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Commercial catch sampling for species proportion, sex, length, and age of jack mackerels in JMA 7 in the 2018–19 fishing year, with a summary of all available data sets

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R. Saunders,
P.L. Horn,
C. Ó Maolagáin,
D. Hulston

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EXECUTIVE SUMMARY

Saunders, R.; Horn, P.L.; Ó Maolagáin, C.; Hulston, D. (2021). Commercial catch sampling for species proportion, sex, length, and age of jack mackerels in JMA 7 in the 2018–19 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 2018–19 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 80% of the 2018–19 landed catch was sampled, and sampling was considered to be representative of the landings both temporally and spatially.

For all three species, the scaled length distributions from 2018–19 were similar to those from the eleven previous years. The age-frequency distributions for all species in 2018–19 had mean weighted CVs of 25% or less, which more than met the target of 30%.

Estimated species proportions based on observer data showed a dominance of *T. declivis* at 61–73% (73% in 2018–19) in the JMA 7 Trawl Catch Effort Processing Return data for all statistical areas and the thirteen years of sampling, whereas *T. novaezelandiae* was 21–33% (21% in 2018–19) and *T. murphyi* was 3–8% (7% in 2018–19).

Species growth curve comparisons using the 2017–18 and 2018–19 observer data suggest the rate of species misidentification by observers was at least 8% for *T. novaezelandiae* and at least 3% for *T. declivis*. Thus, the 2017–18 and 2018–19 derived age and length distributions for these two species should be interpreted cautiously. It is currently not known how pervasive species misidentification has been in the historical JMA 7 catch sampling series and, likewise, it is not known the degree to which the stock assessment utility of this series is compromised.

Observer identification of *Trachurus* spp. needs to improve for future analyses and we recommend that an approach to identify the species via otolith shape analysis be investigated to attempt to retrospectively verify and resolve potential misidentification.

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 Fisheries New Zealand 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. Species proportion estimates are necessary to derive catch histories for each species from aggregated catch data at least back to when observer sampling began and these can 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).

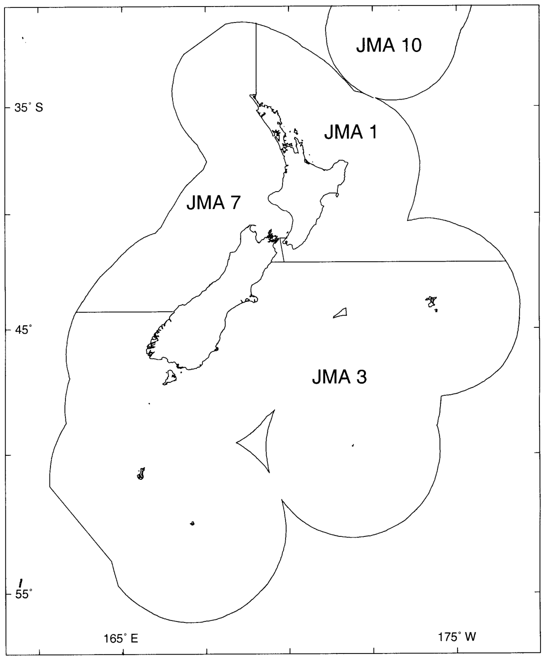

Figure 1: Jack mackerel administrative fishstock areas.

This report provides estimates of relative proportions and catch-at-age for the three *Trachurus* species in the commercial JMA 7 catch for 2018–19 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. (2014) for 2012–13, Horn et al. (2015) for 2013–14, Horn et al. (2017) for 2014–15, Horn et al. (2018) for 2015–16, Horn & Ó Maolagáin (2018) for 2016–17, and Horn et al. (2019) for 2017–18. 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 MID201902 "Routine age determination of hoki and middle depth species from commercial fisheries and trawl surveys", funded by the 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 has been determined annually since 2006–07 and this report adds to that series.

