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The length and age composition of the commercial trawl catch of blue mackerel (*Scomber australasicus*) in EMA 7 during the 2013–14 fishing year, with a summary of all available data sets

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EXECUTIVE SUMMARY

Horn, P.L.; Ó Maolagáin, C. (2018). The length and age composition of the commercial trawl catch of blue mackerel (*Scomber australasicus*) in EMA 7 during the 2013–14 fishing year, with a summary of all available data sets.

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This report describes the scientific observer sampling programme carried out on trawl landings of blue mackerel (*Scomber australasicus*) in JMA 7 (central west coast) during the 2013–14 fishing year, and provides estimates of sex ratio, catch-at-length, and catch-at-age in the landings. Virtually all blue mackerel taken from EMA 7 in 2013–14 were caught as a bycatch of the midwater trawl fishery targeting jack mackerels. About 80% of the landed catch was sampled, and sampling was found to be representative of the landings both temporally and spatially. Just over 60% of the blue mackerel was caught in June–July 2014; a peak in landings around this time has occurred in most years since 1990. Although trawl-caught blue mackerel from EMA 7 are taken primarily as a bycatch of the target midwater trawl fishery for jack mackerels, the blue mackerel landings peak does not coincide with the main jack mackerel peak.

The scaled length distribution from 2013–14 had a strongly dominant adult mode comprising multiple year classes (primarily 7–18 years old), with two minor modes representing 2 and 3-year-old fish. The age-frequency distribution had a mean weighted CV of 22%, which bettered the target of 30%. The available time series of catch-at-age estimates for the EMA 7 trawl catch (2003–04 to 2005–06 and 2013–14) are summarised. There was a marked variation in the catch-at-age distributions from the four years for which data are now available.

1. INTRODUCTION

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

The commercial catch is caught by a variety of methods in all QMAs, but most is caught north of latitude 43 °S (Morrison et al. 2001, Ballara 2016). The largest catches across fishing years are by purse-seine vessels targeting blue mackerel schools in EMA 1–3 and 7. Catches by midwater trawl vessels targeting jack mackerels (*Trachurus* spp.) in EMA 7 are also important. Nevertheless, the target purse-seine catch in EMA 1 is the single largest component of the catch by any method in any QMA (Ballara 2016). Most blue mackerel purse seine catch comes from the Bay of Plenty and East Northland, where it is primarily taken between July and December. The purse seine fishery has accounted for more than 97% of annual EMA 1 landings since at least 1990, and about 90% of this was targeted (Ballara 2016).

Total blue mackerel catches peaked in 1991–92 at more than 15 000 t (Table 1), of which 60–70% was taken by purse seine. More recently, commercial landings of over 12 500 t were taken in 1998–99 (13 500 t), 2000–01 (13 100 t) and 2004–05 (12 750 t), with the highest landings recorded in EMA 1 and EMA 7. EMA 7 landings exceeded the TACC in 2004–05, 2005–06, and 2008–09, but appear to have been steadily declining since about 2010. The EMA 7 landings in 2015–16 were the lowest since the mid 1980s (Table 1). Landings from EMA 2 and EMA 3 have been well below the TACCs since the early to mid 1990s; they are primarily a bycatch of a purse seine fishery targeting jack mackerels (in EMA 2) and mixed trawl fisheries (in EMA 3).

The blue mackerel catch from EMA 7 is now principally non-target catch from the jack mackerel midwater trawl fishery (Ballara 2016). Highest catches are taken during June and July in Statistical Area 035 off the west coast of the South Island (WCSI) and Areas 037, 041 and 801 further north off the west coast of the North Island. Since the late 1990s, a fleet of Ukrainian vessels has taken most of the catch in the JMA 7 target fishery. Since 2004, 0–11% of the EMA 7 catch has been taken annually by purse seine, down from an average of about 25% between 1991 and 2003 (Ballara 2016).

This report presents length and age data collected during commercial catch sampling of blue mackerel by observers in EMA 7 during the 2013–14 fishing year. The data were primarily from catches by midwater trawl vessels targeting jack mackerels in EMA 7. The target mean-weighted coefficient of variation (CV) for the catch-at-age was 30%. The year 2013–14 was chosen as it represented the most recently fished year from which a comprehensive collection of length data and otoliths was available. The 2013–14 sampling results add to previous sets of EMA 7 catch-at-age data from the jack mackerel trawl fishery produced for fishing years 2003–04 (Manning et al. 2007a), 2004–05 (Manning et al. 2007b), and 2005–06 (Devine et al. 2009). This document fulfils the reporting requirements relating to blue mackerel in objective 1 of Project DEE2016-20 "Routine age determination of hoki and middle depth species from commercial fisheries and trawl surveys", funded by the Ministry for Primary Industries (MPI). That objective is "To determine catch-at-age for commercial catches and resource surveys of specified middle depth and deepwater fishstocks".

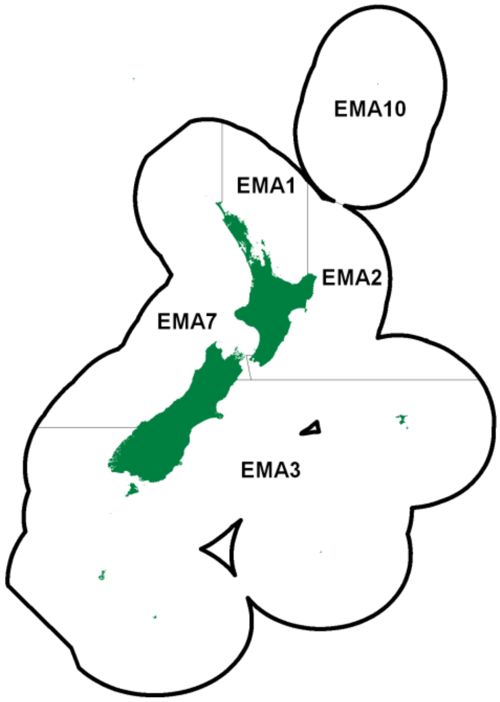

Figure 1: Map of the New Zealand EEZ showing the boundaries of blue mackerel QMAs.

