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Commercial catch sampling for species proportion, sex, length, and age of jack mackerels in JMA 1 in the 2006–07, 2007–08 and 2008–09 fishing years

New Zealand Fisheries Assessment Report 2012/48

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Taylor, P.R.; Horn, P.L.; Ó Maolagáin, C. (2012). Commercial catch sampling for species proportion, sex, length, and age of jack mackerels in JMA 1 in the 2006–07, 2007–08 and 2008–09 fishing years.

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A summary of all commercial jack mackerel landings in JMA 1 for the three fishing years of interest showed that between 93% and 99% were taken by purse seine. Most of the non-purse-seine landings were taken by trawl but it was clear that only the purse seine fishery needed to be sampled to provide an adequate description of the JMA 1 catch-at-age. A total of 80 landings were sampled over the three fishing years and examination of sampling representativeness indicated that overall, sampled landings were representative of the jack mackerel fishery in each year.

Estimated species proportions indicate a predominance of *T. novaezelandiae* in the JMA 1 purse-seine catch throughout the study period which continues a trend that is evident throughout much of the time-series since 1993–94. Estimated length frequencies by size class indicate the presence of two size fractions — one centred in the low 30 centimetres and a second in the mid to high 40 centimetres. This is apparently a function of targeting of small fish to fill traditional markets, which prefer small jack mackerel. This targeting is reflected in the length frequency of *T. novaezelandiae* and the fraction of smaller *T. declivis*. The larger mode is represents larger *T. declivis* and the overall length frequency of *T. murphyi*. It may represent a second, less preferred target that is taken when small fish are unavailable, or it may be the result of size mixing within schools.

The fishing season in JMA 1 straddles the end of each fishing year and the beginning of the next. Consequently, for any fishing year there are two parts to the length data collected for each species. The first begins on October 1 and finishes at the end of the season (usually some time during November) and the second begins at the start of the next fishing season (often some time during July) and finishes at the end of the fishing year (September 30). To simplify this, length data were categorised as being collected during an early (October to March) stratum, and a late (April to September) stratum.

Age frequency distributions of *T. declivis* showed the progression of four year old fish from the late stratum in 2006–07 to five year olds in the same stratum in 2007–08. Annual age class frequency distributions for *T. novaezelandiae* suggest a strong year class originating in 2003 that seems particularly clear in the distribution for 2008–09. There is also evidence of a systematic shift with decreased representation of older age classes and increased representation of younger age classes over time. The age frequency distributions of *T. murphyi* are interesting from the perspective of the position of the mode and its relationship with the peak in abundance of *T. murphyi* in 1995. The mode is centred at 12 years in all distributions, suggesting that either fish have continued to enter the New Zealand zone after the 1995 peak or there has been some successful spawning within the zone.

An important point arising from the summary of factors affecting the choice of target species in the purse-seine fishery is that because jack mackerel prices have increased and stabilised over the past few years fishing companies are more likely to target them now, whereas once there would have been a preference for targeting skipjack tuna.

Information summarised here does not offer strong support for producing a stock assessment for jack mackerel species. Catch-at-age sampling is unlikely to provide an effective monitoring tool for these species. Temporal inconsistencies in the length and age composition of the purse seine catch of *T. declivis* and *T. novaezelandiae* indicate that sampling of the population by the fishery is inconsistent, with the size distribution of the fish being targeted and caught possibly being influenced by the location of fishing and market forces. Thus selectivity appears to vary substantially between years.

1. INTRODUCTION

1.1 Overview

Commercial catches of jack mackerel are recorded as an aggregate of the three species *Trachurus declivis*, *T. murphyi*, and *T. novaezelandiae* under the general code JMA. Consequently, for assessment of the individual stocks, reliable estimates of the proportions caught of the three *Trachurus* species from sources other than catch records are essential. Reliable estimates of species proportions can be used to apportion the catch into individual species catch histories and CPUE series for each species at least back to when sampling began. These can be used in age-structured models (Taylor 1999) or to scale size or age structures from the various fisheries.

Age class monitoring was carried out previously for two species of jack mackerels in New Zealand by Horn (1993). He tracked strong and weak age classes of *T. declivis* and *T. novaezelandiae* through time to provide a qualitative validation for ageing these two species. He found no significant difference in growth rate between sexes for either species, although geographical differences were evident between the Bay of Plenty and the central west coast. Ageing protocols for *T. murphyi* in New Zealand have not been validated.

Taylor (2008) identified a number of factors, including market variables, as having the potential to influence landing volumes and fish size in the purse-seine and TCEPR fleets (vessels recording catch on Trawl Catch Effort and Processing Returns). Because not all were directly related to the marketing of fish and because they influenced the choice of target, they were categorised as “target-choice variables”. The most influential of these target-choice variables were concerned with the preferential targeting of higher valued species, with a combination of mixed-species schooling behaviour, and with the inhibitory influence of bycatch when quota is limited. Within the purse-seine fishery, it was concluded that the preferred-species hierarchy (in order from highest to least valued), based on the persistent relativity in market values, is skipjack tuna, blue mackerel, and jack mackerel. This hierarchy is likely to remain the most important consideration in dictating target choice, unless there are further changes to catch limits, or the market price of a species becomes so low that it is uneconomical to be landed. Fishery monitoring needs to be structured to account for any changes in these target-choice variables, as well as changes in the size, age and species mix of jack mackerel catches.

1.2 Scope of the report

This report updates estimates of the relative proportions of the three *Trachurus* species in the commercial JMA 1 (Figure 1) catch summarised by Taylor & Julian (2008) using market sampling data for 2006–07 to 2008–09. It also presents a time series of length-at-age and catch-at-age estimates for JMA 1, summarises sex ratios, and documents target-choice variables affecting the JMA 1 purse-seine fishery during this period.

The work was completed under the Ministry of Fisheries Research Projects JMA2006/01 and PEL2008/03. Tasks under JMA2006/01 included analyses of jack mackerel fisheries in all Fishstocks, but only those for JMA 1 are reported here. PEL2008/03 only required analyses for jack mackerel in JMA 1, which are reported here. Thus, this report includes analyses of species composition, catch-at-age, and factors affecting purse-seine targeting in JMA 1 from 2006–07 to 2008–09. Specific objectives for these projects relevant to the JMA 1 fishery, and hence the work documented here, are listed below.

JMA2006/01 objectives

1. To collect representative samples from fish processing sheds to determine the age, length, seasonality, and species composition of the commercial catches of *T. declivis*, *T. murphyi*, and *T. novaezelandiae* in JMA 1 in the 2006/2007 and the 2007/08 fishing years. The target coefficient of variation (c.v.) for the catch at age will be 30% (mean weighted c.v. across all age classes), including demonstrating that sampling was representative of the fishery.

6. To explore the time series of catch sampling data, in particular for any significant changes in the species composition of commercial catches and any indications of change in stock status in JMA 1, JMA 3 and JMA 7.

PEL2008/03 objectives

1. To conduct representative sampling and determine the length, sex, age and species composition of the commercial purse seine catches of *T. declivis*, *T. murphyi*, and *T. novaezelandiae* in JMA 1 in the 2008/09 fishing year. The target coefficient of variation (c.v.) for the catch-at-age will be 30% (mean weighted c.v. across all age classes) for each of the two native JMA species (combined sexes).

3. To explore the time series of catch sampling data, in particular, for any significant changes in the length and age composition of commercial catches in JMA 1.

4. To document factors (e.g. market) that relate to the volumes and sizes of fish taken in the purse seine fisheries for JMA in QMA 1 during 2008/09 and 2009/10.

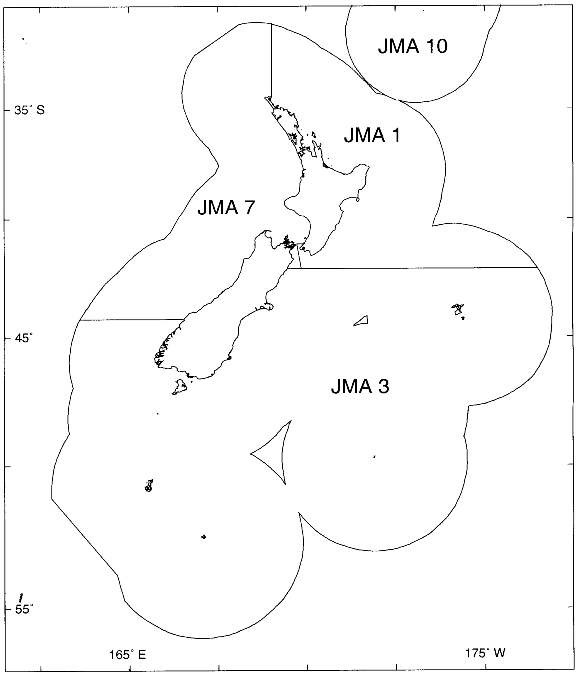

Figure 1: Jack mackerel Fishstocks.

2. METHODS

2.1 Market sampling for length, sex, age, and species composition

Market sampling for length, sex, age, and species composition was carried out at Sanford Ltd, Tauranga, and Pelco NZ Ltd, Mt Maunganui. Sampling at Sanfords was done by Sanford and NIWA staff; sampling at Pelco was done by NIWA staff.

Sanford (Tauranga). It is standard practice in this fish shed to sort jack mackerel by weight into the following grades: 0–200 g, 201–400 g, 401–600 g, 601–1000 g, over 1 kg. These are referred to as "grade-weights". Sampling was designed to utilise the sorting into grades that was carried out by Sanfords, with the understanding that each grade provided a more homogeneous basis than ungraded fish. Sampling to provide data for estimating the total weight of each species in a purse-seine landing of jack mackerel used the following approach:

1. Throughout the landing, which can take up to three days, grade-samples of about 100 fish were taken at random from each grade. Grade-samples were taken at a rate of up to two per day per grade, one each in the morning and afternoon during the landing (see illustration Figure A1, Appendix A).
2. Each grade-sample was sorted by species to give one species-grade-sample per species; weight (species-grade-sample-weight) and number of fish of each species-grade-sample was recorded.

Pelco (Mt Maunganui). NIWA used a similar method to that employed at Sanford (Tauranga) to market sample purse-seine catches landed at this fish shed. Pelco also grade jack mackerel, although their grades are different to those employed at Sanfords.

At both fish sheds, length (to the nearest cm) and sex data were collected from fish in the species-grade-samples. Otoliths were systematically collected by 1 cm length-class strata, at a rate of 25 otoliths for the 5 to 10 smallest and largest size classes, and 15 for each of the other strata.

2.2 Estimating species proportions

Estimation was carried out over three nested strata — grade, landing, total catch over a period of interest — with proportions weighted at each step by the size (weight) of the current stratum. The method comprised the following six steps:

1. Species-grade-sample-weights were summed for each species and grade to give summed-species-grade-sample-weights; grade-sample-weights were summed for each grade to give summed-grade-sample-weights (Figure A1).
2. Summed-species-grade-sample-weights were divided by summed-grade-sample-weights to give estimates of the proportions of each species in the grade (species-grade-proportions).
3. Grade-weights (total weight of each grade) were multiplied by species-grade-proportions to give total weights of the species in the grade (species-grade-weights).
4. For each species, species-grade-weights were summed to provide the total weight of each species in the landing (species-landing-weights).
5. The species-landing-weights were divided by the total weight of the landing (given by the summed species-landing-weights) to give proportions of the species in the landing.

6. To provide species-proportion estimates over a given time-frame (e.g., month), species-landing-weights were summed for each species in each sampled landing over the period of interest and divided by the total of all species-landing weights over the period.

A further stratum was incorporated into the process to examine species proportions for each fishing company. This was achieved by following the six steps above on separate data for each company. The data from the two fish sheds were then aggregated and overall species proportions were estimated.

Because of the way in which the JMA 1 purse-seine fishing season straddles consecutive fishing years (a standard fishing year is defined as beginning on October 1 in one year and finishing on September 30 in the next), the method of estimating species proportions was developed to maximise the available information without constraining the dataset according to the artificial time boundary between September 30 and October 1. Because most jack mackerel taken in JMA 1 are landed between July and December inclusive, the data for estimating species proportions were split at the end of June and at the end of December. Species proportions were estimated for each of the split datasets.

For the study period, data had only been collected between July 1 and December 31, so for the three years 2006–07 to 2008–09, this split included all the data. The resulting species proportions were then assigned to fishing years, with fishing years split into an early period (October to March) and a late period (April to September). Then, species proportions for which the fishing year's contribution was data from October–December were assigned to that fishing year's early period, whereas species proportions for which the fishing year's contribution was July–September were assigned to that fishing year's late period. These proportions were tabulated as single values when expressed in an annual time frame, and imputed for missing month values after 2005–06 when there were no data to estimate monthly species proportions. Before 2005–06, sample data were available over a greater range of months, so estimates for fishing years were based on the data from fishing years and monthly imputations for missing values included these estimates.