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 by 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 2018–19 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 #12828 on 20 February 2020) 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 2018–19.

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 by 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 also used in the analysis of the 2018–19 data presented here. In line with the Horn et al. (2016) stratification, 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.

Species proportions in the catch 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. The percentage catch by species were then calculated for each stratum. The total jack mackerel catch in each 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 2018–19 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 distribution, 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 because of low numbers of available otoliths and a higher potential number of age classes per length class. 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, an approximately 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 of Horn (1993) and Lyle et al. (2000), described in detail by Horn & Ó Maolagáin (2020). 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, Horn & Ó Maolagáin 2020).

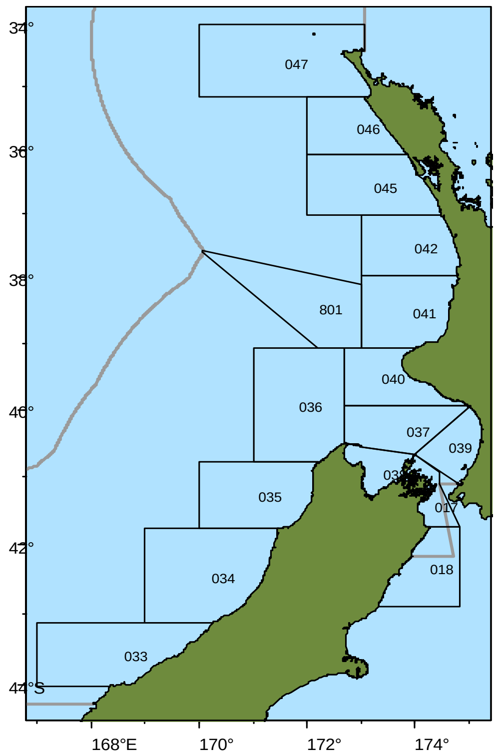

Figure 2: Statistical Areas referred to in the text.

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 (CAA) 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 distinct intra-annual peaks (see Results), so the fishing year was split into two equal temporal periods (i.e., October-March and April-September). To account for the growth of fish, particularly of the younger age classes, separate age-length keys were used for each period. 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 procedure 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 because virtually all sampled fish were close to the asymptotic length of their growth curve. In addition, to investigate the ongoing issues with species identification (see Horn et al. 2019) length-at-age plots using all the raw age and length data were done contrasting all three jack mackerel species for the 2017–18 and 2018–19 years.

3. RESULTS

3.1 Catch sampling

The landings distribution in 2018–19 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-July and concentrated off the northwest South Island (Statistical Areas 034–036) in May-August, in South Taranaki Bight Statistical Area 037 in May-June and North Taranaki Bight Statistical Area 041 in May-July (Figure 3, Table 1). The presence of two quite widely separated fishery peaks is consistent with that observed for previous years (Horn et al. 2019).

In 2018–19, about 80% of the landed weight was sampled by observers (Table 1). Most of the estimated landings were derived from six Statistical Areas (035–037, 040–042), and these were all well sampled (Table 1, Figure 3). The percentages of the catch sampled in the eight most productive months were all greater than 72%, except in May when only 28% was sampled (Table 1). The sampling of the 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 (e.g., 106% for Statistical Area 045 in Table 1). 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.

