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Commercial catch sampling for species proportion, sex, length, and age of jack mackerels in JMA 7 in the 2017–18 fishing year, with a summary of all available data sets

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EXECUTIVE SUMMARY

Horn, P.L.; Ó Maolagáin, C.; Hulston, D. (2019). Commercial catch sampling for species proportion, sex, length, and age of jack mackerels in JMA 7 in 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 jack mackerels (*Trachurus novaezelandiae*, *T. declivis*, and *T. murphyi*) in JMA 7 (central west coast) during the 2017–18 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 88% of the 2017–18 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 2017–18 were similar to those from the eleven previous years. The age-frequency distributions for all species in 2017–18 had mean weighted CVs of 25% 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% (64% in 2017–18) in the JMA 7 TCEPR catch for all statistical areas and the twelve years of sampling, while *T. novaezelandiae* was 24–33% (30% in 2017–18) and *T. murphyi* was 3–8% (6% in 2017–18).

1. INTRODUCTION

Commercial catches of jack mackerels 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 fishstock 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 has been 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).

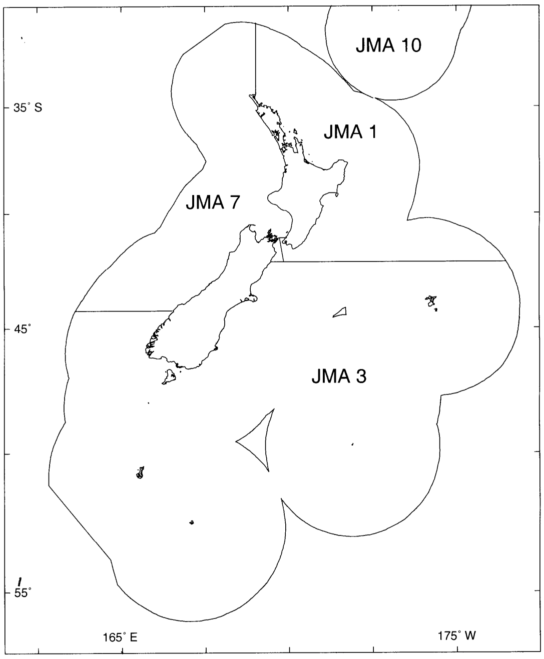

Figure 1: Jack mackerel administrative Fishstock areas.

This report provides estimates of relative proportions and catch-at-age for the three *Trachurus* species in the commercial JMA 7 catch for 2017–18 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, Horn et al. (2018) for 2015–16, and Horn & Ó Maolagáin (2018) for 2016–17. 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 for jack mackerels in objective 1 of Project MID201803 "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".

The JMA 7 age and size structure of the commercial catch was 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 2017–18 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 Fisheries New Zealand catch-effort database "warehou" (Extract #12239 on 22 February 2019) 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 2017–18.

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 2017–18 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 2017–18 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 distribution (constituting about 2% of that length frequency) were over-sampled. Target sample sizes were about 550 per species. Sets of five otoliths were embedded in blocks of clear epoxy resin and cured at 50°C. Once hardened, a 380 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. 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).

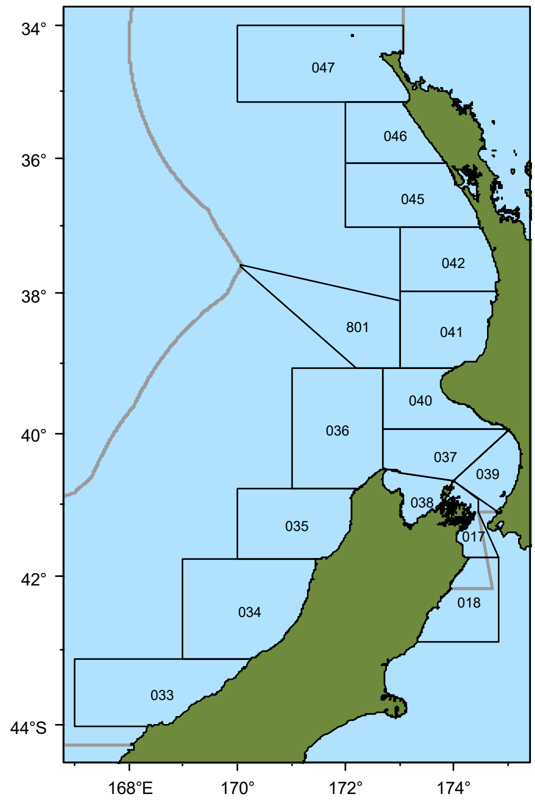

Figure 2: Statistical Areas referred to in the text.

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 2017–18 shows that there was a fishery from October to January concentrated in Statistical Areas 037 and 040–042, followed by a secondary fishery centred around June and concentrated off the northwest South Island (Areas 034–036) in May–August, in South Taranaki Bight Area 037 in April and Area 040 in June (Table 1). The presence of two quite widely separated fishery peaks maintained a trend apparent across all analysed years.

In 2017–18, about 88% of the landed weight was sampled by observers (Table 1). Most of the estimated landings were derived from seven Statistical Areas (034–037, 040–042), and these were all well sampled (Figure 3). The percentages of the catch sampled in the seven most productive months were all greater than 73% (Table 1), and no month was 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.

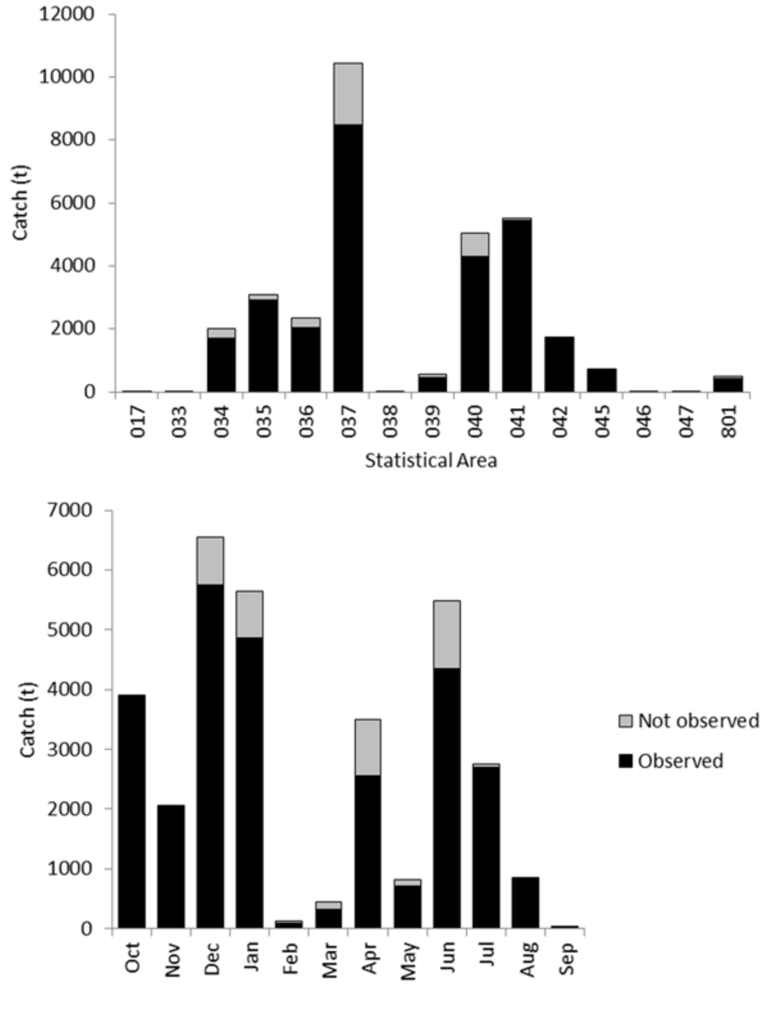

Figure 3: Jack mackerel observed landings and landings that were not observed, by Statistical Area and month, in 2017–18.

