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M. J. Manning
P.M. Marriot
P. R. Taylor

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M. J. Manning[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.; Marriot, P.M.; Taylor, P.R. (2007). Length and age composition of the commercial catch of blue mackerel (*Scomber australasicus*) in EMA 1 & 7 during the 2003–04 fishing year.

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Commercial catches of blue mackerel (*Scomber australasicus*) in the purse-seine fishery in EMA 1 and the trawl fishery in EMA 7 were sampled during the 2003–04 fishing year by staff from the National Institute of Water and Atmospheric Research (NIWA), associated fishing companies, and the Ministry of Fisheries (MFish) Observer Programme as part of MFish-funded research project EMA2003-01 "Stock monitoring of blue mackerel". This project is the second year of a three-year stock monitoring programme of blue mackerel in EMA 1 & 7. Mean-weighted coefficient of variation (mean-weighted c.v.) targets of 30% were set for the catch-at-age calculated from the data collected from both the EMA 1 & 7 fisheries.

Twenty-eight landings were sampled, 9464 fish were measured, and 509 sagittal otolith pairs were collected from landings of catches made in EMA 1. Eleven landings were sampled, 2274 fish were measured, and 353 sagittal otolith pairs were collected at sea or collected from landings of catches made in EMA 7. Sampled landings in EMA 1 accounted for about 66% of the total catch. Sampled landings in EMA 7 accounted for about 12% of the total catch. The data collected from the EMA 1 fishery are thought to be representative of the catch. It is not known whether the data collected from the EMA 7 fishery are representative of the catch or not. The relationship between total estimated catch and total landed catch per fishing trip in the EMA 1 and 7 fisheries is investigated and it is concluded that characterisation and other studies of these fisheries may benefit from the application of an effort restratification and landed-catch allocation algorithm, such as is used in many New Zealand inshore fisheries at this time.

All of the otoliths collected from the EMA 1 & 7 fisheries were prepared as thin sections and read once by one reader using transmitted light. A subset of 100 otoliths was randomly selected from the set of prepared otoliths and read by a second reader and re-read by the first reader to quantify within- and between reader precision and bias. The within-reader Index of Average Percentage Error (IAPE) and mean coefficient of variation (mean c.v.) were 7.45% and 10.67%, respectively. The between-reader IAPE and mean c.v. were 10.55% and 14.92%, respectively. These results compare favourably with the same statistics calculated in other age and growth studies of New Zealand blue mackerel, but diagnostic bias plots suggested systematic differences in the interpretation of blue mackerel otoliths over the course of this study, both within and between readers. The implications of these results are discussed.

Estimated scaled proportions-at-length distributions were calculated separately from the data collected from the EMA 1 & 7 fisheries and scaled to the total reported commercial catch in each fishery. The sets of length-at-age data derived from the otoliths collected from each fishery were converted to age-length keys and used to calculate estimated scaled proportions-at-age distributions from the corresponding length distributions. The mean-weighted c.v.s for the EMA 1 catch-at-age were 27.9%, 27.8%, and 21.1% for male, female, and all fish. The mean-weighted c.v.s for the EMA 7 catch-at-age were 47.9%, 45.6%, and 33.3% for male, female, and all fish. The mean-weighted c.v. for all fish in the EMA 1 catch-at-age was within the 30% target set. The mean-weighted c.v. for all fish in the EMA 7 catch-at-age was not. A revised length-weight relationship for New Zealand blue mackerel is also presented and was used to calculate the catch-at-length in both the EMA 1 & 7 fisheries.

Trends in the EMA 1 catch-at-length and catch-at-age appear similar to those identified in earlier studies where results derived from data collected during earlier fishing years, 1997–98 and 2002–03,

were presented. The 2003–04 EMA 1 catch-at-length is strongly unimodal for both sexes, with few fish less than 30 cm in fork length or over 55 cm in fork length present in the catch. The 2003–04 EMA 1 catch-at-age is broader, and as in the two previous fishing years for which data are available, appears to be based on a number of successive year classes, including fish 4–10 years or so. Relatively few fish less than 3 years of age or more than 15 years are present in the catch. The oldest observed fish was a 51 cm female with an estimated age of 21.90 years. Comparing results across the 1997–98, 2002–03, and 2003–04 fishing years suggests that the maximum age of fish of both sexes in the EMA 1 catch may have decreased over time, but the overall composition of the catch appears to have remained stable over time. There are no unusually strong or weak year classes progressing through the catch, but the issues associated with blue mackerel otolith interpretation may confound our ability to identify these. Size-selective fishing effort and age-estimation error may also impose greater stability on the observed age composition than actually exists in the fished stock.

No data collected from the EMA 7 stock during earlier fishing years are available with which to compare the results obtained during the 2003–04 fishing year. However, the 2003–04 EMA 7 catch-at-length is also highly unimodal within a relatively narrow size range, despite the different fishing gear used in this fishery and the presumably different selectivity effects operating on the fished stock. The 2003–04 EMA 7 catch-at-age appears to contain older fish than in EMA 1, but given that the representativeness of the catch of the data collected from the EMA 7 fishery is not known, it is not known whether these results and other results derived from the analysis of these data are valid. All results derived from the analysis of the EMA 7 data presented in this paper should be interpreted with caution. Future studies of the catch in EMA 7 should make every effort to collect data that are representative of the catch.

Comments by fishers on market variables that may have affected fishing patterns in EMA 1 & 7 were sought and are summarised. It was concluded that international prices and other macro-economic factors play an important part in determining fishing patterns in both fisheries (e.g., the temporal extent of the blue mackerel fishing season during the fishing year). Future blue mackerel catch-composition studies should continue to monitor these factors, as changes in fishing patterns driven by these factors may affect the composition of the observed catch-at-length or catch-at-age without any true change in the composition of the stocks.

1. INTRODUCTION

1.1 General

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 (New Zealand EEZ). Blue mackerel 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) at this time: EMA 1, 2, 3, 7, and 10 (Figure 1).

Commercial catches of blue mackerel are made in all New Zealand QMAs, but most of the catch is caught north of latitude 43° S (Morrison et al. 2001). The largest and most consistent commercial catches are by purse-seine vessels targeting blue mackerel schools in EMA 1–3, and 7, and by midwater trawl vessels targeting jack mackerels (*Trachurus* spp.) in EMA 7. The purse-seine catch in EMA 1 is the single largest component of the total New Zealand catch by any QMA and method (Morrison et al. 2001).

The annual commercial catch in the New Zealand EEZ has varied greatly over time. Total annual reported landings (all QMAs) increased rapidly over the 1989–90 to 1992–93 fishing years, fluctuating between 6000 t and 15 000 t in every fishing year from 1992–93 to 2003–04. Total annual landings from 1992–93 to 2003–04 peaked at 15 128 t during 1991–92, averaging 9871 t over this time (Table 1). The variation in catches between years is thought to reflect variable market demand rather than changes in stock abundance (Morrison et al. 2001). Catch within a given fishing year is highly seasonal. Virtually all of the catch in the EMA 1 target purse-seine fishery is caught between July and December (Morrison et al. 2001). Export sales of New Zealand blue mackerel were worth FOB NZ$8.4 million (Luke Beyers, SeaFIC, pers. comm) during the 2004 calendar year.

1.2 Previous catch-sampling of blue mackerel in the New Zealand EEZ

Commercial catch sampling of blue mackerel in the New Zealand EEZ was first carried out by Morrison et al. (2001) in fishstock EMA 1 during the 1997–98 fishing year. Morrison et al. sampled landings from the target purse-seine fishery exclusively. Their analysis was updated by Manning et al. (2006), who sampled commercial landings from the purse-seine fishery during the 2002–03 fishing year. Morrison et al. also developed an age estimation method for New Zealand blue mackerel based on enumerating opaque zones (sensu Kalish et al. 1995) in sagittal otolith thin-sections that was also used by Manning et al.

Both Morrison et al. (2001) and Manning et al. (2006) found that the EMA 1 purse-seine catch-at-length was strongly unimodal, with no evidence of length modes entering the catch that may correspond to recruitment pulses. In both studies, this was thought to be due to the selectivity effect of the commercial purse-seine gear and size-selective fishing effort rather than poor recruitment. Relatively strong modes were present in the 2002–03 catch-at-age at 4–5 and 7–8 years, suggesting some degree of differential year-class success. A strong mode in the 1997–98 catch-at-age could not be followed through into the 2002–03 catch-at-age, although this is not surprising as fish at least 12 years old during 1997–98 would be at least 17 years old during 2002–03 and proportionally few in number due to natural and fishing mortality. In both studies, the catches-at-age seemed to be composed of a number of successful year classes and there was no evidence of truncation or other gross change in the catch-at-age between the studies. In a quantitative comparison of competing growth models, Manning et al. (2006) found no evidence of differences in growth between male and female blue mackerel.

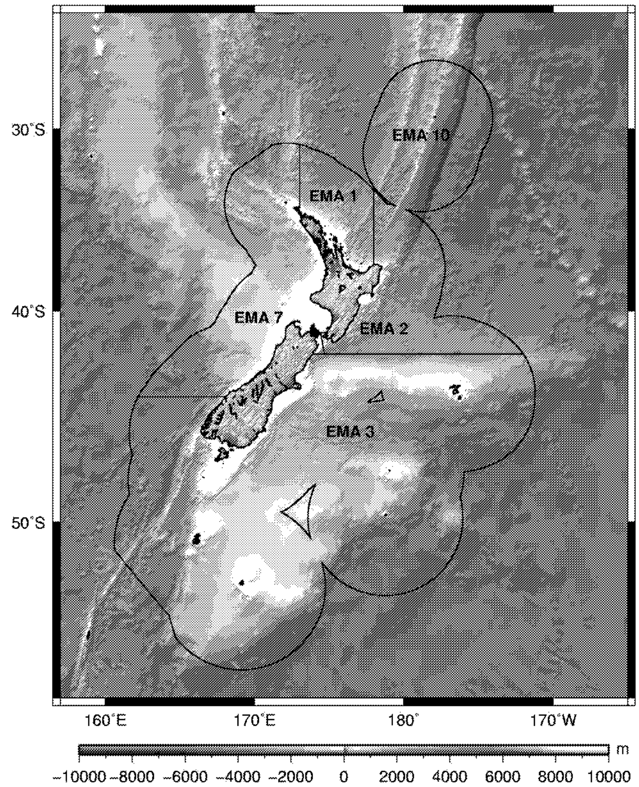


Figure 1: Map of the New Zealand EEZ showing the boundaries of blue mackerel fishstocks during the 2003–04 fishing year and the bathymetry of the New Zealand region.

Unlike the two New Zealand studies, published studies on the age and growth of blue mackerel in Australian waters (Stewart et al. 1999, Stewart & Ferrell 2001) have used an age-estimation method based on reading whole sagittal otoliths immersed in lavender oil. Manning et al. (2006) suggested from a comparison of the length range of fish in the New Zealand and Australian studies, that if the New Zealand age estimation method is assumed to be valid, then the Australian method may lead to under-estimation of the age of fish in the Australian catch. Manning et al. (2006) suggested that Australian researchers, reading whole otoliths, may be missing opaque zones near the margin, which are visible in sectioned otoliths.

Although Stewart et al. (1999) validated the timing of the first opaque zone in blue mackerel otoliths, their results do not cover the complete life history defined using either the Australian or New Zealand method and both methods remain unvalidated.

1.3 Scope of this report

We present the results of the second year of a three-year commercial catch sampling programme in the EMA 1 target purse-seine and EMA 7 trawl bycatch fisheries, spanning the 2002–03 to 2004–05 fishing years. However, no data were collected from EMA 7 during 2002–03, and this is the first year that we are able to present an analysis of data collected from this fishery. This year's sampling effort was funded by the New Zealand Ministry of Fisheries (MFish) as research project EMA2003-01. The project's six specific objectives were:

1. To sample and determine the length and age composition of the commercial purse-seine catch in EMA 1 during the 2003–04 fishing year. A target mean-weighted coefficient of variation (mean-weighted c.v.) of 30% was set for the catch-at-age.

Table 1: Blue mackerel total reported landed catch (t) by fishing year and QMA (adapted from Annala et al. 2004). 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	–	1 141	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	–	–	9 708
1997–98†	4 595	122	77	2 310	–	–	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	–	–	13 134
2001–02†	6 368	177	48	5 101	–	–	11 694
2002–03‡	7 609	115	88	3 562	–	–	11 374
2003–04‡	7 637	115	88	3 578	–	–	11 418

2. To document relevant market variables for the EMA 1 purse-seine fishery during the 2003–04 fishing year.

3. To compare and contrast the results of the work in Specific Objective 1 with the results of previous commercial catch-sampling of blue mackerel in EMA 1.

4. To sample and determine the length and age composition of the commercial purse-seine catch in EMA 7 during the 2003–04 fishing year. A target mean-weighted coefficient of variation (mean-weighted c.v.) of 30% was set for the catch-at-age.

5. To document relevant market variables for the EMA 7 purse-seine fishery during the 2003–04 fishing year.

6. To compare and contrast the results of the work in Specific Objective 4 with the results of previous commercial catch-sampling of blue mackerel in EMA 7.

We present scaled numbers-at-length and scaled numbers-at-age estimated from data collected from the EMA 1 & 7 fisheries during the 2003–04 fishing year using a revised length-weight relationship for New Zealand blue mackerel. We compare the EMA 1 results with those from the two earlier New Zealand studies (Morrison et al. 2001, Manning et al. 2006). However, this is the first time that commercial catch sampling data from the EMA 7 fishery have been presented and no earlier results are available with which to compare these. We also assess the representativeness of the 2003–04 data and give recommendations for future catch sampling in both fishstocks.

2. METHODS

2.1 Catch-effort data extract

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 2004 (the 1989–90 to 2003–04 fishing years) were extracted from the Ministry of Fisheries catch-effort and landings database, *warehou* (Duckworth 2002).