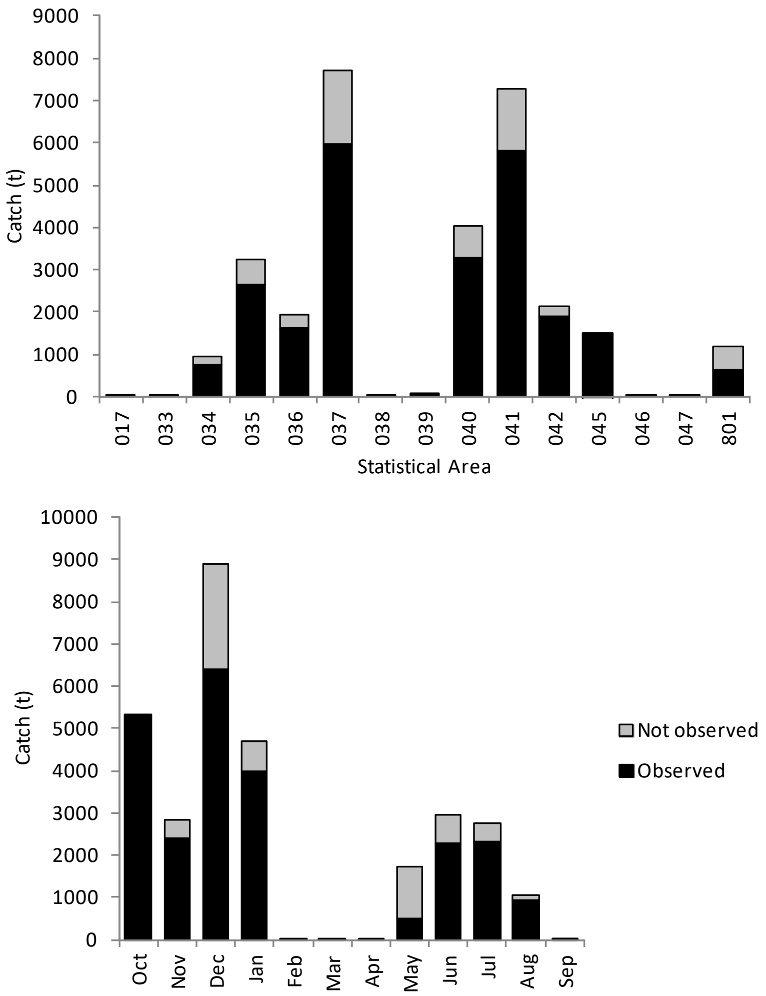

Figure 3: Jack mackerel observed landings and landings that were not observed, by Statistical Area and month, in 2018–19.

Table 1: Distribution of estimated total catch (upper) and sampled landings (lower) (t, rounded to the nearest tonne) of jack mackerels, by month and Statistical Area (Stat Area), in the 2018–19 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.

Stat Area	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	All
	Estimated total catch (t), 2018–19												
017	1	0	0	0	0	0	0	1	1	0	0	1	5
033	8	7	5	6	3	1	4	1	0	0	1	2	38
034	116	3	2	1	0	4	1	0	150	123	558	4	960
035	277	1	3		0	0	0	111	852	1 541	458	0	3 243
036	513	0	18	0		0	0	367	901	133		0	1 932
037	60	514	4 161	2 554	0	0	0	183	199	30	24	0	7 726
038	0	1	0	0	0	0	0	0	0	0	0	1	3
039	1	0	0	20	0	0	0	8	16	0	0	1	47
040	89	394	1 387	2 113	0		0		1	46			4 048
041	908	1 833	3 265	2	0	0	0	469	487	327	0	0	7 292
042	1 468	69	34	0	0	0		49	40		0		2 122
043–044	0	0	0	0	0	0	0	0	0	0	0	0	0
045	1 304	0	0	2	0	2	0	0		91	0	0	1 400
046–047	5	1	3	1	0	1	1	2	0	0	5	3	22
801	364			0					286				1 181
All	5 113	2 823	8 879	4 699	5	7	6	1 727	2 933	2 768	1 048	11	30 019

Stat Area	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	All	%
	Sampled landings (t)													
017										0			0	0
033														0
034	136								79	51	493	0	759	79
035	311							56	346	1504	423	0	2 641	81
036	523							153	886	76	0		1 639	85
037	54	431	3 019	2 126				69	201	26	28		5 955	77
038														0
039				17				3	18				37	79
040	108	294	978	1 841				18	1	57			3 296	81
041	944	1 617	2 363	4				95	493	309			5 825	80
042	1 495	68	31					48	65	190			1 898	89
043–044														0
045	1 407									83			1 490	106
046–047												0	0	0
801	348			0				50	206	18			622	53
All	5 327	2 410	6 391	3 987	0	0	0	491	2 296	2 315	944	1	24 163	80
%	104	85	72	85	0	0	0	28	78	84	90	9	80	

