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Commercial catch sampling for species proportion, sex, length, and age of jack mackerels in JMA 7 in the 2016–17 fishing year, with a summary of all available data sets

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EXECUTIVE SUMMARY

Horn, P.L.; Ó Maolagáin, C. (2018). Commercial catch sampling for species proportion, sex, length, and age of jack mackerels in JMA 7 in the 2016–17 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 jack mackerel (*Trachurus novaezelandiae*, *T. declivis*, and *T. murphyi*) in JMA 7 (central west coast) during the 2016–17 fishing year, and the estimates of species proportions and sex ratios in the landings, catch-at-length, and catch-at-age for these species.

Each tow in the observer data set included estimated total jack mackerel catch and weights by species sampled from the tow. The sampled weights were scaled to give estimated total catch weights by species for the tow. Stratification of the data was required because the observer coverage and catch composition varied with both month and statistical area. About 72% of the 2016–17 landed catch was sampled, and sampling was found to be representative of the landings both temporally and spatially.

For all three species, the scaled length distributions from 2016–17 were similar to those from the ten previous years. The age-frequency distributions for all species in 2016–17 had mean weighted CVs of 20% or less, which more than met the target of 30%. There was clear variation in catch-at-age between years for all species probably because of the progression of year classes with different relative strengths.

Estimated species proportions showed a dominance by *T. declivis* at 61–71% in the JMA 7 TCEPR catch for all statistical areas and the eleven years of sampling, while *T. novaezelandiae* was 24–33% and *T. murphyi* was 3–8%.

1. INTRODUCTION

Commercial catches of jack mackerel are recorded as an aggregate of the three species (*Trachurus declivis*, *T. murphyi*, and *T. novaezelandiae*) under the general code JMA, so separate species catch information is not available from Ministry databases for the jack mackerel quota management areas (Figure 1). Estimates of proportions of the three *Trachurus* species in the catch are essential for assessment of the individual stocks. Reliable estimates of species proportions can be used to apportion the aggregated catch histories to provide individual catch histories for each species at least back to when observer sampling began, which can in turn be used to scale age samples from the various fisheries. Since the mid-2000s the JMA 7 fishery was primarily a trawl fishery with a small proportion of catches made using purse seine or set net. Before then, larger proportions of the catch came from purse seine fishing (Taylor & Julian 2008).

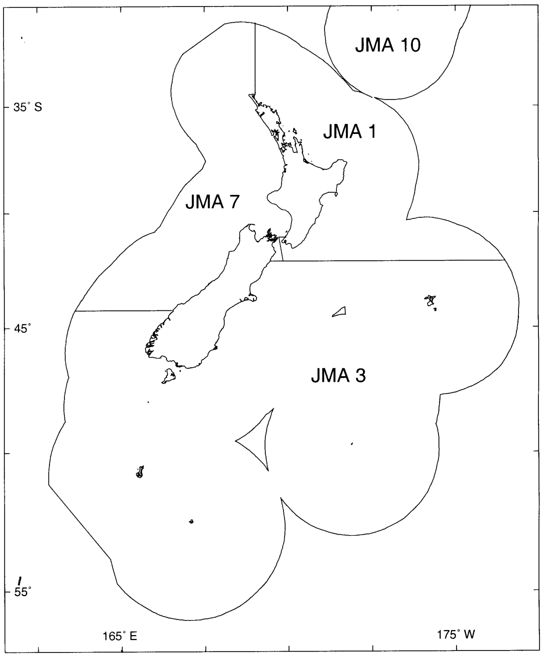

Figure 1: Jack mackerel administrative Fishstock areas.

This report provides estimates of relative proportions and catch-at-age for the three *Trachurus* species in the commercial JMA 7 catch for 2016–17 using observer data. Similar data were presented by Taylor et al. (2011) for 2006–07, 2007–08 and 2008–09, Horn et al. (2012a) for 2009–10, Horn et al. (2012b) for 2010–11, Horn et al. (2013) for 2011–12, Horn et al. (2014b) for 2012–13, Horn et al. (2015) for 2013–14, Horn et al. (2017) for 2014–15, and Horn et al. (submitted) for 2015–16. Summaries of the time series of catch-at-age estimates, sex ratios and species proportions for the JMA 7 catch are also presented. This document fulfils the reporting requirements relating to jack mackerels in objective 1 of Project MID201701 "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".

The JMA 7 age and size structure of the commercial catch has been determined annually since 2006–07. A 'one-off' estimation of the age and size structure of the commercial catch of jack mackerels in JMA 3 in the 2012–13 fishing year was reported by Horn et al. (2014a).

Age monitoring of jack mackerels over time was carried out previously for jack mackerel species in New Zealand by Horn (1993) who tracked strong and weak age classes of *T. declivis* and *T. novaezelandiae* through time to provide a qualitative validation for ageing these two species. There was no significant difference in growth between sexes for either species although geographical differences were evident between the Bay of Plenty and the central west coast.

2. METHODS

Catch sampling for length, sex, age, and species composition was carried out by observers primarily working on board large trawl vessels targeting jack mackerels. Sampling was generally carried out according to instructions developed at NIWA and included in the Scientific Observers Manual. Most tows in the observer dataset included estimated total jack mackerel catch and weights by species sampled from the tow. All observer data on jack mackerels sampled from JMA 7 in the 2016–17 fishing year were extracted for the analyses. As in previous analyses, estimated species proportions (by weight) in each sampled tow were assumed to be the same as the proportions in a randomly selected sample from the catch (Taylor et al. 2011). 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 #11701 on 20 March 2018) were used in these analyses. The data comprised estimated catch and associated date, position, depth, and method data from all fishing events that recorded catches of jack mackerel from JMA 7 (i.e., QMAs 7, 8, and 9) in 2016–17.

Stratification of the data was required because the observer coverage varied with both month and statistical area, the fishery was not consistent throughout the year, and the species composition varied across area and depth (Taylor et al. 2011). The stratification used for years 2006–07 to 2013–14 was derived by Taylor et al. (2011) based on data from the first three years of that series (shown in appendix A of Horn et al. (2012b)). The stratification was re-evaluated in 2016 by Horn et al. (2017) and found to be little different to that developed by Taylor et al. (2011). The 2016 stratification (shown in appendix A of Horn et al. (2017)) was adopted, and was used again in the analysis of the 2016–17 data presented here. Consequently, each fishing event from the catch-effort dataset and the observer dataset was allocated to one of the five strata, i.e.,

- 1, west of longitude 173.15° E (west coast South Island and deeper west coast North Island waters),
- 2, Statistical Area 041 (north Taranaki Bight) shallower than 120.25 m,
- 3, Statistical Area 041 (north Taranaki Bight) deeper than 120.25 m,
- 4, all remaining areas in March and April,
- 5, all remaining areas in October–February and May–September.

Proportions of the catch by species were estimated as follows. For each observed tow, the catch weight of each species was estimated based on the species weight proportions of a random sample. Each observed tow was allocated to one of the five strata. Within each stratum, the estimated landed weights of each species were summed across all observed tows. Percentages of catch by species were then calculated for each stratum. Total jack mackerel catch by stratum was obtained by summing the reported estimated landing weights of all tows (from the catch-effort dataset) in that stratum. The species percentages derived for that stratum were then applied to the total summed catch to estimate catch by species in that stratum. The estimated catch totals were then summed across strata (by species) to produce total estimated catch weight by species for the fishing year, and, consequently, total species proportions by weight.

Ageing was completed for all three *Trachurus* species caught by trawl in Statistical Areas 033–047 and 801 of JMA 7 (Figure 2) in the 2016–17 fishing year, using data and otoliths collected by observers. For each species, samples of otoliths (for each sex separately) from 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. Target sample sizes were about 500 per species. Sets of five otoliths were embedded in blocks of clear epoxy resin and cured at 50°C. Once hardened, a 380μm 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. Otoliths of *T. declivis* and *T. novaezelandiae* were read following the validated methods described by Horn (1993) and Lyle et al. (2000). A validated ageing method has not yet been developed for *T. murphyi* in New Zealand waters (Beentjes et al. 2013). Otoliths from this species were interpreted similarly to those of *T. declivis*. However, they are notably harder to read, with presumed annual zones often being diffuse, split, or containing considerable microstructure (Taylor et al. 2002).

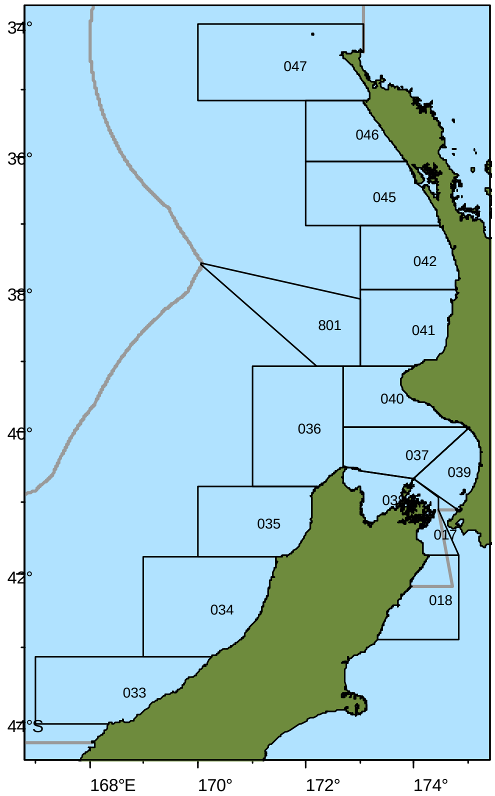

Figure 2: Statistical Areas referred to in the text.