Coefficients of variation (c.v.s) were estimated for all species proportions. Variance in species proportions is a combination of within-landing and between-landing variance. This was estimated by bootstrapping (Efron & Tibshirani 1993) the species proportion estimates and calculating c.v.s using

$$\hat{c.v.} = \frac{\sqrt{\hat{\text{var}}(\text{bootstrapped species proportions})}}{\hat{mean}(\text{bootstrapped species proportions})}$$

Bootstrapping incorporated 1000 sets of species proportions using data resampled from the original grade-sample-weights by landing, with replacement.

2.3 Estimating sex ratios

Sex ratios were estimated using a similar method to that employed for species proportions except that in this case the proportions were for sex instead of species. Sex ratios were summarised by year and month and by early and late period in each fishing year for the period 2006–07 to 2008–09.

2.4 Target choice variables

Senior managers at Sanford Tauranga and Pelco NZ were consulted for information on factors influencing the targeting of fish during the fishing years 2006–07 to 2008–09. These are summarised as suggested by Taylor (2008).

2.5 Age estimation

All ageing was completed by two readers. Reader 1 read *Trachurus declivis* and *T. novaezelandiae* from 2006–07 and 2007–08. Reader 2 read these species from 2008–09, and also the *T. murphyi* otoliths from all three years. Otoliths of *T. declivis* and *T. novaezelandiae* were read following the validated methods described by Horn (1993) and Lyle et al. (2000). A validated ageing method has not yet been developed for *T. murphyi* in New Zealand waters. Otoliths from this species were interpreted similarly to those of *T. declivis*. However, they are notably harder to read, with presumed annual zones often being diffuse, split, or comprising considerable microstructure (Taylor et al. 2002).

Because two readers read the *Trachurus declivis* and *T. novaezelandiae* otoliths, between-reader comparisons were conducted for both species to ensure consistent interpretations. Paired readings were available from 131 *T. novaezelandiae* and 168 *T. declivis* otoliths. The Index of Average Percentage Error (IAPE, Beamish & Fournier 1981) was calculated for each set, and age-bias plots were constructed (Campana et al. 1995).

Otoliths for ageing were selected from the market sampling data using a random stratified selection to ensure adequate representation of the sampled fish. Selected otoliths were embedded in clear epoxy resin in aligned groups of five. A transverse section about 350 µm thick was taken through the primordia of the five embedded otoliths. The sections were mounted on microscope slides under a coverslip, illuminated by transmitted light, and examined under a binocular microscope at ×40 magnification. The number of complete opaque zones (which appear dark using this examination technique) was counted wherever the pattern was clearest.

Opaque zone counts were converted to age as described by Horn (1993). Because almost all otoliths had either a wide translucent or narrow (i.e., incomplete) opaque margin, their age class was equal to their zone count (i.e., the number of complete opaque zones). Because the aged fish were collected between July and December, and a nominal 'birthday' of 1 January has been previously defined (Horn 1993), the decimal age of a fish with a zone count of x is x plus from 0.5 to 0.9 years (depending on the month of capture).

2.6 Estimation of catch-at-age

Catch-at-age and catch-at-length estimates were produced using NIWA's 'catch-at-age' software (Bull & Dunn 2002). The software scaled the length frequency of fish from each landing up to the landed weight from that trip, and the sum of the distributions from each landing is then scaled up to the total landed weight. A descriptive analysis of the JMA 1 fishery (Taylor & Julian 2008) indicated that there were two landings peaks in a fishing year (i.e., October–December and June–September). Consequently, each fishing year was divided at 1 April into two time strata — 'early' and 'late'. Early is October to March; late is April to September.

The landed catch by species from each time stratum (i.e., half fishing year) was obtained from the estimated species proportions described above. The age-length data were used to generate an age-length key, through which length data were passed to estimate numbers-at-age for sexes combined. Numbers-at-age were not estimated by sex as there is no statistically significant difference in growth rate between sexes for the jack mackerel species (Horn 1993, Lyle et al. 2000).

The precision of each length or age frequency was measured by the mean weighted c.v. This was calculated as the average of the c.v.s for the individual length or age classes weighted by the proportion of fish in each class. The c.v.s were calculated by bootstrapping: fish were resampled 300 times with replacement within each landing, and otoliths were randomly resampled from the entire set.

3. RESULTS

3.1 Market sampling

An examination of landings by fishing method showed that between 93% and 99% of the jack mackerel landings from JMA 1 were taken by purse seine (Table 1). Most of the remaining landings were taken by trawl. It is clear, however, that only the purse seine fishery needs to be sampled to provide a comprehensive description of the JMA 1 catch-at-age. It is also apparent that the purse seine landings peak over the June–December period (i.e., at the start and end of the fishing year (Figure 2)), so stratification of the fish year into 'early' and 'late' time strata is logical.

Table 1: Estimated landed catch (t) of jack mackerels in JMA 1, by half fishing year and fishing method. 'Other methods' includes line, beach seine, Danish seine, and set net methods.

Fishing year Stratum	Purse-seine	Bottom trawl	Midwater trawl	Other methods
2005–06 late	4 320	62	14	3
2006–07 early	2 009	58	5	8
2006–07 late	2 865	72	143	3
2007–08 early	5 342	44	1	3
2007–08 late	6 456	75	31	2
2008–09 early	8 005	41	6	5
2008–09 late	2 635	68	20	9

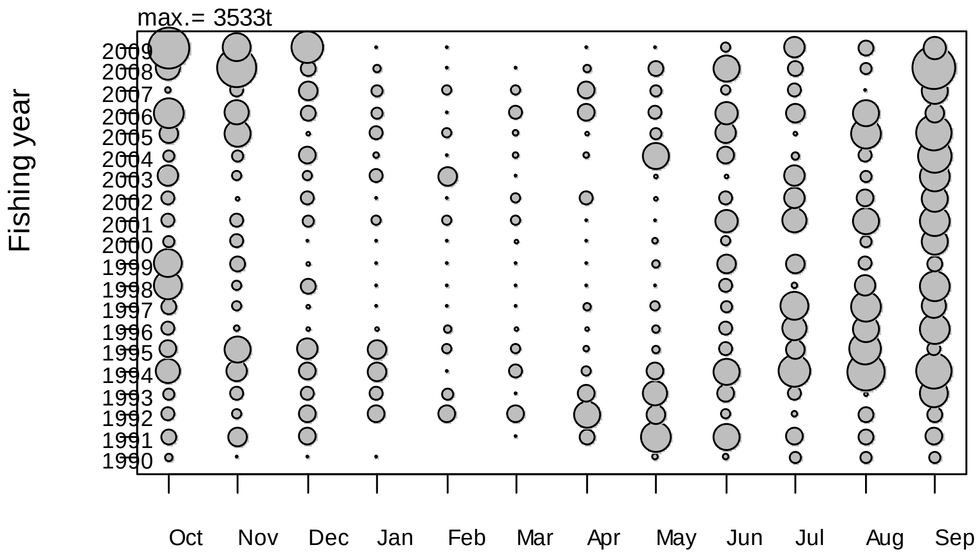

Figure 2: Monthly purse-seine landings of jack mackerel, from 1989–90 to 2008–09. Circle area is proportional to landings.

Eighty purse-seine landings were sampled between July 2006 and September 2009 (Table 2). Sample numbers varied between 7 and 16 per time stratum, and between 20 and 50% of the landed weight per stratum was sampled (Figure 3). The distribution of the sampled landings, relative to total landings by weight, is shown by month in Figure 4. December 2008 was clearly under-sampled, and it would have been desirable to also have some samples from June and November 2008.

The distribution of landings by statistical area (Figure 5) shows that area 009 was the most productive, followed by areas 002 and 003. Sampling by area was generally representative of landings by area, although area 009 was not sampled in late 2006–07 and was under-sampled in late 2007–08 and early 2008–09. Some relatively insignificant landings were recorded in areas 005, 007, 010, and 013; these are not shown in Figure 4 or 5.

Table 2: Numbers (*n*) of purse seine landings sampled by time stratum.

Fishing year stratum	*n*	Fishing year stratum	*n*
2005–06 late	14	2007–08 late	7
2006–07 early	9	2008–09 early	11
2006–07 late	8	2008–09 late	15
2007–08 early	16		

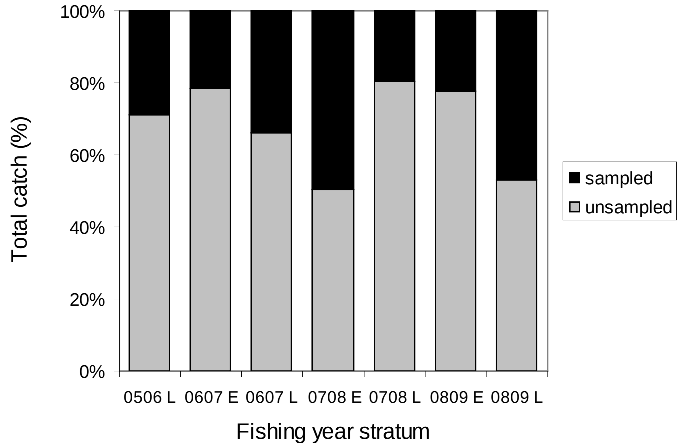

Figure 3: Proportion (%) of total purse seine landings that were sampled, by fishing year stratum, from 2005–06 to 2008–09; 'E' is early (Oct to Mar) and 'L' is late (Apr to Sep).

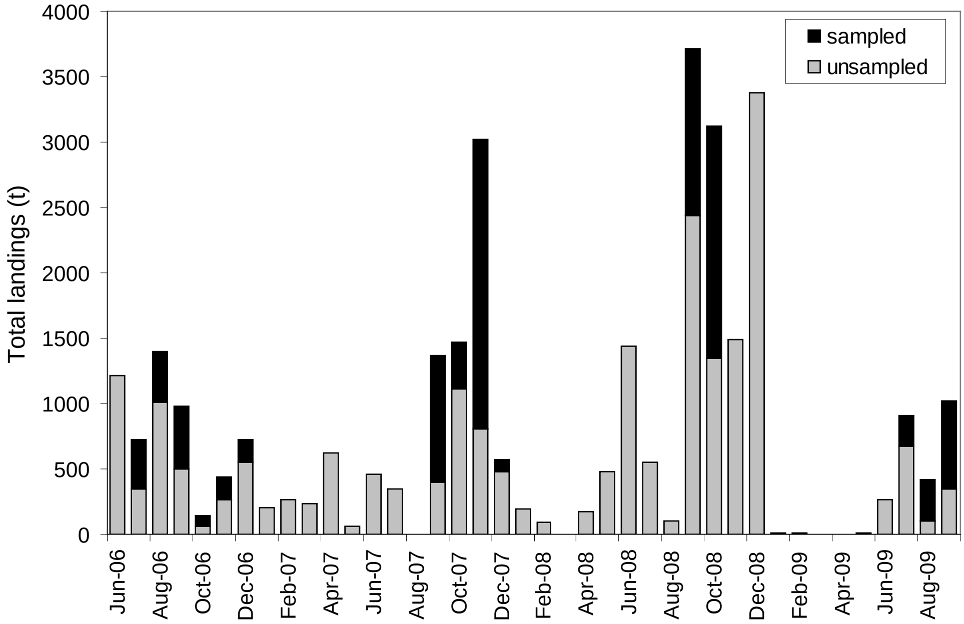

Figure 4: Monthly sampled purse seine landings (t) from July 2006 to September 2007.

Most jack mackerel purse-seine landings are a result of targeting for that species, and sampling covered at least 20% of landings by weight (Figure 5). Of other target species, only blue mackerel in early 2006–07 produced significant jack mackerel landings, and some of these were sampled. Some very small landings of jack mackerel were taken when targeting for kahawai, pilchards, and skipjack.

An examination of samples by landing size showed that most samples were obtained from the moderate (10–100 t) to large (more than 100 t) jack mackerel landings, which is desirable (Figure 6). No purse seine landings less than 1 t were sampled, and one landing of less than 10 t was sampled in early 2006–07. Overall, it appears that sampled landings in all years were probably quite representative of the jack mackerel fishery.

