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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 2011 and September 2013

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EXECUTIVE SUMMARY

Walsh, C.; Bian, R.; McKenzie, J.; Spong, K., Armiger, H. (2016). 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 2011 and September 2013.

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This report presents the results of Objectives 1–3 of the Ministry for Primary Industries project "Catch composition of jack mackerel fisheries in JMA 1" (JMA201101). 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 2011 and September 2013 by catch sampling. In addition, a characterisation was undertaken to describe the fishery catch and assess the representativeness of the sampling programme.

A total of 54 purse-seine landings (47 of which met sampling criteria) in two fishing years, 2011–12 and 2012–13, were sampled as part of this study. These were combined with an additional 12 landings from 1 January – 30 September 2011, collected as part of a previous study, to allow calculations to be made for the 2011 and 2012 calendar years.

Purse-seine landings from JMA 1 were dominated by *T. novaezelandiae* in 52 (88%) of the 59 sampled landings and in all but two sampled months. The estimated proportions for fishing year and calendar year ranged from 10 to 24% for *T. declivis*, 1 to 3% for *T. murphyi*, and 73 to 88% for *T. novaezelandiae.* There was evidence of 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 almost the entire year, often in the absence of the other two species. Large *T. declivis* and *T. murphyi* dominated a handful of East Northland catches, at times in the absence of *T. novaezelandiae*. Precision on species proportion estimates was usually high for *T. novaezelandiae* (mean weighted coefficient of variation (MWCV) less than 0.15), during the study, and well below the target estimate of 0.30. Precision for *T. declivis and T. murphyi* was mostly lower (MWCV 0.13–0.48), reflecting the highly variable occurrence for these species in recent JMA 1 purse-seine landings.

Over 62 000 jack mackerel were measured for length frequency from a total of 47 sampled landings in the JMA 1 purse-seine fishery over the 2011–12 and 2012–13 fishing years. The length compositions for the three species were similar to those in recent years. It is estimated that about 19 and 16 million jack mackerel were landed by purse-seine from JMA 1 over the respective fishing years.

Although sample sizes fell short of the fishing year targets, and on occasions sampling did not occur in months where there were candidate landings, overall, sampling was considered to be distributed in reasonable proportion to, and representative of, the JMA 1 purse-seine fishery operation over the 2011–12 and 2012–13 fishing years. 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 2011 to September 2013. Data are presented by fishing year (October–September) to satisfy the reporting requirements to the New Zealand Ministry for 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, set in 1994–95. An estimated $57 million was earned from jack mackerel exports in 2013, the fourth most important finfish in New Zealand (Seafood New Zealand 2014). 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 an exotic species - *T. murphyi* (JMM; Chilean jack mackerel). 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 (less than 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 2014). *T. murphyi* appeared in New Zealand in the mid-1980s, and is considered one of the world's more important commercial fish species (FAO statistics). There are concerns that the South Pacific *T. murphyi* stock now may be in danger of collapsing due to overfishing and this has resulted in the recent introduction of conservation and management measures by the SPRFMO.

All three jack mackerel species were introduced into the Quota Management System (QMS) in 1 October 1996, under the aggregate general code JMA. Use of the single JMA reporting code means that it is not possible to determine the quantity of each species caught annually from commercial catch landings data. Information on the composition of all three species in commercial catches is however deemed essential for management and assessment of the jack mackerel stocks. Estimates of species proportions have been used to apportion the aggregated JMA catch histories into individual catch histories for each of the three species, going back as far as 1985–86 (Penney et al. 2011).

All three species of jack mackerel occur within the JMA 1 quota management area, which encompasses the entire east coast of the North Island (Figure 1). Over 90% of JMA 1 annual landings are taken by "domestic" purse-seine vessels, in a target fishery operating out of Tauranga that fishes predominantly 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 high, ranging between 81 and 98% of the TACC in subsequent years, although the most recent catch in 2012–13 (8054 t) was the lowest since 2006–07 (Figure 2). The current 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 of jack mackerel (Ministry for Primary Industries 2014).

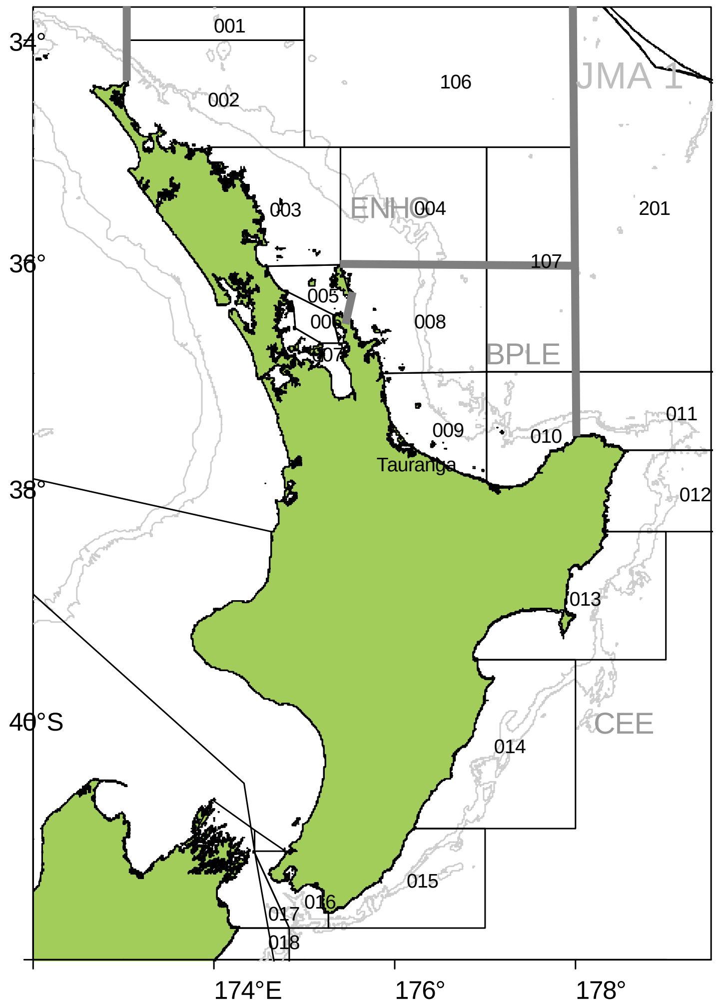

Figure 1: Quota Management Area for the east coast North Island jack mackerel stock, JMA 1 and the three subareas used in this report: East Northland/Hauraki Gulf (ENHG), Bay of Plenty (BPLE), and Central East Coast (CEE) of the North Island.

Increased availability of jack mackerels since the 1980s caused by the influx of *T. murphyi* resulted in increased quotas in JMA 1 from 5970 t to 8000 t in 1993–94 and to 10 000 t in 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 limits and voluntarily introduced monitoring programmes to provide the information necessary for them to be met.

Relative proportions of the jack mackerel species in New Zealand were first estimated by Horn (1991b). The first species compositional estimates for the JMA 1 purse-seine fishery were derived from catch 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). Catch sampling of the JMA 1 purse-seine fishery for species composition has been undertaken in every fishing year (1 October to 30 September) since 1996 (Taylor 1998, 1999, 2000, 2002, 2004a, 2004b, Taylor & Julian 2008, Taylor et al. 2012, Penney et al. 2011, Walsh et al. 2012). Penney et al. (2011) derived monthly JMA 1 species proportion estimates for the period October 1985 to December 2010 to investigate historical catch and catch composition trends, and to provide SPRFMO and the FAO with data for the three jack mackerel species by calendar year.

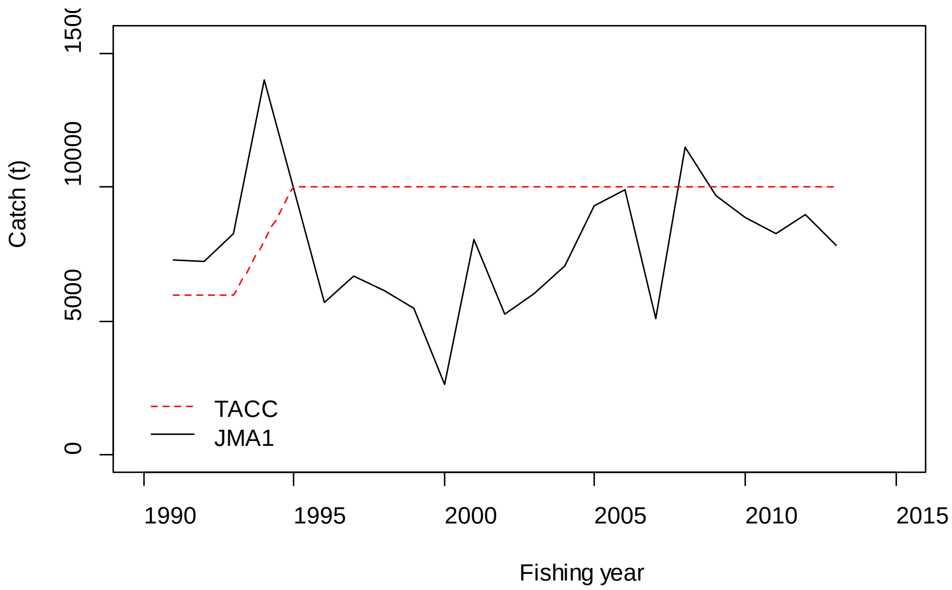

Figure 2: Reported landings of jack mackerel (t) in JMA 1 and gazetted and actual TACCs (t) for 1990–91 to 2012–13.

1.2 Scope of the report

This report presents the results of catch sampling for length, species composition, and seasonality of three *Trachurus* species in the JMA 1 purse-seine fishery between January 2011 and September 2013, which extends the existing time series. The report follows the recommended procedures as specified in Penney et al. (2011) for estimating or substituting missing species catch proportions for months in which sampling data are not available. Incorporated in the analysis are the species proportion estimates sampled during the first nine months (January to September) of the 2011 calendar year from project JMA200901. Adding data from October to December of 2011 allows for the complete 2011 calendar year species proportions to be provided to the SPRFMO and FAO, where previously only the first nine months were available (see Walsh et al. 2012).

In the previous study JMA200901 (Walsh et al. 2012), three different approaches were used for estimating species proportions of the total JMA 1 purse-seine catch, either by fishing year or calendar year: Approach I involves stratification at the monthly level where estimated annual (i.e. fishing year or calendar year) species proportions are derived by summing up the monthly stratified samples and the landings in the corresponding months and ignoring unsampled months; Approach II calculated annual species proportion means from the proportions of all months, with un-sampled months imputed with the annual average proportion of the corresponding calendar year; Approach III introduced a temporal stratification (essentially replacing month with season) of October–December and January–September to calculate annual species proportions.

Walsh et al. (2012) proposed that Approach III be adopted for future sampling of jack mackerel species proportions in JMA 1 using temporal stratification as opposed to individual months. It was expected that this would ensure that more adequate sample sizes would be collected than would normally be possible in individual months and would form a better temporal description of the overall purse-seine catch of jack mackerel. 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, and suggested further review involving scientists with appropriate statistical expertise. However, no further analysis has yet been undertaken to determine which of the three approaches documented in Walsh et al. (2012) and in this current study is more analytically suited to estimating species proportions.

Funding for this project, JMA201101, was provided by the New Zealand Ministry for Primary Industries (MPI). Species composition data are presented by fishing year (October–September) to satisfy the reporting requirements to the MPI, and calendar year, for the SPRFMO and FAO. Length frequency data are presented by fishing year only.

JMA201101 objectives
The specific objectives of this project for 2011–12 and 2012–13 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 length, seasonality, and species composition of the commercial catches of *T. declivis*, *T. murphyi*, and *T. novaezelandiae* in JMA 1 in the 2011/2012 and 2012/2013 fishing years.

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.

2. METHODS

2.1 Characterisation of recent fishery profile data for JMA 1, 1990–91 to 2012–13

A characterisation of patterns in the JMA 1 stock and subarea fisheries (East Northland/Hauraki Gulf (ENHG), Bay of Plenty (BPLE), and Central East Coast (CEE) of the North Island) over the period October 1990 through to September 2013 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 (all jack mackerel species) from all trips landing JMA 1 catch.

Data obtained from the Ministry for Primary Industries (MPI) was groomed and checked for typical reporting errors. Information to perform a characterisation of the JMA 1 fishery was compiled into two tables:

1. Landed catch weight: A file containing the green (unprocessed) landed weight of all JMA 1 trips.
2. Trip effort data: A file containing demographic information (location, method, target species, estimated catch etc).

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 MPI 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 2011–12 and 2012–13

2.2.1 Catch sampling for length and species composition

In the current study (2011–12 and 2012–13) sampling was implemented such that a random sample of ungraded jack mackerel was selected from each vessel hold, essentially following the two-stage sampling design of West (1978). This design involved a random selection of “candidate” landings (first stage) that targeted jack mackerel from the JMA 1 stock and comprised a minimum catch of at least 10 t, with a modification in that each hold (ranging up to between four and eight in purse-seine landings) was treated as a separate stratum from which a random sample (second stage) of approximately 300 ungraded jack mackerel was taken. To maintain randomness throughout the sample selection process, approximately 100 fish were sampled from the top, middle and bottom of each hold during unloading as the hold was vacuumed onto a conveyer belt, with the total sample size roughly equalling the target of 300 ungraded fish, generally equating to around half the capacity of a dolav 1000 (600 L solid box pallet; Figure 3). This sampling regime was instigated at Sanford Ltd while the vessel was being unloaded, but proved to be unworkable at Pelco NZ Ltd, where instead a sample comprising about 300 fish was vacuumed from each hold, usually when the hold was about half empty. It was essential that the jack mackerel designated to be the sample were not graded (i.e., large *T. declivis* and *T. murphyi* were not removed) on the conveyer belt prior to tipping into the dolav. In the event that the hold contained predominantly large fish (i.e., *T. declivis*) the sample volume in the dolav was increased to ensure that around 300 fish were selected. This design ensures that samplers do not choose individual fish from the catch directly, which may introduce bias (West 1978).

Figure 3: Example of jack mackerel (*T. novaezelandiae*) after being vacuumed from a vessel hold onto a conveyer belt and tipped into a 600 litre dolav. A half full dolav for this species generally results in about a 300 fish sample selection, slightly more for a sample of the larger *T. declivis* and *T. murphyi*.

Each hold sample of jack mackerel (within landing strata) was sorted and weighed by species and measured for length. To maintain rigor in the sampling process, it was essential that samples were made independently from all holds comprising a reasonable tonnage (i.e., more than 5 t) of jack mackerel within a landing. This sampling strategy was necessary because the catch of jack mackerel from a single purse-seine shot, dependent on size, is brailed into multiple holds on the vessel to ensure stability at sea. Each successive shot (or part thereof) may therefore be mixed across holds partially filled from previous shots until each hold is full. As a result, each hold may comprise a proportion of jack mackerel from more than one shot, possibly reflecting multiple schools.

Landings where not all holds were sampled, were therefore omitted from the analysis to limit uncertainty arising from inter-school variation in catches. The only exceptions to this rule were when the total catch of jack mackerel was from a single shot (often a catch in excess of 100 t) and from these trips fewer hold samples (i.e., three to four) were allowed, or when an un-sampled hold comprised a very low tonnage of jack mackerel (i.e., less than 5 t).