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 2017–18 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), 2017–18

Stat Area													Month
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	All
017	0	2	0	2	0	1	0	1	0	1	0	0	8
033	6	4	9	3	1	2	1	2	0	0	1	4	33
034	109	1	1	5	1	2	1	76	451	654	705	5	2 011
035	741	25	1		0	0	0	113	699	1 471	19	18	3 089
036	223	5	1	0		3	126	235	1 372	378		0	2 344
037	10	103	2 898	3 444	54	401	2 675	384	259	195	1	1	10 424
038	1	0	1	0	0	0	1	0	0	0	1	2	6
039	2	0	0	11	50	27	471	0	6	1	0	1	568
040	21	15	1 212	1 941	21		216		1 562	53			5 042
041	432	1 785	2 430	153	0	0	0	0	712	0	0	0	5 513
042	1 569	111	0	0	0	0		0	20		0		1 701
43–44	0	0	0	0	0	0	0	0	0	0	0	0	0
045	714	0	0	1	0	1	0	0		0	0	0	718
46–47	2	1	0	0	2	2	1	0	1	1	2	3	14
801	3			86					397				486
All	3 834	2 052	6 552	5 647	128	440	3 491	812	5 480	2 755	729	34	31 955

Sampled landings (t)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	All	%
017		0			0					0	0		0	0
033														0
034	105							24	107	618	834	4	1 692	84
035	830	24	1					124	464	1 425	26	9	2 903	94
036	218	3	0				107	216	1 124	369		0	2 037	87
037	10	98	2 338	2 994	32	291	1 902	356	240	217			8 480	81
038														0
039				10	54	32	375		1				472	83
040	21	55	1 080	1 662	10	0	170		1 224	66			4 290	85
041	381	1 777	2 329	130					827				5 444	99
042	1 601	103							20				1 724	101
43–44														0
045	740												740	103
46–47		0											0	0
801	6			76					346				428	88
All	3 913	2 060	5 749	4 873	96	324	2 555	720	4 353	2 696	860	13	28 211	88
%	102	100	88	86	75	74	73	89	79	98	118	38	88	

3.2 Species proportions

An examination of estimated species proportions by fishing year for all of JMA 7 (Table 2) shows that *T. declivis* (JMD) was the dominant species caught from 2006–07 to 2017–18, 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 2017–18 fishing year produced proportions of *T. declivis* and *T. novaezelandiae* 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
2017–18	29.8	64.0	6.2	9 528	20 464	1 963	10 194	21 896	2 100

3.3 Sex ratios

Sex ratios by fishing year since 2006–07 are shown in Table 3. *Trachurus novaezelandiae* had slightly more females than males in all but three years (average 47.7% males across all years), although the two most recent years were slightly biased towards males. Ratios were around 50% for *T. declivis* (average 50.8% 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 and in 2017–18), although in the three years from 2014–15 to 2016–17 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	49.9	50.1	56.8	43.2	54.8	45.2
2007–08	43.4	56.6	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	44.4	55.6	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
2017–18	54.8	45.2	52.8	47.2	56.2	43.8

3.4 Catch-at-length

The estimated catch-at-length distributions, by species, for trawl-caught jack mackerel from JMA 7 in 2017–18 are plotted in Figure 4. For *T. novaezelandiae* there was a dominant length mode at 29–31 cm, with a secondary mode at 25–27 cm on the shoulder of the main distribution (and most apparent for males). For *T. declivis* there was a strong length mode at 40–43 cm, a secondary mode at 35–37 cm, and a juvenile mode peaking at 20 cm. The length range of *T. murphyi* was narrow, with most males being 49–56 cm, and most females being 48–55 cm.

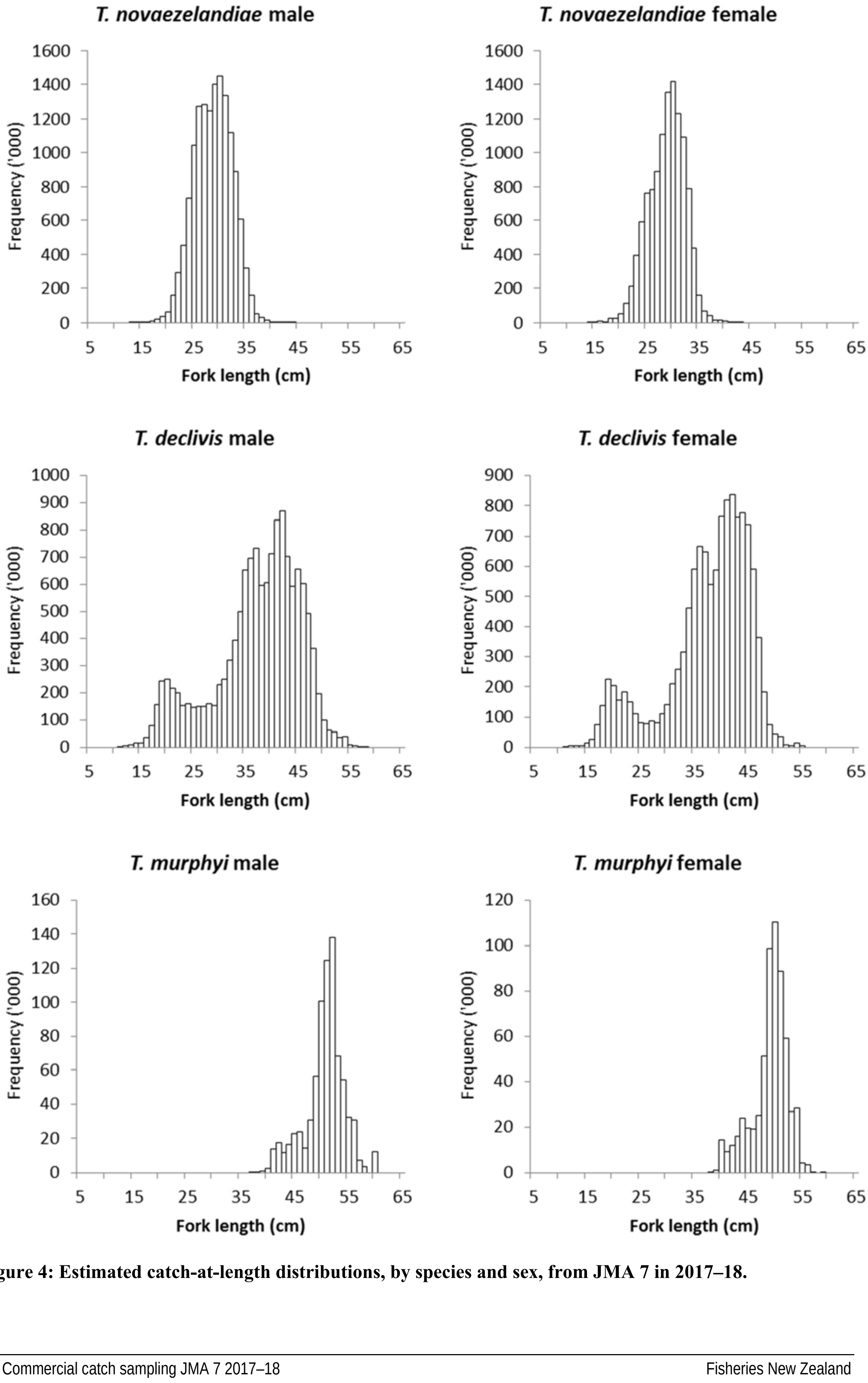

Figure 4: Estimated catch-at-length distributions, by species and sex, from JMA 7 in 2017–18.

3.5 Catch-at-age

The details of the estimated catch-at-age distributions for trawl-caught jack mackerel from JMA 7 in 2017–18 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* (14%), *T. declivis* (16%), and *T. murphyi* (25%) 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 17 years. The catch of *T. declivis* had abundant fish aged 0–8 years old, but with a relatively strong drop-off in fish older than 16 years. The catch of *T. murphyi* was dominated by 18–23 year old fish, with very few fish younger than 15 or older than 25 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 2017–18 fishing year. Summary statistics for the sample are also presented. –, no data.

Age (years)	Male	CV	Female	CV	Total	CV
0	4 788	1.492	13 301	0.723	18 089	0.712
1	200 216	0.304	91 742	0.390	291 958	0.273
2	604 376	0.365	684 013	0.306	1 288 389	0.247
3	2 119 787	0.155	1 909 552	0.163	4 029 339	0.122
4	2 020 907	0.170	1 418 142	0.203	3 439 049	0.137
5	1 712 652	0.170	1 828 592	0.156	3 541 244	0.114
6	2 158 514	0.138	1 373 988	0.168	3 532 502	0.104
7	1 936 082	0.130	1 384 471	0.164	3 320 553	0.098
8	1 019 669	0.185	721 540	0.235	1 741 209	0.154
9	389 718	0.294	498 420	0.234	888 137	0.186
10	336 674	0.241	622 695	0.184	959 369	0.146
11	335 573	0.274	418 462	0.234	754 035	0.179
12	406 491	0.223	169 333	0.364	575 823	0.185
13	245 811	0.281	150 384	0.331	396 195	0.213
14	215 365	0.291	21 109	0.662	236 474	0.268
15	123 724	0.363	115 399	0.473	239 123	0.288
16	115 186	0.339	124 355	0.392	239 541	0.261
17	58 642	0.555	24 253	0.820	82 895	0.461
18	5 915	0.791	0	–	5 915	0.791
19	0	–	0	–	0	–
20	4 035	0.978	0	–	4 035	0.978
21	0	–	0	–	0	–
22	0	–	0	–	0	–
23	4 035	0.941	0	–	4 035	0.941
24	0	–	0	–	0	–
25	0	–	6 737	1.041	6 737	1.041
No. measured		14 895		12 121		27 016
No. aged		278		237		515
No. of tows sampled						273
Mean weighted CV (%)		18.7		20.3		14.1

Table 5: Calculated numbers-at-age, separately by sex, with CVs, for *Trachurus declivis* caught during commercial trawl operations in JMA 7 during the 2017–18 fishing year. Summary statistics for the sample are also presented. –, no data.