The age data were used to construct age-length keys (by species and 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. Sex ratios by species were also derived at this stage. The fishery has consistently had two peaks quite widely separated in time (see Results), so the fishing year was split into two equal parts (i.e., a split between March and April) and separate age-length keys were used for each part (to account for the growth of fish, particularly of the younger age classes). For *T. novaezelandiae*, all age data from fish 28 cm or longer were used in both the October–March and April–September age-length keys (because the annual growth increment is slight or negligible for these larger fish). Age data from *T. novaezelandiae* shorter than 28 cm were applied only in the age-length key applicable to their sampling date. For *T. declivis*, a similar analysis process was used, but with the length cut-off at 38 cm or greater. For *T. murphyi*, a single age-length key was used for the entire year as virtually all the sampled fish were adults that were close to the asymptotic length of their growth curve.

3. RESULTS

3.1 Catch sampling

The landings distribution in 2016–17 shows that there was a fishery from October to January concentrated in Statistical Areas 037 and 040–041 (but also with moderate catches in Areas 036, 042 and 801), followed by a secondary fishery centred around June and concentrated off the northwest South Island (Areas 034–036) in May–August and to a lesser extent in the South Taranaki Bight (Area 037) in April (Table 1). The presence of two quite widely separated fishery peaks maintained a trend apparent across all analysed years. Observer data from the 2016–17 fishing year were split between March and April, and separate age-length keys were applied to data from each period. In each time period, the data were analysed in the five strata described above.

In 2016–17, about 72% of the landed weight was sampled by observers (Table 1). Most of the estimated landings were derived from six Statistical Areas (034–037, 040–041), and these were all well sampled (Figure 3). The percentages of the catch sampled in the four most productive months were all greater than 58% (Table 1), and only May (the ninth most productive month) could be considered under-sampled. Clearly, the sampling of the whole fishery was satisfactory to estimate the overall catch-at-age. The estimated catch weight sampled in some months and areas was slightly greater than the estimated catch. This can occur if observers and skippers record different estimated catch weights for a tow, or if the recorded location of an individual tow differs in the two databases resulting in it being allocated to different statistical areas.

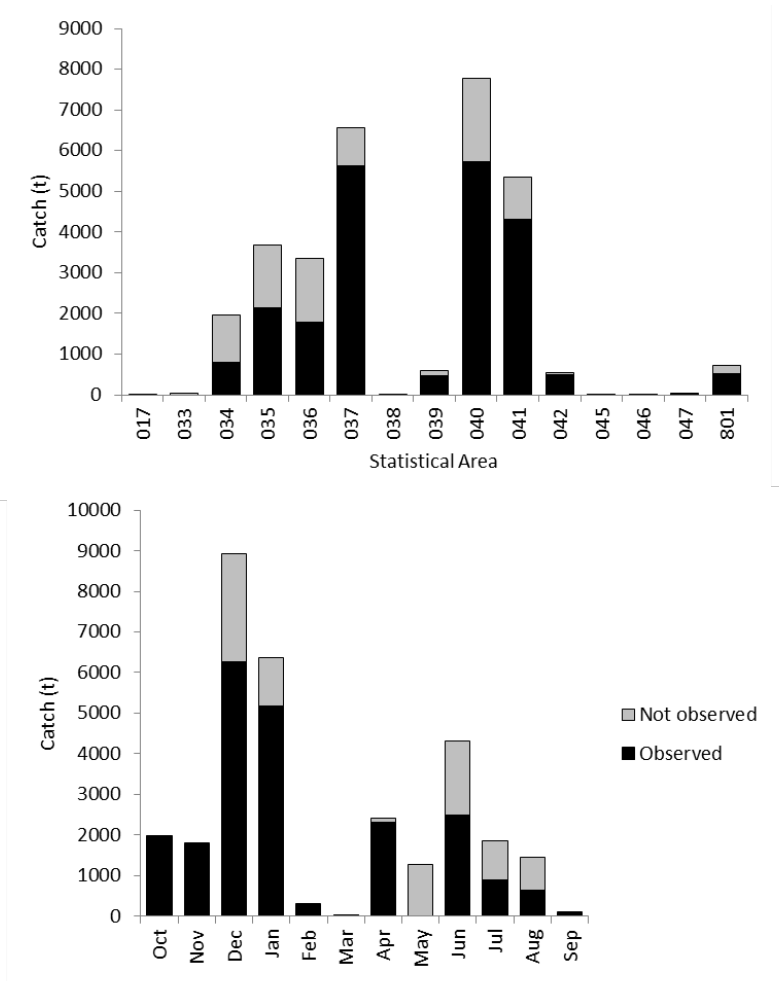

Figure 3: Jack mackerel observed landings and landings that were not observed, by Statistical Area and month, in 2016–17.

Table 1: Distribution of estimated total catch and sampled landings (t, rounded to the nearest tonne) of jack mackerels, by month and Statistical Area (Stat Area), in the 2016–17 fishing year. Values of 0 indicate landings from 1 to 499 kg; blank cells indicate zero landings or samples. %, percentage of estimated total catch that was sampled by observers, by month and statistical area.

Estimated total catch (t), 2016–17

Stat Area	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Month All
017	1	5	1	3	2	0	2	2	1	0	0	0	18
033	1	5	2	9	2	2	1	2	1	0	1	6	32
034	0	2	0	1	2	5	1	46	180	1 006	711	2	1 955
035	260	1	1	0	1	1	0	381	1 459	820	741	10	3 675
036	437	0	0	203			39	591	2 042	20	0	15	3 348
037	203	33	1 843	2 388	67	0	1 705	215	113	0	1	0	6 568
038	1	1	0	1	0	0	1	1	0	0	0	1	7
039	0	0	0		0	0	390	29	108	1	1	56	585
040	71	27	3 613	3 165	227	0	267	0	414			0	7 785
041	510	1 453	3 164	219	1	0	0	0	0	0	0	0	5 348
042	115	247	189	0	0	0	0	0	0	0		0	552
43–44	0	0	0		0	0	0	0	0	0	0	0	0
045	0		0	0	0	0	0		0	0	0	0	2
46–47	0	0	1	0	0	0	1	1	0	0	1	3	8
801	237		109	369									715
All	1 836	1 776	8 925	6 359	302	8	2 406	1 267	4 320	1 848	1 455	95	30 598

Sampled landings (t)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	All	%
017														0
033														0
034	0							0	68	381	340	0	790	40
035	259								1 068	501	302	12	2 141	58
036	455			185			41		1 095			11	1 788	53
037	200		1 413	2 220	69		1 662		70			0	5 634	86
038														0
039							367	0	48			64	479	82
040	84	27	2 492	2 519	205		252		147			0	5 727	74
041	533	1 483	2 204	87			0		0			0	4 307	81
042	137	259	111	0	0		0		0			0	507	92
43–44														0
045	0			0	0	0	0	0	0	0		0	1	50
46–47	0		0	0	0	0	0	2	0	0	0	3	6	75
801	321		51	152									524	73
All	1 990	1 769	6 271	5 164	275	0	2 322	2	2 497	882	642	90	21 905	72
%	108	100	70	81	91	0	97	0	58	48	44	95	72	

3.2 Species proportions

An examination of estimated species proportions by fishing year (Table 2) shows that *T. declivis* (JMD) was the dominant species caught from 2006–07 to 2016–17, with 61–71% of landed weight in all years. *T. novaezelandiae* (JMN) was the second most frequently caught species at 24–33%. *T. murphyi* (JMM) was detected at a much lower and quite variable rate of 3–8%. The 2016–17 fishing year produced proportions of *T. novaezelandiae* and *T. declivis* that were close to the average of all years investigated.

Table 2: Estimated species proportions (by weight) and catch weights by species in JMA 7 since 2006–07. 'Estimated catch' is the sum of all the tow-by-tow estimates of jack mackerel catch.

	Species proportions (%)			Estimated catch (t)			Landed catch (t)		
Fishing year	JMN	JMD	JMM	JMN	JMD	JMM	JMN	JMD	JMM
2006–07	26.8	69.5	3.7	8 188	21 248	1 128	8 583	22 273	1 183
2007–08	27.0	64.8	8.2	8 763	21 033	2 671	9 193	22 064	2 802
2008–09	25.3	66.4	8.3	6 826	17 943	2 236	7 287	19 154	2 387
2009–10	27.6	65.9	6.5	8 155	19 487	1 933	8 590	20 526	2 036
2010–11	26.9	70.6	2.5	7 123	18 679	650	7 587	19 897	692
2011–12	28.1	68.6	3.3	7 456	18 184	880	7 497	19 381	938
2012–13	29.7	67.3	3.3	8 638	19 525	950	9 428	21 311	1 037
2013–14	24.3	70.7	5.0	7 961	23 144	1 626	8 555	24 872	1 748
2014–15	33.0	60.7	6.3	10 447	19 231	1 999	11 204	20 623	2 144
2015–16	28.4	65.0	6.6	7 999	18 312	1 845	8 771	20 080	2 024
2016–17	26.3	69.0	4.7	8 051	21 106	1 440	8 649	22 671	1 547

3.3 Sex ratios

Sex ratios by fishing year since 2006–07 are shown in Table 3. *Trachurus novaezelandiae* consistently had slightly more females than males in all but two years (average 47.0% males across all years). Ratios were around 50% for *T. declivis* (average 50.2% males across all years). The sex ratios for *T. murphyi* indicate a sampled population quite strongly biased towards males (i.e., 54–62% from 2006–07 to 2013–14), although since 2014–15 the samples had almost equal proportions.

Table 3: Estimated sex ratios (%) in the JMA 7 catch by species and fishing year.

