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EXECUTIVE SUMMARY

Devine, J.A.; Manning, M.J.; Taylor, P.R. (2009). The length and age composition of the commercial catch of blue mackerel (*Scomber australasicus*) in EMA 1 & 7 during the 2005–06 fishing year.

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Commercial purse-seine catches of blue mackerel in EMA 1 and EMA 7 and midwater trawl bycatch in EMA 7 were sampled during the 2005–06 fishing year by personnel from NIWA, associated fishing companies, and the Ministry of Fisheries (MFish) Observer Programme as part of the MFish funded research project EMA2004–01 "Stock monitoring of blue mackerel".

The target purse-seine fishery (PS-EMA) in EMA 1 is estimated to have accounted for about 99% of the total catch in EMA 1 during the 2005–06 fishing year. The PS-EMA fishery in EMA 7 is estimated to have accounted for about 7% of the total catch in that fishstock and the midwater jack mackerel (MW-JMA) fishery for about 93% of the total.

Thirty-three landings were sampled in fish processing factories and one fishing trip was sampled at sea by MFish observers, 12 358 fish length observations were collected, and 403 sagittal otolith pairs collected, prepared, and read from the in PS-EMA fishery EMA 1 during the 2005–06 fishing year. In EMA 7, one landing was sampled from the PS-EMA fishery on shore and 7 fishing trips were sampled at sea by MFish observers on trawl vessels. A total of 3706 fish length observations were collected and a total of 500 sagittal otolith pairs were collected, prepared, and read in EMA 7. The data collected from the PS-EMA fishery in EMA 1 and MW-JMA fishery in EMA 7 are thought to be representative of the fisheries, while the data collected from the PS-EMA fishery in EMA 7 are not. Although considered representative, the coverage of the fishery in EMA 7 was poor in comparison with EMA 1.

Estimated numbers-at-length and numbers-at-age were calculated using all available groomed length and length-at-age data separately by sex and scaled to estimates of the total catch from each of the fisheries. The PS-EMA fishery in EMA 1 and EMA 7 and trawl fishery in EMA 7 were analysed separately. Bootstrapped coefficients of variation (c.v.s) and mean-weighted c.v.s were computed for each length and age class and overall for each length- and age-frequency distribution in each analysis. More smaller and younger fish have appeared in each fishery relative to 2004–05. Peaks in the length-frequency curves are similar to analyses from previous years, but the scaled proportions-at-age show younger fish are being captured in all fisheries in both EMA 1 and EMA 7. Age frequencies in EMA 7 are bimodal and it is unknown whether this is due to a change in the population, a change in fishing behaviour, or to sampling inadequacies.

The PS-EMA fishery in EMA 1 appears to be composed of fish between 2 and 20 years, although most fish present in the catch are between 2 and 15 years of age. The purse-seine and trawl fisheries in EMA 7 appear to catch fish between 2 and 22 years of age. There are two modes in age classes caught by both fisheries in EMA 7; one of fish aged 2–13 and the other of fish aged 15–22. The MW c.v.s for both sexes and all fish in the EMA 1 and 7 length analyses were within the 30% target. However, the MW c.v.s for both sexes in both EMA 1 and 7 were above the target 30% for the age analyses, and just within the target c.v.s. for all fish. This may be due to the number of otoliths collected rather than the amount of length-frequency data collected for the fisheries. Suggestions include increasing the number of allocated observed trips and coverage in EMA 7, maintaining the current sampling coverage for the PS-EMA 1, increasing the number of blue mackerel otoliths collected and aged, and using readers that have experience with blue mackerel otoliths for ageing (or ensuring training for those that are inexperienced with this species).

1. INTRODUCTION

Blue mackerel (*Scomber australasicus*) is a small- to medium-sized schooling teleost inhabiting epi- and mesopelagic waters throughout the Indo-Pacific, including the northern half of the New Zealand Exclusive Economic Zone (EEZ). It was introduced into the New Zealand Quota Management System (QMS) at the start of the 2002–03 fishing year and is managed as five separate Quota Management Areas (QMAs) or fishstocks: EMA 1–3, 7, and 10 (Figure 1).

The commercial catch is caught by a variety of methods in all QMAs, but most is caught north of latitude 43 °S (Morrison et al. 2001). The largest and most consistent catches across fishing years are by purse-seine vessels targeting blue mackerel schools in EMA 1–3 & 7. Catches by midwater trawl vessels targeting jack mackerels (*Trachurus* spp.) in EMA 7 are also important. Nevertheless, the target purse-seine catch in EMA 1 is the single largest component of the catch by any method in any QMA (Morrison et al. 2001). Total catches by QMA and fishing year are given in Table 1.

The commercial catch in the New Zealand EEZ varies greatly over time, both within and between fishing years. Catches are highly seasonal, with the target purse-seine fishery in EMA 1 operating between July and December (Morrison et al. 2001). Catches also vary greatly between fishing years. Total annual reported landings increased rapidly from the 1989–90 to the 1992–93 fishing year and have fluctuated between about 6000–15 000 t in every subsequent fishing year. Reported landings peaked at 15 128 t during 1991–92, of which about 70% was caught by purse-seine vessels (Morrison et al. 2001). Inter-annual variation in catches is thought to reflect variable market demand rather than changes in stock abundance (Morrison et al. 2001).

This report presents length and age data collected during commercial catch sampling of blue mackerel in EMA 1 and 7 during the 2005–06 fishing year, funded by the Ministry of Fisheries (MFish) research project EMA 2004–01. The project was a joint contract between NIWA and Sanford Ltd. The aim of the sampling programme was to representatively sample the target purse-seine (PS) catch in EMA 1 and the target purse-seine catch and catches by midwater trawl vessels targeting jack mackerels in EMA 7. The target mean-weighted coefficient of variation (c.v.) for the catch-at-age in both fishstocks was 30%. The 2005–06 sampling results are compared with earlier results from the 1997–98 (Morrison et al. 2001), 2002–03 (Manning et al. 2006), 2003–04 (Manning et al. 2007a), and 2004–05 (Manning et al. 2007b) fishing years. A brief review of the EMA 1 and 7 fisheries during the 2005–06 fishing year is provided. The representivity of the data collected to the catch sectors sampled is reviewed. The required level of sampling to achieve the mean-weighted c.v. target in future fishing years is also discussed. This report fulfils the reporting requirements of specific objective 3 of project EMA2004–01.

2. METHODS

2.1 Catch-effort and landings data

All fishing trips and associated fishing and landing events records where a landing of blue mackerel in EMA 1 or 7 was recorded between 1 October 1989 and 30 September 2006 (the 1989–90 to 2005–06 fishing years) were extracted from the Ministry of Fisheries catch-effort and landings database, *warehou* (Duckworth 2002).

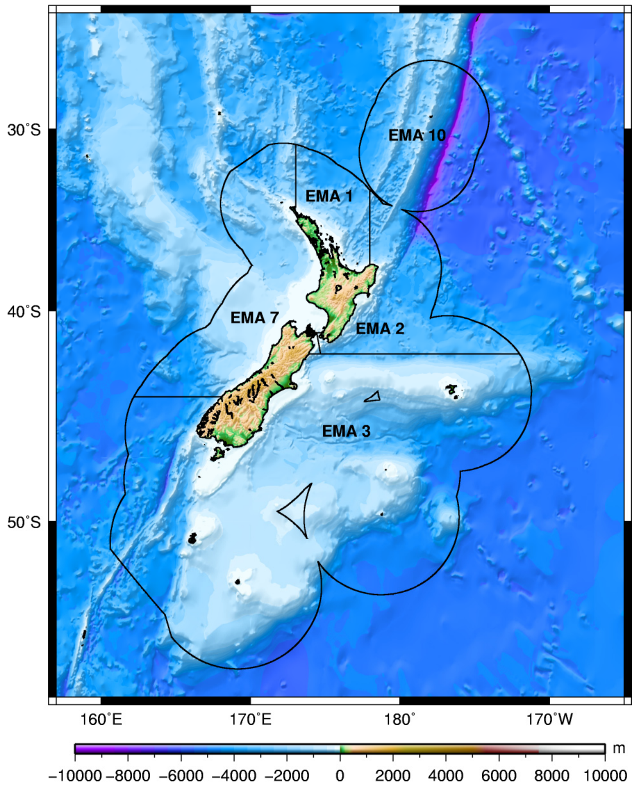

Figure 1: Map of the New Zealand EEZ showing the boundaries of blue mackerel QMAs during the 2005–06 fishing year and the bathymetry of the New Zealand region.

2.2 Overview of the sampling programme design

2.2.1 EMA 1

Landings by purse-seine vessels targeting blue mackerel in EMA 1 during the 2005–06 fishing year were sampled in fish processing factories in Tauranga using a stratified sampling scheme. Landings were sampled systematically from vessel fishholds (e.g., first compartment starboard side, midship compartment, etc.) during the unloading process, similar to the 2004–05 fishing year (Manning et al. 2007b). Samples were collected from the vessel-hold strata in each landing using the following method: about 100 fish were randomly sampled from each hold at a rate of up to two samples per hold per day, one per morning and one per afternoon, until the catch was fully unloaded from each vessel. Fish sex, length to the nearest centimetre below actual fork length, and a five-point macroscopic gonad maturity score were recorded for each sampled fish (the "Stock Monitoring" (SM) scale described by Mackay (2001)). As in the 2002–03, 2003–04, and 2004–05 fishing years, sampling was carried out at the Sanford Ltd factory by Sanford Ltd staff; sampling at a fish processing factory owned by another Licensed Fish Receiver (PelCo NZ Ltd) was carried out by NIWA staff. There was no formal spatial or temporal allocation of sampling effort (e.g., monthly targets based on average trends in the catch over a number of fishing years).

A stratified, fixed-allocation sampling scheme (sensu Davies et al. 2003) was used to collect sagittal otolith pairs from the catches in all sampled landings. Up to 20 otolith pairs per sex per centimetre length-class were collected non-randomly from the fish in the random length-frequency samples. Fish were measured to the nearest centimetre below fork length and fish sex and macroscopic gonad maturity were recorded for all sampled fish from which a sagittal otolith pair was collected. Each otolith pair was cleaned and stored dry in individual 1.5 ml plastic Eppendorf centrifuge tubes immediately following collection. We have found storage of individual blue mackerel sagittal otolith

Table 1: Blue mackerel total reported landed catch by fishing year and QMA (adapted from Ministry of Fisheries 2006). Landings reported from EMA 10 are probably attributable to misreporting of catches made in Statistical Area 010 in the Bay of Plenty (i.e., EMA 1). Unsp., QMA not specified. *, FSU data; †, CELR data; ‡, QMS data.

	QMA						
Fishing year	EMA 1	EMA 2	EMA 3	EMA 7	EMA 10	Unsp.	Total
1983–84*	480	259	43	245	–	1	1 028
1984–85*	565	222	18	865	–	73	1 743
1985–86*	618	30	189	408	–	51	1 296
1986–87†	1 431	7	423	489	–	49	2 399
1987–88†	2 641	168	863	1 895	–	58	5 625
1988–89†	1 580	< 1	1 141	1 021	–	469	4 211
1989–90†	2 158	76	518	1 492	–	< 1	4 245
1990–91†	5 783	94	477	3 004	–	–	9 358
1991–92†	10 926	530	65	3 607	–	–	15 128
1992–93†	10 684	309	133	1 880	–	–	13 006
1993–94†	4 178	218	222	1 402	5	–	6 025
1994–95†	6 734	94	153	1 804	10	149	8 944
1995–96†	4 170	119	172	1 218	–	1	5 680
1996–97†	6 754	78	339	2 537	–	< 1	9 708
1997–98†	4 595	122	77	2 310	–	< 1	7 104
1998–99†	4 505	186	62	8 762	–	4	13 519
1999–00†	3 602	73	3	3 169	–	–	6 847
2000–01†	9 738	113	5	3 278	–	< 1	13 134
2001–02†	6 368	177	48	5 101	–	–	11 694
2002–03‡	7 609	115	88	3 562	–	–	11 375
2003–04‡	6 523	149	1	2 701	–	–	9 373
2004–05‡	7 920	8	< 1	4 817	–	–	12 746
2005–06‡	6 713	13	133	3 784	–	–	10 643

pairs in plastic Eppendorf tubes to be superior to storage in paper otolith envelopes, due to their small size and fragility.