Age (years)	Male	CV	Female	CV	Total	CV
0	740 152	0.375	647 038	0.411	1 387 189	0.375
1	957 114	0.238	673 553	0.262	1 630 668	0.218
2	633 526	0.242	802 248	0.178	1 435 774	0.157
3	2 055 920	0.139	1 313 752	0.181	3 369 671	0.119
4	2 078 888	0.128	1 859 402	0.154	3 938 290	0.104
5	963 556	0.167	1 133 978	0.166	2 097 534	0.121
6	1 196 247	0.151	872 742	0.180	2 068 988	0.113
7	1 336 644	0.118	1 115 852	0.137	2 452 496	0.087
8	775 712	0.162	838 684	0.155	1 614 395	0.112
9	368 227	0.243	351 858	0.264	720 085	0.176
10	431 545	0.229	277 078	0.275	708 624	0.177
11	431 237	0.220	506 582	0.207	937 819	0.150
12	290 155	0.271	371 465	0.239	661 620	0.174
13	102 135	0.434	263 351	0.284	365 487	0.242
14	269 299	0.298	106 203	0.452	375 502	0.252
15	177 544	0.371	265 585	0.289	443 129	0.233
16	226 655	0.318	268 425	0.270	495 080	0.209
17	197 870	0.340	123 855	0.386	321 725	0.263
18	44 158	0.789	176 019	0.369	220 177	0.335
19	49 415	0.700	89 616	0.480	139 030	0.388
20	67 603	0.503	23 941	0.631	91 543	0.406
21	70 668	0.465	36 860	0.758	107 528	0.415
22	9 263	1.193	9 184	0.902	18 447	0.769
23	58 985	0.510	6 897	0.879	65 882	0.472
24	78 322	0.508	40 939	0.720	119 261	0.425
No. measured		15 789		14 371		30 160
No. aged		303		268		571
No. of tows sampled						430
Mean weighted CV (%)		20.1		21.5		15.8

Table 6: Calculated numbers-at-age, separately by sex, with CVs, for *Trachurus murphyi* caught during commercial trawl operations in JMA 7 during the 2017–18 fishing year. Summary statistics for the sample are also presented. –, no data.

Age (years)	Male	CV	Female	CV	Total	CV
5	937	1.253	469	3.075	1 406	1.649
6	1 038	2.024	15 516	0.903	16 554	0.852
7	28 144	0.640	11 863	0.880	40 007	0.541
8	10 622	0.910	0	–	10 622	0.910
9	0	–	22 941	0.705	22 941	0.705
10	16 616	0.677	3 406	1.025	20 022	0.589
11	2 491	1.065	7 983	1.153	10 474	0.945
12	16 711	0.856	7 983	1.172	24 694	0.734
13	7 876	1.012	12 090	1.000	19 966	0.697
14	14 757	0.492	18 904	0.655	33 661	0.429
15	14 425	1.009	23 854	0.577	38 279	0.520
16	33 572	0.293	26 649	0.342	60 220	0.215
17	52 876	0.259	15 118	0.469	67 994	0.210
18	57 704	0.213	84 450	0.219	142 154	0.152
19	103 846	0.210	64 185	0.222	168 031	0.150
20	86 917	0.163	65 184	0.235	152 100	0.139
21	119 837	0.146	72 302	0.197	192 140	0.114
22	100 994	0.160	73 725	0.217	174 719	0.130
23	49 465	0.268	38 047	0.310	87 511	0.202
24	38 638	0.326	14 601	0.602	53 238	0.305
25	17 474	0.351	16 716	0.531	34 190	0.307
26	5 068	0.585	4 308	0.722	9 376	0.439
27	6 553	0.623	9 133	0.598	15 686	0.435
38	0	–	2 694	0.970	2 694	0.970
No. measured		1 157		889		2 046
No. aged		315		189		504
No. of tows sampled						183
Mean weighted CV (%)		29.7		38.8		25.0

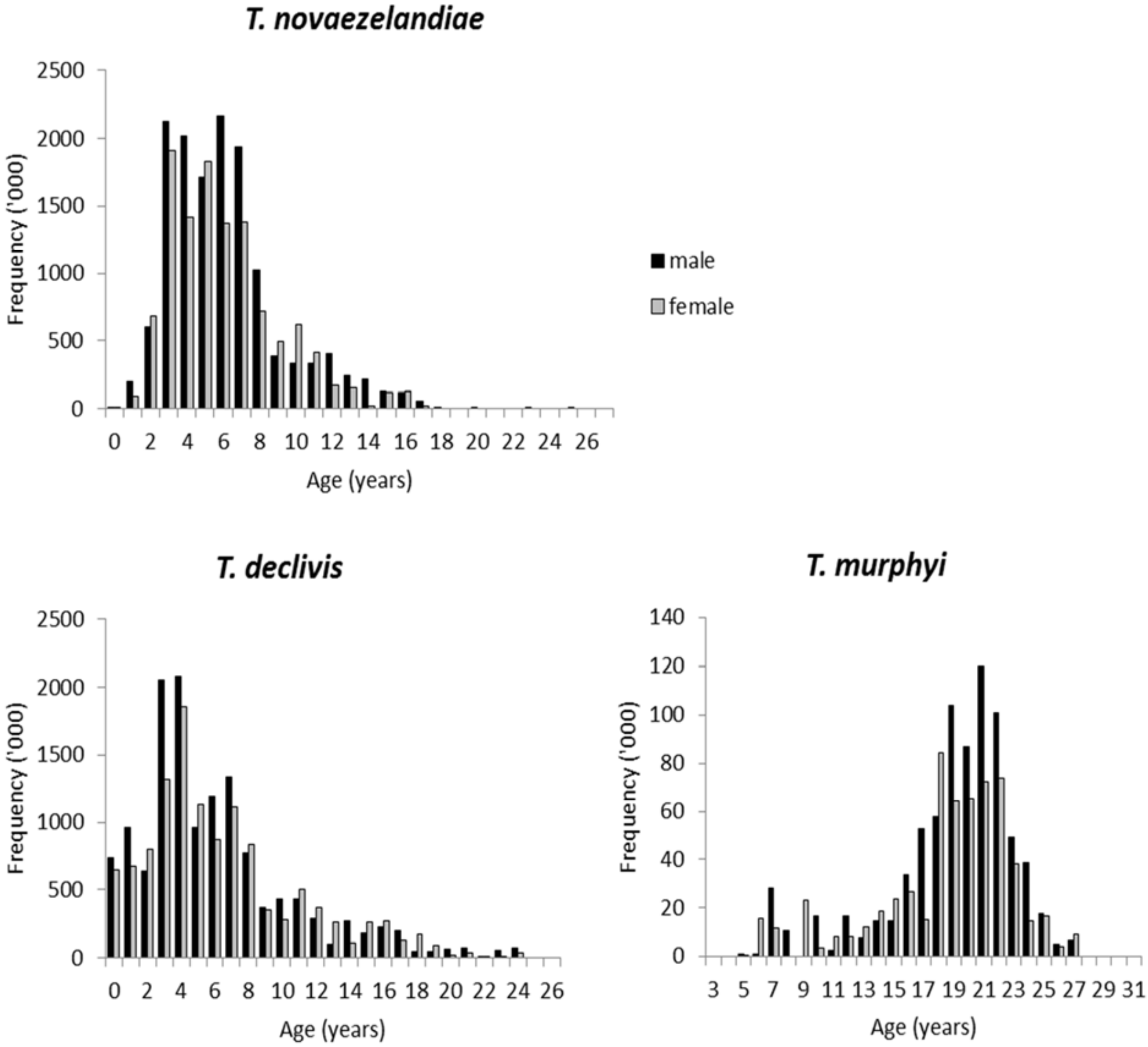

Figure 5: Estimated commercial catch-at-age distributions, by species and sex, from JMA 7 in 2017–18.

3.6 Data summaries

Catch-at-length and catch-at-age data from the JMA 7 fishery are available from twelve 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 A.