2.2 Overview of commercial catch sampling carried out during 2003–04 fishing year

Landings of purse-seine catches made in EMA 1 during the 2003–04 fishing year were sampled using an unstratified sampling scheme. A simple random sample of about 200 fish per 100 t of catch was collected from each sampled landing. Fish sex and length to the nearest centimetre below actual fork length were recorded for each fish in the sample. This differs from sampling carried out during the 2002–03 fishing year, where stratified sampling based on commercial fish weight grades was used. During 2003–04, sampling was carried out by personnel from both NIWA and Sanford Ltd. Landings received by Sanford Ltd were sampled by Sanford Ltd personnel; landings received by other Licensed Fish Receivers were sampled by NIWA personnel. 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 catch during each sampled landing to compile an age-length key for the EMA 1 fishery. Up to 20 otolith pairs per sex for each centimetre length-class in the catch were collected non-randomly from the random length-frequency samples collected during each sampled landing throughout the 2003–04 fishing year. Fish from which sagittal otoliths were collected were also measured to the nearest centimetre below fork length and their sex recorded. Each otolith pair was cleaned and stored dry in individual 1.5 ml plastic Eppendorf centrifuge tubes immediately following collection.

In EMA 7 during 2003–04, the aim was to sample three sectors of the catch. These were: (a) blue mackerel catches made by purse-seine vessels targeting blue mackerel schools; (b) blue mackerel catches made by inshore trawl vessels catching blue mackerel as a bycatch of fishing effort directed at other, more preferred target species; and (c) blue mackerel catches made by large midwater trawl vessels targeting jack mackerels in the Taranaki Bight. Purse-seine landings were to be sampled by NIWA and Sanford Ltd personnel in Tauranga, where these landings are usually unloaded following closure of Sanford Ltd's Nelson wetfish processing site; inshore trawl landings were to be sampled opportunistically by NIWA personnel participating in market-sampling programmes for other species in Nelson and Motueka; and deepwater trawl catches were to be sampled by the MFish Observer Programme (MFish OP) at sea.

The sampling methods applied to the EMA 1 purse-seine fishery during 2003–04 that are described above were also to be applied to EMA 7 purse-seine catches during 2003–04. Different sampling methods were to be used for the inshore and deepwater catches, however. For each inshore trawl landing sampled, a simple random sample of 50 fish was to be collected from the catch, and fish length (to the nearest centimetre below actual fork length) and sex were to be recorded and the sagittal-otolith pair collected for each fish in the sample. There was no formal spatial or temporal allocation of sampling effort for inshore trawl landings to be sampled. The MFish OP sampling protocol for blue mackerel is described in Sutton (2002).

All landings and length-frequency data collected from the EMA 1 & 7 fisheries were processed and loaded onto Ministry of Fisheries database *market* (Fisher & Mackay 2000). All otoliths collected were inventoried and the data loaded onto Ministry of Fisheries database *age* (Mackay & George 2000) and the otoliths lodged in the Ministry of Fisheries otolith collection.

2.3 Otoliths

2.3.1 Terminology

The terminology we use follows the glossary for otolith studies produced by Kalish et al. (1995). We use the terms "opaque" and "translucent" to refer to presumed winter slow 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 July to December 2003 season and prepared and read using the methods of Morrison et al. (2001) and Manning et al. (2006). 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 cement). The upper surface of each slide was then 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 surfaces of the sections were then sealed using a clear lacquer spray (Nuart Crystal Clear).

The otolith sections were read using a Leica MZ12 stereo dissecting microscope and transmitted light. Magnification of 63 × was used to observe zone patterns near the nucleus in each otolith. Magnification of 100 × was used to observe zone patterns near the margin in each otolith. The number of complete opaque zones present in each otolith were 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 always unknown to the reader before reading. All prepared otoliths were read once by one reader (P. M. Marriott) and a subset re-read by the first and a second reader (M. J. Manning) (see below). The protocol set of blue mackerel otoliths developed by Manning et al. (2006) was read by both readers before the otoliths prepared in this study were read.

2.3.3 Quantifying reading precision

Otolith reading precision was quantified by carrying out within- and between-reader comparison tests following Campana et al. (1995). A sub-sample of 100 otoliths was randomly selected from the set of prepared otoliths. The sub-sampled otoliths were then re-read by the first reader and read by the second reader 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 prior to 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.

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

Readability

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

Margin state

Score	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

The IAPE is

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

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 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. Note that where exactly two observations per otolith are compared, the IAPE differs from the mean c.v. only by the multiplicative constant, $\sqrt{2}$ (see Kimura & Anderl 2005); we present both statistics to aid comparison with Manning et al.'s (2006) results and those of other studies in the age and growth literature.

2.3.4 Converting opaque-zone counts to age estimates

Following Manning et al. (2006), 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 $t_{i,\,2}$ 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,

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

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-Jan 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. The matching landing date was substituted for the capture date of each fish. Using this method, a fish with four completed opaque zones counted, a "narrow" otolith margin recorded, and caught during a fishing trip that was landed on 19 November 2003, was estimated to be 3.88 years of age.

2.4 Estimating the length and age composition of the catch using *Catchatage*

2.4.1 *Catchatage*

Catchatage (Bull & Dunn 2002) is a package of *R* functions (R Development Core Team 2004) 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 & 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-weighed 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 A revised length-weight relationship

As no New Zealand relationship (or New Zealand data which which a relationship could be calculated) existed at the time, Manning et al. (2006) used an Australian blue mackerel length-weight relationship (D. Ferrell, NSW Fisheries, Cronoulla, Australia, unpublished data) stored in MFish database *rdb* (Mackay 2001) in their analysis of the EMA 1 market-sampling data collected during the 2002–03 fishing year. We present a length-weight relationship for New Zealand blue mackerel based on linear regression modelling of log-transformed length and weight data collected from the EMA 1 fishery during the 2002–03 and 2003–04 fishing years. Model fits to the data were carried out using the *R* language. The relative goodness-of-fit of the competing models to the data was evaluated using analysis of variance and Akaike's (1973) Information Criterion (AIC) and Schwarz's (1978) Bayesian Information Criterion (BIC) statistics. No weight-at-age data are available for the EMA 7 fishery at this time and a separate length-weight relationship for blue mackerel in EMA 7 could not be computed. The revised length-weight relationship presented for EMA 1 was therefore also used for the EMA 7 analysis described below.

2.4.3 Analyses performed

Catchatage was used to scale length-frequency data collected from the EMA 1 and EMA 7 fisheries during the 2003–04 fishing year to the total catch for each fishstock during this fishing year using the revised length-weight relationship described above. All groomed length-at-age data for each fishstock were converted to age-length keys and used to convert the numbers-at-length in the catch to numbers-at-age. Bootstrapped c.v.s for each length and age class and mean-weighted c.v.s for each length and age-frequency distribution were calculated from 1000 resamples of the data. Although Manning et al. (2006) found no evidence of a difference in growth between the sexes in a quantitative comparison of competing growth models, scaled length and age frequency distributions were calculated for each sex.

3. RESULTS

3.1 Landings sampled

Twenty-eight landings were sampled, 9464 fish were measured, and 509 sagittal otolith pairs were collected from the EMA 1 purse-seine fishery during the 2003–04 fishing year (Table 3). All reported landings, all reported purse-seine landings, all reported purse-seine landings where the total reported catch was greater than 10 t, and all sampled purse-seine landings from July 2003 to September 2004 are plotted by month in Figure 2. The distribution of sampled purse-seine landings by month closely follows that of purse-seine landings greater than 10 t. Sampled landings over the July–December 2003 season account for about 80% of the total catch over this time, but account for about 66% of the total catch over the October–September months of the 2003–04 fishing year (Table 4). With the exception of September 2004, all months where more than 250 t of blue mackerel was landed were sampled. These results suggest that the data collected from the EMA 1 fishery are representative of the catch.

In EMA 7, no purse-seine or inshore trawl landings were sampled. However, there were only eight fishing trips by purse-seine vessels where a landed catch of EMA 7 was recorded in the catch-effort and landings data extracted from *warehou* for this analysis. Furthermore, of a total of 173 sets recorded during these trips, only 2 had blue mackerel recorded as the nominated target species, suggesting that virtually no target purse-seine fishery for blue mackerel in EMA 7 operated during the 2003–04 fishing year. When contacted to arrange access to blue mackerel catches, fishing companies in the Nelson and Motueka region reported that blue mackerel catches by inshore trawl vessels are small and irregular. This is confirmed by the *warehou* data, where of 2379 t of estimated blue

Table 3: Summary of data collected from the EMA 1 & 7 fisheries during the 2003–04 fishing year.

Total number of landings sampled, total weight of landed catch sampled, and total sample weights

Fishery	Landings sampled	Sampled landing weight (t)	Total Sample weight (t)
EMA 1	28	4 383	11
EMA 7	11	561	4
Total	39	4 944	15

Total number of fish measured and total number of otoliths prepared and read

Fishery	Fish measured	Otoliths	
		All prepared and read	In groomed dataset
EMA 1	9 464	509	505
EMA 7	2 274	353	336
Total	11 738	862	841

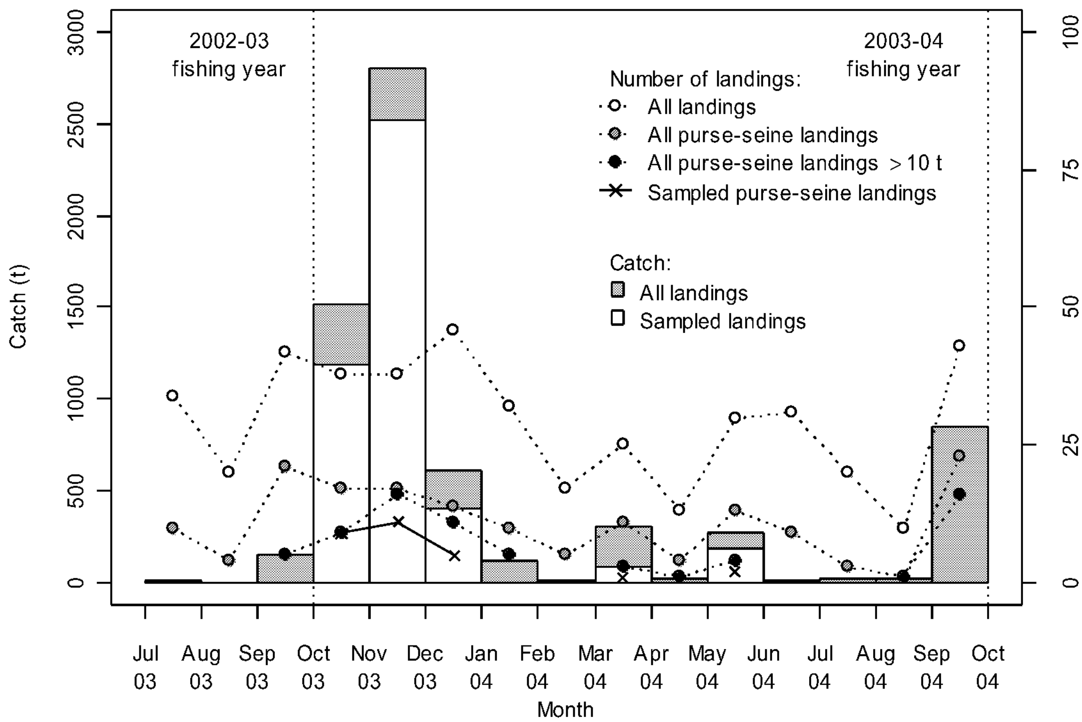
mackerel catch during the 2003–04 fishing year, 2117 t (88.9%) was caught by large, deepwater vessels targeting jack mackerels. We note that while the total estimated blue mackerel catch by trawl vessels recorded in the *warehou* data is likely to be an underestimate of the true removals from the stock by these vessels (see below), nevertheless, the relative trend (i.e., dominance of the catch, whatever its true value is, by vessels targeting jack mackerels) is likely to be real.

Eleven landings were sampled, 2274 fish were measured, and 353 sagittal otolith pairs were collected from the EMA 7 deepwater trawl fishery during 2003–04 (see Table 3). Nine of these landings were sampled in port during or after vessel unloading, and two were sampled at sea by the Ministry of Fisheries OP. All reported landings, all bottom or midwater trawl landings, all purse-seine landings, and all sampled bottom and midwater trawl landings in EMA 7 from July 2003 to September 2004 are plotted by month in Figure 2(B). Sampled landings accounted for about 12% of the total reported catch in EMA 7 during the 2003–04 fishing year (Table 4). The distribution of sampled bottom and midwater trawl landings by month does not closely follow the distribution of bottom and midwater trawl landings by month. Sampling was carried out from July to September 2004, and there is no coverage of landings made earlier in the 2003–04 fishing year. It is unclear whether the data collected from the EMA 7 fishery are representative of the catch.

