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The length and age composition of the commercial trawl catch of blue mackerel (*Scomber australasicus*) in EMA 7 during the 2017–18 fishing year, with a summary of all available data sets

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Horn, P.L.; Ó Maolagáin, C. (2019). The length and age composition of the commercial trawl catch of blue mackerel (*Scomber australasicus*) in EMA 7 during the 2017–18 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 EMA 7 (west coast New Zealand) during the 2017–18 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 2017–18 were caught as a bycatch of the midwater trawl fishery targeting jack mackerels. About 79% of the landed catch was sampled, and sampling was found to be representative of the landings both temporally and spatially. About 44% of the blue mackerel was caught in June–July 2018; a peak in landings around this time 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 usually coincide with the main jack mackerel peak.

The scaled length distribution from 2017–18 had a strongly dominant juvenile mode comprising multiple year classes (primarily 3–5 years old), with a minor mode representing adult fish. The age-frequency distribution had a mean weighted CV of 15%, 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, 2013–14, and 2017–18) are summarised. There was a marked variation in the catch-at-age distributions from the five years for which data are now available. In particular, the 2017–18 distribution comprised mainly juvenile fish, while all the earlier distributions were primarily adult fish.

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 was caught by a variety of methods in all QMAs, but most was caught north of latitude 43 °S (Morrison et al. 2001, Ballara 2016). The largest catches across fishing years were 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 were also important. Nevertheless, the target purse-seine catch in EMA 1 was the single largest component of the catch by any method in any QMA (Ballara 2016). Most blue mackerel purse seine catch came from the Bay of Plenty and East Northland, where it was primarily taken between July and December. The purse seine fishery 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 (3350 t) in 2004–05, 2005–06, and 2008–09, but declined steadily since 2008–09 to a low of 625 t in 2016–17. The EMA 7 landings in 2017–18 then exhibited a large jump to 3254 t (Table 1). Landings from EMA 2 and EMA 3 were well below the TACCs since the early to mid 1990s; they were 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 was principally non-target catch from the jack mackerel midwater trawl fishery (Ballara 2016). Highest catches were generally 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 was 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 2017–18 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%. This analysis was completed to add an additional year of catch-at-age data for use in a pending assessment of the EMA 7 stock. It also represented a recent year from which a comprehensive collection of length data and otoliths was available. The 2017–18 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), 2005–06 (Devine et al. 2009) [all reanalysed by Horn & Ó Maolagáin 2018], and 2013–14 (Horn & Ó Maolagáin 2018). This document fulfils the reporting requirements relating to blue mackerel in objective 2 of Project MID2018-03 "Routine age determination of hoki and middle depth species from commercial fisheries and trawl surveys", funded by Fisheries New Zealand. That objective is "To determine catch-at-age for commercial catches and resource surveys of specified middle depth and deepwater fishstocks".

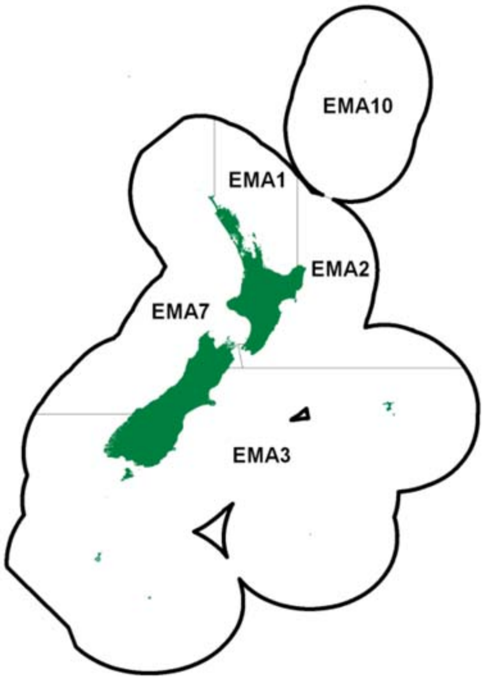

Figure 1: Map of the New Zealand EEZ showing the boundaries of blue mackerel QMAs.

Table 1: Reported landings (t) of blue mackerel by QMA, and where area was unspecified (Unsp.), from 1983–84 to 2017–18. CELR data from 1986–87 to 2000–01. MHR data from 2001–02 to 2017–18. 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
2016–17	7 551	83	126	625	0	0	8 385
2017–18	7 988	112	46	3 254	0	0	11 400
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 Observers from the Scientific Observer Programme 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 Observers for target and bycatch species are 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 2017–18 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 EMA 7 catch.