The sampling design for 2011–12 and 2012–13 required sampling 30 purse-seine landings in each fishing year allocated to the two main JMA 1 fishing companies (Sanford Ltd and Pelco NZ Ltd) roughly in proportion to their quota allocations (Table 1). No temporal stratification was imposed on the sampling design other that it be in proportion to the commercial purse-seine catch of jack mackerel over the consecutive fishing years, and that sampling take place over all months where candidate landings occur.

Table 1: Level of sampling proposed to describe the JMA 1 purse-seine fishery for length and species composition data in 2011–12 and 2012–13.

Fishery	Fishing year	Fishing company	Method	Number of targeted JMA landings >10 t	Number of fish sampled from each vessel hold
JMA 1	2011–12	Sanford Ltd	Purse-seine	20	300
		Pelco NZ Ltd	Purse-seine	10	300
	2012–13	Sanford Ltd	Purse-seine	20	300
		Pelco NZ Ltd	Purse-seine	10	300

Sampling was carried out at Sanford Ltd by Sanford staff, and Pelco NZ Ltd by the National Institute of Water and Atmospheric Research (NIWA). The final derived species proportion estimates were for the purse-seine fishery as a whole, i.e. as combined proportions from the two companies.

2.3 Data analysis for JMA 1

2.3.1 Deriving fishing year and calendar year species proportion estimates

The proportions of *T. declivis*, *T. murphyi* and *T. novaezelandiae* (referred to in 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:

1) **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 a weighted average of the sampled month estimates ignoring un-sampled months.

2) **Using substituted monthly estimates for un-sampled months:** Include catch from un-sampled months in the fishing and calendar year estimates by assigning them the species proportion estimates for the corresponding calendar year (i.e., each fishing year will require two calendar year estimates) and calculate weighted average species proportions by fishing year and calendar year.

3) **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 average of the component seasons.

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

Landings were temporally stratified by month for the estimation of proportions of the three jack mackerel species for a fishing year and calendar year. Species proportions for the sampled landings were calculated from the landings' species weights, which were the sums of the holds' species weights.

The weight of jack mackerel in each hold was often not known and hence, where possible, was derived by prorating the known total landed weight from the vessel skipper's pelagic vessel trip summary, which documents relative catch by species and estimated weight across holds. Where information to prorate the hold weights was unavailable the hold weight was derived by dividing the total landed weight by the number of holds sampled.

Species proportions for months were the weighted means of the landing species proportions, 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 (CV) of each species proportion was estimated by bootstrapping fish within sampled landings, from landings bootstrapped within months, for each calendar or fishing year.

Given *h* is a hold within landing *l*, let $\widetilde{w}_h^{(.)}$ and $\widetilde{w}_l^{(.)}$ be the sample weights of one of the species (JMD, JMM or JMN) in hold *h* and landing *l*, $\widetilde{w}_h$ and $\widetilde{w}_l$ be the combined sample weights of all jack mackerel species in hold *h* and landing *l*, w_h and w_l be the total catch weights of all jack mackerel species in hold *h* and landing *l*, then the proportion of one of the three species for hold h, $p_h^{(.)}$ and $p_l^{(.)}$, can be calculated by

$$p_h^{(.)} = \frac{\widetilde{w}_h^{(.)}}{\widetilde{w}_h} \qquad (1)$$

$$p_l^{(.)} = \frac{1}{\sum_{h \in l}(w_h)} \sum_{h \in l} (p_h^{(.)} \cdot w_h) \qquad (2)$$

The species proportions for months ($p_m^{(.)}$) were calculated by $p_m^{(.)} = \frac{1}{\sum_{l \in m}(w_l)} \sum_{l \in m}(p_l^{(.)} \cdot w_l)$, which can be derived from Equation (2) with replacement of hold *h* to landing *l* and landing *l* to month *m* and will be referred as Equation (2m). Similarly the equation for the calculation of species proportions for fishing years was derived from Equation (2) by replacing hold *h* with month *m* and landing *l* with fishing year *f* and the derived equation will be referred as Equation (2f). Equation (2) was also modified by replacing hold *h* with month *m* and landing *l* with calendar year *y*, which will be referred as Equation (2y), and used in calculation of species proportions for calendar years.

Bootstrap (randomly sample with replacement) was used to estimate the uncertainty associated with species proportion estimates for month, fishing year and calendar year. The sampled landings were firstly bootstrapped and then in each of the landings fish were bootstrapped within the holds. Species proportions for month, fishing year and calendar year are calculated for each bootstrap and the bootstrap was repeated n times. CVs were calculated from those proportions for month, fishing year and calendar year.

Step 1. Estimating CVs for monthly species proportion estimates

a) bootstrap the sampled landings within month m

b) bootstrap fish within the holds in each of the bootstrapped landings and calculate weight of all three species for each hold

Assuming h is a hold within bootstrapped landing l and K, M and N are the numbers of fish of species JMD, JMM and JMN in the sample data of hold h, 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.

ii) sample the string with replacement

iii) use each species length-weight relationship to calculate weight for the fish that length data are available for and use average weight per fish for the fish that length data are not available for 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 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 hold h and landing l using Equation (1) and (2)

d) calculate species proportions for month m using Equation (2m)

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

f) calculate CV for the monthly species proportion estimate $p_m^{(.)}$

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

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

Step 2. Estimating CVs for fishing year and calendar year species proportions

The methods for calculating species proportions for fishing year and calendar year are identical, so the process described below for determining CVs 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 within holds from each bootstrapped landing and calculate weights for the holds, see b) in Step 1 for details

c) calculate species proportions for holds, landings and months using Equation (1), (2) and (2m). Note: the months in a bootstrap are not necessarily the same as the months in the original landing sample data.

d) calculate annual species proportions for calendar years using Equation (2y)

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

f) calculate CV for the species proportion of season *s*

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

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

Equation (4) was also used to calculate CVs for fishing year f, $\mathrm{CV}(p_f^{(.)})$, 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

In Approach II, monthly proportions of jack mackerel species were calculated for the months that jack mackerel landings were sampled in the same manner as Approach I. The species proportions for the months in which no landings were sampled were assigned with the estimated species proportions for the corresponding calendar year by Approach I (Penney et al. (2011) and personal communication with Marc Griffiths, MPI). Because Approach II relies on calendar year species proportions for the un-sampled months, it cannot give a species proportion estimate for a fishing year or calendar year with un-sampled months when a full calendar year (12 months) of data are not available. For example, when only nine months (January to September) data were available for year 2013 in this study and in some of the months, landings were not sampled, the species proportions for both calendar year 2013 and fishing year 2012–13 cannot be determined using Approach II.

After having obtained the species proportions for months and calendar years (Section 2.3.1.1), those un-sampled months were assigned with the annual species proportions and the final species proportion for calendar year *y*, $p_y^{(.)}$, was calculated by

$$p_y^{(.)} = \frac{1}{\sum_{M\in y}(w_M)}\sum_{M\in y}(p_M^{(.)}\cdot w_M), \qquad (5)$$

where $p_M^{(.)}$ is the species proportions for all 12 months (sampled and un-sampled) in year *y*, and w_M is the landed catch in the 12 months. The species proportions for fishing years were also calculated from an equation derived from Equation (5) with the replacement of calendar year *y* by fishing year *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 introduce bias and influence the precision of the species proportions estimated with the methods outlined in Section 2.3.1.1 (Walsh et al. 2012). The method discussed in Section 2.3.1.2 reflects the effort that has been made to try to address the issue of sampling gaps. For the samples that have been taken, 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 the considerations, two seasons were determined as 1 January to 30 September and 1 October 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. Equation (1) and (2) were used in the estimation of species proportions for holds and landings. Species proportions for seasons, fishing years and calendar years were calculated from equations derived from Equations (2m), (2f) and (2y) with the replacement of month $\boldsymbol{m}$ by season $\boldsymbol{s}$.

CVs were estimated for the seasonal, annual and fishing year species proportion estimates using bootstrap methods and the calculation of CVs follows the same process as discussed in Step 1 and Step 2 of Section 2.3.1.1 with the replacement of month $\boldsymbol{m}$ by season $\boldsymbol{s}$.

2.3.2 Estimating species length compositions

Length measurements were made from the selected jack mackerel species samples to obtain length frequency distributions. Fish length data for the three species were collected with stratification of holds within each sampled landing. 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 frequency distributions were estimated for the catches in fishing years.

Length frequency distributions obtained from the length data for holds within a sampled landing were scaled to the total catches of the holds and scaled hold length frequency distributions were summed up to the landing's length frequency distribution. Although two methods were considered for the scaling, i.e., to scale by proportion or to scale to weight, to be consistent with the methods used in the species proportion estimates and with the previous publication (Walsh et al. 2012), we chose to use method scaling-to-weight in the catch-at-length analysis.

To scale to weight means that the length frequency distribution estimated from a sample for a hold within a sampled landing is multiplied by a ratio so that the total weight of all fish in the length frequency distribution will be equal to the total catch of the hold. In the estimation of a hold's length frequency distribution in a sampled landing, the weights of both the hold and its sample are known and therefore a ratio can be calculated for the scaling. In the process of estimating CVs by bootstrap, the weight of each bootstrap of the sample is unknown and needs to be estimated from the fish lengths of the bootstrapped sample using the length-weight relationship. The ratio for scaling will vary for different bootstraps, because the sample weight changes while the total catch remains unchanged. With the method of scaling to weight, each species length frequency distribution for a fishing year was calculated by scaling holds' length frequency distributions to the holds' total catches of the species and then summing holds' species length frequency distribution to the landing's length frequency distribution and finally summing all sampled landings' length frequency distributions in the fishing year.

The hold weights for *T. declivis* and *T. novaezelandiae*, and *T. murphyi* were calculated from the hold weights of jack mackerel and the species proportions estimated in Section 2.3.1.

The precision of each length frequency composition is measured by the mean weighted CV (MWCV). This was calculated as the average of the CVs for the individual length classes weighted by the proportion of fish in each class. The CVs 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 hold and 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 2012–13

3.1.1 Data grooming errors

The "true" landed catch weights were derived after removing non-terminating catch records (for example records of fish retained on board the vessel) from the landed catch data (Table 2). Non-terminating 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 2).

The amount of annual catch that could be linked to (and prorated across) effort events varied between 78–99% (Table 2). 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 linked to trips occurring in JMA 3 and JMA 7 only. From the records it is not possible to determine if 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 therefore the effort demographics of the proportion of linkable JMA 1 catch are the same as of the catch that could not be linked to effort (difference between "Actual landed" and "Effort link" totals in Table 2).

Table 2: Breakdown of total JMA 1 reported landed catch (t) by fishing year, showing total non-terminating (retained, not landed), actual landed weights, and the amount of catch that could be included in the characterisation (linked to effort).

Fishing year	Total reported landed catch	Non-terminating	% Non-terminating	Actual landed catch	Effort link	% Effort link
1990–91	7 376	0	0	7 376	7 303	99.0
1991–92	7 956	1	0.01	7 955	7 239	91.0
1992–93	8 918	0	0	8 918	8 266	92.7
1993–94	14 256	0	0	14 256	13 992	98.2
1994–95	10 454	0	0	10 454	9 933	95.0
1995–96	6 341	0	0	6 341	5 722	90.2
1996–97	6 994	99	1.42	6 895	6 665	96.7
1997–98	7 539	1	0.01	7 538	6 123	81.2
1998–99	5 551	0	0	5 551	5 469	98.5
1999–20	2 920	0	0	2 920	2 630	90.1
2000–01	8 243	1	0.01	8 242	8 021	97.3
2001–02	5 708	220	3.85	5 488	5 258	95.8
2002–03	6 078	6	0.1	6 072	6 036	99.4
2003–04	7 496	52	0.69	7 444	7 083	95.2
2004–05	9 509	150	1.58	9 359	9 290	99.3
2005–06	10 104	160	1.58	9 944	9 920	99.8
2006–07	6 597	4	0.06	6 593	5 101	77.4
2007–08	11 937	435	3.64	11 502	11 483	99.8
2008–09	10 418	628	6.03	9 790	9 706	99.1
2009–10	9 685	596	6.15	9 089	8 861	97.5
2010–11	8 683	288	3.32	8 395	8 237	98.1
2011–12	9 106	130	1.43	8 976	8 966	99.9
2012–13	8 021	111	1.38	7 910	7 819	98.9

3.1.2 Relative JMA 1 catch by subarea and method

Between 1990–91 and 2012–13, 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 4; Appendix 1). Catches from the Central East Coast (CEE) subarea in particular, have been consistently low for more than two decades (Figure 4; Appendix 1).

The total reported catch for the subareas of JMA 1 (see Appendix 1) may have subtle differences from the previously published results in Walsh et al. (2012) which may be due to: 1) the analyses were based on different extracts, which may differ due to database maintenance and updates; 2) the catch and effort data were groomed using different tools, ACCESS for the former and R script for the latter. The same reason may also cause slight differences in the catches for fishing methods, statistical areas and target species in other Appendices.

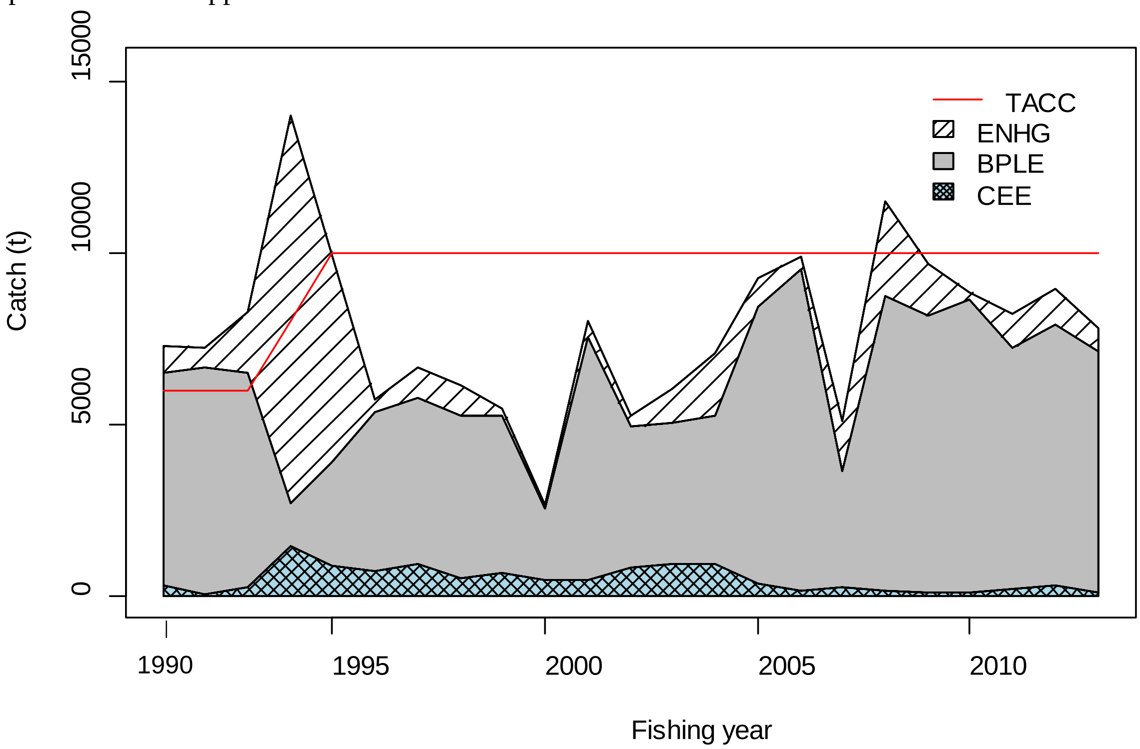

Figure 4: Annual JMA 1 catch (t) by substock (ENHG, East Northland/Hauraki Gulf; BPLE, Bay of Plenty; CEE, Central East Coast). Note: effort-linked ratio data has been scaled up to allocated LFR totals (Table 2).