3.2 The relationship between total estimated and landed greenweight catches in the EMA 1 & 7 fisheries, 1989–90 to 2003–04

The relationships between the estimated greenweight catch and the total reported landed catch per fishing trip in both the EMA 1 & 7 fisheries are plotted in Figure 3. This was to test whether future studies involving analysis of blue mackerel catch-effort and landings data (e.g., characterisation or catch-per-unit-effort analyses) should use a restratification and catch-allocation algorithm, such as that devised by Starr (2003) and implemented by Manning et al. (2004). In some New Zealand fisheries, species estimated catches recorded in fishing event records for a given fishing trip in the *warehou* database are an under- or otherwise biased estimate of the total landed greenweight catch recorded in the corresponding landing event records. Starr's procedure attempts to overcome this and certain other issues associated with the analysis of catch-effort data in New Zealand fisheries (e.g., the different spatial and temporal resolution of data recorded on different catch-effort form types) by restratifying the catch-effort data to a common level of stratification and allocating the total landed greenweight

(A) EMA 1



(B) EMA 7

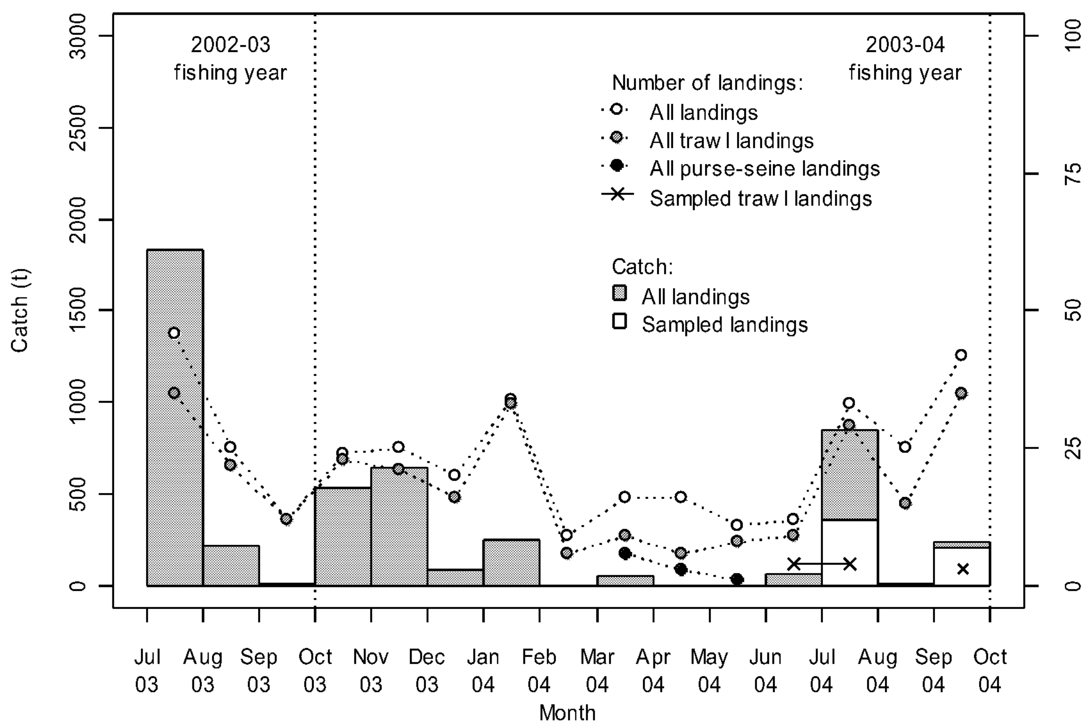


Figure 2: Summaries of fishing and sampling activity for (A) EMA 1 and (B) EMA 7 during the 2003–04 fishing year. Histograms of the total reported landed (grey bars) and sampled (white bars) catch are overlaid on each plot. Numbers of landings by selected fleets in each area are also overlaid for comparison with the sampled landings.

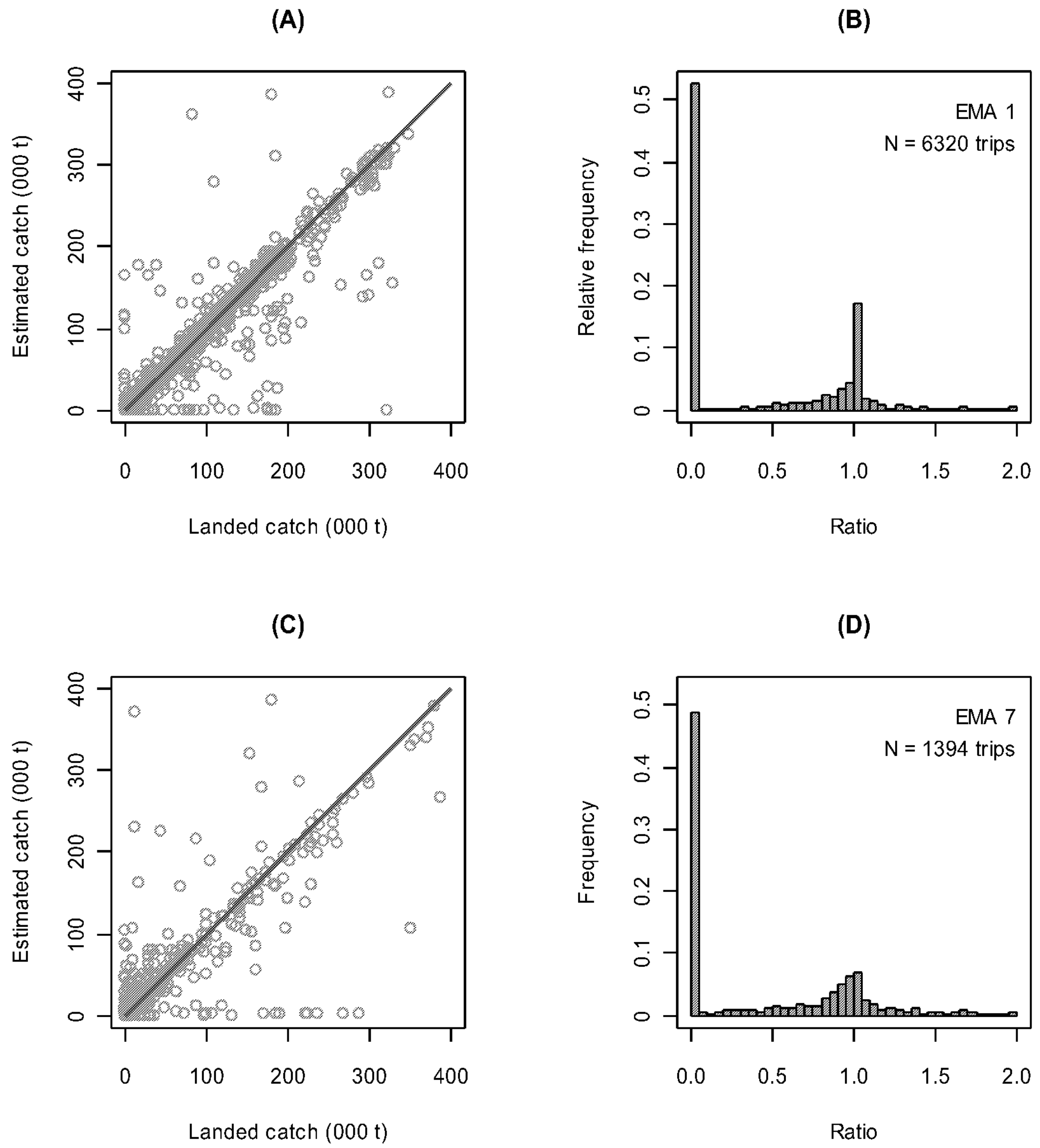


Figure 3: Investigating the relationship between total estimated and total landed catch for all valid EMA 1 (A, B) and 7 (C, D) fishing trips, 1 October 1989 to 30 September 2004: (A, C) scatter plots of total estimated catch by total landed catch for all valid trips for each stock; (B, D) histograms of the ratio between total estimated catch and total landed catch (i.e., total estimated catch / total landed catch). The solid red line in (A) and (C) is the expected 1:1 relationship.

catch to the new effort strata. For further information, see Starr's (2003) notes, or Manning et al. (2004), where one implementation is described in detail.

Systematic deviation by some or all of the data below the one-to-one line would suggest that some fishers may have recorded some processed weight. Histograms of the ratio between total estimated and total landed catch per trip are plotted for both fisheries in Figures 3(B) and 3(D). The large number of zero values (where a zero total estimated catch per trip is divided by a non-zero total landed catch), about 50% in both the EMA 1 & 7 fisheries, suggest that some fishers in both EMA 1 & 7 are not recording an estimated blue mackerel catch for some or all fishing events in fishing trips where blue mackerel appear to have been landed. This suggests that future studies involving analysis of blue mackerel catch-effort and landings data may benefit by adopting Starr's procedure.

Table 4: Summary of the blue mackerel total reported landed catch and numbers of reported landings by month, July 2003 to September 2004, in EMA 1 & EMA 7. PS, purse-seine; BT-MW, bottom and midwater trawl vessels.

EMA 1

		Catch (t)			Numbers of landings (frequency)			
Calendar year	Month	Total	Sampled	(%)	All	PS (all)	PS (> 10 t)	Sampled
2003	Jul	15	–	–	34	10	–	–
	Aug	3	–	–	20	4	–	–
	Sep	156	–	–	42	21	5	–
	Oct	1519	1187	78	38	17	9	9
	Nov	2801	2518	90	38	17	16	11
	Dec	610	409	67	46	14	11	5
2004	Jan	126	–	–	32	10	5	–
	Feb	8	–	–	17	5	–	–
	Mar	303	85	28	25	11	3	1
	Apr	23	–	–	13	4	1	–
	May	276	184	66	30	13	4	2
	Jun	14	–	–	31	9	–	–
	Jul	25	–	–	20	3	–	–
	Aug	18	–	–	10	1	1	–
	Sep	849	–	–	43	23	16	–
Total	All	6745	4383	65	439	162	71	28

EMA 7

		Catch (t)			Numbers of landings (frequency)			
Calendar year	Month	Total	Sampled	(%)	All	BT-MW	PS	Sampled
2003	Jul	1827	–	–	46	35	–	–
	Aug	219	–	–	25	22	–	–
	Sep	7	–	–	12	12	–	–
	Oct	533	–	–	24	23	–	–
	Nov	645	–	–	25	21	–	–
	Dec	89	–	–	20	16	–	–
2004	Jan	247	–	–	34	33	–	–
	Feb	–	–	–	9	6	–	–
	Mar	55	–	–	16	9	6	–
	Apr	–	–	–	16	6	3	–
	May	5	–	–	11	8	1	–
	Jun	71	< 1	< 1	12	9	–	4
	Jul	851	356	42	33	29	–	4
	Aug	10	–	–	25	15	–	–
	Sep	241	205	85	42	35	–	3
Total	All	4800	561	12	350	279	10	11

Total estimated catches for all fishing trips in the catch-effort and landings dataset extracted from *warehou* were plotted against the corresponding total landed greenweight catch for each trip in Figures 3(A) and 3(C). Although scatter in the data is apparent, most values surround the expected one-to-one line, suggesting that most fishers in both fisheries accurately record greenweight on their catch-effort returns.

Table 5: Results of log(weight) ~ log(length) regressions. Numbers of parameters (p), proportion of variance explained (R^2), parameter estimates and associated 95% confidence intervals (CI) for each fitted model are provided.

Model	Description	p	R^2	Parameter	Estimate	95% CI LB	95% CI UB
1	Same parameters for all groups	2	0.9855	a	3.3489×10^{-6}	3.1153×10^{-6}	3.6000×10^{-6}
				b	3.4058	3.3862	3.4254
2	Separate parameters for males and females	4	0.9999	a_{M}	3.3743×10^{-6}	3.0587×10^{-6}	3.7224×10^{-6}
				a_{F}	3.2305×10^{-6}	2.8943×10^{-6}	3.6058×10^{-6}
				b_{M}	3.4047	3.3779	3.4315
				b_{F}	3.4145	3.3850	3.4440
3	Separate parameters for each year	6	0.9999	a_{2002}	2.5661×10^{-6}	2.2747×10^{-6}	2.8948×10^{-6}
				a_{2003}	3.5962×10^{-6}	3.2349×10^{-6}	3.9978×10^{-6}
				a_{2004}	2.7407×10^{-6}	2.1871×10^{-6}	3.4344×10^{-6}
				b_{2002}	3.4746	3.4420	3.5073
				b_{2003}	3.3927	3.3633	3.4220
				b_{2004}	3.4570	3.3973	3.5167
4	Separate parameters for each year-sex group	12	0.9999	$a_{\mathrm{M},2002}$	2.4858×10^{-6}	2.0828×10^{-6}	2.9669×10^{-6}
				$a_{\mathrm{F},2002}$	2.5909×10^{-6}	2.1858×10^{-6}	3.0711×10^{-6}
				$a_{\mathrm{M},2003}$	3.4978×10^{-6}	3.0516×10^{-6}	4.0091×10^{-6}
				$a_{\mathrm{F},2003}$	3.5768×10^{-6}	3.0115×10^{-6}	4.2482×10^{-6}
				$a_{\mathrm{M},2004}$	2.4106×10^{-6}	1.7282×10^{-6}	3.3626×10^{-6}
				$a_{\mathrm{F},2004}$	3.0495×10^{-6}	2.2344×10^{-6}	4.1619×10^{-6}
				$b_{\mathrm{M},2002}$	3.4840	3.4357	3.5323
				$b_{\mathrm{F},2002}$	3.4714	3.4258	3.5170
				$b_{\mathrm{M},2003}$	3.4025	3.3643	3.4407
				$b_{\mathrm{F},2003}$	3.3916	3.3444	3.4389
				$b_{\mathrm{M},2004}$	3.4913	3.4028	3.5797
				$b_{\mathrm{F},2004}$	3.4287	3.3467	3.5107

3.3 A length-weight relationship for New Zealand blue mackerel

Four separate log(length)-log(weight) regression models were fitted to the blue mackerel weight-at-length data collected from the EMA 1 fishery over the 2002–04 calendar years. These were: (1.) a model that assumed the same parameters for all groups in the data; (2.) a model that assumed separate parameters for males and females; (3.) a model that assumed separate parameters for each calendar year (2002, 2003, and 2004); and (4.) a model that assumed separate parameters for each calendar year-sex group in the data. Parameter estimates and associated confidence intervals for each model are given in Table 5.

