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M. J. Manning[1]
J. A. Devine[1]
P. M. Marriot[1]
P. R. Taylor[2]

[1]NIWA
Private Bag 14901
Wellington

[2]NIWA
P O Box 11115
Hamilton

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EXECUTIVE SUMMARY

Manning, M.J.; Devine, J.A.; Marriott, P.M.; Taylor, P.R. (2007). The length and age composition of the commercial catch of blue mackerel (*Scomber australasicus*) in EMA 1 & 7 during the 2004–05 fishing year.

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Commercial purse-seine catches of blue mackerel in EMA 1 and EMA 7 were sampled during the 2004–05 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".

Thirty-two landings were sampled, 12 789 fish length observations collected, and 456 sagittal otolith pairs collected, prepared, and read from the target purse-seine fishery (PS-EMA) in EMA 1 during the 2004–05 fishing year. All sampling was carried out in fish processing factories. In EMA 7, four landings were sampled from the PS-EMA fishery on shore and seven fishing trips were sampled at sea by MFish observers in the bycatch midwater trawl fishery targeting trachurid mackerels (MW-JMA). A total of 1040 fish length observations were collected from the PS-EMA fishery and 3903 fish length observations were collected from the MW-JMA fishery (total across both fisheries in EMA 7 = 4993 length observations). A total of 490 sagittal otolith pairs were collected, prepared, and read from both fisheries in EMA 7. The data collected from the PS-EMA fisheries in EMA 1 & 7 are thought to be representative of the fisheries. The data collected from the MW-JMA fishery in EMA 7 may be representative of the fishery.

The PS-EMA fishery in EMA 1 is estimated to have accounted for about 92% of the total catch in EMA 1 during the 2004–05 fishing year. The PS-EMA fishery in EMA 7 is estimated to have accounted for about 12% of the total catch in that fishstock and the MW-JMA fishery for about 85% of the total. All landings of blue mackerel by vessels active in the PS-EMA fishery in EMA 7 during the 2004–05 fishing year were sampled.

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 three fisheries. The PS-EMA fishery in EMA 1 was treated as one separate analysis. The PS-EMA and MW-JMA fisheries in EMA 7 were treated as separate analytical strata within the same, separate analysis. Bootstrapped coefficients of variation (c.v.s) and mean-weighted c.v.s (MW c.v.s) were computed for each length- and age class and overall for each length- and age-frequency distribution in each analysis. Results are generally consistent with those from previous fishing years, although the apparent presence of relatively few young fish in each sampled fishery is noted. How much of this is due to gear selectivity effects and how much is due to differential year-class (recruitment) success is unknown.

The PS-EMA fishery in EMA 1 appears to be composed of fish between 2 and 21 years, although most fish present in the catch are between 5 and 15 years of age. The PS-EMA fishery in EMA 7 appears to be composed of fish between 2 and 24 years of age, although most are between 5 and 15 years. The MW-JMA catch-at-age in EMA 7 appears somewhat broader, with fish between 2–24 years represented, and with small peaks between 10 and 11 years in both sexes. The MW c.v. target of 30% was met in the PS-EMA analyses in both EMA 1 and 7, but not in the MW-JMA fishery in EMA 7. Given that the data collected from all three fisheries are thought to be representative of the fisheries, this is probably due to the amount of length-frequency data collected from the MW-JMA fishery, rather than failure to adequately sample the fishery. Maintaining the increased numbers of observed trips allocated to the MW-JMA fishery during the 2005–06 and 2006–07 fishing years and increasing the amount of blue mackerel data collected within a given observed trip are suggested.

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, & 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 amount of 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 and 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 2004–05 fishing year funded by the Ministry of Fisheries (MFish) as research project EMA2004-01. 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 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 2004–05 sampling results are compared with earlier results from the 1997–98 (Morrison et al. 2001), 2002–03 (Manning et al. 2006), and 2003–04 (Manning et al. 2007) fishing years. A brief review of the EMA 1 and 7 fisheries during the 2004–05 fishing year is provided. The representivity of the data collected to the catch sectors sampled is considered. 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 objectives 1 & 6 of project EMA2004-01. An analysis of market variables that may have affected fishing patterns in EMA 1 & 7 during the 2004–05 fishing year is in preparation by Taylor.

2. METHODS

2.1 Catch-effort and landings data

All fishing trips and associated fishing and landing events records where a landing of EMA 1 or 7 was recorded between 1 October 1989 and 30 September 2005 (the 1989–90 to 2004–05 fishing years) were extracted from the Ministry of Fisheries catch-effort and landings database, *warehou* (Duckworth 2002).

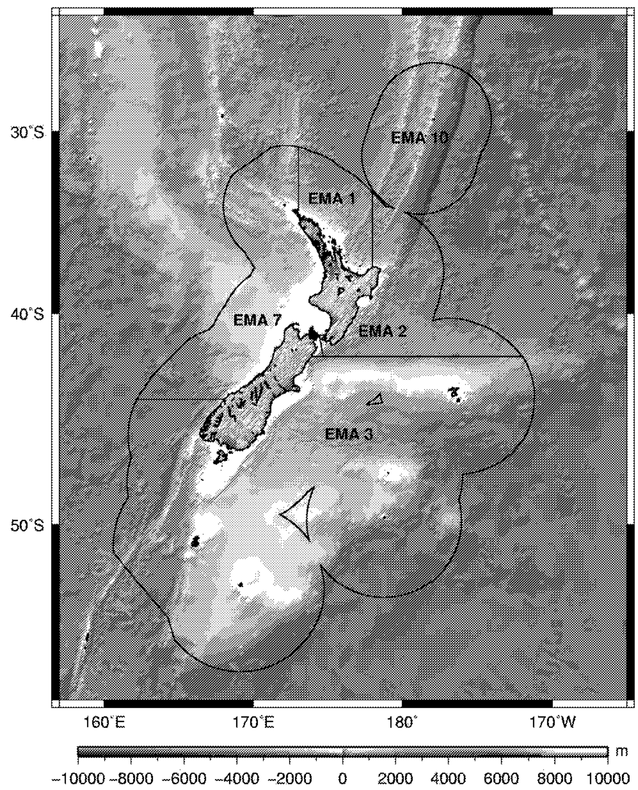

Figure 1: Map of the New Zealand EEZ showing the boundaries of blue mackerel QMAs during the 2004–05 fishing year and the bathymetry of the New Zealand region.

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 2004–05 fishing year were sampled in fish processing factories in Tauranga using a stratified sampling scheme. Landings were not stratified by commercial weight grades as was done in the 2002–03 fishing year (Manning et al. 2006), but were sampled systematically from vessel fishholds (e.g., first compartment starboard side, midship compartment, etc.) during the unloading process. 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 and 2003–04 fishing years, sampling was carried out at the Sanford Ltd factory by Sanford Ltd staff; sampling at a fish processing factory belonging to 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.

Fishing year	EMA 1	EMA 2	EMA 3	EMA 7	EMA 10	Unsp.	QMA 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

pairs in these 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 2004–05. Firstly, landings by purse-seine vessels targeting blue mackerel in EMA 7 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. Secondly, 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). Usually, samples of about 100 fish were randomly selected 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 and from particular trawls where blue mackerel was targeted. 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.

Table 2: Observer coverage (number of days) allocated to the target trachurid mackerel and target blue mackerel fisheries in JMA 7 and EMA 7 during the 2004–05 to 2006–07 financial years (the year ending 30 June) (A. Martin, MFish OP, pers. comm.). *, 2006–07 days achieved are from 1 July 2006 to 1 March 2007.

	Target blue mackerel (EMA 7)		Target trachurid mackerel (JMA 7)	
Financial year	Allocated	Achieved	Allocated	Achieved
2004–05	180	244	20	13
2005–06	399	420	18	17
2006–07	457	338*	20	21*

Sagittal otolith pairs were collected from subsamples of fish randomly sampled for length measurements in each Fisheries Management Area in each observed fishing trip.

Relatively little observer coverage (in terms of the number of observer days at sea) was assigned specifically to target blue mackerel fishing in EMA 7 during the 2004–05 financial year (Table 2). Much more coverage was assigned to target jack mackerel fishing in JMA 7[1], within which blue mackerel are often caught as a bycatch (Taylor 2002), and from which blue mackerel data and specimens can be obtained for analysis. However, 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, the otoliths lodged in the MFish otolith collection, and the data entered into 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). Thus we use the terms "opaque" and "translucent" to 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. We do not use the term "hyaline", and like Kalish et al., suggest that this term is redundant, misleading, and should be abandoned.

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 2004–05 fishing year and prepared and read using the methods of

[1] The EMA 7 and JMA 7 QMAs overlap exactly.

Table 3: 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

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 opaque zones present in each otolith was counted and recorded. A five-point "readability" score and a three-point "margin-state" score were also recorded (Table 3). 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 (P.M. Marriott).

A protocol set of blue mackerel otoliths was developed 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 developed and read before the remaining otoliths were prepared and read.

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 114 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 then re-read by the first reader and read by a second reader (M.J. Manning) and both sets of results compared with the first reader's first set of results. The first and second readers 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

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

and the mean c.v. is

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

where X_{ij} is the ith count of the jth 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 ith fish, $\hat{a}_i$, is

$$\hat{a}_i = t_{i,1} + t_{i,2} + t_{i,3}, \quad (3)$$

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 ith fish was captured. Hence,

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

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 7 was dropped from the analysis. It was the largest fish captured, but was only age 10; the maximum age of fish in EMA 7 was 24 years. No other data grooming was carried out before the analyses.

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

2.4.1 *Catchatage*

Catchatage (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 of Bull & 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 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:

$$\textit{males}:\ w = 3.3743 \times 10^{-6} (l^{3.4047}) \tag{5}$$

$$\textit{females}:\ w = 3.2305 \times 10^{-6} (l^{3.4145}) \tag{6}$$

$$\textit{unsexed}:\ w = 3.3489 \times 10^{-6} (l^{3.4058}) \tag{7}$$

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. 2007). 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 2004–05

The most common gear method and recorded target species were 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 crosstabulated by these variables and divided by the total to yield proportions by weight estimates, which were then multiplied by the total reported catch from the QMS for 2004–05 (EMA 1 = 7920 t; EMA 7 = 4817 t; see Table 1) to yield estimates of the total reported catch partitioned by these factors (Table 4). Purse-seine vessels where blue mackerel was the most common recorded target species dominated the EMA 1 catch in 2004–05, accounting for an estimated 87% of the total catch. Midwater trawl vessels in EMA 7 where trachurid mackerels were the most common recorded target species accounted for about 68% of the total catch.

Partitioning the catch in this manner was done as Manning et al. (2007) showed that the total reported estimated catch in a given fishing trip is, on average, an underestimate of the total reported landed catch, with the latter thought to be a more accurate estimate of total removals. However, the definitions used above may lead to underestimates of the total catch from the fisheries. If, for example, a purse-seine vessel in EMA 1 recorded fishing effort during a particular fishing trip where EMA was targeted but this was not the most-common recorded target species during the trip, its catch will not have been recorded in the PS-EMA cells in Table 4. Broadening the definitions of the target purse-seine fisheries in EMA 1 and 7 to include any fishing trips in both fishstocks where at least one purse-seine set was recorded where EMA was targeted in valid statistical areas for each fishstock, and the midwater trachurid mackerel bycatch fishery in EMA 7 to include all fishing trips where at least one midwater tow was recorded targeting trachurid mackerels in valid statistical areas in EMA 7 yields the following results. Using these definitions, the target purse-seine fishery in EMA 1 accounted for about 92% (7329 t) of the total catch, the target purse-seine fishery in EMA 7 accounted for about 12% (557 t) of the total catch, and the midwater trawl bycatch fishery in EMA 7 accounted for about 85% (4113 t) of the total catch. The catch estimates derived from the broader fishery definitions were used in the following length- and age-frequency calculations.