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	25	20	17	16	14
	2007–08	28	27	22	17	12	13
	2008–09	39	40	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
	2017–18	19	20	14	15	14	11
T. declivis	2006–07	31	38	26	12	12	9
	2007–08	26	34	23	13	13	12
	2008–09	35	40	28	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	21	20	16	17	15	14
	2015–16	27	24	20	19	15	15
	2016–17	19	19	14	15	14	12
	2017–18	20	21	16	15	15	13
T. murphyi	2006–07	39	55	35	37	37	31
	2007–08	34	50	31	17	21	14
	2008–09	36	49	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
	2017–18	30	39	25	28	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 for fish shorter than 25 cm, presumably related 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. 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 class 7 in 2009–10 and 10 in 2011–12 were weak. The 2+ year class in 2011–12 was also relatively strong, and it progressed as a dominant year class in subsequent years but was not particularly strong in 2017–18. The two subsequent year classes (age classes 3+ and 4+ in 2014–15) also appeared to be relatively strong in the last four years of sampling.

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 and 2017–18 where the strongest modes were at 39–41 cm and 41–42 cm respectively. There were lesser modes for smaller fish in the distributions for some years, e.g., 30 cm in 2012–13 and 2016–17, and 19–20 cm in 2014–15 and 2017–18. 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 and 2014–15 1+ year classes maintained relatively strong presences through to 2017–18 where they were aged 7 and age 4 respectively.

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 year classes had lost much of its dominance. Fish aged 18 years old dominated the 2014–15 distribution, and this cohort was still dominant at age 21 in 2017–18. This year class has been relatively strong since 2011–12 (when it was age 15) and also contributed substantially to the catch throughout the time series (since 2006–07 when it was age 10). The length and age distributions from 2017–18 were, however, notably different to those from all previous years. There was a distinct left-hand tail of relatively small fish (i.e., smaller than 45 cm), which manifests as ages 5 to about 13 years in the age distribution. Fish in that age range occurred rarely in age distributions since 2010–11.

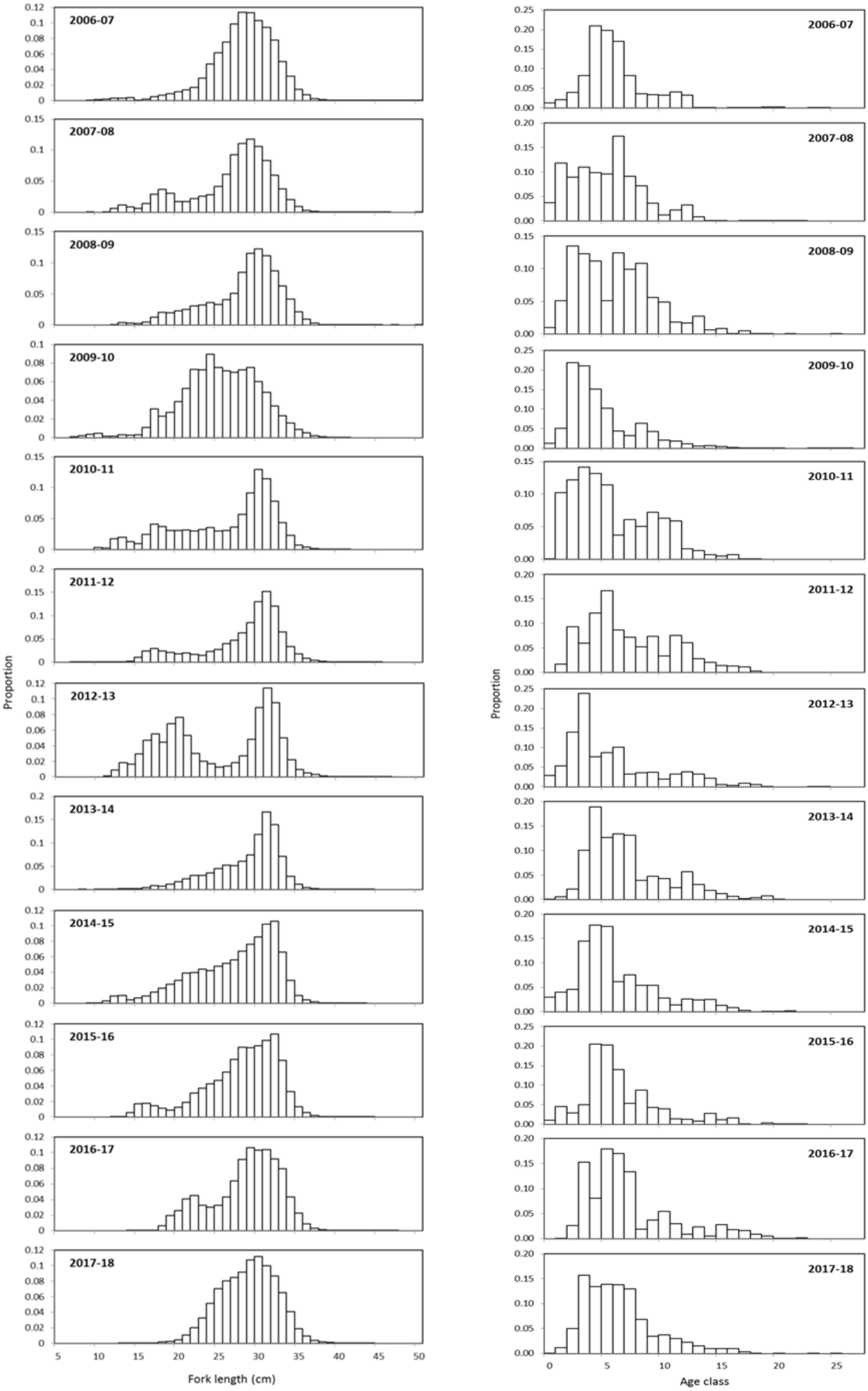

Figure 6: Scaled catch-at-length (left panel) and catch-at-age (right panel, age class in years) proportions for the catch of *Trachurus novaezelandiae* sampled from the 2006–07 to 2017–18 fishing years.