Overall, purse-seine has been the dominant fishing method in all three subareas of JMA 1, and although catches have diminished from that of the mid 1990s in the East Northland/Hauraki Gulf and since 2003–04 in the Central East Coast subarea, they have remained consistently high in the Bay of Plenty for the last decade where they account for 84% on average of the annual landed JMA 1 catch (Figure 5; Appendix 2).

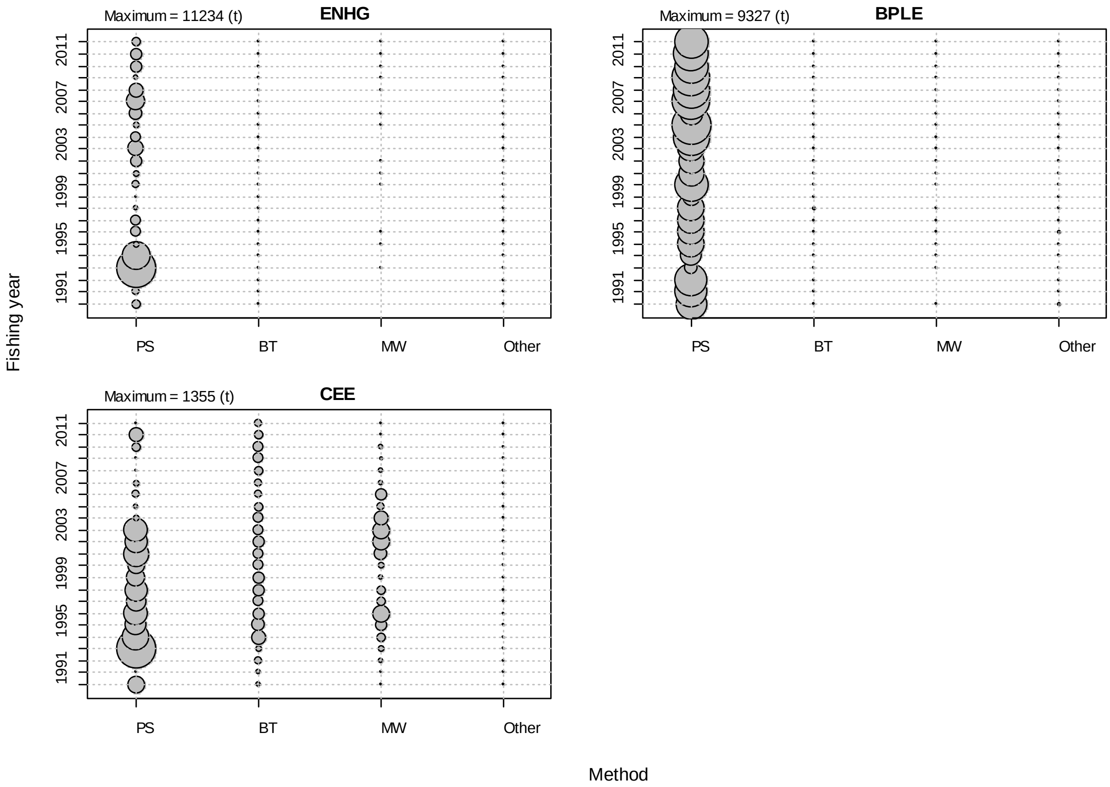

Figure 5: Relative annual catch (t) by method in subareas in JMA 1 from 1990–91 to 2012–13 (PS, purse-seine; BT, bottom trawl; MW, mid water trawl). The largest circle is the maximum tonnage of each plot and the tonnages are represented by the circle areas.

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 6, Appendix 3). The main exception to this spatial catch pattern was 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. During the 2011–12 and 2012–13 fishing years, the only other statistical areas comprising a notable catch of jack mackerel were 002 and 003 in East Northland and 008 in the Bay of Plenty (Figure 6, Appendix 3).

Purse-seine catches of jack mackerel from East Northland in the early 1990s were predominately taken during late winter and early spring (Figure 7; Appendix 4). In the Bay of Plenty, the temporal distribution of the catch over the past two decades has mostly been during the winter and early spring months, principally June to September, but more recently there has been a notable increase during late spring and early summer, specifically October to December (Figure 7; 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 7; Appendix 4). The low volume of the Central East coast catch of jack mackerel has generally been sporadic and spread over those months associated with warmer seasons, spring to autumn.

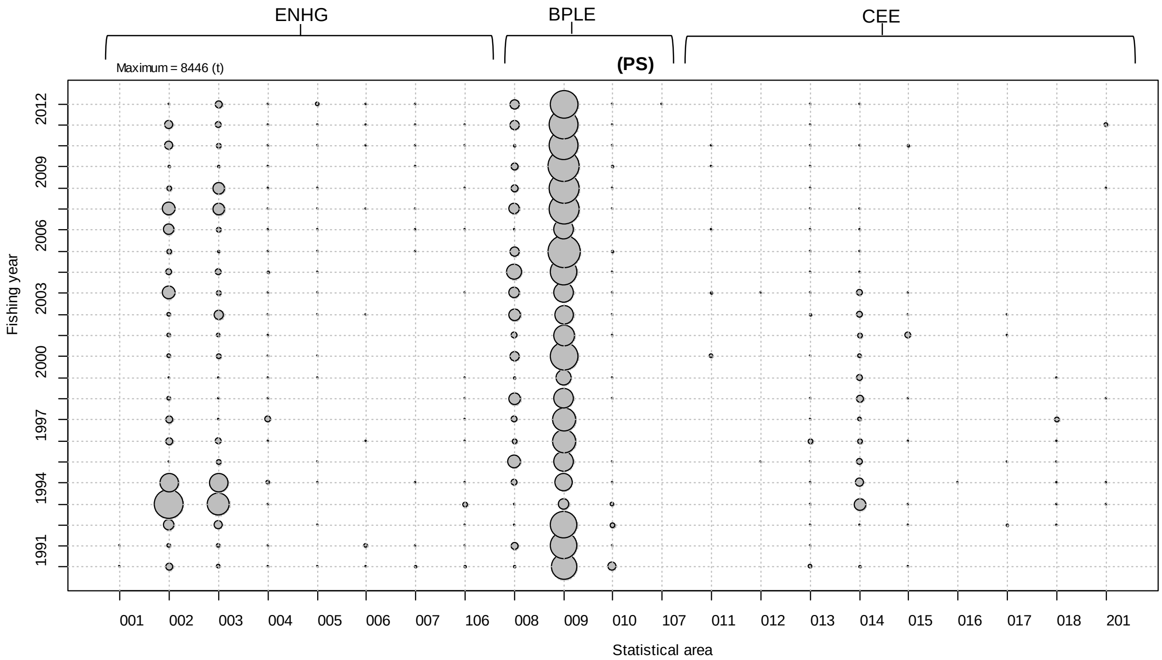

Figure 6: Annual purse-seine catch (t) by statistical area landed in JMA 1 from 1990–91 to 2012–13. The largest circle is the maximum tonnage of the plot and the tonnages are represented by the circle areas.

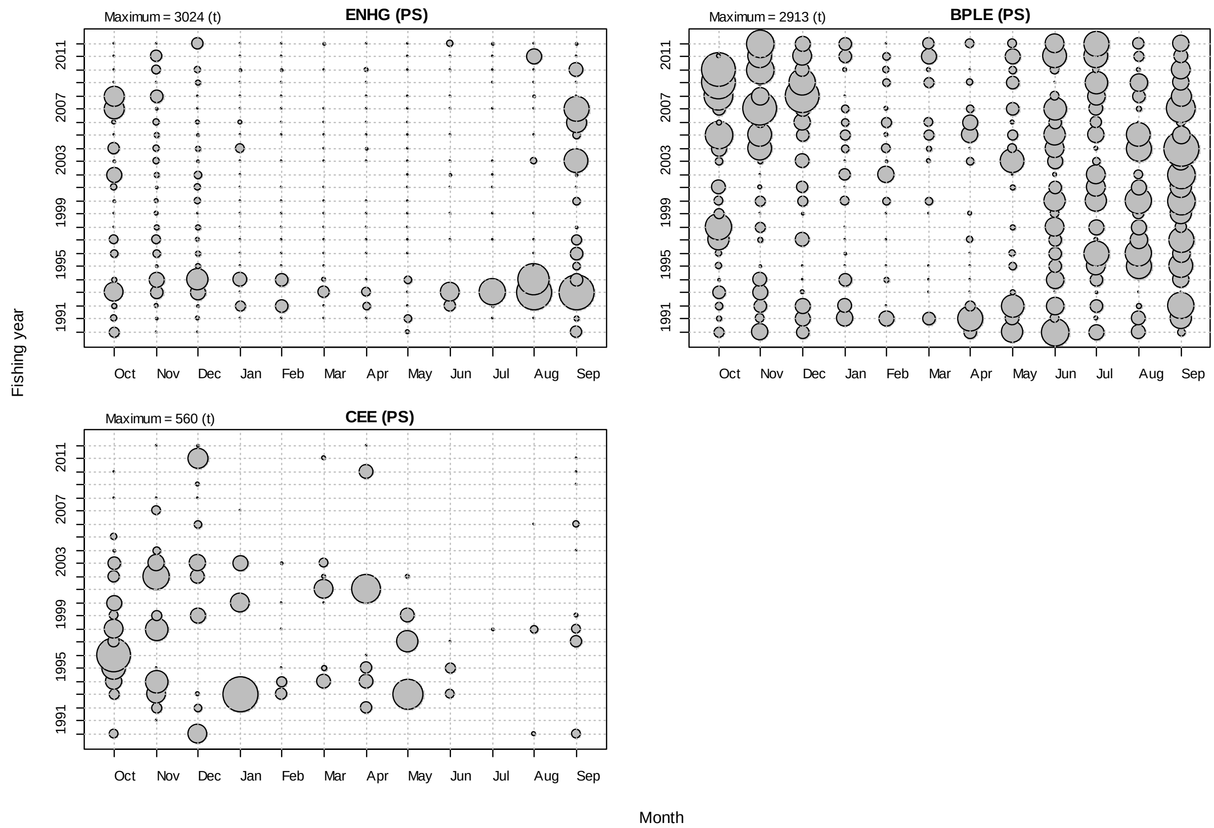

Figure 7: Relative annual purse-seine catch (t) by month and subarea in JMA 1 from 1990–91 to 2012–13. The largest circle is the maximum tonnage of each plot and the tonnages are represented by the circle areas.

The JMA 1 purse-seine fishery is almost exclusively a target fishery in the East Northland/Hauraki Gulf and Bay of Plenty subareas (Figure 8; Appendix 5), with small amounts of jack mackerel taken when targeting blue mackerel (*Scomber australasicus*, EMA) and kahawai (*Arripis trutta*, KAH). In the

Central East Coast subarea, relatively low jack mackerel catches are taken either as a target or as a bycatch to kahawai.

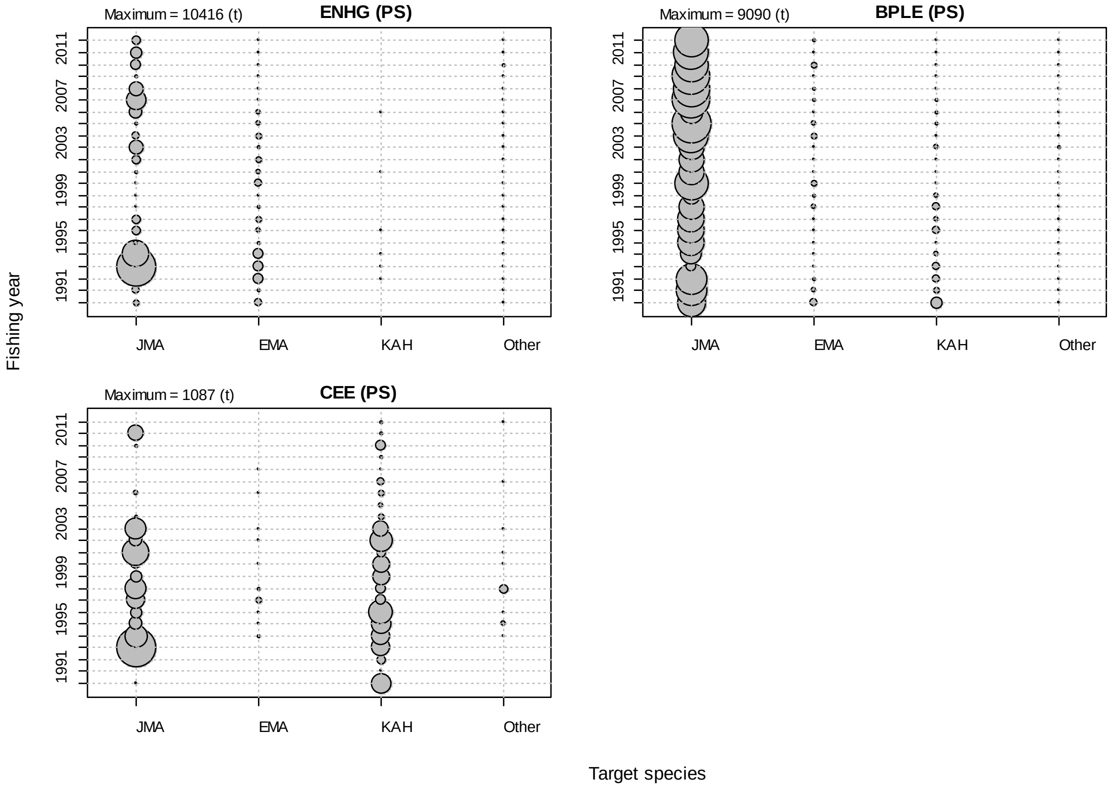

Figure 8: Relative annual purse-seine catch (t) by target species and subarea in JMA 1 from 1990–91 to 2012–13. The largest circle is the maximum tonnage of each plot and the tonnages are represented by the circle areas.

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). Landings data supplied by licensed fish receivers (LFRs) to the Ministry (effectively since the 1990–91 fishing year) represent a second source of official catch reporting in which the actual or true landed greenweight of fish caught against quota is recorded. Ideally, annual catch totals derived from both reporting systems should match exactly, but for stocks where comparisons have been made, exact matches are rare, although the two totals are usually within one or two percentage points of each other (Jeremy McKenzie, pers. obs.). Differences in the two reporting systems can occur because the landed catches are sometimes reported twice, often by different individuals (e.g. the quota holder and the fisher) at different times. An alternative and parsimonious explanation is that the differences are 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, in our opinion, consistent with this explanation and should not be cause for concern, whereas differences greater than 5–10% warrant further investigation/explanation.