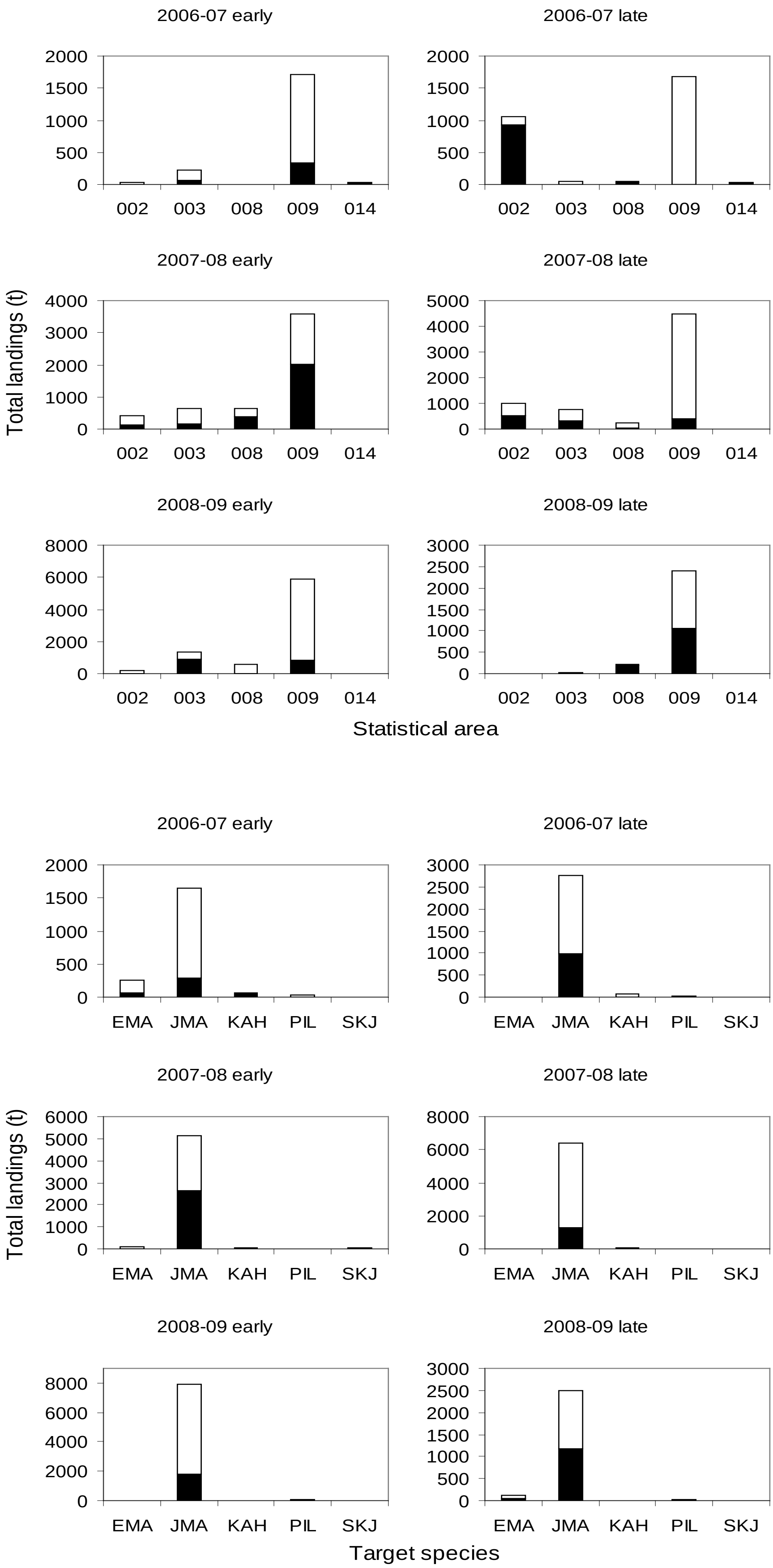

Figure 5: Proportions of sampled (black bars) and unsampled (clear bars) jack mackerel purse-seine landings, by statistical area (upper six plots) and target species (lower six plots), for individual time strata. EMA, blue mackerel; JMA, jack mackerel, KAH, kahawai; PIL, pilchards; SKJ, skipjack tuna.

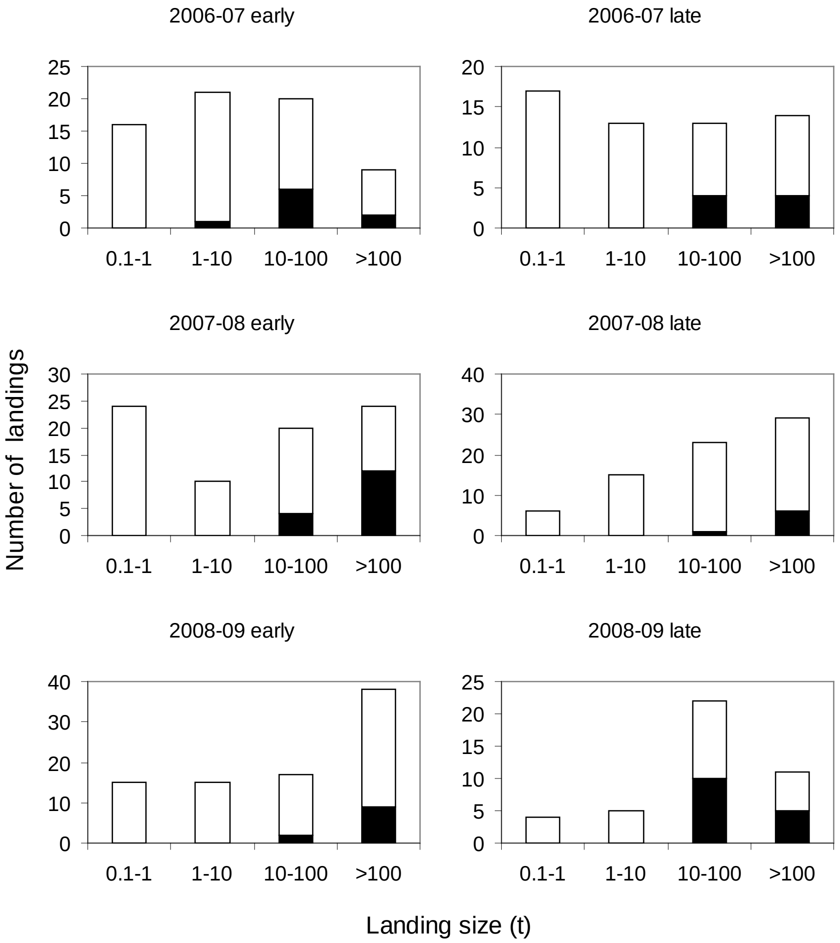

Figure 6: Proportions of sampled (black bars) and unsampled (clear bars) jack mackerel purse seine landings, by landing size, for individual time strata.

3.2 Species proportions

The number of landings sampled for species proportions during the study period and the number of grade-landing samples (about 100 fish per sample) are shown in Table 3; the number of samples by landing and grade are shown in Appendix B (Table B1). In most cases before the beginning of 2009, samples were selections of graded fish. The number of grades varied between landings (Appendix B, Table B1). The number of grades encountered during each month of sampling are summarised in Table 3. In months where the summary shows that only one grade was sampled (e.g., December 2006), sampling was of ungraded fish. Most sampling during 2009 was of ungraded fish because the factory grading technique changed and the sampling method was revised accordingly.

An examination of estimated species proportions for the months when sampling was carried out (Table 4a) indicates that sampled landings at Pelco comprised *T. novaezelandiae* only. By contrast, landings at Sanfords comprised one, two, or three species. The dominant species throughout the study period was *T. novaezelandiae*, as it has been throughout a considerable number of the months since sampling began in 1994 (Appendix C, Table C1). In the months that *T. declivis* was present within the study period, it was the most highly represented species 50% of the time (Table 4b).

Six monthly summaries (Table 5) showed *T. novaezelandiae* predominating (about 70%) from late 2005–06 to early 2007–08. In late 2007–08, relative proportions of *T. declivis* and *T. novaezelandiae* were more similar at 35% and 50% respectively, although in late 2008–09, only *T. novaezelandiae* was present. *T. murphyi* was present from late 2006–07 but had disappeared again by late 2008–09. The predominance of *T. novaezelandiae* is consistent throughout most fishing years since 1995–96 (Appendix C, Table C2). *T. murphyi* peaked in 1994–95 but has been almost absent since 1999–00.

Table 3: No of landings sampled monthly for species proportions, the number of samples taken, and the number of unique grades requiring sampling, in the JMA 1 purse-seine fishery during the three fishing years 2006–07 to 2008–09.

		Calendar year			
	Month	2006	2007	2008	2009
No of landings					
	7	0	0	0	4
	8	0	0	0	3
	9	0	8	8	8
	10	6	2	10	10
	11	2	12	0	0
	12	1	1	0	0
No of samples					
	7	0	0	0	31
	8	0	0	0	18
	9	0	70	128	32
	10	26	14	145	52
	11	13	188	0	0
	12	3	17	0	0
No of grades					
	7	0	0	0	3
	8	0	0	0	1
	9	0	6	5	1
	10	5	2	6	1
	11	2	6	0	0
	12	1	3	0	0

Table 4a: Estimated species proportions by year, month, and fishing company for months when samples were taken; JMD is *Trachurus declivis*, JMM is *T. murphyi*, JMN is *T. novaezelandiae*; bootstrapped mean weighted c.v.s are in parentheses.

		Fishing Company					
		Pelco			Sanford		
Year	Month	JMD	JMM	JMN	JMD	JMM	JMN
2006	Oct			1.00(0.41)	0.62 (0.36)		0.38 (0.67)
2006	Nov				0.81 (0.20)		0.19 (0.85)
2006	Dec						1.00 (0.77)
2007	Sep				0.64 (0.10)	0.23 0.26)	0.14 (0.57)
2007	Oct						1.00 (0.24)
2007	Nov			1.00 (0.14)	0.03 (0.89)		0.97 (0.03)
2007	Dec						1.00 (0.20)
2008	Sep				0.60 (0.26)	0.03 (0.40)	0.38 (0.41)
2008	Oct			1.00 (0.74)	0.21 (0.30)	0.28 (0.36)	0.51 (0.31)
2009	Jul						1.00 (0.04)
2009	Aug						1.00 (0.24)
2009	Sep			1.00 (0.73)			1.00 (0)
2009	Oct			1.00 (0.23)			1.00 (0)

Table 4b: Estimated species proportions by year and month for all data (i.e., samples from two fishing companies combined) for months when samples were taken; JMD is *Trachurus declivis*, JMM is *T. murphyi*, JMN is *T. novaezelandiae*; bootstrapped mean weighted c.v.s are in parentheses.

		All data		
Year	Month	JMD	JMM	JMN
2006	Oct	0.23 (0.72)		0.77 (0.27)
2006	Nov	0.81 (0.21)		0.19 (0.88)
2006	Dec			1.00 (0.78)
2007	Sep	0.64 (0.10)	0.23 (0.25)	0.14 (0.54)
2007	Oct			1.00 (0.24)
2007	Nov	0.02 (0.90)		0.98 (0.02)
2007	Dec			1.00 (0.22)
2008	Sep	0.60 (0.27)	0.03 (0.40)	0.38 (0.42)
2008	Oct	0.18 (0.34)	0.25 (0.40)	0.57 (0.27)
2009	Jul			1.00 (0)
2009	Aug			1.00 (0.23)
2009	Sep			1.00 (0)
2009	Oct			1.00 (0)

Table 5: Estimated species proportions of the three jack mackerel species in the JMA 1 purse-seine fishery for the three fishing years 2006–07 to 2008–09, where fishing years are split into early (Oct–Mar) and late (Apr–Sep) periods; JMD is *Trachurus declivis*, JMM is *T. murphyi*, JMN is *T. novaezelandiae*; bootstrapped mean weighted c.v.s are in parentheses.

Fishing	Early			Late		
year	JMD	JMM	JMN	JMD	JMM	JMN
2006–07	0.30 (0.47)	0	0.70 (0.23)	0.21	0.07	0.72
2007–08	0.21 (0.30)	0.07 (0.43)	0.72 (0.12)	0.35	0.16	0.49
2008–09	0.35 (0.27)	0.16 (0.39)	0.49 (0.23)	0	0	1.00

3.3 Sex ratios

Proportions of females for early (October–March) and late (April–September) periods for each fishing year in the study period are shown in Table 6. Generally, proportions are around 50%, although for *T. novaezelandiae* there was an estimated value for females in early 2006–07 of 62% and several estimates of 100% females: for *T. Murphyi* in early 2006–07 and late 2008–09 and for *T. Declivis* in 2008–09. This estimate appears to be driven by data from October and November 2006 (Table 7).
Monthly estimates of female proportions (Table 6) suggest several deviations from 50% including *T. murphyi* in September 2008 (62%) and *T. novaezelandiae* in October 2007 (30%).

Table 6: Estimated proportions of females for the three jack mackerel species in the JMA 1 purse-seine fishery for the three fishing years 2006–07 to 2008–09, where fishing years are split into early (Oct–Mar) and late (Apr–Sep) periods; JMD is *Trachurus declivis*, JMM is *T. murphyi*, JMN is *T. novaezelandiae.*

		Early period			Late period		
		JMD	JMM	JMN	JMD	JMM	JMN
Females	2006–07	0.52	1.00	0.38	0.45	0.56	0.49
	2007–08	0.45	0.56	0.49	0.49	0.48	0.49
	2008–09	0.49	0.48	0.49	1.00	1.00	0.49

Table 7: Proportions of females in catch samples for the three jack mackerel species in the JMA 1 purse-seine fishery for the three fishing years 2006–07 to 2008–09 and the incomplete fishing year 2009–10, by calendar year and month.