All landings and length-frequency data were entered into MFish database *market* (Fisher & Mackay 2000). All otoliths were inventoried, the otoliths lodged in the MFish otolith collection, and the data entered into MFish database *age* (Mackay & George 2000).

2.2.2 EMA 7

Landings from two different sectors in the EMA 7 catch were sampled during 2005–06. Landings by purse-seine vessels targeting blue mackerel were sampled in fish processing factories in Tauranga using the same sampling scheme and methods that were used to sample the target purse-seine catch in EMA 1. Blue mackerel catches by midwater-trawl vessels targeting trachurid mackerels in EMA 7 were sampled at sea by staff from the MFish Observer Programme (MFish OP).

The sampling scheme for blue mackerel used by MFish observers at this time was described in full by Sutton (2002). Typically, about 100 fish were randomly sampled from the catch every two to three days during each fishing trip for length measurements. Samples were collected more frequently when larger catches of blue mackerel were made. Fork length, to the nearest centimetre below actual length, and sex were collected from each fish in these samples and a five-point macroscopic gonad maturity score was assigned to female fish. Sagittal otolith pairs were collected from subsamples of fish randomly sampled for length measurements in each Fisheries Management Area for each observed fishing trip.

The sampling protocols used by the MFish OP for target and bycatch species are quite different. Generally, target species data are collected from every observed fishing event or trawl, whereas bycatch species data are collected at most from a single observed fishing event per observed day (Sutton 2002). Allocation of observers to vessels and the briefing and debriefing of observers before and after assignments were handled entirely by the MFish OP with no input from NIWA-Sanford Ltd during the fishing year. Observers were assigned to vessels opportunistically with no formal spatial or temporal allocation of observer sampling effort (A. Martin, MFish OP, pers. comm.).

All catch and biological data collected during the sampled fishing trips were entered into MFish databases *obs* (Sanders & Mackay 2005) and *obs_lfs* (Sanders & Mackay 2004). All otoliths collected were inventoried and lodged in the MFish otolith collection, and the data were entered into the MFish database *age* (Mackay & George 2000).

2.3 Otolith preparation and analysis

2.3.1 Terminology

The terminology we use follows the glossary for otolith studies by Kalish et al. (1995). The terms "opaque" and "translucent" refer to presumed winter slow-growth and summer fast-growth zones, respectively. A single year's growth, an "annulus", is composed of a single completed opaque zone followed by a single completed translucent zone.

2.3.2 Preparation and reading

Up to 15 otoliths per sex per centimetre length-class were randomly sampled from the set of all otoliths collected during the 2005–06 fishing year and prepared and read using the methods of Morrison et al. (2001). Up to five otoliths were embedded in rows in blocks of clear epoxy resin (Araldite K142) and left to cure at 50 °C overnight. After the resin blocks had cured, a 1 mm transverse section was cut from each block along the nuclear plane in each otolith, using a Struers Accutom-2 revolving diamond-edged saw. The sections were ground and polished on one side and mounted polished surface down on glass microscope slides using a quick-setting epoxy resin ("5-minute" Araldite). The upper surface of each slide was ground down on a Struers Planopol-2 grinder with progressively finer carborundum papers (400 and 800 grades) to a thickness of about 350 μm. The upper, ground surface of the section was then sealed using a commercial artist's clear lacquer spray (Nuart Crystal Clear).

The otolith sections were read using a Leica MZ12 stereo dissecting microscope and transmitted light. Magnification of 63 times was used to observe zone patterns near the nucleus and magnification of 100 times was used to observe zone patterns near the margin in each otolith. The number of complete annuli present in each otolith was counted and recorded. A five-point "readability" score and a three-point "margin-state" score were also recorded (Table 2). All otoliths were read "blind" – fish length and sex were unknown to the reader before reading. All prepared otoliths were read at least once by one reader.

A protocol set of blue mackerel otoliths was assembled and lodged in the Ministry of Fisheries otolith collection. The protocol set includes otoliths from fish over a wide range of sizes and includes otoliths that display common features that hinder interpretation. Digital images of the protocol set have been made and archived. The protocol set was created and read before the remaining otoliths were prepared and read.

Table 2: Five-point otolith readability and three-point otolith margin-state scores used in all readings.

Readability

Readability	Description
1	Otolith very easy to read; excellent contrast between successive opaque and translucent zones; ± 0 or so between subsequent opaque-zone counts in this otolith
2	Otolith easy to read; good contrast between successive opaque and translucent zones, but not as marked as in 1; ± 1 or so between subsequent opaque-zone counts in this otolith
3	Otolith readable; less contrast between successive opaque and translucent zones than in 2, but alternating zones still apparent; ± 2 or so between subsequent opaque-zone counts in this otolith
4	Otolith readable with difficulty; poor contrast between successive opaque and translucent zones; ± 3 or more or so between subsequent opaque-zone counts in this otolith
5	Otolith unreadable

Margin-state

Margin	Description
Narrow	Last opaque zone present deemed to be fully formed; a very thin, hairline layer of translucent material is present outside the last opaque zone
Medium	Last opaque zone present deemed to be fully formed; a thicker layer of translucent material, not very thin or hairline in width, is present outside the last opaque zone; some new opaque material may be present outside the thicker layer of translucent material, but generally does not span the entire margin of the otolith.
Wide	Last opaque zone present deemed not to be fully formed; a thick layer of translucent material is laid down on top of the last fully formed translucent zone, with new opaque material present outside the translucent layer, spanning the entire margin of the otolith

2.3.3 Quantifying reader precision

Otolith reading precision was quantified by carrying out within and between-reader comparison tests following Campana et al. (1995). A subsample of 308 otoliths was randomly selected from the set of all otoliths prepared in this study. These were stratified by the first reader's first recorded age with up to six otoliths randomly sampled from each available age class to ensure that each putative age class in the catch was adequately covered. The subsampled otoliths were read by a second reader and the results were compared with the first reader's set of results. The second reader re-read the protocol set before carrying out their readings. The Index of Average Percentage Error, IAPE (Beamish & Fournier 1981), and mean coefficient of variation, c.v. (Chang 1982), were calculated for each test. The IAPE is

$$\mathrm{IAPE} = 100 \times \frac{1}{N} \sum_{j=1}^{N} \left[\frac{1}{R} \sum_{i=1}^{R} \frac{\left| X_{ij} - X_j \right|}{X_j} \right], \tag{1}$$

and the mean c.v. is

$$\text{mean c.v.} = 100 \times \frac{1}{N} \sum_{j=1}^{N} \left[\frac{\sqrt{\sum_{i=1}^{R} \frac{\left(X_{ij} - X_j\right)^2}{R-1}}}{X_j} \right], \tag{2}$$

where X_{ij} is the *i*th count of the *j*th otolith, R is the number of times each otolith is read, and N is the number of otoliths read or re-read.

2.3.4 Converting opaque-zone counts to age estimates

Opaque-zone counts were converted to estimated ages by treating estimated fish age as the sum of three time components. The estimated age of the *i*th fish, $\hat{a}_i$, is

$$\hat{a}_i = t_{i,1} + t_{i,2} + t_{i,3}, \tag{3}$$

where $t_{i,1}$ is the elapsed time from spawning to the end of the first opaque zone present, $t_{i,2}$ is the elapsed time from the end of the first opaque zone present to the end of the outermost fully formed opaque zone, and $t_{i,3}$ is the elapsed time from the end of the outermost fully formed opaque zone to the date when the *i*th fish was captured. Hence,

$$\begin{aligned} t_{i,1} &= t_{i,\text{ end first opaque zone}} - t_{i,\text{ spawning date}} \\ t_{i,2} &= (n_i + w) - 1 \\ t_{i,3} &= t_{i,\text{ capture}} - t_{i,\text{ end last opaque zone}} \end{aligned} \quad . \tag{4}$$

where n_i is the total number of opaque zones present for fish *i*, and w is an edge interpretation correction after Francis et al. (1992) applied to n_i: $w = 1$ if the recorded margin state = "wide" *and* fish *i* was collected *after* the date when opaque zones are assumed to be fully formed, $w = -1$ if the recorded margin state = "narrow" *and* fish *i* was collected *before* the date when opaque zones are assumed to be fully formed, otherwise $w = 0$. A standardised "birth-date" of 1 January and a standardised opaque zone completion date of 1 November were used for all fish. Stewart et al. (1999) found that opaque zones in Australian fish, although formed during winter, were not always visible until spring or summer on the edge of the otolith. Landing date was substituted for the capture date of each fish. Thus a fish with four completed opaque zones counted and a "narrow" otolith margin recorded that was caught during a fishing trip that landed on 19 November 2004 is estimated to be 3.88 years of age.

2.3.5 Data grooming

All estimated ages derived from otoliths where a readability score of "4" or better was recorded by the first reader were used in the following analyses. One female fish in EMA 1 was dropped from the analysis because it had a readability score of 5 and the fish could not be aged. No other data grooming was carried out before the analyses.

2.4 Estimating the length- and age-composition of the catch

2.4.1 *Catch-at-age*

Catch-at-age (Bull & Dunn 2002) is a package of *R* (R Development Core Team 2005) functions developed by NIWA that computes scaled length-frequency distributions by sex and by stratum from commercial catch- and length-frequency data using the calculations in Bull and Gilbert (2001). If passed a set of length-at-age data, it constructs an age-length key, which is then applied to the estimated scaled length-frequency distributions to compute estimated scaled age-frequency distributions. It computes the c.v. for each length and age class and the overall mean-weighted c.v. (MW c.v.) for each length and age distribution using a bootstrapping routine: fish length records are resampled within each landing, landings are resampled within each stratum, and the length-at-age data are resampled, all with replacement. The bootstrap length- and age-frequency distributions are computed for each resample, and the c.v.s for each length and age class are computed from the bootstrap distributions.

2.4.2 Length-weight relationship

Three length-weight relationships were used to calculate the catch-at-length for males, females and unsexed fish in EMA 1 and EMA 7:

$$\textit{males}:\ w = 3.3743\times10^{-6}(l^{3.4047}) \tag{5}$$

$$\textit{females}:\ w = 3.2305\times10^{-6}(l^{3.4145}) \tag{6}$$

$$\textit{unsexed}:\ w = 3.3489\times10^{-6}(l^{3.4058}) \tag{7}$$

where l is fish length in centimetres and w is fish weight in kilogrammes. The relationship is from a linear regression of log-transformed length and weight data for blue mackerel from the EMA 1 fishery (Manning et al. 2007a). This relationship supersedes an earlier relationship derived from Australian data that was used in the 2002–03 fishing year analysis (Manning et al. 2006). Differences in growth between EMA 1 and EMA 7 fish were assumed to be less than differences in growth of fish in New Zealand versus Australian waters.

2.4.3 Analyses performed

Numbers-at-length were calculated for each catch sector sampled in each fishstock. Each fishstock was treated as a separate analysis. The EMA 1 analysis assumed a single stratum that represented the target purse-seine fishery. The EMA 7 analysis assumed two strata, one corresponding to the target purse-seine fishery, and the second corresponding to the midwater trawl bycatch fishery. Stratum weights were estimated by multiplying the total reported catch in each fishstock by proportions of catch by weight calculated from the corresponding effort and landings data extracted from the *warehou* database. Age-length keys were computed from the groomed length-at-age data subsets for each fishstock and used to convert the calculated numbers-at-length distributions to numbers-at-age. Bootstrapped c.v.s and MW c.v.s were calculated for each length and age class and frequency distribution by resampling the data 1000 times.