The relative goodness of fits of the competing models to the data were first compared using conventional analysis of variance (ANOVA). To test for a sex effect within the data, model 1 (reduced) was compared with model 2 (full); to test for a year effect within the data, model 1 (reduced) was compared with model 3 (full); to test for a sex effect within year, model 2 (reduced) was compared with model 4 (full); to test for a year effect within sex, model 3 (reduced) was compared with model 4 (full). ANOVA test results are given in Table 6. The sex effect and sex-within-year test results provided only weak evidence against the null hypothesis that the variation in the data explained by the full and reduced models is equivalent. In contrast, the year effect and year-

Table 6: Comparing the log(weight) ~ log(length) regressions fitted using analysis of variance (ANVOA) and AIC and BIC model comparison statistics. AIC, Akaike's Information Criterion (Akaike 1973); BIC, Bayesian Information Criterion (Schwarz 1978); Res DF, residual degrees of freedom; RSS, residual sum-of-squares; DF, degrees of freedom; SSQ, sum of squares; *F*, ANOVA test statistic; $P(F \mid H_0)$, probability of obtaining the *F* test statistic given the null hypothesis.

Testing for a sex effect

	Model	AIC	BIC	Res. DF	RSS	DF	SSQ	F	$P(F \mid H_0)$
Reduced	1	-3841.26	-3832.38	1708	10.5541				
Full	2	-3841.38	-3821.61	1706	10.5287	2	0.0254	2.0573	0.1281

Testing for a year effect

	Model	AIC	BIC	Res. DF	RSS	DF	SSQ	F	$P(F \mid H_0)$
Reduced	1	-3841.26	-3832.38	1708	10.5541				
Full	3	-3923.39	-3892.73	1704	10.0122	4	0.5419	23.055	$< 2\times10^{-16}$

Testing for a year effect within sex

	Model	AIC	BIC	Res. DF	RSS	DF	SSQ	F	$P(F \mid H_0)$
Reduced	2	-3841.38	-3821.61	1706	10.5287				
Full	4	-3919.44	-3856.11	1698	9.9652	8	0.5635	12.002	$< 2\times10^{-16}$

Testing for a sex effect within year

	Model	AIC	BIC	Res. DF	RSS	DF	SSQ	F	$P(F \mid H_0)$
Reduced	3	-3923.39	-3892.73	1704	10.0122				
Full	4	-3919.44	-3856.11	1698	9.9652	6	0.047	1.3354	0.2379

within-sex tests provided strong evidence against the null hypothesis for each test. However, the AIC and BIC statistics calculated for each of the fitted models, suggests that model 3 (separate parameters by year) is a better, more parsimonious description of the data than model 4 (separate parameters for each year-and-sex group).

Fitted values from all the fitted models are overlaid on the data in Figure 4. Given that the fitted values from all models are visually indistinguishable, we suggest that the statistically significant effects described above are not biologically significant, and the composition of the year- and year-and-sex-specific subsets in the data are due to sampling effects, which are driving the year (and year-within-sex) effects described above. We suggest that the parameter estimates from model 1, the model assuming the same parameters for all groups in the data, are an appropriate description of mean weight-at-length for blue mackerel in EMA 1.

3.4 Otolith readings and results of the within- and between-reader comparison tests and the length-at-age relationship for blue mackerel in the 2003–04 catch

As described above, one otolith from each pair of otoliths collected from the EMA 1 & 7 catches was prepared and read once by reader 1 (P. M. Marriott). Most otoliths exhibited alternate light (translucent) and dark(opaque) regions when viewed with transmitted light. All otoliths read are

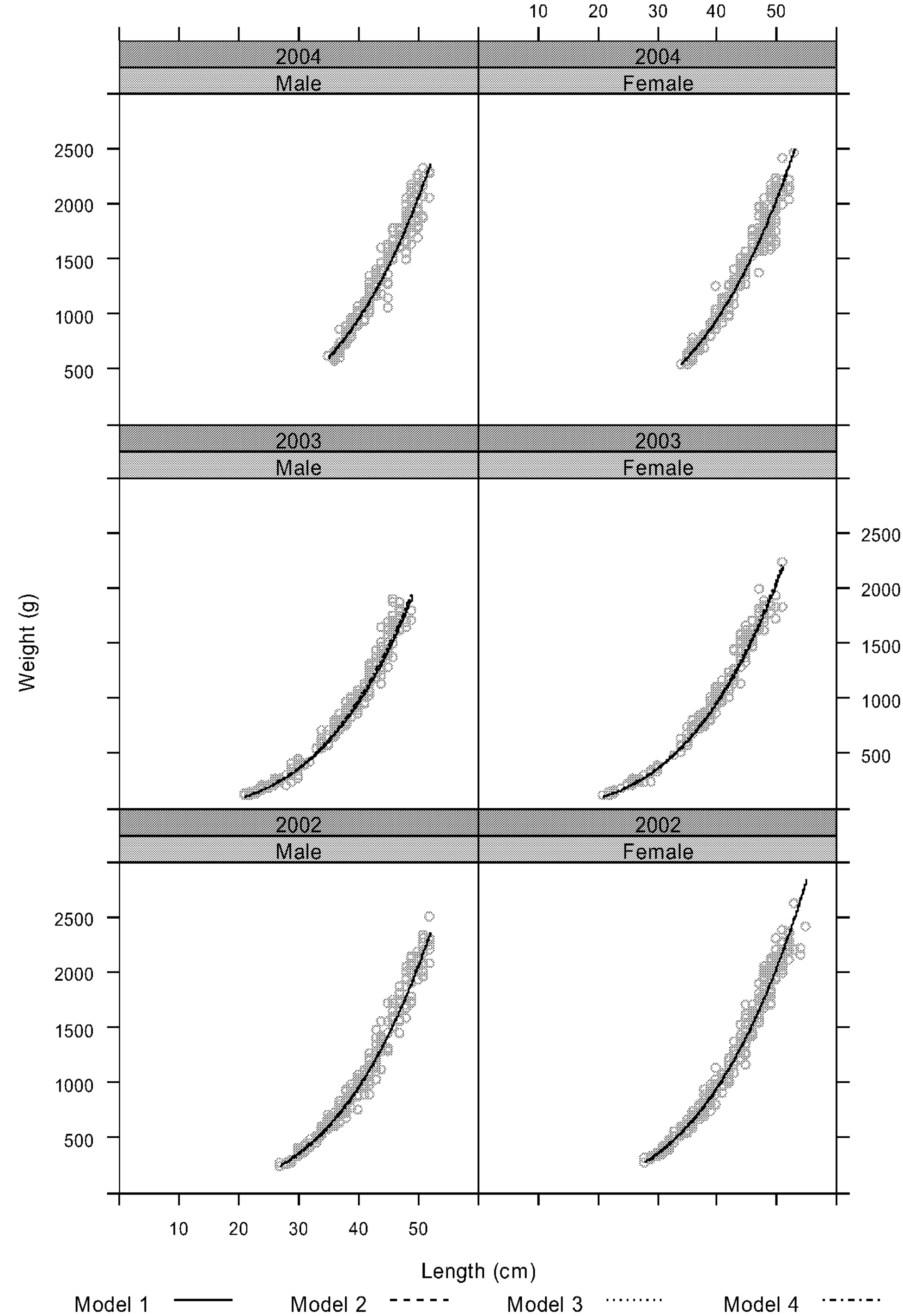


Figure 4: Blue mackerel weight-at-length data collected from the EMA 1 purse-seine over the 2002 to 2004 calendar years by sex and calendar year. Fitted curves from the model assuming separate parameters by sex and from the model assuming separate parameters for each year and sex group in the data are overlaid (Models 2 and 4; Table 5). Note that the fitted values from both models are virtually identical, despite a statistically-significant difference between the two (Table 6).

tabulated by the readability and margin-state scores assigned by reader 1 in Table 7. A subsample of 100 otoliths was randomly sampled from the set of all prepared otoliths, read by a second reader and re-read by reader 1. These results were compared with the first reader's first set of results once the

Table 7: Results of otolith readings by reader 1.

Readability scores

	Readability					
Fishery	1	2	3	4	5	Not assigned
EMA 1	9	181	272	43	2	2
EMA 7	0	34	221	81	5	12
Total	9	215	493	124	7	14

Margin-state scores

	Margin state			
Fishery	N	M	W	Not assigned
EMA 1	220	154	133	2
EMA 7	74	229	35	15
Total	294	383	168	17

opaque-zone counts had been converted to estimated ages. Both readers re-read the protocol set of 20 blue mackerel otoliths held in the MFish otolith collection before starting their readings. Both readers had read blue mackerel otoliths during the analysis of data collected from the EMA 1 fishery during the 2002–03 fishing year (Manning et al. 2006).

As in the 2002–03 study, both readers found the prepared sections to be difficult to read. Precision was moderate (within-reader IAPE and mean c.v. of 7.45% and 10.67%, between-reader IAPE and mean c.v. of 10.55% and 14.92%), and comparable in magnitude to precision achieved during the 2002–03 study (within-reader IAPE and mean c.v. of 9.93% and 14.04%, between-reader IAPE and mean c.v. of 10.24% and 14.48%, Manning et al. (2006)). However, unlike the 2002–03 study, there was some evidence of an inconsistent interpretation of blue mackerel otoliths over the course of this study. Diagnostic bias-plots following Campana et al. (1995) are plotted in Figure 5. The lack of symmetry of the histograms in Figure 5(A) and the deviation of the actual relationship between the first and second readings in each comparison test from the expected one-to-one relationship in Figure 5(B)–(C) suggest inconsistencies over the course of the study in reader 1's interpretation of blue mackerel otoliths and between reader 1 and 2. Figures 5(B)–(C) suggest that reader 1 may have under-estimated the ages of younger blue mackerel in the dataset relative to his later results and those produced by reader 2 for the same otoliths. Some implications of these results are discussed below. Age-frequency tables following Campana et al. (1995) for both the within- and between-reader comparison tests are given in Appendix A.

Nevertheless, to preserve homogeneity of method, no attempt was made to resolve disagreements either within or between the readers, and the first reader's first set of results was used in all subsequent analyses presented in this report. The empirical length-at-age relationship for blue mackerel in the EMA 1 & 7 fisheries during the 2003–04 fishing year derived from these results is presented in Figure 6.

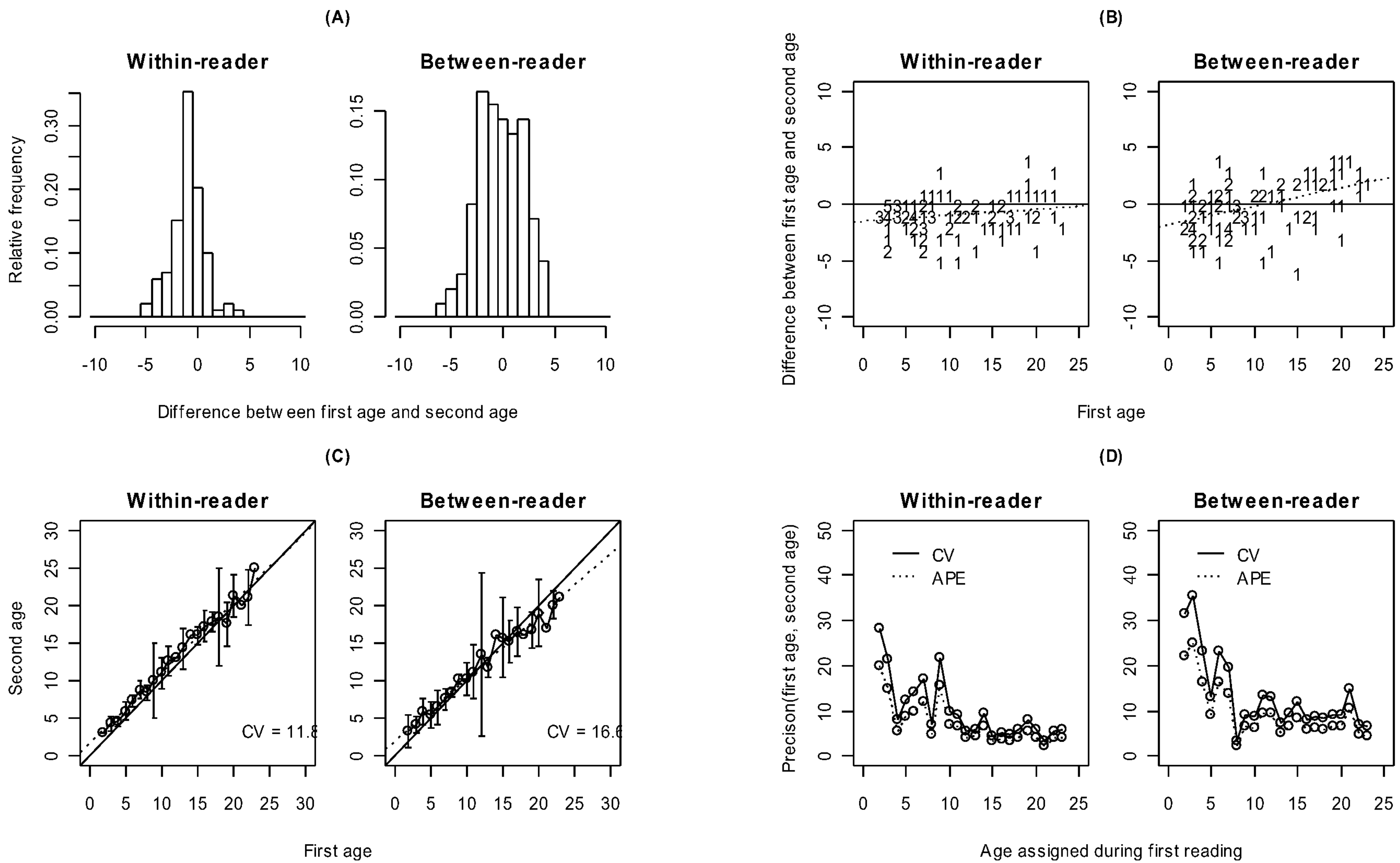


Figure 5: **Results of within- and between-reader comparison tests. For each test: (A) histograms of differences between ages; (B) differences between first and second ages relative to the first age; (C) bias plots; and (D) c.v. and APE profiles for both ages relative to the first age in each test. The expected one-to-one (solid line) and actual relationship (dashed line) between the first and second ages are overlaid on (B) and (C).**