	Trachurus declivis				*T. murphyi*				*T. novaezelandiae*			
	2006	2007	2008	2009	2006	2007	2008	2009	2006	2007	2008	2009
Females												
Jul												0.59
Aug												0.51
Sep		0.55	0.57			0.44	0.62			0.56	0.55	0.48
Oct	0.46		0.45				0.44		0.63	0.30	0.49	0.51
Nov	0.52	0.47							0.66	0.52		
Dec									0.55	0.58		

3.4 Target choice variables

In addition to those discussed by Taylor (2008), a number of factors have had an important influence on the choice of target species during the study period.

1. The world price for jack mackerel has increased and stabilised, placing its relative value higher than blue mackerel at times.
2. A combination of well developed roe and stomachs full of krill can cause jack mackerel to burst on capture, potentially reducing product quality if fished after October.
3. Trevally can often be mixed with kahawai, which can reduce their accessibility.
4. Traditional markets for jack mackerel prefer small fish.
5. Large jack mackerel, particularly *T. murphyi*, have seldom been available.
6. The high costs associated with fishing skipjack tuna (mainly because individuals of this species will damage each other when stored in holds and unloaded in an un-frozen state), in tandem with the recent higher relative value of jack and blue mackerel, can result in these species being targeted preferentially; maintaining skipjack as frozen product on board vessels results in increased costs of brine because of the need for a much higher salt content and much higher numbers of staff to manually unload because frozen product cannot be pumped.
7. The availability on the west coast of larger skipjack with a higher commercial value also introduces the need to consider higher fuel costs; the tradeoff of this factor and those discussed in 6 above, may also depend on volume capability, with some minimum cut-off based on hold size/number of vessels.

3.5 Ageing

Trachurus declivis and *T. novaezelandiae* are relatively straightforward to age, with both species (but particularly *T. novaezelandiae*) having clear annual zones.

Age bias plots depicting a comparison of age estimates generated by the two readers indicate that the interpretation methods were identical (Figure 7). Estimates of between-reader average percentage error (APE) were 1.9% for *Trachurus novaezelandiae* and 2.4% for *T. declivis*; such low values are also indicative of a very consistent interpretation of the otoliths by the two readers.

3.6 Catch-at-length and catch-at-age

Catch-at-age estimates were required for each half of the fishing year, because of the strong seasonality of the fishery and the consequent sampling only at the start and end of each fishing year (Figure 8).

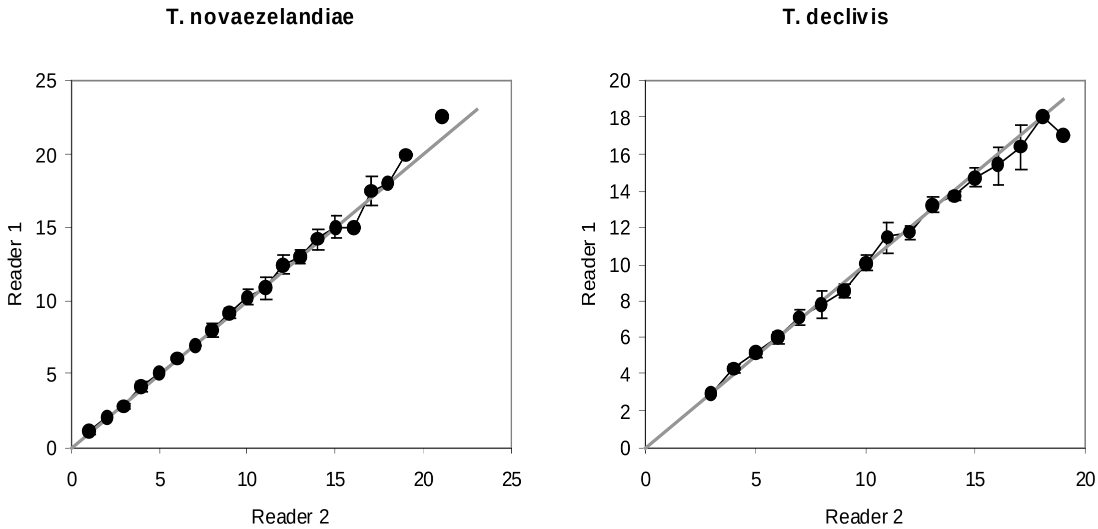

Figure 7: Between-reader age bias plots for *Trachurus novaezelandiae* and *T. declivis*. Error bars are plus or minus two standard errors.

However, to maximise the information from the aged fish, age data were generally used in two age-length keys (e.g., all age data from Sep–Dec 2007 were used as the age-length key for late 2006–07 and early 2007–08 time strata). A summary of the final available amount of data by species and time stratum is given in Table 8. Most samples contained only one or two of the three species.

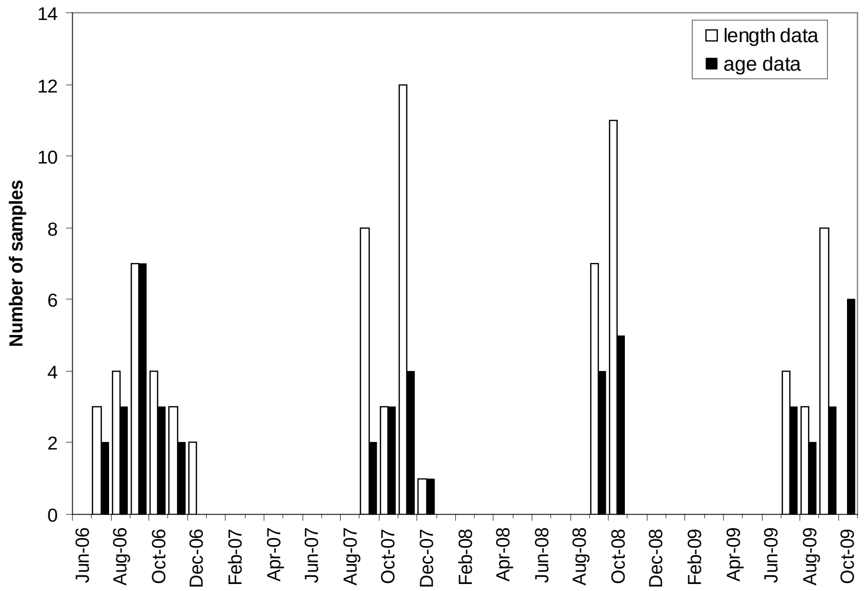

Figure 8: Frequency and distribution over time of samples that provided length frequency and age data.

Table 8: Amount of available data, by species and time stratum; Samples are the number of samples producing length data, Lengths are the total number of length measurements, and Ages are the number of fish ages in the age-length key.

	T. novaezelandiae			*T. declivis*			*T. murphyi*		
Stratum	Samples	Lengths	Ages	Samples	Lengths	Ages	Samples	Lengths	Ages
2006–07 early	6	2 074	366	6	2 117	360	0	0	0
2006–07 late	5	2 081	403	6	3 018	398	6	627	250
2007–08 early	15	20 115	403	4	823	398	0	0	0
2007–08 late	4	5 320	344	5	4 841	404	4	209	393
2008–09 early	8	9 660	344	4	1 778	404	4	1 247	393
2008–09 late	15	9 933	397	0	0	0	0	0	0

3.6.1 *Trachurus novaezelandiae*

Scaled length-frequencies for *Trachurus novaezelandiae*, by time stratum, are shown in Figure 9. There are modes at 31 or 32 cm in all distributions. The distributions are all generally similar, except that the peak in early 2006–07 is less pronounced than in other years.

Scaled age-frequencies for *Trachurus novaezelandiae*, by time stratum, are shown in Figure 10. Most fish in the catch from the three years are aged from 5 to 9 years, but the distributions are quite variable between years. Year classes rather than age classes are presented in Figure 11, because fish had a birthday between the early and late fishing year periods. This summary suggests a systematic shift in the age structure, with an apparent decline in older year classes over time, and an apparent increase in younger fish (i.e., year classes since 2000). Mean weighted c.v.s (over all year classes) are 23%, 16%, and 16% for 2006–07, 2007–08, and 2008–09, respectively.

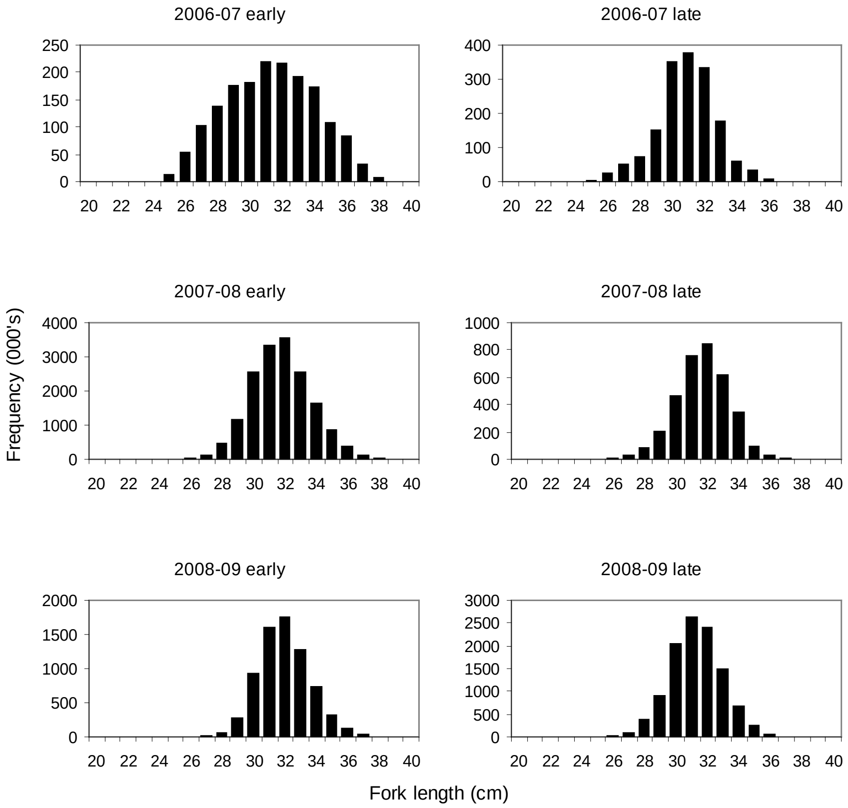

Figure 9: Scaled length-frequency distributions of *Trachurus novaezelandiae*, by time stratum. Note different scales on the *y*-axes.

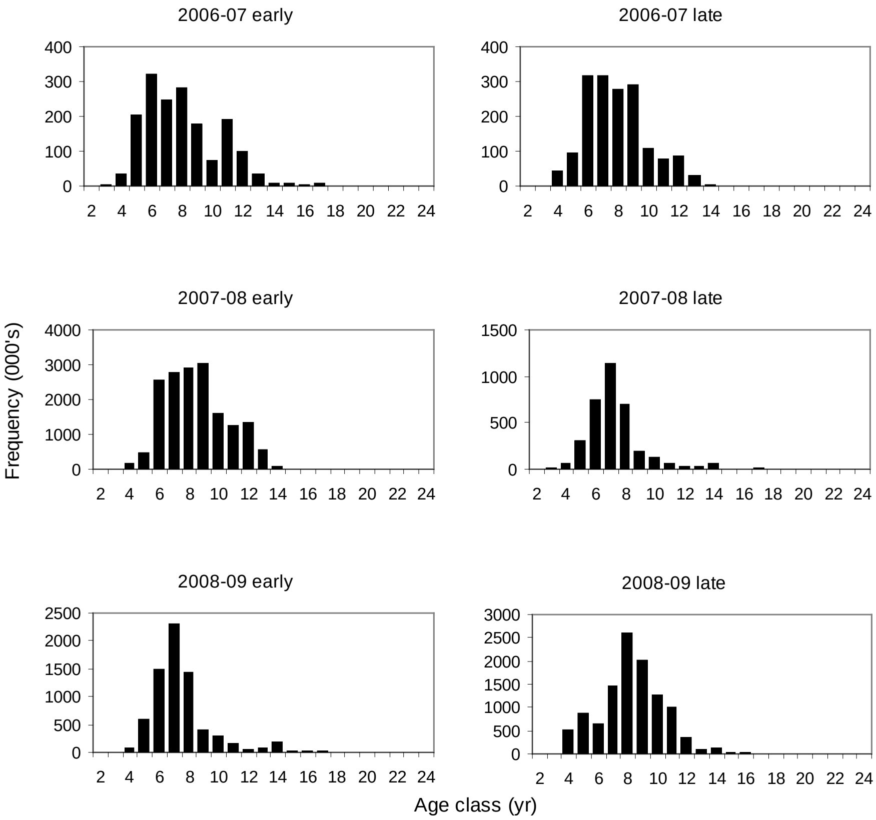

Figure 10: Scaled age-frequency distributions of *Trachurus novaezelandiae*, by time stratum. Note different scales on the *y*-axes.

