–01	39	55	158	0	14	9	4	11	0	0	0	181
2001–02	150	28	120	3	3	1	0	3	1	0	0	23
2002–03	650	100	169	0	0	0	0	3	37	0	0	43
2003–04	43	153	36	3	1	20	11	3	4	6	134	1 492
2004–05	391	134	88	217	0	5	23	5	0	0	0	0
2005–06	0	97	35	3	0	9	20	13	12	0	15	156
2006–07	58	139	54	50	11	3	21	0	0	0	0	1 090
2007–08	1 022	25	1	1	4	0	2	18	10	15	2	1 635
2008–09	1 023	409	22	5	8	0	4	15	12	0	33	0
2009–10	0	17	104	15	4	0	12	0	0	12	4	7
2010–11	16	232	131	27	40	2	47	0	6	22	1	497

Bay of Plenty

Fishing year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1990–91	283	653	392	0	0	0	415	1 144	1 919	633	546	196
1991–92	94	234	662	721	615	492	1 725	565	255	77	545	1 277
1992–93	214	442	639	510	0	0	308	1 407	817	429	78	1 926
1993–94	439	630	47	0	0	10	0	77	0	35	0	4
1994–95	34	558	8	435	82	22	0	0	785	464	23	685
1995–96	160	26	3	1	2	0	0	180	496	1 054	1 644	1 543
1996–97	130	0	0	30	0	0	0	121	438	1 550	1 818	795
1997–98	1 443	107	670	0	0	0	159	0	509	86	995	2 036
1998–99	1 758	262	0	1	0	0	0	105	875	560	635	339
1999–20	305	8	32	0	8	0	58	0	238	0	363	1 255
2000–01	241	292	273	220	187	167	0	0	1 156	1 162	1 701	1 866
2001–02	564	72	363	14	0	0	0	76	414	918	604	1 221
2002–03	0	0	0	337	713	0	0	7	45	856	226	1 878
2003–04	186	95	569	20	39	51	205	1 544	638	184	30	967
2004–05	555	1 345	0	163	230	79	13	245	924	61	1 566	2 935
2005–06	1 817	1 428	463	258	48	308	661	295	1 165	728	1 385	794
2006–07	84	298	647	155	256	237	604	60	466	353	0	255
2007–08	454	2 733	568	157	69	0	171	460	1 256	531	98	2 088
2008–09	2 006	771	2 864	8	0	0	0	0	254	801	392	1 034
2009–10	2 835	128	1 746	0	198	282	147	427	14	1 359	857	741
2010–11	2 780	1 973	493	70	149	56	0	181	253	129	62	943

Fishing												Central East
year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1990–91	41	0	179	0	0	0	0	0	0	0	11	49
1991–92	0	0	0	0	0	0	0	0	0	0	0	0
1992–93	0	60	39	0	0	0	0	0	0	0	0	0
1993–94	51	176	12	571	74	0	0	447	50	0	0	0
1994–95	135	265	0	0	58	95	105	0	0	0	0	0
1995–96	313	0	0	0	2	20	82	0	0	0	0	0
1996-97	534	0	0	0	0	0	0	0	0	0	0	0
1997–98	78	0	0	0	0	0	0	0	0	0	0	90
1998–99	171	240	0	0	0	0	0	0	0	8	30	48
1999–20	53	54	124	0	0	0	0	116	0	0	0	14
2000–01	114	0	0	187	0	0	0	0	0	0	0	0
2001–02	0	0	0	0	0	177	418	0	0	0	0	0
2002–03	62	319	101	0	0	9	0	12	0	0	0	0
2003–04	85	145	136	129	5	48	0	0	0	0	0	0
2004–05	5	36	0	0	0	0	0	0	0	0	0	2
2005–06	23	0	0	0	0	0	0	0	0	0	0	0
2006–07	0	0	29	0	0	0	0	0	0	0	0	24
2007–08	0	45	0	0	0	0	0	0	0	0	0	0
2008–09	0	0	0	0	0	0	0	0	0	0	0	0
2009–10	0	0	10	0	0	0	0	0	0	0	0	0
2010–11	1	0	0	0	0	0	92	0	0	0	0	0

Appendix 5: Landed purse-seine catch (t) from JMA 1 by fishing year, subarea and target species.

Fishing	East Northland/Hauraki Gulf				Bay of Plenty				Central East			
year	JMA	EMA	KAH	Other	JMA	EMA	KAH	Other	JMA	EMA	KAH	Other
1990–91	330	437	0	0	4991	371	818	0	0	0	280	0
1991–92	453	111	0	0	6650	228	325	60	0	0	0	0
1992–93	998	791	42	10	6158	111	501	0	33	0	66	0
1993–94	10613	803	21	9	784	50	398	10	1108	0	273	0
1994–95	5423	891	0	2	2848	64	184	0	388	12	256	3
1995–96	224	139	0	3	4983	26	55	46	77	0	313	27
1996-97	646	253	0	2	4369	30	476	6	101	0	434	0
1997–98	688	339	0	36	5787	31	185	0	35	40	92	0
1998–99	55	127	0	4	4006	151	359	17	333	9	86	69
1999–20	0	62	0	4	1990	82	175	20	116	0	245	0
2000–01	2	422	0	46	6905	296	43	21	89	0	211	0
2001–02	111	210	0	11	4198	9	26	14	524	0	71	0
2002–03	673	330	0	0	3980	62	11	10	148	0	356	0
2003–04	1740	121	0	45	4272	0	160	97	358	2	183	5
2004–05	507	318	0	38	7731	322	62	2	9	0	34	0
2005–06	102	190	0	69	9114	146	72	20	0	0	23	0
2006–07	1172	212	0	42	3246	47	100	20	24	0	29	0
2007–08	2677	49	0	9	8363	84	82	56	0	0	45	0
2008–09	1447	24	0	59	8051	72	0	8	0	0	0	0
2009–10	124	0	0	52	8651	40	14	29	0	0	10	0
2010–11	920	0	0	100	6733	290	47	20	14	0	79	0