3. RESULTS

3.1 Summary of the EMA 1 & 7 fisheries during 2005–06

The most common gear method was identified for each valid fishing trip in the catch-effort and landings datasets for each fishstock. The reported greenweight catch in the landings data was cross-tabulated by gear and area to yield estimates of the total reported catch by these factors (Table 3). Purse-seine vessels where blue mackerel was the most common recorded target species dominated the EMA 1 catch in 2005–06, accounting for an estimated 99% of the total catch. In EMA 7, purse-seine vessels accounted for about 7% of the total catch, while midwater trawls took 93% of the catch.

Table 3: Reported greenweight (t) catch of blue mackerel by fishing method and QMA from the catch-effort and landings datasets for the 2005–06 fishing year.

	EMA 1	EMA 7
Bottom long-line	1	0
Bottom pair-trawl	0	1
Bottom trawl	1	2
Handlining	73	
Mid-water trawl	0	3 624
Purse-seine	6 515	260
Set-net	1	1

Data were not provided in the same format as previous studies and thus a breakdown of catch by target fishery as done by Manning et al. (2007b) was not possible. The landings data for each QMA does not sum to the catch reported in Table 1, most likely because, on average, total reported estimated catch in a given fishing trip is an underestimate of the total reported landed catch (Manning et al. 2007a).

3.2 Summary of sampling results

A total of 33 landings were sampled on shore and one trip was sampled at sea by MFish OP observers from the PS-EMA fishery in EMA 1. A total of 12 358 fish were measured from EMA1 and 403 sagittal otolith pairs were collected, prepared, and read. The temporal distribution of the catch and sampling effort is plotted in Figure 2(a).

One landing was sampled from the PS-EMA fishery on shore and MFish OP observers were deployed on seven trips by vessels fishing in the midwater trawl fishery for a total of eight landings (trips) sampled. A total of 3706 fish were measured across both fisheries in EMA 7. Five hundred otolith pairs were collected, prepared, and read. The temporal distribution of the catch and sampling effort is plotted in Figure 2(b).

The temporal distributions of catch and sampling effort in the EMA 1 and 7 fisheries suggested that the sampling data collected from EMA 1 may be representative of the fishery, but that the data collected from EMA 7 may not be representative. To further investigate whether this was so, the total estimated catch and the total numbers of sets or tows for sampled vessels and the entire fleet by recorded target species, statistical area, and fishery for EMA 1 and 7 were plotted. If the estimated catch proportions for the sampled sector of each fleet and the fleet as a whole show a close match, then the fishing practices of the sampled sectors are the same as the rest of the fleet and hence that the sampled data are representative of the fisheries. The PS-EMA fishery in EMA 1 showed a close match, therefore the sampled data were representative of the fishery (Figure 3). The PS-EMA fishery in EMA 7 was poorly sampled (Figure 4), while the MW-JMA fishery in EMA 7 appeared to be adequately sampled (Figure 5). Overall, the data collected were thought to be representative of the PS-

EMA fishery in EMA 1, were most likely representative of the MW-JMA fishery in EMA 7, and were not representative of the PS-EMA fishery in EMA 7.

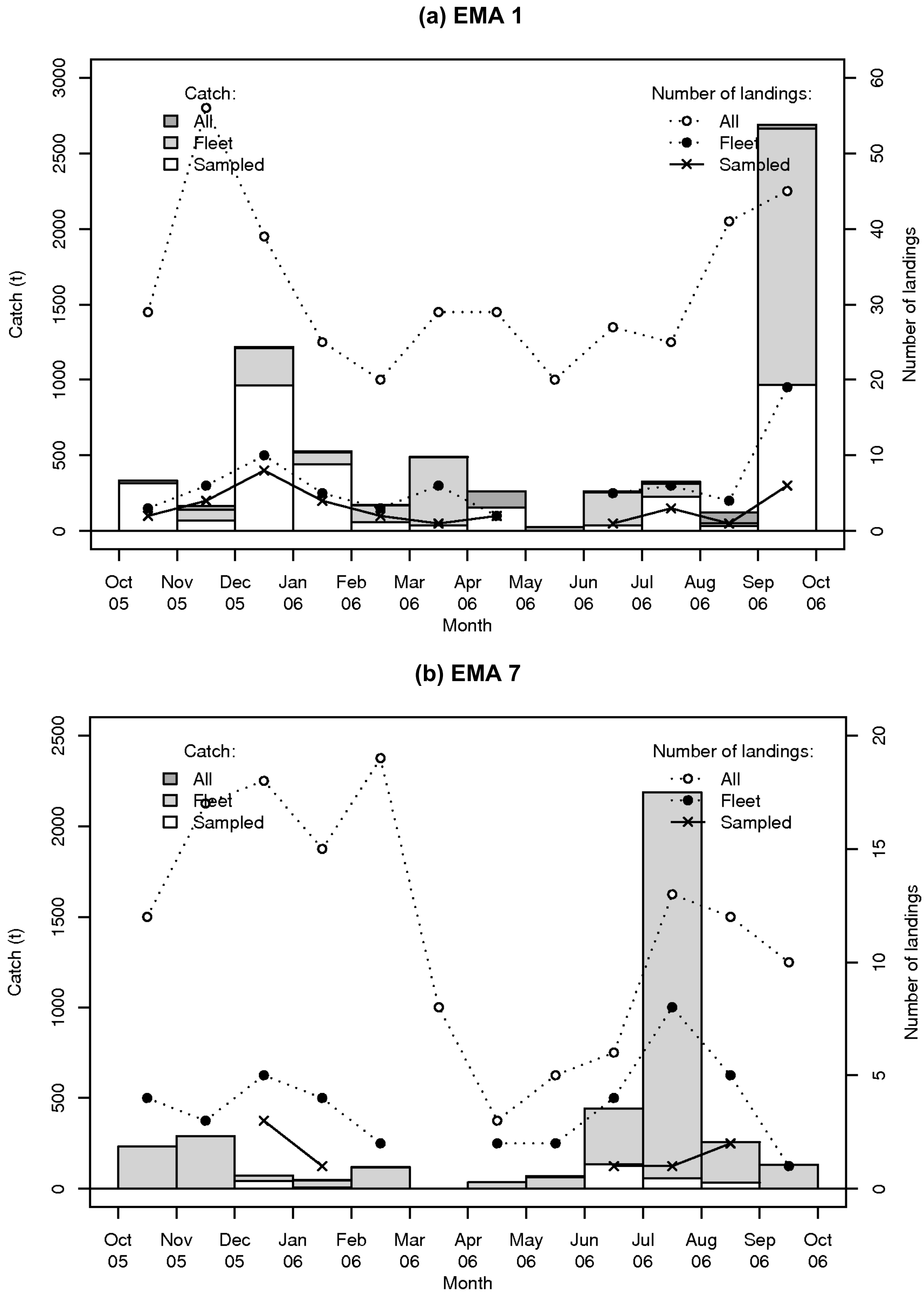

Figure 2: Summaries of fishing and sampling activity for (a) EMA 1 and (b) EMA 7 during the 2005–06 fishing year. Histograms of the total reported landed (grey bars) and sampled (white bars) catch are overlaid on each plot. Numbers of landings by selected fleets in each area are also overlaid for comparison with the sampled landings.

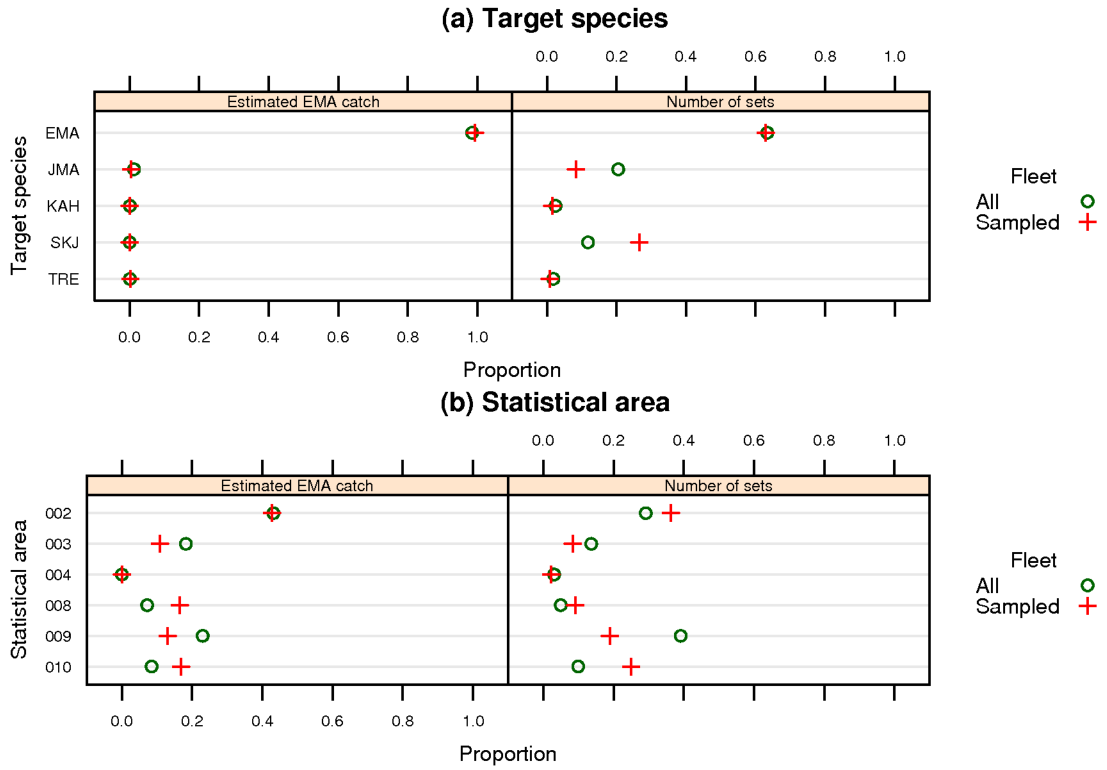

Figure 3: Comparing the total reported estimated catch and number of sets by (a) target species and (b) statistical area for the PS-EMA fishery in EMA 1 during the 2005–06 fishing year for all sampled landings and the fleet as a whole (plotted separately and overlaid).