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 2018–19, with 61–73% of landed weight in all years. *T. novaezelandiae* (JMN) was the second most frequently caught species at 21–33%. *T. murphyi* (JMM) was detected at a much lower and quite variable rate of 3–8%. The 2018–19 fishing year, however, produced proportions of *T. declivis* and *T. novaezelandiae* that were the highest and lowest, respectively, of all years investigated. *Trachurus* spp. are not straightforward to identify and misidentification by observers does occur (Appendix B). The rate of misidentification is likely below 10% for *T. declivis* and *T. novaezelandiae* and much lower for the more easily distinguished *T. murphyi* (see Appendix B).

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. JMM = *Trachurus murphyi*, JMN = *Trachurus novaezelandiae*, and JMD = *Trachurus declivis*.

Fishing	Species proportions (%)			Estimated catch (t)			Landed catch (t)		
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
2018–19	20.9	72.5	6.5	6 284	21 774	1 961	6 647	23 031	2 075

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 three years (average 47.6% males across all years), although two of the last three years were slightly biased towards males. Ratios were around 50% for *T. declivis* (average 50.6% 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. See Table 2 caption for definition of species codes.

Fishing	JMN		JMD		JMM	
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
2018–19	46.9	53.1	48.4	51.6	51.9	48.1

3.4 Catch-at-length

The estimated catch-at-length distributions, by species, for trawl-caught jack mackerel from JMA 7 in 2018–19 are plotted in Figure 4. For *T. novaezelandiae* there was a dominant length mode at 29–31 cm. For *T. declivis* there was a strong length mode at 37–39 cm, a secondary mode at 27–29 cm, and a juvenile mode peaking at 18 cm. The length range of *T. murphyi* was narrow, with most males being 49–56 cm, and most females being 48–55 cm.