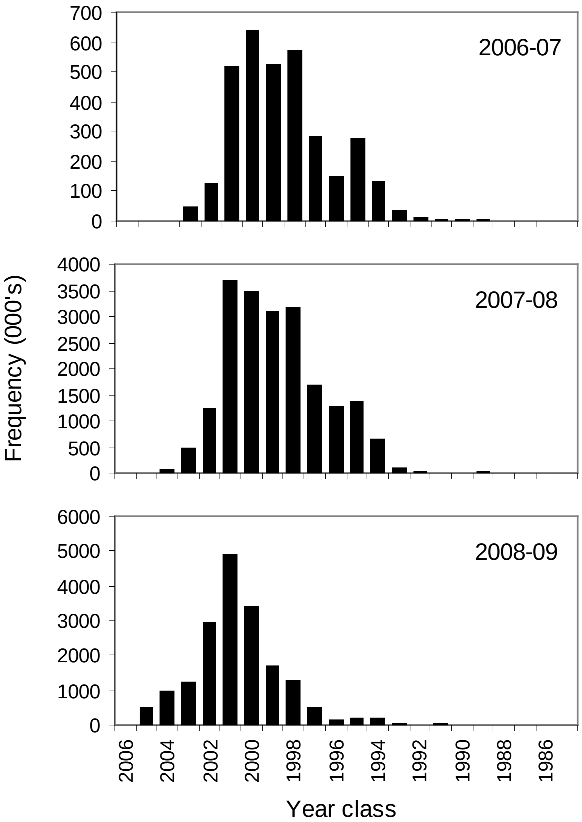

Figure 11: Scaled year-class-frequency distributions of *Trachurus novaezelandiae*, by fishing year. Note different scales on the *y*-axes.

3.6.2 *Trachurus declivis*

Scaled length-frequencies for *Trachurus declivis*, by time stratum, are shown in Figure 12. The distributions are often bimodal and can vary markedly between time strata. In 2006–07 there is clear indication of growth of the 31 cm mode (at the start of the year) to 36 cm (by the end of the year). Some variation in year class strengths is indicated; strong juvenile modes are apparent in the early strata of both 2006–07 and 2008–09, but not in 2007–08. No *T. declivis* were recorded in any of the samples from late 2008–09.

Scaled age-frequencies for *Trachurus declivis,* by time stratum, are shown in Figure 13. There is a wide range of ages in the catch from the three years, and the distributions are quite variable between years. There is evidence of a strong year class progression of four-year-old fish in late 2006–07 to 5-year-old fish late in the following year, but they are not apparent in the early period of 2007–08. Year classes are presented rather than age class in Figure 14, because fish had a birthday between the early and late periods. The main feature in this age-class summary is the strong year class for 2003 evident in 2006–07 and 2007–08. However, in 2008–09 the 2003 year class is much less apparent and the 2005 year class is strongly represented at a similar level to the 2003 year class in 2007–08.

Mean weighted c.v.s (over all year classes) are 21%, 32%, and 53% for 2006–07, 2007–08, and 2008–09, respectively. Note that the 2008–09 distribution comprises samples from the early stratum only.

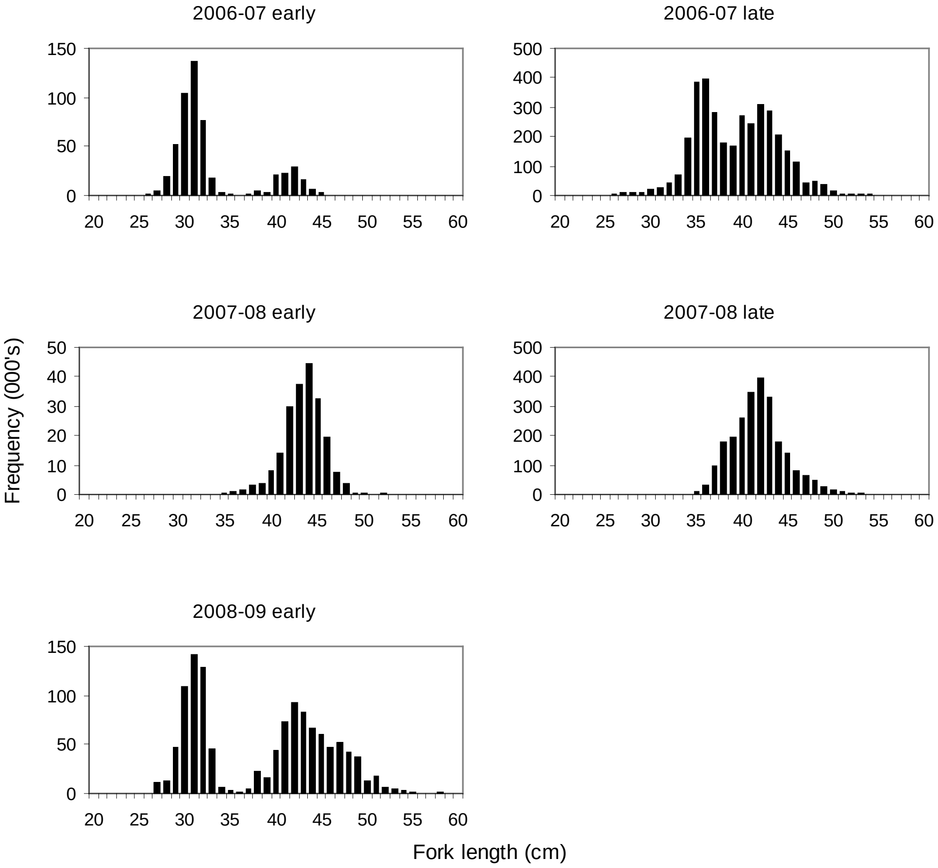

Figure 12: Scaled length-frequency distributions of *Trachurus declivis*, by time stratum. Note different scales on the *y*-axes.

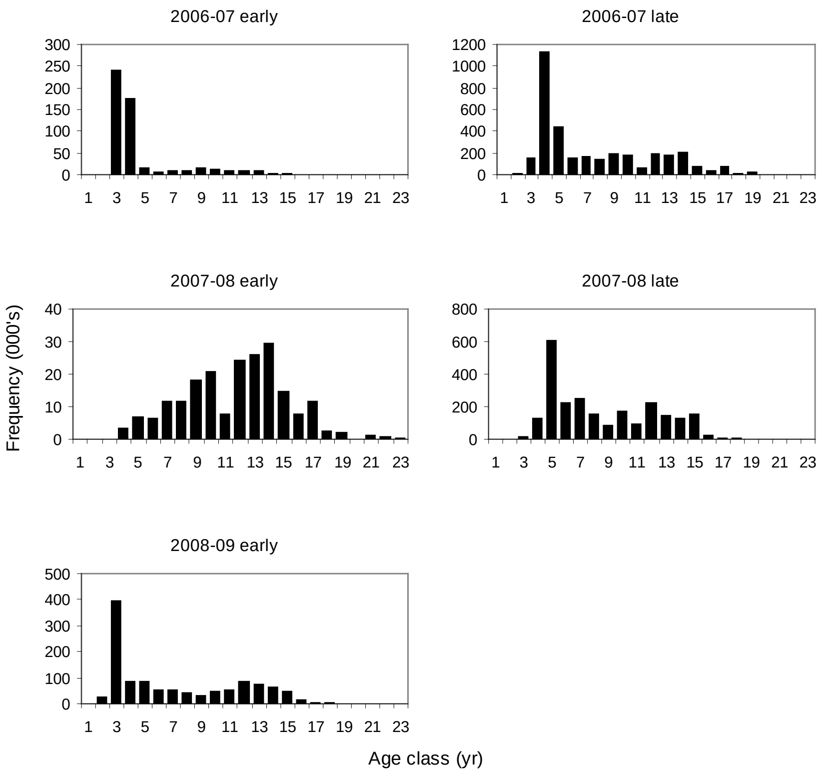

Figure 13: Scaled age-frequency distributions of *Trachurus declivis*, by time stratum. Note different scales on the *y*-axes.

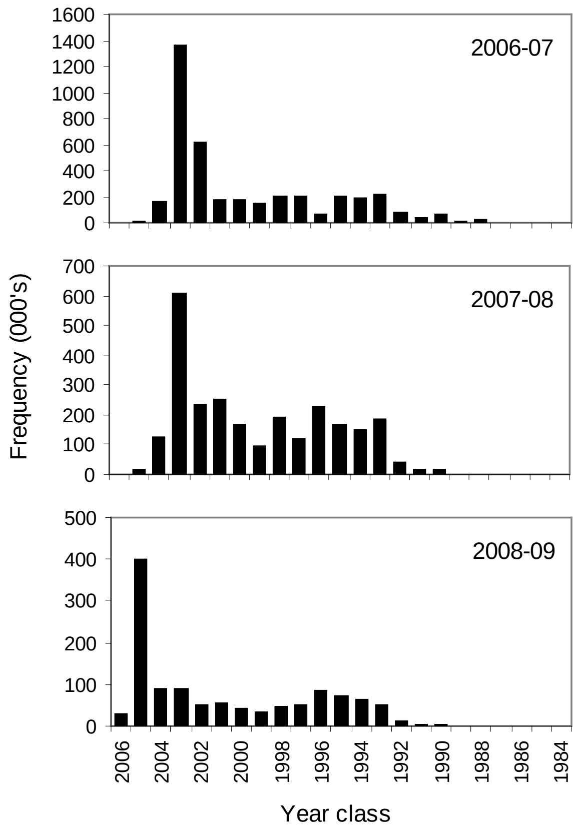

Figure 14: Scaled age-frequency distributions of *Trachurus declivis*, by fishing year. Note different scales on the *y*-axes.

3.6.3 *Trachurus murphyi*

Scaled length-frequencies for *Trachurus murphyi*, by time stratum, are shown in Figure 15. Samples were available from only three of the six time strata. All the distributions are unimodal, peaking at 47–49 cm. The distributions are all generally similar, with fish smaller than 40 cm being absent from the samples.

Scaled age-frequencies for *Trachurus murphyi*, by time stratum, are shown in Figure 16. There is a wide range of ages in the catch, but the distributions are all quite similar between years. Mean weighted c.v.s (over all year classes) are 23%, 26%, and 23% for 2006–07, 2007–08, and 2008–09, respectively.

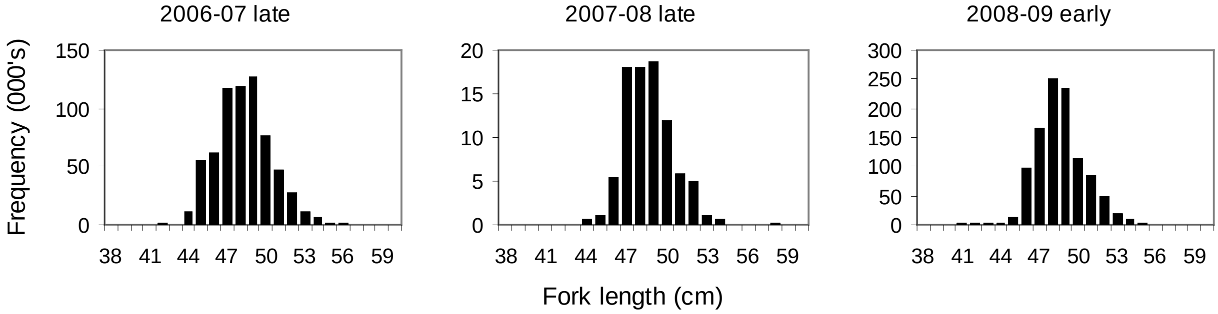

Figure 15: Scaled length-frequency distributions of *Trachurus murphyi*, by time stratum. Note different scales on the *y*-axes.

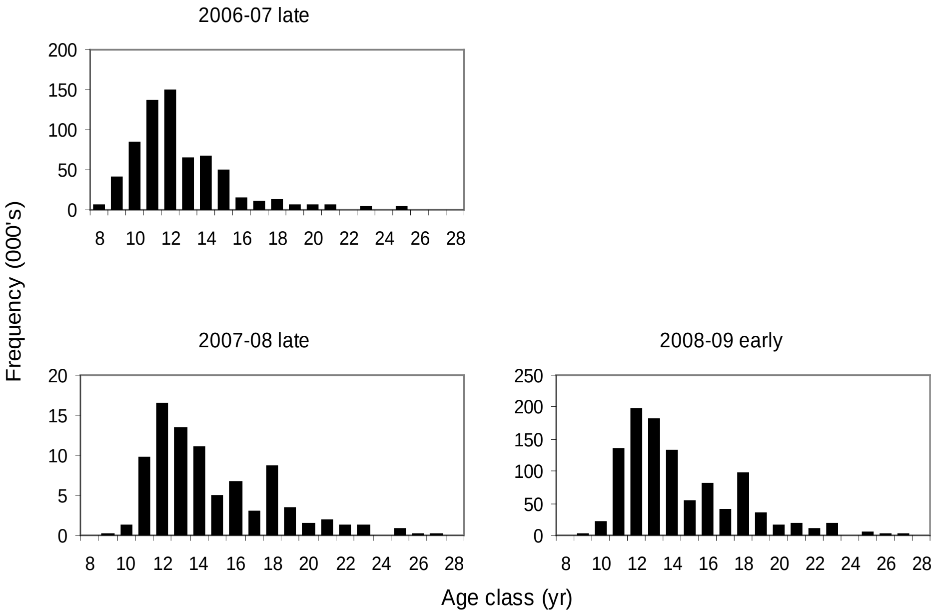

Figure 16: Scaled age-frequency distributions of *Trachurus murphyi*, by time stratum. Note different scales on the *y*-axes.