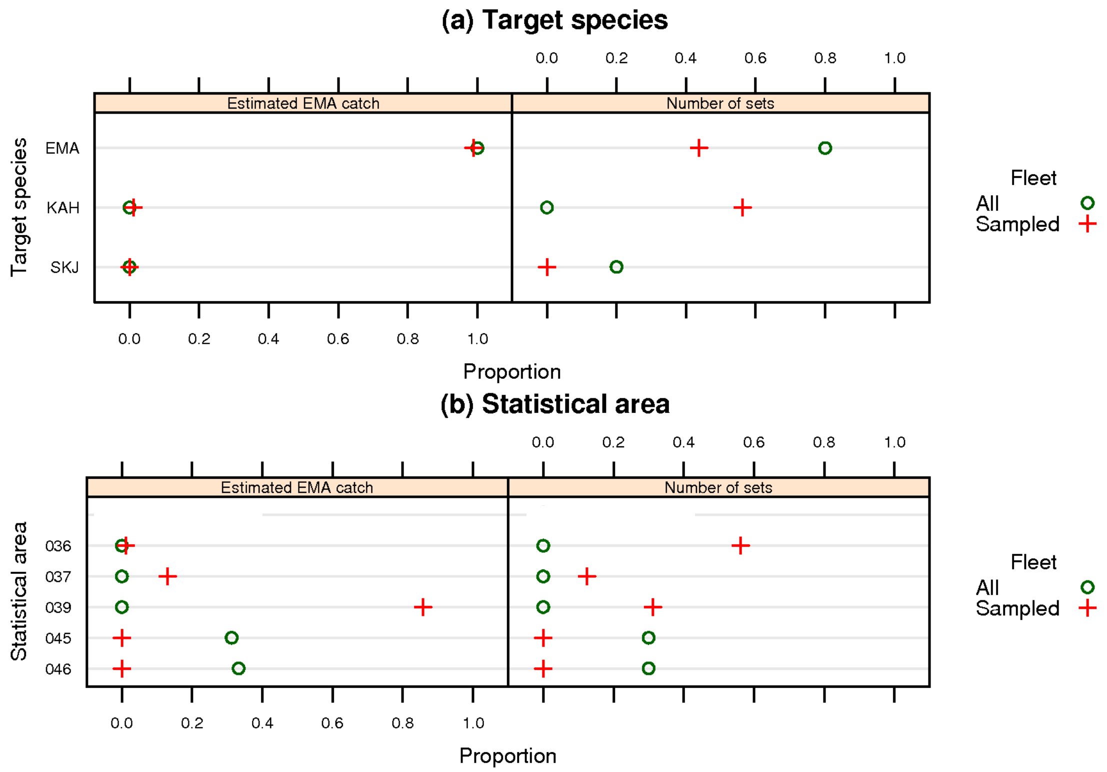

Figure 4: Comparing the total reported estimated catch and number of sets by (a) target species and (b) statistical area for the PS-EMA fishery in EMA 7 during the 2005–06 fishing year for all sampled landings and the fleet as a whole (plotted separately and overlaid).

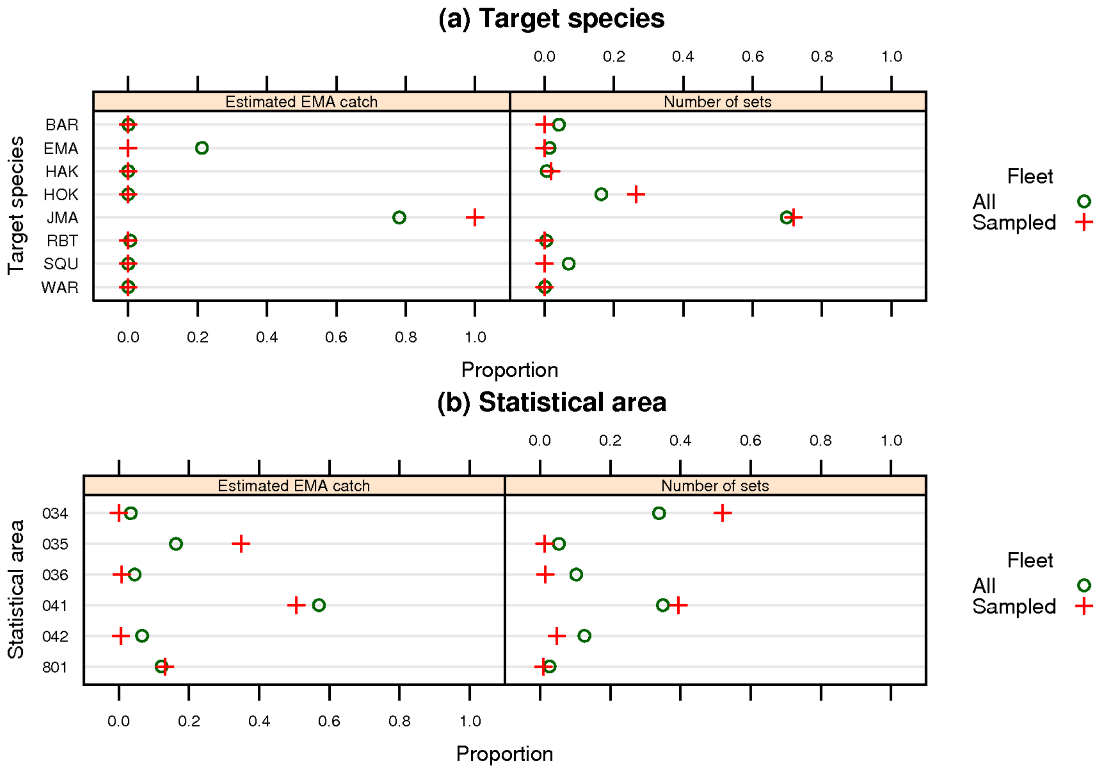

Figure 5: Comparing the total reported estimated catch and number of tows by (a) target species and (b) statistical area for the MW-JMA fishery in EMA 7 during the 2005–06 fishing years for all sampled landings and the fleet as a whole (plotted separately and overlaid).

3.3 Otolith reading results

Precision and apparent accuracy in the otolith readings were not very encouraging; most readability scores were 3 or 4 (Table 4). The mean c.v. and IAPE calculated for the two sets of readings produced by the two readers for the same otoliths in this study were 28.94% and 20.46%, respectively. The skewed histogram in Figure 6(a), the clustering of points below the zero-line in Figure 6(b) and above the one-to-one line in Figure 6(c), and the steeply declining curve of the c.v. and APE profiles in Figure 6(d) all suggest that there were systematic differences (bias) in interpretation of blue mackerel otoliths in this study. The negative weighting in Figure 6(a) means that the second reader over-counted opaque zones present relative to the first reader (i.e., there was an inconsistency between readers in identifying the first true opaque zone present). Between-reader precision was markedly worse in this study than in earlier New Zealand studies where reader error was investigated (Manning et al. 2006, 2007a, 2007b)

Otoliths were read by a third reader and the results are presented in Figure 7. All of EMA 1 otoliths and 25% of EMA 7 otoliths were re-read by the third reader. The mean c.v. and IAPE calculated for the two sets of readings (reader 1 and reader 3) for the same otoliths were 16.3% and 11.5%; these results are similar to results in previous years (between-reader mean c.v.s of 14.42% and 14.92%, respectively; Manning et al. 2006, 2007a). The *slight* negative weighting in Figure 7(a), clustering of points beneath the zero-line in Figure 7(b), and above the one-to-one line in Figure 7(c) may mean the third reader is slightly over-counting opaque zones present relative to the first reader. Because the mean c.v. and IAPE results were similar to previous studies, it is likely that reader 1 was accurately ageing blue mackerel otoliths. Both readers 1 and 3 are familiar with ageing blue mackerel, whereas reader 2 was relatively inexperienced with this species.

Table 4: Readability scores for blue mackerel otoliths in EMA 1 and EMA 7 by readers. See Section 2.3.2 for the description of readability scores.

EMA 1

	Reader A Readability scores					Reader B Readability scores				
Band Count	1	2	3	4	5	1	2	3	4	5
1	–	1	10	7	–	–	–	–	–	–
2	–	–	52	65	–	–	–	1	–	–
3	–	–	32	35	–	–	1	5	3	–
4	–	–	7	8	–	–	1	10	6	–
5	–	–	17	7	–	–	1	5	7	–
6	–	1	8	5	–	–	2	12	7	–
7	–	–	8	7	–	–	1	7	6	–
8	–	1	8	5	–	–	–	3	4	–
9	–	3	7	7	–	–	2	9	1	–
10	–	–	8	2	–	–	–	2	–	–
11	–	–	9	2	–	–	1	5	2	–
12	–	2	12	5	–	–	1	3	–	–
13	–	–	11	1	–	–	2	7	2	–
14	–	–	16	–	–	–	1	4	2	–
15	–	1	10	2	–	–	2	4	–	–
16	–	2	4	–	–	–	–	1	1	–
17	–	–	8	–	–	–	–	5	1	–
18	–	2	3	–	–	–	1	1	–	–
19	–	–	–	–	–	–	1	2	2	–
20	–	–	1	–	–	–	–	1	1	–
21	–	–	–	–	–	–	2	1	1	–
22	–	–	–	–	–	–	–	–	1	–
23	–	–	–	–	–	–	–	–	–	–
24	–	–	–	–	–	–	–	–	1	–

EMA 7

	Reader A Readability scores					Reader B Readability scores				
Band count	1	2	3	4	5	1	2	3	4	5
1	–	–	–	–	–	–	–	–	–	–
2	–	–	2	5	–	–	–	–	–	–
3	–	–	3	13	–	–	–	–	–	–
4	–	–	3	17	–	–	–	–	2	–
5	–	–	12	25	–	–	–	–	2	–
6	–	–	17	19	–	–	–	–	1	–
7	–	–	13	15	–	–	–	1	2	–
8	–	–	17	17	–	–	1	5	5	–
9	–	1	27	8	–	–	1	3	5	–
10	–	2	28	8	–	–	1	6	6	–
11	–	2	24	3	–	–	–	3	8	–
12	–	2	20	5	–	–	1	9	9	–
13	–	1	11	1	–	–	–	7	3	–
14	–	1	5	2	–	–	–	2	4	–
15	–	2	13	3	–	–	–	1	3	–
16	–	5	16	4	–	–	2	–	1	–
17	–	3	19	1	–	–	–	4	2	–
18	–	6	24	3	–	–	5	5	3	–
19	–	7	17	2	–	–	2	5	1	–
20	–	5	15	1	–	–	2	2	2	–
21	–	6	10	3	–	–	2	4	2	–
22	–	2	2	–	–	–	1	3	2	–
23	–	–	2	–	–	–	–	3	2	–
24	–	–	–	–	–	–	–	2	–	–
25	–	–	–	–	–	–	–	–	3	–

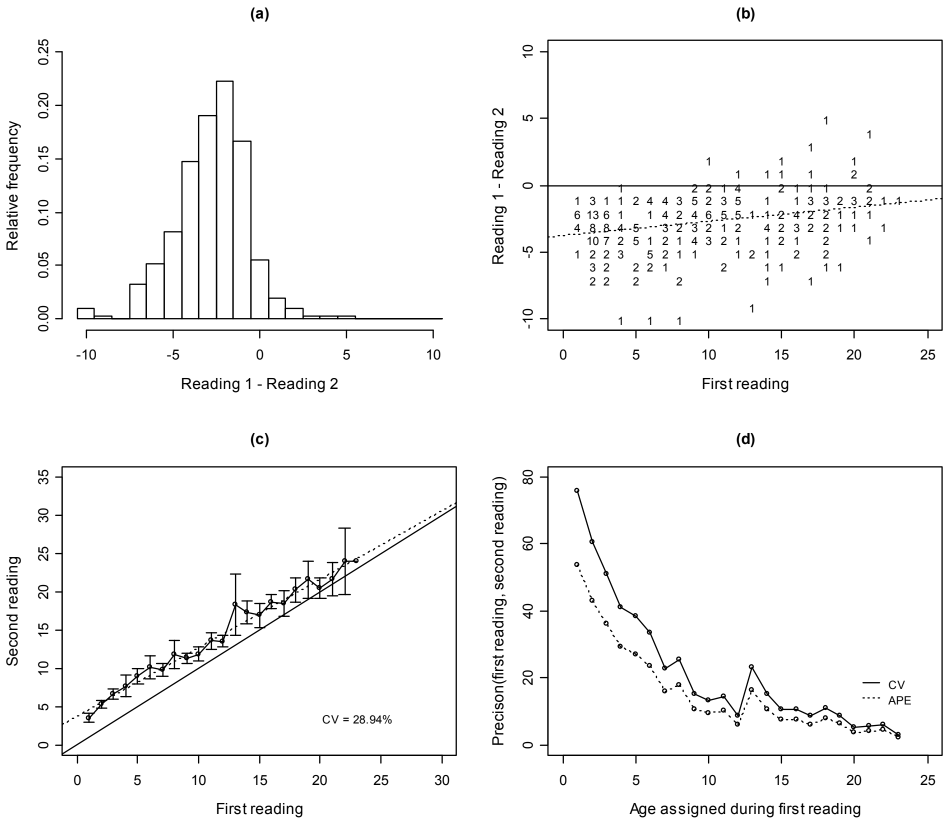

Figure 6: **Results of the between-reader comparison test (reader 1 and 2): (a) histograms of differences between readings for the same otolith; (b) differences between the first and second reading for a given age assigned during the first reading; (c) bias plots; and (d) c.v. and APE profiles relative to the ages assigned during the first set of readings. The expected one-to-one (solid line) and actual relationship (dashed line) between the first and second ages are overlaid on (b) and (c).**