Table 4: Partitioning the total reported EMA 1 & 7 catches by most common recorded vessel gear method and target species. Estimated proportions by weight of the catch were calculated from catch-effort and landings data and multiplied by the total reported catch from the QMS to yield the total catch estimates given.

EMA 1

Estimated proportions by weight calculated from the effort and landings data

Gear	EMA	JMA	KAH	PIL	SKJ	TRE	Other	Total
BLL	–	–	–	–	–	–	< 0.01	< 0.01
BT	–	–	–	–	–	< 0.01	< 0.01	< 0.01
PS	0.87	0.09	< 0.01	< 0.01	0.02	0.01	–	0.99
SN	–	–	< 0.01	–	–	< 0.01	< 0.01	< 0.01
Other	0.01	< 0.01	< 0.01	–	–	< 0.01	< 0.01	0.01

Total catch estimates

Gear	EMA	JMA	KAH	PIL	SKJ	TRE	Other	Total
BLL	–	–	–	–	–	–	< 1	< 1
BT	–	–	–	–	–	< 1	1	1
PS	6865	729	27	4	152	57	–	7834
SN	–	–	< 1	–	–	< 1	< 1	1
Other	66	11	< 1	–	–	< 1	6	84

EMA 7

Estimated proportions by weight calculated from the effort and landings data

Gear	BAR	EMA	HAK	HOK	JMA	RBT	SBW	SQU	Other	Total
BT	< 0.01	–	< 0.01	< 0.01	–	–	–	< 0.01	< 0.01	< 0.01
MW	0.16	–	–	0.02	0.68	–	0.02	< 0.01	–	0.88
PS	–	0.12	–	–	–	–	–	–	< 0.01	0.12
SN	–	–	–	–	–	–	–	–	< 0.01	< 0.01
Other	–	–	–	–	–	–	–	–	< 0.01	< 0.01

Total catch estimates

Gear	BAR	EMA	HAK	HOK	JMA	RBT	SBW	SQU	Other	Total
BT	< 1	–	< 1	< 1	–	–	–	< 1	5	5
MW	792	–	–	95	3258	–	100	9	–	4253
PS	–	556	–	–	–	–	–	–	< 1	557
SN	–	–	–	–	–	–	–	–	< 1	< 1
Other	–	–	–	–	–	–	–	–	1	1

A more satisfying way of characterising the fishery and deriving these kinds of statistics would be to use a data merging and catch allocation algorithm that allows the effort and landings data to be combined in the same analysis such as that of Starr (2003) and implemented by Manning et al. (2004) among others. However, such an analysis was beyond the scope of this study.

3.2 Summary of sampling results

A total of 32 landings were sampled from the PS-EMA fishery in EMA 1, comprising about 65% of the total reported landed catch in the fishstock generally and about 70% of the total catch from the PS-EMA fishery in particular using the revised definition of the fishery above (Table 5). Monthly sampled catches as a proportion of the total reported monthly catch ranged between 28 and 83%. A total of 12 789 fish were measured and 456 sagittal otolith pairs were collected from the fishery, prepared and read. The temporal distribution of the catch and sampling effort is plotted in Figure 2(a).

Four landings were sampled from the PS-EMA fishery on shore and MFish OP observers were deployed on 7 trips by vessels fishing in the MW-JMA fishery for a total of 11 landings (trips) sampled across both fisheries in EMA 7 (Table 5). The four purse-seine landings sampled were all from April–May 2005. One other landing of blue mackerel caught in EMA 7 was reported by a purse-seine vessel, but this vessel was targeting skipjack tuna (*Katsuwonus pelamis*) throughout its trip and the reported landed blue mackerel catch was very small. The catch sampled from both fisheries represents 65% of the total reported landed catch from the fishstock, comprising virtually all of the catch from the PS-EMA fishery and about 18% of the catch from the MW-JMA fishery. A total of 4993 fish were measured across both fisheries, of which 1040 fish were measured from the PS-EMA fishery, and the remainder, 3903 fish, were measured from the MW-JMA fishery. A total of 490 otolith pairs were collected, prepared, and read from both fisheries. 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 & 7 fisheries suggests that the sampling data collected from EMA 1 are representative of the fishery and that the data collected from EMA 7 may be representative of the fishery. To further investigate whether this is so, the total estimated catch and the total numbers of sets or tows for sampled vessels and the entire fleet in the PS-EMA fishery in EMA 1 by recorded target species and statistical area are plotted in Figure 3, for the PS-EMA fishery in EMA 7 in Figure 4, and for the MW-JMA fishery in EMA 7 in Figure 5. A close match between the estimated catch proportions for the sampled sector of each fleet and the fleet as a whole suggests that 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.

Close matches are noted between the distributions of (estimated) catch and numbers of purse-seine sets in the PS-EMA fishery in EMA 1. The distributions of catch and numbers of sets are identical for the PS-EMA fishery in EMA 7, as well they should be given that every fishing trip where blue mackerel was targeted in EMA 7 during the 2004–05 fishing year was sampled. The distributions of catch and numbers of tows are fairly close between the sampled sector of the MW-JMA fishery and the fleet as whole in EMA 7, although some slight divergences are noted, in particular the amount of estimated catch caught when blue mackerel was targeted is higher in the sampled sector of the fleet compared with the fleet as a whole although the total number of tows is only slightly different. This suggests that catch rates, or at least reporting practices, may have been slightly different aboard the sampled vessels than was the norm throughout the fleet during 2004–05. Nevertheless, overall, the data collected are thought to be representative of the PS-EMA fisheries in EMA 1 and 7 and are probably representative of the MW-JMA fishery in EMA 7.

3.3 Otolith reading results

Precision and apparent accuracy in the otolith readings was very encouraging relative to performances in the earlier studies. 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 9.42% and 6.66%, respectively. The symmetry in Figure 6(a), the clustering of points about the zero-line in Figure 6(b) and the one-to-one line in Figure 6(c), and the relative flatness of the c.v. and APE profiles in Figure 6(d) all suggest that there

Table 5: Summary of total reported landed catches and numbers of reported landings by month for EMA 1 and 7 over the 2004–05 fishing year. The total reported catch and the sampled catch by month are provided. Sampled catches as a percentage by weight of the total reported catch for each month are given in parentheses. All reported landings, all purse-seine landings, all purse-seine landings where the total reported catch was greater than 10 t, and all sampled landings by month are provided.

EMA 1

		Landed catch (greenweight kg)			Numbers of landings		
Year	Month	Total	Sampled	(%)	All	PS > 10 t	Sampled
2004	Oct	2 251 527	1 543 096	(69)	25	21	8
	Nov	1 293 943	800 811	(62)	23	15	5
	Dec	2 668 857	2 209 679	(83)	16	15	10
2005	Jan	644 357	252 585	(39)	11	8	3
	Feb	75 770	–	–	4	3	–
	Mar	361 901	102 357	(28)	12	7	2
	Apr	250 056	139 548	(56)	9	4	2
	May	36 701	–	–	11	1	–
	Jun	64 030	–	–	9	3	–
	Jul	180	–	–	1	–	–
	Aug	148 315	53 835	(36)	17	5	2
	Sep	109 041	–	–	24	3	–
	Total	7 904 678	5 101 911	(65)	162	85	32

EMA 7

		Landed catch (greenweight kg)			Numbers of landings			
Year	Month	Total	Sampled	(%)	All	BT-MW > 10 t	PS > 10 t	Sampled
2004	Oct	1 140 442	84 816	(7)	45	9	–	2
	Nov	211 168	35 352	(17)	24	4	–	2
	Dec	392 847	99 286	(25)	25	3	–	1
2005	Jan	439 920	–	–	29	6	–	–
	Feb	12 854	–	–	30	–	–	–
	Mar	241	–	–	18	–	–	–
	Apr	296 851	296 412	(100)	13	–	3	2
	May	281 271	275 093	(98)	13	–	2	2
	Jun	48 171	–	–	10	1	–	–
	Jul	777 838	11 775	(2)	44	7	–	1
	Aug	1 349 287	423 528	(31)	26	4	–	1
	Sep	1 367	–	–	12	–	–	–
	Total	4 952 257	1 226 262	(25)	289	34	5	11

was a good level of consistency between readers, suggesting that there were no or few systematic differences (bias) in interpretation of blue mackerel otoliths in this study. The *slight* positive weighting in Figure 6(a) may mean that the second reader is *slightly* under-counting opaque zones present relative to the first reader (e.g., an "off-by-one" error where there is an inconsistency between readers in identifying the first true opaque zone present). Between-reader precision was markedly better in this study than in the two earlier New Zealand studies (Manning et al. 2006, 2007) where reader error was investigated (between-reader mean c.v.s of 14.42% and 14.92%, respectively). Morrison et al. (2001) did not attempt to quantify or investigate reader error.