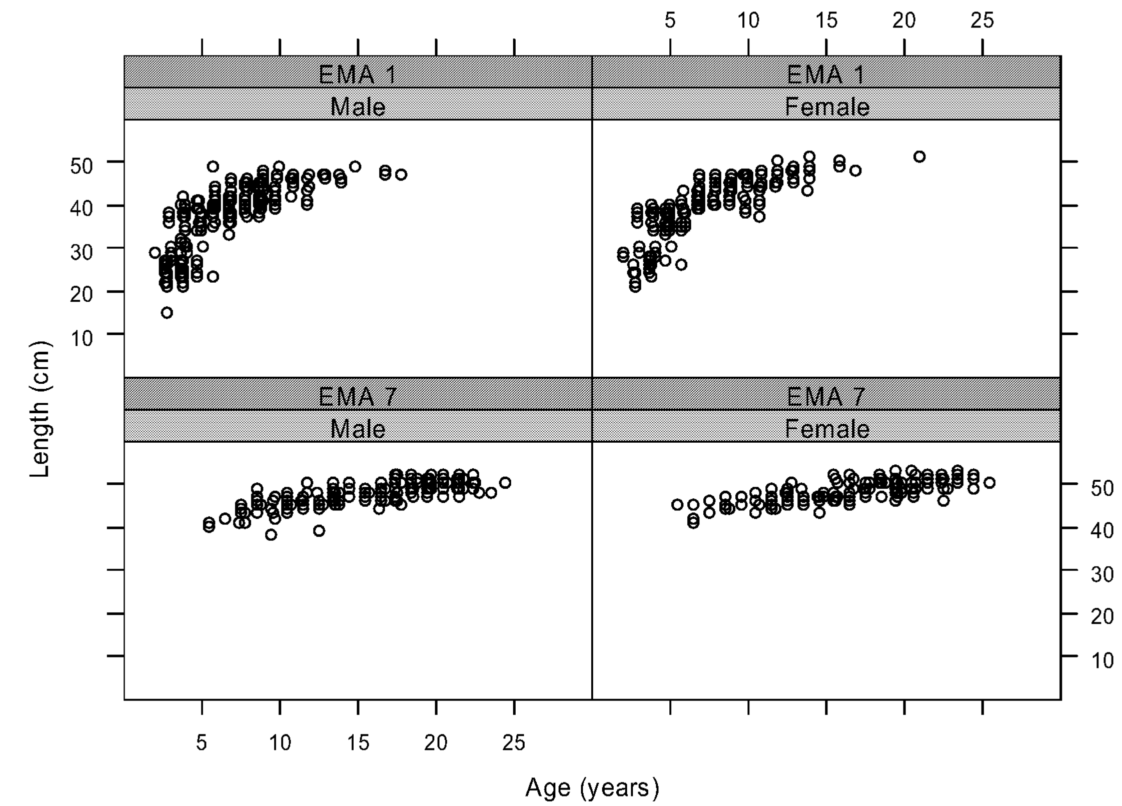


Figure 6: Empirical length-at-age relationship for blue mackerel in the EMA 1 & 7 fisheries during the 2003–04 fishing year. These data were converted to age-length keys and data and used to calculate the proportions-at-age distributions in Figure 8 from the scaled length-frequency distributions in Figure 7.

3.5 The length and age composition of the catch in EMA 1 & 7

Estimated scaled proportions-at-length distributions for male, female, and all fish in both EMA 1 & 7 are plotted in Figure 7. The length-at-age data derived from the first reader's first set of readings were used to construct separate age-length keys for EMA 1 & 7 (Appendix A). The age-length keys were then used to compute estimate-scaled-proportions-at-age distributions for male, female, and all fish in the EMA 1 & 7 catches from the corresponding scaled length distributions. The age distributions are plotted in Figure 8. Numbers at length for each sex and fishery are given in Appendix C. Numbers at age for each sex and fishery are given in Appendix D. Bootstrapped c.v.s for each length- and age class are provided. Bootstrapped mean-weighted c.v.s for each length and age distribution in each fishery are given in Table 8.

The mean-weighted c.v.s for male, female, and all fish in the EMA 1 2003–04 catch-at-length were 18.3%, 15.7%, and 15.1%, respectively. In the EMA 7 catch-at-length, these were 42.7%, 38.4%, and 33.0%. The mean-weighted c.v.s for male, female, and all fish in the EMA 1 2003–04 catch-at-age were 27.9%, 27.8%, and 21.1%, respectively. In the EMA 7 catch-at-age, these were 47.9%, 45.6%, and 33.3%. The mean-weighted c.v.s for the EMA 1 catch-at-length and catch-at-age compare favourably with the results from the 2002–03 fishing year (Manning et al. 2006). The significantly worse mean-weighted c.v.s for the EMA 7 fishery catch-at-length and catch-at-age compared to the EMA 1 results from this fishing year reflect the much lower sampling effort spent in the EMA 7 fishery compared with EMA 1.

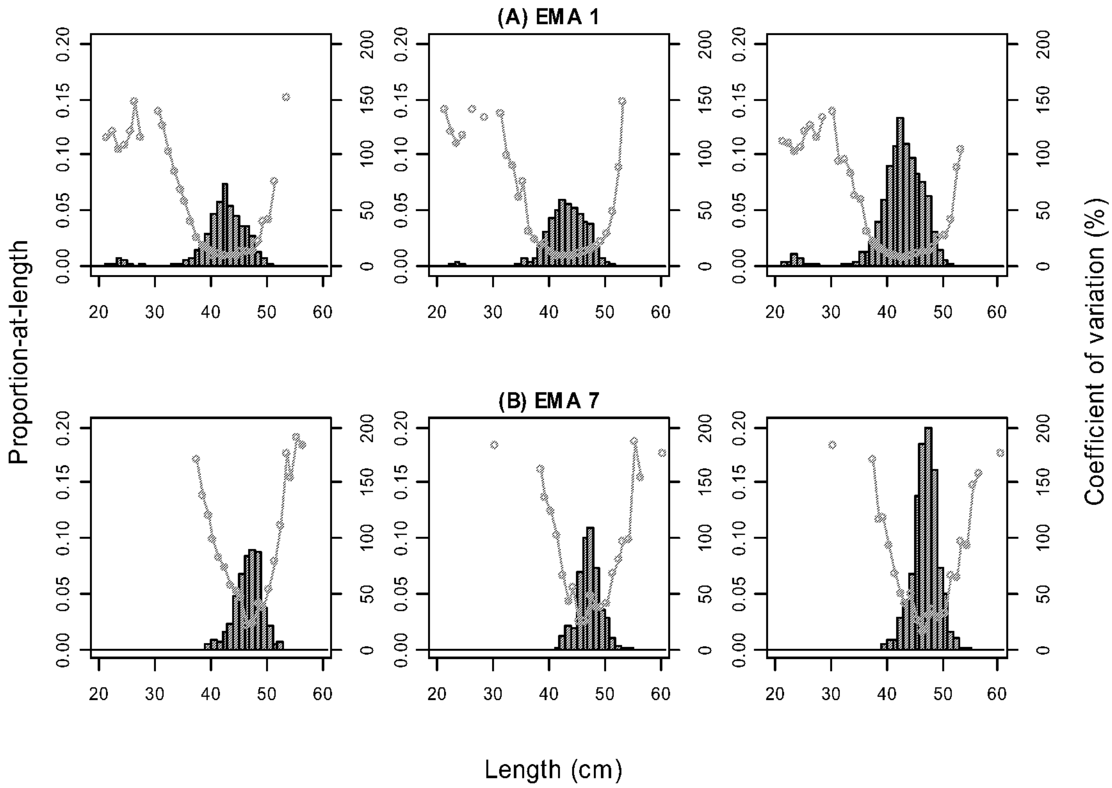


Figure 7: Estimated scaled proportions-at-length for males, females, and all fish in the (A) EMA 1 and (B) EMA 7 fisheries sampled during the 2003–04 fishing year.

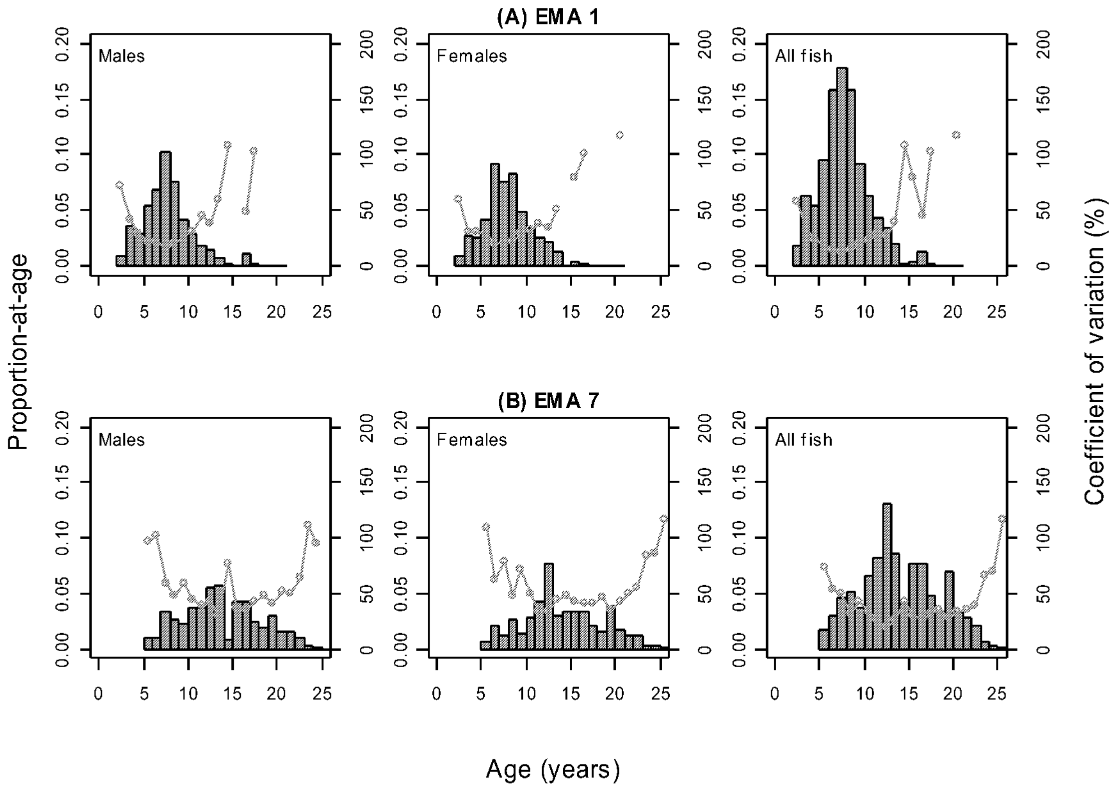


Figure 8: Estimated scaled proportions-at-age for males, females, and all fish in the (A) EMA 1 and (B) EMA 7 fisheries sampled during the 2003–04 fishing year.

Table 8: Mean-weighted coefficients of variation by sex for the estimated scaled length- and age-frequency distributions calculated for the EMA 1 & 7 fisheries sampled during the 2003–04 fishing year.

Length-frequency distributions

Fishery	Males	Females	Unsexed	All fish
EMA 1	18.3	15.7	–	15.1
EMA 7	42.7	38.4	184.8	33.0

Age-frequency distributions

Fishery	Males	Females	Unsexed	All fish
EMA 1	27.9	27.8	–	21.1
EMA 7	47.9	45.6	–	33.3

As with the 2002–03 proportions-at-length distributions, the corresponding distributions for EMA 1 during 2003–04 were strongly unimodal for both males and females. As during 2002–03, the 2003–04 distributions are roughly centred between about 40–45 cm, with relatively few fish less than 30 cm or greater than 50 cm in the catch for either sex. The 2003–04 EMA 7 proportions-at-length are also strongly unimodal for either sex, but appear to be centred between about 45–50 cm. The overall length range in the catch also appears narrower for both sexes than in EMA 1.

There is a suggestion of a small pulse of young, small fish entering the 2003–04 EMA 1 catch-at-length. No similar pulses were observed in either the 1997–98 or 2002–03 catch-at-length in EMA 1 (Manning et al. 2006), or the 2003–04 catch-at-length in EMA 7 (this study). An examination of the raw data suggested that this was driven by length observations from 1 of the 28 EMA 1 landings sampled in Tauranga in October 2003, where unusually small blue mackerel were caught. Nevertheless, the catch-at-length is clearly dominated by larger fish within a relatively narrow size range. Comparing cumulative proportions-at-length distributions for the EMA 1 catch-at-length for 1997–98, 2002–03, and 2003–04 (Figure 9), suggests that no gross changes in the catch-at-length distribution have occurred over these years; the fatter tail-region in the 2003–04 distributions reflects the greater uncertainty about the apparent pulse of small (20–30 cm) fish described above entering the catch, also reflected in the c.v. trace in Figure 7.

As in EMA 1 in 1997–98 and 2002–03, the 2003–04 catches-at-age for both males and females display less unimodality than the corresponding catches-at-length. Also as in EMA 1 in 1997–98 and 2002–03, the 2003–04 catch-at-age appears to be composed mostly of fish between about 4 to about 10 years of age, with no young-of-the-year and relatively few fish between 1 and 3 years of age present in the catch. The oldest observed fish in the catch during 2003–04 was a 51 cm female with an estimated age of 20.94 years, caught during October 2003; relatively few fish older than 15 years of either sex were present. Comparing cumulative proportions-at-age distributions for the EMA 1 catch-at-age for 1997–98, 2002–03, and 2003–04 (Figure 10) suggests the catch-at-age was composed of proportionally more younger female fish in 2002–03 than in either 1997–98 or 2003–04; the corresponding male distributions more obviously overlap. Interestingly, the age of the oldest fish observed in the catch-at-age of each sex during each of the 1997–98, 2002–03, and 2003–04 fishing as indicated by the extent of the confidence regions in Figure 10, appears to be decreasing with time. The oldest fish in the 2002–03 catch-at-age was a 54 cm female with an estimated age of 21.90 years (Manning et al. 2006). The oldest fish in the 1997–98 catch-at-age was a 23.9 year old female (Morrison et al. 2001). There is no obvious progression of very strong or weak year-classes through the EMA 1 catch-at-age at this time (Figure 11).