Commercial catch data extracted from the Fisheries New Zealand catch-effort database “warehou” (Extract #12272 on 5 March 2019) 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 2017–18. 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 599 blue mackerel otoliths collected by observers in 2017–18 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 ith 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 ith 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 $t_{i,\ capture}$

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.

3. RESULTS

3.1 Catch sampling

The landings distribution in 2017–18 shows that there were three months with substantial catches concentrated adjacent to and northwest of Cape Egmont (Statistical Areas 040, 041, and 801) — October, January and June (Table 3, Figure 2). Moderate catches were also taken in the South Taranaki Bight (Area 037) from January to April, and off the west coast of South Island (Areas 034 and 035) in June–July. 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) as used in previous catch-at-age analyses of this fishery (Horn & Ó Maolagáin 2018).

There were some discrepancies between the three catch records for 2017–18 shown in Figure 3. 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 one month (June), however, the MHR landings are much lower than both the observed and estimated landings. In the subsequent month (July), MHR landings are much higher than those estimated, so it appears likely that the MHR reports for July include some landings that were taken in June. The estimated and observed landings data show that over 500 t of blue mackerel were caught in the last four days of June; this volume of landings would account for the MHR discrepancy between June and July. In some months, observed landings were higher than estimated landings, particularly outside the peak fishery times. 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 minor 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 was often greater than estimated landings weights, and consequently, that the percentage of estimated total catch sampled by observers was often much greater than 100% (Table 3). For 2017–18, the total observed landed weight was 6% higher than the total estimated event-by-event landed weight. Relative to the total MHR landings from EMA 7, the observed catch accounts for 79% 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 substantial landings were consistently matched with corresponding observed landings in the bottom half of the table. Clearly, the observer sampling was satisfactory to estimate the overall catch-at-age.

Virtually all (99.5%) of the estimated landings were taken by midwater trawl. One purse seine landing targeting trevally in Area 047 accounted for 0.4% of estimated landings. Of the midwater trawl estimated landings, 60% were a bycatch of jack mackerel targeting, and 38.5% were reported as blue mackerel target.

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 2017–18 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), 2017–18

Stat Area												Month
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	All
034			0.0			0.1		10.1	50.5	10.2	4.1		74.9
035								1.0	40.3	60.5			101.7
036							1.8	2.4	18.7	17.5			40.3
037	0.0		2.5	69.8		37.2	90.3	0.5	0.4		0.0		200.6
039				0.3	0.5		20.9		0.1				21.7
040	0.0	0.0	3.3	225.7	0.0	0.0	3.1		53.7	1.1			286.8
041	644.5	14.2	44.6	1.6	0.0		0.0	0.0	84.3		0.0		789.4
042	0.4	2.5											2.9
045	0.5		0.0	0.0									0.5
047						0.0		0.0	0.0		10.0		10.0
801	162.0								722.0				884.0
All	807.4	16.7	50.4	297.4	0.5	37.2	115.9	14.0	969.7	89.3	14.1		2412.8

Sampled landings (t)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	All	%
034	0.0							14.7	2.4	14.7	8.0		39.8	53
035	0.3							1.8	12.7	64.5	0.1	0.0	79.4	78
036	0.6						5.5	3.5	22.3	31.1		0.3	63.3	157
037	0.1	0.0	34.2	122.4	0.6	31.6	50.7	4.8	0.1	0.1			244.6	122
039				1.8	0.5	0.1	28.8						31.2	144
040	0.2	1.0	4.2	216.2	0.2		6.1		70.9	2.1			300.9	105
041	677.4	39.3	73.5	2.1					121.3				913.5	116
042	10.0	0.9											10.9	374
045	4.9												4.9	974
047													0.0	0
801	163.0			0.0					705.8				868.8	98
All	856.4	41.2	111.8	342.5	1.3	31.7	91.0	24.8	935.5	112.6	8.1	0.3	2557.3	106
%	106	246	222	115	249	85	78	177	96	126	57		106	