Large discrepancies in the JMA 1 annual catch totals from the two reporting systems are evident prior to 1995–96 (Figure 9), which, in our opinion, are inconsistent with the parsimonious explanation (see Section 3.3)

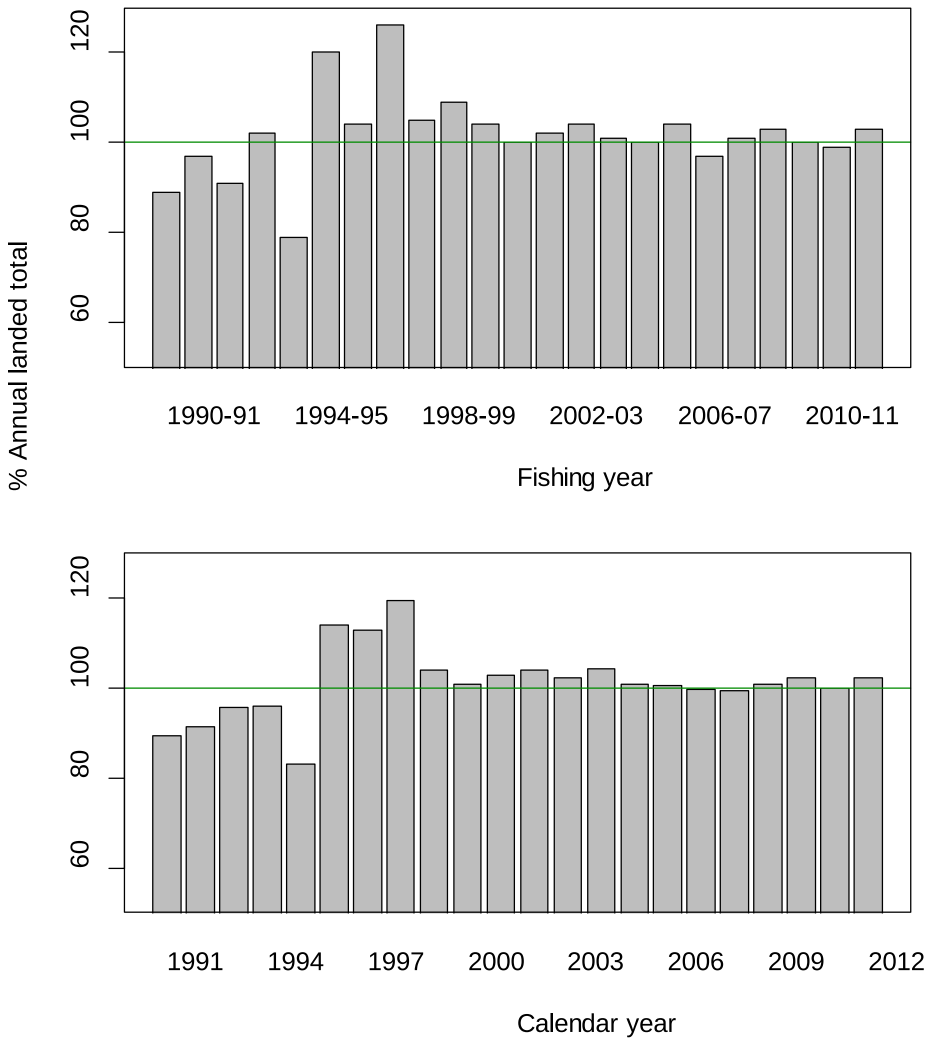

Figure 9: Annual JMA 1 catch from MHR reporting (official Plenary) expressed as a percentage of reported landed catch totals (LFR returns) by fishing year (top panel) and calendar year (bottom panel).

3.2 Species composition of the JMA 1 purse-seine fishery

3.2.1 Sample collections

A total of 66 candidate landings were initially sampled for species proportions between January 2011 and September 2013, and accounted for 49% by weight and 38% by number of the total purse-seine candidate landings available for sampling in JMA 1 (Figure 10, Appendix 6). A monthly summary of the landings and samples of jack mackerel by number and weight used in determining the fishery characterisation, species proportions and length frequency estimates in the JMA 1 purse-seine fishery is given in Appendix 6.

Of the 66 sampled landings 54 comprised jack mackerel caught only in the Bay of Plenty subarea, nine in East Northland and Hauraki Gulf, one in Central East Coast and two of mixed subarea origin. The average weight of the sampled landings was 124 t, with a broad range spanning 7 to 315 t. Jack mackerel was a target species in 53 of the 66 sampled landings, with kahawai the only other main target species used. Jack mackerel were also taken in small quantities 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 the JMA 1 fishery and accounted for almost the entire JMA 1 purse-seine catch, all of which was landed into Tauranga. 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 typically excluded in the analysis as they were most often bycatch to other targeted species, although an exception was made for a 7 t landing sampled during the previous study (JMA200901).

3.2.2 Fishing year analysis, 2011–12 and 2012–13

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, early summer and winter months (Figure 10, Appendix 6). Catch sampling mostly occurred during months when substantial tonnages of jack mackerel were landed, although sampling was proportionally low in June and July 2012 and to a lesser degree in March 2012 and September 2013 (Figure 10, Appendix 6). Although landings were available for sampling, no samples were collected during January, March or April 2013.

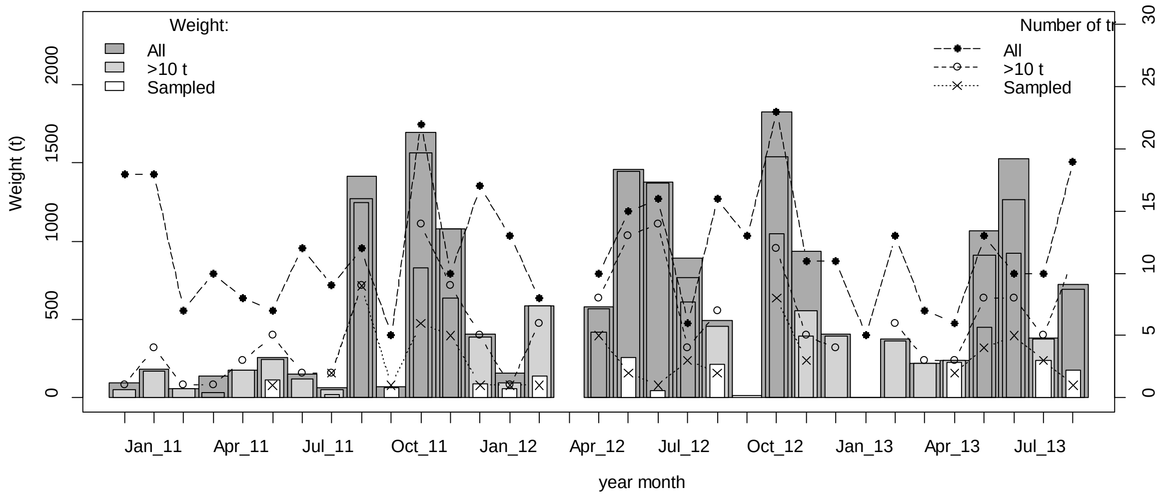

Figure 10: Comparison of the monthly distribution of landed weight (t) (grey bars) and numbers of landings (dashed line) of jack mackerel in the JMA 1 purse-seine fishery for all landings and those over 10 t where jack mackerel was caught, between January 2011 and September 2013. Included are corresponding estimates for all sampled candidate landings (white bars and dotted line) to show representativeness of sampling.

The sampling performance relative to the cumulative catch of the fishery illustrates that sampling was, by and large, distributed in proportion to, and representative of, the JMA 1 purse-seine fishery over the 2011–12 and 2012–13 fishing years (Figure 11).

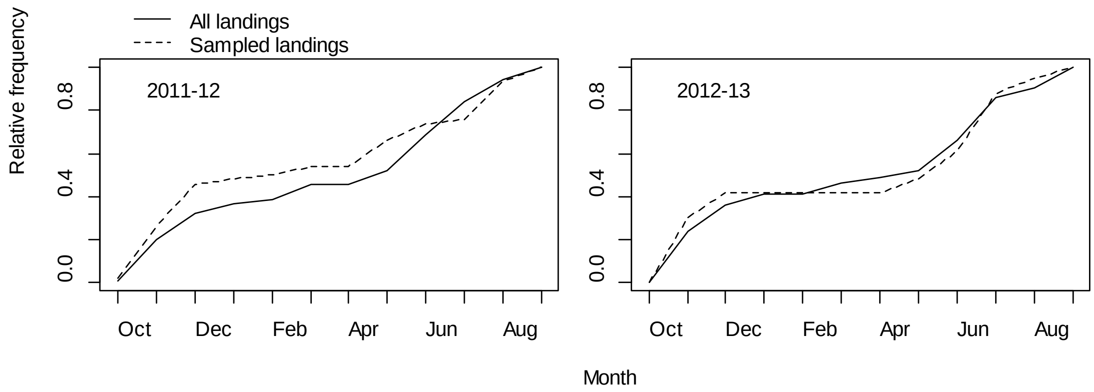

Figure 11: The cumulative proportion of the number of landings and samples taken from the JMA 1 purse-seine fishery in 2011–12 and 2012–13.

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 2011–12 and 2012–13 are presented in Figures 12 and 13. Almost the entire JMA 1 catch over the consecutive fishing years was taken in the northern half of the stock with approximately 90% of the catch taken from the Bay of Plenty subarea; around 10% from Statistical Area 008 and 80% from Statistical Area 009 (Figures 12–14, Appendix 3). Moderate catches of jack mackerel were also taken from the East Northland subarea, Statistical Areas 002 and 003 in 2011–12 and Statistical Area 003 in 2012–13. The sampled component was generally spread throughout most areas where the commercial purse-seine fishery operated, and although underrepresented in Statistical Area 003 in 2012–13, suggests that sampled landings are spatially representative of the fishery (Figures 12–14). Almost the entire (98%) 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 15, Appendix 5). 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.

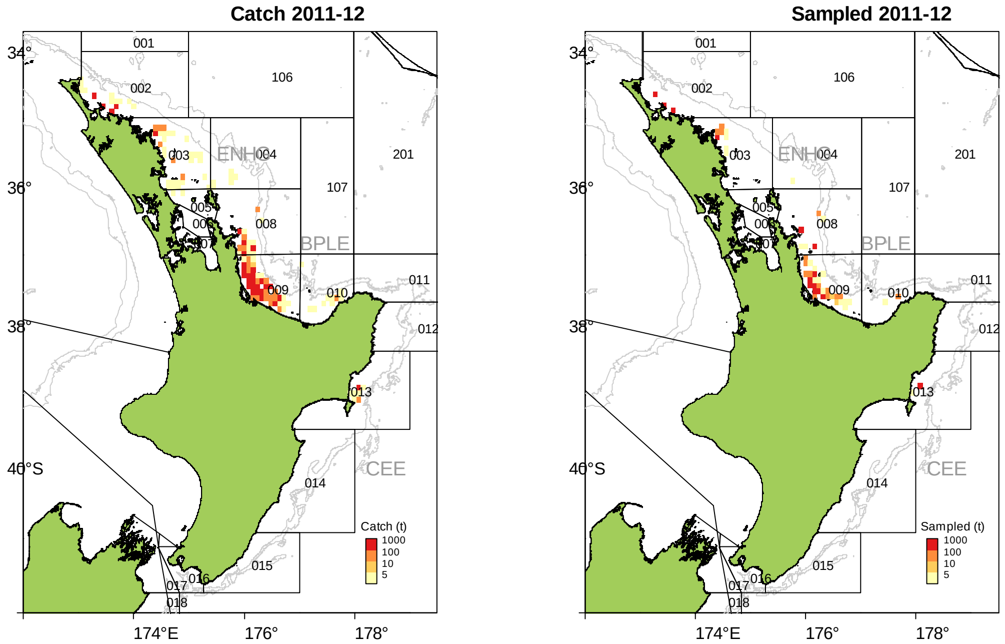

Figure 12: Comparison of the spatial distribution of the purse-seine catch and the sampled component for the JMA 1 stock in 2011–12.

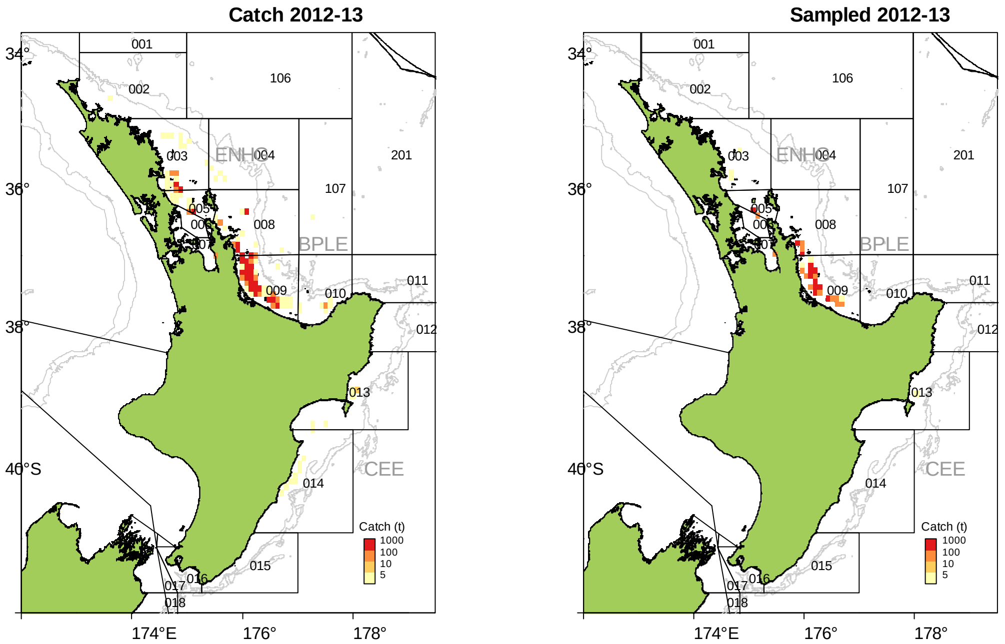

Figure 13: Comparison of the spatial distribution of the purse-seine catch and the sampled component for the JMA 1 stock in 2012–13.