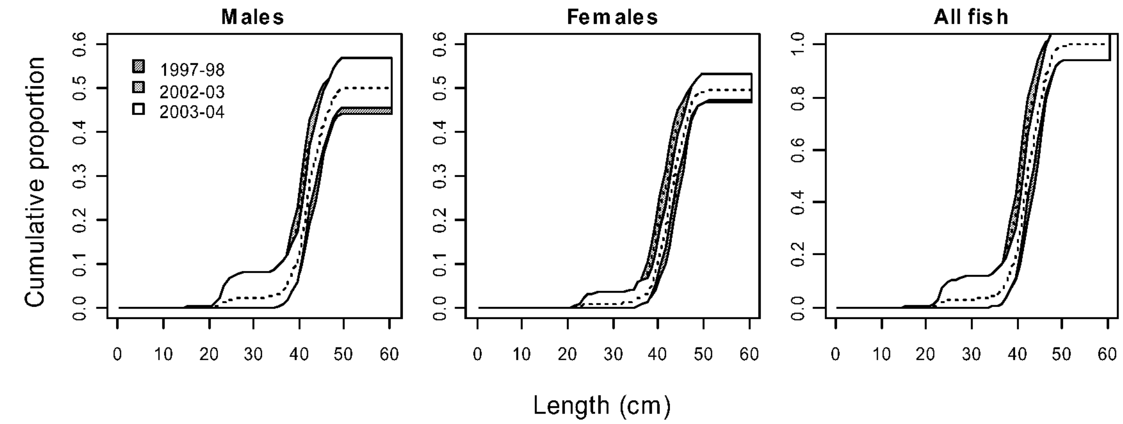


Figure 9: Cumulative proportions-at-length for males, females, and all fish in the EMA 1 fishery sampled during the 1997–98, 2002–03, and 2003–04 fishing years (overlaid). The dashed lines are the cumulative proportions-at-length. The surrounding regions are bootstrapped 95% confidence regions about the cumulative proportions-at-length.

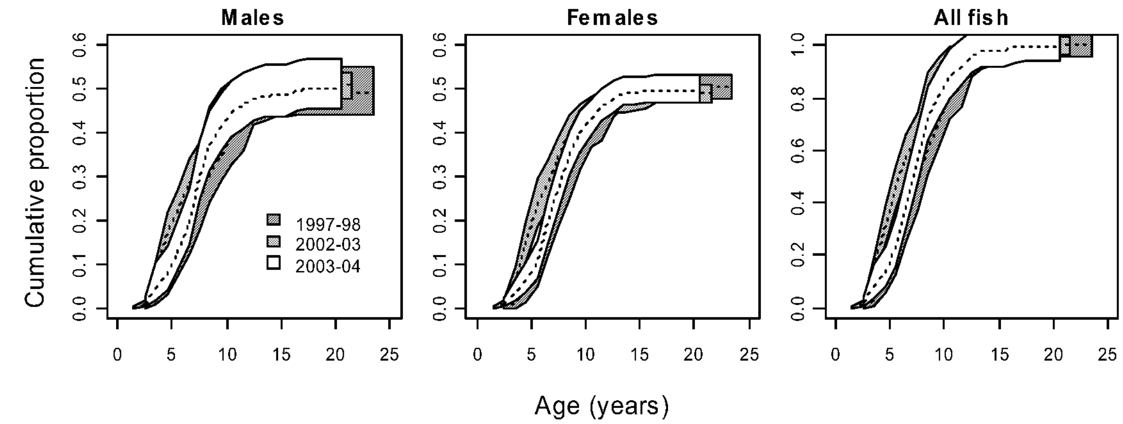


Figure 10: Cumulative proportions-at-age for males, females, and all fish in the EMA 1 fishery sampled during the 1997–98, 2002–03, and 2003–04 fishing years (overlaid). The dashed lines are the cumulative proportions-at-age. The surrounding regions are bootstrapped 95% confidence regions about the cumulative proportions-at-age.

3.6 Market variables that may have influenced fishing patterns in EMA 1 & 7 during the 2003–04 fishing year

Comments on market variables that may have influenced fishing patterns in either the EMA 1 purse-seine fishery or the EMA 7 midwater trawl fishery for blue mackerel during the 2003–04 fishing year were sought from fishing companies active in either fishery. We summarise these here.

In the EMA 1 purse-seine fishery, blue mackerel is the second-preferred target species after skipjack tuna (*Katsuwonus pelamis*). Blue mackerel schools will not be targeted if skipjack schools are available at the same time and place. The blue mackerel season is usually between July and December in a given calendar year, with most fishing occurring between the months of August and October. The end of the blue mackerel season is defined by fishers shifting effort from blue mackerel to skipjack tuna, when skipjack schools become available to the purse-seine fishery following their migration into the New Zealand region during early–late Summer (from about December–March). There is generally little overlap in target fishing for either species, although the occasional landing of blue mackerel can occur between January and March during the skipjack season. Companies with markets requiring fish

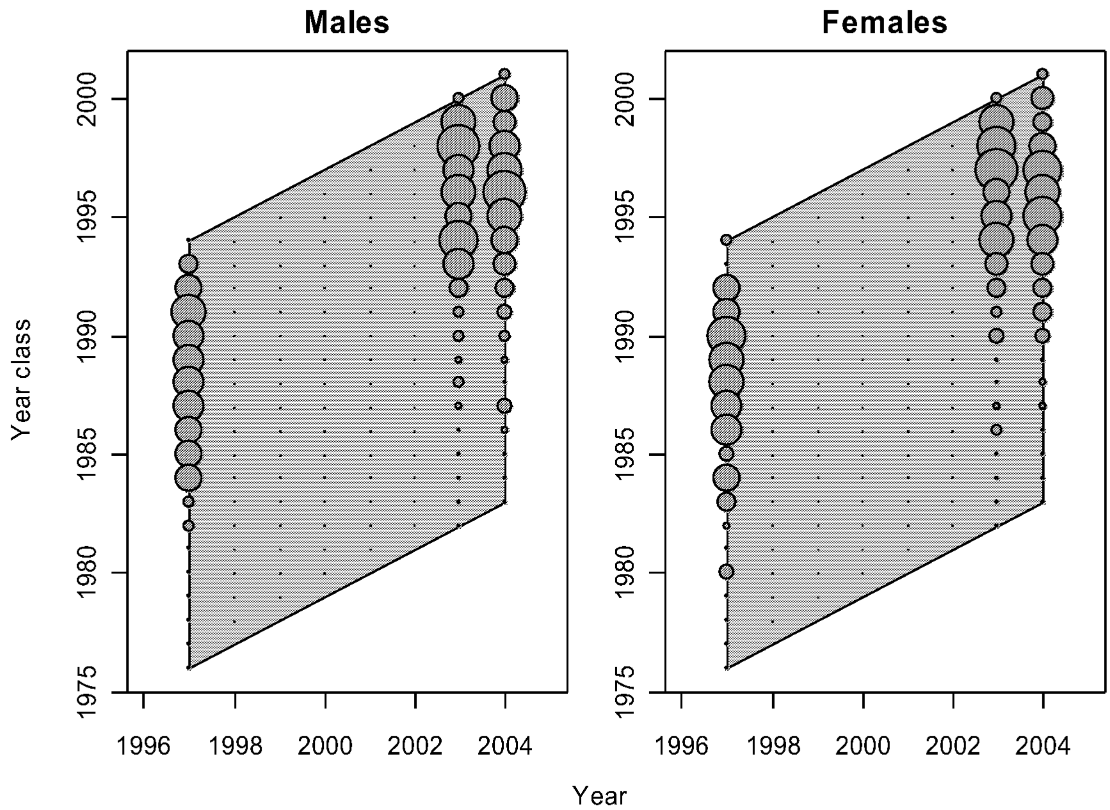


Figure 11: Estimated scaled proportions-at-age (ages 2 to 20 years) by year class and fishing year for males and females in the EMA 1 fishery over the 1997–98 to 2003–04 fishing years. Circle area is proportional to the corresponding proportion-at-age within each sampling event; circle sizes are equivalent 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 dots represent fishing years during which no data were collected from the fishery. Note that age 2 is a "minus group" (the sum of the proportions-at-age for all ages less than or equal to 2) and age 20 is a "plus group" (the sum of the proportions-at-age for all ages greater than or equal to 20).

late in the fishing year (e.g., September) manage their quota to ensure that orders can be met without storing fish caught during the previous season (i.e., the previous July–December).

In the EMA 7 trawl fishery, blue mackerel are caught as a bycatch of fishing effort directed at jack mackerels (*Trachurus* spp.) The preference for blue mackerel catch differs by fishing company and depends on the amount of blue mackerel quota each company owns. Generally, a simple rule applies: for fishing companies with little quota, blue mackerel catch is avoided, while those with more quota manage their blue mackerel bycatch to ensure that the best harvest levels are achieved without exceeding their quota. Extracting a full harvest of blue mackerel from both the EMA 1 purse-seine and EMA 7 trawl fisheries has been attractive for at least the last five years, with international prices relatively high. A small price slump did occur during the 2003–04 fishing year, but prices had recovered at the time of writing.

4. DISCUSSION

4.1 On sampling adequacy in the EMA 1 & 7 fisheries during the 2003–04 fishing year and suggestions for future catch-sampling studies of blue mackerel in EMA 1 & 7

Although sampling effort in the EMA 1 fishery was reduced in 2003–04 compared with the 2002–03 fishing year, given that the distribution of sampling effort through the fishing year closely follows the distribution of catch over the same time, the relatively large numbers of landings sampled and the relatively large numbers of length measurements collected per landing suggest the data collected from this fishery during the 2003–04 fishing year are representative of the catch. This in turn suggests that the results of the analyses of these data presented in this paper are valid. However, whether the data collected from the EMA 7 trawl fishery during the 2003–04 fishery are representative of the EMA 7 catch is not clear. The data collected from the EMA 7 fishery were collected over a relatively short amount of time (July–September 2004), despite the catch being distributed throughout the whole of the fishing year. Given this, we are unsure whether our analysis of the EMA 7 data presented above is valid.

We suggest that the same sampling methods that were used to sample the EMA 1 purse-seine fishery during the 2003–04 fishing year be used during subsequent fishing years. We suggest that that excellent coverage and results obtained during 2002–03 and 2003–04 fishing years has proved the usefulness of the cooperative NIWA-Industry approach that was adopted in this fishery. Despite reducing sampling effort in 2003–04 compared with that spent in the fishery during 2002–03, very good coverage was obtained in 2003–04. Although the value of the use of the mean-weighted coefficient of variation as a target or yardstick to compare success in sampling programmes can be debated, low mean-weighted c.v.s within the target of 30% set for the catch-at-age were obtained during both 2002–03 and 2003–04, and despite the reduction in sampling effort, the mean-weighted c.v.s on the catch-at-age obtained in 2003–04 were very close to those obtained in 2002–03.

As noted, we are unsure whether our analysis of the EMA 7 trawl fishery data collected during 2003–04 presented above is valid, given that we are unsure whether the data collected form the fishery are representative of the fishery or not. The usefulness of these data in future studies of the blue mackerel stock in EMA 7, such as a future quantitative stock assessment, is probably low. To overcome these issues, additional sampling effort *must* be spent in the fishery in such a manner that the data collected from the fishery are representative of the catch in time and space.

Monitoring the EMA 7 trawl fishery is based on coverage of the fishery by the Ministry of Fisheries Observer Programme. However, until the 2004–05 fishing year, no observer coverage has been allocated *specifically* to cover the blue mackerel catch. Instead, MFish has relied on obtaining coverage from observers stationed on trawl vessels targeting jack mackerels. This appears sensible, given that these are the vessels aboard which most of blue mackerel catch in EMA 7 is taken, but coverage of the blue mackerel catch was negligible during the 2002–03 fishing year and low during 2003–04. To achieve coverage of the EMA 7 catch in the future, MFish has increased the number of observer days allocated to the jack and blue mackerel catch. The number of observer days allocated to trawl vessels targeting jack mackerels in EMA 7 was increased from 95 during 2003–04 to 150 days during 2004–05 and is proposed to rise to 250 days during the 2005–06 fishing year (Ministry of Fisheries 2004). For the first time, during 2004–05, an additional 20 days will be allocated specifically to cover blue mackerel caught during the winter jack mackerel season in the Taranaki Bight.

Nevertheless, if monitoring of the blue mackerel trawl fishery in EMA 7 is to succeed, then the MFish OP must achieve the increased allocated coverage, and furthermore, the coverage must be applied to the fishery in a manner that is representative of the catch.

4.2 On implications of the within- and between reader comparison tests for the results presented here and other studies of blue mackerel involving age estimation

Results of the within- and between-reader comparison tests presented here suggest that some systematic differences in interpretation existed both between the two readers for the same otoliths and between subsequent readings of the same otoliths by the first reader. Between-reader precision (IAPE and mean c.v.) was fair, and comparable with that obtained by Manning et al. (2006) for otoliths collected during the 2002–03 fishing year, but in the presence of systematic differences such as those identified here, precision (or imprecision) is not meaningful.