4. DISCUSSION

4.1 Sampling

Sampling appeared to be generally representative of the fishery, although there were some months when landings were high and sampling coverage was low or non-existent.

A number of factors determine the effectiveness of sampling. Care was taken to obtain good coverage through the main part of the season in each year when the number of landings was high, but this strategy can result in late catches not being adequately sampled, particularly if there is a pulse outside the expected timeframe as happens in this fishery from time to time.

Holding sampling effort in reserve is also necessary to ensure that sampling covers variations between fish sheds. For example, a company working with one vessel is under different constraints than a company with a fleet of four vessels, and differences in target selections may reflect different strategies for maximising return on fishing effort. As a result, fishing season for a particular species may vary between companies as they develop independent strategies that best suit their resources.

4.2 Target-choice variables

For the fisheries considered, the overall conclusion by Taylor (2008) was that the most influential target-choice variables were related to the preferential targeting of higher valued species, a combination of mixed-species schooling behaviour, and the inhibitory influence of bycatch when quota is limited in some way. Within the purse-seine fishery it was concluded that the preferred-species hierarchy, based on the persistent relativity in market values (in order from highest to least valued) is: skipjack tuna, blue mackerel, and jack mackerel. This hierarchy remains the most important consideration in dictating target choice.

The information summarised here adds to this conclusion in two ways. Firstly, the knowledge that the targeting of trevally within the QMA 1 purse-seine fishery is inhibited by the frequent presence of kahawai in mixed schools with trevally. This provides a parallel to the influence of kahawai on jack mackerel targeting in JMA 1 described by Taylor (2008).

Perhaps of more interest and greater influence is the second point, which concerns the global increase and stabilisation of jack mackerel prices. Through the increase in value and hence the importance of this species in the fishery, fishing companies are provided with a cost-effective alternative to targeting according to the traditional species hierarchy. Because this option includes an appreciable reduction in costs, returns from fishing blue and/or jack mackerel locally may rival returns from the skipjack tuna fishery, particularly when the somewhat distant west coast skipjack fishery is the only other choice.

4.3 Catch-at-length and catch-at-age

Overall, purse-seine landings in JMA 1 appear to comprise two distinct modes in the length frequency distributions of the three species — one representing smaller fish in the low 30s, as is exemplified by *T. novaezelandiae* and smaller *T. declivis*, and another in the mid to high 40s as is exemplified by larger *T. declivis* and *T. murphyi*. Traditional markets prefer small jack mackerel (Steve Keeves, Sanford Tauranga, pers. comm.) and the consequent small fish targeting is reflected in the greater emphasis on *T. novaezelandiae*. Fish larger than 35 cm may represent a second, less preferred option that is taken when small fish are unavailable, or it may be the result of size mixing within schools. What is missing is the fraction of large fish, mainly represented by *T. murphyi*, which has not been seen in the JMA 1 fishery for several years now.

The age frequency distributions for *T. novaezelandiae* are mostly uninformative, mainly because of the variation between late and early time strata that obscures any possible patterns. The annual age class distributions for *T. novaezelandiae* provide more information, suggesting a possible strong year class originating in 2003 that seems particularly clear in the distribution for 2008–09. There is also evidence in this summary of a systematic shift in the age structure, with an apparent decline in older year classes over time and an apparent increase in younger fish (i.e., year classes since 2000).

The strong mode of very young fish persistent in age frequency distributions of *T. declivis* is interesting, with the apparent progression of four year old fish from late stratum in 2006–07 to five year olds in the same stratum in 2007–08, although it is absent in the final year. This pattern is repeated in the annual summaries.

The age frequency distributions of *T. murphyi* are interesting from the perspective of the position of the mode and its relationship with the peak in abundance of *T. murphyi* in 1995. The mode is centred at 12 years in all distributions, suggesting that either fish have continued to enter the New Zealand zone after the 1995 peak or there has been some successful spawning within the zone. Whether the high numbers of 18 year old fish represents a second, older, declining mode is uncertain, but it is represented in all frequency distributions.

The reliability and precision of the age estimates vary by species for two main reasons. Firstly, there is an increasing difficulty in deriving annulus counts as one moves from *T. novaezelandiae* to *T. declivis* to *T. murphyi*, with otoliths from *T. murphyi* being considerably more difficult to read than otoliths from the other two species. And secondly, of the two New Zealand species, age is most precisely estimated for *T. novaezelandiae* because it is very abundant in the catch and has a relatively short length range, while *T. declivis* is not so precisely estimated because it is more sporadic in the catch and has a wider, more spaced length range. In general, the greater the length range, the greater the number of data points required for a precise estimate.

4.4 Species proportions and sex ratios

The predominance of *T. novaezelandiae* in the JMA 1 purse-seine catch throughout much of the time-series since 1993–94 is most likely a function of the preferred targeting of small fish to fill traditional markets. The fraction of small *T. declivis* is also part of this targeting by size, but the presence of larger fish, a fraction that comprises both *T. declivis* and *T. murphyi*, is the result of either alternative targeting of larger fish, or the mixing of a wider range of fish in some schools. It is difficult to test this using the data summarised here because data for individual schools are not available and these species seem to school by size. It is not clear what length range might be expected from a particular school.

A reduction in the amount of *T. murphyi* observed since the mid to late 1990s has been noted (authors' unpublished data).

Apart from several minor deviations, sex ratios show nothing unusual, and generally the proportions of females remain quite close to 50%.

4.5 Implications for stock assessments

Information summarised here does not offer strong support for producing a stock assessment for jack mackerel species. Catch-at-age sampling is unlikely to provide an effective monitoring tool for these species. Temporal inconsistencies in the length and age composition of the purse seine catch of *T. declivis* and *T. novaezelandiae* indicate that sampling of the population by the fishery is inconsistent, with size distribution of the fish targeted/caught possibly being influenced by the location of fishing and market forces. Thus selectivity appears to vary substantially between years.

4.6 Other issues

Information on species composition is essential to calculating the annual landings of each species. This information is required for international obligations and is necessary for monitoring catches of jack mackerel species over time. The size composition of the catch assists with understanding behavioural aspects of both fish and fishers, and given that sheds will be sampled for species composition, collecting length measurements should not be expensive.

5. ACKNOWLEDGMENTS

We thank members of the staff and management at Sanford Tauranga and Pelco NZ for their assistance in sampling the purse-seine landings; also Shane Grayling and Bruce Davison (previously NIWA technical staff), for coordinating and contributing to the sampling. We also thank Dan Fu for Figure 2 and for the catch history data, and members of the Northern Inshore Fisheries Assessment Working Group for comments and suggestions. Dave Rowe, NIWA, and Marc Griffiths, Ministry for Primary Industries, reviewed versions of this report. This work was funded by the Ministry of Fisheries under projects JMA2006-01 and PEL2009-02.

6. REFERENCES

Beamish, R.J.; Fournier, D.A. (1981). A method for comparing the precision of a set of age determinations. *Canadian Journal of Fisheries and Aquatic Sciences 38*: 982–983.

Bull, B.; Dunn, A. (2002). Catch-at-age: User manual v1.06.2002/09/12. NIWA Internal Report 114. 23 p. (Unpublished report held in NIWA library, Wellington.)

Campana, S.E.; Annand, M.C.; McMillan, J.I. (1995). Graphical and statistical methods for determining the consistency of age determinations. *Transactions of the American Fisheries Society 124*: 131–138.

Efron, B.; Tibshirani, B.J. (1993). An introduction to the bootstrap. Chapman and Hall, New York. 436 p.

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

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

Taylor, P.R. (1999). An examination of species proportion estimates, standardised stock indices, and the use of age-structured stock assessment models for jack mackerel, *Trachurus declivis* and *T. novaezelandiae*, in JMA 7. New Zealand Fisheries Assessment Research Document 99/54. 54 p. (Unpublished report held in NIWA library, Wellington.).

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

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

Taylor, P.R., Manning, M.J., Marriott, P.M. (2002). Age and growth estimation of Murphy's mackerel, *Trachurus symmetricus murphyi*. Final Research Report for Ministry of Fisheries Project JMA2000/02. 62 p. (Unpublished report available from Ministry for Primary Industries, Wellington.)

APPENDIX A: SAMPLED LANDINGS

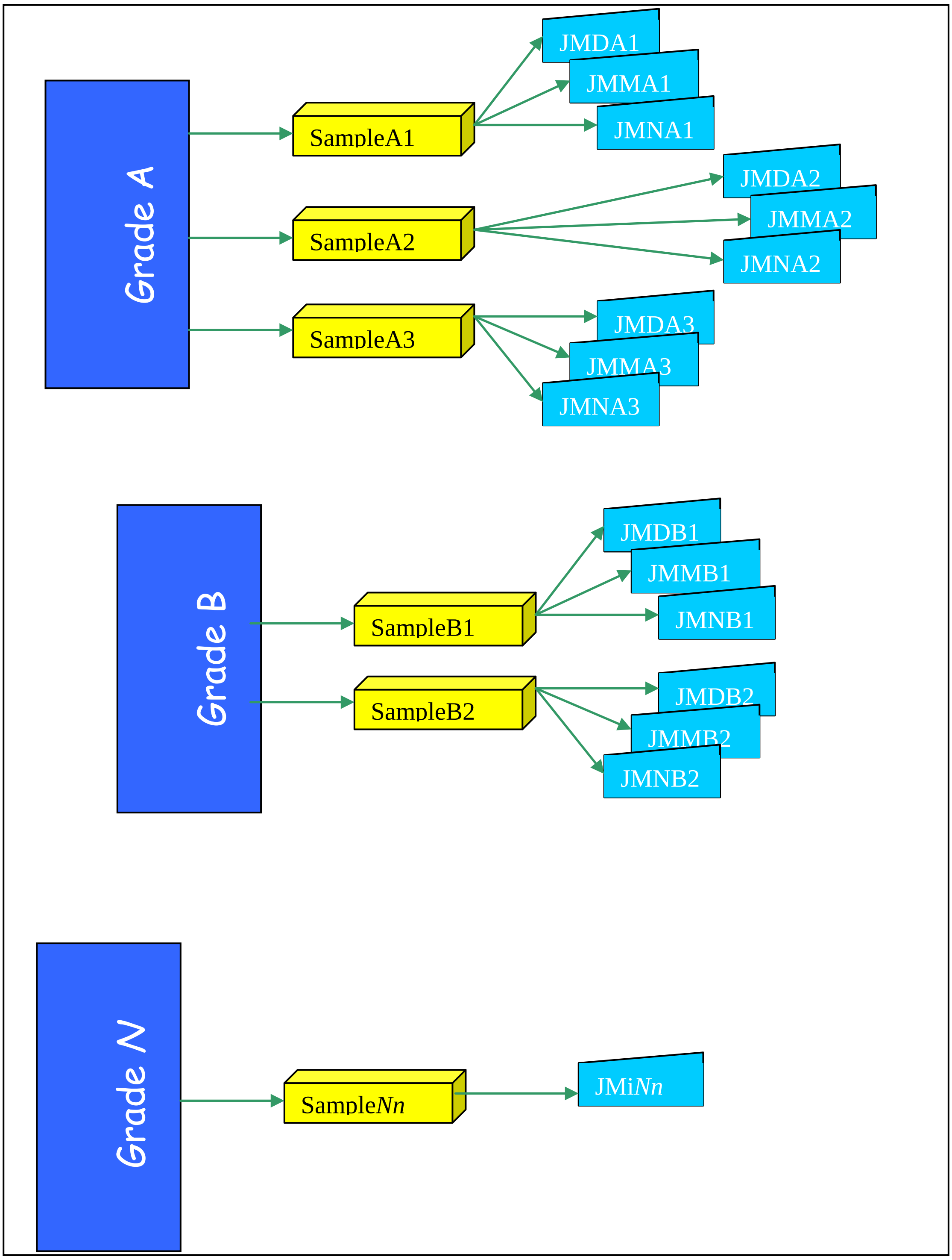

Figure A1: Schematic diagram of sampling hierarchy used to produce species-grade-samples (final-stage light blue trapezoids on right hand side) from grade-samples (yellow 3-d boxes), which in turn were randomly derived from each grade; note that grade-sample numbers are dependent on grade size and that the weight (kg) of any species-grade-sample will be zero if that species is not represented in the grade or landing. Labeling of the species-grade-samples comprises an initial three letters indicating the species, followed by an A or B denoting the grade the sample is from, and a final number denoting the relevant grade-sample; this protocol is summarised in the bottom row which shows the hierarchy resulting in the species-grade-sample for the *i*th jack mackerel species from the *n*th sample in the *N*th grade.

APPENDIX B: SUMMARY OF SAMPLES BY LANDING

Table B1: Number of samples taken by landing and grade.