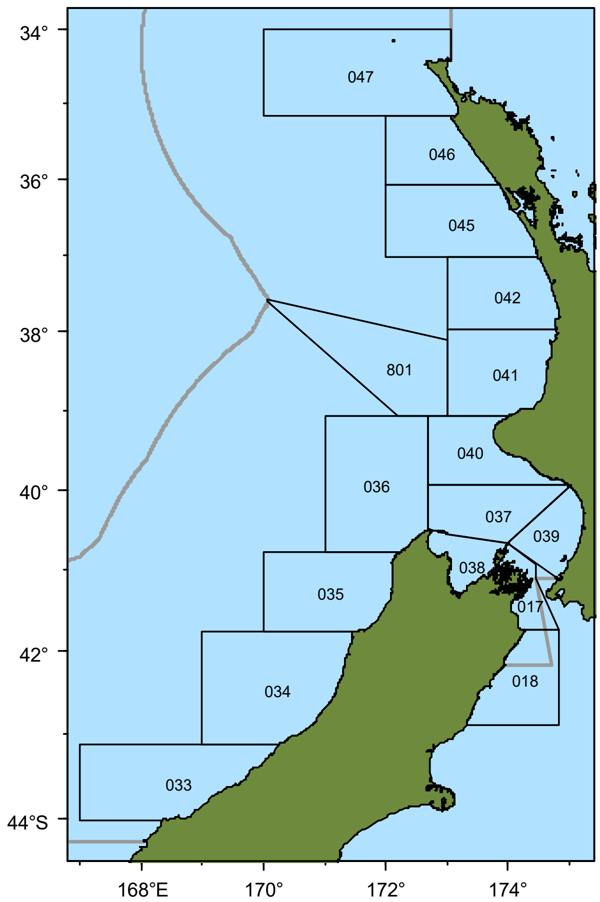

Figure 2: Statistical Areas in the EMA 7 fishstock area.

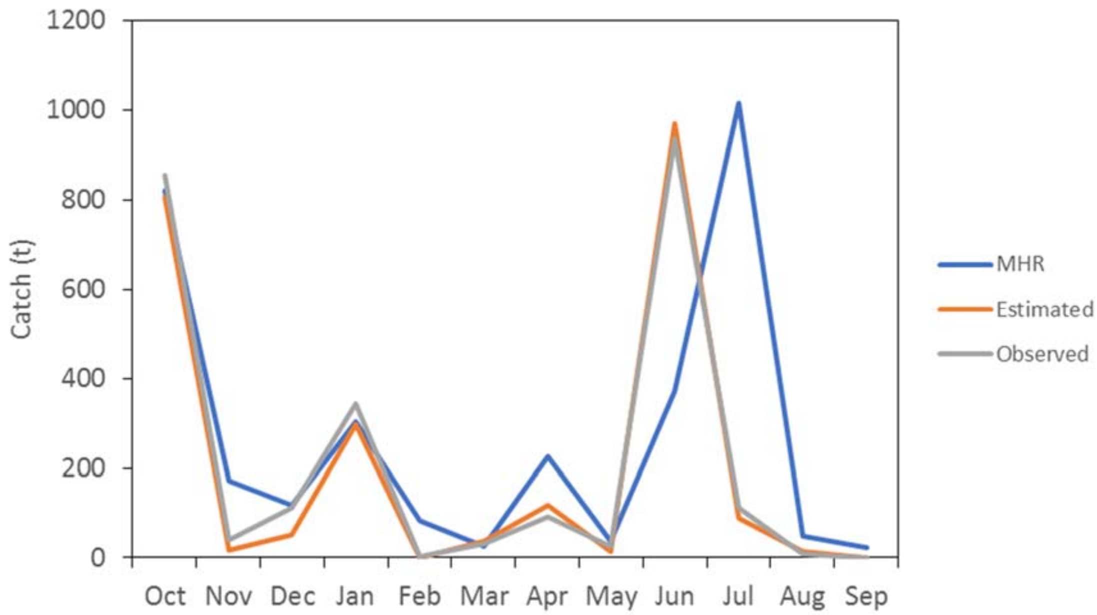

Figure 3: Landings of blue mackerel, by month, from EMA 7 in 2017–18, as reported on Monthly Harvest Returns (MHR) and as estimated catches by fishing event primarily on TCEPR forms (Estimated). Observed landings are also shown.

3.2 Sex ratios

The sex ratio for blue mackerel sampled from the 2017–18 fishing year was slightly biased towards males (Table 4). Ratios from the other four sampled years indicate that the fishery consistently takes a greater proportion of males than females.

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
2017–18	52.3	47.7

3.3 Catch-at-length

The estimated catch-at-length distributions for trawl-caught blue mackerel from EMA 7 in 2017–18 are plotted in Figure 4. The distribution was dominated by fish of lengths 37–43 cm, with two modes across this range. A smaller mode of larger fish at 48–52 cm was also apparent.