Many features make blue mackerel otoliths difficult to interpret. These include the relatively diffuse nature of many early opaque zones, the generally poor contrast between opaque and translucent zones, and the large number of presumably false opaque zones that are present in the otoliths. Indeed, some Australian scientists regard interpreting blue mackerel sections as impossible (Stewart et al. 1999, Stewart & Ferrell 2001). We do not agree, but note that estimating blue mackerel ages from otolith thin sections is still in development. To our knowledge, this is only the third published study on blue mackerel age and growth that has used the thin-section approach (Morrison et al. 2001, Manning et al. 2006, this study), with a total of fewer than 2000 otoliths prepared and read in all three studies. While Australian scientists claim to have validated blue mackerel age estimation based on reading whole otoliths immersed in lavender oil (Stewart et al. 1999), we note that they succeeded in only validating the first opaque zone present, and as Manning et al. (2006) noted, the whole-otolith method may under-estimate blue mackerel ages.

Nevertheless, differences in interpretation of blue mackerel otoliths may result in systematic mis-assignment of blue mackerel to the wrong age classes, invalidating analyses based on these data. An upcoming research project, EMA2005-02 "Investigation of blue mackerel ageing error", will investigate the effect of different age estimation error scenarios on the catch-at-age computed from these data using Monte Carlo simulation methods with the aim of incorporating these results in a quantitative stock assessment of the EMA 1 stock proposed for the 2007–08 fishing year (Ministry of Fisheries 2004). This project will also review and refine if necessary the New Zealand thin-section method as described by Manning et al. (2006), and investigate the feasibility of radiochemical validation of blue mackerel age estimates derived using the New Zealand method.

4.3 On trends in the catch-at-length and catch-at-age in the EMA 1 & 7 fisheries

Trends in the EMA 1 catch-at-length during the 2003–04 fishing year are very similar to those identified in the catch-at-length during the 1997–98 (Morrison et al. 2001) and 2002–03 (Manning et al. 2006) fishing years. As in 1997–98 and 2002–03, the 2003–04 catch-at-length was strongly unimodal within a relatively narrow (about 30–55 cm) size range, with few obvious differences between the sexes. Manning et al. (2006) found no statistically-significant differences in growth between male and female blue mackerel in EMA 1.

No data from the EMA 7 fishery have been analysed and presented before now, so a comparison of the results from this study with those from earlier fishing years is not possible. However, as noted above, given that the representativeness of the catch of the data collected from the EMA 7 fishery during 2003–04 is uncertain, the validity of the analyses of these data presented above is also uncertain. Nevertheless, the EMA 7 catch-at-length *appears* superficially similar to that in EMA 1, in that a single large mode occupying a relatively narrow size-range exists in both sets of length-frequency distributions, despite the different gear types and probable different gear selectivity effects these have on the fished populations in each stock.

As with the catch-at-length, trends in the EMA 1 catch-at-age during the 2003–04 fishing year were also very similar to those identified during the 1997–98 (Morrison et al. 2001) and 2002–03 (Manning et al. 2006) fishing years. As in 1997–98 and 2002–03, the 2003–04 catch-at-age appears to be based on a number of successive year-classes, mostly fish between 4 and 10 years of age. There appear to be relatively few fish 3 years of age or less or 15 years of age or more present in the catch. There are no suggestions of large changes in the composition of the catch-at-age over the three fishing years to date for which data are available, but based on a comparison of cumulative proportions-at-age distributions for each sex, the maximum age of each sex in the catch-at-age may have decreased slightly over time. Size-selective fishing effort and the issues associated with interpreting blue mackerel otoliths discussed above could lead to the appearance of greater consistency over time in the catch-at-age than actually exists. The analysis of data collected from the fishery during the 2004–05 fishing year should consider this issues more thoroughly. Purse-seine catch-per-unit-effort models fitted to data from certain other fisheries (e.g., Clark & Mangel 1979, Allen & Punsly 1984) show evidence of hyperstability (sensu Hilborn & Walters 1992, but see Harley et al. (2001) for a more recent discussion). We suggest that the possible effect of hyperstability in purse-seine catch and effort on the EMA 1 catch-at-age also needs further consideration.

Although the results of the analysis of the data collected from the EMA 7 fishery presented here should be considered warily, the EMA 7 catch-at-age during 2003–04 appears to be composed of older fish than the catch-at-age in EMA 1. There were relatively few fish of either sex less than 3 years or older than 15 years in the EMA 1 catch, but proportionally greater numbers of fish 15 years or age or older (15–25 years) and no fish less than 5 years of age appeared to be present in the EMA 7 catch. Future analysis of data from the EMA 7 fishery that are representative of the catch will allow whether these trends are real or not to be evaluated.

The general comments by fishers on market variables that may have affected fishing patterns in EMA 1 & 7 suggest that international prices and other macro-economic factors play an important part in determining fishing patterns in both fisheries (e.g., the temporal extent of the blue mackerel fishing season during the fishing year). Future blue mackerel catch-composition studies should continue to monitor these factors, as changes in fishing patterns driven by these factors may affect the composition of the observed catch-at-length or catch-at-age without any true change in the composition of the stocks.

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Appendix A: Age-frequency tables for within- and between-reader comparison test results

Table A1: Age-frequency table for results of within-reader comparison test.

First age (years)	Second 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
0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	–	–	–	3	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3	–	–	–	2	6	–	2	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4	–	–	–	–	2	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
5	–	–	–	–	–	1	1	2	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6	–	–	–	–	–	–	2	2	3	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
7	–	–	–	–	–	–	–	3	2	1	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–
8	–	–	–	–	–	–	–	–	1	4	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
9	–	–	–	–	–	–	1	–	1	–	–	–	1	–	1	–	–	–	–	–	–	–	–	–	–	–
10	–	–	–	–	–	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
11	–	–	–	–	–	–	–	–	–	1	–	2	2	1	–	–	1	–	–	–	–	–	–	–	–	–
12	–	–	–	–	–	–	–	–	–	–	–	–	2	3	1	–	–	–	–	–	–	–	–	–	–	–
13	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–
14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–
15	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3	–	1	1	1	–	–	–	–	–	–
16	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	1	–	–	–	–	–	–
17	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	3	–	1	–	–	–	–	–
18	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–
19	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1	1	–	1	–	–	–	–	–
20	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	2	–	–	1	–
21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
22	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1	–	1	–	–
23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
24	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Table A2: Age-frequency table for results of between-reader comparison test.

First age (years)	Second 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
0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	–	–	–	3	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3	–	–	–	2	6	–	2	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4	–	–	–	–	2	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
5	–	–	–	–	–	1	1	2	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6	–	–	–	–	–	–	2	2	3	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
7	–	–	–	–	–	–	–	3	2	1	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–
8	–	–	–	–	–	–	–	–	1	4	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
9	–	–	–	–	–	–	1	–	1	–	–	–	1	–	1	–	–	–	–	–	–	–	–	–	–	–
10	–	–	–	–	–	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
11	–	–	–	–	–	–	–	–	–	1	–	2	2	1	–	–	1	–	–	–	–	–	–	–	–	–
12	–	–	–	–	–	–	–	–	–	–	–	–	2	3	1	–	–	–	–	–	–	–	–	–	–	–
13	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–
14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–
15	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3	–	1	1	1	–	–	–	–	–	–
16	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	1	–	–	–	–	–	–
17	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	3	–	1	–	–	–	–	–
18	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–
19	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1	1	–	1	–	–	–	–	–
20	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	2	–	–	1	–
21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
22	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1	–	1	–	–
23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
24	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Appendix B: Age-length key used to calculate the scaled age-frequency distributions

Table B1: Age-length key used to calculate estimated scaled age frequency distributions for males in the EMA 1 purse-seine fishery during the 2003–04 fishing year. The proportions-at-age in each length-class (row) sum to 1. The total number of observations from which the proportions-at-age given length were calculated are also provided (*n*).

	Age (years)																										
Length (cm)	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*
≤ 15	–	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
16	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
17	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
18	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
19	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
20	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
21	–	–	0.33	0.67	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
22	–	–	0.67	0.33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
23	–	–	0.17	0.58	0.17	0.08	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12
24	–	–	0.12	0.81	0.06	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16
25	–	–	0.17	0.83	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6
26	–	–	0.29	0.65	0.06	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	17
27	–	–	0.22	0.67	0.11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9
28	–	–	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
29	–	–	0.27	0.27	0.45	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11
30	–	–	–	0.67	0.22	0.11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9
31	–	–	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
32	–	–	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
33	–	–	–	–	–	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
34	–	–	–	0.38	0.62	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8
35	–	–	–	0.50	0.25	0.25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4
36	–	–	0.09	–	0.55	0.18	0.18	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11
37	–	–	0.07	0.29	0.29	0.07	0.14	0.07	0.07	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14
38	–	–	0.08	0.15	0.15	0.23	0.15	0.08	0.15	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13
39	–	–	–	0.07	0.21	0.36	0.07	0.14	0.07	0.07	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14
40	–	–	–	0.11	–	0.28	0.06	0.33	0.11	0.06	–	0.06	–	–	–	–	–	–	–	–	–	–	–	–	–	–	18
41	–	–	–	–	0.12	0.06	0.29	0.12	0.18	0.18	–	0.06	–	–	–	–	–	–	–	–	–	–	–	–	–	–	17
42	–	–	–	0.05	–	0.10	0.20	0.30	0.20	0.10	0.05	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	20
43	–	–	–	–	–	0.08	0.23	0.38	0.15	0.08	–	0.08	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13
44	–	–	–	–	–	0.08	–	0.31	0.15	0.15	0.23	0.08	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13
45	–	–	–	–	–	–	0.08	0.33	0.42	–	0.08	–	–	0.08	–	–	–	–	–	–	–	–	–	–	–	–	12
46	–	–	–	–	–	–	0.20	0.13	0.07	0.07	0.27	0.07	0.13	0.07	–	–	–	–	–	–	–	–	–	–	–	–	15
47	–	–	–	–	–	–	–	–	0.08	0.17	0.08	0.08	0.33	0.08	–	–	0.08	0.08	–	–	–	–	–	–	–	–	12
48	–	–	–	–	–	–	–	–	0.33	–	–	–	–	–	–	–	0.67	–	–	–	–	–	–	–	–	–	3
49	–	–	–	–	–	0.33	–	–	–	0.33	–	–	–	–	0.33	–	–	–	–	–	–	–	–	–	–	–	3
50	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
≥ 51	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0

Table B2: Age-length key used to calculate estimated scaled age frequency distributions for females in the EMA 1 purse-seine fishery during the 2003–04 fishing year. The proportions-at-age in each length-class (row) sum to 1. The total number of observations from which the proportions-at-age given length were calculated are also provided (*n*).

Length (cm)	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*
≤ 15	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
16	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
17	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
18	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
19	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
20	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
21	–	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
22	–	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
23	–	–	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4
24	–	–	0.67	0.33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6
25	–	–	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
26	–	–	0.12	0.75	–	0.12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8
27	–	–	–	0.33	0.67	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
28	–	–	0.25	0.50	0.25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4
29	–	–	0.20	0.20	0.60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10
30	–	–	–	0.60	0.20	0.20	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5
31	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
32	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
33	–	–	–	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
34	–	–	–	0.33	0.50	0.17	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6
35	–	–	–	0.22	0.56	0.22	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9
36	–	–	0.14	0.29	0.29	0.29	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7
37	–	–	0.11	0.44	0.33	–	–	–	–	–	0.11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9
38	–	–	0.07	0.36	0.29	0.21	–	–	–	0.07	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14
39	–	–	0.07	0.14	0.21	0.21	0.29	–	–	0.07	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14
40	–	–	–	0.07	0.07	0.21	0.36	0.14	0.07	–	0.07	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14
41	–	–	–	–	–	0.20	0.30	0.10	0.20	0.10	0.10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10
42	–	–	–	–	–	–	0.30	0.40	0.10	0.20	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10
43	–	–	–	–	–	0.15	0.23	0.23	0.23	–	0.08	–	–	0.08	–	–	–	–	–	–	–	–	–	–	–	–	13
44	–	–	–	–	–	–	0.23	0.15	0.08	0.15	0.23	0.15	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13
45	–	–	–	–	–	–	–	0.15	0.46	0.08	0.08	0.15	0.08	–	–	–	–	–	–	–	–	–	–	–	–	–	13
46	–	–	–	–	–	–	0.09	0.18	0.36	0.18	–	–	0.09	0.09	–	–	–	–	–	–	–	–	–	–	–	–	11
47	–	–	–	–	–	–	0.13	0.13	0.27	0.27	0.07	0.13	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15
48	–	–	–	–	–	–	–	–	–	–	0.11	0.11	0.56	0.11	–	–	0.11	–	–	–	–	–	–	–	–	–	9
49	–	–	–	–	–	–	–	–	–	–	–	–	0.50	0.25	–	0.25	–	–	–	–	–	–	–	–	–	–	4
50	–	–	–	–	–	–	–	–	–	–	–	0.67	–	–	–	0.33	–	–	–	–	–	–	–	–	–	–	3
≥ 51	–	–	–	–	–	–	–	–	–	–	–	–	–	0.50	–	–	–	–	–	–	0.50	–	–	–	–	–	2

Table B3: Age-length key used to calculate estimated scaled age frequency distributions for males in the EMA 7 trawl fishery during the 2003–04 fishing year. The proportions-at-age in each length-class (row) sum to 1. The total number of observations from which the proportions-at-age given length were calculated are also provided (*n*).