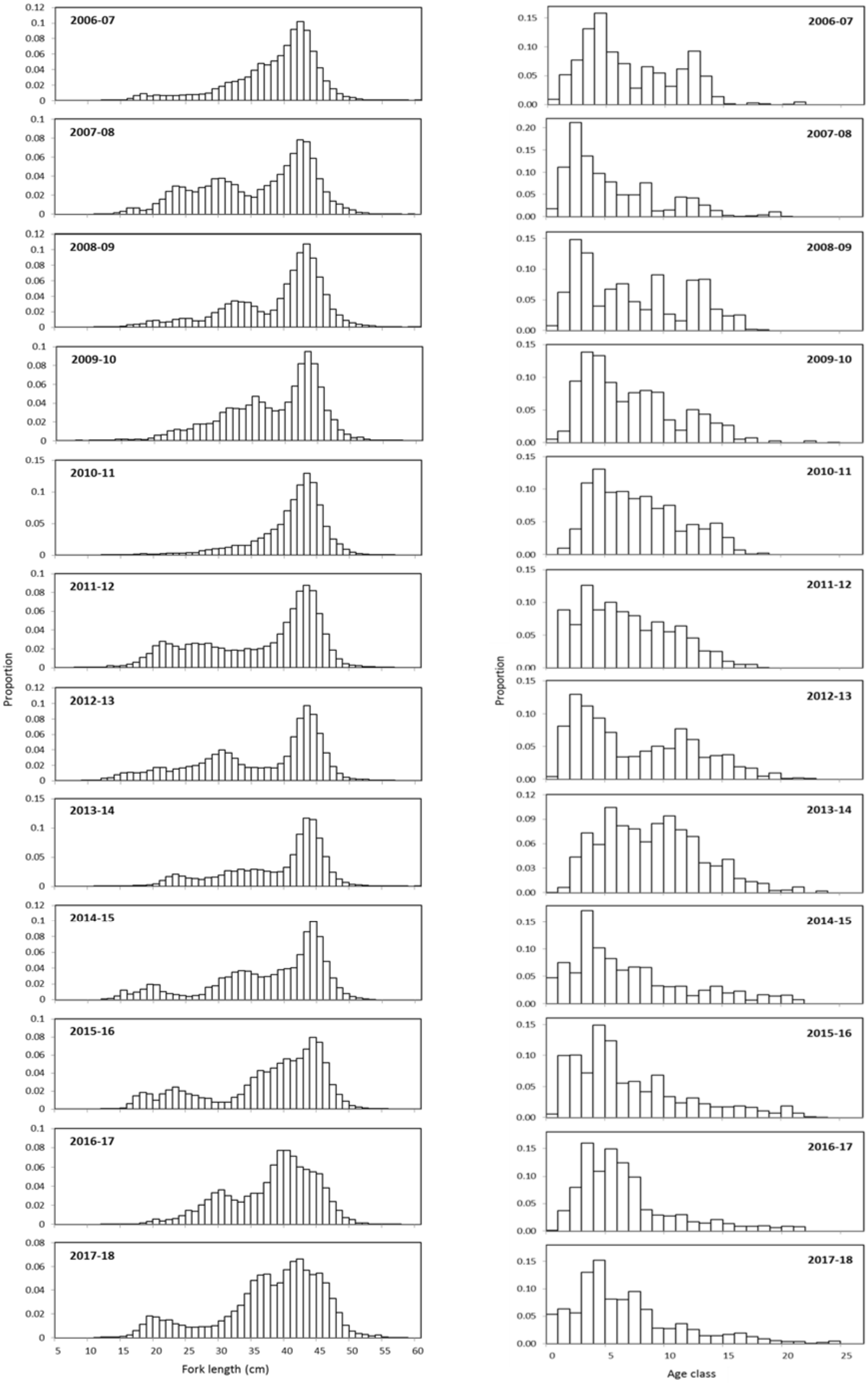

Figure 7: Scaled catch-at-length (left panel) and catch-at-age (right panel, age in years) proportions for the catch of *Trachurus declivis* sampled from the 2006–07 to 2017–18 fishing years.

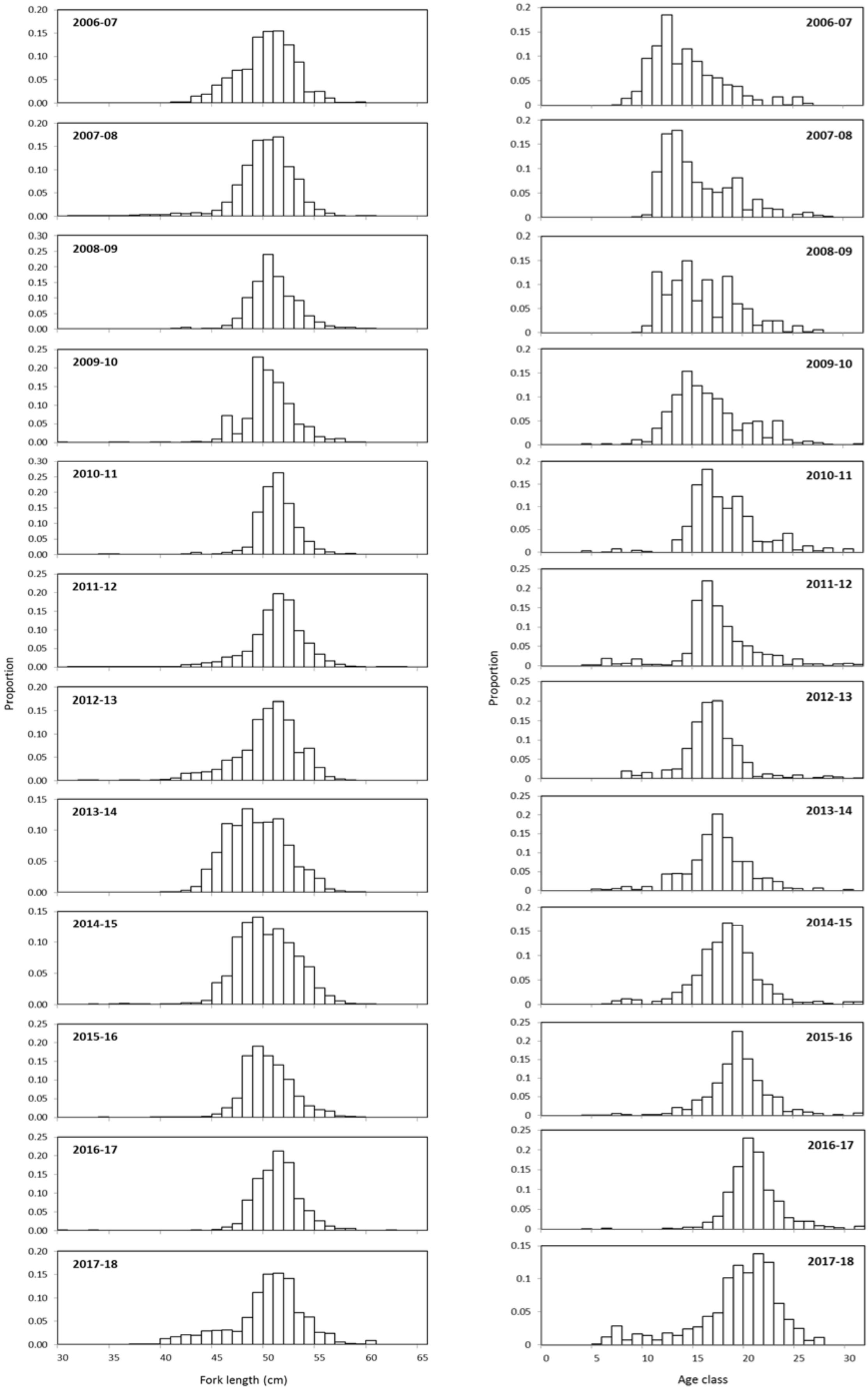

Figure 8: Scaled catch-at-length (left panel) and catch-at-age (right panel, age in years) proportions for the catch of *Trachurus murphyi* sampled from the 2006–07 to 2017–18 fishing years.

4. DISCUSSION

The 2017–18 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 73% of the catch was sampled in each month that produced substantial landings. Spatially, there was very good coverage of catch in the heavily fished Statistical Areas (034–037, 040–042). Estimates of the 2017–18 catch-at-age for all three jack mackerel species had mean weighted CVs over all age classes of 25% or less, well below the target of 30%.

The distribution of the 2017–18 catch was similar to that in 2016–17, which 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, than in years up to 2015–16. This may be because of a southerly shift in mackerel concentrations, or a change in fishing practice, or a combination of both. Thirty-eight large mackerel catches (i.e., 20–65 t per tow, 1340 t total) from Area 034 were taken by midwater trawl in June–August, with jack mackerel declared to be the target species on 25 of these tows (940 t catch), and barracouta as the target on the rest. Target fishing of this intensity was not recorded before 2016–17 in this area (and large by-catches were also rare), so it appears likely that vessels found and fished on 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, 4% of the aged *T. declivis* appeared as outliers that fitted well on the growth curve for *T. novaezelandiae*, and 9% of aged *T. novaezelandiae* were outliers that fitted well on the *T. declivis* growth curve (although 43% of the *T. novaezelandiae* outliers were 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 twelve 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 were 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 was 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 in the length distributions between years were primarily in the abundance of fish shorter than 37 cm, which was likely to be due to 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, and it appeared that fish in this mode had grown to modal lengths of 41–42 cm by 2017–18 (see Figure 7). A length of 40 cm is close to the median expected for 5–7 year old fish (age classes abundant in 2016–17), and fish aged 6–8 years (relatively abundant in 2017–18) would be expected to have a modal length of about 41 cm. These relatively strong year classes have progressed through the distributions since 2011–12. It appears likely that these age classes are now collectively more dominant in the population than the combined older adult age classes (i.e., 10 years and older) that previously made up much of the 42–44 cm length-frequency mode.

The *T. novaezelandiae* catch also had a consistent strong adult length mode (at 28–32 cm) in most sampled years, particularly in 2009–10 when the relative abundance of 2–4 year old fish (i.e., lengths of about 20–27 cm) outweighed the adult mode. Fish aged 3–7 years dominated samples taken since 2013–14. 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, but year class progressions are still apparent for *T. novaezelandiae* under this sampling regime.

The mean age of *T. murphyi* in the catch generally increased over the twelve sampled years. In 2006–07, most fish were 10–15 years old, compared with 15–20 years old in 2010–11 and 2011–12, and 18–21 years old in 2015–16. 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 (up to 2016–17) of any substantial new immigration or recruitment through spawning success. The age distribution in 2017–18 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 were only weakly abundant in the 2017–18 catch as 24 year olds). In 2017–18 a relatively large number of small *T. murphyi* (40–46 cm) were identified in the catch. It was initially considered possible that these were misidentified *T. declivis*, but an examination of the data showed that they were derived from 32 tows sampled across 11 trips. Hence, those fish are unlikely to be attributable to species misidentifications by a small number of inexperienced observers. It is hypothesised, therefore, that there was a new episode of migration of multiple year classes of *T. murphyi* into New Zealand waters. Analyses of data from future years will be needed to confirm or reject this hypothesis.