	JMN		JMD		JMM	
Fishing year	Males	Females	Males	Females	Males	Females
2006–07	49.5	50.5	51.6	48.4	54.8	45.2
2007–08	43.0	57.0	51.7	48.3	60.7	39.3
2008–09	45.7	54.3	52.5	47.5	56.9	43.1
2009–10	49.1	50.9	51.5	48.5	54.3	45.7
2010–11	43.4	56.6	46.8	53.2	56.9	43.1
2011–12	48.0	52.0	47.7	52.3	61.6	38.4
2012–13	50.0	50.0	50.8	49.2	55.3	44.7
2013–14	45.4	54.6	51.2	48.8	57.6	42.4
2014–15	44.5	55.5	46.2	53.8	50.2	49.8
2015–16	46.2	53.8	50.7	49.3	48.3	51.7
2016–17	51.8	48.2	51.3	48.7	50.4	49.6

3.4 Catch-at-length

The estimated catch-at-length distributions, by species, for trawl-caught jack mackerel from JMA 7 in 2016–17 are plotted in Figure 4. For *T. novaezelandiae* there was a dominant length mode at 28–32 cm, with a minor secondary mode at 21–23 cm. For *T. declivis* there was a strong length mode at 39–41 cm, and a secondary mode at 29–31 cm. One other mode (43–44 cm) was also apparent in the female distribution. The length range of *T. murphyi* was very narrow, with most males being 49–54 cm, and most females being 48–53 cm.

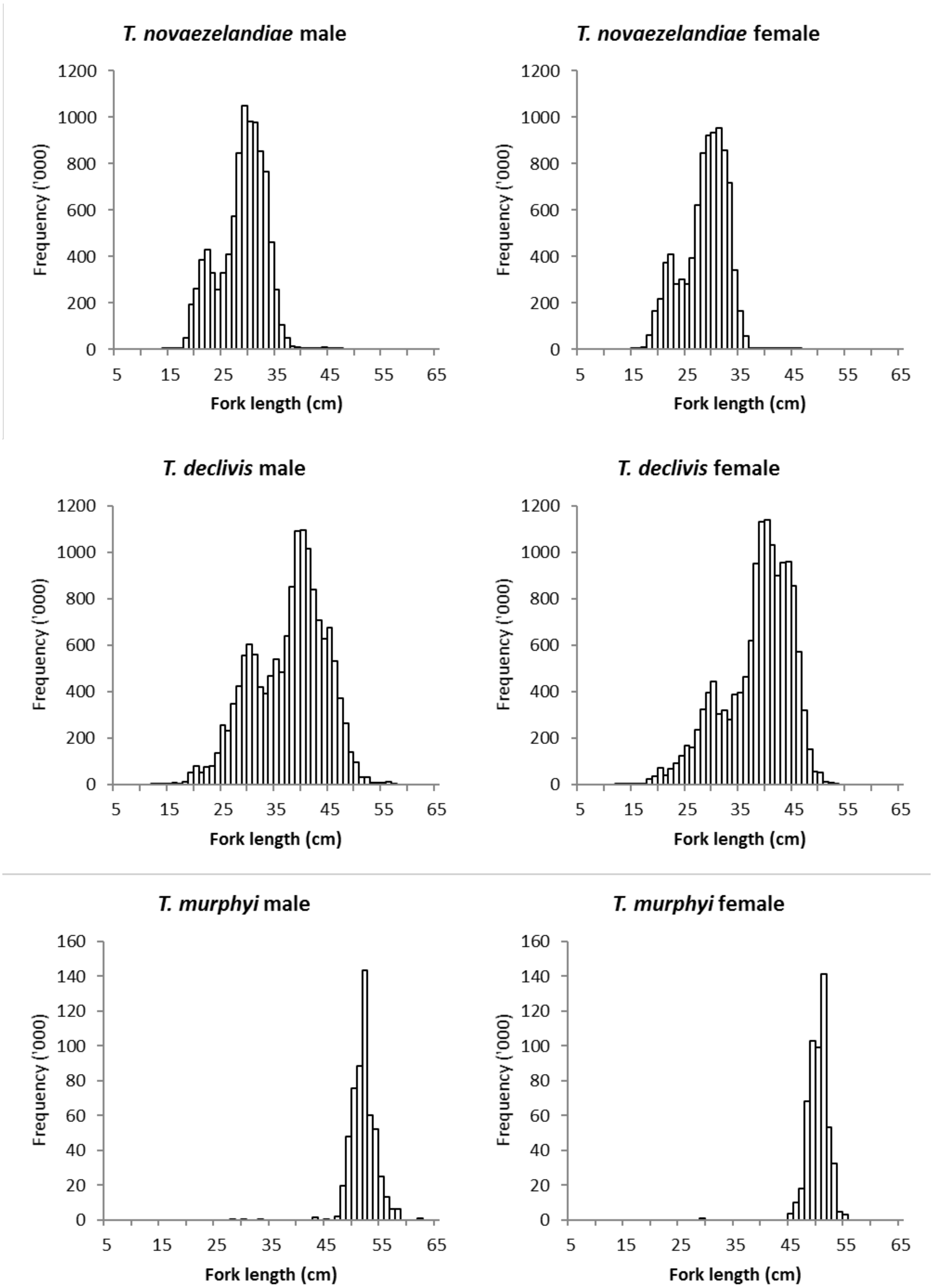

Figure 4: Estimated catch-at-length distributions, by species and sex, from JMA 7 in 2016–17.

3.5 Catch-at-age

The details of the estimated catch-at-age distributions for trawl-caught jack mackerel from JMA 7 in 2016–17 are presented for *T. novaezelandiae* in Table 4, *T. declivis* in Table 5, and *T. murphyi* in Table 6. The mean weighted CVs for *T. novaezelandiae* (15%), *T. declivis* (14%), and *T. murphyi* (20%) were all well below the target value of 30%. The estimated distributions are plotted in Figure 5. The catch of *T. novaezelandiae* was dominated by 3–7 year old fish, with very few fish older than 19 years. The catch of *T. declivis* had abundant fish aged 2–7 years old, but with a relatively strong drop-off in fish older than 14 years. The catch of *T. murphyi* was dominated by 18–23 year old fish, with very few fish younger than 16 or older than 26 years.

Table 4: Calculated numbers-at-age, separately by sex, with CVs, for *Trachurus novaezelandiae* caught during commercial trawl operations in JMA 7 during the 2016–17 fishing year. Summary statistics for the sample are also presented. –, no data.

Age (years)	Male	CV	Female	CV	Total	CV
1	8 429	1.305	6 551	1.137	14 980	1.064
2	379 011	0.457	111 567	0.631	490 578	0.415
3	1 274 571	0.228	1 548 531	0.196	2 823 102	0.190
4	794 102	0.238	705 103	0.225	1 499 205	0.170
5	1 882 582	0.119	1 428 375	0.141	3 310 956	0.092
6	1 516 784	0.137	1 636 193	0.121	3 152 978	0.093
7	1 355 700	0.116	1 132 252	0.139	2 487 952	0.092
8	118 171	0.441	222 416	0.350	340 587	0.268
9	417 307	0.191	273 247	0.289	690 555	0.157
10	495 448	0.203	517 136	0.221	1 012 584	0.153
11	283 861	0.250	260 057	0.300	543 918	0.191
12	73 440	0.472	80 367	0.589	153 807	0.374
13	133 955	0.327	304 650	0.263	438 603	0.206
14	84 364	0.415	16 527	0.856	100 890	0.378
15	288 414	0.240	236 877	0.292	525 291	0.184
16	175 984	0.291	161 496	0.373	337 481	0.238
17	130 519	0.324	170 139	0.352	300 658	0.244
18	104 374	0.299	57 874	0.635	162 249	0.294
19	61 746	0.393	40 954	0.662	102 700	0.349
20	6 288	0.806	7 975	0.795	14 263	0.581
21	0	–	2 424	1.016	2 424	1.016
22	20 929	0.550	0	–	20 929	0.550
No. measured		9 047		8 838		17 885
No. aged		243		225		468
No. of tows sampled						235
Mean weighted CV (%)		19.8		20.7		15.3

Table 5: Calculated numbers-at-age, separately by sex, with CVs, for *Trachurus declivis* caught during commercial trawl operations in JMA 7 during the 2016–17 fishing year. Summary statistics for the sample are also presented. –, no data.

Age (years)	Male	CV	Female	CV	Total	CV
0	23 297	0.852	11 171	0.961	34 467	0.756
1	647 781	0.326	440 203	0.433	1 087 984	0.341
2	1 161 639	0.228	1 135 538	0.191	2 297 177	0.157
3	2 844 573	0.148	1 778 253	0.156	4 622 826	0.119
4	1 552 988	0.159	1 607 117	0.155	3 160 106	0.117
5	2 041 800	0.112	2 268 780	0.107	4 310 581	0.083
6	1 948 868	0.110	1 652 689	0.119	3 601 556	0.080
7	1 481 276	0.131	1 365 676	0.132	2 846 952	0.095
8	389 017	0.265	746 895	0.189	1 135 912	0.161
9	429 027	0.235	410 020	0.291	839 047	0.184
10	376 470	0.237	414 245	0.272	790 715	0.182
11	419 194	0.235	457 570	0.240	876 764	0.173
12	173 516	0.392	320 063	0.282	493 578	0.223
13	251 610	0.298	162 453	0.409	414 063	0.244
14	341 034	0.247	264 692	0.347	605 725	0.200
15	208 932	0.339	173 336	0.399	382 268	0.260
16	107 218	0.454	142 326	0.444	249 544	0.328
17	70 898	0.561	183 281	0.335	254 179	0.282
18	121 236	0.491	142 984	0.431	264 220	0.324
19	139 510	0.429	36 734	0.731	176 244	0.373
20	56 947	0.579	192 769	0.401	249 718	0.329
21	57 220	0.623	179 952	0.415	237 172	0.355
No. measured		13 132		12 439		25 571
No. aged		326		2286		612
No. of tows sampled						335
Mean weighted CV (%)		18.6		19.4		14.3

Table 6: Calculated numbers-at-age, separately by sex, with CVs, for *Trachurus murphyi* caught during commercial trawl operations in JMA 7 during the 2016–17 fishing year. Summary statistics for the sample are also presented. –, no data.