Table 1: Reported landings (t) of blue mackerel by QMA, and where area was unspecified (Unsp.), from 1983–84 to 2015–16. CELR data from 1986–87 to 2000–01. MHR data from 2001–02 to the present. The TACCs (bottom row of table) have not changed since their inception in 2002–03.

Fishing year	QMA 1	QMA 2	QMA 3	QMA 7	QMA 10#	Unsp.	Total
1983–84*	480	259	44	245	0	1	1 028
1984–85*	565	222	18	865	0	73	1 743
1985–86*	618	30	190	408	0	51	1 296
1986–87	1 431	7	424	489	0	49	2 399
1987–88	2 641	168	864	1 896	0	58	5 625
1988–89	1 580	< 1	1 141	1 021	0	469	4 211
1989–90	2 158	76	518	1 492	0	< 1	4 245
1990–91	5 783	94	478	3 004	0	0	9 358
1991–92	10 926	530	65	3 607	0	0	15 128
1992–93	10 684	309	133	1 880	0	0	13 006
1993–94	4 178	218	223	1 402	5	0	6 025
1994–95	6 734	94	154	1 804	10	149	8 944
1995–96	4 170	119	173	1 218	0	1	5 680
1996–97	6 754	78	340	2 537	0	< 1	9 708
1997–98	4 595	122	78	2 310	0	< 1	7 104
1998–99	4 505	186	62	8 756	0	4	13 519
1999–00	3 602	73	3	3 169	0	0	6 847
2000–01	9 738	113	6	3 278	0	< 1	13 134
2001–02	6 368	177	49	5 101	0	0	11 694
2002–03	7 609	115	88	3 563	0	0	11 375
2003–04	6 523	149	1	2 701	0	0	9 373
2004–05	7 920	9	< 1	4 817	0	0	12 746
2005–06	6 713	13	133	3 784	0	0	10 643
2006–07	7 815	133	42	2 698	0	0	10 688
2007–08	5 926	6	122	2 929	0	0	8 982
2008–09	3 147	2	88	3 503	0	0	6 740
2009–10	8 539	3	14	3 260	0	0	11 816
2010–11	6 630	2	9	1 996	0	0	8 638
2011–12	8 080	2	28	2 707	0	0	10 817
2012–13	7 213	3	100	2 401	0	0	9 716
2013–14	6 860	4	29	1 200	0	0	8 092
2014–15	8 134	16	87	892	0	0	9 129
2015–16	7 226	18	27	761	0	0	8 033
TACC	**7 630**	**180**	**390**	**3 350**	**0**	**–**	**11 550**

* FSU data,

\# Landings reported from QMA 10 are probably attributable to Statistical Area 010 in the Bay of Plenty (i.e., QMA 1).

2. METHODS

The recommended sampling scheme for blue mackerel used by MPI observers was described in full by Sutton (2002). Typically, about 100 fish were randomly sampled from the catch for length measurements every two to three days during each fishing trip. Samples were collected more frequently when larger catches of blue mackerel were made. Fork length, to the nearest centimetre below actual length, and sex were collected from each fish in these samples. Sagittal otolith pairs were collected from subsamples of fish randomly sampled for length measurements. The sampling protocols used by the MPI observers for target and bycatch species are quite different. Generally, target species data are collected from every observed fishing event or trawl, whereas bycatch species data are collected at most from a single observed fishing event per observed day (Sutton 2002).

Catch sampling for length, sex, and age of blue mackerel was carried out by observers primarily working on board large trawl vessels targeting jack mackerels. All observer data on blue mackerel sampled from EMA 7 in the 2013–14 fishing year were extracted for the analyses. The observer data were examined for spatial and temporal variability, and this was compared with the spatial and temporal distribution of the entire commercial JMA 7 catch.

Commercial catch data extracted from the Ministry for Primary Industries catch-effort database "warehou" (Extract #11284 on 1 August 2017) were used in this analysis. The data comprised estimated catch and associated date, position, depth, and method data from all fishing events that recorded catches of blue mackerel from EMA 7 (i.e., QMAs 7, 8, and 9) in 2013–14. The timing and distribution of the reported and observed catches were compared to determine whether the observer sampling was representative of the commercial fishery.

A sample of 608 blue mackerel otoliths collected by observers in 2013–14 was aged. Otoliths from fish (for each sex separately) in each 1 cm length class were selected approximately proportionally to their occurrence in the scaled length frequency, with the constraint that the number of otoliths in each length class (where available) was at least one. In addition, otoliths from fish in the extreme right hand tail of the scaled length frequency (constituting about 2% of that length frequency) were over-sampled. Otoliths were prepared and read following the methods of Marriott & Manning (2011). In summary, sets of six otoliths were embedded in blocks of clear epoxy resin and cured at 50°C. Once hardened, a 350 µm thin transverse section was cut from each block through the primordia using a high-speed saw. The thin section was washed, dried, and embedded under a cover slip on a glass microscopic slide. Thin sections were read with a bright field stereomicroscope at up to ×100 magnification. Zone counts were based on the number of complete opaque zones (i.e., opaque zones with translucent material outside them), which were counted to provide data for age estimates. A three-point "margin-state" score was also recorded for each otolith section (Table 2).

Table 2: Three-point otolith margin-state scores used in all readings.

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

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, a_i, is

$$a_i = t_{i,1} + t_{i,2} + t_{i,3},$$

where $t_{i,1}$ is the elapsed time from spawning to the end of the first opaque zone present, $t_{i,2}$ is the elapsed time from the end of the first opaque zone present to the end of the outermost fully formed opaque zone, and $t_{i,3}$ is the elapsed time from the end of the outermost fully formed opaque zone to the date when the *i*th fish was captured. A standardised "birth-date" of 1 January and a standardised opaque zone completion date of 1 November were used for all fish. Stewart et al. (1999) found that opaque zones in Australian fish, although formed during winter, were not always visible until spring or summer on the edge of the otolith. Hence,

$t_{i,1}$ = 1 January to 1 November (= 10 months or 0.83 years)
$t_{i,2} = (n_i + w) - 1$
$t_{i,3}$ = time between 1 November and $t_{i,\text{capture}}$

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 $w = 0$.