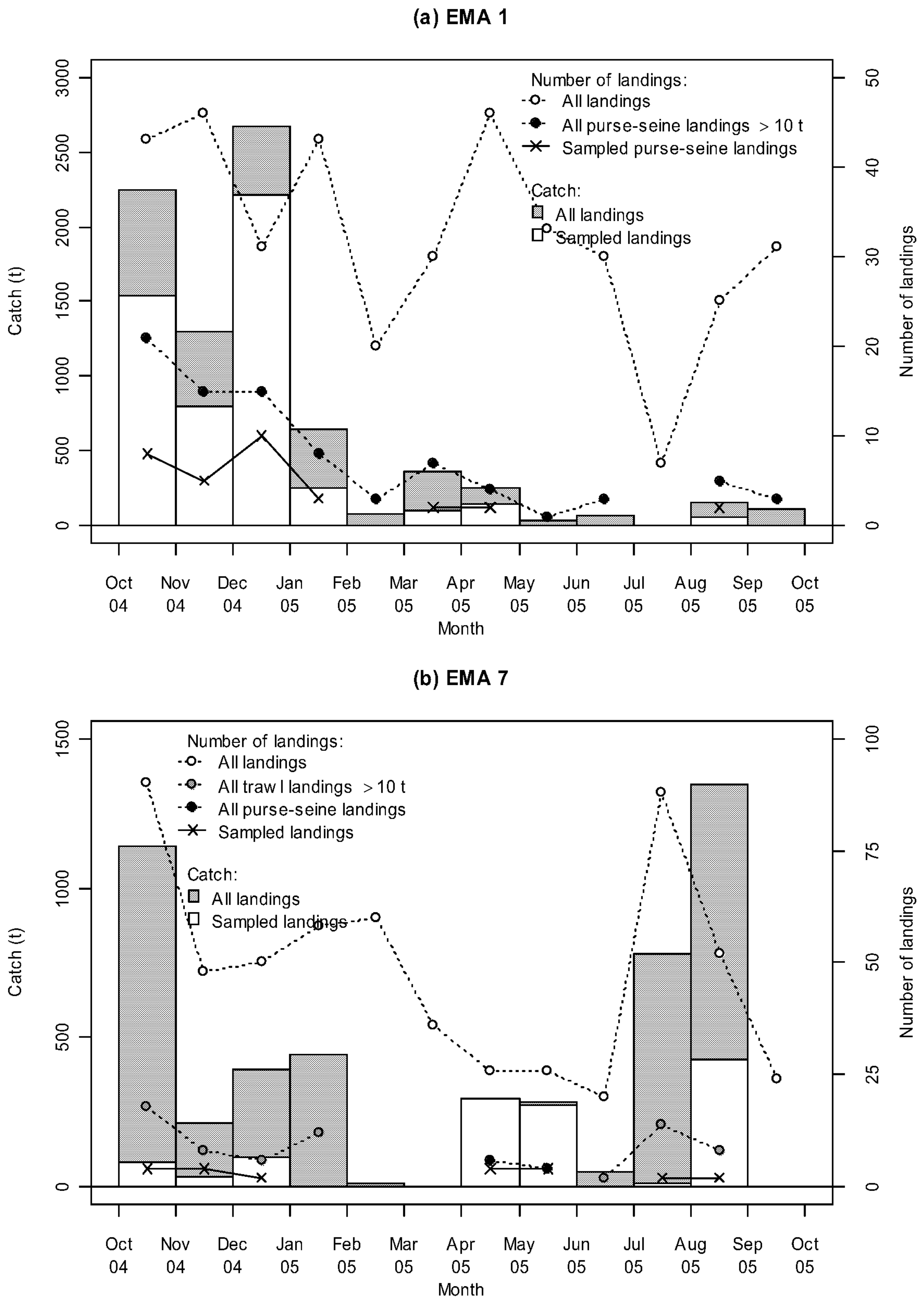

Figure 2: **Summaries of fishing and sampling activity for (a) EMA 1 and (b) EMA 7 during the 2004–05 fishing year. Histograms of the total reported landed (grey bars) and sampled (white bars) catch are overlaid on each plot. Numbers of landings by selected fleets in each area are also overlaid for comparison with the sampled landings.**

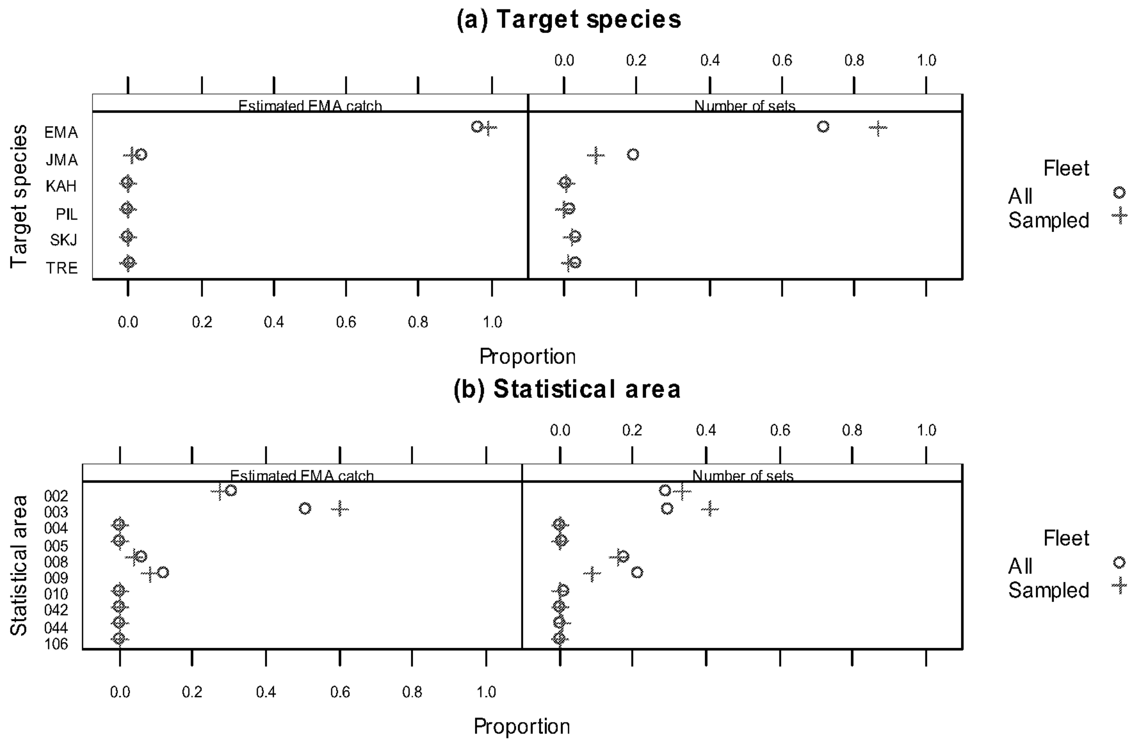

Figure 3: **Comparing the total reported estimated catch and number of sets by (a) target species and (b) statistical area for the PS-EMA fishery in EMA 1 during the 2004–05 fishing year for all sampled landings and the fleet as a whole (plotted separately and overlaid).**

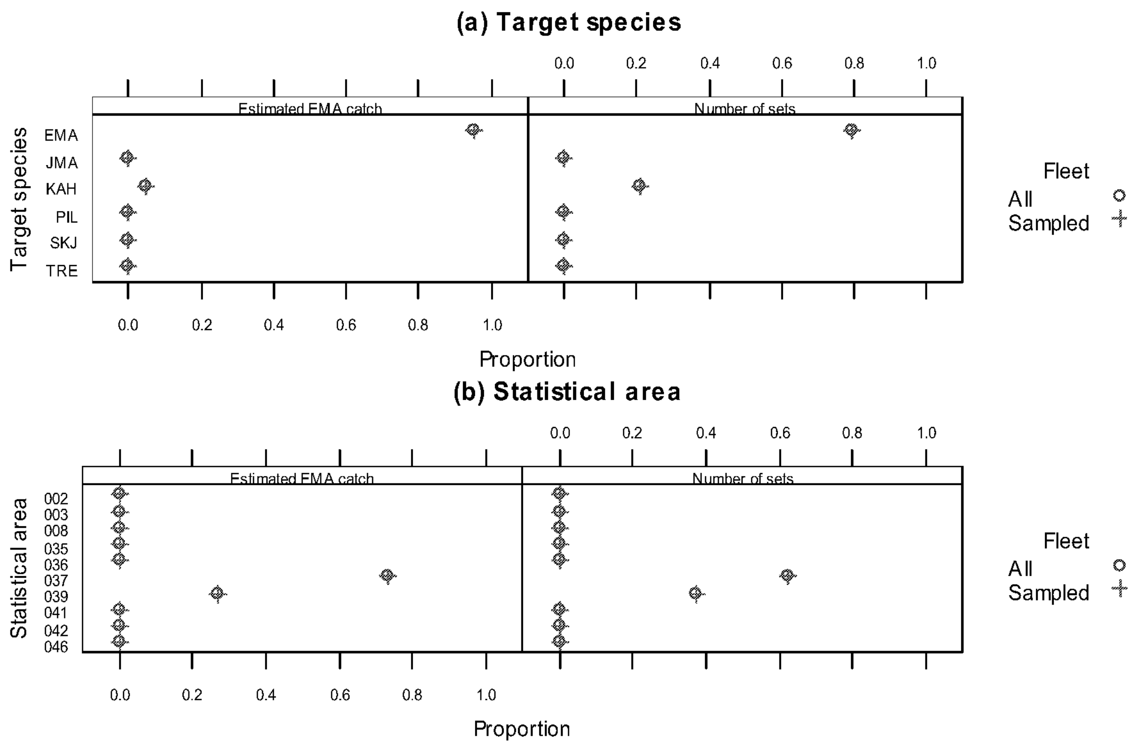

Figure 4: **Comparing the total reported estimated catch and number of sets by (a) target species and (b) statistical area for the PS-EMA fishery in EMA 7 during the 2004–05 fishing year for all sampled landings and the fleet as a whole (plotted separately and overlaid).**

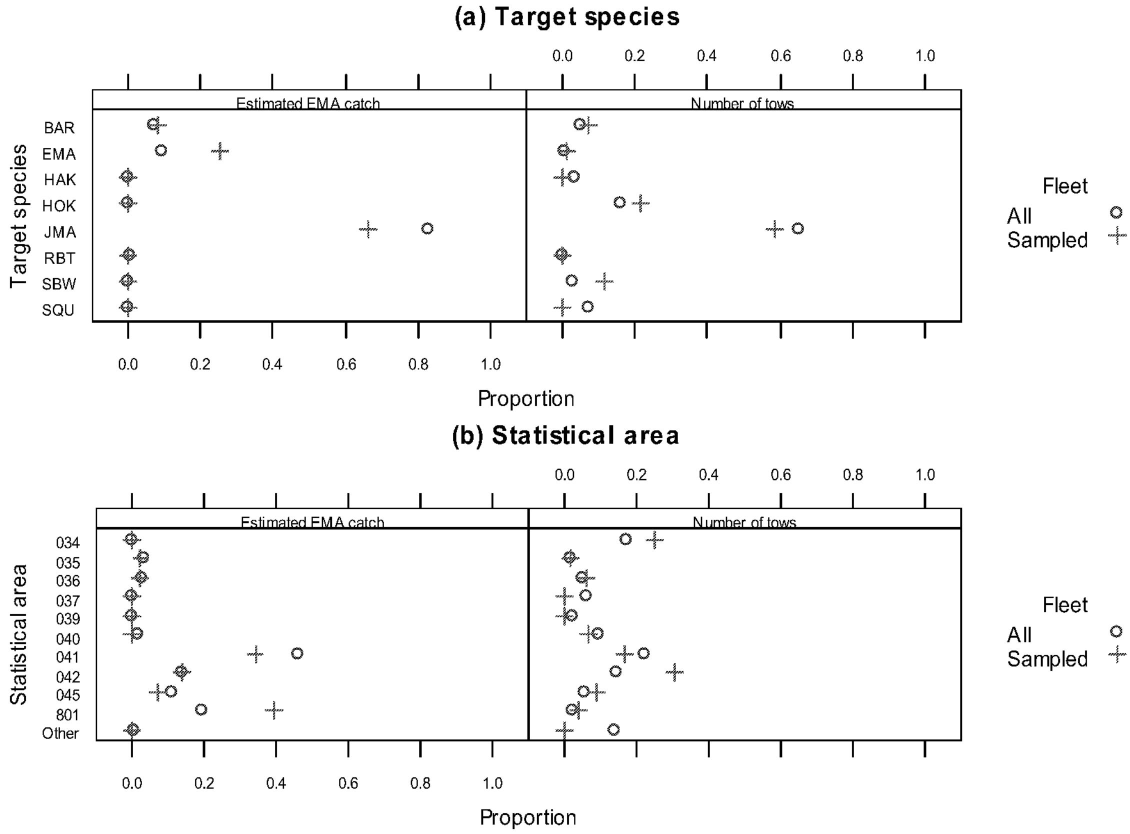

Figure 5: Comparing the total reported estimated catch and number of tows by (a) target species and (b) statistical area for the MW-JMA fishery in EMA 7 during the 2004–05 fishing year for all sampled landings and the fleet as a whole (plotted separately and overlaid).