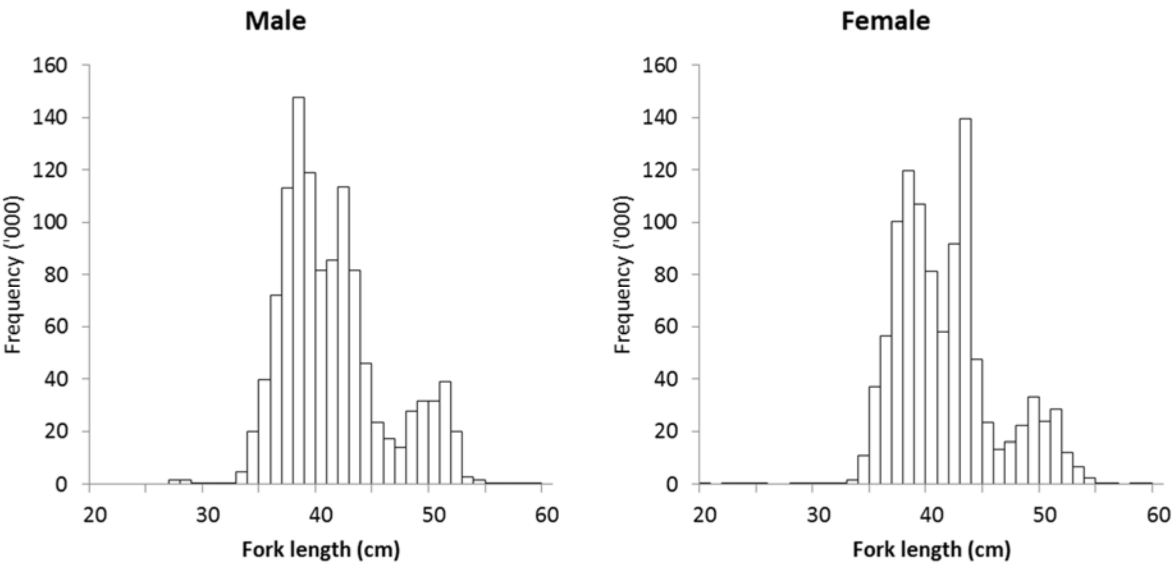

Figure 4: Estimated catch-at-length distributions, by sex, for blue mackerel from EMA 7 in 2017–18.

There were differences in the length-frequency distributions between the two strata for both small and large fish (Figure 5). The distributions in both strata were clearly bimodal. The earlier stratum (October–April) had modes at 38 and 52 cm; the smaller mode was primarily 3 and 4 year-olds, and the larger mode was older adults. The later stratum (May–September) had modes at 43 and 49 cm; the smaller mode was primarily 4 and 5 year-olds, and the larger mode was younger adults.