Appendix 6: Summary of the catch (total number and weight of landings) and samples (number of landings and weight sampled, and number of fish measured) for each month in the JMA 1 purse-seine fishery between January 2009 and September 2011.

	Number of landings			Weight of landings (t)			No. of fish
Month-year	Total	Sampled	% of total	Total	Sampled	% of total	measured
Jan-09	0	0	0	0	0	0	0
Feb-09	0	0	0	0	0	0	0
Mar-09	0	0	0	0	0	0	0
Apr-09	0	0	0	0	0	0	0
May-09	0	0	0	0	0	0	0
Jun-09	4	0	0	264	0	0	0
Jul-09	10	1	10.0	843	37	4.4	3 220
Aug-09	4	3	75.0	410	320	77.9	2 312
Sep-09	14	8	57.1	1 024	678	66.2	3 801
Oct-09	17	10	58.8	2 746	1 460	53.2	6 378
Nov-09	1	0	0	125	0	0	0
Dec-09	14	0	0	1 813	0	0	0
Jan-10	1	0	0	11	0	0	0
Feb-10	3	0	0	179	0	0	0
Mar-10	4	0	0	310	0	0	0
Apr-10	5	0	0	154	0	0	0
May-10	10	4	40.0	447	220	49.2	1 409
Jun-10	1	0	0	14	0	0	0
Jul-10	13	8	61.5	1 325	911	68.7	7 231
Aug-10	11	5	45.5	836	526	63.0	3 506
Sep-10	10	7	70.0	722	558	77.3	3 683
Oct-10	23	11	47.8	2 728	1 475	54.1	8 219
Nov-10	20	3	15.0	2 147	228	10.6	1 284
Dec-10	8	0	0	594	0	0	0
Jan-11	3	0	0	76	0	0	0
Feb-11	4	0	0	171	0	0	0
Mar-11	1	0	0	55	0	0	0
Apr-11	2	0	0	126	0	0	0
May-11	3	0	0	175	0	0	0
Jun-11	5	1	20.0	243	112	46.0	1 307
Jul-11	2	0	0	120	0	0	0
Aug-11	2	2	100.0	49	17	34.6	626
Sep-11	10	9	90.0	1 404	1 249	89.0	11 107
All months	205	72	36.6	19 109	7 791	40.8	54 083

Appendix 7: Estimated proportions and c.v.'s of the three jack mackerel species (JMD, *Trachurus declivis*; JMM, *T. murphyi*; JMN, *T. novaezelandiae*) landed by month from the JMA 1 purse-seine fishery between January 2009 and September 2011.

	Estimated proportion			Coefficient of variation			
Month/year	JMD	JMM	JMN	JMD	JMM	JMN	Catch (t)
7/2009	0.000	0.000	1.000	–	–	0.00	843
8/2009	0.000	0.000	1.000	–	–	0.00	410
9/2009	0.003	0.000	0.997	0.66	–	0.00	1 024
10/2009	0.012	0.001	0.987	0.35	0.89	0.00	2 746
5/2010	0.000	0.000	1.000	–	–	0.00	310
7/2010	0.000	0.000	1.000	–	–	0.00	1 325
8/2010	0.041	0.000	0.959	0.63	–	0.02	836
9/2010	0.021	0.000	0.979	0.87	–	0.02	722
10/2010	0.076	0.027	0.897	0.42	0.63	0.05	2 728
11/2010	0.184	0.038	0.778	0.53	0.52	0.24	2 147
6/2011	0.002	0.000	0.998	0.99	0.00	0.00	243
8/2011	0.000	0.000	1.000	0.00	0.00	0.00	49
9/2011	0.365	0.024	0.610	0.57	0.70	0.34	1 404

Appendix 8: Estimated proportions and c.v.'s of the three jack mackerel species (JMD, *Trachurus declivis*; JMM, *T. murphyi*; JMN, *T. novaezelandiae*) landed by season from the JMA 1 purse-seine fishery between January 2009 and September 2011.

	Estimated proportion			Coefficient of variation			Proportion mean			
Fishing year season	JMD	JMM	JMN	JMD	JMM	JMN	JMD	JMM	JMN	Catch (t)
2008–09 late	0.002	0.000	0.998	0.690	–	0.001	0.002	0.000	0.998	2 541
2009–10 early	0.012	0.001	0.987	0.340	0.900	0.004	0.017	0.003	0.980	5 184
2009–10 late	0.014	0.000	0.986	0.560	–	0.006	0.017	0.001	0.982	3 498