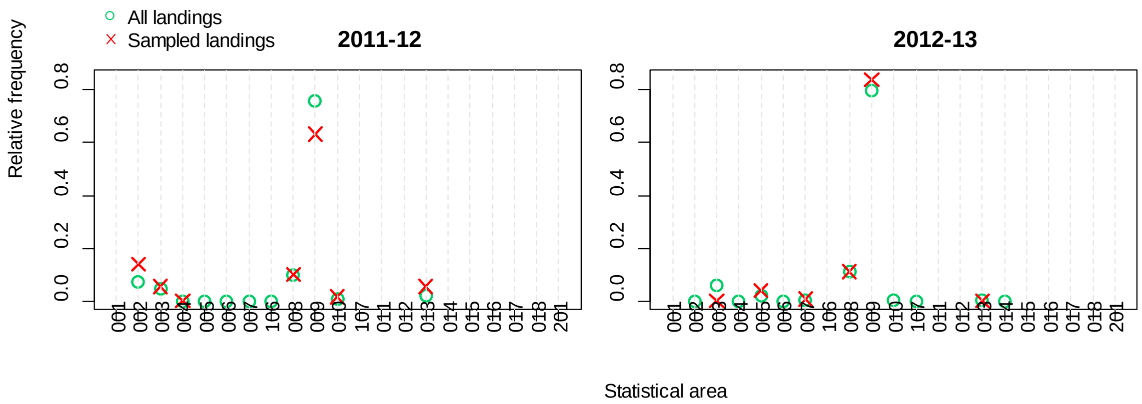

Figure 14: Comparison of the proportional distribution of the purse-seine catch and the sampled component by statistical area over the sampling period for the JMA 1 stock 2011–12 and 2012–13.

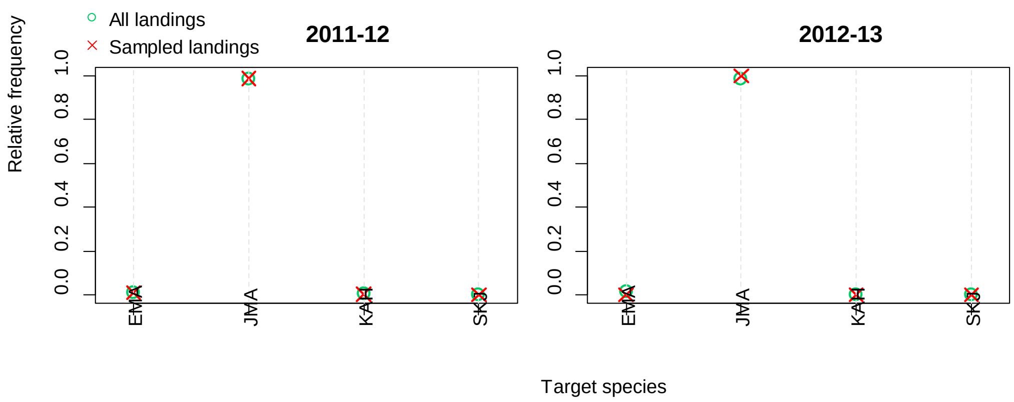

Figure 15: Comparison of the proportional distribution of the purse-seine catch and the sampled component by target species over the sampling period for the JMA 1 stock in 2011–12 and 2012–13. EMA, blue mackerel; JMA, jack mackerel; KAH, kahawai; SKJ, skipjack tuna.

3.2.3 JMA 1 species proportions – January 2011 to September 2013

Summaries of the species proportion sample sizes for purse-seine landings sampled from the JMA 1 fishery between January 2011 and September 2013 relate to data collected over three distinct temporal periods; January–September 2011 (Project JMA200901; Walsh et al. 2012), the 2011–12 fishing year and the 2012–13 fishing year (Project JMA201101; current study) (Table 3). The initial total of 66 candidate landings used in the characterisation of the JMA 1 fishery in this report (Sections 3.2.1 to 3.2.2) was reduced to 59 candidate landings for the species proportions analysis (Section 3.2.3) as seven landings did not meet the sampling criteria. As a result, the initial 54 candidate landings sampled over the fishing year periods 2011–12 and 2012–13 was reduced to 47 (Table 3) and fell short of the proposed target of 60 landings (see Tables 1 and 3). These were combined with the additional twelve landings from January–September 2011 collected during the previous study, to allow for calculations to be made for the 2011 and 2012 calendar years. During this period, more than 75 000 jack mackerel were sampled for species proportions (Table 3).

Table 3: Summary of the catch (total number and weight of landings) and samples (number of landings and weight sampled, and number of fish measured and sampled for species proportions) in the JMA 1 purse-seine fishery in January–September 2011 (Walsh et al. 2012) and the 2011–12 and 2012–13 fishing years.

Method*	Sampling period	Source	Number of candidate landings		Weight of candidate landings (t)		Number of sampled fish
			Total	Sampled	Total	Sampled	
PS	Jan–Sep 2011	Walsh et al. (2012)	27	12	2 058	1 378	13 040
	2011–12	This study	81	23	8 314	2 668	30 339
	2012–13	This study	65	24	6 558	3 182	31 746
	Jan 11–Sep 13	Combined	173	59	16 930	7 228	75 125

*PS, purse-seine.

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 2011 to September 2013 for those months in which samples were collected are presented in Figure 16 and Appendix 7. Over this period, *T. novaezelandiae* represented the most common jack mackerel species (by weight) in 52 of the 59 sampled landings (88%), and in all but two sampled months, August 2012 and May 2013, where large *T. declivis* from East Northland were more dominant (Figure 16). *T. declivis* was well represented in individual catches over seven months and often in association with a smaller catch of *T. murphyi.*

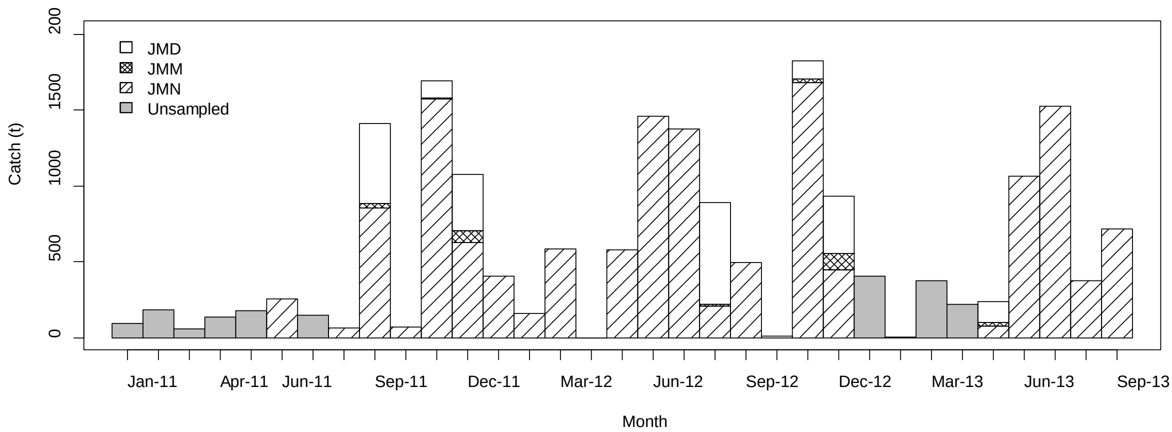

Figure 16: Estimated monthly total catch of the jack mackerel species in the JMA 1 purse-seine fishery from October 2011 to September 2013: JMD, *T. declivis*; JMM, *T. murphyi*; JMN, *T. novaezelandiae.*

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.

T. novaezelandiae was also the most dominant jack mackerel species in the JMA 1 purse-seine fishery by calendar year and fishing year making up 75–88% of overall catch followed by *T. declivis* (10–22%) and *T. murphyi* (1–3%) (Table 4). Precision on species proportion estimates was high for *T. novaezelandiae* (MWCV under 0.10), but generally lower (MWCV 0.13–0.36) for the other two jack mackerels in the catch, *T. declivis* and *T. murphyi* (Table 4).

Table 4: Estimated proportions and MWCVs 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 2011 to September 2013.

	Estimated proportion			Coefficient of variation (MWCV)			
Year	JMD	JMM	JMN	JMD	JMM	JMN	Catch (t)
Calendar year							
2011	0.222	0.025	0.753	0.340	0.234	0.103	5 575
2012	0.135	0.016	0.849	0.245	0.362	0.041	8 868
Fishing year							
2011–12	0.132	0.010	0.858	0.245	0.128	0.038	8 966
2012–13	0.096	0.023	0.881	0.307	0.335	0.037	7 819

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

Calendar year proportion means were calculated for 2011 and 2012, based on the species proportion estimates in sampled months and imputed estimates for un-sampled months during the same season (Table 5). Compared to estimated proportions (Table 5), the derived proportion means were identical for both the 2011 and 2012 calendar year proportions and the 2011–12 fishing year proportions, the latter because all months within the 2011–12 fishing year were sampled (see Figure 16). Note that the 2012–13 fishing year proportion means are unable to be determined because the 2013 calendar year was not fully complete by the end of the project (September 2013) which is required for analysis using Approach II.

Table 5: 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 2011 to September 2013.

	Proportion mean			
Year	JMD	JMM	JMN	Catch (t)
Calendar year				
2011	0.222	0.025	0.753	5 575
2012	0.135	0.016	0.849	8 868
Fishing year				
2011–12	0.132	0.010	0.858	8 966

3.2.3.3 Approach III: stratification by season

The range of the species proportions estimated with seasonal stratification tended to be slightly broader than 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 6). *T. novaezelandiae* remained the most dominant species in the fishery by season, fishing year and calendar year making up 64–92% of overall catch followed by *T. declivis* (7–34%) and *T. murphyi* (1–4%). Species proportions for *T. declivis* in early 2011 (34%) (as noted by Walsh et al. 2012) and early 2012 (25%) were higher than in all other seasons and reflected clean catches of large *T. declivis* caught from East Northland from four trips, two each in September 2011 and August 2012, respectively (Section 3.2.3.1). Precision estimates for seasons varied between the three jack mackerel species but was considerably lower for both *T. declivis* and *T. murphyi* which most likely reflects the high between-landing variability for these two species in the catch compared to *T. novaezelandiae* (Table 6). Calendar and fishing year species proportions determined from seasonal stratification (Approach III) differed slightly to those estimated using Approaches I and II (Tables 4 and 5) and with lower precision (Table 6).

Table 6: Estimated proportions and MWCVs of the three jack mackerel species (JMD, *Trachurus declivis*; JMM, *T. murphyi*; JMN, *T. novaezelandiae*) landed by season (early, January–September; late October–December), calendar year and fishing year in the JMA 1 purse-seine fishery from January 2011 to September 2013.

	Estimated proportion			Coefficient of variation (MWCV)			
Season/year	JMD	JMM	JMN	JMD	JMM	JMN	Catch (t)
Season							
2011 early	0.337	0.022	0.641	0.559	0.719	0.294	2 690
2011 late	0.162	0.026	0.812	0.444	0.561	0.094	2 886
2012 early	0.251	0.004	0.745	0.575	0.930	0.186	6 080
2012 late	0.157	0.041	0.802	0.470	0.530	0.112	2 788
2013 early	0.071	0.012	0.917	0.936	0.948	0.081	5 031
Calendar year							
2011	0.244	0.024	0.732	0.395	0.447	0.134	5 575
2012	0.221	0.015	0.763	0.460	0.477	0.131	8 868
Fishing year							
2011–12	0.222	0.011	0.767	0.454	0.483	0.127	8 966
2012–13	0.102	0.022	0.876	0.474	0.479	0.064	7 819

3.2.4 JMA 1 species length compositions for the 2011–12 and 2012–13 fishing years

Fishing year length distributions and CVs for *T. declivis*, *T. murphyi* and *T. novaezelandiae* sampled from the JMA 1 purse-seine fishery in 2011–12 and 2012–13 are presented as a series of histograms and a proportional comparison of the size distributions for the three species over the consecutive fishing years given in cumulative plots (Figures 17 and 18). As outlined in Section 3.2.3, a total of 47 candidate landings were used to estimate JMA 1 species proportions for 2011–12 and 2012–13, and these were also used to determine the length compositions over the respective fishing years as well.

Although the length compositions of *T. declivis* over the successive years were based on reasonable samples sizes (n = 4342 and 2688) they varied considerably between years in the size of *T. declivis* landed. Samples from 2011–12 mainly comprised one dominant mode of moderate to large fish centred around 42 cm while samples from 2012–13 were dominated by a mode of small fish centred around 26 cm and a broad but smaller proportion of moderate to large fish (Figure 17).

Despite the very low numbers of *T. murphyi* (the largest of the three species) sampled over both fishing years (*n* = 164 and 623) the length compositions were of a similar size structure in 2011–12 and 2012–13, with most fish occupying a narrow size range between 44 and 53 cm, comprising two possible modes centred around 45–46 and 49–50 cm (Figure 17).

The length compositions of *T. novaezelandiae* (the smallest of the three species) also shows a consistent size structure within the fishery, with fish occupying a single mode centred around 30 cm in 2011–12 and 31 cm in 2012–13, and where 98% of the landed catch ranged between 25 and 36 cm (0.261–0.736 g) (Figures 17 and 18). Sample sizes for *T. novaezelandiae* were comprehensive with more than 25 000 fish sampled over each of the respective fishing years (Figure 17, Appendix 6).

Estimates of mean lengths and proportion-at-length MWCVs of the three jack mackerel species sampled from JMA 1 over the consecutive fishing years were as follows: *T. declivis*, 40.0 and 30.6 cm (0.43 and 0.51); *T. murphyi*, 49.4 and 47.1 cm (0.51 and 0.35); *T. novaezelandiae*, 30.1 and 31.0 cm (0.15 and 0.12).

It is estimated that about 19 and 16 million jack mackerel were landed by purse-seine from JMA 1 over the 2011–12 and 2012–13 fishing years.

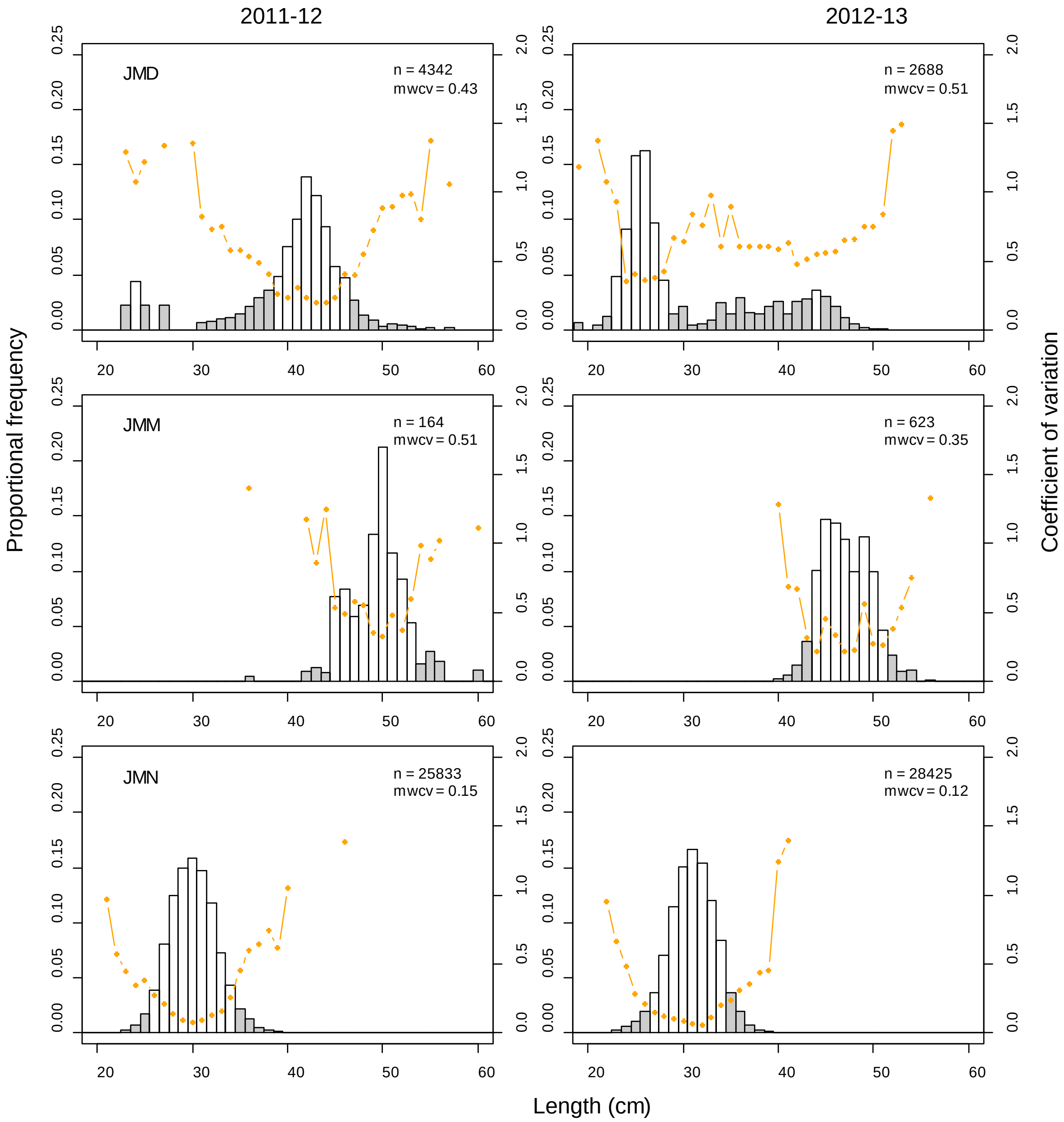

Figure 17: Proportional frequency distributions (histograms) and CVs (lines) of *T. declivis* (top), *T. murphyi* (middle) and *T. novaezelandiae* (bottom) by fishing year sampled from JMA 1 purse-seine fishery in 2011–12 and 2012–13.