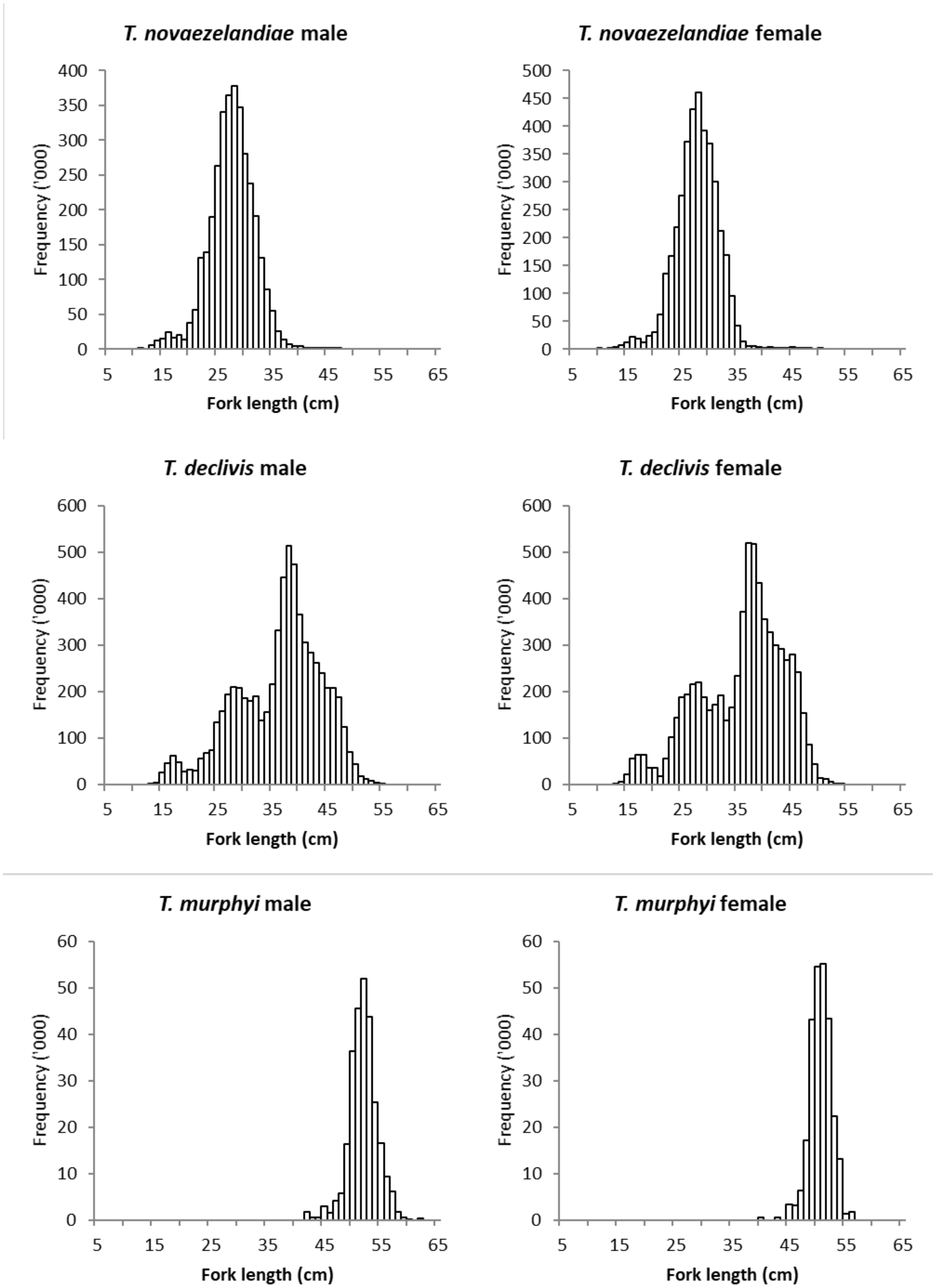

Figure 4: Estimated catch-at-length distributions, by species and sex, from JMA 7 in 2018–19.

3.5 Catch-at-age

The details of the estimated catch-at-age distributions for trawl-caught jack mackerel from JMA 7 in 2018–19 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* (19%), *T. declivis* (17%), 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 6–12 year old fish, with very few fish older than 17 years. The catch of *T. declivis* had abundant fish aged 5–10 years, but with a relatively strong drop-off in fish older than 16 years and no fish under 2 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 2018–19 fishing year. Summary statistics for the sample are also presented. –, no data.

Age (years)	Male	CV	Female	CV	Total	CV
2	0	–	18 584	1.011	18 584	1.01
3	10 421	1.21	20 908	1.042	31 329	0.89
4	36 676	0.72	38 231	0.707	74 906	0.53
5	216 039	0.29	51 443	0.747	267 482	0.28
6	159 583	0.39	297 770	0.269	457 353	0.23
7	412 146	0.21	385 007	0.219	797 153	0.15
8	309 920	0.26	432 654	0.235	742 574	0.18
9	527 657	0.18	516 640	0.193	1 044 298	0.13
10	416 158	0.19	512 677	0.205	928 836	0.14
11	350 136	0.19	444 550	0.204	794 685	0.14
12	244 632	0.24	303 799	0.236	548 432	0.17
13	178 430	0.28	266 701	0.226	445 130	0.18
14	182 072	0.23	69 370	0.477	251 442	0.21
15	51 568	0.44	136 093	0.302	187 661	0.25
16	84 058	0.30	76 644	0.358	160 703	0.24
17	61 824	0.40	61 610	0.413	123 434	0.30
18	58 888	0.42	71 198	0.494	130 085	0.34
19	22 004	0.48	34 837	0.536	56 841	0.38
20	17 037	0.71	53 868	0.486	70 904	0.41
21	23 732	0.68	19 166	0.579	42 897	0.46
22	7 394	0.85	6 944	0.737	14 338	0.59
23	8 534	0.97	0	0.000	8 534	0.97
24	0	–	0	–	0	–
25	0	–	2 22	1.09	2 221	1.09
26	0	–	4 76	1.05	4 759	1.05
No. measured	8 471		10 029		18 661	
No. aged	225		211		438	
No. of tows sampled					244	
Mean weighted CV (%)	25.9		26.9		19.2	