Thus, a fish with four completed opaque zones counted and a "narrow" otolith margin recorded that was caught during a fishing trip that landed on 19 November is estimated to be 3.88 years of age.

The age data were used to construct age-length keys by sex which in turn were used to convert the weighted length composition of the catch to catch-at-age by sex using the NIWA catch-at-age software (Bull & Dunn 2002). This software also provided estimates of CVs-at-age using a bootstrap procedure. The fish length-weight relationship used was from a linear regression of log-transformed length and weight data for blue mackerel from the EMA 1 fishery (Manning et al. 2007a), and is the same as that used in previous estimates of EMA 7 catch-at-age.

The data collected by observers from the EMA 7 trawl fishery in 2003–04 to 2005–06 that had previously been analysed to produce catch-at-age distributions using a single stratum (Manning et al. 2007a, 2007b, Devine et al. 2009) was re-analysed here using the strata developed below.

3. RESULTS

3.1 Catch sampling

The landings distribution in 2013–14 shows that there was a dominant fishery in June and July concentrated in Statistical Areas 035, 041, and 801 (Table 3, Figure 2). A secondary fishery occurred primarily from December to April in Areas 037 and 040. The dominant fishery took significant catches from the North Taranaki Bight and off north-west South Island, while the secondary fishery was primarily in the South Taranaki Bight (Figure 3). Because of the apparent differences in timing and location of catches it was considered desirable to split the data into two strata based on time (i.e., stratum 1, October–April; and stratum 2, May–September).

There are some discrepancies between the three catch records for 2013–14 shown in Figure 2. It would be expected that in each month the Monthly Harvest Return (MHR) total would be higher than both the estimated and observed catches because not all catch would be observed, and some small catches of blue mackerel would not be recorded on the TCEPR or TCER forms. In two months (November and March), however, the MHR landings are much lower than both the observed and estimated landings. In the subsequent months (December and April), MHR landings are much higher than those estimated, and based on this it appears likely that the MHR reports for December and April include some landings that had actually been taken in the previous months. In some months, observed landings are higher than estimated landings, particularly outside the peak fishery time of June–July. This is likely to be a function of observers sampling small landings of blue mackerel that were taken as a bycatch of much larger jack mackerel landings. Although some hundreds of kilograms of blue mackerel may have been captured in such tows it is still quite likely that they would often not be recorded on the TCEPR form because their weight would be insignificant relative to the target species, and often to other bycatch species such as barracouta, frostfish, redbait, and tarakihi.

It is not surprising, therefore, to find that the weight of observed landings in many months and statistical areas is often greater than estimated landings weights, and consequently, that the percentage of estimated total catch sampled by observers is often much greater than 100% (Table 3). For 2013–14, the total observed landed weight was 5% higher than the total estimated event-by-event landed weight. Relative to the total MHR landings from EMA 7, the observed catch accounts for 80% of the blue mackerel. It is apparent that the distribution of estimated catch across months and statistical areas is very similar to the distribution of observed landings; cells in the top half of Table 3 containing significant landings are consistently matched with corresponding observed landings in the bottom half of the table. Clearly, the sampling of the whole fishery was satisfactory to estimate the overall catch-at-age. Because estimated landings on TCEPR forms clearly underestimated true catch (particularly in time stratum 1 from October to April) the scaling process scaled the length and age data up to the reported MHR landings from each of the two time strata.

One notable characteristic of the 2013–14 EMA 7 fishery was that 157 t of blue mackerel was landed from one midwater trawl tow in July in Statistical Area 801. Fortunately, this tow was reasonably well sampled for length (n = 64).

Table 3: Distribution of estimated total catch and sampled landings (t, rounded to the nearest 0.1 tonne) of blue mackerel, by month and Statistical Area (Stat Area), in the 2013–14 fishing year. Values of 0.0 indicate landings from 1 to 49 kg; blank cells indicate zero estimated landings or samples. %, percentage of estimated total catch that was sampled by observers, by month and statistical area.

Estimated total catch (t), 2013–14

Stat Area												Month
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	All
034								0.0	10.1	0.1			10.2
035								5.8	93.2	54.9	5.0		158.9
036						1.3	0.3	1.2	25.5				28.3
037			4.7	7.4	42.1	81.0	16.6	0.9					152.6
039					3.3	10.7	3.5	0.3					17.8
040			7.7	39.1	11.6	7.5		1.3	3.5	0.9			71.5
041	1.0	0.9	16.4	7.9	0.2	0.1	0.3	6.1	88.6	0.5			121.9
042	0.2	14.7	3.2						0.4				18.5
045													0.0
801								22.0	55.9	255.9			333.8
All	1.2	15.6	32.0	54.3	57.2	100.6	20.8	37.4	277.1	312.3	5.0		913.4

Sampled landings (t)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	All	%
34								0.0	12.2	0.9		0.0	13.1	128
35								7.5	59.4	73.7			140.6	88
36				0.0		2.8	0.6	3.9	44.2				51.6	183
37	0.2	0.0	14.4	11.6	34.1	101.4	28.6	1.1	0.1				191.5	126
39						18.0	9.9	0.2	0.7				28.9	162
40	0.0	0.0	13.7	73.7	12.1	2.0	1.5	2.9	3.8				109.8	154
41	9.5	7.1	36.7	12.4	0.1		1.2	2.2	73.8	1.3			144.4	119
42	2.7	16.1	6.7		0.0		0.6			0.1			26.2	142
45	2.4				0.0								2.4	
801				0.1			0.2	33.5	47.8	172.6			254.1	76
All	14.8	23.2	71.6	97.8	46.3	124.3	42.6	51.4	242.1	248.6		0.0	962.6	105
%	1232	149	224	180	81	124	205	137	87	80	0		105	