3.4 Length- and age-frequency distributions

The estimated scaled proportions-at-length distributions calculated for all three fisheries are plotted in Figure 7. Cumulative proportions-at-length for the 1997–98, 2002–03, 2003–04, and 2004–05 fishing years are plotted and compared in Figure 8. The estimated scaled proportions-at-age distributions calculated by applying the age-length keys derived from the prepared and read otoliths are plotted in Figure 9. Cumulative proportions-at-age for the 1997–98, 2002–03, 2003–04, and 2004–05 fishing years are plotted and compared in Figure 10.

All length distributions were roughly centred around 45 cm, with no fish smaller than about 35 cm or larger than 55 cm present in any of the three fisheries sampled. The cumulative proportions-at-length by sex for EMA 1 suggests that the catch in 2004–05 contained slightly larger males than in past years (1997–98, 2002–03, or 2003–04); females are roughly the same size as past years (Figure 8). A higher proportion of females was captured in 2004–05 than in previous years. The estimated scaled proportions-at-length in EMA 7 for males and females in the MW-JMA fishery showed one main mode centred around 48 cm (Figure 7b). Fish in the PS-EMA fishery in EMA 7 appear to be slightly smaller than those captured in the trawl fishery (Figure 7b). The distributions of all fish, males, and females was strongly unimodal in the purse-seine fisheries in both EMA 1 & 7.

The estimated scaled proportions-at-age show that catches in the PS-EMA fishery in EMA 1 were mostly of fish 5–15 years old, although fish as old as 21 appear to be present in the catch (Figure 9a). The cumulative proportions-at-age plotted in Figure 10 suggest that there are relatively more older fish

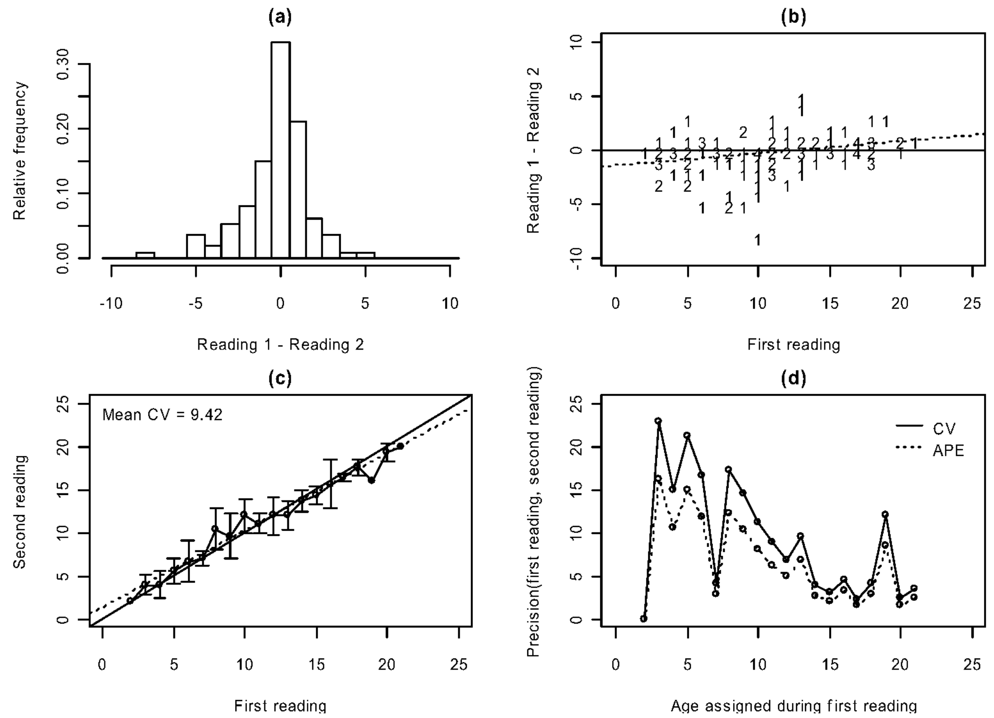

Figure 6: Results of the between-reader comparison test: (a) histograms of differences between readings for the same otolith; (b) differences between the first and second reading for a given age assigned during the first reading; (c) bias plots; and (d) c.v. and APE profiles relative to the ages assigned 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).

in the catch in EMA 1 in 2004–05 than in previous fishing years. It also appears that there are relatively fewer younger fish entering the catch (Figure 11). The 1999 year class appears to be the last strong year class to recruit to the fishery; there were very few fish 2–4 years of age present in the catch in 2004–05 (Figure 11). This trend is consistent across both sexes. How much of this is due to gear selectivity effects and how much is due to true differential year-class (recruitment) success is unknown at this time.

There are different patterns between the strata in the proportions-at-age distributions calculated for the PS-EMA and MW-JMA fisheries in EMA 7. The PS-EMA catch appears to be composed of younger fish, with most of the fish caught also apparently between the ages of 5 and 15 years, although the tail stretches out to at least 22 years (Figure 9c); the MW-JMA catch appears to be broader, and is made up of fish between 5 and 24 years, with a small peak at around 10–11 years in both sexes (Figure 9b). There were very few fish in the MW-JMA catch younger than 5 years in 2003–04 (Manning et al. 2007), but this also appears to be the case in 2004–05 as well.

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 6. The MW c.v.s for the catch-at-length for both sexes and for all fish were higher in EMA 7 than in EMA 1, reflecting the reduced amount of data available for that analysis relative to the EMA 1 analysis (roughly one-third the number of sampled landings and one-fourth as many fish length observations across both fisheries compared with the PS-EMA fishery sampled in EMA 1). Nevertheless, the representivity analysis above suggests that these results are probably representative of the fisheries sampled (the data collected from the PS-EMA fishery in EMA 7 certainly are, given that all landings in this fishery during the 2004–05 fishing year were sampled). These results are imprecise rather than inaccurate. The MW c.v. for all fish in the PS-EMA fishery stratum in the EMA 7 analysis (25.1%) was within the 30% target (MW c.v.s 34–35% across the sexes). In contrast, the MW c.v. for all fish in the MW-JMA stratum (68.7%) exceeded the target by

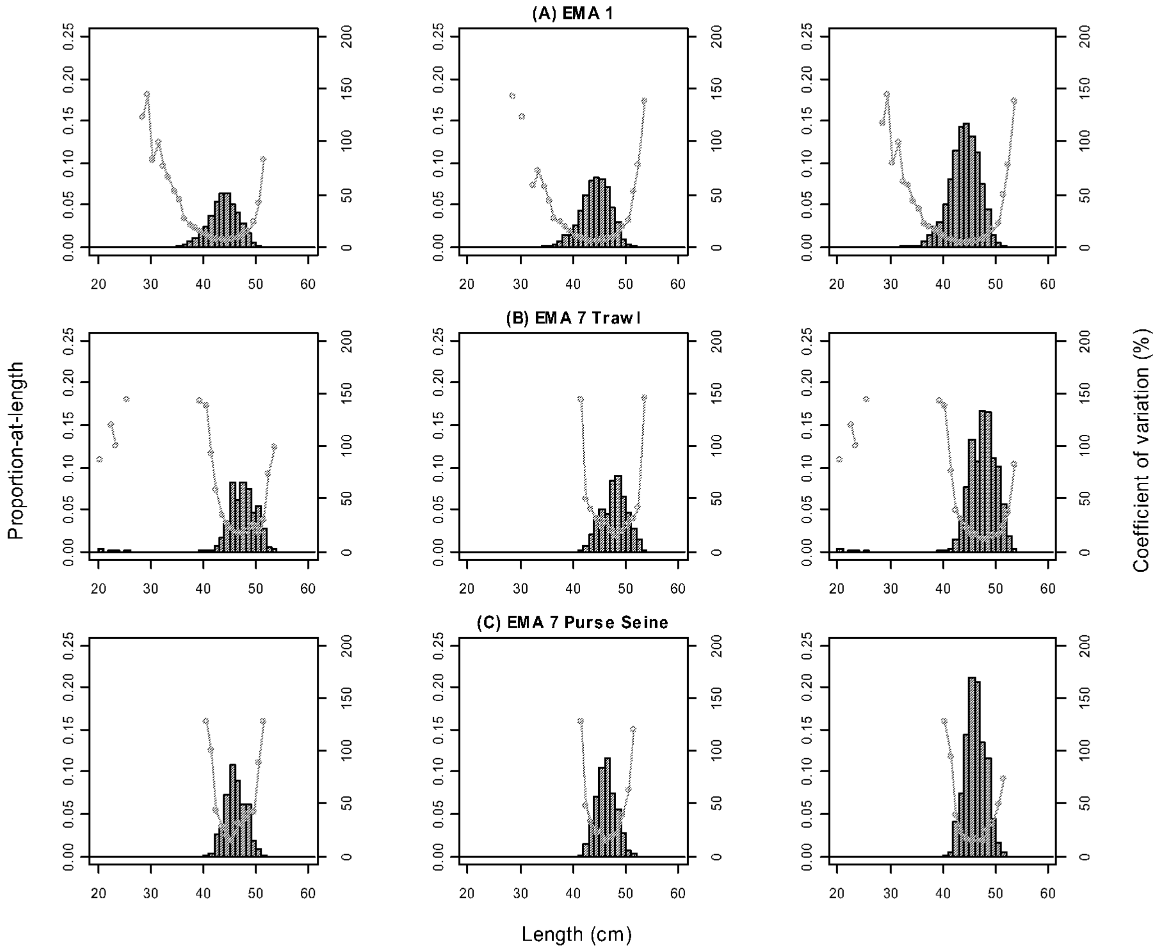

Figure 7: Estimated scaled proportions-at-length for male, female, and all fish combined for the EMA 1 purse-seine fishery and EMA 7 trawl and purse-seine fisheries in the 2004–05 fishing year with bootstrapped 95% coefficient of variation for each length class.

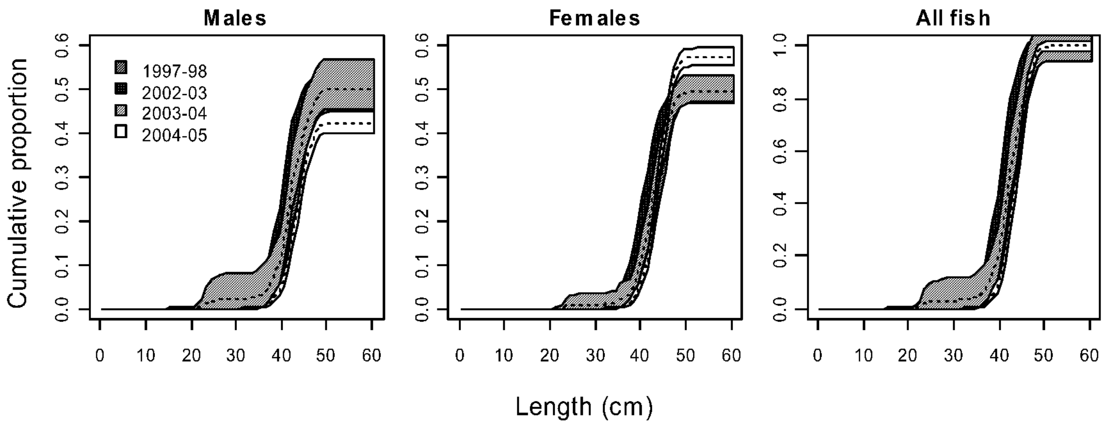

Figure 8: Overlaid cumulative proportions-at-length from data collected during the 2004–05 fishing year in EMA 1 and previous years (1997–98, 2002–03, 2003–04). The dashed line in each plot is the cumulative proportion-at-length or age and the surrounding region is a bootstrapped 95% confidence region about the cumulative proportion-at-length.