Age (years)	Male	CV	Female	CV	Total	CV
3	826	1.366	834	2.243	1 660	1.316
4	310	1.866	0	–	310	1.866
5	0	–	0	–	0	–
6	1 778	1.417	1 152	1.578	2 930	1.096
7	0	–	0	–	0	–
8	0	–	0	–	0	–
9	0	–	0	–	0	–
10	0	–	0	–	0	–
11	0	–	0	–	0	–
12	0	–	2 847	1.057	2 847	1.057
13	0	–	1 152	1.259	1 152	1.259
14	2 385	1.096	3 019	0.951	5 404	0.722
15	2 773	1.136	1 972	1.243	4 745	0.850
16	11 548	0.667	7 232	0.695	18 780	0.495
17	17 106	0.508	17 996	0.458	35 102	0.350
18	47 913	0.280	52 662	0.266	100 576	0.187
19	87 927	0.184	81 883	0.203	169 810	0.136
20	123 739	0.173	124 268	0.158	248 006	0.098
21	107 622	0.194	101 924	0.202	209 546	0.122
22	60 236	0.263	45 364	0.271	105 600	0.180
23	49 077	0.294	26 765	0.336	75 842	0.225
24	11 817	0.578	18 739	0.415	30 556	0.332
25	8 831	0.693	12 950	0.534	21 782	0.434
26	3 545	1.309	17 273	0.557	20 818	0.502
27	2 990	0.851	5 781	0.675	8 772	0.528
28	2 994	0.839	3 368	1.138	6 362	0.700
29	0	–	3 368	1.109	3 368	1.109
30	0	–	0	–	0	–
31	1 467	1.190	6 387	0.711	7 854	0.604
No. measured		352		356		708
No. aged		187		192		379
No. of tows sampled						132
Mean weighted CV (%)		28.1		30.1		20.1

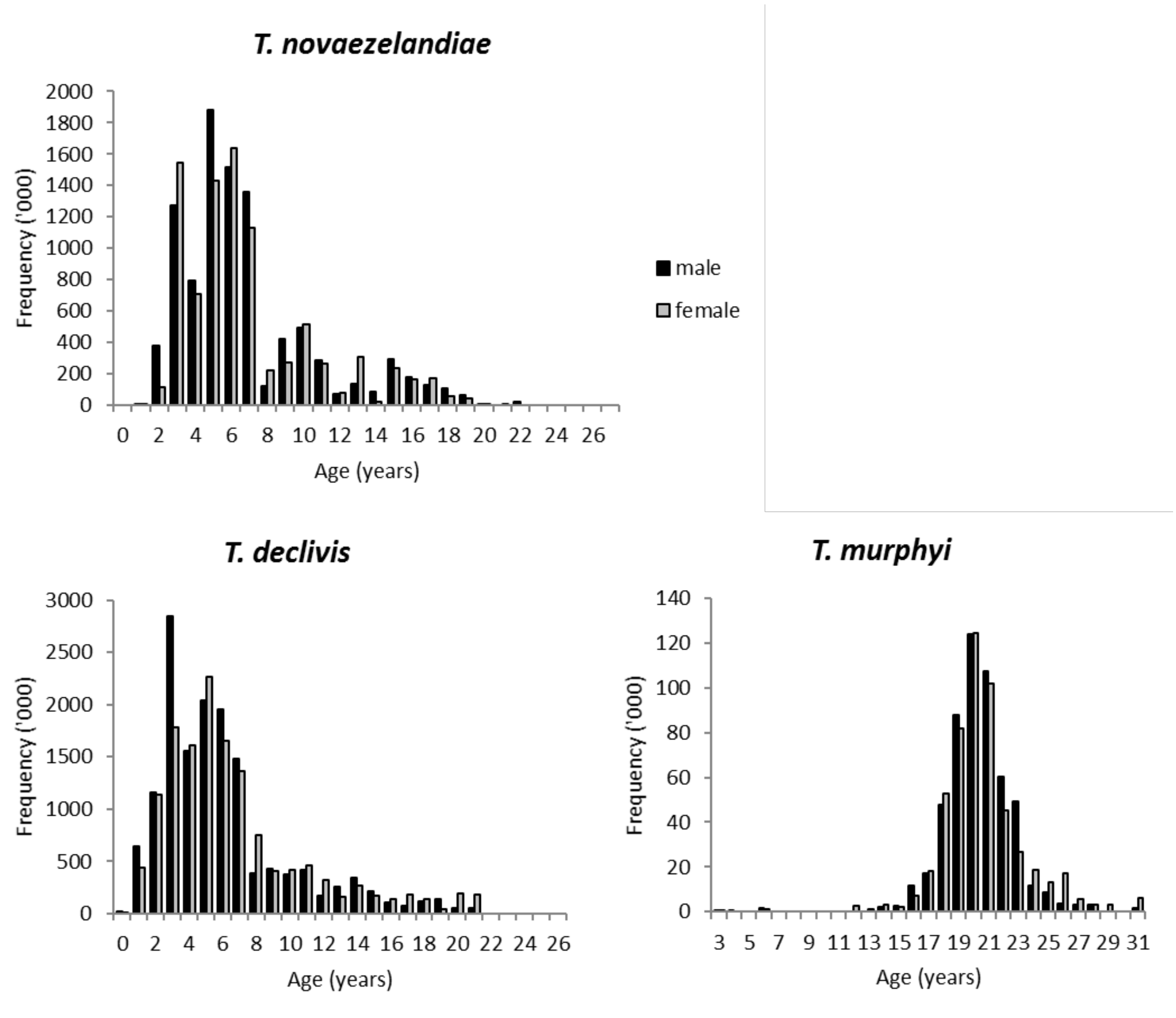

Figure 5: Estimated commercial catch-at-age distributions, by species and sex, from JMA 7 in 2016–17.

3.6 Data summaries

Catch-at-length and catch-at-age data from the JMA 7 fishery are available from eleven consecutive years since 2006–07. Mean weighted CVs for the length and age distributions, by sex and year, are listed for each species in Table 7. The CVs for the total age distributions met or exceeded the target of 30% for all species in all years, except for *Trachurus murphyi* in 2006–07.

Total (i.e., sexes combined) scaled length and age distributions, by species and fishing year are shown in Figures 6–8. The data used to produce these catch-at-age distributions are listed in Appendix B.

Table 7: Mean weighted CVs (mwCV) for catch-at-age and catch-at-length distributions, by species, sex, and fishing year.

		Catch-at-age mwCV (%)			Catch-at-length mwCV (%)		
Species	Fishing year	Males	Females	Total	Males	Females	Total
T. novaezelandiae	2006–07	26	24	19	17	16	14
	2007–08	27	25	22	17	12	13
	2008–09	39	39	30	14	11	11
	2009–10	32	27	23	16	15	12
	2010–11	28	24	20	20	16	15
	2011–12	23	21	16	17	16	14
	2012–13	24	25	19	19	17	16
	2013–14	19	19	14	15	13	12
	2014–15	21	19	15	14	11	10
	2015–16	26	25	19	12	11	10
	2016–17	20	21	15	16	14	13
T. declivis	2006–07	31	38	25	12	12	9
	2007–08	26	34	24	13	13	12
	2008–09	34	40	27	11	10	9
	2009–10	25	28	20	13	12	10
	2010–11	25	23	18	12	11	9
	2011–12	21	20	16	15	15	13
	2012–13	22	22	17	17	16	14
	2013–14	20	21	15	16	14	13
	2014–15	22	21	16	17	15	14
	2015–16	27	24	20	19	15	15
	2016–17	19	19	14	15	14	12
T. murphyi	2006–07	41	57	38	37	37	31
	2007–08	34	48	30	17	21	14
	2008–09	35	48	30	20	21	15
	2009–10	35	47	30	27	28	23
	2010–11	31	36	23	28	28	21
	2011–12	26	30	20	20	22	16
	2012–13	26	35	21	30	33	24
	2013–14	27	33	21	26	26	18
	2014–15	24	28	19	19	19	14
	2015–16	25	27	19	22	18	15
	2016–17	28	30	20	33	29	23

Trachurus novaezelandiae

Scaled catch-at-length frequencies by fishing year are shown in Figure 6. They had single strong modes at 28–32 cm in all distributions except 2009–10, 2012–13, and 2016–17 when there were second modes at 24, 20 and 22 cm respectively. Most variation in abundance occurred with the fish shorter than 25 cm, presumably relating to the relative strengths of juvenile year classes. Scaled catch-at-age frequencies by fishing year, varied between years (Figure 6). However, some possible year class progressions can be postulated. The 1+ year class was strong in 2007–08, and maintained a relatively high abundance in all subsequent years. The 2+ year class in 2011–12 was also relatively strong, and it progressed as the dominant year class in the subsequent three years, but was not particularly strong in 2015–16 or 2016–17. Year classes 4, 5, and 6 in 2006–07 also appeared to be relatively strong throughout the series, although there were some inconsistencies e.g., year classes 7 in 2009–10 and 10 in 2011–12 were weak.

Trachurus declivis

Scaled catch-at-length frequencies by fishing year are shown in Figure 7 with most of the fish 16–50 cm. There was a strong mode at 42–44 cm in all years except 2016–17 where the strongest mode was at 39–41 cm. There were lesser modes for smaller fish in the distributions for some years, e.g., 30 cm in 2012–

13 and 2016–17. Most variation in abundance occurred with the fish shorter than 37 cm, presumably related to the relative strengths of juvenile year classes. Scaled catch-at-age-frequencies by fishing year, are shown in Figure 7. There was a wide range of ages in the catches, and the distributions varied between years. There was evidence of two relatively strong year classes aged 1+ and 2+ years in 2007–08 that maintained a relatively high abundance up to 2011–12, but were relatively weak from 2012–13. The 2011–12 1+ and 3+ year classes appeared to be relatively strong, and both were still strong as 5+ and 7+ in 2015–16, but not obvious in 2016–17.