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 next three years of sampling, however, produced ratios closer to 50:50. The most recent 2017–18 year had a ratio that reverted back to being biased strongly towards males (56% male). *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).

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* (0.3) and lower for *T. declivis* (0.2). The similarity of *Z* estimates from the same fishery 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 0.17–0.20 yr^{-1} for both species, and by Broadhurst et al. (2018) to be 0.17–0.26 yr^{-1} for *T. novaezelandiae*), suggested that *T. novaezelandiae* and *T. declivis* in JMA 7 are not over-exploited. The *Z* estimates were not updated in the current work.

An examination of the age distributions for *T. novaezelandiae* shows that the numbers of older fish in have not changed consistently or noticeably over the twelve years of sampling. This further supports the hypothesis that this species is not over-exploited in JMA 7. For *T. declivis* however, the samples in the last four years appear to have reduced proportions of fish aged at least 10 years old relative to previous distributions. It is not known whether this is a consequence of some recent strong juvenile recruitment, or fishing down of older ages classes, or to changes in either the distribution of fishing effort or the distribution of *T. declivis*.

5. ACKNOWLEDGMENTS

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6. REFERENCES

Beentjes, M.P.; Neil, H.L.; Taylor, P.R.; Marriot, P. (2013). Further studies on age validation of Murphy's mackerel (*Trachurus symmetricus murphyi*). *New Zealand Fisheries Assessment Report 2013/14*. 38 p.

Broadhurst, M.K.; Kienzle, M.; Stewart, J. (2018). Natural mortality of *Trachurus novaezelandiae* and its size selection by purse seines off south-eastern Australia. *Fisheries Management and Ecology 2018*: 1–7. https://doi.org/10.1111/fme.12286

Bull, B.; Dunn, A. (2002). Catch-at-age: User manual v1.06.2002/09/12. NIWA Internal Report 114. 23 p. (Unpublished report held in NIWA library, Wellington.)

Horn, P.L. (1993). Growth, age structure, and productivity of jack mackerels (*Trachurus* spp.) in New Zealand waters. *New Zealand Journal of Marine and Freshwater Research 27*: 145–155.

Horn, P.L.; Hulston, D.; Ó Maolagáin, C. (2012b). Commercial catch sampling for species proportion, sex, length, and age of jack mackerels in JMA 7 in the 2010–11 fishing year, with a summary of all available data sets. *New Zealand Fisheries Assessment Report 2012/42*. 21 p.

Horn, P.L.; Hulston, D.; Ó Maolagáin, C. (2013). Commercial catch sampling for species proportion, sex, length, and age of jack mackerels in JMA 7 in the 2011–12 fishing year, with a summary of all available data sets. *New Zealand Fisheries Assessment Report 2013/43*. 23 p.

Horn, P.L.; Hulston, D.; Ó Maolagáin, C. (2014a). Commercial catch sampling for species proportion, sex, length, and age of jack mackerels in JMA 3 in the 2012–13 fishing year. *New Zealand Fisheries Assessment Report 2014/57*. 16 p.

Horn, P.L.; Hulston, D.; Ó Maolagáin, C. (2018). Commercial catch sampling for species proportion, sex, length, and age of jack mackerels in JMA 7 in the 2015–16 fishing year, with a summary of all available data sets. *New Zealand Fisheries Assessment Report 2018/46*. 24 p.

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. *New Zealand Fisheries Assessment Report 2018/61*. 27 p.

Horn, P.L.; Ó Maolagáin, C.; Hulston, D. (2014b). Commercial catch sampling for species proportion, sex, length, and age of jack mackerels in JMA 7 in the 2012–13 fishing year, with a summary of all available data sets. *New Zealand Fisheries Assessment Report 2014/58*. 24 p.

Horn, P.L.; Ó Maolagáin, C.; Hulston, D. (2015). Commercial catch sampling for species proportion, sex, length, and age of jack mackerels in JMA 7 in the 2013–14 fishing year, with a summary of all available data sets. *New Zealand Fisheries Assessment Report 2015/43*. 23 p.

Horn, P.L.; Ó Maolagáin, C.; Hulston, D.; Ballara, S.L. (2017). Commercial catch sampling for species proportion, sex, length, and age of jack mackerels in JMA 7 in the 2014–15 fishing year, with a summary of all available data sets. *New Zealand Fisheries Assessment Report 2017/39*. 29 p.

Horn, P.; Sutton, C.; Hulston, D.; Marriott, P. (2012a). Catch-at-age for jack mackerels (*Trachurus* spp.) in the 2009–10 fishing year, and barracouta (*Thyrsites atun*) and silver warehou (*Seriolella punctata*) in the 2004–05 and 2009–10 fishing years. Final Research Report for Ministry of Fisheries Project MID2010-01A, Objectives 6 & 8. 19 p. (Unpublished report available from Fisheries New Zealand, Wellington.)

Hurst, R.J.; Bagley, N.W. (1997). Trends in Southland trawl surveys of inshore and middle depth species, 1993–96. *New Zealand Fisheries Technical Report 50*, 67 p.

Lyle, J.M.; Krusic-Golub, K.; Morison, A.K. (2000). Age and growth of jack mackerel and the age structure of the jack mackerel purse seine catch. FRDC Final Report on Project 1995/034. Tasmanian Aquaculture and Fisheries Institute, Marine Research Laboratories, Taroona, Tasmania 7053, Australia. 49 p.

Taylor, P.R. (2008). Factors affecting fish size and landed volumes in the purse-seine and TCEPR charter-boat fisheries in 2004–05 and 2005–06. *New Zealand Fisheries Assessment Report 2008/32*. 17 p.

Taylor, P.R.; Julian, K.A. (2008). Species composition and seasonal variability in commercial catches of jack mackerel (*Trachurus declivis*, *T. murphyi*, *T. novaezelandiae*) in JMA 1, 3, and 7 during 2004–05. *New Zealand Fisheries Assessment Report 2008/25*. 24 p.

Taylor, P.R.; Manning M.J.; Marriott, P.M. (2002). Age and growth estimation of Murphy's mackerel, *Trachurus symmetricus murphyi*. Final Research Report for Ministry of Fisheries Project JMA2000/02. 62 p. (Unpublished report available from Fisheries New Zealand, Wellington.)

Taylor, P.R.; Smith, M.H.; Horn, P.L.; Ó Maolagáin, C. (2011). Commercial catch sampling for species proportion, sex, length, and age of jack mackerels in JMA 7 in the 2006–07, 2007–08 and 2008–09 fishing years. Final Research Report for Ministry of Fisheries Project JMA2006-01 & JMA2009-02. 57 p. (Unpublished report available from Fisheries New Zealand, Wellington.)

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. In the proportions-at-age tables, “0” indicates that there were no fish of that age, “0.00000” indicates that there were fish of that age but that they comprised less than $5e^{-4}$ % of the sample.

Note: Values reported previously for *T. declivis* and *T. novaezelandiae* for years 2015 and 2016 were in error. Corrected values are presented below.