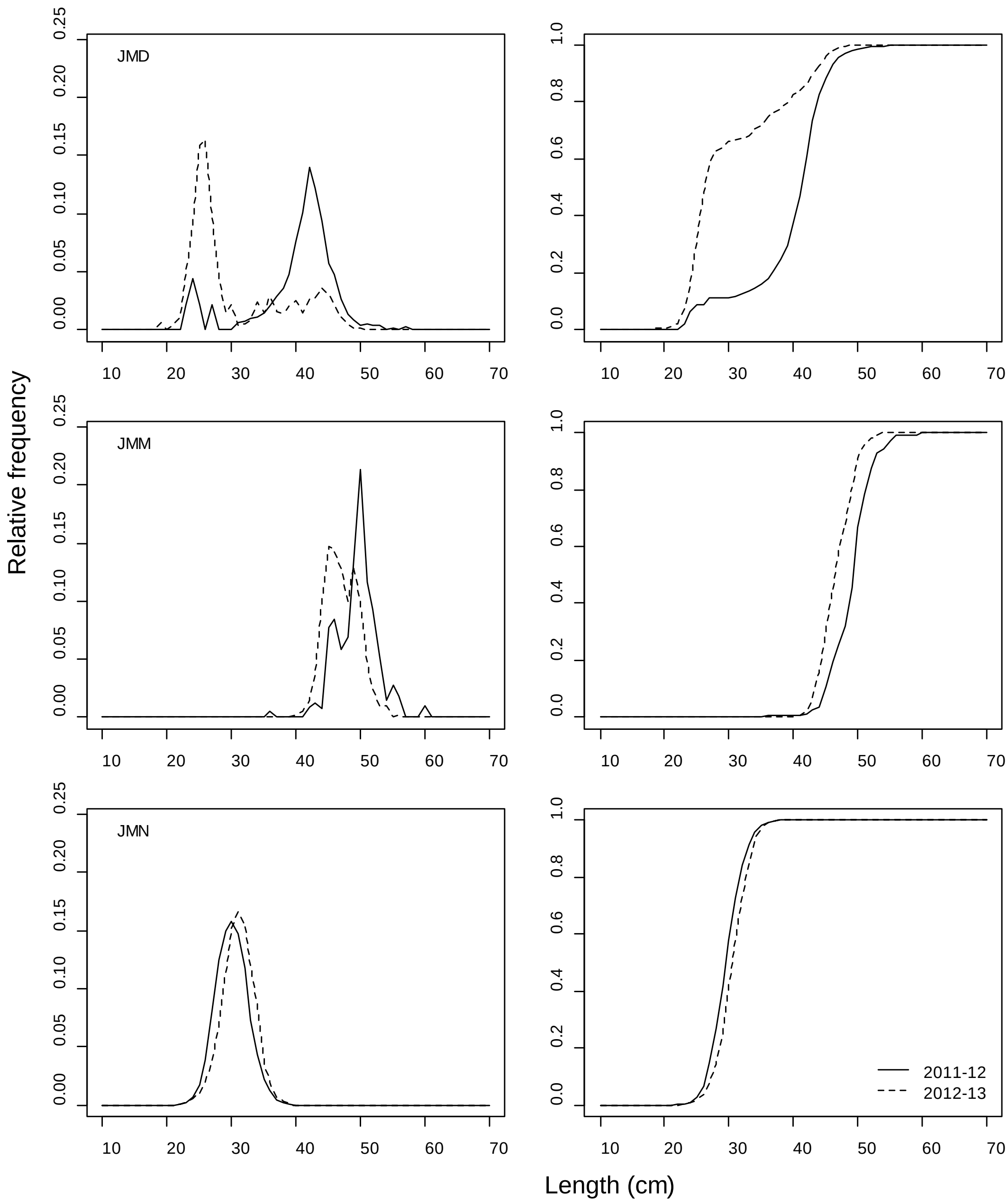

Figure 18: Comparison of the proportion and cumulative proportion at length distributions of *T. declivis* (top), *T. murphyi* (middle) and *T. novaezelandiae* (bottom) sampled from the JMA 1 purse-seine fishery in 2011–12 and 2012–13.

3.3 Time series analysis

Species composition estimates (using Approach II) 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 and those documented by Walsh et al. (2012) to include the 2011 and 2012 calendar years (Table 7) and the 2011–12 and 2012–13 fishing years (Table 8). In using Approach II however, the 2010–11 and 2012–13 fishing year proportion means could not be determined because the 2011 and 2013 calendar years were not fully complete by the end of the JMA200901 and JMA201101 projects (i.e., September), but nevertheless are estimable using Approach I (see Table 8).

Table 7: 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) and Walsh et al. (2012). Shaded years represent updates from this report. The time series data is based on proportions using Approach II, with bracketed proportions determined with Approach I.

Calendar year	JMD	JMM	JMN	MHR/QMR annual totals	Landed (LFR)	% annual landed total
1985	0.68	0	0.32			
1986	0.16	0	0.84	2 691		
1987	0.16	0	0.84	2 973		
1988	0.16	0	0.84	3 214		
1989	0.14	0.10	0.76	3 737		
1990	0.16	0	0.84	4 573		
1991	0.14	0.14	0.72	5 808	6 508	89%
1992	0.10	0.36	0.54	6 928	7 581	91%
1993	0.11	0.32	0.57	9 677	10 108	96%
1994	0.19	0.76	0.05	12 994	13 528	96%
1995	0.13	0.39	0.48	6 392	7 686	83%
1996	0.02	0.12	0.86	7 103	6 235	114%
1997	0.05	0.37	0.58	8 868	7 862	113%
1998	0.09	0.36	0.55	7 608	6 374	119%
1999	0.12	0.15	0.73	3 634	3 498	104%
2000	0.04	0.02	0.94	3 220	3 198	101%
2001	0.04	0.01	0.95	8 350	8 114	103%
2002	0.30	0.01	0.69	5 635	5 418	104%
2003	0.15	0.02	0.83	6 147	6 008	102%
2004	0.38	0.12	0.50	8 595	8 257	104%
2005	0	0	1.00	10 663	10 585	101%
2006	0.25	0	0.75	7 410	7 371	101%
2007	0.17	0.06	0.77	8 609	8 640	100%
2008	0.40	0.13	0.47	13 588	13 671	99%
2009	0.01 (0.01)	0	0.99 (0.99)	7 476	7 414	101%
2010	0.08 (0.08)	0.02 (0.02)	0.90 (0.90)	9 862	9 649	102%
2011	0.22 (0.22)	0.03 (0.03)	0.75 (0.75)	5 569	5 575	100%
2012	0.13 (0.13)	0.02 (0.02)	0.85 (0.85)	9 075	8 868	102%

Table 8: 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) and Walsh et al. (2012). Shaded years represent updates from this report. The time series data is based on proportions using Approach II, with bracketed proportions determined with Approach I.

Fishing year	JMD	JMM	JMN	Plenary (MHR/QMR)	Landed (LFR)	% annual landed total
1985–86	0.16	0	0.84	1 268		
1986–87	0.16	0	0.84	4 056		
1987–88	0.16	0	0.84	3 108		
1988–89	0.14	0.07	0.79	2 986		
1989–90	0.15	0.04	0.81	4 226		
1990–91	0.15	0.09	0.76	6 472	7 303	89%
1991–92	0.11	0.32	0.57	7 017	7 239	97%
1992–93	0.11	0.33	0.56	7 529	8 266	91%
1993–94	0.17	0.65	0.18	14 256	13 992	102%
1994–95	0.14	0.50	0.36	7 832	9 933	79%
1995–96	0.03	0.10	0.87	6 874	5 722	120%
1996–97	0.05	0.26	0.69	6 912	6 665	104%
1997–98	0.05	0.43	0.52	7 695	6 123	126%
1998–99	0.12	0.29	0.59	5 767	5 469	105%
1999–00	0.07	0.08	0.85	2 866	2 630	109%
2000–01	0.02	0.01	0.97	8 360	8 021	104%
2001–02	0.18	0.01	0.81	5 247	5 258	100%
2002–03	0.21	0.02	0.77	6 172	6 036	102%
2003–04	0.40	0.08	0.52	7 396	7 083	104%
2004–05	0.10	0.06	0.84	9 418	9 290	101%
2005–06	0.15	0	0.85	9 924	9 920	100%
2006–07	0.34	0.10	0.56	5 293	5 101	104%
2007–08	0.30	0.04	0.66	11 167	11 483	97%
2008–09	0.22	0.13	0.65	9 791	9 706	101%
2009–10	0.01 (0.02)	0	0.99 (0.98)	9 086	8 861	103%
2010–11	(0.17)	(0.03)	(0.80)	8 262	8 237	100%
2011–12	0.13 (0.13)	0.01 (0.01)	0.86 (0.86)	8 911	8 966	99%
2012–13	(0.10)	(0.02)	(0.88)	8 054	7 819	103%

Purse-seine catches of jack mackerel throughout the 1990s comprised large quantities of *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).

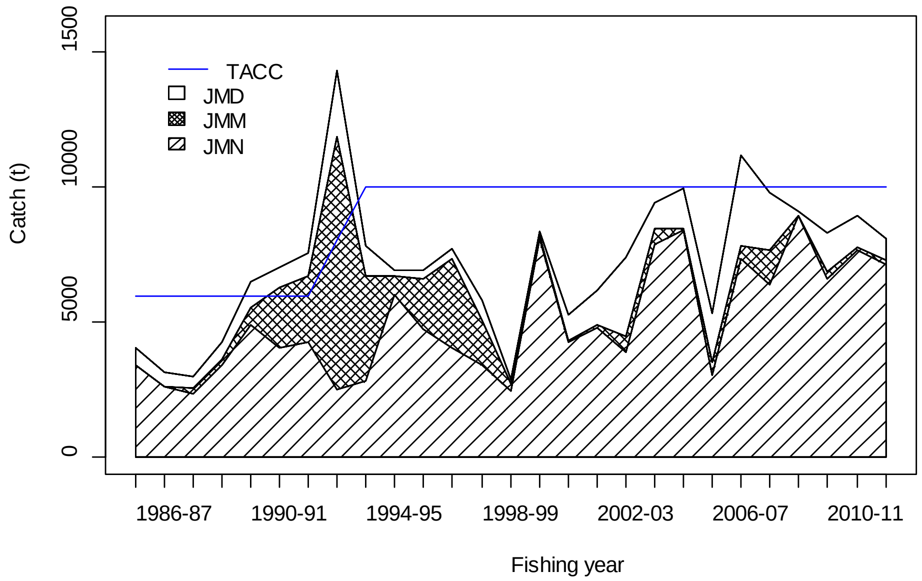

Figure 19: Species proportion estimates for (JMD, *T. declivis*; JMM, *T. murphyi*; JMN, *T. novaezelandiae*) of JMA 1 catches by fishing year scaled to the plenary (QMR/MHR) annual reported catch.

The years of high *T. murphyi* catch in the JMA 1 fishery correspond strongly 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 truer reflection of the JMA 1 catch during the 1990s than the QMR/MHR totals (Figure 20).

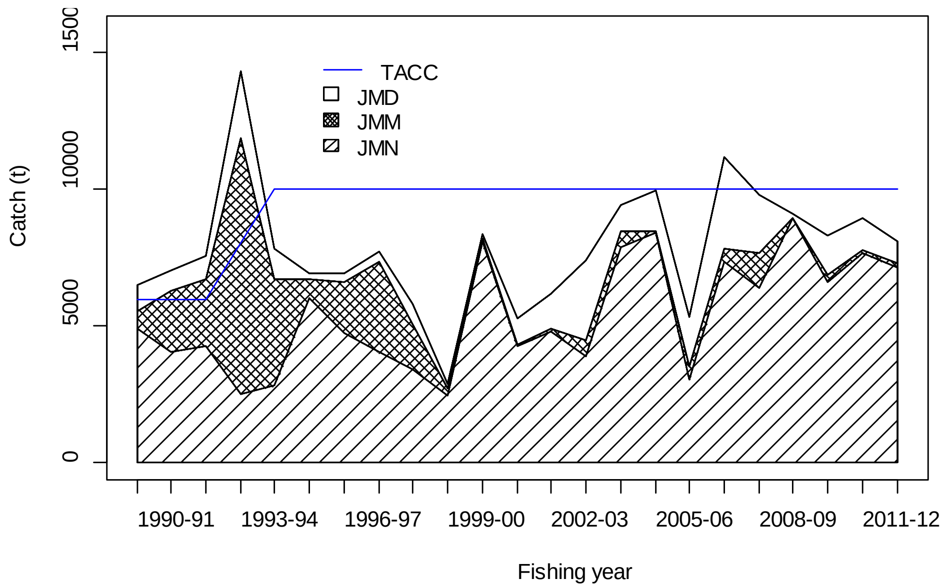

Figure 20: Species proportion estimates (JMD, *T. declivis*; JMM, *T. murphyi*; JMN, *T. novaezelandiae*) of JMA 1 catches by fishing year scaled to the landed annual reported catch.

4. DISCUSSION

This is the eleventh report to summarise the species composition of the three jack mackerel species from purse-seine landings in JMA 1, and continues an unbroken time series of collections dating back to 1994–95 (Taylor 1998, 1999, 2000, 2002, 2004a, 2004b, Taylor & Julian 2008, Taylor et al. 2012, Penney et al. 2011, Walsh et al. 2012).