Trachurus murphyi

Scaled catch-at-length frequencies by fishing year, are shown in Figure 8. All the distributions were unimodal at 49–51 cm (except for the 2013–14 distribution which had a broad mode from 46–51 cm), and were generally similar with few fish smaller than 45 cm. Scaled catch-at-age frequencies by fishing year (Figure 8) exhibited a wide range of ages although few fish younger than 10 years were recorded in any year. There was evidence of relatively strong year classes at ages 11 and 12 years in 2006–07 that progressed to ages 16 and 17 in 2011–12. Since about 2012–13, the older of these two years classes had lost much of its dominance. Fish aged 19 years old dominated the 2015–16 distribution, and were still dominant at age 20 in 2016–17. This year class was relatively strong since 2011–12 (when it was age 15), but also contributed quite substantially to the catch throughout the entire time series.

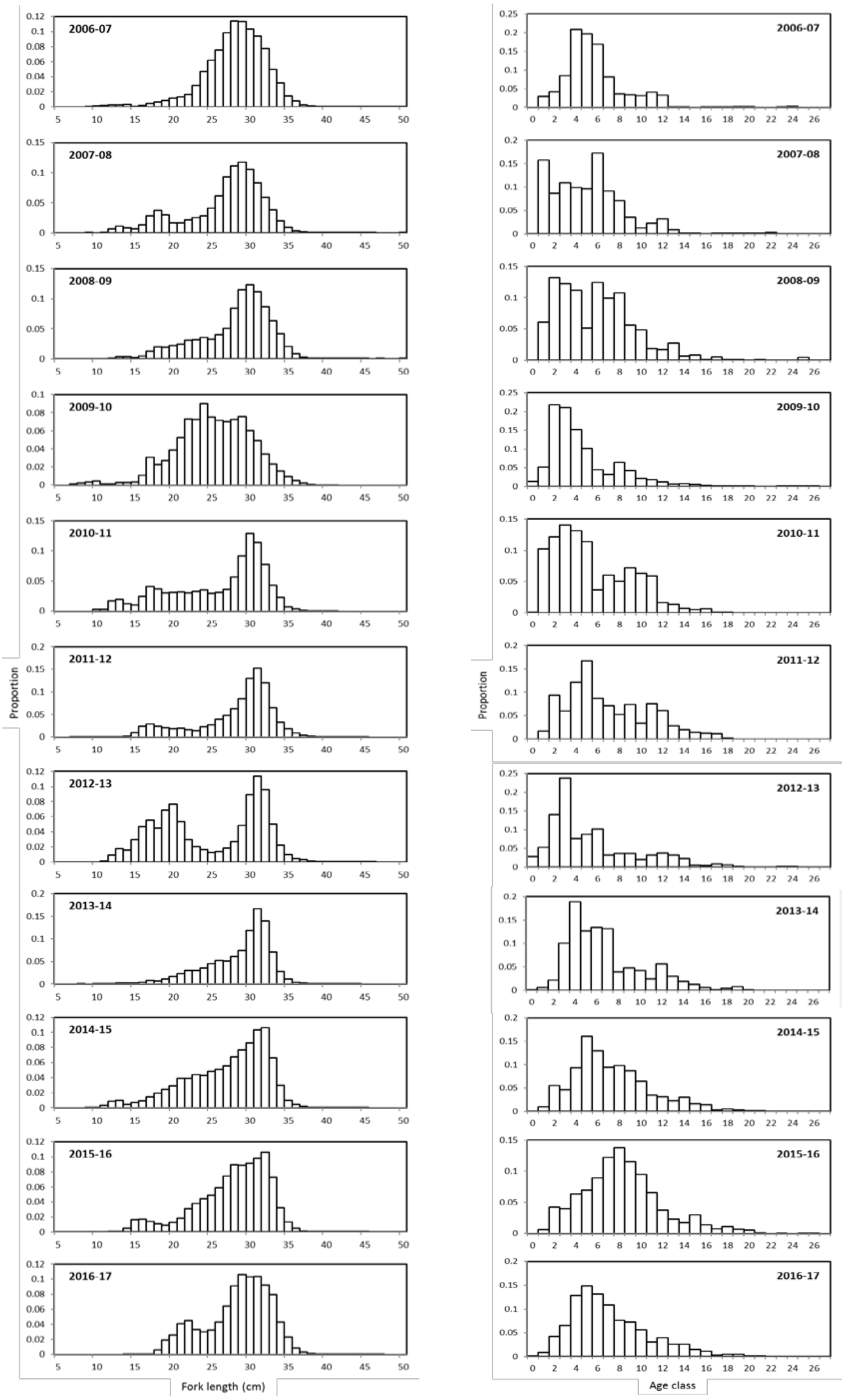

Figure 6: Scaled catch-at-length (left panel) and catch-at-age (right panel, age class in years) proportions for the catch of *Trachurus novaezelandiae* sampled from the 2006–07 to 2016–17 fishing years.

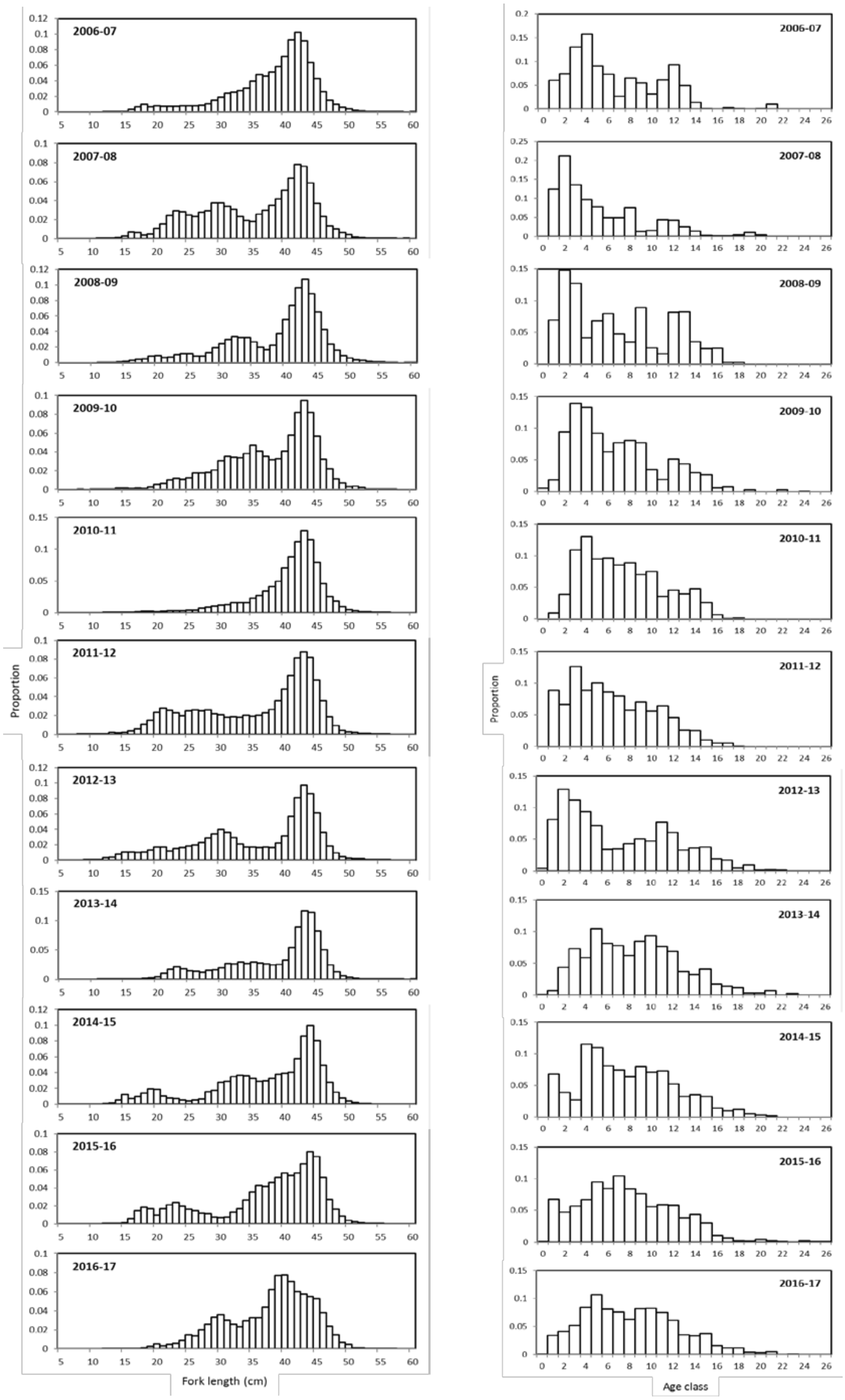

Figure 7: Scaled catch-at-length (left panel) and catch-at-age (right panel, age in years) proportions for the catch of *Trachurus declivis* sampled from the 2006–07 to 2016–17 fishing years.