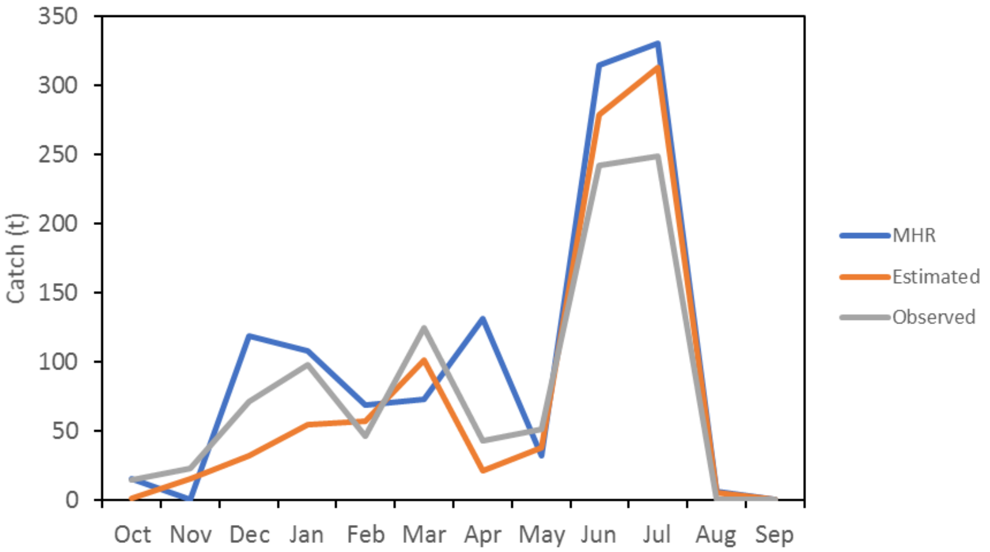

Figure 2: Landings of blue mackerel, by month, from EMA 7 in 2013–14, as reported on Monthly Harvest Returns (MHR) and as estimated catches by fishing event primarily on TCEPR forms (Estimated). Observed landings are also shown.

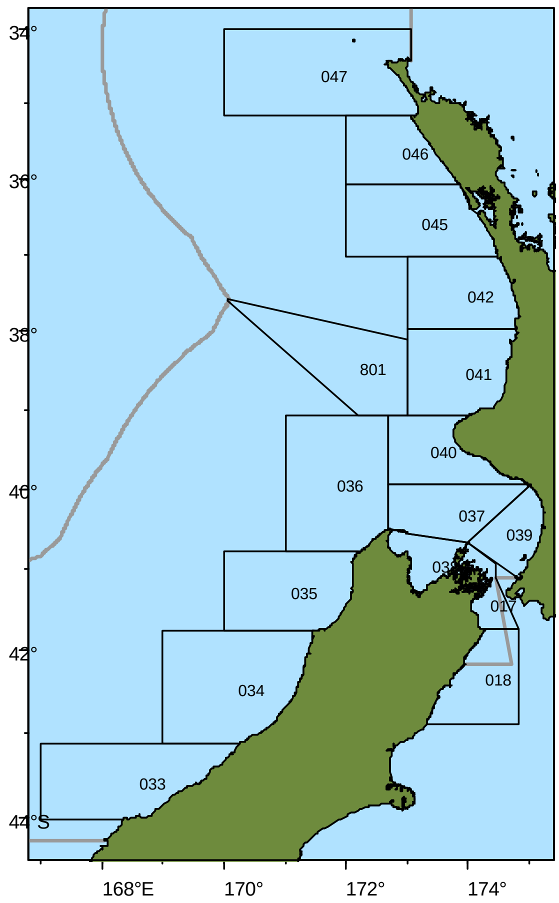

Figure 3: Statistical Areas in the EMA 7 fishstock area.

3.2 Sex ratios

The sex ratio for blue mackerel sampled from the 2013–14 fishing year was slightly biased towards males (Table 4). Ratios from the other three available samples indicate that the fishery consistently takes a greater proportion of males than females. Note that the ratios presented here are from the re-analysed earlier data (Appendix A).

Table 4: Estimated sex ratios (%) in the EMA 7 trawl catch by sampled fishing year.

Fishing year	Males	Females
2003–04	52.8	47.2
2004–05	55.8	44.2
2005–06	51.5	48.5
2013–14	56.7	43.3

3.3 Catch-at-length

The estimated catch-at-length distributions for trawl-caught blue mackerel from EMA 7 in 2013–14 are plotted in Figure 4. There was a dominant length mode at 46–53 cm, a secondary mode at 35–37 cm, and a trace of even smaller fish centred around 29 cm. The main mode for females is 1 cm larger than for males.

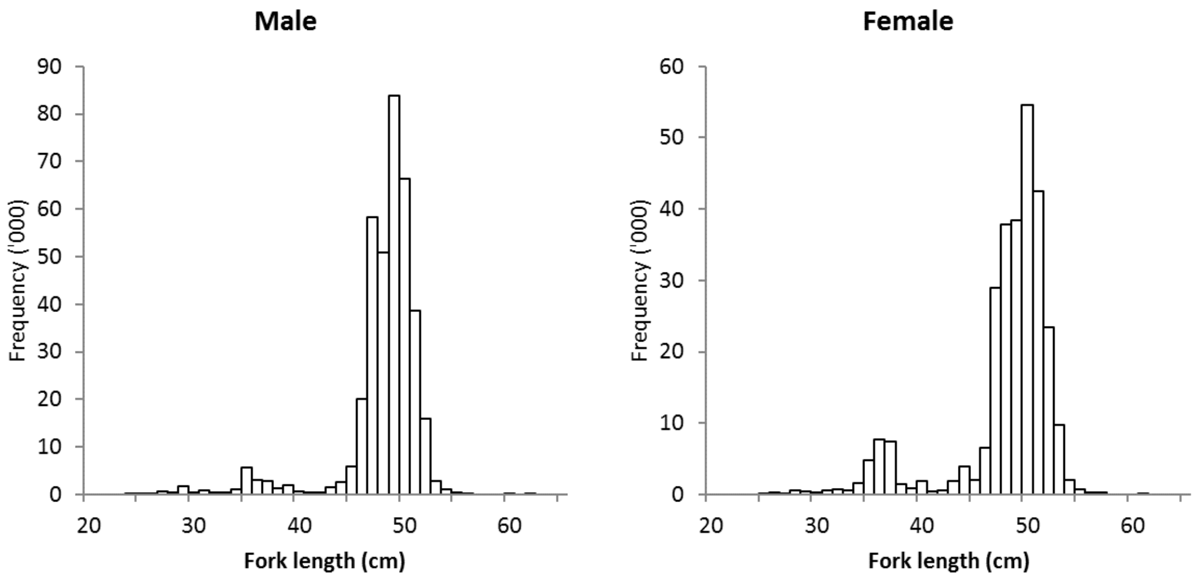

Figure 4: Estimated catch-at-length distributions, by sex, for blue mackerel from EMA 7 in 2013–14.