The operation of the Tauranga based domestic purse-seine fleet in the JMA 1 fishery has continued to remain comparatively stable with the same core group of five vessels taking approximately 97% of the annual landed JMA 1 catch (about 8500 t) over the 2011–12 and 2012–13 fishing years. However, from the previous study (Walsh et al. 2012), it became apparent that a more rigorous approach was required in sampling the high-volume JMA 1 purse-seine fishery for species composition data, which involved the stratification of each vessel landing by hold, and the random selection of an ungraded sample from all holds that comprised jack mackerel.

A revised sampling design was implemented in October 2011 to increase the accuracy and representativeness of the JMA 1 purse-seine species composition time series. The new design better accounts for the uncertainty arising from inter-school variation in catches and is expected to ensure that samples for length and species composition for *T. declivis*, *T. murphyi*, and *T. novaezelandiae* are more representative of the commercial catch. We believe past sampling procedures that made use of manual or mechanical grading systems had the potential to cause bias in the sample data (Rohan et al. 2006, Taylor & Julian 2008). The downside of the new hold-based sampling approach is that it may require 1–2 days to sample the landing for those catches exceeding 100–200 t. We believe that increased sampling time is justified to ensure that representativeness is maintained and bias minimised at the sampling level in estimating fish length and species composition data.

Sampling landings and representativeness

As reported by Walsh et al. (2012) in the previous study, the cooperation of the fishing companies, Sanford Ltd and Pelco NZ Ltd, was found to be essential for minimising the spatial, temporal, and size selective bias typical of most fish sampling programmes. In part, and as a result of the new sampling measures, the current study successfully sampled a total of 47 JMA 1 purse-seine landings over the 2011–12 and 2012–13 fishing years, amounting to about one-third (32%) of all candidate landings available for sampling. Despite falling short of the target threshold of 60 landings, further exacerbated by seven landings being omitted from the study for not meeting the sampling criteria, more than 62 000 jack mackerel were successfully sorted by species and measured for length. Most sampling occurred during months when substantial tonnages of jack mackerel were landed, but was on occasions proportionally low in some months and not undertaken in others, the latter when the landing size and/or volume of jack mackerel were generally low. Nevertheless, the temporal and spatial fishing and sampling effort of the JMA 1 purse-seine fishery over the consecutive years suggest that a good level of representativeness was achieved, although it is unknown what impact the removal of the seven landings from the collection may have had on the species composition estimates.

Factors affecting fish size and landed volume of jack mackerel

Aside from environmental and operational variables that may influence the apparent abundance 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, Walsh et al. 2012). Walsh et al. (2012) reported that JMA 1 species composition data were likely to be affected by a number of such factors including market value, preferred fish size, availability of other important species (i.e., skipjack, blue mackerel), bycatch issues (i.e., kahawai), and the amount of available ACE (annual catch entitlement). In the current study, the preference for small fish (such as *T. novaezelandiae*) demanded by overseas markets continues to be the key driver as it has done for over a decade in the increasingly valuable and economically buoyant JMA 1 fishery. However, the availability and quantity of *T. novaezelandiae* in close proximity to the port of Tauranga at certain times of the year also appears to be an influential factor. In the period January 2011–September 2013, *T. novaezelandiae* represented the most common jack mackerel species (by weight) in 52 of the 59 sampled landings (88%), and in all but two sampled months, August 2012 and May 2013, when large *T. declivis* were more dominant. These occasional catches of large *T. declivis,* often in association with a small component of large *T. murphyi,* were caught mainly through the late winter to early summer periods, the largest of these usually from East Northland and at times in the absence of *T. novaezelandiae*. This is similar to the findings of Walsh et al. (2012).

Although the main catch of jack mackerel has been reported in the past to be largely constrained to the end of one fishing year and the beginning of the next (Taylor 2008), i.e. winter and early spring, probably because the fishery has operated in this manner for decades, the current study shows that increased targeting now occurs during the late spring and early summer months. This may primarily be due to the significant growth in the value of jack mackerel (primarily *T. novaezelandiae* in JMA 1) as an export commodity, ranked the fourth most important New Zealand finfish ($57m) in 2013 (Seafood New Zealand Exports 2014). Recent export sale prices for whole frozen jack mackerel have continued to increase to $NZ1.60 per kg in 2013 (Seafood New Zealand Exports 2014), where traditionally the purse-seine catch was considered a high-volume low-value fishery (Taylor 2008). Large jack mackerel (*T. murphyi*, *T. declivis*) were more sought after throughout the early 1990s by the domestic purse-seine fleet, particularly when the numbers of *T. murphyi* in JMA 1 were high (Taylor 2008) but also later when large *T. declivis* (over 600 g) were highly valued for exports (pers comm. factory managers). However, the demand over the past decade has been for the small product (400–600 g), principally *T. novaezelandiae,* in developed markets (Taylor 2008, Walsh et al. 2012), chiefly in the African continent, but also in Asia and eastern Europe.

Species proportions

Although referred to as a single species grouping under the general code JMA (Walsh et al. 2012), *T. novaezelandiae,* the smallest of the three jack mackerels, continued to be the preferential target for domestic purse-seine fleet in 52 (88%) of the 59 sampled landings, and was estimated to make up between 73% and 88% of the JMA 1 catch by fishing year and calendar year in this current study. The overwhelming predominance of *T. novaezelandiae* in sampled landings, reflective of a fishery where almost the entire commercial catch (about 90%) over the 2011–12 and 2012–13 fishing years was caught in the Bay of Plenty, principally (about 80%) from Statistical Area 009 alone, suggests that *T. novaezelandiae* is highly sought after, remains readily abundant for most of the year, and when available, is easily accessible and caught in large volumes in close proximity to the home port of Tauranga. These findings are consistent with reports that document species proportions in JMA 1 over the past decade (Taylor 2002, 2004a,b, Taylor & Julian 2008, Taylor et al. 2012, Penney et al. 2011, Walsh et al. 2012) and illustrate the main reason for the steady increase in landings of *T. novaezelandiae* in recent years. Nevertheless, a commercial catch of 8054 t from JMA 1 in 2012–13 marks the lowest in six years (MPI 2014), and at around 81% of the TACC may raise some concern given the recent economic growth incentive associated with exported jack mackerel.

Furthermore, increases in JMA 1 quotas to 8000 t in 1993–94 and to 10 000 t in 1994–95 were principally to allow for the increase in the abundance of the invading *T. murphyi*, (which diminished to low levels in the fishery around 1999–2000), and not directly allocated to the two New Zealand species, *T. novaezelandiae* and *T. declivis.* As a result, for a period of more than two decades, the two native species have largely made up the catch which has exceeded the original quota of 5970 t set in 1986–87 (see Figures 19 and 20). As the current stock status of the two native species is unknown due to different mobility and spatial distributions, further complicated by the unknown status of *T. murphyi*, it remains uncertain whether recent catch levels, including those from JMA 1, are sustainable in the long-term (MPI 2014).

Catches of *T. declivis* in the current study made up between 10% and 24% of the JMA 1 catch by fishing year and calendar year and were slightly higher than those reported by Walsh et al. (2012), where it was suggested that spatial and temporal variation in fish size and relative abundance may exist for this species. For the period January 2011 to September 2013, *T. declivis* were present over seven different months, but dominated only two as the most common species, August 2012 and May 2013. For individual sampled landings, *T. declivis* was found to be the most dominant species in seven landings, two sampled in September 2011 (see Walsh et al. 2012) which were included here for determining species proportions for the 2011 calendar year, and five sampled during the two fishing years, 2011–12 and 2012–13. All seven landings comprised mainly large *T. declivis*, either from East Northland (5) or the Bay of Plenty (2), six, with a small catch of large *T. murphyi*. The presence of large jack mackerels (i.e., *T. declivis* and *T. murphyi*) in JMA 1 landings was postulated by Taylor et al. (2012) as being the result of a less preferred option in the absence of small fish, or the result of size mixing within schools. Walsh et al. (2012) suggested that a spatial or temporal heterogeneous 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. We found this to be the case for two clean landings of *T. declivis* (i.e., absent of *T. novaezelandiae* but with a small amount of *T. murphyi*) in East Northland during August 2012 and another in the Bay of Plenty during December 2012, where the majority of year-round landings appear to comprise mostly (often entirely) of *T. novaezelandiae*, further supporting the suggestion of spatial and temporal heterogeneity for species proportions in JMA 1. Given the enormous demand for *T. novaezelandiae* in the JMA 1 purse-seine fishery, we believe that significant landings of *T. declivis* during 2011–12 and 2012–13 most likely reflect opportunistic catches when vessels were some distance from the home port and looking to fill their holds (Walsh et al. 2012) or the result of size mixing within schools (Taylor et al. 2012) closer to home.

The insignificant proportion (less than 3%) of *T. murphyi* in JMA 1 purse-seine landings by fishing year and calendar year during this study matches the recent reported estimates (Walsh et al. 2012) and continues to support the overall reduction in the New Zealand wide catch of *T. murphyi*, observed since the mid to late 1990s (Penney & Taylor 2008, Taylor & Julian 2008, Penney et al. 2011, Walsh et al. 2012, Taylor et al. 2013). Precision on species proportions for fishing year and calendar year was most often high for *T. novaezelandiae* (MWCV less than 0.15), being the most common and abundant jack mackerel species caught, and well below the target estimate of 0.30. Precision was generally low (MWCV 0.13–0.48) 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.

Size compositions

Although length compositions varied considerably between the three 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 species, and similar to previous findings (Taylor 2002, Taylor et al. 2012, Walsh et al. 2012). The size composition of the *T. novaezelandiae* catch varied little, being consistent between years, with the 2011–12 mode centred at 30 cm, increasing by 1 cm in 2012–13. *T. declivis* illustrated considerable inter-annual variability in size, with samples in 2011–12 comprised mainly of moderate to large fish centred around 42 cm while samples from 2012–13 were dominated by a mode of small fish centred around 26 cm and a broad but smaller proportion of moderate to large fish. Despite the very low sample sizes (n = 164 and 623), the size range (about 40 to 60 cm) for *T. murphyi* from JMA 1 in 2011–12 and 2012–13 were temporally consistent and closely aligned with the most recent New Zealand estimates (Penney & Taylor 2008, Walsh et al. 2012), 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 & Julian 2008, Penney & Taylor 2008, Penney et al. 2011, Walsh et al. 2012, Taylor et al. 2013) associated with the Pacific-wide decline of the Chilean mackerel stock (SPRFMO 2010). Nevertheless, a report on the status of *T. murphyi* in New Zealand waters as of 2008 (Taylor et al. 2013) found that although maximum age had increased over time and was consistent with an ageing New Zealand population, minimum age had not and was consistent with a population that is self-sustaining. As the current status of the New Zealand *T. murphyi* stock is unknown, so too is the sustainability of current commercial harvest levels (MPI 2014).

It is estimated that about 19 and 16 million jack mackerel were landed by purse-seine from JMA 1 over the 2011–12 and 2012–13 fishing years.

Revised temporal sampling stratification

In the current study, both analytical Approaches I and II determined identical species proportion means for the 2011 and 2012 calendar years and 2011–12 fishing year, but only because all months within the first fishing year (2011–12) were sampled, unlike in Walsh et al. (2012) where estimates for 2009–10 differed.

In using Approach II, the 2012–13 fishing year proportion mean could not be determined because the 2013 calendar year was not fully complete by the end of the project (in September 2013), but could be estimated using Approach I. It is the authors' opinion that Approach I offers the best analytical solution in determining robust species proportion estimates for the JMA 1 fishery, but is heavily reliant on sample representation across all months when target fishing for jack mackerel occurs.

Calendar and fishing year species proportion means determined from seasonal stratification (Approach III) differed slightly to those estimated using Approaches I and II but with considerably lower precision, and in the authors' opinion is the least preferred of the three approaches for estimating species proportions.

5. ACKNOWLEDGMENTS

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7. APPENDICES

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

Fishing year	East Northland/ Hauraki Gulf	Bay of Plenty	Central East Coast	Total JMA 1	TACC
1990–91	794	6 198	310	7 303	5 970
1991–92	558	6 653	28	7 239	5 970
1992–93	1 745	6 277	244	8 266	5 970
1993–94	11 287	1 265	1 440	13 992	8 000
1994–95	6 044	2 999	890	9 933	10 000
1995–96	373	4 600	748	5 722	10 000
1996–97	902	4 834	928	6 665	10 000
1997–98	868	4 727	527	6 123	10 000
1998–99	210	4 570	690	5 469	10 000
1999–00	79	2 075	476	2630	10 000
2000–01	471	7 104	446	8 021	10 000
2001–02	333	4 111	814	5 258	10 000
2002–03	1 002	4 094	939	6 036	10 000
2003–04	1 819	4 332	932	7 083	10 000
2004–05	865	8 074	352	9 290	10 000
2005–06	392	9 367	161	9 920	10 000
2006–07	1 432	3 408	260	5 101	10 000
2007–08	2 748	8 592	143	11 483	10 000
2008–09	1 532	8 076	98	9 706	10 000
2009–10	192	8 549	121	8 861	10 000
2010–11	1 019	6 988	229	8 237	10 000
2011–12	1 049	7 623	294	8 966	10 000
2012–13	666	7 075	78	7 819	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 Coast			
year	PS	BT	MW	Other	PS	BT	MW	Other	PS	BT	MW	Other
1990–91	758	11	0	25	6 104	23	0	71	276	32	2	0
1991–92	513	16	0	29	6 607	41	0	5	0	27	1	0
1992–93	1 693	28	0	24	6 224	50	0	3	157	66	22	0
1993–94	11 234	33	0	20	1 218	43	0	4	1 355	47	38	0
1994–95	5 997	34	0	13	2 939	57	0	2	625	192	73	0
1995–96	329	32	0	12	4 551	45	0	4	430	176	141	2
1996–97	870	23	0	9	4 714	48	0	73	516	123	288	1
1997–98	831	28	0	10	4 698	27	0	2	349	98	80	1
1998–99	183	21	0	6	4 465	103	0	1	489	124	77	0
1999–00	60	12	0	7	2 042	34	0	0	326	122	29	0
2000–01	457	10	0	3	7 068	35	0	0	293	106	47	0
2001–02	318	11	0	3	4 067	44	0	0	570	96	149	0
2002–03	994	6	0	2	4 027	66	0	1	499	142	298	0
2003–04	1 813	4	0	2	4 307	24	0	1	521	114	297	0
2004–05	857	5	0	2	8 057	17	0	1	43	116	193	0
2005–06	360	30	0	2	9 327	38	1	0	23	76	62	0
2006–07	1 413	17	0	3	3 382	24	0	2	53	60	147	0
2007–08	2 730	14	0	5	8 570	21	0	1	45	64	33	0
2008–09	1 518	11	0	3	8 059	15	0	2	0	73	25	0
2009–10	171	13	0	8	8 514	34	0	1	10	96	14	0
2010–11	1 001	15	0	3	6 956	32	0	0	92	111	27	0
2011–12	1 024	10	0	15	7 574	31	0	18	199	86	9	1
2012–13	647	5	0	14	7 054	20	0	1	10	63	5	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	008	009	010	107
1990–91	0	462	143	0	0	1	70	81	111	5 407	586	0
1991–92	0	131	182	0	0	146	37	17	515	6 092	0	0
1992–93	0	1 049	580	0	9	0	0	55	63	5 924	237	0
1993–94	0	6 827	4 120	0	0	0	0	287	4	1 061	154	0
1994–95	0	2 975	2 866	156	0	0	0	0	429	2 509	1	0
1995–96	0	36	293	0	0	0	0	0	1 394	3 155	2	0
1996–97	0	480	354	0	0	12	0	24	273	4 441	0	0
1997–98	0	487	33	311	0	0	0	0	366	4 331	0	0
1998–99	0	138	46	0	0	0	0	0	1 339	3 126	0	0
1999–00	0	56	1	0	2	0	0	0	70	1 945	27	0
2000–01	0	187	271	0	0	0	0	0	890	6 179	0	0
2001–02	0	150	169	0	0	0	0	0	349	3 717	0	0
2002–03	0	179	773	0	0	43	0	0	1 212	2 799	16	0
2003–04	0	1 538	269	0	6	0	0	0	962	3 320	24	0
2004–05	0	411	363	79	5	0	0	0	1 946	6 111	0	0
2005–06	0	236	119	0	4	0	0	0	808	8 446	73	0
2006–07	0	1 091	263	0	11	0	0	48	50	3 332	0	0
2007–08	0	1 562	1 165	0	3	0	0	0	997	7 569	4	0
2008–09	0	219	1 267	30	1	0	0	0	448	7 605	7	0
2009–10	0	101	70	0	0	0	0	0	442	7 955	118	0
2010–11	0	714	251	0	27	1	9	0	102	6 815	39	0
2011–12	0	623	397	1	0	2	1	0	868	6 653	53	0
2012–13	0	0	469	0	144	5	30	0	866	6 152	36	0