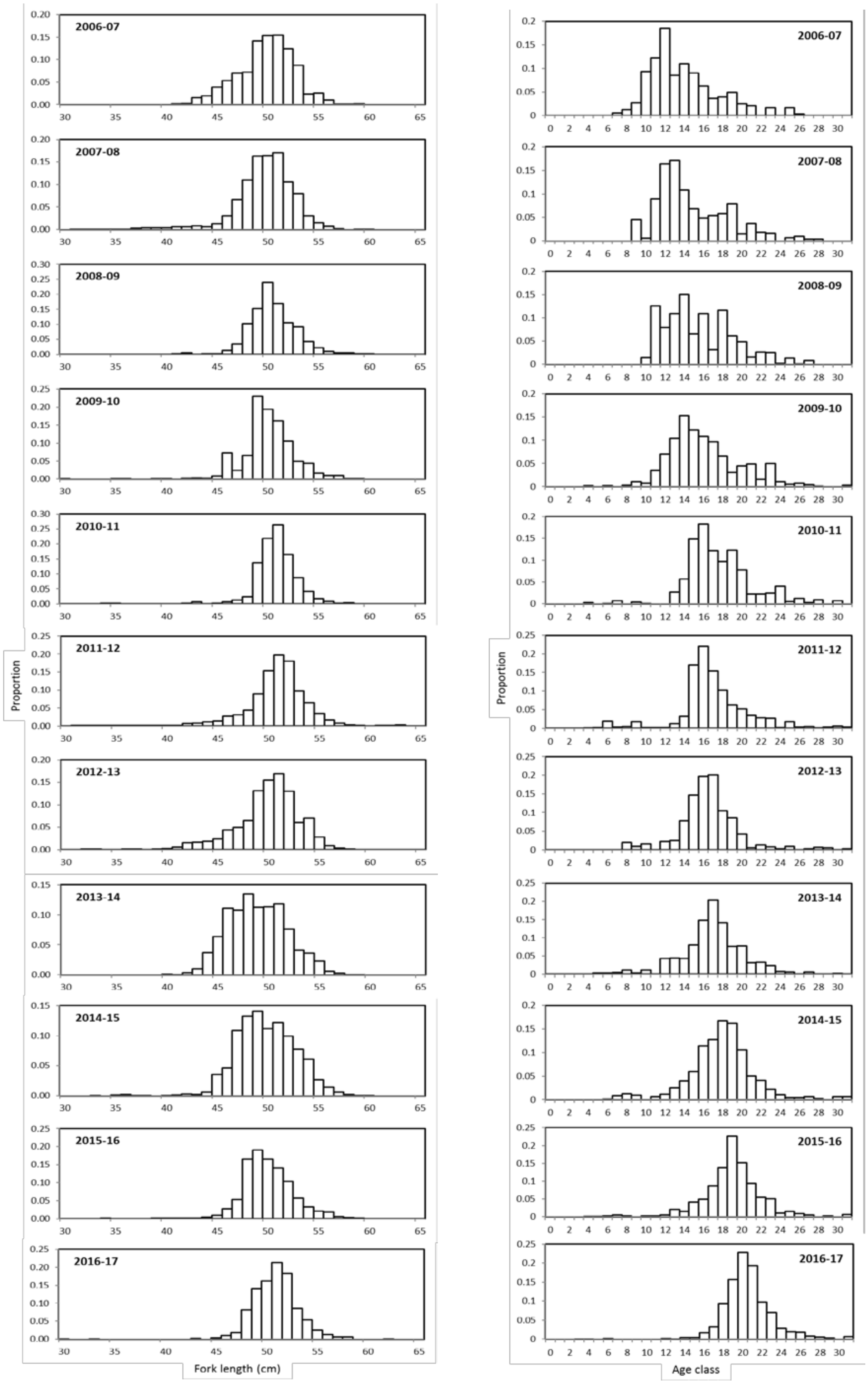

Figure 8: Scaled catch-at-length (left panel) and catch-at-age (right panel, age in years) proportions for the catch of *Trachurus murphyi* sampled from the 2006–07 to 2016–17 fishing years.

4. DISCUSSION

The 2016–17 jack mackerel trawl fishery was comprehensively sampled (as it was in all years since at least 2006–07). Sampling intensity was high overall, and at least 58% of the catch was sampled in all months that produced substantial landings. Spatially, there was very good coverage of catch in the heavily fished Statistical Areas (034–037, 040–041). Estimates of the 2016–17 catch-at-age for all three jack mackerel species had mean weighted CVs over all age classes of 20% or less, well below the target of 30%.

The distribution of the 2016–17 catch was slightly different to recent previous years; the proportion of the catch from Statistical Area 034 was much higher, and that from Area 042 was much lower. This may have been a consequence of a southerly shift in mackerel concentrations, or a change in fishing practice, or a combination of both. Forty large mackerel catches (i.e., 20–70 t per tow) from Area 034 were taken by midwater trawl in July–August, and jack mackerel was declared to be the target species on almost every occasion. Target fishing of this intensity had not been recorded previously in this area (and large by-catches were also rare), so it appears likely that advantage was being taken of unusual aggregations of mackerel in that area.

Although sampling intensity was high, there was clearly an issue (also apparent in previous years) of some misidentification of the different jack mackerel species. When the raw age data were plotted against length, 2% of the aged *T. declivis* appeared as outliers that fitted well on the growth curve for *T. novaezelandiae*, and 14% of aged *T. novaezelandiae* were outliers that fitted well on the *T. declivis* growth curve (although half of the *T. novaezelandiae* outliers were from three sampled tows from a single trip). Such misidentifications are particularly apparent for the older and larger fish of both these species (for which the growth curves are clearly divergent), but less so for smaller and younger fish because the length-at-age ranges of both species overlapped substantially for fish aged 4 years or less. So the actual misidentification percentages of *T. declivis* and *T. novaezelandiae* are likely to be higher than the values noted above. It was also possible that some misidentification occurred between *T. declivis* and *T. murphyi*, but because the length-at-age ranges for these species overlapped substantially it was difficult to estimate any percentages.

Estimates of species proportions indicated a consistent predominance of *T. declivis* at 61–71% of total catch weight in the eleven fishing years from which data were available. The percentage of *T. novaezelandiae* was also consistent temporally at 24–33%. The predominance of *T. declivis* overall is expected given that this species generally occurs deeper and further offshore than *T. novaezelandiae* and because most of the vessels targeting jack mackerels are restricted to fishing at least 12 n. miles, and often 25 n. miles off the coast. The lowest proportion of *T. declivis* and highest proportion of *T. novaezelandiae* in the time series were reported in 2014–15. This probably relates to relatively low catches in the autumn–winter fishery, which is usually strongly dominated by landings of *T. declivis* off the west coast of South Island.

Most of the *T. declivis* catch in all years comprised adult fish at least 37 cm long. Differences between years in the length distributions were primarily in the abundance of fish shorter than 37 cm, and was a consequence of variation in year class strengths. The position of the mode of large *T. declivis* in JMA 7 (centred on 42–44 cm in most years) differed to the mode in JMA 3 (centred on 48 cm), and Horn et al. (2014a) proposed that this was a consequence of large *T. declivis* migrating south out of the JMA 7 area. The 2016–17 fishing year was the first in the series where the strongest *T. declivis* length mode (at 39–41 cm) was outside the 42–44 cm range. Fish of 39–41 cm were dominant in all sample strata both early and late in the fishing year, except for stratum 5 (primarily the South Taranaki Bight) in the early fishery where 43–46 cm fish were slightly more dominant. A length of 40 cm is close to the median expected for 5–7 year old fish, and these are a group of relatively strong cohorts that have progressed through the catch-at-age distributions since 2011–12. It appears likely that these age classes may now be collectively more dominant in the population than the combined older adult ages classes (i.e., 10 years and older) that previously made up much of the 42–44 cm length-frequency mode.

The mean age of *T. murphyi* in the catch generally increased over the eleven sampled years. In 2006–07, most fish were 10–15 years old, compared with 15–20 years old in 2010–11 and 2011–12. This is indicative of a strong recruitment pulse, comprising several year classes, possibly as a result of immigration from international waters. These year classes are now growing through, with no evidence of any substantial new immigration or recruitment through spawning success. The age distribution in 2016–17 comprised fish mainly 18–23 years old, but the age distribution mode continued its shift to the right supporting the hypothesis of a single migration pulse. This modal shift in the age distributions has occurred despite the 2013–14, 2014–15 and 2015–16 length distributions having relatively more smaller fish (i.e. 45–48 cm) than in other sampled years. It appears likely that some of the older dominant year classes that initially recruited to New Zealand waters are now dying off and becoming much less dominant in the catch (e.g., the relatively abundant 14 year old fish in 2006–07 are now negligible in the most recent year's catch as 24 year olds). The data on sex of *T. murphyi* collected over years 2006–07 to 2013–14 indicated a population consistently biased towards males (i.e., 54–62% of sampled fish, average 57.3%). The three most recent years of sampling, however, have produced ratios closer to 50:50. *T. murphyi* can, at times, be quite difficult to sex (author's unpublished data), with deposits of fat in the body cavity often appearing like male gonads when the gonads are in a regressed state. However, in four research surveys conducted on the Stewart-Snares shelf in February each year from 1993 to 1996 males were also dominant, comprising 62–71% of the sexed fish (Hurst & Bagley 1997).

The *T. novaezelandiae* catch also had a consistent strong adult length mode (at 28–32 cm) in all sampled years, although in 2009–10 the relative abundance of 2–4 year old fish (i.e., lengths of about 20–27 cm) outweighed the adult mode. The progression of some relatively strong year classes through the time series is apparent. Taylor (2008) noted that there was a preference in the JMA 7 trawl fishery for larger jack mackerel (i.e., *T. declivis*). Vessels attempting to maximise their catch of *T. declivis* may consequently not comprehensively sample the *T. novaezelandiae* population in the area, which would result in a greater degree of between-year variation in the *T. novaezelandiae* length and age distributions. It is pleasing, therefore, that year class progressions are still apparent for *T. novaezelandiae* under this sampling regime.