			Grade									Total	
Year	Month	Landing	A	B	C	D	E	F	G	H	I	samples	Shed
2006	10	20066120	0	0	0	0	5	0	0	0	0	5	2
2006	10	20066808	0	0	0	0	1	0	0	0	0	1	2
2006	10	20066809	0	1	0	0	0	0	0	2	0	3	1
2006	10	20066810	0	0	4	0	0	0	0	0	0	4	1
2006	10	20066811	0	0	6	0	0	2	0	0	0	8	1
2006	10	20068922	0	0	5	0	0	0	0	0	0	6	1
2006	11	20068930	0	0	4	0	0	3	0	0	0	3	1
2006	11	20066814	0	0	4	0	0	2	0	0	0	5	1
2006	12	20066816	0	0	0	0	0	3	0	0	0	7	1
2007	9	20076201	0	0	0	0	0	0	0	0	7	7	1
2007	9	20076202	0	0	0	0	0	0	0	0	12	12	1
2007	9	20076203	0	2	0	0	0	0	0	3	5	10	1
2007	9	20076204	0	3	0	0	0	5	0	3	0	11	1
2007	9	20076205	0	5	3	0	0	0	0	2	0	10	1
2007	9	20076206	0	0	4	0	0	3	0	0	0	7	1
2007	9	20076207	0	2	0	5	0	0	0	3	0	10	1
2007	9	20076208	0	0	0	0	0	3	0	0	0	3	1
2007	10	20076210	0	0	4	0	0	5	0	0	0	9	1
2007	10	20076211	0	0	0	0	0	5	0	0	0	5	1
2007	11	20076212	0	0	6	0	0	8	0	2	0	16	1
2007	11	20076213	0	2	8	0	0	8	0	0	0	18	1
2007	11	20076214	17	0	0	0	0	0	0	0	0	17	2
2007	11	20076215	12	0	0	0	0	0	0	0	0	12	2
2007	11	20076216	0	0	10	0	0	12	0	0	0	22	1
2007	11	20076217	15	0	0	0	0	0	0	0	0	15	2
2007	11	20076218	0	0	4	0	0	8	0	2	0	14	1
2007	11	20076219	0	0	10	0	0	6	5	0	0	21	1
2007	11	20076220	15	0	0	0	0	0	0	0	0	15	2
2007	11	20076221	0	0	5	0	0	6	0	3	0	14	1
2007	11	20076222	0	0	10	0	0	6	0	1	0	17	1
2007	11	20076223	0	0	4	0	0	2	0	1	0	7	1
2007	12	20076224	0	0	10	0	0	3	4	0	0	17	1
2008	9	20086101	0	8	0	0	0	0	0	7	0	15	1
2008	9	20086102	0	0	3	0	0	6	0	0	12	21	1
2008	9	20086103	0	0	9	0	0	5	0	0	0	14	1
2008	9	20086104	0	6	0	0	0	0	0	0	0	6	1
2008	9	20086105	0	0	0	0	0	0	0	0	27	27	1
2008	9	20086106	0	8	0	0	0	0	0	7	0	15	1
2008	9	20086107	0	0	3	0	0	12	0	0	0	15	1
2008	9	20086108	0	0	9	0	0	6	0	0	0	15	1
2008	10	20086109	0	0	0	0	10	0	0	0	0	10	2
2008	10	20086110	0	0	11	0	0	6	0	0	0	17	1
2008	10	20086111	0	0	10	0	0	11	0	0	0	21	1
2008	10	20086112	0	0	19	0	0	5	0	0	0	24	1

Table B1 (continued)

Year	Month	Landing	A	B	C	D	E	F	G	H	Grade I	samples	Shed
2008	10	20086113	0	0	10	0	0	6	0	0	0	16	1
2008	10	20086114	0	0	10	0	0	5	0	0	0	15	1
2008	10	20086116	0	8	10	0	0	5	0	0	0	23	1
2008	10	20086117	0	5	0	0	0	0	0	0	0	5	1
2008	10	20086118	0	5	0	0	0	0	0	0	2	7	1
2008	10	20086119	0	3	0	0	0	0	0	4	0	7	1
2009	7	20096801	0	0	5	0	0	5	0	0	0	10	1
2009	7	20096802	0	0	9	0	0	5	0	0	0	14	1
2009	7	20096803	0	0	2	0	0	1	0	0	0	3	1
2009	7	20096804	0	0	0	0	0	0	0	0	4	4	1
2009	8	20096805	0	0	0	0	0	0	0	0	6	6	1
2009	8	20096806	0	0	0	0	0	0	0	0	6	6	1
2009	8	20096807	0	0	0	0	0	0	0	0	6	6	1
2009	9	20096808	0	0	0	0	0	0	0	0	2	2	1
2009	9	20096809	0	0	0	0	0	0	0	0	4	4	1
2009	9	20096810	0	0	0	0	0	0	0	0	2	2	1
2009	9	20096811	0	0	0	0	0	0	0	0	4	4	1
2009	9	20096812	0	0	0	0	0	0	0	0	2	2	1
2009	9	20096813	0	0	0	0	0	0	0	0	4	4	1
2009	9	20096814	0	0	0	0	0	0	0	0	8	8	2
2009	9	20096815	0	0	0	0	0	0	0	0	6	6	1
2009	10	20096816	0	0	0	0	0	0	0	0	4	4	1
2009	10	20096817	0	0	0	0	0	0	0	0	4	4	2
2009	10	20096818	0	0	0	0	0	0	0	0	4	4	1
2009	10	20096819	0	0	0	0	0	0	0	0	4	4	1
2009	10	20096820	0	0	0	0	0	0	0	0	6	6	1
2009	10	20096821	0	0	0	0	0	0	0	0	6	6	2
2009	10	20096822	0	0	0	0	0	0	0	0	6	6	2
2009	10	20096823	0	0	0	0	0	0	0	0	6	6	1
2009	10	20096824	0	0	0	0	0	0	0	0	6	6	1
2009	10	20096825	0	0	0	0	0	0	0	0	6	6	1

APPENDIX C: LONG TERM SUMMARIES OF SPECIES PROPORTIONS IN JMA 1

Table C1: Species proportions in JMA1, by year and month; original values were estimated from sample data collected for that month; imputed values (highlighted) are the estimates by fishing year up until March 2006 and early or late period estimates thereafter; JMD is *T. declivis*, JMM is *T. murphyi*, and JMN is *T. novaezelandiae*.

		Original			Imputed		
Year	Month	JMD	JMM	JMN	JMD	JMM	JMN
1994	O	0.71	0.29	0	0.71	0.29	0
1994	N	0.12	0.88	0	0.12	0.88	0
1994	D	0.15	0.73	0.12	0.15	0.73	0.12
1995	J	0.2	0.54	0.26	0.2	0.54	0.26
1995	F	0.07	0.36	0.56	0.07	0.36	0.56
1995	M	0.01	0	0.99	0.01	0	0.99
1995	A	0	0	1	0	0	1
1995	M	0	0	1	0	0	1
1995	J	0	0	1	0	0	1
1995	J	0	0	1	0	0	1
1995	A	0.24	0.73	0.02	0.24	0.73	0.02
1995	S	0.06	0.28	0.66	0.06	0.28	0.66
1995	O	0.17	0.45	0.38	0.17	0.45	0.38
1995	N	0.15	0.2	0.66	0.15	0.2	0.66
1995	D	0.02	0.01	0.96	0.02	0.01	0.96
1996	J	0	0	1	0	0	1
1996	F	0	0	1	0	0	1
1996	M	0	0.02	0.98	0	0.02	0.98
1996	A	0.13	0	0.86	0.13	0	0.86
1996	M	0.26	0.74	0	0.26	0.74	0
1996	J	0	0.18	0.82	0	0.18	0.82
1996	J	0	0.12	0.88	0	0.12	0.88
1996	A	0	0	1	0	0	1
1996	S	0	0.01	0.99	0	0.01	0.99
1996	O	0.03	0.52	0.45	0.03	0.52	0.45
1996	N	0.18	0.38	0.44	0.18	0.38	0.44
1996	D	0.02	0.21	0.77	0.02	0.21	0.77
1997	J	0.08	0	0.92	0.08	0	0.92
1997	F	0	0	0	0.05	0.30	0.65
1997	M	0	0	0	0.05	0.30	0.65
1997	A	0	0	1	0	0	1
1997	M	0	0	1	0	0	1
1997	J	0	0	1	0	0	1
1997	J	0.01	0.22	0.77	0.01	0.22	0.77
1997	A	0.01	0.34	0.65	0.01	0.34	0.65
1997	S	0.18	0.27	0.55	0.18	0.27	0.55
1997	O	0.05	0.55	0.4	0.05	0.55	0.4
1997	N	0.26	0.07	0.67	0.26	0.07	0.67
1997	D	0.02	0.87	0.11	0.02	0.87	0.11
1998	J	0	0	0	0.05	0.42	0.53
1998	F	0	0	0	0.05	0.42	0.53

Table C1: continued

Year	Month	JMD	JMM	JMN	JMD	JMM	JMN
1998	M	0	0	0	0.05	0.42	0.53
1998	A	0	0	1	0	0	1
1998	M	0.11	0.89	0	0.11	0.89	0
1998	J	0	0	1	0	0	1
1998	J	0	0	1	0	0	1
1998	A	0.08	0.8	0.12	0.08	0.8	0.12
1998	S	0.04	0.16	0.8	0.04	0.16	0.8
1998	O	0.15	0.47	0.38	0.15	0.47	0.38
1998	N	0.21	0.55	0.24	0.21	0.55	0.24
1998	D	0	0.04	0.96	0	0.04	0.96
1999	J	0	0	0	0.14	0.30	0.56
1999	F	0	0	0	0.14	0.30	0.56
1999	M	0	0	0	0.14	0.30	0.56
1999	A	0.69	0.31	0	0.69	0.31	0
1999	M	0	0	0	0.14	0.30	0.56
1999	J	0.19	0.33	0.48	0.19	0.33	0.48
1999	J	0.02	0	0.98	0.02	0	0.98
1999	A	0.03	0.02	0.95	0.03	0.02	0.95
1999	S	0	0	1	0	0	1
1999	O	0.36	0.49	0.15	0.36	0.49	0.15
1999	N	0.11	0.01	0.87	0.11	0.01	0.87
1999	D	0.08	0	0.92	0.08	0	0.92
2000	J	0	0	0	0.01	0.01	0.98
2000	F	0	0	1	0	0	1
2000	M	0	1	0	0	1	0
2000	A	0	0	0	0.01	0.01	0.98
2000	M	0	0	0	0.01	0.01	0.98
2000	J	0	0	1	0	0	1
2000	J	0	0	0	0.01	0.01	0.98
2000	A	0	0	1	0	0	1
2000	S	0	0	1	0	0	1
2000	O	0	0	1	0	0	1
2000	N	0.14	0.12	0.74	0.14	0.12	0.74
2000	D	0.19	0	0.81	0.19	0	0.81
2001	J	0	0	1	0	0	1
2001	F	0	0	1	0	0	1
2001	M	0	0	1	0	0	1
2001	A	0	0	0	0.02	0.01	0.97
2001	M	0	0	0	0.02	0.01	0.97
2001	J	0	0	1	0	0	1
2001	J	0	0	1	0	0	1
2001	A	0	0	1	0	0	1
2001	S	0.03	0.02	0.95	0.03	0.02	0.95
2001	O	0.56	0.07	0.37	0.56	0.07	0.37
2001	N	0.29	0	0.71	0.29	0	0.71
2001	D	0	0	1	0	0	1
2002	J	0	0	1	0	0	1
2002	J	0	0	1	0	0	1
2002	M	1	0	0	1	0	0
2002	A	0.93	0	0.07	0.93	0	0.07