Differences in the length-frequency distributions between the two strata occur mainly for smaller fish of lengths 20–40 cm (Figure 5). The mode around 29 cm occurs almost exclusively in stratum 1 (October–April); this mode is dominated primarily by fish aged 1 year old, but also with some 2 year old fish. The mode around 36 cm is much more prevalent in stratum 2 (May–September), and it comprises fish aged both 2 and 3 years old. The strong mode of adult fish is about 1 cm larger in the October–April stratum than in the May–September stratum.

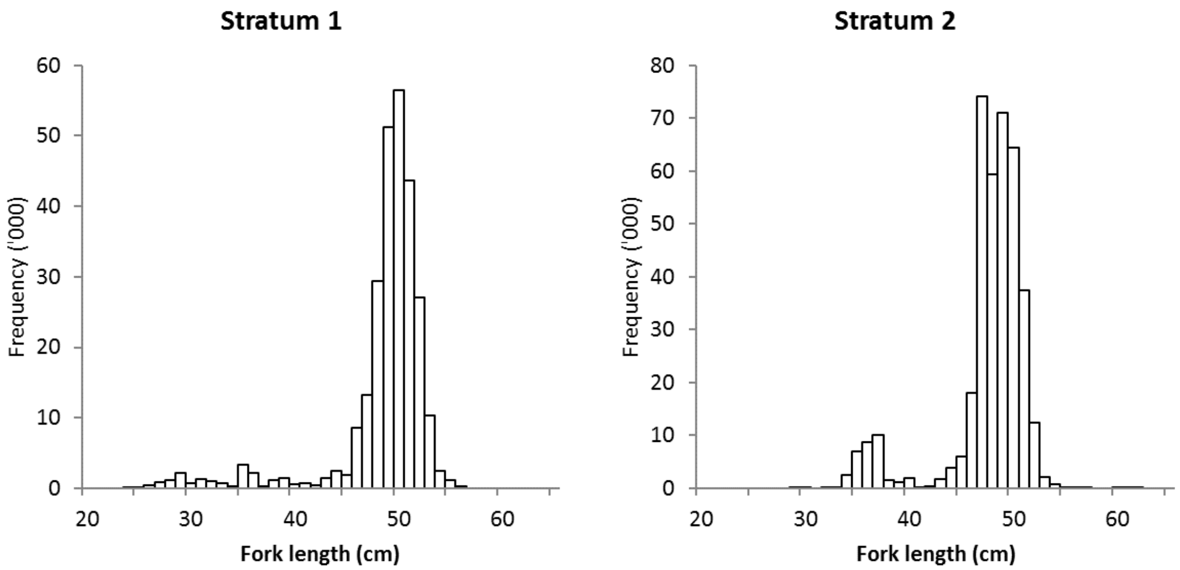

Figure 5: Estimated catch-at-length distributions for blue mackerel from EMA 7 in 2013–14, by stratum (stratum 1, October–April; stratum 2, May–September).

3.4 Catch-at-age

The details of the estimated catch-at-age distribution for trawl-caught blue mackerel from EMA 7 in 2013–14 are presented in Table 5. The mean weighted CV of 22% bettered the target value of 30%. The estimated distribution (Figure 6) was dominated by fish 2–3 and 7–18 years old, with none older than 21 years.

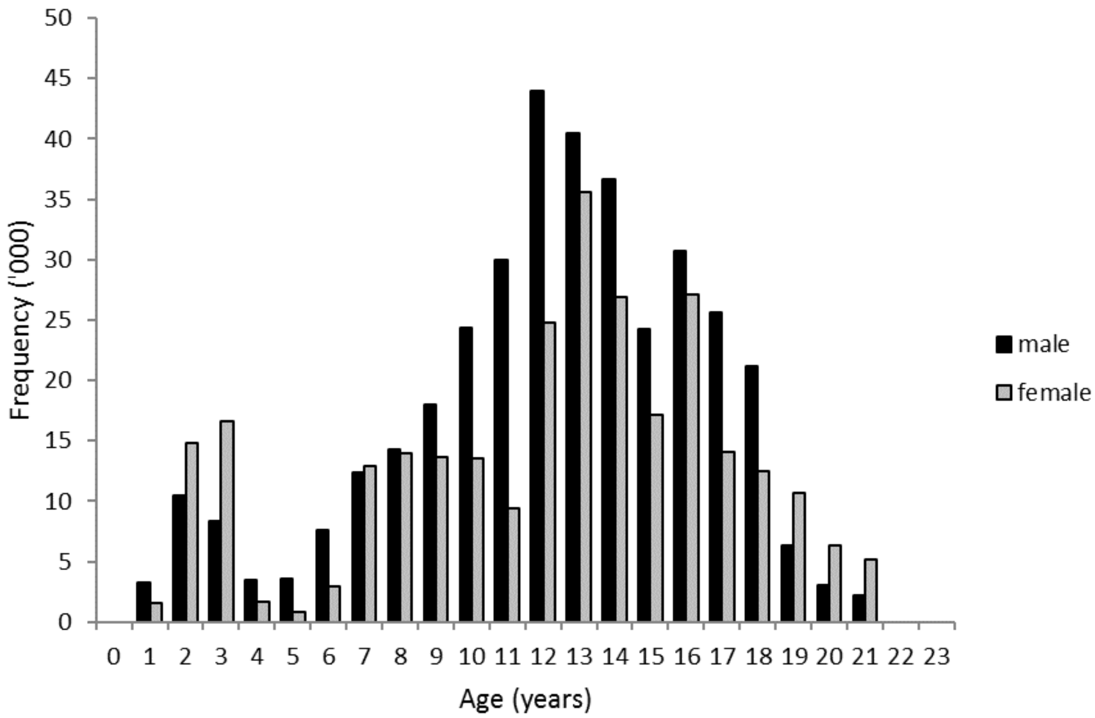

Figure 6: Estimated commercial trawl catch-at-age distributions for blue mackerel from EMA 7 in 2013–14.