Estimates of instantaneous total mortality (Z) for *T. novaezelandiae* and *T. declivis* from commercial trawl fishery samples in JMA 7 in 1989–1991 were 0.22–0.23 yr^{-1} for both species (Horn 1993). Re-estimates of Z for JMA 7 using data from 2007–2013 (Horn et al. 2014b) produced values slightly higher for *T. novaezelandiae* (0.30) and lower for *T. declivis* (0.2). The general similarity of Z estimates from the same fishery but separated by about 20 years, and the conclusion that Z is close to or slightly higher than the likely value of M (estimated by Horn (1993) to be 0.18 yr^{-1} for both species), suggested that *T. novaezelandiae* and *T. declivis* in JMA 7 are not over-exploited. The Z estimates were not updated in the current work.

A comparison of the age distributions for *T. novaezelandiae* and *T. declivis* shows that the numbers of older fish in the distributions for both species has not changed consistently or noticeably over the eleven years of sampling. This further supports the hypothesis that these species in JMA 7 are not over-exploited.

5. ACKNOWLEDGMENTS

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Appendix A: Proportions-at-age by species and fishing year

This appendix lists the estimated proportions-at-age in the JMA 7 trawl fishery, by species and fishing year. The columns in each table are headed so that, for example, the year 2016 refers to the 2015–16 fishing year. Data are presented with sexes combined, in a format that can easily be converted to a CASAL input file in a single-sex model.

Table A1a: Proportions-at-age (male, female, and unsexed combined) for *T. novaezelandiae*, by fishing year.

											Proportion
Age (Yr)	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
0	0	0	0	0.0127	0.0007	0	0.0284	0.0001	0	0	0
1	0.0294	0.1574	0.0605	0.0510	0.1021	0.0168	0.0531	0.0056	0.0095	0.0058	0.0008
2	0.0422	0.0871	0.1319	0.2183	0.1216	0.0934	0.1399	0.0216	0.0548	0.0425	0.0265
3	0.0846	0.1091	0.1225	0.2108	0.1408	0.0598	0.2380	0.1004	0.0456	0.0394	0.1524
4	0.2088	0.0985	0.1116	0.1517	0.1312	0.1210	0.0765	0.1890	0.0932	0.0634	0.0809
5	0.1970	0.0959	0.0509	0.1020	0.1137	0.1668	0.0875	0.1268	0.1608	0.0699	0.1787
6	0.1693	0.1727	0.1244	0.0443	0.0367	0.0868	0.1012	0.1342	0.1301	0.0894	0.1702
7	0.0819	0.0911	0.0992	0.0319	0.0604	0.0712	0.0320	0.1314	0.0946	0.1221	0.1343
8	0.0358	0.0712	0.1079	0.0639	0.0503	0.0523	0.0360	0.0388	0.0981	0.1376	0.0184
9	0.0334	0.0357	0.0557	0.0426	0.0722	0.0739	0.0370	0.0478	0.0874	0.1154	0.0373
10	0.0316	0.0121	0.0485	0.0206	0.0631	0.0334	0.0199	0.0424	0.0643	0.0949	0.0547
11	0.0404	0.0220	0.0180	0.0181	0.0586	0.0757	0.0321	0.0243	0.0345	0.0654	0.0294
12	0.0324	0.0321	0.0167	0.0115	0.0160	0.0609	0.0379	0.0564	0.0306	0.0374	0.0083
13	0.0010	0.0080	0.0270	0.0058	0.0131	0.0277	0.0323	0.0303	0.0226	0.0226	0.0237
14	0.0012	0.0006	0.0062	0.0066	0.0071	0.0200	0.0224	0.0189	0.0301	0.0174	0.0054
15	0	0.0002	0.0081	0.0046	0.0051	0.0143	0.0053	0.0123	0.0163	0.0299	0.0284
16	0.0004	0	0.0003	0.0027	0.0067	0.0127	0.0038	0.0060	0.0142	0.0136	0.0182
17	0.0008	0.0012	0.0048	0.0005	0.0006	0.0110	0.0087	0.0015	0.0035	0.0073	0.0162
18	0.0006	0.0004	0.0004	0.0001	0.0001	0.0024	0.0062	0.0038	0.0053	0.0112	0.0088
19	0.0026	0.0011	0.0003	0.0001	0	0	0.0011	0.0077	0.0034	0.0072	0.0055
20	0.0025	0.0003	0	0.0000	0	0	0	0.0008	0.0003	0.0051	0.0008
21	0	0.0003	0.0009	0	0	0	0	0	0.0008	0.0010	0.0001
22	0	0.0029	0	0	0	0	0	0	0	0	0.0011
23	0.0010	0	0	0.0000	0	0	0.0005	0	0	0.0005	0
24	0.0034	0	0	0.0001	0	0	0.0002	0	0	0	0
25	0	0	0.0042	0.0000	0	0	0	0	0	0.0003	0
26	0	0	0	0.0002	0	0	0	0	0	0.0006	0

Table A1b: CVs for proportions-at-age (male, female, and unsexed combined) for *T. novaezelandiae*, by fishing year.

											CV
Age (yr)	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
0				0.913	2.006		0.524	1.709			
1	0.419	0.416	0.327	0.389	0.378	0.487	0.463	0.516	0.545	0.857	1.064
2	0.349	0.138	0.162	0.213	0.249	0.209	0.244	0.349	0.333	0.500	0.415
3	0.224	0.144	0.188	0.186	0.185	0.219	0.151	0.201	0.249	0.364	0.190
4	0.124	0.171	0.309	0.172	0.114	0.109	0.179	0.117	0.158	0.219	0.170
5	0.106	0.176	0.399	0.209	0.124	0.097	0.101	0.108	0.100	0.195	0.092
6	0.126	0.131	0.277	0.281	0.228	0.133	0.089	0.083	0.096	0.154	0.093
7	0.193	0.203	0.330	0.227	0.193	0.176	0.183	0.093	0.109	0.119	0.092
8	0.276	0.216	0.293	0.211	0.189	0.187	0.172	0.167	0.113	0.104	0.268
9	0.301	0.243	0.314	0.204	0.141	0.157	0.159	0.163	0.108	0.123	0.157
10	0.319	0.463	0.356	0.230	0.160	0.252	0.226	0.174	0.115	0.134	0.153
11	0.281	0.328	0.459	0.274	0.170	0.145	0.163	0.247	0.172	0.142	0.191
12	0.311	0.302	0.518	0.252	0.328	0.166	0.144	0.147	0.175	0.206	0.374
13	1.040	0.341	0.313	0.327	0.316	0.222	0.165	0.163	0.197	0.242	0.206
14	0.944	1.193	0.454	0.367	0.429	0.272	0.179	0.199	0.173	0.281	0.378
15		1.358	0.655	0.336	0.392	0.305	0.358	0.232	0.232	0.212	0.184
16	1.203		1.060	0.494	0.451	0.311	0.458	0.275	0.248	0.315	0.238
17	0.643	1.028	1.002	0.594	1.160	0.374	0.280	0.512	0.453	0.409	0.244
18	0.864	1.021	1.251	2.105	1.712	0.565	0.317	0.385	0.401	0.348	0.294
19	0.671	0.949	0.884	1.916			0.769	0.287	0.547	0.419	0.349
20	0.898	0.895		1.253				0.673	0.606	0.510	0.581
21		0.835	0.769						0.812	0.606	1.016
22		0.572									0.550
23	1.022			1.134			0.835			0.697	
24	0.544			0.887			0.903				
25			0.518	2.166						1.043	
26				1.049						1.853	

Table A2a: Proportions-at-age (male, female, and unsexed combined) for *T. declivis*, by fishing year.

											Proportion
Age (yr)	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
0	0	0	0	0.0054	0	0	0.0041	0.0002	0	0.0009	0.0012
1	0.0605	0.1245	0.0693	0.0180	0.0092	0.0889	0.0813	0.0066	0.0680	0.0678	0.0376
2	0.0737	0.2125	0.1478	0.0942	0.0390	0.0659	0.1290	0.0437	0.0384	0.0474	0.0794
3	0.1307	0.1357	0.1273	0.1387	0.1091	0.1261	0.1118	0.0729	0.0272	0.0565	0.1598
4	0.1574	0.0972	0.0416	0.1327	0.1301	0.0886	0.0933	0.0589	0.1152	0.0670	0.1092
5	0.0907	0.0784	0.0678	0.0923	0.0949	0.1004	0.0718	0.1042	0.1095	0.0952	0.1490
6	0.0728	0.0492	0.0798	0.0629	0.0963	0.0859	0.0341	0.0816	0.0810	0.0845	0.1245
7	0.0270	0.0491	0.0475	0.0767	0.0851	0.0796	0.0351	0.0779	0.0744	0.1046	0.0984
8	0.0654	0.0755	0.0343	0.0801	0.0883	0.0575	0.0429	0.0623	0.0639	0.0843	0.0393
9	0.0549	0.0131	0.0894	0.0768	0.0701	0.0700	0.0503	0.0845	0.0796	0.0765	0.0290
10	0.0315	0.0154	0.0257	0.0345	0.0750	0.0556	0.0469	0.0936	0.0705	0.0563	0.0273
11	0.0618	0.0443	0.0160	0.0192	0.0354	0.0642	0.0771	0.0768	0.0728	0.0588	0.0303
12	0.0934	0.0422	0.0819	0.0507	0.0458	0.0454	0.0605	0.0689	0.0522	0.0582	0.0171
13	0.0496	0.0260	0.0823	0.0435	0.0391	0.0256	0.0330	0.0367	0.0325	0.0381	0.0143
14	0.0137	0.0138	0.0352	0.0299	0.0478	0.0254	0.0363	0.0325	0.0355	0.0440	0.0209
15	0.0015	0.0024	0.0240	0.0264	0.0256	0.0099	0.0372	0.0408	0.0328	0.0300	0.0132
16	0	0.0005	0.0251	0.0057	0.0068	0.0055	0.0193	0.0173	0.0142	0.0105	0.0086
17	0.0031	0.0017	0.0023	0.0075	0.0004	0.0051	0.0172	0.0138	0.0101	0.0064	0.0088
18	0.0013	0.0042	0.0028	0	0.0020	0.0005	0.0048	0.0115	0.0119	0.0018	0.0091
19	0	0.0104	0	0.0023	0	0	0.0094	0.0028	0.0053	0.0016	0.0061
20	0.0006	0.0038	0	0	0	0	0.0011	0.0031	0.0033	0.0044	0.0086
21	0.0104	0	0	0	0	0	0.0021	0.0072	0.0016	0.0018	0.0082
22	0	0	0	0.0023	0	0	0.0013	0	0	0.0001	0
23	0	0	0	0	0	0	0	0.0020	0	0	0
24	0	0	0	0.0003	0	0	0	0	0	0.0018	0
25	0	0	0	0	0	0	0	0	0	0.0006	0
26	0	0	0	0	0	0	0	0	0	0.0010	0

Table A2b: CVs for proportions-at-age (male, female, and unsexed combined) for *T. declivis*, by fishing year.