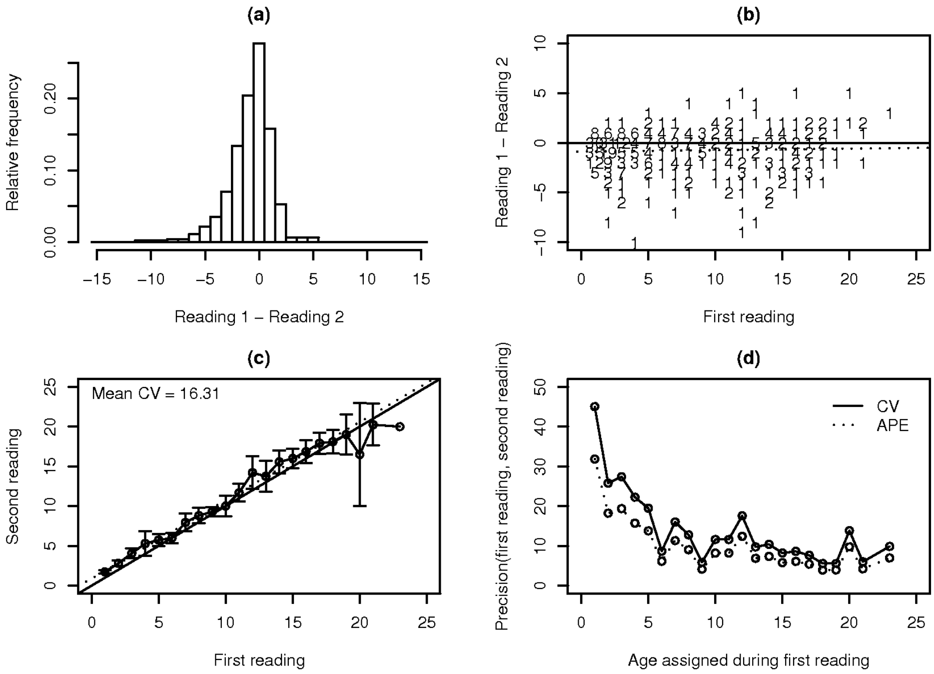

Figure 7: **Results of the between-reader comparison test (reader 1 and 3): (a) histograms of differences between readings for the same otolith; (b) differences between the first and second reading for a given age assigned during the first reading; (c) bias plots; and (d) c.v. and APE profiles relative to the ages assigned during the first set of readings. The expected one-to-one (solid line) and actual relationship (dashed line) between the first and second ages are overlaid on (b) and (c).**

3.4 Length- and age-frequency distributions

The estimated scaled proportions-at-length distributions calculated for all three fisheries are plotted in Figure 8. Cumulative proportions-at-length for the 1997–98, 2002–03, 2003–04, 2004–05, and 2005–06 fishing years are plotted and compared in Figure 9. The estimated scaled proportions-at-age distributions calculated by applying the age-length keys derived from the prepared and read otoliths are plotted Figure 10. Cumulative proportions-at-age for the 1997–98, 2002–03, 2003–04, 2004–05, and 2005–06 fishing years are plotted and compared in Figure 11.

Length distributions were roughly centred around 45 cm in EMA 1 and 48 cm in EMA 7, with no fish smaller than 30 cm or larger than 55 cm in any of the fisheries sampled (Figure 8). The distributions of all fish, males, and females were strongly unimodal in the purse-seine fisheries in EMA 7. The purse-seine fishery in EMA 7 did not catch fish in the 30–40 cm range (Figure 8b). The trawl bycatch fishery in EMA 7 caught few fish in the 30–40 cm size range (Figure 8c). The cumulative proportions-at-length by sex for EMA 1 suggests that the catch in 2005–06 contained slightly smaller males than in the previous year (2004–05); females were also slightly smaller than in 2004–05 (Figure 9).

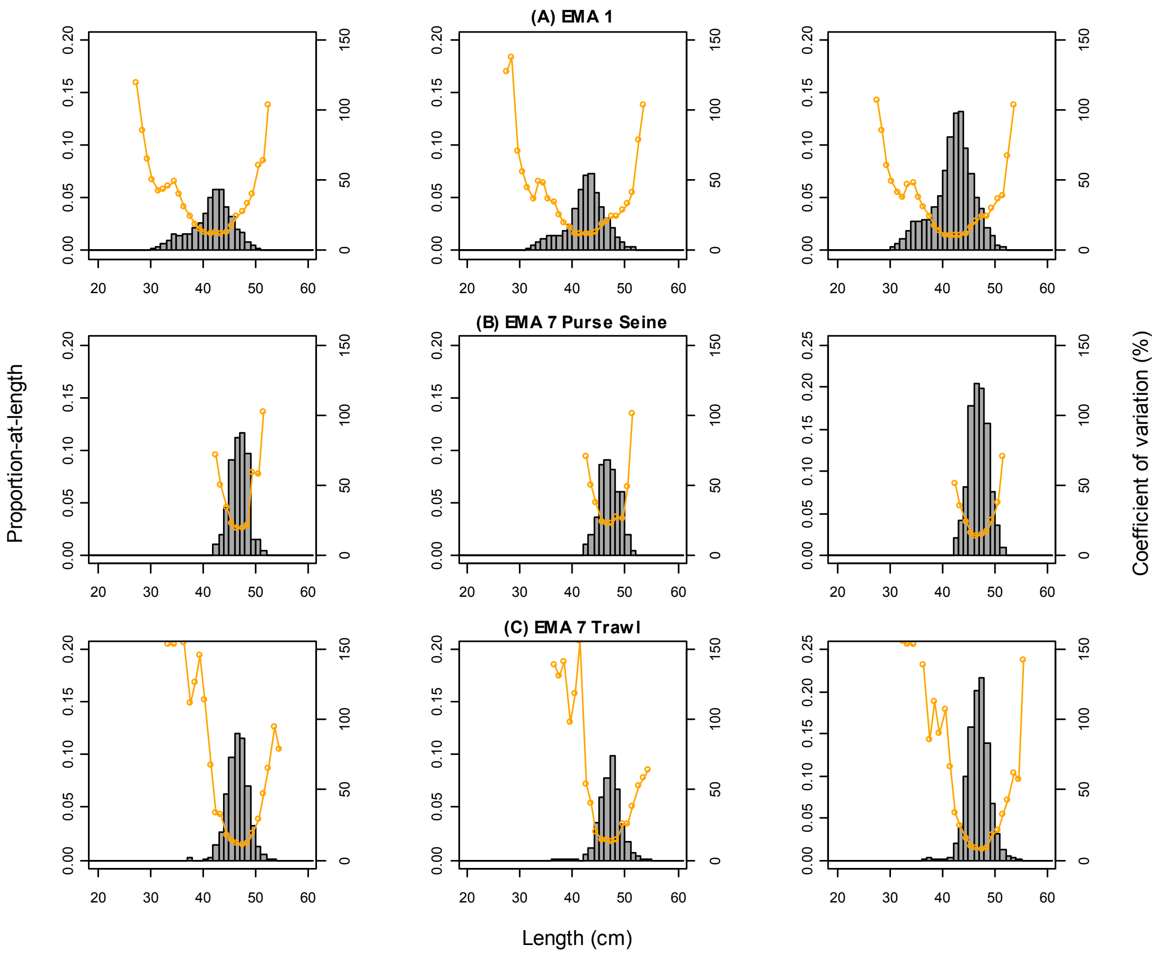

Figure 8: Estimated scaled proportions-at-length for male, female, and all fish combined for the EMA 1 and EMA 7 fisheries in the 2005–06 fishing year with bootstrapped 95% coefficient of variation for each length class.

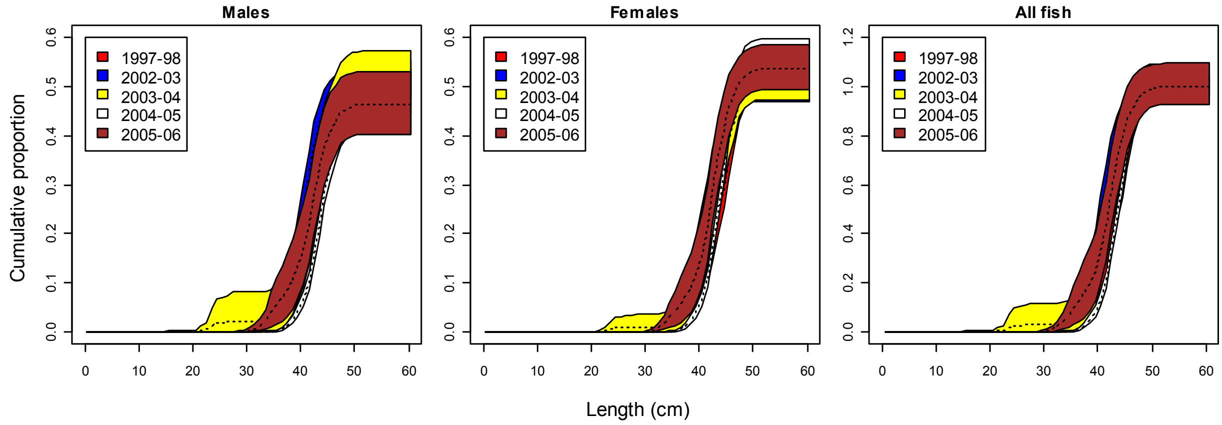

Figure 9: Overlaid cumulative proportions-at-length from data collected during the 2005–06 fishing years in EMA 1 and previous years (1997–98, 2002–03, 2003–04, 2004–05). The dashed line in each plot is the cumulative proportion-at-length or age and the surrounding region is a bootstrapped 95% confidence region about the cumulative proportion-at-length.

The estimated scaled proportions-at-age show that catches in the PS-EMA fishery in EMA 1 were mostly of fish 2–15 years old, although fish as old as 20 appear to be present in the catch (Figure 10a). Both the purse-seine and trawl fisheries in EMA 7 appeared to capture two modes of age classes; one mode contained fish aged 2–13 and the second included fish aged 15–22 (Figures 10b and 10c). The cumulative proportions-at-age for EMA 1 plotted in Figure 11 showed that there were more younger fish in the catch in 2005–06 than in previous fishing years. This trend was also apparent in the scaled proportions-at-age (Figure 12). Strong year classes appeared to recruit to the fishery in 2001, 2003, and 2004; the trend was consistent for both sexes (Figure 12). How much of this was due to gear selectivity or catchability effects and how much was due to true differential year-class (recruitment) success is unknown at this time.