Fishing	Central East Coast								
year	011	012	013	014	015	016	017	018	201
1990–91	0	0	177	99	0	0	0	0	0
1991–92	0	0	0	0	0	0	0	0	0
1992–93	0	0	34	27	11	0	65	19	0
1993–94	0	0	27	1 225	7	0	0	48	49
1994–95	0	0	23	591	0	0	0	0	11
1995–96	0	0	39	337	0	0	54	1	0
1996–97	0	0	249	267	0	0	0	0	0
1997–98	0	0	0	131	0	0	0	217	0
1998–99	0	0	0	471	18	0	0	0	0
1999–00	0	0	0	326	0	0	0	0	0
2000–01	149	0	0	143	0	0	0	0	0
2001–02	0	0	0	224	323	0	23	0	0
2002–03	0	0	85	394	16	0	5	0	0
2003–04	123	3	5	346	45	0	0	0	0
2004–05	0	0	20	22	0	0	0	0	0
2005–06	0	0	0	23	0	0	0	0	0
2006–07	0	0	0	53	0	0	0	0	0
2007–08	0	0	45	0	0	0	0	0	0
2008–09	0	0	0	0	0	0	0	0	0
2009–10	10	0	0	0	0	0	0	0	0
2010–11	0	0	1	0	91	0	0	0	0
2011–12	0	0	199	0	0	0	0	0	0
2012–13	0	0	10	0	0	0	0	0	0

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

Fishing	East Northland/Hauraki Gulf											
year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1990–91	265	26	1	3	3	2	5	76	3	1	4	413
1991–92	179	9	73	10	4	3	42	163	2	22	8	98
1992–93	89	64	43	347	458	8	189	5	416	55	3	220
1993–94	654	442	629	6	4	349	255	7	1 413	2 066	3 047	2 629
1994–95	432	638	935	858	124	79	6	205	7	517	2 561	3
1995–96	3	99	44	3	1	3	2	8	16	4	6	227
1996–97	46	183	60	1	4	2	4	3	2	2	2	625
1997–98	289	298	47	9	4	16	13	21	5	6	3	401
1998–99	1	81	80	0	1	4	4	3	10	4	0	26
1999–00	3	63	2	0	3	1	3	5	4	1	1	1
2000–01	39	57	159	1	14	9	4	14	2	1	3	182
2001–02	152	28	121	5	3	1	0	7	5	1	0	25
2002–03	690	97	135	0	0	0	0	32	10	2	0	45
2003–04	45	152	36	4	2	20	13	3	4	6	413	1 214
2004–05	391	182	41	219	0	5	25	5	0	0	2	0
2005–06	1	99	36	5	6	15	25	14	12	1	18	160
2006–07	58	140	56	53	12	5	22	2	0	1	2	1 093
2007–08	894	25	2	2	6	1	4	21	10	15	331	1 442
2008–09	1 150	283	23	5	10	2	4	16	12	1	35	3
2009–10	1	122	2	16	4	2	14	2	3	13	7	10
2010–11	17	323	43	27	41	4	47	2	6	23	6	499
2011–12	8	345	0	16	2	0	0	17	8	2	623	3
2012–13	13	20	337	8	3	28	18	12	145	25	6	33

Fishing	Bay of Plenty											
year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1990–91	253	655	462	0	1	0	417	1 517	1 550	635	554	229
1991–92	94	237	668	733	615	685	1 539	566	256	79	550	1 290
1992–93	221	449	643	513	0	2	376	1 698	469	475	55	1 927
1993–94	426	633	51	10	7	15	3	77	5	37	3	20
1994–95	34	559	131	336	77	28	9	5	787	471	217	504
1995–96	144	33	4	7	5	4	1	272	447	1 340	1 637	1 270
1996–97	91	2	0	30	0	1	62	214	289	1 723	1 959	634
1997–98	1 452	106	674	2	2	1	160	2	509	86	1 074	1 972
1998–99	1 643	264	12	22	1	7	3	201	790	743	482	473
1999–00	237	19	26	7	6	61	2	2	239	4	365	1 336
2000–01	248	346	224	222	188	169	2	2	1 187	1 323	1 667	1 723
2001–02	292	76	364	17	2	1	1	78	420	927	652	1 465
2002–03	6	2	0	358	695	0	2	10	55	870	360	1 773
2003–04	145	98	570	22	39	54	206	1 547	641	187	33	1 013
2004–05	568	1 336	1	165	231	80	14	245	926	63	1 828	2 677
2005–06	1 958	1 263	465	280	29	430	549	344	1 129	786	1 334	824
2006–07	84	299	648	214	199	238	606	317	212	353	6	264
2007–08	367	2 817	487	183	43	2	173	462	1 260	532	101	2 181
2008–09	2 101	1 388	2 154	8	2	3	2	1	255	804	395	1 035
2009–10	2 840	261	1 616	2	204	285	180	401	16	1 388	833	742
2010–11	3 057	1 724	468	70	155	62	7	316	123	146	49	945
2011–12	66	1 349	891	389	156	578	0	563	1 450	1 373	270	491
2012–13	0	1 803	589	396	1	348	203	227	920	1 503	372	691

Appendix 4–continued:

Fishing year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
												Central East Coast
1990–91	47	2	179	1	2	0	0	0	1	1	24	38
1991–92	1	2	2	1	2	4	1	2	4	2	6	4
1992–93	7	75	35	3	8	9	3	10	6	13	8	16
1993–94	122	110	13	654	2	1	3	453	64	7	26	12
1994–95	141	273	1	36	39	171	118	41	22	13	28	47
1995–96	324	12	10	31	15	41	140	63	60	6	33	29
1996–97	558	14	4	10	11	32	102	64	90	35	16	20
1997–98	89	3	9	5	12	15	28	41	41	16	6	123
1998–99	248	180	3	8	28	23	14	21	27	20	44	83
1999–20	59	187	7	10	14	18	12	145	17	6	15	38
2000–01	125	7	10	203	6	8	7	21	38	8	10	14
2001–02	13	6	3	10	6	190	424	122	36	12	10	15
2002–03	162	235	107	14	10	27	35	194	61	25	19	42
2003–04	91	154	141	143	8	61	51	173	127	7	9	11
2004–05	26	46	9	14	4	9	18	183	13	10	10	11
2005–06	28	5	3	4	5	9	6	55	21	5	12	7
2006–07	15	6	31	7	2	7	4	127	23	4	5	31
2007–08	9	49	5	4	3	5	8	35	4	5	5	10
2008–09	6	5	4	6	4	6	12	16	8	8	12	9
2009–10	12	9	16	4	5	9	3	13	11	9	13	18
2010–11	11	7	3	3	6	8	109	15	16	24	15	14
2011–12	0	0	186	0	0	11	0	0	0	0	0	2
2012–13	0	3	7	0	0	0	0	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 Coast			
year	JMA	EMA	KAH	Other	JMA	EMA	KAH	Other	JMA	EMA	KAH	Other
1990–91	331	437	0	36	5 058	371	818	28	0	0	280	17
1991–92	453	111	1	49	6 654	228	325	106	0	0	0	29
1992–93	998	791	44	65	6 160	111	501	55	33	0	66	93
1993–94	10 613	803	22	62	784	50	398	58	1 108	0	273	87
1994–95	5 423	891	1	50	2 848	64	184	63	388	12	256	276
1995–96	225	139	1	50	4 983	26	55	100	77	0	313	373
1996–97	646	253	0	34	4 442	30	476	58	101	0	434	421
1997–98	688	339	0	83	5 787	31	185	38	35	40	92	220
1998–99	56	127	0	31	4 006	151	359	123	333	9	86	270
1999–20	0	62	0	25	1 990	82	175	58	117	0	245	165
2000–01	2	422	0	60	6 906	296	43	57	107	0	211	139
2001–02	112	210	0	25	4 198	9	26	61	527	0	71	249
2002–03	673	330	0	8	3 980	62	11	78	148	0	356	426
2003–04	1 740	121	0	52	4 272	0	160	124	358	2	183	433
2004–05	507	318	0	45	7 731	322	62	20	18	0	34	301
2005–06	102	190	0	101	9 114	146	72	60	2	0	23	135
2006–07	1 172	212	0	61	3 247	47	101	46	76	0	29	157
2007–08	2 677	49	0	28	8 363	84	82	78	22	0	45	74
2008–09	1 448	24	0	73	8 051	72	0	24	0	0	0	98
2009–10	124	0	0	73	8 651	40	14	64	0	0	10	113
2010–11	920	0	0	118	6 733	290	47	52	14	0	79	140
2011–12	942	54	0	28	7 492	30	46	5	185	0	14	0
2012–13	609	0	0	38	6 929	106	16	3	0	0	10	0

Appendix 6: Summary[*] of the catch (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 2011 and September 2013.

	Number of landings					Weight of landings (t)					Number
Month_year	Total	Candidate	Characterisation	Proportion	Length	Total	Candidate	Characterisation	Proportion	Length	sampled
Jan_11	18	1	0	0	-	95	51	0	0	-	0
Feb_11	18	4	0	0	-	185	171	0	0	-	0
Mar_11	7	1	0	0	-	57	55	0	0	-	0
Apr_11	10	1	0	0	-	137	35	0	0	-	0
May_11	8	3	0	0	-	178	175	0	0	-	0
Jun_11	7	5	1	1	-	254	243	112	112	-	1 307
Jul_11	12	2	0	0	-	148	120	0	0	-	0
Aug_11	9	2	2	2	-	62	49	17	17	-	626
Sep_11	12	9	9	9	-	1 413	1 159	1 249	1 249	-	11 107
Oct_11	5	0	1	1	1	72	0	65	65	65	1 307
Nov_11	22	14	6	4	4	1 694	1 564	828	471	471	5 964
Dec_11	10	9	5	2	2	1 077	1 077	637	294	294	3 152
Jan_12	17	5	1	1	1	405	385	90	90	90	1 599
Feb_12	13	1	1	1	1	158	95	60	60	60	1 154
Mar_12	8	6	1	1	1	589	589	140	140	140	1 741
Apr_12	0	0	0	0	0	0	0	0	0	0	0
May_12	10	8	5	5	5	580	566	420	420	420	4 746
Jun_12	15	13	2	2	2	1 458	1 444	258	258	258	3 129
Jul_12	16	14	1	1	1	1 375	1 373	46	46	46	618
Aug_12	6	4	3	3	3	892	767	613	613	613	4 436
Sep_12	16	7	2	2	2	496	454	215	215	215	2 493
Oct_12	13	0	0	0	0	13	0	0	0	0	0
Nov_12	23	12	8	7	7	1 827	1 540	1 192	1 080	1080	8 728
Dec_12	11	5	3	3	3	933	554	394	394	394	3 352
Jan_13	11	4	0	0	0	403	396	0	0	0	0
Feb_13	5	0	0	0	0	4	0	0	0	0	0
Mar_13	13	6	0	0	0	376	365	0	0	0	0
Apr_13	7	3	0	0	0	221	217	0	0	0	0
May_13	6	3	2	2	2	239	239	227	227	227	2 478
Jun_13	13	8	4	4	4	1 065	913	447	447	447	4 395
Jul_13	10	8	5	4	4	1 528	1 268	923	759	759	7 398
Aug_13	10	5	3	3	3	379	372	240	240	240	2 772
Sep_13	19	11	1	1	1	724	694	177	177	177	2 623
All months	380	173	66	59	47	19 037	16 930	8 350	7 374	5 996	75 125

[*]Total, all landings; Candidate, landings >10 t; Characterisation, landings in characterisation; Proportion, landings in species proportion analysis; Length, landings in length frequency analysis.

Appendix 7: Estimated proportions and MWCVs 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 2011 and September 2013.

	Estimated proportion			Coefficient of variation			
Month/year	JMD	JMM	JMN	JMD	JMM	JMN	Catch (t)
6/2011	0.002	0.000	0.998	1.012	-	0.002	254
8/2011	0.000	0.000	1.000	-	-	0.000	62
9/2011	0.372	0.024	0.604	0.556	0.721	0.340	1 413
10/2011	0.000	0.000	1.000	-	-	0.000	72
11/2011	0.069	0.001	0.930	0.441	1.025	0.034	1 694
12/2011	0.345	0.072	0.583	0.451	0.095	0.273	1 077
1/2012	0.000	0.000	1.000	-	-	0.000	405
2/2012	0.000	0.000	1.000	-	-	0.000	158
3/2012	0.003	0.000	0.997	0.450	-	0.001	589
5/2012	0.000	0.000	1.000	-	-	0.000	580
6/2012	0.000	0.000	1.000	-	-	0.000	1 458
7/2012	0.000	0.000	1.000	-	-	0.000	1 375
8/2012	0.754	0.011	0.235	0.330	0.798	0.936	892
9/2012	0.000	0.000	1.000	-	-	0.000	496
11/2012	0.067	0.013	0.920	0.529	0.878	0.042	1 827
12/2012	0.403	0.117	0.480	0.437	0.426	0.429	933
5/2013	0.574	0.095	0.331	0.583	0.585	0.671	239
6/2013	0.000	0.000	1.000	-	-	0.000	1 065
7/2013	0.000	0.000	1.000	-	-	0.000	1 528
8/2013	0.000	0.000	1.000	-	-	0.000	379
9/2013	0.008	0.000	0.992	0.185	-	0.001	724