Table 5: Calculated numbers-at-age, separately by sex, with CVs, for blue mackerel caught during commercial trawl operations in EMA 7 during the 2013–14 fishing year. Summary statistics for the sample are also presented.

Age (years)	Male	CV	Female	CV	Total	CV
1	3 273	0.746	1 562	0.682	4 835	0.664
2	10 481	0.430	14 783	0.465	25 263	0.412
3	8 322	0.473	16 641	0.503	24 963	0.443
4	3 521	0.586	1 687	1.270	5 207	0.573
5	3 557	0.564	867	0.916	4 424	0.468
6	7 642	0.408	2 987	0.727	10 629	0.349
7	12 386	0.370	12 939	0.325	25 325	0.241
8	14 293	0.339	13 937	0.321	28 230	0.221
9	18 000	0.300	13 618	0.293	31 618	0.201
10	24 352	0.233	13 504	0.274	37 856	0.178
11	29 987	0.214	9 457	0.359	39 445	0.176
12	43 972	0.205	24 785	0.242	68 757	0.161
13	40 440	0.199	35 594	0.194	76 034	0.133
14	36 679	0.212	26 946	0.218	63 625	0.157
15	24 263	0.263	17 169	0.293	41 432	0.174
16	30 691	0.241	27 130	0.217	57 822	0.167
17	25 675	0.247	14 121	0.310	39 797	0.197
18	21 219	0.261	12 528	0.334	33 747	0.213
19	6 314	0.472	10 732	0.351	17 047	0.286
20	3 086	0.727	6 323	0.435	9 408	0.391
21	2 204	1.000	5 155	0.513	7 359	0.476
No. measured		3 025		2 786		5 811
No. aged		324		281		605
No. of trips sampled						28
No. of tows sampled						203
Mean weighted CV (%)		27.9		31.5		21.7

3.5 Data summaries

Catch-at-length and catch-at-age data from the EMA 7 trawl fishery are now available for four years: 2003–04 to 2005–06, and 2013–14. Mean weighted CVs for the length and age distributions, by sex and year, are listed in Table 6. The CVs for the total age distributions bettered the target of 30% in all but 2004–05 when the sample sizes of measured and aged fish were relatively small (see Appendix A).

Table 6: Mean weighted CVs (mwCV) for catch-at-age and catch-at-length distributions, by sex and fishing year.

	Catch-at-age mwCV (%)			Catch-at-length mwCV (%)		
Fishing year	Males	Females	Total	Males	Females	Total
2003–04	39	40	28	23	23	16
2004–05	56	59	41	50	55	39
2005–06	29	30	21	16	17	12
2013–14	28	32	22	22	28	18

Total (i.e., sexes combined) scaled age distributions for the four available samples, by fishing year, varied markedly between years (Figure 7). There is no clear indication of any year class progressions in the first three consecutive year samples. The relatively abundant 5 and 6-year-old fish in 2005–06 may have progressed through to constitute part of the modal peak at ages 12 to 14 in 2013–14.

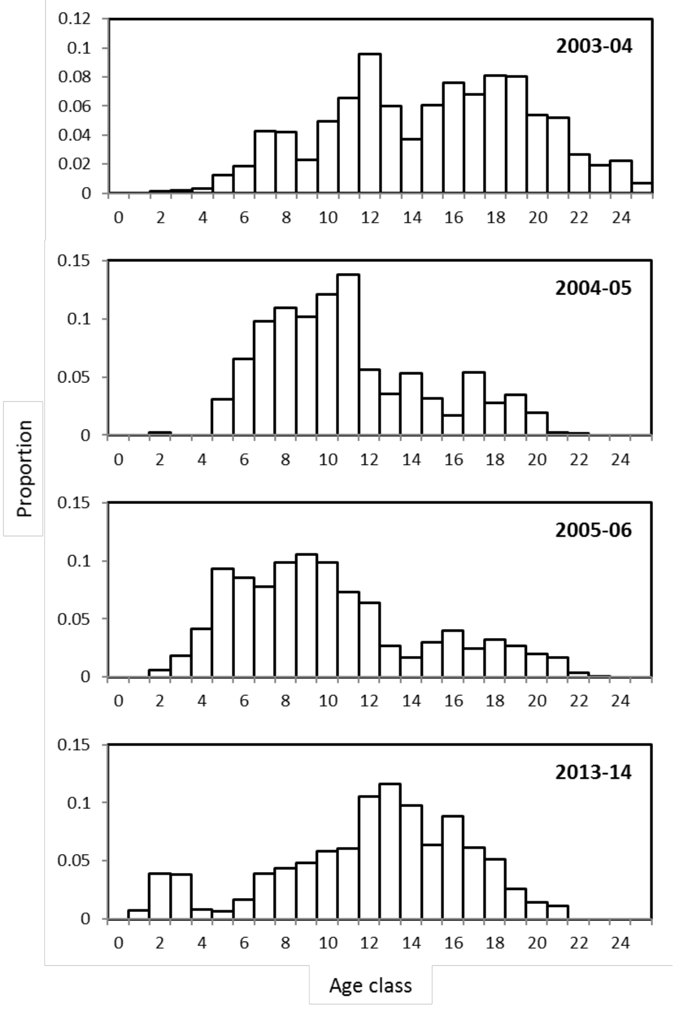

Figure 7: Scaled catch-at-age proportions for the trawl catch of blue mackerel sampled from the 2003–04 to 2005–06 and 2013–14 fishing years. The data for the three early years are as derived from the re-analyses (see Appendix A). The 2004–05 distribution was derived using all available (i.e., sexed and unsexed) data.