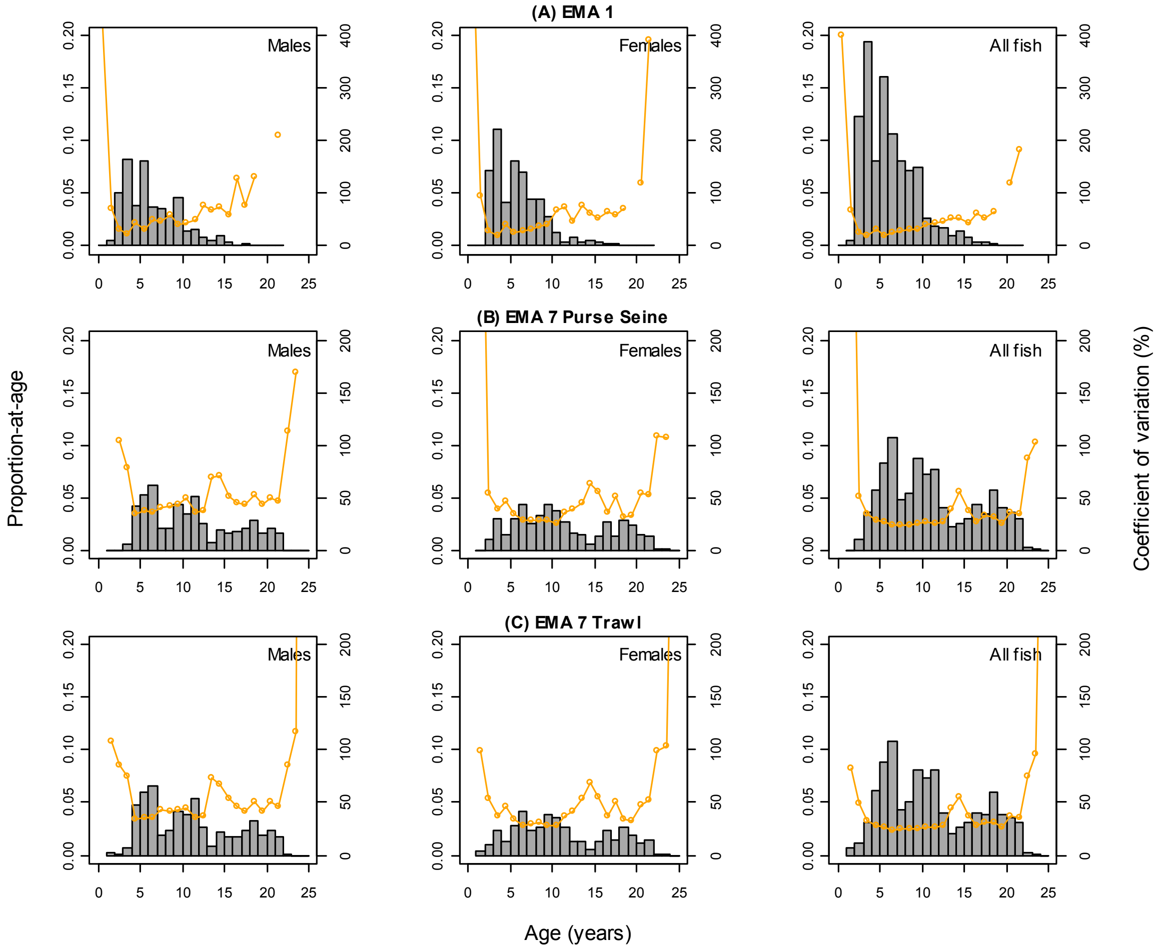

Figure 10: Estimated scaled proportions-at-age for male, female, and all fish combined for the EMA 1 and EMA 7 fisheries in the 2005–06 fishing year with bootstrapped 95% coefficient of variation for each length class.

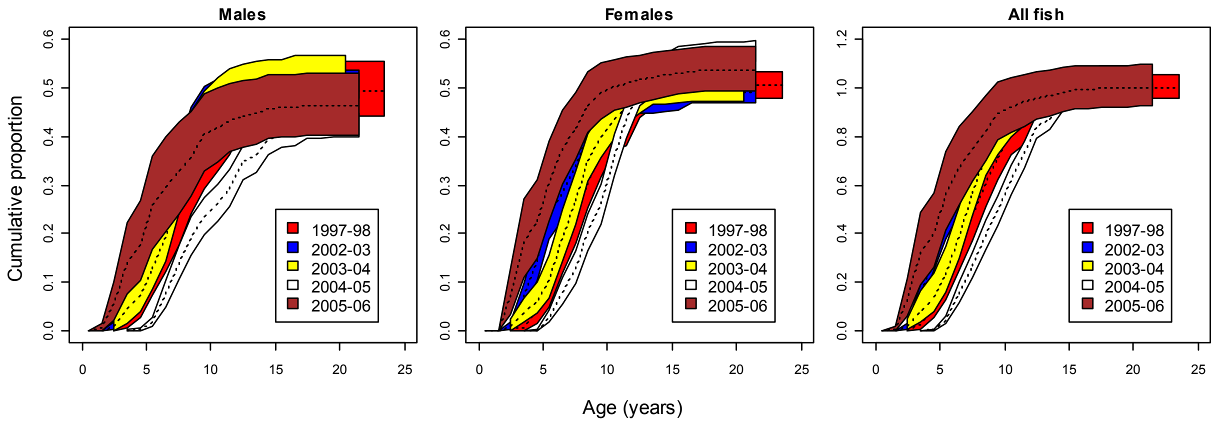

Figure 11: Overlaid cumulative proportions-at-age calculated from data collected during the 2005–06 fishing years in EMA 1 and previous years (1997–98, 2002–03, 2003–04, 2004–05). The dashed line in each plot is the cumulative proportion-at-length or age and the surrounding region is a bootstrapped 95% confidence region about the cumulative proportion-at-age.

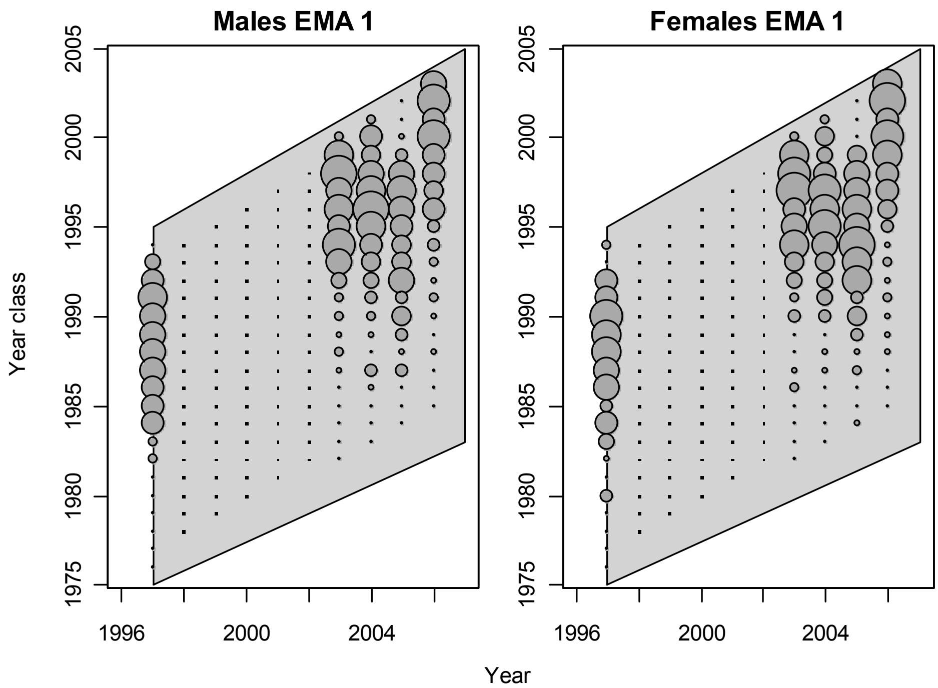

Figure 12: Estimated scaled proportions-at-age (ages 2–20) by year class and fishing year for males and females in the EMA 1 purse-seine fishery over the 1997–98 to 2005–06 fishing years. Circle area is proportional to the corresponding proportion-at-age within each sampling event. Circle sizes are equivalent from plot to plot; the area of a circle 0.5 cm in diameter is equal to a proportion-at-age of 0.30. The dashes represent year classes where the proportion-at-age is zero or was not estimated (i.e., fishing years during which the fishery was not sampled). Age 2 is a minus group and age 20 is a plus group.

The MW c.v.s for the proportions-at-length and proportions-at-age distributions in the EMA 1 & 7 fisheries are given in Table 5. The MW c.v.s for the catch-at-length for both sexes and for all fish were similar for the purse-seine fisheries in both QMAs even though there were fewer data collected for EMA 7. The representivity analysis above suggests that these results are probably representative of the fisheries sampled with one exception, the data collected from the PS-EMA fishery in EMA 7 certainly are not. These results are imprecise rather than inaccurate. The MW c.v.s for both sexes and all fish in the EMA 1 and 7 length analyses were within the 30% target. However, the MW c.v.s for both sexes in both EMA 1 and 7 were above the target 30% for the age analyses, and just within the target c.v.s. for all fish.

Table 5: Mean-weighted coefficients of variation (%) for the scaled length- and age-frequency distributions calculated for EMA 1 and 7 by fishstock, fishery, and sex. The analysis for each fishstock was carried out separately.

Length

		Sex			
Fishstock	Stratum	Males	Females	Unsexed	All fish
EMA 1	PS-EMA	20.4	17.8	–	17.4
EMA 7	PS-EMA	26.9	29.4	–	19.4
EMA 7	BT-EMA	16.5	19.1	–	12.7

Age

		Sex			
Fishstock	Stratum	Males	Females	Unsexed	All fish
EMA 1	PS-EMA	40.7	32.8	–	28.2
EMA 7	PS-EMA	44.1	36.8		29.4
EMA 7	BT-EMA	43.1	37.7	–	30.0

Estimated scaled numbers-at-length and c.v.s. by sex, fishery, and fishstock (analysis) are given in Appendix A. Estimated scaled numbers-at-age and c.v.s by sex, fishery, and fishstock (analysis) are given in Appendix B. The age-length keys used to convert the scaled numbers-at-length distributions to numbers-at-age are given in Appendix C.

4. DISCUSSION

4.1 Catch-sampling success and recommendations for future sampling

The mean weighted c.v. targets for the MW-JMA fishery in EMA 7 were exceeded slightly in the catch-at-age analyses, although better than those estimated in the 2004–05 analysis (Manning et al. 2007b). Given that the data collected from all but the PS-EMA fishery in EMA 7 are thought to be representative of the fisheries, the high c.v.s may partially be due to the number of otoliths collected. Although the MW-JMA EMA 7 sampled sectors were the same as the rest of the fleet and the conclusion was that the sampled data were representative of the fishery, the coverage of the fishery was poor – especially in comparison with EMA 1. Recommendations include increasing the number of allocated observed trips and coverage of both fisheries in EMA 7, maintaining the current sampling coverage (and number of trips) for the PS-EMA 1, and increasing the amount of blue mackerel otoliths collected and aged.

As noted, there were problems with ageing blue mackerel. The results of the between-reader comparison test were not very encouraging, especially compared to results in earlier studies. Problems occurred because more inexperienced (with regards to reading blue mackerel otoliths) readers were used for this analysis than in previous years. Because having the same experienced readers age blue mackerel for subsequent analyses may not be possible, a procedural manual and training for those that are inexperienced with this species is highly recommended.

A third reader, who had read blue mackerel otoliths for previous studies, was used and between-reader comparison showed that reader 1 was ageing fish similar to an experienced reader for this species. Reader 1 was accurately ageing blue mackerel otoliths. These results show that all samples may not have to be re-aged if a stock assessment is planned. Results from reader 2 should not be used in any further analyses.