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	2018
0	0.01321	0.03725	0.00935	0.01267	0.00073	0	0.02842	0.00003	0.02970	0.01028	0	0.00071
1	0.02091	0.11805	0.05117	0.05100	0.10213	0.01682	0.05307	0.00564	0.03966	0.04578	0.00081	0.01141
2	0.03921	0.08945	0.13462	0.21826	0.12161	0.09338	0.13993	0.02163	0.04576	0.02926	0.02648	0.05034
3	0.08228	0.10983	0.12296	0.21079	0.14075	0.05978	0.23802	0.10037	0.14410	0.05014	0.15238	0.15743
4	0.20901	0.09878	0.11173	0.15171	0.13125	0.12095	0.07646	0.18902	0.17775	0.20456	0.08092	0.13437
5	0.19822	0.09602	0.05099	0.10195	0.11373	0.16678	0.08754	0.12679	0.17515	0.20209	0.17871	0.13836
6	0.16968	0.17309	0.12458	0.04429	0.03665	0.08684	0.10115	0.13419	0.06151	0.13981	0.17019	0.13802
7	0.08227	0.09136	0.09923	0.03191	0.06038	0.07120	0.03203	0.13137	0.07492	0.05333	0.13429	0.12974
8	0.03604	0.07130	0.10806	0.06385	0.05033	0.05233	0.03601	0.03885	0.05358	0.08667	0.01838	0.06803
9	0.03356	0.03584	0.05580	0.04261	0.07219	0.07388	0.03698	0.04782	0.05391	0.04283	0.03727	0.03470
10	0.03189	0.01209	0.04857	0.02056	0.06306	0.03340	0.01990	0.04237	0.02826	0.03916	0.05466	0.03748
11	0.04065	0.02205	0.01810	0.01806	0.05858	0.07569	0.03210	0.02426	0.01392	0.01409	0.02936	0.02946
12	0.03277	0.03203	0.01677	0.01151	0.01598	0.06087	0.03787	0.05635	0.02566	0.01230	0.00830	0.02250
13	0.00097	0.00819	0.02686	0.00583	0.01313	0.02769	0.03231	0.03028	0.02395	0.00766	0.02367	0.01548
14	0.00116	0.00058	0.00629	0.00662	0.00707	0.02005	0.02240	0.01895	0.02531	0.02832	0.00545	0.00924
15	0	0.00019	0.00808	0.00463	0.00511	0.01431	0.00531	0.01227	0.01266	0.01120	0.02835	0.00934
16	0.00037	0	0.00026	0.00266	0.00665	0.01266	0.00375	0.00597	0.00809	0.01647	0.01822	0.00936
17	0.00075	0.00120	0.00487	0.00052	0.00058	0.01101	0.00865	0.00145	0.00289	0.00148	0.01623	0.00324
18	0.00058	0.00045	0.00040	0.00005	0.00008	0.00236	0.00622	0.00382	0	0	0.00876	0.00023
19	0.00260	0.00114	0.00024	0.00006	0	0	0.00114	0.00775	0.00088	0.00322	0.00554	0
20	0.00235	0.00063	0	0.00000	0	0	0	0.00083	0.00092	0.00095	0.00077	0.00016
21	0	0.00029	0.00082	0	0	0	0	0	0.00143	0.00013	0.00013	0
22	0	0.00016	0	0	0	0	0	0	0	0.00030	0.00113	0
23	0.00097	0	0	0.00000	0	0	0.00051	0	0	0	0	0.00016
24	0.00056	0	0	0.00012	0	0	0.00022	0	0	0	0	0
25	0	0	0.00026	0.00000	0	0	0	0	0	0	0	0.00026
26	0	0	0	0.00024	0	0	0	0	0	0	0	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	2018
0	0.488	0.460	0.759	0.913	2.006		0.524	1.709		0.711		0.712
1	0.515	0.305	0.297	0.389	0.378	0.487	0.463	0.516	0.481	0.450	1.064	0.273
2	0.347	0.134	0.184	0.213	0.249	0.209	0.244	0.349	0.355	0.495	0.415	0.247
3	0.218	0.147	0.175	0.186	0.185	0.219	0.151	0.201	0.274	0.263	0.190	0.122
4	0.134	0.182	0.316	0.172	0.114	0.109	0.179	0.117	0.133	0.108	0.170	0.137
5	0.118	0.198	0.397	0.209	0.124	0.097	0.101	0.108	0.084	0.082	0.092	0.114
6	0.130	0.135	0.278	0.281	0.228	0.133	0.089	0.083	0.070	0.105	0.093	0.104
7	0.195	0.210	0.314	0.227	0.193	0.176	0.183	0.093	0.138	0.178	0.092	0.098
8	0.281	0.216	0.272	0.211	0.189	0.187	0.172	0.167	0.123	0.126	0.268	0.154
9	0.335	0.253	0.336	0.204	0.141	0.157	0.159	0.163	0.135	0.210	0.157	0.186
10	0.304	0.451	0.398	0.230	0.160	0.252	0.226	0.174	0.144	0.201	0.153	0.146
11	0.265	0.331	0.432	0.274	0.170	0.145	0.163	0.247	0.208	0.316	0.191	0.179
12	0.288	0.313	0.527	0.252	0.328	0.166	0.144	0.147	0.289	0.317	0.374	0.185
13	1.023	0.320	0.321	0.327	0.316	0.222	0.165	0.163	0.225	0.443	0.206	0.213
14	0.949	1.264	0.480	0.367	0.429	0.272	0.179	0.199	0.187	0.238	0.378	0.268
15		1.348	0.625	0.336	0.392	0.305	0.358	0.232	0.180	0.349	0.184	0.288
16	1.059		1.035	0.494	0.451	0.311	0.458	0.275	0.296	0.291	0.238	0.261
17	0.731	1.006	1.042	0.594	1.160	0.374	0.280	0.512	0.325	0.509	0.244	0.461
18	0.818	1.092	1.148	2.105	1.712	0.565	0.317	0.385	0.512	0.000	0.294	0.791
19	0.702	1.023	0.972	1.916			0.769	0.287	0.000	0.611	0.349	
20	0.896	0.940		1.253				0.673	0.434	0.645	0.581	0.978
21		0.869	0.832						0.862	1.155	1.016	
22		1.138								0.773	0.550	
23	1.079			1.134			0.835					0.941
24	1.065			0.887			0.903					
25			1.037	2.166								1.041
26				1.049								

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	2018
0	0.00893	0.01782	0.00806	0.00539	0	0	0.00410	0.00023	0.04777	0.00583	0.00119	0.05380
1	0.05147	0.11061	0.06219	0.01797	0.00917	0.08889	0.08129	0.00658	0.07537	0.09972	0.03761	0.06324
2	0.07715	0.21069	0.14881	0.09418	0.03899	0.06589	0.12900	0.04371	0.05627	0.10037	0.07940	0.05568
3	0.13149	0.13626	0.12663	0.13873	0.10908	0.12607	0.11182	0.07295	0.17127	0.07203	0.15979	0.13068
4	0.15853	0.09736	0.04033	0.13272	0.13015	0.08856	0.09327	0.05894	0.10254	0.14848	0.10923	0.15273
5	0.09108	0.07846	0.06792	0.09225	0.09495	0.10043	0.07181	0.10419	0.08304	0.12368	0.14900	0.08134
6	0.07142	0.04928	0.07629	0.06288	0.09627	0.08595	0.03411	0.08160	0.06172	0.05553	0.12449	0.08024
7	0.02851	0.04917	0.04758	0.07667	0.08508	0.07956	0.03508	0.07788	0.06723	0.05806	0.09841	0.09511
8	0.06552	0.07556	0.03432	0.08013	0.08833	0.05749	0.04294	0.06227	0.06664	0.04160	0.03926	0.06261
9	0.05500	0.01309	0.09075	0.07678	0.07007	0.06999	0.05031	0.08451	0.03254	0.06786	0.02900	0.02793
10	0.03159	0.01537	0.02699	0.03447	0.07495	0.05556	0.04689	0.09361	0.03089	0.03389	0.02733	0.02748
11	0.06188	0.04438	0.01596	0.01922	0.03545	0.06416	0.07710	0.07679	0.03161	0.02394	0.03031	0.03637
12	0.09305	0.04229	0.08242	0.05073	0.04577	0.04540	0.06055	0.06892	0.01506	0.03134	0.01706	0.02566
13	0.04966	0.02600	0.08367	0.04349	0.03910	0.02561	0.03305	0.03672	0.02444	0.02229	0.01431	0.01417
14	0.01375	0.01372	0.03512	0.02986	0.04785	0.02543	0.03635	0.03249	0.03146	0.01753	0.02094	0.01456
15	0.00149	0.00241	0.02400	0.02638	0.02556	0.00993	0.03722	0.04085	0.01949	0.01730	0.01321	0.01718
16	0	0.00042	0.02509	0.00566	0.00680	0.00554	0.01925	0.01730	0.02311	0.01852	0.00863	0.01920
17	0.00313	0.00172	0.00225	0.00753	0.00041	0.00505	0.01721	0.01378	0.00682	0.01674	0.00879	0.01248
18	0.00127	0.00417	0.00163	0	0.00203	0.00050	0.00477	0.01154	0.01641	0.01050	0.00913	0.00854
19	0	0.01041	0	0.00234	0	0	0.00942	0.00284	0.01405	0.00711	0.00609	0.00539
20	0.00048	0.00083	0	0	0	0	0.00107	0.00306	0.01535	0.01846	0.00863	0.00355
21	0.00459	0	0	0	0	0	0.00208	0.00722	0.00693	0.00715	0.00820	0.00417
22	0	0	0	0.00234	0	0	0.00131	0	0	0.00170	0	0.00072
23	0	0	0	0	0	0	0	0.00201	0	0.00038	0	0.00255
24	0	0	0	0.00028	0	0	0	0	0	0	0	0.00463
25	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	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	2018
0	0.465	0.320	0.354	0.428			0.793	1.197	0.337	0.913	0.756	0.375
1	0.230	0.193	0.198	0.326	0.355	0.267	0.238	0.441	0.190	0.488	0.341	0.218
2	0.175	0.138	0.140	0.207	0.191	0.229	0.199	0.409	0.188	0.220	0.157	0.157
3	0.145	0.128	0.145	0.141	0.134	0.162	0.161	0.222	0.104	0.151	0.119	0.119
4	0.121	0.170	0.293	0.130	0.113	0.182	0.161	0.191	0.098	0.107	0.117	0.104
5	0.237	0.195	0.264	0.160	0.143	0.115	0.153	0.129	0.100	0.102	0.083	0.121
6	0.328	0.324	0.340	0.190	0.153	0.114	0.170	0.114	0.120	0.119	0.080	0.113
7	0.452	0.264	0.424	0.168	0.169	0.117	0.149	0.136	0.114	0.125	0.095	0.087
8	0.324	0.344	0.436	0.186	0.175	0.140	0.135	0.123	0.111	0.162	0.161	0.112
9	0.310	0.471	0.268	0.177	0.176	0.124	0.125	0.099	0.167	0.124	0.184	0.176
10	0.497	0.486	0.488	0.300	0.184	0.137	0.140	0.093	0.184	0.182	0.182	0.177
11	0.266	0.286	0.682	0.367	0.230	0.127	0.099	0.108	0.169	0.219	0.173	0.150
12	0.241	0.289	0.307	0.214	0.216	0.158	0.113	0.111	0.258	0.197	0.223	0.174
13	0.360	0.448	0.293	0.236	0.237	0.208	0.149	0.142	0.201	0.208	0.244	0.242
14	0.564	0.466	0.458	0.268	0.209	0.183	0.143	0.146	0.182	0.266	0.200	0.252
15	0.921	0.851	0.386	0.273	0.295	0.339	0.149	0.138	0.218	0.262	0.260	0.233
16		0.747	0.312	0.469	0.545	0.472	0.211	0.221	0.200	0.259	0.328	0.209
17	1.019	1.015	0.636	0.647	1.049	0.438	0.243	0.230	0.358	0.288	0.282	0.263
18	1.056	0.376	0.841		1.091	0.690	0.399	0.254	0.251	0.310	0.324	0.335
19		0.784		1.020			0.292	0.456	0.254	0.365	0.373	0.388
20	1.052	1.018					0.868	0.409	0.277	0.255	0.329	0.406
21	1.006						0.701	0.335	0.369	0.336	0.355	0.415
22				0.963			0.801			0.487		0.769
23								0.624		0.827		0.472
24				1.254								0.425
25												
26												