4. DISCUSSION

A characterisation of blue mackerel fisheries in New Zealand waters (Ballara 2016) showed that in recent years the EMA 7 landings were primarily a bycatch of the midwater trawl fishery for jack mackerels (*Trachurus* species). The 2013–14 fishery sampled here was an example of this; more than 99% of the EMA 7 blue mackerel landings were taken by midwater trawl, and 91% of these were when jack mackerels were the stated target species (Ballara 2016). Almost all the remainder of the blue mackerel landings were taken when the stated target species was barracouta or blue mackerel. The distribution of the 2013–14 trawl catch, both temporally and geographically, was also similar to other years. Since 1990 more than 60% of the catch has been taken in June and July, and since 2010 more than 75% of the catch has been from Statistical Areas 035, 037, 041 and 801 (Ballara 2016). The comparable percentages for 2013–14 were 65% and 85%.

The second main fishing method that has regularly taken substantial catches of blue mackerels in EMA 7 is purse seine. Since 2003–04, however, the proportions of annual EMA 7 landings taken by this method have all been less than (often much less than) 20% (Ballara 2016). Purse seine landings have been taken generally from the South Taranaki Bight or off western Northland. Less than 0.5 t of blue mackerel was taken by purse seine from EMA 7 in 2013–14.

The 2013–14 blue mackerel trawl catch from EMA 7 was comprehensively sampled. Sampling intensity was high in all months producing substantial landings; it is likely that about 80% of the catch was sampled. Spatially, there was also very good coverage of catch in the heavily fished Statistical Areas (035, 037, 041 and 801). The estimate of the 2013–14 catch-at-age had a mean weighted CV over all age classes of 22%, better than the target of 30%. It appears likely that the current observer sampling regime for blue mackerel in the JMA 7 midwater trawl fishery is providing satisfactory coverage for this species. The trend of a reduction in EMA 7 trawl landings in recent years has, however, meant that observer samples may now be barely adequate to produce comprehensive and precise estimates of the age distribution in the catch.

Most of the 2013–14 catch comprised adult fish in a single narrow length-frequency mode from 45 to 53 cm. This mode comprised fish aged mainly from 7 to 18 years, with age classes 12–14 and 16 appearing to be most abundant. The age classes of 5 and 6 year old fish were relatively abundant in the 2005–06 fishing year. These age classes would be 13 and 14 years old in 2013–14, hence the progression of at least two strong year classes can be postulated. Relatively strong year classes aged 8–10 years in 2005–06 have not all progressed to be strong at ages 16–18 in 2013–14, although age class 16 alone is strong. There were no apparent progressions of strong year classes in the three consecutive samples from 2003–04 to 2005–06. Devine et al. (2009) concluded that the 2005–06 sample well represented the trawl fishery, but the 2003–04 and, particularly, the 2004–05 samples were believed to be much less representative (Manning et al. 2007a, 2007b).

The catch-at-age distributions presented here for the re-analysed years 2003–04 to 2005–06 are, as expected, different to those reported initially by Manning et al. (2007a, 2007b) and Devine et al. (2009). For 2003–04 and 2005–06 the differences are a consequence of using two strata based on time (October–April, May–September), rather than a single stratum. For the 2004–05 distribution, however, there are additional differences. Not only were two time strata introduced, but the age-length key used markedly fewer data that in the initial analysis. That analysis by Manning et al. (2007b) had inadvertently incorporated some age data from 2003–04 in the age-length key for the subsequent year. The 2004–05 analysis was further complicated because about 60% of the measured fish were unsexed, all from time stratum 2 and resulting in only 83 sexed fish from that stratum. Consequently, the results of two analyses are presented in Appendix Table A2. One used only sexed fish and age-length keys by sex; the other used all fish and a single unsexed age-length key. The total distributions from these two analyses are quite different (see Table A2). The distribution from the unsexed analysis is presented in Figure 7; it is believed to better represent the 2004–05 catch because it enables the landings peak in stratum 2 to be comprehensively represented. Because there is no statistically significant between-sex difference in growth rates of blue mackerel (Manning et al. 2006), an unsexed age-length key should not produce markedly different results than when using separate sex age-length keys.

The jack mackerel target midwater trawl fishery, responsible for most of the EMA 7 catch, consistently exhibits two peaks of jack mackerel landings in the year, the main one being around October–January with a secondary peak around April–June (Horn et al. 2017). Although blue mackerel is taken by this fishery throughout the year there is a consistent dominant peak in blue mackerel landings in June–July (Ballara 2016). Fu & Taylor (2007) suggested that blue mackerel change their behaviour in June–August and thus become more vulnerable to the midwater fleet, or that the fleet switch their strategy to take advantage of the change in fish behaviour. Clearly there is some behavioural change (by either the fish or the fishers) which results in the blue mackerel landings peak not coinciding with the peaks in the jack mackerel target fishery landings. During summer, surface schools of blue mackerel have been targeted around the North Island and off the Kaikoura coast, but they generally disappear during winter (Morrison et al. 2001, Ballara 2016). This suggests that an increased proportion of the population is in deeper water during winter, reflecting an observed behavioural characteristic of the related Atlantic species, *Scomber scombrus* (Sette 1950). In 2013–14, the average bottom depth of observed tows where blue mackerel were measured was 106 m in October–April, and 172 m in May–September, i.e., deeper in the winter months. This postulated behavioural change by the fish (schooling up in deeper waters during winter) can then be taken advantage of by the fishery. It is uncertain whether the behavioural change could be related to blue mackerel spawning: most observed running ripe females in EMA 7 were recorded from October to January, but some were also recorded off west coast North Island in June (Ballara 2016).

Analyses of the EMA 7 purse seine catch compositions have been reported previously based on on-shore sampling of landings from 2004–05 (Manning et al. 2007b) and 2005–06 (Devine et al. 2009). Catch-at-age analyses of shore-based sampling of the EMA 1 purse seine catch has also been produced for 1997–98 (Morrison et al. 2001), and for the five consecutive years from 2002–03 to 2006–07 (Manning et al. 2006, 2007a, 2007b, Devine et al. 2009, Taylor et al. 2014).

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APPENDIX A. EMA 7 trawl catch-at-age data, 2003–04 to 2005–06

This appendix reports re-analysed catch-at-age distributions for trawl-caught blue mackerel from EMA 7, using two time strata (October–April, May–September), rather than the single stratum used previously.