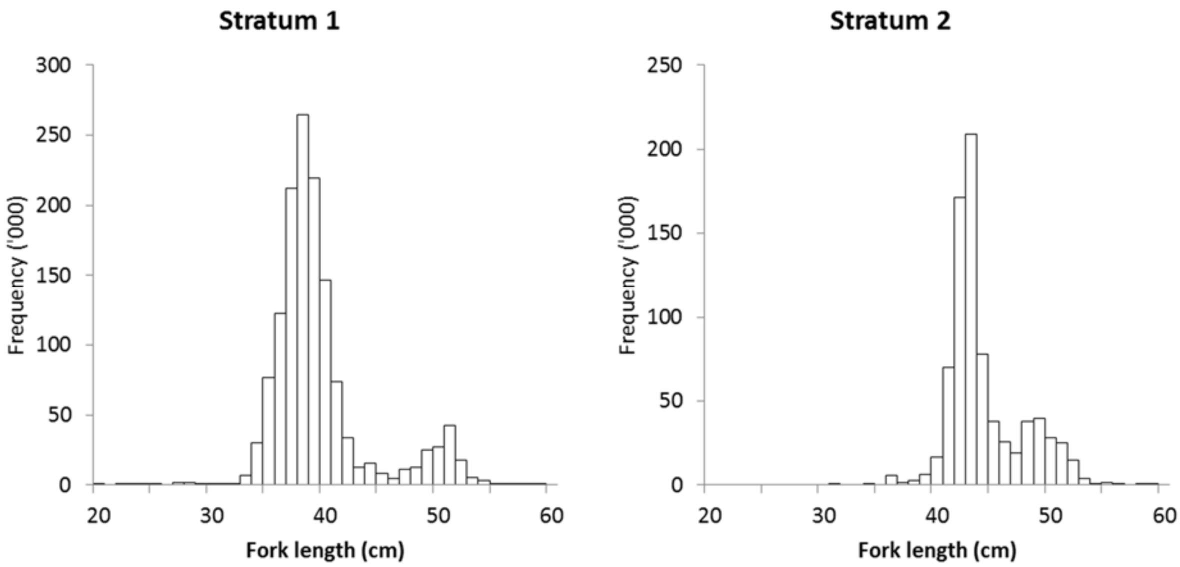

Figure 5: Estimated catch-at-length distributions for blue mackerel from EMA 7 in 2017–18, by stratum (stratum 1, October–April; stratum 2, May–September).

3.4 Catch-at-age

The details of the estimated catch-at-age distribution for trawl-caught blue mackerel from EMA 7 in 2017–18 are presented in Table 5. The mean weighted CV of 15% bettered the target value of 30%. The estimated distribution (Figure 6) was strongly dominated by fish 3–5 years old, with adults being most abundant in the 13–19 year age range. There were no fish older than 24 years.

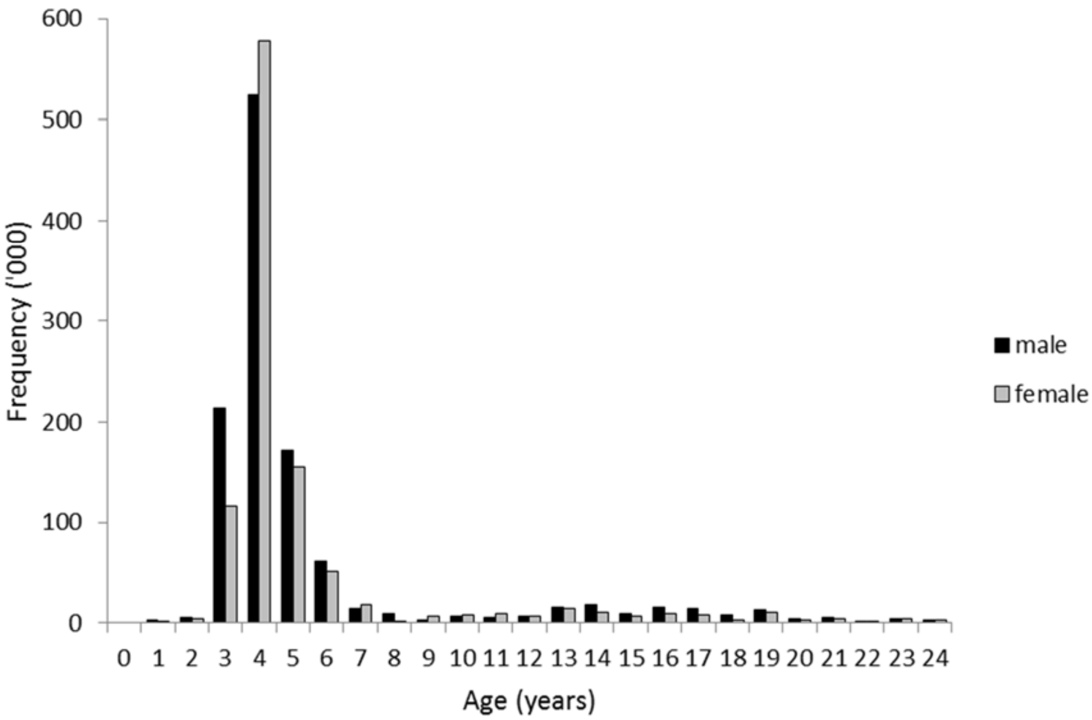

Figure 6: Estimated commercial trawl catch-at-age distributions for blue mackerel from EMA 7 in 2017–18.

Table 5: Calculated numbers-at-age, separately by sex, with CVs, for blue mackerel caught during commercial trawl operations in EMA 7 during the 2017–18 fishing year. Summary statistics for the sample are also presented.