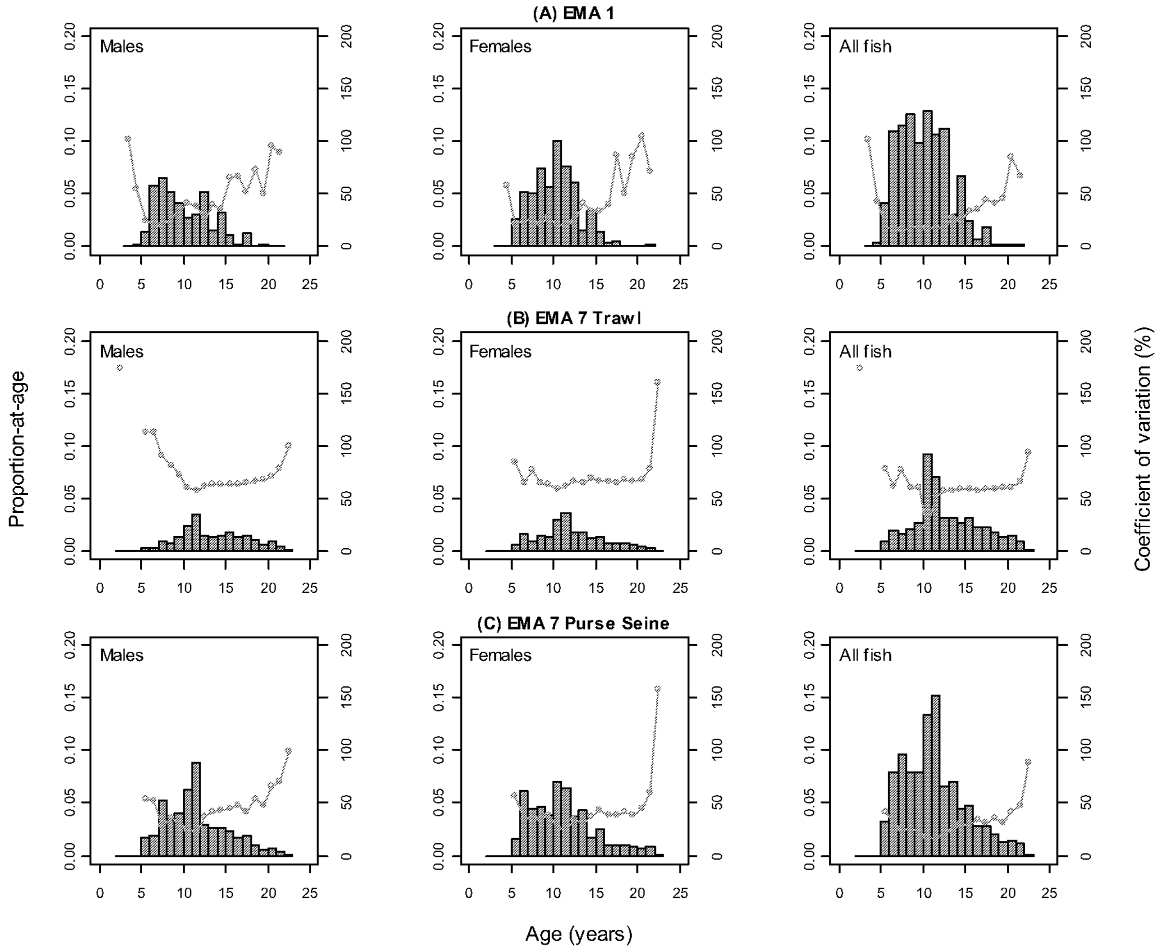

Figure 9: Estimated scaled proportions-at-age for male, female, and all fish combined for the EMA 1 purse-seine fishery and EMA 7 trawl and purse-seine fisheries in the 2004–05 fishing year with bootstrapped 95% coefficient of variation for each length class.

Figure 10: Overlaid cumulative proportions-at-age calculated from data collected during the 2004–05 fishing year in EMA 1 and previous years (1997–98, 2002–03, 2003–04). 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.

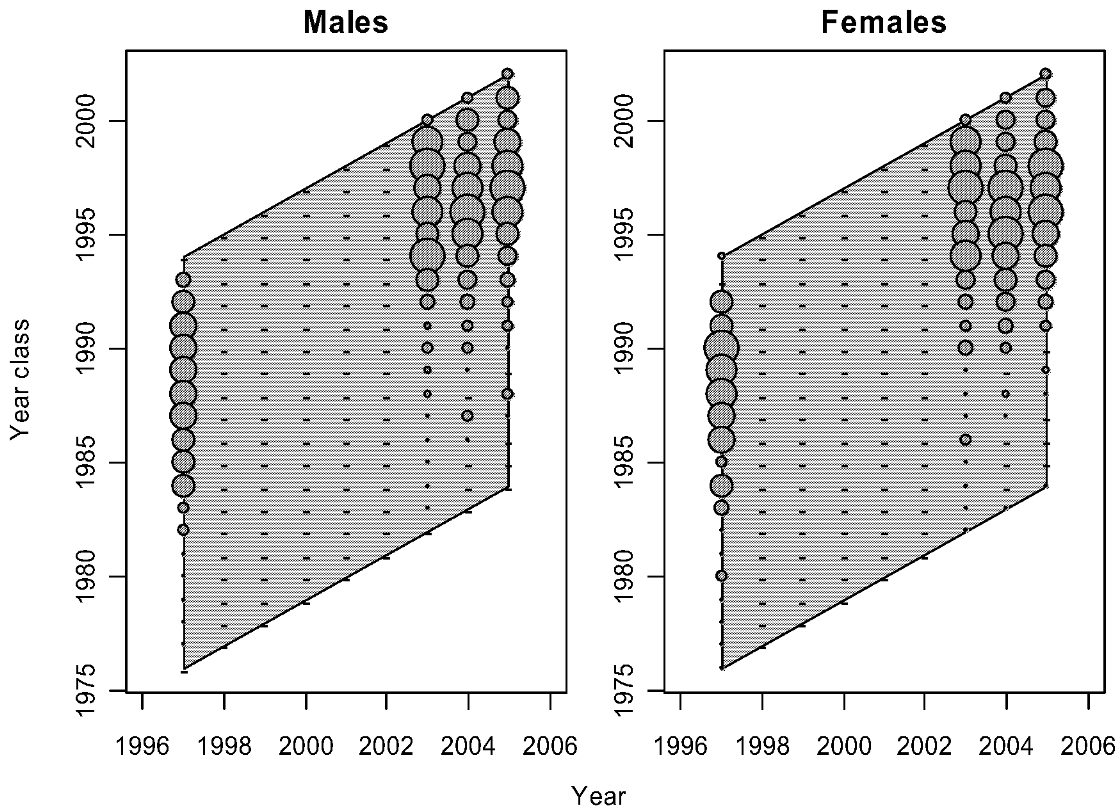

Figure 11: Estimated scaled proportions-at-age (ages 2 to 20 years) by year class and fishing year for males and females in the EMA 1 purse-seine fishery over the 1997–98 to 2004–05 fishing years. Circle area is proportional to the corresponding proportion-at-age within each sampling event. Circle size 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.

Table 6: Mean-weighted coefficients of variation (%) for the scaled length- and age-frequency distributions calculated for EMA 1 & 7 by fishstock, analysis stratum, and sex. The analysis for each fishstock was carried out separately.

Length

					Sex
Fishstock	Stratum	Males	Females	Unsexed	All fish
EMA 1	PS-EMA	9.7	8.4	–	6.9
EMA 7	PS-EMA	29.7	24.6	–	20.3
	MW-JMA	59.0	64.5	37.9	20.6
	Total	46.1	48.9	37.9	18.4

Age

					Sex
Fishstock	Stratum	Males	Females	Unsexed	All fish
EMA 1	PS-EMA	31.6	25.9	–	20.4
EMA 7	PS-EMA	34.8	35.1	–	25.1
	MW-JMA	55.4	63.4	87.1	68.7
	Total	46.2	51.3	87.1	61.3

roughly a factor of two (MW c.v.s. 63–87% across the sexes). The MW c.v. for all fish in the PS-EMA fishery in the EMA 1 analysis (20.4%) was well within the 30% target and ranged between 25 and 29% across the sexes.

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 MW c.v. targets for the PS-EMA catch-at-age in the EMA 1 & 7 analysis were met. Although the target for the MW-JMA catch-at-age was not met, given that the data are representative of the fishery, these results should be regarded as reflecting imprecision in the data rather than inaccuracy or bias in its collection. We suggest a two fold approach to improve precision in future catch-at-age sampling in this fishery.

Firstly, we recommend that the increased number of observer days that have been allocated to the MW-JMA fishery in subsequent fishing years be maintained. Typically, most of the variation in fish length and other quantities observed in sampling programmes such as this is between rather than within fishing trips. Increasing the number of fishing trips (or landings) sampled will likely produce a gain (decrease) in the MW c.v. achieved in the catch-at-age. Increasing the number of days allocated obviously increased the number of individual trips that can be covered. We note the increases in both the allocated and achieved observer days in the MW-JMA fishery during the 2005–06 and 2006–07 fishing years compared with 2004–05 (see Table 2) and suggest that these be maintained or further increased if warranted (see below).

Secondly, we recommend that the frequency with which blue mackerel length observations are collected from the catch in observed trips be increased. The sampling scheme in the MFish OP manual (Sutton 2002) states that observers should aim to collect length-frequency and other data for bycatch species from a sample of about 100–150 fish every two to three days. We strongly recommend that the frequency with which blue mackerel are sampled during observed trips in this fishery be increased. We suggest that blue mackerel should be added to the trachurid mackerel sampling scheme in this fishery and that blue mackerel data should be collected from every tow where they are caught rather than once a day or less often during the fishing trip.

However, we note that determining the optimum level of sampling effort for the catch-at-age in the MW-JMA fishery in EMA 7 will require a simulation study that is also beyond the scope of this study. However, if catch-at-age sampling in these fisheries is carried out in future fishing years, we recommend a quantitative evaluation of the sampling design. The adequacy of the age-length key approach for these fisheries should also be considered, given that more catch appears to be being caught from months outside (i.e., later than) the usual July–December season. The data collected from this fishery during the 2004–05 to 2006–07 fishing years may be sufficient to facilitate such an analysis.

4.2 Apparent trends in the catch-at-length and catch-at-age in EMA 1 & 7 during the 2004–05 fishing year

The 2004–05 catch-at-length for EMA 1 and EMA 7 have no distinct modes of smaller, and presumably younger, fish entering the catch that may correspond to recruitment pulses. No young-of-the-year and age 1 fish are present in the catch-at-age for either QMA. This probably reflects the selectivity of commercial purse-seine gear with smaller fish less vulnerable to the gear and hence under-represented in the catch, and size-selective fishing effort where fishers prefer to target schools with particular size compositions, rather than poor recruitment. Blue mackerel schools are composed mostly of fish of the same size and young fish probably are not as vulnerable to commercial purse-seine gear nor as attractive to the market as older and larger fish. From the shape of the catch-at-age, blue mackerel are probably fully recruited to the purse-seine fishery in EMA 1 at age 8–10 and 45 cm in fork length. Blue mackerel in EMA 7 appear to be fully recruited to the trawl fisheries by age 12 and 47–48 cm fork length, and fully recruited to the purse-seine fishery by age 12 and 45–46 cm fork length. As noted, the results of the between-reader comparison test were very encouraging compared to results in earlier studies, suggesting no reason to doubt the validity, and hence the extrapolability, of the age data produced and the conclusions drawn from these data.