											CV
Age (yr)	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
0				0.428			0.793	1.197		1.410	0.756
1	0.220	0.175	0.170	0.326	0.355	0.267	0.238	0.441	0.298	0.532	0.341
2	0.172	0.145	0.134	0.207	0.191	0.229	0.199	0.409	0.257	0.406	0.157
3	0.141	0.119	0.144	0.141	0.134	0.162	0.161	0.222	0.255	0.309	0.119
4	0.118	0.176	0.311	0.130	0.113	0.182	0.161	0.191	0.141	0.207	0.117
5	0.244	0.227	0.299	0.160	0.143	0.115	0.153	0.129	0.142	0.140	0.083
6	0.303	0.325	0.322	0.190	0.153	0.114	0.170	0.114	0.131	0.140	0.080
7	0.503	0.256	0.385	0.168	0.169	0.117	0.149	0.136	0.127	0.104	0.095
8	0.310	0.371	0.437	0.186	0.175	0.140	0.135	0.123	0.121	0.116	0.161
9	0.309	0.503	0.260	0.177	0.176	0.124	0.125	0.099	0.105	0.110	0.184
10	0.486	0.482	0.463	0.300	0.184	0.137	0.140	0.093	0.112	0.128	0.182
11	0.272	0.329	0.635	0.367	0.230	0.127	0.099	0.108	0.110	0.142	0.173
12	0.254	0.301	0.286	0.214	0.216	0.158	0.113	0.111	0.139	0.138	0.223
13	0.363	0.454	0.281	0.236	0.237	0.208	0.149	0.142	0.169	0.170	0.244
14	0.537	0.456	0.476	0.268	0.209	0.183	0.143	0.146	0.172	0.152	0.200
15	0.858	0.912	0.400	0.273	0.295	0.339	0.149	0.138	0.179	0.210	0.260
16		0.686	0.335	0.469	0.545	0.472	0.211	0.221	0.259	0.310	0.328
17	0.973	0.966	0.581	0.647	1.049	0.438	0.243	0.230	0.290	0.344	0.282
18	1.050	0.395	0.633		1.091	0.690	0.399	0.254	0.310	0.531	0.324
19		0.762		1.020			0.292	0.456	0.450	0.640	0.373
20	1.101	0.975					0.868	0.409	0.559	0.451	0.329
21	0.430						0.701	0.335	0.889	0.724	0.355
22				0.963			0.801			1.178	
23								0.624			
24				1.254						0.725	
25										0.925	
26										0.862	

Table A3a: Proportions-at-age (male, female, and unsexed combined) for *T. murphyi*, by fishing year.

											Proportion
Age (yr)	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
4	0	0	0	0.0020	0.0026	0.0018	0	0	0	0.0013	0.0003
5	0	0	0	0	0	0.0021	0	0.0039	0	0.0014	0
6	0	0	0	0.0021	0.0005	0.0193	0	0.0028	0.0012	0.0016	0.0027
7	0.0055	0	0	0	0.0073	0.0044	0	0.0049	0.0076	0.0046	0
8	0.0126	0	0	0.0026	0	0.0059	0.0201	0.0107	0.0119	0.0025	0
9	0.0272	0.0458	0	0.0105	0.0036	0.0180	0.0086	0.0028	0.0094	0	0
10	0.0935	0.0053	0.0144	0.0071	0.0012	0.0030	0.0157	0.0111	0	0.0022	0
11	0.1216	0.0895	0.1258	0.0350	0	0.0030	0	0	0.0064	0.0024	0
12	0.1857	0.1634	0.0784	0.0692	0	0.0021	0.0219	0.0431	0.0115	0.0048	0.0026
13	0.0847	0.1708	0.1092	0.1040	0.0273	0.0128	0.0252	0.0448	0.0250	0.0212	0.0011
14	0.1092	0.1083	0.1499	0.1530	0.0567	0.0320	0.0779	0.0432	0.0401	0.0159	0.0050
15	0.0900	0.0687	0.0657	0.1227	0.1488	0.1694	0.1466	0.0802	0.0595	0.0418	0.0044
16	0.0628	0.0484	0.1092	0.1080	0.1823	0.2194	0.1972	0.1479	0.1133	0.0489	0.0174
17	0.0363	0.0538	0.0305	0.0965	0.1224	0.1544	0.2004	0.2028	0.1276	0.0868	0.0324
18	0.0395	0.0580	0.1163	0.0658	0.0962	0.1019	0.1044	0.1405	0.1678	0.1388	0.0930
19	0.0489	0.0783	0.0606	0.0308	0.1227	0.0633	0.0860	0.0766	0.1621	0.2259	0.1570
20	0.0244	0.0154	0.0486	0.0450	0.0784	0.0514	0.0417	0.0769	0.1055	0.1520	0.2292
21	0.0211	0.0364	0.0159	0.0492	0.0233	0.0349	0.0055	0.0314	0.0502	0.0935	0.1937
22	0	0.0180	0.0256	0.0151	0.0223	0.0288	0.0125	0.0324	0.0413	0.0546	0.0976
23	0.0168	0.0160	0.0251	0.0501	0.0255	0.0270	0.0076	0.0233	0.0214	0.0502	0.0701
24	0	0	0.0024	0.0103	0.0409	0.0030	0.0034	0.0068	0.0104	0.0106	0.0282
25	0.0168	0.0063	0.0138	0.0048	0.0051	0.0177	0.0092	0.0055	0.0040	0.0161	0.0201
26	0.0033	0.0097	0.0009	0.0076	0.0134	0.0041	0	0	0.0044	0.0094	0.0192
27	0	0.0041	0.0078	0.0046	0.0031	0.0047	0.0024	0.0060	0.0060	0.0048	0.0081
28	0	0.0039	0	0.0011	0.0092	0.0007	0.0063	0	0.0020	0	0.0059
29	0	0	0	0	0	0.0046	0.0049	0	0	0.0018	0.0031
30	0	0	0	0	0.0073	0.0066	0	0.0023	0.0059	0	0
31	0	0	0	0.0027	0	0.0039	0.0023	0	0.0057	0.0068	0.0073

Table A3b: CVs for the proportions-at-age for *T. murphyi*, by fishing year.

											CV
Age (yr)	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
4				2.236	1.146	1.047				1.313	1.866
5						0.747		0.766		1.457	
6				1.423	2.163	0.420		1.105	0.848	1.423	1.096
7	1.041				1.841	1.093		0.741	0.632	0.684	
8	0.625			1.481		0.891	0.710	0.519	0.452	1.021	
9	0.413	0.333		0.948	0.873	0.596	0.869	0.972	0.577		
10	0.335	0.594	0.615	0.803	1.888	1.225	0.714	0.531		1.479	
11	0.301	0.263	0.222	0.383		1.119			0.593	1.200	
12	0.201	0.190	0.304	0.584		1.043	0.499	0.237	0.445	0.761	1.057
13	0.282	0.172	0.241	0.178	0.363	0.511	0.432	0.261	0.338	0.346	1.259
14	0.231	0.248	0.208	0.233	0.235	0.322	0.231	0.252	0.245	0.378	0.722
15	0.300	0.323	0.318	0.271	0.144	0.119	0.142	0.184	0.188	0.243	0.850
16	0.410	0.309	0.235	0.192	0.130	0.102	0.111	0.145	0.133	0.219	0.495
17	0.514	0.318	0.299	0.178	0.174	0.119	0.107	0.113	0.133	0.152	0.350
18	0.476	0.380	0.243	0.222	0.183	0.165	0.145	0.142	0.110	0.120	0.187
19	0.639	0.306	0.334	0.304	0.155	0.182	0.164	0.183	0.109	0.095	0.136
20	0.722	0.521	0.371	0.235	0.228	0.198	0.245	0.192	0.128	0.119	0.098
21	0.647	0.436	0.821	0.269	0.374	0.231	0.664	0.313	0.201	0.160	0.122
22		0.770	0.406	0.433	0.392	0.267	0.479	0.312	0.220	0.183	0.180
23	1.119	0.755	0.541	0.273	0.340	0.298	0.487	0.368	0.301	0.215	0.225
24			0.778	0.576	0.295	0.831	0.894	0.643	0.431	0.469	0.332
25	1.093	1.019	0.854	0.655	0.763	0.336	0.532	0.607	0.720	0.353	0.434
26	1.247	1.032	1.217	0.564	0.543	0.788			0.679	0.498	0.502
27		0.980	0.643	0.791	1.018	0.673	0.915	0.688	0.644	0.600	0.528
28		0.933		1.060	0.630	1.301	0.816		1.069		0.700
29						0.780	0.785			0.988	1.109
30					0.836	0.645		0.997	0.610		
31				1.014		0.693	1.045		0.539	0.464	0.604