Age (years)	Male	CV	Female	CV	Total	CV
1	3 080	1.485	697	1.509	3 777	1.232
2	5 402	0.984	3 991	1.377	9 393	0.930
3	214 412	0.271	116 562	0.304	330 974	0.240
4	523 890	0.101	578 119	0.100	1 102 009	0.071
5	172 226	0.201	155 610	0.193	327 836	0.141
6	61 867	0.249	50 895	0.272	112 762	0.170
7	13 831	0.360	18 863	0.340	32 694	0.249
8	9 245	0.420	1 516	1.204	10 761	0.412
9	3 425	0.610	7 108	0.514	10 533	0.419
10	6 313	0.455	8 453	0.487	14 766	0.354
11	6 082	0.475	9 404	0.427	15 486	0.340
12	6 938	0.485	6 677	0.473	13 615	0.358
13	15 688	0.333	14 888	0.331	30 576	0.226
14	17 833	0.286	10 009	0.395	27 842	0.236
15	8 932	0.471	6 647	0.443	15 580	0.318
16	15 312	0.341	9 302	0.381	24 614	0.272
17	14 081	0.359	7 626	0.416	21 707	0.282
18	7 852	0.462	3 450	0.722	11 303	0.423
19	13 652	0.357	11 093	0.340	24 744	0.269
20	4 372	0.563	3 488	0.540	7 860	0.398
21	5 754	0.483	4 769	0.514	10 523	0.372
22	833	1.174	419	1.228	1 252	0.883
23	4 339	0.550	3 846	0.590	8 185	0.409
24	3 441	0.604	3 195	0.690	6 636	0.473
No. measured		2 115		1 902		4 017
No. aged		308		305		613
No. of trips sampled						29
No. of tows sampled						141
Mean weighted CV (%)		20.7		19.5		15.1

3.5 Data summaries

Catch-at-length and catch-at-age data from the EMA 7 trawl fishery are now available for five years: 2003–04 to 2005–06, 2013–14, and 2017–18. 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 Horn & Ó Maolagáin 2018). Catch-at-age for all available years are listed (sexes combined) in 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
2017–18	21	20	15	25	26	21

Total (i.e., sexes combined) scaled age distributions for the five 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. The 2 and 3-year-old fish in 2013–14 do appear in 2017–18, particularly as 6-year-olds, but that most recent distribution is very strongly dominated by even younger fish (3–5 year-olds).