Length (cm)	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*
≤ 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	–	–	–	–	–	–	–	–	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
39	–	–	–	–	–	–	–	–	–	–	–	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	1
40	–	–	–	–	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
41	–	–	–	–	–	0.33	–	0.67	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
42	–	–	–	–	–	–	0.67	–	–	0.33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
43	–	–	–	–	–	–	–	0.33	0.33	0.17	0.17	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6
44	–	–	–	–	–	–	–	0.18	–	0.09	0.18	0.18	0.27	–	–	–	0.09	–	–	–	–	–	–	–	–	–	11
45	–	–	–	–	–	–	–	0.20	0.10	–	0.15	0.15	0.30	0.10	–	–	–	–	–	–	–	–	–	–	–	–	20
46	–	–	–	–	–	–	–	–	0.05	0.05	0.05	0.11	0.16	0.21	–	0.16	0.11	0.11	–	–	–	–	–	–	–	–	19
47	–	–	–	–	–	–	–	–	0.06	0.06	0.06	0.06	–	0.06	0.06	0.12	0.12	0.06	0.06	0.12	0.06	0.06	–	–	–	–	16
48	–	–	–	–	–	–	–	–	–	–	0.05	0.05	0.05	0.27	–	0.18	0.14	0.05	0.05	0.09	–	–	0.05	0.05	–	–	22
49	–	–	–	–	–	–	–	–	0.05	–	–	–	–	0.05	0.05	0.05	0.14	0.10	0.14	0.14	0.10	0.14	0.05	–	–	–	21
50	–	–	–	–	–	–	–	–	–	–	–	0.03	–	0.03	0.03	–	0.06	0.06	0.09	0.20	0.17	0.14	0.14	–	0.06	–	35
51	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.09	0.18	0.18	0.27	0.27	–	–	–	–	11
52	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.29	0.14	0.14	0.14	0.14	0.14	–	–	–	7
53	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
54	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
≥ 55	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0

Table B4: Age-length key used to calculate estimated scaled age frequency distributions for females in the EMA 7 trawl fishery during the 2003–04 fishing year. The proportions-at-age in each length-class (row) sum to 1. The total number of observations from which the proportions-at-age given length were calculated are also provided (*n*).

Length (cm)	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*
≤ 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	–	–	–	–	–	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
43	–	–	–	–	–	–	–	0.33	–	–	0.33	–	–	–	0.33	–	–	–	–	–	–	–	–	–	–	–	3
44	–	–	–	–	–	–	–	–	0.40	–	–	0.60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5
45	–	–	–	–	–	0.09	0.09	–	0.09	0.09	0.09	0.09	0.27	0.09	–	–	0.09	–	–	–	–	–	–	–	–	–	11
46	–	–	–	–	–	–	–	0.06	–	–	0.12	0.12	0.18	0.18	0.06	0.12	0.06	–	–	0.06	–	–	0.06	–	–	–	17
47	–	–	–	–	–	–	–	–	0.11	0.07	–	0.11	0.22	0.04	0.15	0.07	0.04	0.04	0.07	0.04	0.04	–	–	–	–	–	27
48	–	–	–	–	–	–	–	–	–	–	0.06	–	0.17	–	0.06	0.17	0.17	0.11	–	0.22	0.06	–	–	–	–	–	18
49	–	–	–	–	–	–	–	–	–	–	–	0.05	0.05	0.05	–	–	0.05	0.18	–	0.18	0.09	0.23	0.09	–	0.05	–	22
50	–	–	–	–	–	–	–	–	–	–	–	–	0.04	–	–	0.04	0.08	0.12	0.20	0.12	0.20	0.08	0.04	0.04	–	0.04	25
51	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.08	0.08	–	0.15	0.23	–	0.15	0.15	0.08	0.08	–	13
52	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.10	0.10	–	0.20	–	0.10	0.20	0.10	0.10	0.10	–	10
53	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.25	0.50	–	–	0.25	–	–	4
54	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
≥ 55	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0

Appendix C: Estimated scaled numbers-at-length

Table C1: Estimated scaled numbers-at-length (NAL), bootstrapped coefficients of variation (c.v.), and bootstrapped mean-weighted coefficients of variation (MW c.v.) for blue mackerel in the EMA 1 purse-seine fishery during the 2003–04 fishing year.

Length	Males		Females		Unsexed		All fish	
(cm)	NAL	c.v. (%)	NAL	c.v. (%)	NAL	c.v. (%)	NAL	c.v. (%)
≤ 15	4 422	141.9	0	–	0	–	4 422	141.9
16	0	–	0	–	0	–	0	–
17	0	–	0	–	0	–	0	–
18	0	–	0	–	0	–	0	–
19	0	–	0	–	0	–	0	–
20	0	–	0	–	0	–	0	–
21	13 265	118.8	4 422	143.4	0	–	17 687	115.7
22	8 844	123.5	8 844	122.9	0	–	17 687	113.0
23	44 218	107.6	18 109	112.7	0	–	62 326	105.8
24	26 531	110.9	13 265	120.9	0	–	39 796	109.4
25	8 844	122.9	0	–	0	–	8 844	122.9
26	4 422	149.9	4 422	143.7	0	–	8 844	128.5
27	9 265	118.1	0	–	0	–	9 265	118.1
28	0	–	4 422	135.9	0	–	4 422	135.9
29	0	–	0	–	0	–	0	–
30	341	139.0	0	–	0	–	341	139.0
31	683	125.4	591	138.3	0	–	1 274	93.9
32	2 364	103.4	3 546	100.0	0	–	5 911	96.5
33	8 858	85.6	3 945	91.5	0	–	12 803	84.8
34	12 272	69.7	11 194	61.8	0	–	23 466	64.0
35	31 501	59.5	37 976	77.2	0	–	69 478	61.9
36	44 757	40.9	22 530	31.9	0	–	67 287	32.1
37	79 673	27.1	44 978	25.0	0	–	124 650	23.1
38	115 615	19.3	100 594	18.8	0	–	216 209	17.6
39	161 918	15.9	171 007	21.3	0	–	332 924	16.0
40	259 695	10.7	240 331	13.1	0	–	500 026	11.0
41	318 704	10.9	281 261	10.4	0	–	599 965	9.5
42	404 673	9.4	328 965	8.7	0	–	733 638	7.9
43	303 006	8.7	307 034	8.5	0	–	610 040	7.0
44	248 226	8.3	293 675	7.4	0	–	541 900	6.4
45	198 805	10.5	259 279	9.3	0	–	458 084	7.7
46	199 704	11.4	219 644	11.5	0	–	419 348	10.0
47	145 796	11.4	207 461	13.1	0	–	353 257	10.9
48	69 208	19.7	102 994	17.4	0	–	172 202	14.9
49	36 513	39.4	39 466	20.1	0	–	75 979	23.5
50	10 142	41.2	22 296	27.8	0	–	32 438	26.4
51	2 068	75.6	5 819	47.9	0	–	7 888	41.1
52	0	–	1 190	88.0	0	–	1 190	88.0
53	689	151.8	666	145.9	0	–	1 355	104.7
54	0	–	0	–	0	–	0	–
≥ 55	0	–	0	–	0	–	0	–
Total	2 775 022		2 759 926		0		5 534 946	
MW c.v.	18.3		15.7		–		15.1	

Table C2: Estimated scaled numbers-at-length (NAL), bootstrapped coefficients of variation (c.v.), and bootstrapped mean-weighted coefficients of variation (MW c.v.) for blue mackerel in the EMA 7 trawl fishery during the 2003–04 fishing year.

	Males		Females		Unsexed		All fish	
Length (cm)	NAL	c.v. (%)	NAL	c.v. (%)	NAL	c.v. (%)	NAL	c.v. (%)
≤ 20	0	–	0	–	0	–	0	–
21	0	–	0	–	0	–	0	–
22	0	–	0	–	0	–	0	–
23	0	–	0	–	0	–	0	–
24	0	–	0	–	0	–	0	–
25	0	–	0	–	0	–	0	–
26	0	–	0	–	0	–	0	–
27	0	–	0	–	0	–	0	–
28	0	–	0	–	0	–	0	–
29	0	–	0	–	0	–	0	–
30	0	–	57	180.8	0	–	57	180.8
31	0	–	0	–	0	–	0	–
32	0	–	0	–	0	–	0	–
33	0	–	0	–	0	–	0	–
34	0	–	0	–	0	–	0	–
35	0	–	0	–	0	–	0	–
36	0	–	0	–	0	–	0	–
37	59	168.9	0	–	0	–	59	168.9
38	74	136.0	59	160.7	0	–	133	114.9
39	7 485	122.6	94	134.5	0	–	7 580	120.7
40	14 615	101.0	572	122.7	0	–	15 187	96.7
41	10 405	84.5	2 979	102.5	0	–	13 384	69.6
42	26 762	76.7	20 916	66.2	0	–	47 679	53.2
43	39 170	59.4	35 527	45.3	24	184.8	74 721	44.5
44	82 381	55.4	32 056	57.2	0	–	114 437	53.0
45	114 048	49.8	118 087	25.7	0	–	232 136	29.0
46	141 229	22.1	169 047	25.4	0	–	310 276	17.4
47	150 443	22.3	182 550	46.0	0	–	332 992	28.9
48	147 178	39.8	124 437	35.6	0	–	271 615	33.4
49	63 537	35.6	59 070	35.5	0	–	122 607	26.0
50	35 956	51.6	47 632	41.0	0	–	83 588	30.8
51	7 373	77.1	18 884	66.1	0	–	26 257	64.7
52	12 956	109.9	5 613	77.9	0	–	18 569	62.7
53	171	173.3	2 939	93.9	0	–	3 110	94.5
54	339	152.8	1 850	96.9	0	–	2 189	90.9
55	171	186.5	169	183.5	0	–	340	144.8
56	171	179.8	43	154.1	0	–	214	155.0
57	0	–	0	–	0	–	0	–
58	0	–	0	–	0	–	0	–
59	0	–	0	–	0	–	0	–
≥ 60	0	–	57	175.4	0	–	57	175.4
Total	854 523		822 638		24		1 677 187	
MW c.v.	42.7		38.4		184.8		33.0	

Appendix D: Estimated scaled numbers-at-age

Table D1: Estimated scaled numbers-at-length (NAA), bootstrapped coefficients of variation (c.v.), and bootstrapped mean-weighted coefficients of variation (MW c.v.) for blue mackerel in the EMA 1 purse-seine fishery during the 2003–04 fishing year.

	Males		Females		Unsexed		All fish	
Age (years)	NAA	c.v. (%)	NAA	c.v. (%)	NAA	c.v. (%)	NAA	c.v. (%)
0	0	–	0	–	0	–	0	–
1	0	–	0	–	0	–	0	–
2	48 912	75.7	51 383	61.7	0	–	100 295	62.4
3	200 381	44.4	145 420	34.0	0	–	345 800	36.4
4	163 093	29.8	138 210	32.5	0	–	301 303	25.7
5	295 860	22.3	230 897	28.9	0	–	526 757	19.3
6	373 261	21.9	504 013	19.9	0	–	877 274	14.7
7	568 990	16.5	417 566	21.7	0	–	986 556	13.1
8	417 248	19.8	454 621	20.1	0	–	871 868	13.6
9	233 983	27.7	273 703	27.8	0	–	507 686	20.0
10	159 487	30.9	186 898	32.7	0	–	346 386	23.2
11	101 041	43.8	139 039	37.0	0	–	240 080	28.8
12	75 226	37.2	116 864	33.4	0	–	192 090	25.5
13	42 030	59.5	67 806	49.3	0	–	109 836	38.4
14	12 171	108.6	0	–	0	–	12 171	108.6
15	0	–	17 298	78.6	0	–	17 298	78.6
16	58 288	48.6	11 444	99.9	0	–	69 732	43.9
17	12 150	102.2	0	–	0	–	12 150	102.2
18	0	–	0	–	0	–	0	–
19	0	–	0	–	0	–	0	–
20	0	–	2 910	116.7	0	–	2910	116.7
21	0	–	0	–	0	–	0	–
22	0	–	0	–	0	–	0	–
23	0	–	0	–	0	–	0	–
24	0	–	0	–	0	–	0	–
≥ 25	0	–	0	–	0	–	0	–
Undefined	12 899	73.4	1 855	147.8	0	–	14 755	68.3
Total	2 775 020		2 759 927		0		5 534 947	
MW c.v.	27.9		27.8		–		21.1	

Table D2: Estimated scaled numbers-at-length (NAA), bootstrapped coefficients of variation (c.v.), and bootstrapped mean-weighted coefficients of variation (MW c.v.) for blue mackerel in the EMA 7 trawl fishery during the 2003–04 fishing year.

	Males		Females		Unsexed		All fish	
Age (years)	NAA	c.v. (%)	NAA	c.v. (%)	NAA	c.v. (%)	NAA	c.v. (%)
0	0	–	0	–	0	–	0	–
1	0	–	0	–	0	–	0	–
2	0	–	0	–	0	–	0	–
3	0	–	0	–	0	–	0	–
4	0	–	0	–	0	–	0	–
5	18 084	99.9	10 735	109.0	0	–	28 819	76.4
6	17 842	104.6	34 630	62.4	0	–	52 472	55.6
7	57 781	62.3	21 786	80.0	0	–	79 568	53.4
8	44 323	49.6	43 841	48.3	0	–	88 164	34.0
9	39 848	61.7	24 257	70.3	0	–	64 106	43.6
10	62 140	46.3	49 379	51.5	0	–	111 518	35.1
11	64 072	41.8	72 825	35.3	0	–	136 921	28.5
12	93 157	46.0	127 934	31.8	0	–	221 090	21.3
13	94 732	30.1	50 013	45.1	0	–	144 745	25.5
14	13 456	77.1	55 744	48.0	0	–	69 199	42.7
15	70 890	37.2	58 069	41.9	0	–	128 959	29.8
16	72 362	34.7	56 689	39.5	0	–	129 051	26.0
17	43 436	41.3	37 043	40.2	0	–	80 480	29.9
18	31 442	47.7	27 076	44.8	0	–	58 519	33.4
19	51 644	40.2	65 906	33.4	0	–	117 550	26.8
20	25 479	50.9	30 602	41.6	0	–	56 081	33.0
21	27 477	48.0	21 263	49.7	0	–	48 741	34.4
22	16 703	62.4	20 686	54.9	0	–	37 389	38.1
23	6 690	110.0	4 654	83.0	0	–	11 344	64.2
24	2 055	94.1	4 699	84.6	0	–	6 753	68.2
≥25	0	–	1 905	115.8	0	–	1 905	115.8
Undefined	911	221.3	2 902	141.4	0	–	3812	123.2
Total	854 524		822 638		0		1 677 186	
MW c.v.	47.9		45.6		–		33.3	