4.3 Comparing the 2004–05 catches-at-length and catches-at-age to previous years

There was a higher proportion of females caught in 2004–05 than in previous years. Catches-at-length show the size of fish caught in EMA 1 in 2004–05 is slightly larger than in previous years. Catches-at-age in 2004–05 in EMA 1 are made up of fish older than in previous years and fewer younger fish are being captured in the purse-seine fishery. How much of the relative lack of young fish in the fisheries sampled is due to gear selectivity effects and how much is due to true differential year-class (recruitment) success is unknown. Nevertheless, the fisheries appear to be continuing to exploit a number of successful year classes.

5. ACKNOWLEDGMENTS

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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.)

Bull, B.; Gilbert, D.J. (2001). Catch-at-age sampling. *New Zealand Fisheries Assessment Report 2001/53*. 19 p.

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.

Chang, W.Y.B. (1982). A statistical method for evaluating the reproducibility of age determination. *Canadian Journal of Fisheries and Aquatic Sciences 39*: 1208–1210.

Davies, N.M.; Hartill, B.; Walsh, C. (2003). A review of methods used to estimate snapper catch-at-age and growth in SNA 1 and SNA 8. *New Zealand Fisheries Assessment Report 2003/10*. 63 p.

Duckworth, K. (2002). Catch-effort reference library. Version 1.0. CD–ROM available from Ministry of Fisheries, Feltex House, 156–158 Victoria Street, Wellington.

Fisher, D.O.; Mackay, K.A. (2000). Database documentation: *market*. NIWA Internal Report 93. 37 p. (Unpublished report held in NIWA library, Wellington.)

Francis, R.I.C.C.; Paul, L.J.; Mulligan, K.P. (1992). Ageing of adult snapper (*Pagrus auratus*) from otolith annual ring counts: validation by tagging and oxytetracycline injection. *Australian Journal of Marine and Freshwater Research 43*: 1069–1089.

Kalish, J.M.; Beamish, R.J.; Brothers, E.B.; Casselman, J.M.; Francis, R.I.C.C.; Mosegaard, H.; Panfilli, J.; Prince, E.D.; Thresher, R.E.; Wilson, C.A.; Wright, P.J. (1995). Glossary for otolith studies. pp. 723–729. *In*: Secor, D.H.; Dean, J.M.; Campana, S.E. (eds). Recent developments in fish otolith research. University of South Carolina Press, Columbia.

Mackay, K.A. (2001). Database documentation: *rdb*. NIWA Internal Report. 34 p. (Unpublished report held in NIWA library, Wellington.)

Mackay, K.A.; George, K. (2000). Database documentation: *age*. NIWA Internal Report 68. 35 p. (Unpublished report held in NIWA library, Wellington.)

Manning, M.J.; Hanchet, S.M.; Stevenson, M.L. (2004). A description and analysis of New Zealand's spiny dogfish (*Squalus acanthias*) fisheries and recommendations on appropriate methods to monitor the status of the stocks. *New Zealand Fisheries Assessment Report 2004/61*. 135 p.

Manning, M.J.; Marriott, P.M.; Taylor, P.R. (2006). The length and age composition of the commercial catch of blue mackerel (*Scomber australasicus*) in EMA 1 during the 2002–03 fishing year, including a comparison with data collected during the 1997–98 fishing year, and some remarks on estimating blue mackerel ages from otoliths. *New Zealand Fisheries Assessment Report 2006/42*. 42 p.

Manning, M.J.; Marriott, P.M.; Taylor, P.R. (2007). The length and age composition of the commercial catch of blue mackerel (*Scomber australasicus*) in EMA 1 during the 2003–04 fishing year. *New Zealand Fisheries Assessment Report 2007/13*. 41 p.

Ministry of Fisheries (2006). Report from the Fishery Assessment Plenary, May 2006: stock assessments and yield estimates. 875 p.

Morrison, M.A.; Taylor, P.R.; Marriott, P.M.; Sutton, C.P. (2001). An assessment of information on blue mackerel (*Scomber australasicus*) stocks. *New Zealand Fisheries Assessment Report 2001/44*. 26 p.

R Development Core Team (2005). R: A language and environment for statistical computing. Version R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org.

Sanders, B.M.; Mackay, K.A. (2004). Database documentation: *obs_lfs*. NIWA Fisheries Data Management Database Documentation Series. 64 p. (Unpublished report held in NIWA library, Wellington.)

Sanders, B.M.; Mackay, K.A. (2005). Database documentation: *obs*. NIWA Fisheries Data Management Database Documentation Series. 39 p. (Unpublished report held in NIWA library, Wellington.)

Starr, P.J. (2003). Procedure for merging MFish landing and effort data. Version 1.0. 13 p. (Unpublished report available from the author: paul@starrfish.net.)

Stewart, J.; Ferrell, D.J.; Andrew, N.L. (1999). Validation of the formation and appearance of annual marks in the otoliths of yellowtail (*Trachurus novaezelandiae*) and blue mackerel (*Scomber australasicus*) in New South Wales. *Australian Journal of Marine and Freshwater Research 50*: 389–395.

Sutton, C.P. (ed.) (2002). Biological data collection manual for Ministry of Fisheries observers. Unpublished technical manual held by Ministry of Fisheries, Wellington. 476 p.

Taylor, P.R. (2002). A summary of information on blue mackerel (*Scomber australasicus*), characterisation of its fishery in QMAs 7, 8, and 9, and recommendations on appropriate methods to monitor the status of this stock. *New Zealand Fisheries Assessment Report 2002/50*. 68 p.

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 2004–05 fishing season and scaled to the total reported catch landed for EMA 1.

	Males		Females		Unsexed		All	
Length	NAL	c.v. (%)	NAL	c.v. (%)	NAL	c.v. (%)	NAL	c.v. (%)
≤ 25	–	–	–	–	–	–	–	–
26	–	–	–	–	–	–	–	–
27	–	–	–	–	–	–	–	–
28	345	129.1	173	142.6	–	–	518	120.5
29	173	146.2	–	–	–	–	173	146.2
30	859	83.8	493	119.7	–	–	1 352	77.3
31	487	96.7	–	–	–	–	487	96.7
32	2 344	79.2	1 559	61.9	–	–	3 903	64.5
33	1 926	64.4	832	68.7	–	–	2 758	58.1
34	2 162	52.9	3 209	60.3	–	–	5 370	44.6
35	4 872	42.4	4 542	43.9	–	–	9 414	33.7
36	21 936	27.6	19 278	26.8	–	–	41 214	23.3
37	46 051	21.4	43 869	23.9	–	–	89 920	20.2
38	65 986	18.9	79 785	18.5	–	–	145 771	16.7
39	95 706	15.5	80 670	15.5	–	–	176 376	13.3
40	140 979	12.4	153 456	10.6	–	–	294 436	9.8
41	225 491	9.3	255 149	8.9	–	–	480 640	7.2
42	316 588	7.0	365 051	7.1	–	–	681 640	5.5
43	376 388	7.2	465 657	5.9	–	–	842 046	4.8
44	376 835	6.2	490 547	6.0	–	–	867 382	4.1
45	303 958	7.4	481 616	5.8	–	–	785 573	4.4
46	242 710	7.7	423 195	6.6	–	–	665 904	5.2
47	164 897	10.2	282 617	8.0	–	–	447 514	6.5
48	94 382	14.2	176 717	9.6	–	–	271 100	8.8
49	29 245	23.7	55 443	17.4	–	–	84 689	14.1
50	8 345	38.3	23 030	22.8	–	–	31 374	19.9
51	1 568	82.2	5 481	44.8	–	–	7 049	43.5
52	–	–	1 975	68.8	–	–	1 975	68.8
53	–	–	74	139.9	–	–	74	139.9
54	–	–	–	–	–	–	–	–
≥55	–	–	–	–	–	–	–	–
Total	2 524 233		3 414 418		0		5 938 652	
MWCV (%)	9.7		8.4		–		6.9	

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 June 2004-Sept 2005 and scaled to the total reported catch landed by purse-seines in the 2004–05 fishing season for EMA 7.

	Males		Females		Unsexed		All	
Length	NAL	c.v. (%)	NAL	c.v. (%)	NAL	c.v. (%)	NAL	c.v. (%)
≤ 20	–	–	–	–	–	–	–	–
21	–	–	–	–	–	–	–	–
22	–	–	–	–	–	–	–	–
23	–	–	–	–	–	–	–	–
24	–	–	–	–	–	–	–	–
25	–	–	–	–	–	–	–	–
26	–	–	–	–	–	–	–	–
27	–	–	–	–	–	–	–	–
28	–	–	–	–	–	–	–	–
29	–	–	–	–	–	–	–	–
30	–	–	–	–	–	–	–	–
31	–	–	–	–	–	–	–	–
32	–	–	–	–	–	–	–	–
33	–	–	–	–	–	–	–	–
34	–	–	–	–	–	–	–	–
35	–	–	–	–	–	–	–	–
36	–	–	–	–	–	–	–	–
37	–	–	–	–	–	–	–	–
38	–	–	–	–	–	–	–	–
39	–	–	–	–	–	–	–	–
40	678	127.9	–	–	–	–	678	127.9
41	1 356	102.4	678	128.5	–	–	2 034	96.5
42	9 333	47.0	5 544	46.4	–	–	14 878	41.1
43	11 888	28.4	15 277	35.2	–	–	27 165	25.4
44	26 887	21.0	25 809	23.0	–	–	52 696	17.6
45	39 573	14.4	38 254	26.4	–	–	77 827	16.2
46	32 915	29.5	42 806	14.2	–	–	75 721	14.6
47	22 262	27.9	27 286	18.4	–	–	49 549	13.1
48	22 383	41.0	20 386	20.9	–	–	42 769	24.7
49	6 343	40.3	10 253	35.6	–	–	16 597	29.3
50	3 232	88.4	2 433	64.2	–	–	5 665	48.3
51	678	127.1	1 077	121.1	–	–	1 755	71.3
52	–	–	–	–	–	–	–	–
53	–	–	–	–	–	–	–	–
54	–	–	–	–	–	–	–	–
≥55	–	–	–	–	–	–	–	–
Total	177 528		189 803		0		367 334	
MWCV (%)	29.7		24.6		–		20.3	

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 June 2004-Sept 2005 and scaled to the total reported catch landed by trawls in the 2004–05 fishing season for EMA 7.