4.2 Apparent trends in the catch-at-length and catch-at-age in EMA 1 & 7 during the 2005–06 fishing year

The 2005–06 catch-at-length for EMA 1 and EMA 7 shows smaller and younger fish entering the catch and this may correspond to recruitment pulses or changes in behaviour of the fish and/or fishers. Age 1 fish are appearing in the catches in EMA 1. The youngest age of fish appearing in the purse-seine catch in EMA 7 is age 2, while midwater trawls are capturing fish of age 1 as bycatch. From the shape of the catch-at-age, blue mackerel appear to be fully recruited to the purse-seine fishery in EMA 1 between ages 3–10 and 45 cm in fork length. Blue mackerel in EMA 7 appear to be fully recruited to both the purse-seine and midwater trawl fisheries by age 6 and 47–48 cm fork length.

4.3 Comparing the 2005–06 catches-at-length and catches-at-age to previous years

Fish in EMA 1 and 7 appear to be recruiting to the fisheries at a much smaller size than in 2004–05 (Manning et al. 2007b) and at a younger age than in previous analyses (1997–98, 2002–03, 2003–04, and 2004–05; Manning et al. 2005, 2006, 2007a). Whether this is due to gear selectivity effects, changes in catchability (either changing fishing behaviour of the fleet or changing fish behaviour), or to true differential year-class (recruitment) success is unknown.

The fisheries appear to be continuing to exploit a number of successful year classes. However, the EMA 7 fisheries are catching a large proportion of fish older than 15 years of age, while the EMA 1 fishery is not. The proportions-at-age distribution is bimodal for both fisheries in EMA 7, which has not been seen in previous analyses (Manning et al. 2007a, 2007b). The bimodal peaks in the age distribution indicate that the population may not have been sampled adequately in 2005–06. Such changes may reflect behaviour changes by either fish and/or fishers. Fu and Taylor (2007) suggested that blue mackerel change their behaviour in June–August and thus become more vulnerable to the midwater fleet, or that the fleet switch their strategy to take advantage of the change in fish behaviour. That the bimodal peaks are seen in both the purse-seine and midwater trawl fisheries, which sample different parts of the population's habitat and range, indicates fishing behaviour may not be solely responsible for the observations as the two fisheries. The movements of blue mackerel are unknown, including whether older fish migrate between areas or QMAs. This will have implications for any future stock assessment and future work may include investigating whether this change is a real change in the population, a change in the behaviour of the fishery, or due to sampling inadequacies.

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Appendix A: Scaled length distributions

Table A1: Estimated scaled numbers-at-length (NAL), bootstrapped coefficients of variation (c.v.), and bootstrapped mean-weighted coefficients of variation (MWCV) calculated from the data collected during the 2005–06 fishing season and scaled to the total reported catch landed for EMA 1.

	Males		Females		All	
Length	NAL	c.v. (%)	NAL	c.v. (%)	NAL	c.v. (%)
≤ 26	–	–	–	–	–	–
27	935	120.4	104	128.3	1 038	108.7
28	2 102	85.8	460	138.8	2 562	86.3
29	2 366	66.0	2 315	72.7	4 681	62.4
30	15 439	53.0	6 553	57.7	21 993	51.8
31	20 277	45.4	15 388	46.8	35 665	43.8
32	37 602	46.4	28 315	40.0	65 916	41.0
33	59 193	49.4	47 109	53.1	106 302	50.4
34	96 027	53.6	70 391	52.0	166 418	52.4
35	82 618	44.2	82 716	40.6	165 334	41.8
36	88 629	34.7	85 565	38.3	174 193	35.8
37	90 790	28.4	84 569	29.3	175 359	27.9
38	127 100	21.9	113 309	23.7	240 409	21.7
39	154 219	18.2	148 312	19.5	302 531	17.4
40	212 298	14.7	232 199	14.1	444 497	13.3
41	295 575	13.0	342 965	11.6	638 539	10.8
42	338 268	12.4	426 064	9.6	764 332	9.0
43	342 193	9.8	434 313	9.9	776 506	8.3
44	247 932	10.3	321 039	9.8	568 971	8.6
45	193 267	13.8	240 817	15.0	434 084	13.1
46	120 883	21.8	179 013	17.9	299 896	17.1
47	101 282	24.5	129 447	20.6	230 729	20.5
48	46 536	30.9	78 675	21.8	125 210	21.6
49	34 228	38.2	46 695	26.1	80 923	27.1
50	9 377	59.3	21 177	31.5	30 554	34.2
51	5 177	62.8	19 772	39.6	24 949	37.4
52	1 650	103.0	2 342	78.3	3 992	67.1
53	–	–	1 650	103.7	1 650	103.7
≥ 54	–	–	–	–	–	–
Total	2 725 963		3 161 274		5 887 233	
MWCV (%)	20.4		17.8		17.4	

Table A2: Estimated scaled numbers-at-length (NAL), bootstrapped coefficients of variation (c.v.), and bootstrapped mean-weighted coefficients of variation (MWCV) calculated from the data collected during the 2005–06 fishing season and scaled to the total reported catch landed for the EMA 7 purse-seine fishery.

	Males		Females		All	
Length	NAL	c.v. (%)	NAL	c.v. (%)	NAL	c.v. (%)
≤ 41	–	–	–	–	–	–
42	1 609	71.0	1 609	70.5	3 218	51.2
43	3 218	50.3	3 218	50.5	6 436	35.5
44	7 240	33.9	5 631	37.9	12 872	24.5
45	14 481	22.5	13 676	24.3	28 157	15.7
46	17 699	19.7	14 481	22.7	32 180	14.1
47	18 503	19.6	12 872	23.0	31 375	14.4
48	15 285	21.6	9 654	26.9	24 939	16.2
49	2 413	58.3	9 654	26.3	12 067	24.1
50	2 413	57.2	3 218	48.8	5 631	37.0
51	804	101.4	804	100.2	1 609	70.4
≥ 52	–	–	–	–	–	–
Total	83 665		74 817		158 484	
MWCV (%)	26.9		29.4		19.4	

Table A3: Estimated scaled numbers-at-length (NAL), bootstrapped coefficients of variation (c.v.), and bootstrapped mean-weighted coefficients of variation (MWCV) calculated from the data collected during the 2005–06 fishing season and scaled to the total reported catch landed for the EMA 7 midwater trawl fishery.

	Males		Females		All	
Length	NAL	c.v. (%)	NAL	c.v. (%)	NAL	c.v. (%)
≤ 27	–	–	–	–	–	–
28	75	160.6	–	–	75	160.6
29	–	–	–	–	–	–
30	–	–	–	–	–	–
31	–	–	–	–	–	–
32	–	–	–	–	164	155.7
33	4	153.3	–	–	4	153.3
34	4	153.5	–	–	4	153.5
35	–	–	–	–	–	–
36	9	154.0	1 530	139.7	1 539	138.8
37	4 758	111.9	1 394	130.7	6 481	86.9
38	19	126.0	2 001	141.2	2 512	113.1
39	137	145.4	3 534	97.9	3 835	90.0
40	345	113.2	435	117.9	780	107.3
41	6 276	67.6	75	155.5	6 351	66.7
42	31 364	34.8	12 752	54.8	44 280	34.3
43	58 571	33.1	26 857	40.8	85 428	25.7
44	139 199	17.7	78 921	20.3	218 449	15.7
45	215 604	14.6	133 440	15.2	349 541	10.6
46	268 294	11.9	172 931	14.9	444 441	8.2
47	256 343	11.0	218 907	12.9	480 117	7.5
48	154 917	11.9	149 310	14.5	310 243	8.2
49	72 415	18.3	74 224	24.7	149 883	16.4
50	28 090	28.8	39 050	25.5	69 804	19.9
51	11 285	46.9	14 381	38.0	27 195	32.0
52	3 302	65.4	7 245	52.2	11 151	41.7
53	2 846	93.8	2 029	58.1	4 879	60.9
54	209	78.4	641	64.0	1 019	57.3
≥ 55	–	–	–	–	5	142.1
Total	1 254 066		939 657		2 218 180	
MWCV (%)	16.5		19.1		12.7	

Appendix B: Scaled age distributions

Table B1: Estimated scaled numbers-at-age (NAA), bootstrapped coefficients of variation (c.v.), and bootstrapped mean-weighted coefficients of variation (MWCV) calculated from the data collected during the 2005–06 fishing season, scaled to the total reported catch, for EMA 1.

	Males		Females		All	
Age	NAA	c.v. (%)	NAA	c.v. (%)	NAA	c.v. (%)
0	–	–	–	–	–	–
1	30 321	72.9	1 071	95.4	31 392	70.8
2	300 390	34.9	421 654	32.0	722 044	30.9
3	487 702	27.1	650 757	23.3	1 138 459	21.6
4	227 283	42.8	244 913	41.1	472 197	31.4
5	475 615	31.0	472 187	26.2	947 802	20.2
6	212 951	48.7	409 264	28.5	622 215	25.4
7	210 641	47.7	264 547	31.2	475 188	27.7
8	161 807	57.5	262 576	35.3	424 383	30.9
9	273 903	40.3	164 708	40.0	438 612	29.8
10	83 594	40.7	74 445	66.9	158 039	39.5
11	89 192	47.2	24 688	71.3	113 881	41.1
12	49 598	74.3	49 823	46.1	99 421	45.7
13	28 326	66.6	25 003	74.7	53 329	51.9
14	55 465	72.4	31 799	60.9	87 264	51.2
15	22 942	56.8	25 370	52.7	48 312	41.1
16	1 726	126.7	16 304	63.8	18 030	59.6
17	13 461	74.3	11 332	57.3	24 793	50.1
18	1 042	128.8	7 242	69.0	8 283	64.1
19	–	–	–	–	–	–
20	–	–	3 592	116.3	3 592	116.3
Total	2 725 959		3 161 275		5 887 236	
MWCV (%)	40.7		32.8		28.2	

Table B2: Estimated scaled numbers-at-age (NAA), bootstrapped coefficients of variation (c.v.), and bootstrapped mean-weighted coefficients of variation (MWCV) calculated from the data collected during the 2005–06 fishing season, scaled to the total reported catch, for the EMA 7 purse-seine fishery.

	Males		Females		All	
Age	NAA	c.v. (%)	NAA	c.v. (%)	NAA	c.v. (%)
1	–	–	–	–	–	–
2	99	105.2	1 675	54.1	1 774	51.2
3	916	79.4	4 802	39.2	5 717	34.8
4	6 630	35.0	2 395	46.6	9 025	28.3
5	8 389	38.6	4 722	34.5	13 111	27.5
6	9 869	36.8	7 056	29.3	16 925	24.4
7	3 386	40.8	4 184	29.1	7 570	23.8
8	3 451	42.8	5 190	28.4	8 641	23.6
9	6 856	44.4	6 940	28.2	13 795	25.4
10	5 487	49.7	5 959	26.0	11 446	26.5
11	8 051	35.9	4 267	37.0	12 317	25.8
12	3 980	38.1	2 521	38.9	6 501	26.7
13	1 274	70.1	2 287	45.2	3 562	39.2
14	3 224	70.5	923	63.1	4 148	56.1
15	2 605	51.9	2 149	55.5	4 753	37.3
16	2 830	44.9	4 214	35.8	7 044	27.1
17	3 269	43.5	2 146	51.6	5 415	32.4
18	4 578	53.1	4 481	31.9	9 060	31.1
19	2 662	44.5	3 818	32.5	6 480	25.5
20	3 273	49.3	2 395	54.9	5 668	36.2
21	2 737	46.8	2 101	53.4	4 837	35.0
22	85	113.6	297	109.2	382	87.3
23	16	169.0	297	107.8	313	102.9
Total	83 667		74 819		158 484	
MWCV (%)	44.1		36.8		29.4	

Table B3: Estimated scaled numbers-at-age (NAA), bootstrapped coefficients of variation (c.v.), and bootstrapped mean-weighted coefficients of variation (MWCV) calculated from the data collected during the 2005–06 fishing season, scaled to the total reported catch, for the EMA 7 midwater trawl fishery.