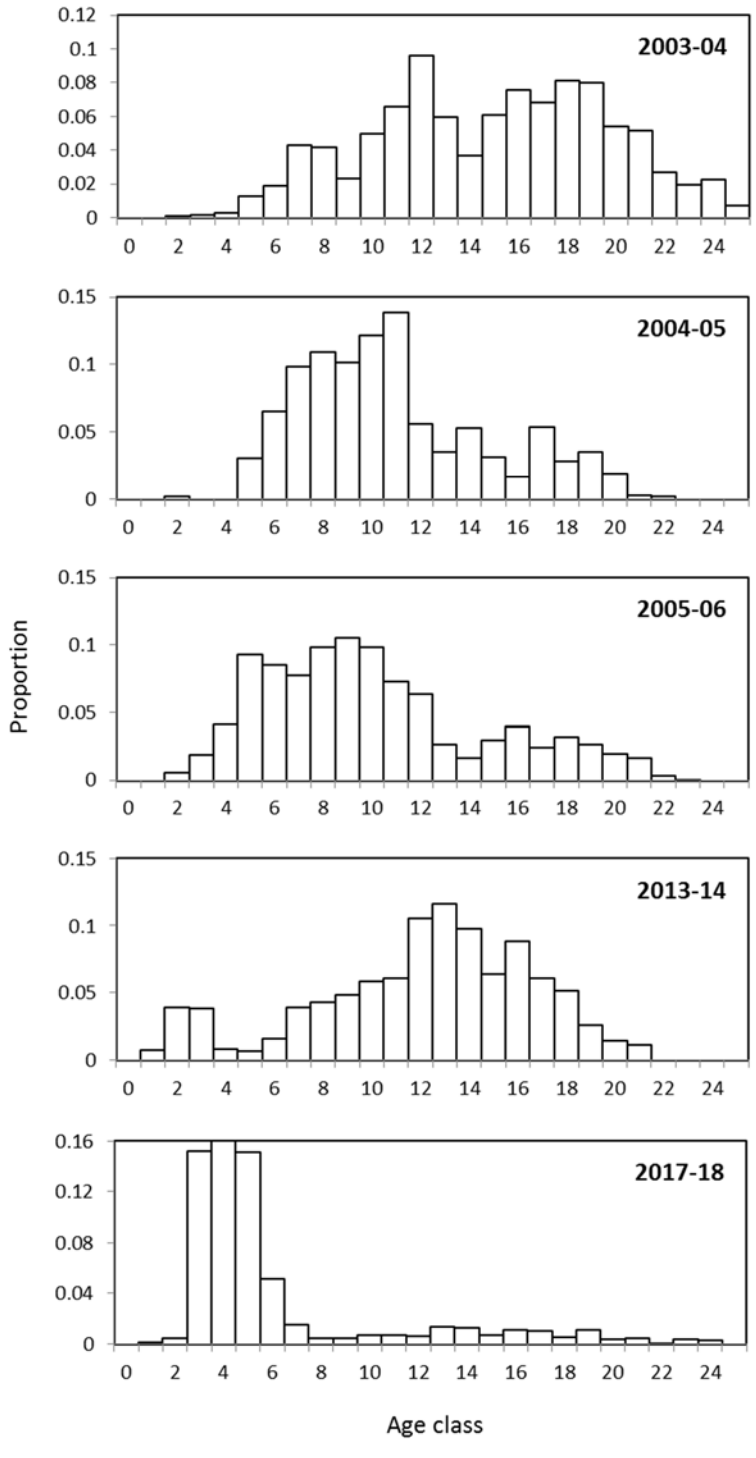

Figure 7: Scaled catch-at-age proportions for the trawl catch of blue mackerel sampled from the 2003–04 to 2005–06, 2013–14, and 2017–18 fishing years. The bar representing age 4 fish in 2017–18 was truncated (from 0.51) to make the pattern of older year classes more apparent.

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). That work showed that 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 with the remainder taken when the stated target species was barracouta or blue mackerel. The 2017–18 fishery sampled here exhibited some variation to that trend; although more than 99% of the EMA 7 blue mackerel landings were taken by midwater trawl, only 60% was reported as a jack mackerel bycatch, with almost all of the remainder being from target blue mackerel tows. Since 1990 more than 60% of the catch was taken in June and July, and since 2010 more than 75% of the catch was from Statistical Areas 035, 037, 041 and 801 (Ballara 2016). The comparable percentages for 2017–18 were 44% and 81%. Much of the temporal difference in 2017–18 is attributable to target fishing for blue mackerel in October 2017 in Areas 041 and 801, producing estimated landings of 740 t. The residual targeted landings of blue mackerel were from the same statistical areas, but in June 2018.

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 were less than (often much less than) 20% (Ballara 2016). Purse seine landings were taken generally from the South Taranaki Bight or off western Northland. Only one substantial catch of blue mackerel was taken by purse seine from EMA 7 in 2017–18, a 10 t shot west of North Cape when targeting for trevally.

The 2017–18 blue mackerel trawl catch from EMA 7 was comprehensively sampled. Sampling intensity was high in all months that produced substantial landings; it is likely that more than 75% of the catch was sampled. Spatially, there was also very good coverage of catch in the heavily fished Statistical Areas (035, 037, 040, 041 and 801). The estimate of the 2017–18 catch-at-age had a mean weighted CV over all age classes of 15%, 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 reducing EMA 7 trawl landings in recent years was markedly reversed in 2017–18; landings were five times those recorded from the previous year. The reason for this turn-around is not certain. The abundance of blue mackerel vulnerable to the trawl may have markedly increased. A very high proportion of the catch was relatively small fish (35–45 cm) aged 3 to 5 years. A very strong year class of 4+ fish may have recruited to the fishery; the examination of data from subsequent years will be necessary to clarify this. However, in the previous (2016–17) fishing year, many of these fish would have been vulnerable to the trawl if they were present in the fishing area, yet the EMA 7 landings in that year were the lowest since 1988. There was clearly an increase in reported targeting for blue mackerel in 2017–18. If this is a genuine increase in targeting, then either the abundance of available blue mackerel has markedly increased, or there was improved desirability of this species as a landed catch. It is also possible that blue mackerel were mixed more with jack mackerels than they were in previous years, and so were more often caught with jack mackerels. Consultations with fishing industry representatives suggested that there was no increased desirability for catches of blue mackerel in 2017–18, although there are distinct areas where it is possible to target blue mackerel and expect to get relatively high catches of it as well as jack mackerels. It was suggested, however, that increased availability of blue mackerel in the 'traditional' jack mackerel fishery areas may have resulted from relatively high water temperatures off west coast North Island. In addition, the unusually high landings around October 2017 were likely to have been a consequence of some vessels leaving the WCSI hoki fishery early because of low catch rates in that fishery (and moving north to the jack mackerel grounds).