	Males		Females		Unsexed		All	
Length	NAL	c.v. (%)	NAL	c.v. (%)	NAL	c.v. (%)	NAL	c.v. (%)
≤ 20	115	108.9	–	–	–	–	115	108.9
21	–	–	–	–	–	–	–	–
22	60	139.9	–	–	–	–	60	139.9
23	55	114.6	–	–	–	–	55	114.6
24	–	–	–	–	–	–	–	–
25	30	166.4	–	–	–	–	30	166.4
26	27	161.6	–	–	–	–	27	161.6
27	–	–	–	–	–	–	–	–
28	–	–	–	–	–	–	–	–
29	–	–	–	–	–	–	–	–
30	–	–	–	–	–	–	–	–
31	–	–	–	–	–	–	–	–
32	–	–	–	–	–	–	–	–
33	–	–	–	–	641	160.5	641	160.5
34	–	–	–	–	1 269	105.7	1 269	105.7
35	–	–	–	–	537	151.0	537	151.0
36	38	157.7	77	136.6	2 322	77.9	2 438	73.2
37	63	150.0	–	–	–	–	63	150.0
38	–	–	263	121.0	1 806	89.0	2 070	78.1
39	93	115.4	63	153.5	3 835	71.3	3 991	68.7
40	1 101	145.0	507	114.0	5 364	83.4	6 971	68.7
41	3 018	69.1	3 560	93.0	19 666	55.6	26 244	46.0
42	4 428	72.1	15 163	98.2	42 136	47.6	61 727	31.5
43	15 665	57.9	21 507	65.2	101 284	40.4	138 455	29.9
44	28 171	59.2	16 789	59.2	196 043	37.7	241 002	34.0
45	50 528	42.3	90 156	54.2	257 618	35.9	398 303	17.4
46	101 530	46.0	108 677	65.3	276 199	33.8	486 405	9.2
47	133 512	56.4	177 913	66.3	272 456	34.9	583 881	15.0
48	136 128	65.0	102 084	69.2	151 939	36.7	390 152	24.2
49	47 149	69.8	39 506	55.5	84 694	38.9	171 349	19.3
50	38 811	58.6	25 054	55.7	43 757	43.0	107 622	23.3
51	6 684	81.3	4 787	59.0	17 646	54.6	29 117	44.3
52	13 509	118.0	2 469	75.0	7 266	63.0	23 244	57.1
53	225	134.8	806	123.5	2 230	98.6	3 260	78.9
54	–	–	–	–	–	–	–	–
≥55	–	–	–	–	–	–	–	–
Total	580 940		609 381		1 488 708		2 679 028	
MWCV (%)	59.0		64.5		37.9		20.6	

Table A4: 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 June 2004-Sept 2005 and scaled to the total reported catch landed in the 2004–05 fishing season for EMA 7, all strata combined.

	Males		Females		Unsexed		All	
Length	NAL	c.v. (%)	NAL	c.v. (%)	NAL	c.v. (%)	NAL	c.v. (%)
≤ 20	115	108.9	–	–	–	–	115	108.9
21	–	–	–	–	–	–	–	–
22	60	139.9	–	–	–	–	60	139.9
23	55	114.6	–	–	–	–	55	114.6
24	–	–	–	–	–	–	–	–
25	30	166.4	–	–	–	–	30	166.4
26	27	161.6	–	–	–	–	27	161.6
27	–	–	–	–	–	–	–	–
28	–	–	–	–	–	–	–	–
29	–	–	–	–	–	–	–	–
30	–	–	–	–	–	–	–	–
31	–	–	–	–	–	–	–	–
32	–	–	–	–	–	–	–	–
33	–	–	–	–	641	160.5	641	160.5
34	–	–	–	–	1 269	105.7	1 269	105.7
35	–	–	–	–	537	151.0	537	151.0
36	38	157.7	77	136.6	2 322	77.9	2 438	73.2
37	63	150.0	–	–	–	–	63	150.0
38	–	–	263	121.0	1 806	89.0	2 070	78.1
39	93	115.4	63	153.5	3 835	71.3	3 991	68.7
40	1 779	103.7	507	114.0	5 364	83.4	7 649	63.9
41	4 374	56.4	4 238	82.1	19 666	55.6	28 278	43.3
42	13 762	39.5	20 707	70.6	42 136	47.6	76 605	26.7
43	27 552	36.6	36 785	40.1	101 284	40.4	165 620	25.4
44	55 057	33.8	42 598	29.0	196 043	37.7	293 698	28.5
45	90 102	25.1	128 410	37.7	257 618	35.9	476 130	14.8
46	134 445	35.5	151 482	45.2	276 199	33.8	562 126	8.3
47	155 775	47.8	205 200	56.4	272 456	34.9	633 430	13.8
48	158 511	55.8	122 470	56.9	151 939	36.7	432 921	22.1
49	53 492	61.3	49 760	44.2	84 694	38.9	187 946	17.7
50	42 043	54.5	27 488	50.7	43 757	43.0	113 287	22.2
51	7 362	74.7	5 864	53.4	17 646	54.6	30 872	42.0
52	13 509	118.0	2 469	75.0	7 266	63.0	23 244	57.1
53	225	134.8	806	123.5	2 230	98.6	3 260	78.9
54	–	–	–	–	–	–	–	–
≥55	–	–	–	–	–	–	–	–
Total	758 469		799 187		1 488 708		3 046 362	
MWCV (%)	46.1		48.9		37.9		18.4	

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 2004–05 fishing season, scaled to the total reported catch, for EMA 1.

	Males		Females		Unsexed		All	
Age	NAA	c.v. (%)	NAA	c.v. (%)	NAA	c.v. (%)	NAA	c.v. (%)
0	–	–	–	–	–	–	–	–
1	–	–	–	–	–	–	–	–
2	–	–	–	–	–	–	–	–
3	3 473	101.5	–	–	–	–	3 473	101.5
4	13 408	55.5	7 235	58.8	–	–	20 643	43.0
5	84 705	24.8	158 973	22.6	–	–	243 678	19.5
6	343 230	22.5	304 887	25.5	–	–	648 117	17.2
7	389 627	20.5	296 810	26.5	–	–	686 437	16.5
8	307 045	28.1	441 266	22.4	–	–	748 311	17.4
9	249 001	34.2	339 365	28.3	–	–	588 366	21.9
10	169 553	41.6	593 042	19.7	–	–	762 594	17.8
11	182 810	37.9	447 878	22.0	–	–	630 688	18.9
12	310 900	25.5	360 916	23.5	–	–	671 816	17.0
13	90 354	39.4	95 616	40.9	–	–	185 969	28.0
14	192 790	35.6	202 513	34.2	–	–	395 303	25.4
15	70 637	65.2	80 895	34.0	–	–	151 532	34.2
16	12 134	67.3	25 008	40.1	–	–	37 143	35.5
17	74 903	51.8	35 106	85.9	–	–	110 008	43.7
18	3 629	72.5	6 351	49.7	–	–	9 980	40.7
19	8 895	50.5	1 782	84.8	–	–	10 677	45.0
20	7 856	95.8	1 097	104.3	–	–	8 953	84.9
21	988	90.1	12 623	71.5	–	–	13 611	66.5
Undefined	8 296	53.6	3 056	63.0	–	–	11 352	49.7
Total	2 524 234		3 414 419		0		5 938 651	
MWCV (%)	31.6		25.9		–		20.4	

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 June 2004 to September 2005, scaled to the total reported landed catch by purse-seines in the 2004–05 fishing year, for EMA 7.

	Males		Females		Unsexed		All	
Age	NAA	c.v. (%)	NAA	c.v. (%)	NAA	c.v. (%)	NAA	c.v. (%)
0	–	–	–	–	–	–	–	–
1	–	–	–	–	–	–	–	–
2	0	1 921.5	–	–	–	–	0	1 921.5
3	–	–	–	–	–	–	–	–
4	–	–	–	–	–	–	–	–
5	6 206	55.4	5 672	57.7	–	–	11 878	43.2
6	6 983	53.0	22 295	35.5	–	–	29 278	32.3
7	18 919	29.3	16 404	40.5	–	–	35 322	26.3
8	12 376	36.2	17 008	35.2	–	–	29 384	25.6
9	15 002	30.5	14 232	40.2	–	–	29 234	23.9
10	23 270	24.3	25 692	26.7	–	–	48 962	17.2
11	32 438	21.7	23 470	23.9	–	–	55 909	14.9
12	10 819	35.9	13 538	34.1	–	–	24 356	23.8
13	10 024	40.3	15 682	31.0	–	–	25 706	23.3
14	9 667	41.5	6 492	37.3	–	–	16 159	28.2
15	8 503	42.7	9 185	43.5	–	–	17 688	28.8
16	6 636	47.1	3 560	38.9	–	–	10 196	33.1
17	6 871	40.9	3 722	37.3	–	–	10 593	30.4
18	3 856	52.7	3 638	41.2	–	–	7 494	35.1
19	1 778	46.8	3 173	37.7	–	–	4 951	29.8
20	2 500	64.1	2 789	43.7	–	–	5 289	40.1
21	1 372	69.9	3 053	59.0	–	–	4 425	47.6
22	219	97.8	120	157.3	–	–	339	87.5
23	90	150.9	–	–	–	–	90	150.9
24	–	–	81	132.4	–	–	81	132.4
Undefined	–	–	0	300.0	–	–	0	300
Total	177 529		189 806		0		367 334	
MWCV (%)	34.8		35.1		–		25.1	

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 June 2004 to September 2005, scaled to the total reported landed catch by trawls in the 2004–05 fishing year, for EMA 7.

	Males		Females		Unsexed		All	
Age	NAA	c.v. (%)	NAA	c.v. (%)	NAA	c.v. (%)	NAA	c.v. (%)
0	–	–	–	–	–	–	–	–
1	–	–	–	–	–	–	–	–
2	325	99.5	–	–	–	–	325	99.5
3	–	–	–	–	–	–	–	–
4	–	–	–	–	–	–	–	–
5	7 381	72.2	16 142	76.6	–	–	23 522	52.5
6	7 844	71.3	45 803	59.1	–	–	53 647	49.4
7	23 605	51.0	22 300	57.6	–	–	45 905	42.7
8	19 004	51.9	39 429	61.0	–	–	58 432	47.2
9	35 927	47.3	36 169	60.0	–	–	72 096	44.9
10	63 978	44.7	81 501	58.1	101 284	91.2	246 763	36.2
11	94 967	44.7	95 879	64.1	–	–	190 846	50.0
12	38 871	55.0	46 912	68.3	–	–	85 783	55.7
13	36 926	58.9	49 883	66.5	–	–	86 809	57.2
14	39 786	58.8	32 896	72.5	–	–	72 682	58.0
15	49 579	62.1	35 606	70.5	–	–	85 185	59.6
16	37 427	59.5	21 370	63.2	–	–	58 797	54.3
17	38 848	59.9	20 404	57.3	–	–	59 252	52.6
18	27 072	64.4	21 658	59.0	–	–	48 730	53.9
19	17 898	60.2	17 116	53.9	–	–	35 014	49.5
20	25 583	67.1	14 038	56.7	–	–	39 621	54.8
21	12 293	75.1	9 997	71.4	–	–	22 290	60.7
22	2 549	81.9	532	101.7	–	–	3 081	68.1
23	1 078	121.2	–	–	–	–	1 078	121.2
24	–	–	835	120.0	–	–	835	120.0
Undefined	0	177.3	910	142.5	1 387 427	86.8	1 388 337	86.5
Total	580 941		609 380		1 488 711		2 679 030	
MWCV (%)	55.4		63.4		87.1		68.7	

Table B4: 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 June 2004 to September 2005, scaled to the total reported landed catch in the 2004–05 fishing year, for EMA 7, all strata combined.