	Males		Females		All	
Age	NAA	c.v. (%)	NAA	c.v. (%)	NAA	c.v. (%)
1	4 870	109.4	8 969	100	13 839	83.5
2	2 040	85.7	21 606	53.5	23 646	49.2
3	16 703	75.7	50 603	36.7	67 307	32.9
4	106 148	34.4	27 002	47.0	133 150	28.9
5	132 251	36.1	60 470	34.1	192 721	27.1
6	143 202	35.4	92 846	27.7	236 048	24.1
7	43 077	43.0	51 326	29.7	94 403	25.0
8	52 176	41.4	59 139	30.4	111 315	24.9
9	92 584	43.0	86 005	28.5	178 590	25.7
10	84 871	44.8	77 172	28.0	162 042	27.0
11	118 928	36.1	59 027	37.2	177 955	26.3
12	59 508	38.0	29 440	41.4	88 948	28.0
13	17 419	72.7	28 445	53.7	45 864	44.4
14	46 827	67.1	11 850	68.9	58 677	55.4
15	39 698	53.5	29 618	55.2	69 316	37.7
16	37 496	46.4	51 075	36.9	88 571	28.2
17	52 636	41.1	30 861	50.3	83 497	31.3
18	71 930	50.1	58 820	34.0	130 749	31.5
19	40 169	41.9	43 036	32.5	83 205	26.0
20	51 490	50.5	25 455	48.3	76 944	36.8
21	38 801	46.7	30 934	51.5	69 735	34.9
22	1 024	84.9	3 057	98.5	4 081	75.6
23	221	117.4	2 901	102.8	3 122	95.7
Total	1 254 069		939 657		2 193 725	
MWCV (%)	43.1		37.7		30.0	

Appendix C: Age-length keys

Table C1: Age-length key used to convert the scaled length distributions to age distributions; data collected during the 2005–06 fishing year in EMA 1. Each row gives the proportion at age of each length class. The total number of observations in each length class is also provided.

Males

	Age (years)																										
Length	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	≥ 25	*n*
≤ 26	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
27	–	1.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
28	–	0.67	0.33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
29	–	0.32	0.68	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	19
30	–	0.17	0.83	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12
31	–	–	0.76	0.24	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	17
32	–	–	0.75	0.25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4
33	–	–	–	1.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5
34	–	0.12	0.38	0.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8
35	–	–	0.57	0.43	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7
36	–	0.14	0.43	0.43	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7
37	–	–	0.62	–	0.12	0.25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8
38	–	–	0.5	0.17	0.33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6
39	–	–	–	0.8		0.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5
40	–	–	–	0.5	0.3	0.1	–	0.1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10
41	–	–	–	0.14	0.14	0.43	0.14	0.14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7
42	–	–	–	–	0.2	0.2	0.4	0.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5
43	–	–	–	–	–	0.5	–	–	0.25	0.25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4
44	–	–	–	–	–	0.14	0.14	–	–	0.57	–	–	–	–	0.14	–	–	–	–	–	–	–	–	–	–	–	7
45	–	–	–	–	–	–	–	0.33	0.17	0.17	–	0.17	0.17	–	–	–	–	–	–	–	–	–	–	–	–	–	6
46	–	–	–	–	–	–	–	0.12	0.12	–	0.12	0.38	–	0.12	0.12	–	–	–	–	–	–	–	–	–	–	–	8
47	–	–	–	–	–	–	–	–	0.29	0.14	0.57	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7
48	–	–	–	–	–	–	–	–	–	–	0.17	0.17	–	0.17	–	0.33	–	0.17	–	–	–	–	–	–	–	–	6
49	–	–	–	–	–	–	–	–	–	–	0.08	0.08	0.42	–	0.08	0.17	–	0.17	–	–	–	–	–	–	–	–	12
50	–	–	–	–	–	–	–	–	–	–	–	0.11	0.33	0.22	0.22	–	–	–	0.11	–	–	–	–	–	–	–	9
51	–	–	–	–	–	–	–	–	–	–	–	–	–	0.33	–	0.33	0.33	–	–	–	–	–	–	–	–	–	3
52	–	–	–	–	–	–	–	–	–	–	–	–	–	1.0	–	–	–	–	–	–	–	–	–	–	–	–	1
≥ 53	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0

Table C1: Continued.

Females

	Age (years)																										
Length	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	≥ 25	*n*
≤ 25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
26	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
27	–	0.67	0.33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
29	–	0.33	0.67	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6
30	–	–	1.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13
31	–	–	1.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8
32	–	–	0.73	0.27	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11
33	–	–	0.6	0.4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5
34	–	–	0.29	0.71	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7
35	–	–	0.75	0.25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8
36	–	–	0.75	0.25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8
37	–	–	0.67	0.33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6
38	–	–	0.12	0.75	0.12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8
39	–	–	–	0.78	0.11	0.11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9
40	–	–	0.2	0.4	0.2	0.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5
41	–	–	0.25	0.25	0.25	0.25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8
42	–	–	–	0.2	0.1	0.2	0.4	–	0.1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10
43	–	–	–	0.09	0.09	0.18	0.27	0.09	0.18	0.09	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11
44	–	–	–	–	–	0.25	0.38	0.12	0.12	–	0.12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8
45	–	–	–	–	–	0.22	–	0.56	0.11	0.11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9
46	–	–	–	–	–	0.14	–	0.29	0.14	0.29	0.14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7
47	–	–	–	–	–	–	–	–	0.38	0.12	–	0.12	0.12	0.12	0.12	–	–	–	–	–	–	–	–	–	–	–	8
48	–	–	–	–	–	–	–	–	–	0.33	0.11	–	0.22	–	–	0.22	0.11	–	–	–	–	–	–	–	–	–	9
49	–	–	–	–	–	–	–	–	–	0.08	–	0.15	0.23	0.08	0.08	–	0.08	0.15	0.08	–	0.08	–	–	–	–	–	13
50	–	–	–	–	–	–	–	–	–	0.06	–	0.06	0.19	0.12	0.31	–	0.19	0.06	–	–	–	–	–	–	–	–	16
51	–	–	–	–	–	–	–	–	–	–	–	–	0.07	0.07	0.21	0.36	–	0.14	0.14	–	–	–	–	–	–	–	14
52																											
53	–	–	–	–	–	–	–	–	–	–	–	–	–	0.5	0.5	–	–	–	–	–	–	–	–	–	–	–	2
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.5	–	–	0.5	–	–	–	–	–	–	–	2

Table C2: Age-length key used to convert the scaled length distributions to age distributions; data collected during the 2005–06 fishing year in EMA 7. Each row gives the proportion at age of each length class. The total number of observations in each length class is also provided.

Males

	Age (years)																										
Length	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	≥ 25	*n*
≤38	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
39	–	–	–	0.33	–	–	–	–	–	–	–	–	0.33	–	–	–	–	0.33	–	–	–	–	–	–	–	–	3
40	–	–	0.08	0.17	0.08	0.08	0.08	0.08	0.17	–	–	0.08	–	–	–	–	0.08	–	0.08	–	–	–	–	–	–	–	12
41	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
42	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
43	–	–	–	0.14	0.29	–	–	–	–	–	–	–	0.29	–	–	0.14	–	0.14	–	–	–	–	–	–	–	–	7
44	–	–	–	–	0.14	0.29	0.14	–	–	–	–	0.14	–	–	–	–	–	–	0.14	–	0.14	–	–	–	–	–	7
45	–	–	–	–	0.2	0.1	0.05	0.05	0.05	–	0.1	0.05	–	–	0.05	0.05	0.05	0.05	–	0.1	0.05	0.05	–	–	–	–	20
46	–	–	–	–	0.05	0.1	0.14	0.05	0.1	0.05	0.05	0.14	0.05	0.05	–	0.05	0.05	0.05	–	–	0.05	0.05	–	–	–	–	21
47	–	–	–	–	–	0.11	0.22	–	–	0.22	0.11	0.11	–	–	0.11	–	–	–	0.11	–	–	–	–	–	–	–	9
48	–	–	–	–	0.04	0.05	0.07	0.11	0.04	0.09	0.04	0.09	0.11	0.02	0.02	0.02	0.07	0.04	0.05	0.05	0.04	0.05	–	–	–	–	55
49	–	–	–	–	–	0.06	–	–	0.06	0.06	0.19	0.06	0.06	–	0.06	–	–	0.12	0.12	0.12	–	0.06	–	–	–	–	16
50	–	–	–	0.09	0.03	–	0.11	0.03	0.06	0.14	0.03	0.03	0.06	0.06	–	0.06	0.03	0.09	0.09	–	0.03	0.06	0.03	–	–	–	35
51	–	–	0.04	–	0.02	0.1	0.02	0.02	0.08	0.02	0.08	0.04	0.04	0.02	0.02	0.06	0.02	0.08	0.1	0.1	0.06	0.06	0.02	0.02	–	–	51
52	–	–	–	–	–	0.33	–	–	–	–	0.33	–	0.33	–	–	–	–	–	–	–	–	–	–	–	–	–	3
53	–	–	–	–	–	–	0.33	–	–	–	–	–	–	–	–	–	–	–	0.33	–	0.33	–	–	–	–	–	3
54																											
≤ 55	–	–	–	–	–	0.5	–	–	–	–	0.25	–	–	–	–	–	0.25	–	–	–	–	–	–	–	–	–	4
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0

Table C2: Continued.

Females

Length	Age (years) 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	≥ 25	*n*
≤ 38	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
39	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
40	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
41	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
42	–	–	–	0.67	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.33	–	–	–	–	–	3
43	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
44	–	–	–	0.1	0.1	0.1	0.3	–	–	0.2	–	0.1	–	–	–	–	0.1	–	–	–	–	–	–	–	–	–	10
45	–	–	0.02	0.02	0.02	0.07	0.07	0.15	0.13	0.09	0.09	0.04	0.02	0.02	0.02	–	0.09	–	0.04	0.04	–	0.02	0.02	0.02	–	–	46
46	–	–	0.06	0.06	0.06	0.06	0.13	–	0.06	0.13	0.06	0.03	0.06	–	–	–	–	0.03	0.06	0.13	–	0.03	–	–	–	–	31
47	–	–	0.03	0.03	–	0.03	0.07	0.1	0.03	0.07	0.14	0.1	0.03	0.03	0.03	–	0.03	0.03	0.1	0.03	0.03	0.03	–	–	–	–	29
48	–	–	–	–	–	0.08	0.08	–	0.08	0.08	0.08	0.08	–	0.08	–	0.15	0.08	0.08	0.08	–	–	0.08	–	–	–	–	13
49	–	–	–	0.02	0.04	0.04	0.02	0.06	0.09	0.08	0.11	0.02	0.06	0.08	0.02	0.04	0.08	0.02	0.08	0.09	0.08	–	–	–	–	–	53
50	–	–	–	0.02	0.02	0.09	0.05	0.07	0.12	0.02	0.07	0.07	0.09	0.02	–	0.09	0.07	0.05	0.05	–	0.05	0.05	–	–	–	–	43
51	–	–	–	–	–	0.4	0.2	–	–	–	–	–	–	–	–	–	0.2	0.2	–	–	–	–	–	–	–	–	5
52	–	–	–	–	–	–	0.2	0.2	–	–	0.2	–	–	–	–	–	–	–	–	–	0.2	0.2	–	–	–	–	5
53	–	–	–	–	–	0.08	–	–	–	0.15	0.08	0.08	–	–	–	–	–	0.08	0.15	0.08	0.15	0.08	0.08	–	–	–	13
54																											
≤ 55	–	–	–	–	–	–	–	–	–	0.33	–	–	–	–	–	0.33	–	–	–	0.33	–	–	–	–	–	–	3
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0