Table C1: continued

Year	Month	JMD	JMM	JMN	JMD	JMM	JMN
2002	M	0.59	0.02	0.39	0.59	0.02	0.39
2002	J	0	0	1	0	0	1
2002	J	0	0	1	0	0	1
2002	A	0	0	1	0	0	1
2002	S	0	0	0.99	0	0	0.99
2002	O	0.87	0.01	0.12	0.87	0.01	0.12
2002	N	0.61	0.06	0.33	0.61	0.06	0.33
2002	D	0.52	0.03	0.44	0.52	0.03	0.44
2003	J	0	0	0	0.30	0.02	0.68
2003	F	0.05	0	0.95	0.05	0	0.95
2003	M	0	0	1	0	0	1
2003	A	0.9	0	0.1	0.9	0	0.1
2003	M	0.75	0.18	0.07	0.75	0.18	0.07
2003	J	0	0	1	0	0	1
2003	J	0	0	1	0	0	1
2003	A	0	0	1	0	0	1
2003	S	0	0	1	0	0	1
2003	O	0.13	0	0.87	0.13	0	0.87
2003	N	0.84	0.05	0.12	0.84	0.05	0.12
2003	D	0.4	0.08	0.52	0.4	0.08	0.52
2004	J	0	0	1	0	0	1
2004	F	0	0	1	0	0	1
2004	M	0	0	1	0	0	1
2004	A	0	0	1	0	0	1
2004	M	0.05	0	0.95	0.05	0	0.95
2004	J	0	0	1	0	0	1
2004	J	0	0	1	0	0	1
2004	A	0.98	0.02	0	0.98	0.02	0
2004	S	0.77	0.18	0.05	0.77	0.18	0.05
2004	O	0.38	0.21	0.41	0.38	0.21	0.41
2004	N	0.37	0.24	0.39	0.37	0.24	0.39
2004	D	0.38	0	0.62	0.38	0	0.62
2005	J	0.01	0	0.99	0.01	0	0.99
2005	F	0	0	0	0.11	0.07	0.82
2005	M	0	0	1	0	0	1
2005	A	0	0	1	0	0	1
2005	M	0	0	1	0	0	1
2005	J	0	0	1	0	0	1
2005	J	0	0	0	0.11	0.07	0.82
2005	A	0	0	1	0	0	1
2005	S	0	0	1	0	0	1
2005	O	0	0	1	0	0	1
2005	N	0.02	0	0.98	0.02	0	0.98
2005	D	0	0	1	0	0	1
2006	J	0	0	0	0.01	0.00	0.99
2006	F	0	0	0	0.01	0.00	0.99
2006	M	0	0	0	0.01	0.00	0.99
2006	A	0	0	0	0.30	0.00	0.70
2006	M	0	0	0	0.30	0.00	0.70
2006	J	0	0	0	0.30	0.00	0.70

Table C1: continued

Year	Month	JMD	JMM	JMN	JMD	JMM	JMN
2006	J	0.99	0.01	0	0.99	0.01	0
2006	A	0	0	1	0	0	1
2006	S	0	0.01	0.99	0	0.01	0.99
2006	O	0.23	0	0.77	0.23	0	0.77
2006	N	0.81	0	0.19	0.81	0	0.19
2006	D	0	0	1.00	0	0	1.00
2007	J	0	0	0	0.30	0.00	0.70
2007	F	0	0	0	0.30	0.00	0.70
2007	M	0	0	0	0.30	0.00	0.70
2007	A	0	0	0	0.21	0.07	0.72
2007	M	0	0	0	0.21	0.07	0.72
2007	J	0	0	0	0.21	0.07	0.72
2007	J	0	0	0	0.21	0.07	0.72
2007	A	0	0	0	0.21	0.07	0.72
2007	S	0.636	0.23	0.137	0.636	0.23	0.137
2007	O	0	0	1	0	0	1
2007	N	0.02	0	0.98	0.02	0	0.98
2007	D	0	0	1	0	0	1
2008	J	0	0	0	0.21	0.07	0.72
2008	F	0	0	0	0.21	0.07	0.72
2008	M	0	0	0	0.21	0.07	0.72
2008	A	0	0	0	0.35	0.16	0.49
2008	M	0	0	0	0.35	0.16	0.49
2008	J	0	0	0	0.35	0.16	0.49
2008	J	0	0	0	0.35	0.16	0.49
2008	A	0	0	0	0.35	0.16	0.49
2008	S	0.60	0.03	0.38	0.60	0.03	0.38
2008	O	0.18	0.25	0.57	0.18	0.25	0.57
2008	N	0	0	0	0.35	0.16	0.49
2008	D	0	0	0	0.35	0.16	0.49
2009	J	0	0	0	0.35	0.16	0.49
2009	F	0	0	0	0.35	0.16	0.49
2009	M	0	0	0	0.35	0.16	0.49
2009	A	0	0	0	0	0	1
2009	M	0	0	0	0	0	1
2009	J	0	0	0	0	0	1
2009	J	0	0	1.00	0	0	1.00
2009	A	0	0	1.00	0	0	1.00
2009	S	0	0	1.00	0	0	1.00

Table C2: Species proportions in the JMA 1 purse-seine fishery, by fishing year; JMD is *T. declivis*, JMM is *T. murphyi*, and JMN is *T. novaezelandiae*; bootstrapped mean weighted c.v.s are in parentheses.

Fishing year	JMD	JMM	JMN
1993–94	0.67	0.30	0.03
1994–95	0.13	0.45	0.42
1995–96	0.03	0.13	0.84
1996–97	0.05	0.30	0.65
1997–98	0.05	0.42	0.53
1998–99	0.14	0.30	0.56
1999–00	0.01	0.01	0.98
2000–01	0.02	0.01	0.97
2001–02	0.17	0.01	0.82
2002–03	0.30	0.02	0.68
2003–04	0.46	0.11	0.43
2004–05	0.11	0.07	0.82
2005–06	0.01	0.00	0.99
2006–07	0.58 (0.12)	0.19 (0.29)	0.23 (0.39)
2007–08	0.22 (0.39)	0.01 (0.49)	0.77 (0.12)
2008–09	0.10 (0.39)	0.13 (0.45)	0.77 (0.12)

APPENDIX D: SUMMARIES OF THE SAMPLED LANDINGS

Table D1: Details of sampled jack mackerel purse seine landings from JMA 1 in 2005–06, 2006–07, 2007–08, and 2008–09. Trip, *warehou* trip identifier; sample no., sample identifier in the *market* database; start date, start date of trip; target, target species; weight, greenweight (t) of sampled JMA catch. For trips with multiple target species or fishing events in more than one statistical area, the target species and statistical area producing the most jack mackerel catch are listed.

Stratum	Trip	Sample no	Start date	Landing date	Target	Statarea	Weight
2005−06 late	3941562	20066101	2006-07-18	2006-07-19	JMA	9	69.5
2005−06 late	3450213	20066102	2006-07-18	2006-07-20	JMA	9	145.2
2005−06 late	4245394	20066103	2006-07-24	2006-07-31	JMA	9	162.6
2005−06 late	3450214	20066104	2006-08-02	2006-08-16	JMA	9	34.9
2005−06 late	3564718	20066106	2006-08-15	2006-08-22	JMA	9	160.5
2005–06 late	4463290	20066108	2006-08-24	2006-08-28	JMA	9	138.9
2005–06 late	3564719	20066120	2006-08-24	2006-08-30	JMA	9	55.4
2005–06 late	4027153	20066110	2006-09-01	2006-09-04	JMA	8	67.1
2005–06 late	3450316	20066116	2006-08-31	2006-09-08	JMA	8	139.7
2005–06 late	4245395	20066114	2006-09-02	2006-09-08	JMA	8	83.2
2005–06 late	3450415	20066118	2006-09-11	2006-09-17	EMA	2	60.5
2005–06 late	4463291	20066119	2006-09-11	2006-09-18	EMA	2	40.7
2005–06 late	3450217	20068921	2006-09-21	2006-09-27	EMA	3	24.2
2005–06 late	3564722	20066801	2006-09-24	2006-09-30	JMA	9	66.8
2006–07 early	3450319	20066809	2006-10-18	2006-10-21	EMA	3	20.6
2006–07 early	3564625	20066808	2006-10-17	2006-10-24	KAH	9	36.4
2006–07 early	4554818	20066810	2006-10-19	2006-10-26	EMA	3	3.5
2006–07 early	3450418	20066811	2006-10-24	2006-10-31	EMA	3	19.3
2006–07 early	274365	20068930	2006-11-01	2006-11-06	EMA	3	11.7
2006–07 early	4245399	20066814	2006-11-02	2006-11-08	EMA	3	16.5
2006–07 early	3450320	20066121	2006-11-27	2006-11-30	JMA	9	147.2
2006–07 early	4554820	20066816	2006-12-03	2006-12-14	KAH	14	28.7
2006–07 early	3450321	20066122	2006-12-11	2006-12-19	JMA	9	145.7
2006–07 late	4255442	20076201	2007-09-03	2007-09-07	JMA	2	66.6
2006–07 late	4455902	20076202	2007-09-04	2007-09-10	JMA	2	164.6
2006–07 late	4718476	20076203	2007-09-03	2007-09-13	JMA	2	97.9
2006–07 late	4830051	20076204	2007-09-10	2007-09-14	JMA	2	169.1
2006–07 late	4710223	20076205	2007-09-11	2007-09-18	JMA	2	290.4
2006–07 late	4554837	20076206	2007-09-13	2007-09-20	JMA	14	24.2
2006–07 late	4718478	20076208	2007-09-26	2007-09-27	JMA	8	30.1
2006–07 late	4014816	20076207	2007-09-25	2007-09-30	JMA	2	131.5
2007–08 early	4830053	20076209	2007-10-10	2007-10-15	JMA	3	146.5
2007–08 early	4463303	20076210	2007-10-12	2007-10-18	JMA	2	117.3
2007–08 early	4718480	20076211	2007-10-21	2007-10-26	JMA	9	92.6
2007–08 early	4463304	20076212	2007-11-03	2007-11-06	JMA	9	140.5
2007–08 early	4710225	20076213	2007-11-01	2007-11-08	JMA	9	452.7
2007–08 early	4953853	20076214	2007-11-06	2007-11-09	JMA	9	139.0
2007–08 early	4954953	20076215	2007-11-09	2007-11-11	JMA	9	188.5
2007–08 early	4255445	20076216	2007-11-01	2007-11-12	JMA	9	156.5
2007–08 early	4953854	20076217	2007-11-10	2007-11-14	JMA	9	183.9
2007–08 early	4455904	20076218	2007-11-07	2007-11-15	JMA	9	249.4
2007–08 early	4244780	20076219	2007-11-11	2007-11-19	JMA	9	271.9
2007–08 early	4830055	20076221	2007-11-15	2007-11-20	JMA	8	172.8
2007–08 early	4954955	20076220	2007-11-16	2007-11-22	JMA	9	133.3
2007–08 early	4710226	20076222	2007-11-20	2007-11-27	JMA	8	88.2
2007–08 early	4014818	20076223	2007-11-22	2007-11-29	JMA	8	39.8

2007–08 early	3450225	20076224	2007-11-24	2007-12-03	JMA	8	87.8
2007–08 late	5076922	20086101	2008-08-27	2008-09-01	JMA	2	255.4
2007–08 late	4680707	20086102	2008-08-29	2008-09-08	JMA	2	116.3
2007–08 late	3450238	20086103	2008-09-05	2008-09-09	JMA	9	126.1
2007–08 late	3450333	20086105	2008-09-12	2008-09-16	JMA	3	303.1
2007–08 late	4718492	20086106	2008-09-13	2008-09-18	JMA	2	161.8
2007–08 late	4244794	20086107	2008-09-25	2008-09-29	JMA	9	262.5
2007–08 late	3982821	20086108	2008-09-29	2008-09-30	JMA	8	50.3
2008–09 early	5256914	20086110	2008-10-02	2008-10-06	JMA	9	60.4
2008–09 early	4825145	20086109	2008-10-06	2008-10-07	JMA	9	181.0
2008–09 early	5256614	20086111	2008-10-01	2008-10-07	JMA	9	124.8
2008–09 early	5256664	20086112	2008-10-09	2008-10-13	JMA	9	274.8
2008–09 early	5256714	20086113	2008-10-09	2008-10-15	JMA	9	167.9
2008–09 early	5256616	20086114	2008-10-14	2008-10-17	JMA	9	52.3
2008–09 early	5256765	20086115	2008-10-18	2008-10-20	JMA	3	145.0
2008–09 early	5256665	20086116	2008-10-18	2008-10-21	JMA	3	274.9
2008–09 early	5256865	20086117	2008-10-18	2008-10-23	JMA	3	184.8
2008–09 early	5256915	20086118	2008-10-15	2008-10-25	JMA	3	145.3
2008–09 early	5256766	20086119	2008-10-22	2008-10-28	JMA	3	167.8
2008–09 late	5257050	20096801	2009-07-14	2009-07-22	JMA	9	87.5
2008–09 late	5256872	20096802	2009-07-21	2009-07-23	JMA	9	25.6
2008–09 late	5256774	20096803	2009-07-16	2009-07-29	JMA	9	85.2
2008–09 late	5256824	20096804	2009-07-26	2009-07-30	JMA	9	37.4
2008–09 late	5256723	20096805	2009-08-03	2009-08-06	JMA	9	94.8
2008–09 late	5257051	20096806	2009-08-04	2009-08-07	JMA	9	114.3
2008–09 late	5257052	20096807	2009-08-28	2009-08-31	JMA	8	110.5
2008–09 late	5256825	20096809	2009-09-06	2009-09-11	JMA	9	60.6
2008–09 late	5256931	20096808	2009-09-06	2009-09-12	JMA	8	24.9
2008–09 late	5256635	20096810	2009-09-15	2009-09-19	JMA	9	152.5
2008–09 late	5256875	20096811	2009-09-15	2009-09-19	EMA	8	48.4
2008–09 late	5256725	20096812	2009-09-17	2009-09-23	JMA	9	27.8
2008–09 late	5256676	20096813	2009-09-22	2009-09-25	JMA	9	146.2
2008–09 late	4825169	20096814	2009-09-29	2009-09-30	JMA	9	133.4
2008–09 late	5257056	20096815	2009-09-27	2009-09-30	JMA	9	85.8