	Males		Females		Unsexed		All	
Age	NAA	c.v. (%)	NAA	c.v. (%)	NAA	c.v. (%)	NAA	c.v. (%)
0	–	–	–	–	–	–	–	–
1	–	–	–	–	–	–	–	–
2	325	102.5	–	–	–	–	325	102.5
3	–	–	–	–	–	–	–	–
4	–	–	–	–	–	–	–	–
5	13 587	54.5	21 813	63.9	–	–	35 400	42.3
6	14 827	54.9	68 098	44.1	–	–	82 925	36.8
7	42 523	36.5	38 704	43.5	–	–	81 228	30.6
8	31 380	41.0	56 437	46.7	–	–	87 816	35.0
9	50 929	38.2	50 401	47.5	–	–	101 330	34.4
10	87 247	35.3	107 194	45.4	101 284	91.2	295 724	30.0
11	127 405	35.1	119 349	51.7	–	–	246 754	39.0
12	49 690	46.1	60 450	54.6	–	–	110 140	44.1
13	46 950	50.4	65 565	52.2	–	–	112 515	45.3
14	49 453	50.7	39 388	62.2	–	–	88 842	48.7
15	58 082	54.8	44 791	59.8	–	–	102 873	50.6
16	44 063	53.1	24 930	56.9	–	–	68 994	47.7
17	45 719	53.0	24 126	50.9	–	–	69 845	45.9
18	30 928	58.8	25 296	53.6	–	–	56 224	48.3
19	19 676	55.8	20 289	48.0	–	–	39 965	44.4
20	28 083	63.1	16 826	50.7	–	–	44 910	49.6
21	13 665	70.8	13 050	63.4	–	–	26 715	54.1
22	2 769	78.5	652	94.7	–	–	3 420	64.5
23	1 168	118.2	–	–	–	–	1 168	118.2
24	–	–	916	116.1	–	–	916	116.1
Undefined	0	177.3	910	145.8	1 387 427	86.8	1 388 337	86.4
Total	758 469		799 185		1488711		3 046 366	
MWCV (%)	46.2		51.3		87.1		61.3	

Appendix C: Age-length keys

Table C1: Age-length key used to convert the scaled length distributions to age distributions; data collected during the 2004–05 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*
≤ 25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
26	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
27	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
29	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
30	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
31	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
32	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
34	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
35	–	–	–	–	0.33	0.67	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
36	–	–	–	–	0.13	0.40	0.27	0.07	0.07	0.07	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15
37	–	–	–	–	0.08	0.62	0.15	0.08	0.08	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13
38	–	–	–	0.05	–	0.37	0.32	0.21	0.05	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	19
39	–	–	–	–	0.06	0.11	0.39	0.33	0.11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	18
40	–	–	–	–	–	0.07	0.40	0.27	0.20	–	0.07	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15
41	–	–	–	–	–	–	0.33	0.42	0.25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12
42	–	–	–	–	–	–	–	0.42	0.17	0.17	0.08	0.08	–	–	0.08	–	–	–	–	–	–	–	–	–	–	–	12
43	–	–	–	–	–	–	–	–	0.30	0.20	0.10	0.10	0.20	–	0.10	–	–	–	–	–	–	–	–	–	–	–	10
44	–	–	–	–	–	–	0.30	0.20	0.10	0.20	0.10	–	–	–	–	0.10	–	–	–	–	–	–	–	–	–	–	10
45	–	–	–	–	–	–	0.09	–	–	–	0.09	0.18	0.36	–	0.18	–	–	0.09	–	–	–	–	–	–	–	–	11
46	–	–	–	–	–	–	–	–	–	0.18	–	0.18	0.18	0.18	0.09	0.09	–	0.09	–	–	–	–	–	–	–	–	11
47	–	–	–	–	–	–	–	–	–	–	0.14	–	0.43	0.21	0.21	–	–	–	–	–	–	–	–	–	–	–	14
48	–	–	–	–	–	–	–	–	–	–	0.08	0.15	0.08	0.08	0.15	0.08	0.08	0.23	–	–	0.08	–	–	–	–	–	13
49	–	–	–	–	–	–	–	–	–	–	–	0.17	0.08	0.08	–	0.08	0.17	0.08	0.08	0.25	–	–	–	–	–	–	12
50	–	–	–	–	–	–	–	–	–	–	–	–	0.07	0.14	0.14	0.14	–	0.07	0.14	0.14	0.07	0.07	–	–	–	–	14
51	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.25	–	–	0.25	–	0.25	–	0.25	–	–	–	–	4
52	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.50	–	0.50	–	–	–	–	2
53	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
54	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
≥ 55	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0

(Table C1 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*
≤ 25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
26	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
27	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
29	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
30	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
31	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
32	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
34	–	–	–	–	–	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
35	–	–	–	–	0.25	0.50	0.25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8
36	–	–	–	–	0.15	0.31	0.38	–	0.08	–	0.08	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13
37	–	–	–	–	0.07	0.36	0.57	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14
38	–	–	–	–	–	0.83	0.17	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6
39	–	–	–	–	–	0.38	0.25	0.38	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8
40	–	–	–	–	–	0.25	0.25	0.25	0.08	0.08	0.08	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12
41	–	–	–	–	–	–	0.08	0.31	0.38	0.08	0.15	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13
42	–	–	–	–	–	–	0.23	0.23	0.31	0.15	0.08	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13
43	–	–	–	–	–	–	0.07	0.07	0.33	0.27	0.13	0.07	–	–	0.07	–	–	–	–	–	–	–	–	–	–	–	15
44	–	–	–	–	–	–	0.12	–	0.12	0.06	0.25	0.19	0.12	0.06	0.06	–	–	–	–	–	–	–	–	–	–	–	16
45	–	–	–	–	–	–	–	0.07	–	0.07	0.36	0.14	0.36	–	–	–	–	–	–	–	–	–	–	–	–	–	14
46	–	–	–	–	–	–	–	–	–	0.14	0.29	0.36	–	–	0.14	–	–	0.07	–	–	–	–	–	–	–	–	14
47	–	–	–	–	–	–	–	–	–	–	0.06	0.25	0.31	0.06	0.19	0.12	–	–	–	–	–	–	–	–	–	–	16
48	–	–	–	–	–	–	–	–	–	–	0.07	0.14	0.14	0.21	0.07	0.21	0.07	–	–	–	–	0.07	–	–	–	–	28
49	–	–	–	–	–	–	–	–	–	–	0.04	0.13	0.17	0.13	0.22	0.09	0.13	0.04	0.04	–	–	–	–	–	–	–	23
50	–	–	–	–	–	–	–	–	–	0.05	0.05	0.05	0.19	0.10	0.10	0.10	0.14	0.05	0.10	0.05	0.05	–	–	–	–	–	21
51	–	–	–	–	–	–	–	–	–	–	–	0.12	–	–	–	0.12	0.25	0.25	0.12	0.12	–	–	–	–	–	–	8
52	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.25	–	0.25	–	0.50	–	–	–	–	–	–	–	4
53	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.00	–	–	–	–	–	–	–	1
54	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
≥ 55	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0

Table C2: Age-length key used to convert the scaled length distributions to age distributions, data collected between June 2004–September 2005 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*
≤ 20	–	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
22	–	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
24	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
25	–	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
26	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
27	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
29	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
30	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
31	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
32	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
34	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
35	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
36	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
37	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
38	–	–	–	–	–	–	–	–	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
39	–	–	–	–	–	–	–	–	–	–	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
40	–	–	–	–	–	0.67	0.33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
41	–	–	–	–	–	0.50	0.50	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4
42	–	–	–	–	–	0.14	0.14	0.29	0.43	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7
43	–	–	–	–	–	0.18	–	0.18	0.18	0.27	0.18	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11
44	–	–	–	–	–	0.06	0.12	0.18	–	0.12	0.24	0.12	0.06	0.06	–	–	–	0.06	–	–	–	–	–	–	–	–	17
45	–	–	–	–	–	–	0.04	0.20	0.08	0.08	0.12	0.32	0.08	0.04	0.04	–	–	–	–	–	–	–	–	–	–	–	25
46	–	–	–	–	–	–	–	0.04	0.09	0.09	0.13	0.26	0.04	0.09	0.13	0.04	0.09	–	–	–	–	–	–	–	–	–	23
47	–	–	–	–	–	–	–	–	–	0.12	0.12	0.23	0.08	0.08	0.04	0.12	0.04	0.12	0.04	–	0.04	–	–	–	–	–	26
48	–	–	–	–	–	–	–	–	–	–	0.12	0.12	0.12	0.09	0.09	0.16	0.06	0.06	0.09	–	0.03	0.03	–	–	–	–	32
49	–	–	–	–	–	–	–	–	0.03	–	0.06	–	–	0.03	0.12	0.12	0.18	0.15	0.06	0.18	0.03	0.06	–	–	–	–	34
50	–	–	–	–	–	–	–	–	–	–	–	0.03	0.03	–	0.03	0.06	0.11	0.08	0.14	0.17	0.22	0.06	0.06	0.03	–	–	36
51	–	–	–	–	–	–	–	–	–	–	–	–	0.06	–	–	0.12	0.06	0.18	0.12	0.18	0.06	0.18	0.06	–	–	–	17
52	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.14	0.14	–	0.14	0.43	0.14	–	–	–	–	7
53	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.00	–	–	–	–	–	–	–	1
54	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
≤ 55	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0

(Table C2 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*
≤ 20	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
22	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
24	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
26	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
27	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
29	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
30	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
31	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
32	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
34	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
35	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
36	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
37	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
38	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
39	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
40	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
41	–	–	–	–	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
42	–	–	–	–	–	0.25	0.50	–	–	–	–	–	0.25	–	–	–	–	–	–	–	–	–	–	–	–	–	4
43	–	–	–	–	–	0.10	0.20	0.30	0.10	0.10	0.10	–	–	0.10	–	–	–	–	–	–	–	–	–	–	–	–	10
44	–	–	–	–	–	–	0.18	0.27	0.18	0.18	0.18	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11
45	–	–	–	–	–	–	0.25	0.12	0.06	0.12	0.12	0.12	0.06	0.06	–	0.06	–	–	–	–	–	–	–	–	–	–	16
46	–	–	–	–	–	0.04	0.04	–	0.14	–	0.14	0.18	0.14	0.18	0.04	0.07	–	–	–	–	–	0.04	–	–	–	–	28
47	–	–	–	–	–	–	0.03	–	0.05	0.07	0.20	0.25	0.10	0.05	0.07	0.07	0.05	–	0.05	–	–	–	–	–	–	–	40
48	–	–	–	–	–	0.03	–	–	0.03	0.05	0.08	0.19	0.03	0.14	0.14	0.05	0.03	0.11	0.03	0.05	0.05	–	–	–	–	–	37
49	–	–	–	–	–	–	–	–	0.04	–	0.14	0.04	0.04	–	–	0.04	0.11	0.07	0.11	0.14	0.14	0.14	–	–	–	–	28
50	–	–	–	–	–	–	–	–	–	0.03	–	–	–	–	0.07	0.07	0.20	0.20	0.13	0.20	0.07	–	–	–	0.03	–	30
51	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.06	0.06	0.28	0.28	0.11	0.06	0.06	0.11	–	–	–	18
52	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.08	–	0.08	0.08	0.25	0.17	0.25	0.08	–	–	–	–	12
53	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.60	–	0.40	–	–	–	–	–	5
54	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
≤ 55	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0