Most of the 2017–18 catch comprised juvenile fish aged mainly from 3 to 5 years old. This distribution was markedly different to the other four available samples (see Figure 7). Adult fish aged 7 years or older dominated the earlier distributions; the 2017–18 distribution had only 13% of fish 7 years or older. The sample from the fishery in 2013–14 appeared to have relatively strong cohorts of 2 and 3-year-old fish, particularly when compared to the three earliest sampled years (2003–04 to 2005–06). However, those 2 and 3-year-old cohorts do not appear to have progressed to being strong in the 2017–18 distribution.

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 (although in 2017–18 there were two blue mackerel landings peaks that did generally coincide with jack mackerel landings peaks; see Horn et al. in prep.). 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 2017–18, the average bottom depth of observed tows where blue mackerel were measured was 102 m in October–April, and 163 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) was possibly exploited 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).

It is clear that the fishery for blue mackerel in 2017–18 was markedly different to that in recent previous years. The reason for this, however, is uncertain — it may be a change in fish behaviour, fisher behaviour, or a combination of both. The 2017–18 EMA 7 fishery was sampled comprehensively by observers, but this has not been the case in all years over the last two decades. If there is a desire to understand the change in the fishery then observer sampling intensity on this species needs to be maintained at least at current levels. Future ageing of this species, perhaps biennially, could also be considered.

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APPENDIX A. EMA 7 trawl catch-at-age data

This appendix reports catch-at-age distributions for trawl-caught blue mackerel from EMA 7, using two time strata (October–April, May–September). For data separately by sex in all years before 2017–18, see Horn & Ó Maolagáin (2018).

Table A1: Calculated numbers-at-age, sexes combined, with CVs, for blue mackerel caught during commercial trawl operations in EMA 7, for all years where data are available.

Age	2003–04		2004–05		2005–06		2013–14		2017–18	
(years)	Number	CV	Number	CV	Number	CV	Number	CV	Number	CV
1	0	–	0	–	0	–	4 835	0.664	3 777	1.232
2	2 117	1.742	6 166	0.558	12 320	0.531	25 263	0.412	9 393	0.930
3	3 082	1.064	0	–	39 943	0.404	24 963	0.443	330 974	0.240
4	4 960	1.117	0	–	88 091	0.240	5 207	0.573	1 102 009	0.071
5	20 547	0.594	89 957	0.515	198 875	0.167	4 424	0.468	327 836	0.141
6	30 987	0.500	192 064	0.342	183 227	0.174	10 629	0.349	112 762	0.170
7	70 427	0.360	287 638	0.298	166 109	0.189	25 325	0.241	32 694	0.249
8	69 226	0.338	320 070	0.283	211 274	0.164	28 230	0.221	10 761	0.412
9	37 957	0.405	297 917	0.279	225 944	0.172	31 618	0.201	10 533	0.419
10	81 924	0.317	354 942	0.253	211 151	0.176	37 856	0.178	14 766	0.354
11	108 356	0.265	404 654	0.214	156 710	0.187	39 445	0.176	15 486	0.340
12	158 089	0.200	164 476	0.345	136 073	0.205	68 757	0.161	13 615	0.358
13	98 398	0.250	102 781	0.462	57 919	0.287	76 034	0.133	30 576	0.226
14	60 742	0.350	155 169	0.407	36 478	0.382	63 625	0.157	27 842	0.236
15	99 968	0.243	92 608	0.432	63 899	0.286	41 432	0.174	15 580	0.318
16	125 242	0.225	48 932	0.435	85 686	0.231	57 822	0.167	24 614	0.272
17	112 046	0.227	158 153	0.300	52 025	0.262	39 797	0.197	21 707	0.282
18	133 434	0.220	81 621	0.335	68 222	0.241	33 747	0.213	11 303	0.423
19	132 048	0.198	102 578	0.325	57 487	0.240	17 047	0.286	24 744	0.269
20	89 092	0.234	56 411	0.413	42 108	0.259	9 408	0.391	7 860	0.398
21	85 537	0.235	7 453	1.024	35 836	0.294	7 359	0.476	10 523	0.372
22	44 152	0.310	5 437	1.208	8 029	0.589	0	–	1 252	0.883
23	31 789	0.460	0	–	1 703	0.827	0	–	8 185	0.409
24	37 096	0.384	0	–	0	–	0	–	6 636	0.473
25	11 619	0.725	0	–	0	–	0	–	0	–