Table A1: Calculated numbers-at-age, separately by sex, with CVs, for blue mackerel caught during commercial trawl operations in EMA 7 during the 2003–04 fishing year. Summary statistics for the sample are also presented.

Age (years)	Male	CV	Female	CV	Total	CV
2	1 968	1.856	149	4.636	2 117	1.742
3	2 510	1.192	573	2.260	3 082	1.064
4	3 052	1.377	1 908	1.619	4 960	1.117
5	13 114	0.705	7 432	1.171	20 547	0.594
6	9 227	0.756	21 760	0.616	30 987	0.500
7	54 937	0.387	15 490	0.829	70 427	0.360
8	40 805	0.442	28 421	0.504	69 226	0.338
9	22 198	0.601	15 759	0.618	37 957	0.405
10	54 981	0.391	26 944	0.547	81 924	0.317
11	55 695	0.400	52 661	0.348	108 356	0.265
12	72 424	0.325	85 665	0.264	158 089	0.200
13	65 203	0.309	33 195	0.445	98 398	0.250
14	25 330	0.504	35 413	0.467	60 742	0.350
15	61 495	0.329	38 472	0.359	99 968	0.243
16	71 104	0.278	54 138	0.360	125 242	0.225
17	64 492	0.330	47 554	0.316	112 046	0.227
18	75 449	0.297	57 985	0.295	133 434	0.220
19	56 692	0.314	75 356	0.272	132 048	0.198
20	45 695	0.352	43 398	0.341	89 092	0.234
21	30 770	0.410	54 767	0.316	85 537	0.235
22	15 896	0.509	28 257	0.377	44 152	0.310
23	11 261	0.742	20 528	0.597	31 789	0.460
24	9 006	0.797	28 091	0.437	37 096	0.384
25	7 287	1.013	4 333	0.987	11 619	0.725
No. measured		938		1 060		1 998
No. aged		182		155		337
No. of trips sampled						3
No. of tows sampled						38
Mean weighted CV (%)		39.3		39.8		28.1

Table A2: Calculated numbers-at-age with CVs, for blue mackerel caught during commercial trawl operations in EMA 7 during the 2004–05 fishing year. Results from two analyses are presented; one used all available length data that had been sexed to produce numbers-at-age separately by sex, the other used all available data (sexed and unsexed) applied to an unsexed age-length key. Summary statistics for the samples are also presented.

	All sexed data						All data	
Age (years)	Male	CV	Female	CV	Total	CV	Total	CV
2	2 637	1.227	0	–	2 637	1.227	6 166	0.558
3	0	–	0	–	0	–	0	–
4	0	–	0	–	0	–	0	–
5	6 543	1.420	29 385	1.066	35 928	0.906	89 957	0.515
6	33 906	0.762	41 305	0.789	75 211	0.587	192 064	0.342
7	53 713	0.641	77 470	0.657	131 183	0.467	287 638	0.298
8	78 959	0.654	76 311	0.506	155 271	0.427	320 070	0.283
9	116 902	0.528	76 939	0.537	193 841	0.395	297 917	0.279
10	109 025	0.464	167 860	0.377	276 885	0.272	354 942	0.253
11	224 335	0.371	176 045	0.386	400 380	0.254	404 654	0.214
12	71 894	0.572	42 556	0.749	114 451	0.439	164 476	0.345
13	68 594	0.636	22 654	0.830	91 248	0.523	102 781	0.462
14	101 531	0.542	73 898	0.553	175 429	0.395	155 169	0.407
15	94 906	0.585	43 823	0.939	138 729	0.511	92 608	0.432
16	65 008	0.767	30 024	1.099	95 032	0.622	48 932	0.435
17	148 493	0.428	108 897	0.545	257 390	0.311	158 153	0.300
18	85 469	0.578	73 647	0.645	159 116	0.411	81 621	0.335
19	125 569	0.561	81 260	0.558	206 830	0.392	102 578	0.325
20	83 934	0.715	41 296	0.847	125 229	0.546	56 411	0.413
21	0	–	12 426	1.122	12 426	1.122	7 453	1.024
22	12 801	1.526	0	–	12 801	1.526	5 437	1.208
No. measured		448		439		887		3 288
No. aged		97		101		198		198
No. of trips sampled						6		6
No. of tows sampled						21		21
Mean weighted CV (%)		55.8		58.9		40.8		31.6

Table A3: Calculated numbers-at-age, separately by sex, with CVs, for blue mackerel caught during commercial trawl operations in EMA 7 during the 2005–06 fishing year. Summary statistics for the sample are also presented.

Age (years)	Male	CV	Female	CV	Total	CV
2	4 126	0.920	8 194	0.541	12 320	0.531
3	17 350	0.547	22 594	0.479	39 943	0.404
4	40 484	0.340	47 606	0.326	88 091	0.240
5	111 067	0.227	87 807	0.236	198 875	0.167
6	89 827	0.245	93 400	0.255	183 227	0.174
7	77 134	0.266	88 975	0.260	166 109	0.189
8	91 632	0.252	119 643	0.243	211 274	0.164
9	113 746	0.219	112 197	0.267	225 944	0.172
10	123 429	0.207	87 721	0.272	211 151	0.176
11	116 680	0.232	40 030	0.357	156 710	0.187
12	86 374	0.262	49 699	0.362	136 073	0.205
13	26 089	0.441	31 831	0.402	57 919	0.287
14	20 229	0.550	16 249	0.515	36 478	0.382
15	23 433	0.468	40 467	0.361	63 899	0.286
16	42 345	0.352	43 341	0.298	85 686	0.231
17	19 528	0.418	32 497	0.350	52 025	0.262
18	36 378	0.342	31 844	0.303	68 222	0.241
19	30 469	0.367	27 018	0.294	57 487	0.240
20	12 355	0.476	29 753	0.301	42 108	0.259
21	14 556	0.496	21 280	0.368	35 836	0.294
22	4 274	0.818	3 755	0.827	8 029	0.589
23	1 021	1.089	681	1.123	1 703	0.827
No. measured		1 660		1 618		3 278
No. aged		250		250		500
No. of trips sampled						7
No. of tows sampled						67
Mean weighted CV (%)		28.7		30.1		21.0