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	2018
4	0	0	0	0.00205	0.00259	0.00176	0	0	0	0.00134	0.00029	0
5	0	0	0	0	0	0.00211	0	0.00393	0	0.00144	0	0.00101
6	0	0	0	0.00209	0.00049	0.01934	0	0.00283	0.00118	0.00162	0.00271	0.01186
7	0.00018	0	0	0	0.00726	0.00436	0	0.00485	0.00759	0.00459	0	0.02866
8	0.01384	0	0	0.00264	0	0.00587	0.02012	0.01073	0.01191	0.00247	0	0.00761
9	0.02858	0.00161	0.00036	0.01051	0.00357	0.01798	0.00865	0.00280	0.00935	0	0	0.01643
10	0.09570	0.00555	0.01443	0.00710	0.00123	0.00300	0.01566	0.01110	0	0.00216	0	0.01434
11	0.12119	0.09376	0.12603	0.03502	0	0.00300	0	0	0.00644	0.00241	0	0.00750
12	0.18510	0.17118	0.07832	0.06924	0	0.00209	0.02195	0.04305	0.01152	0.00484	0.00264	0.01769
13	0.08478	0.17870	0.10889	0.10402	0.02734	0.01276	0.02521	0.04480	0.02497	0.02122	0.00107	0.01430
14	0.11525	0.11388	0.14963	0.15299	0.05670	0.03200	0.07794	0.04321	0.04011	0.01592	0.00500	0.02411
15	0.08987	0.07196	0.06621	0.12274	0.14876	0.16939	0.14660	0.08019	0.05947	0.04176	0.00439	0.02742
16	0.06119	0.05845	0.10982	0.10803	0.18226	0.21936	0.19724	0.14793	0.11335	0.04888	0.01739	0.04314
17	0.05582	0.05184	0.03163	0.09647	0.12240	0.15442	0.20045	0.20283	0.12763	0.08682	0.03250	0.04871
18	0.04196	0.06025	0.11673	0.06577	0.09623	0.10191	0.10438	0.14046	0.16779	0.13884	0.09311	0.10183
19	0.03892	0.08091	0.06023	0.03084	0.12267	0.06330	0.08599	0.07661	0.16213	0.22588	0.15721	0.12037
20	0.01919	0.01560	0.04916	0.04496	0.07841	0.05144	0.04172	0.07686	0.10548	0.15196	0.22960	0.10896
21	0.01118	0.03763	0.01568	0.04920	0.02333	0.03487	0.00552	0.03144	0.05015	0.09355	0.19400	0.13764
22	0	0.01883	0.02495	0.01512	0.02230	0.02878	0.01253	0.03243	0.04128	0.05464	0.09776	0.12516
23	0.01679	0.01674	0.02514	0.05006	0.02552	0.02702	0.00761	0.02328	0.02143	0.05017	0.07021	0.06269
24	0.00038	0	0.00215	0.01035	0.04088	0.00300	0.00340	0.00681	0.01036	0.01056	0.02829	0.03814
25	0.01679	0.00654	0.01377	0.00481	0.00511	0.01772	0.00917	0.00555	0.00401	0.01612	0.02016	0.02449
26	0.00327	0.01014	0.00133	0.00757	0.01335	0.00414	0	0	0.00435	0.00944	0.01927	0.00672
27	0	0.00425	0.00554	0.00460	0.00309	0.00466	0.00244	0.00599	0.00598	0.00481	0.00812	0.01124
28	0	0.00218	0	0.00113	0.00921	0.00066	0.00628	0	0.00196	0	0.00589	0
29	0	0	0	0	0	0.00457	0.00488	0	0	0.00180	0.00312	0
30	0	0	0	0	0.00729	0.00655	0	0.00231	0.00588	0	0	0
31	0	0	0	0.00268	0	0.00394	0.00226	0	0.00569	0.00676	0.00727	0

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	2018
4				2.236	1.146	1.047				1.313	1.866	
5						0.747		0.766		1.457		1.649
6				1.423	2.163	0.420		1.105	0.848	1.423	1.096	0.852
7	2.343				1.841	1.093		0.741	0.632	0.684		0.541
8	0.605			1.481		0.891	0.710	0.519	0.452	1.021		0.910
9	0.420	1.054	1.736	0.948	0.873	0.596	0.869	0.972	0.577			0.705
10	0.322	0.581	0.663	0.803	1.888	1.225	0.714	0.531		1.479		0.589
11	0.301	0.251	0.227	0.383		1.119			0.593	1.200		0.945
12	0.189	0.178	0.291	0.584		1.043	0.499	0.237	0.445	0.761	1.057	0.734
13	0.266	0.184	0.255	0.178	0.363	0.511	0.432	0.261	0.338	0.346	1.259	0.697
14	0.221	0.225	0.206	0.233	0.235	0.322	0.231	0.252	0.245	0.378	0.722	0.429
15	0.332	0.347	0.333	0.271	0.144	0.119	0.142	0.184	0.188	0.243	0.850	0.520
16	0.344	0.299	0.242	0.192	0.130	0.102	0.111	0.145	0.133	0.219	0.495	0.215
17	0.480	0.337	0.351	0.178	0.174	0.119	0.107	0.113	0.133	0.152	0.350	0.210
18	0.427	0.339	0.233	0.222	0.183	0.165	0.145	0.142	0.110	0.120	0.187	0.152
19	0.665	0.314	0.365	0.304	0.155	0.182	0.164	0.183	0.109	0.095	0.136	0.150
20	0.699	0.543	0.345	0.235	0.228	0.198	0.245	0.192	0.128	0.119	0.098	0.139
21	0.878	0.461	0.781	0.269	0.374	0.231	0.664	0.313	0.201	0.160	0.122	0.114
22		0.767	0.451	0.433	0.392	0.267	0.479	0.312	0.220	0.183	0.180	0.130
23	1.041	0.860	0.495	0.273	0.340	0.298	0.487	0.368	0.301	0.215	0.225	0.202
24	4.020		0.823	0.576	0.295	0.831	0.894	0.643	0.431	0.469	0.332	0.305
25	1.074	1.120	0.898	0.655	0.763	0.336	0.532	0.607	0.720	0.353	0.434	0.307
26		1.083	0.869	0.564	0.543	0.788			0.679	0.498	0.502	0.439
27		1.018	0.654	0.791	1.018	0.673	0.915	0.688	0.644	0.600	0.528	0.435
28		1.070		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	