Table 5: Calculated numbers-at-age, separately by sex, with CVs, for *Trachurus declivis* caught during commercial trawl operations in JMA 7 during the 2018–19 fishing year. Summary statistics for the sample are also presented. –, no data.

Age (years)	Male	CV	Female	CV	Total	CV
2	0	–	115 770	0.714	11 5770	0.71
3	245 647	0.48	298 285	0.501	54 3932	0.39
4	259 024	0.49	320 654	0.412	57 9678	0.33
5	756 736	0.24	741 207	0.203	1 497 944	0.17
6	719 704	0.23	620 301	0.265	134 0005	0.18
7	634 774	0.20	870 741	0.201	1 505 516	0.15
8	901 701	0.15	666 148	0.173	1 567 849	0.12
9	408 275	0.20	649 569	0.179	1 057 845	0.13
10	803 114	0.13	679 721	0.141	1 482 835	0.10
11	391 747	0.16	334 545	0.168	726 293	0.11
12	353 199	0.16	409 271	0.162	762 469	0.12
13	194 347	0.22	268 071	0.202	462 418	0.15
14	160 535	0.26	251 530	0.211	412 066	0.16
15	180 572	0.25	194 647	0.232	375 219	0.17
16	191 637	0.22	112 272	0.329	303 910	0.19
17	60 189	0.40	102 553	0.358	162 742	0.27
18	53 251	0.40	148 633	0.262	201 884	0.22
19	53 220	0.41	23 495	0.787	76 715	0.37
20	21 286	0.70	0	–	21 286	0.70
21	16 005	0.82	17 439	0.766	33 444	0.56
22	49 639	0.42	25 787	0.619	75 427	0.35
23	3 503	0.98	20 133	0.837	23 635	0.74
24	0	–	8 992	0.996	8 992	1.00
25	0	–	4 087	0.915	4 087	0.92
26	2 044	1.19	0	–	2 044	1.19
No. measured	15 800		15 989		32 113	
No. aged	270		258		528	
No. of tows sampled					388	
Mean weighted CV (%)	22.3		23.9		17.3	

Table 6: Calculated numbers-at-age, separately by sex, with CVs, for *Trachurus murphyi* caught during commercial trawl operations in JMA 7 during the 2018–19 fishing year. Summary statistics for the sample are also presented. –, no data.

Age (years)	Male	CV	Female	CV	Total	CV
7	967	0.99	0	-–	967	0.99
8	2 356	1.26	0	–	2 356	1.26
9	0	0	849	0.96	849	0.96
10	1 233	1.11	991	1.11	2 225	0.79
11	1 233	1.01	2 223	0.95	3 456	0.69
12	2 883	0.90	0	–	2 883	0.90
13	1 010	1.00	3 580	0.58	4 590	0.51
14	3 874	0.65	2 744	0.69	6 618	0.51
15	0	–	991	1.02	991	1.02
16	4 020	0.48	4 886	0.42	8 906	0.31
17	15 314	0.30	13 268	0.27	28 583	0.21
18	20 929	0.24	25 691	0.21	46 620	0.15
19	35 111	0.17	38 389	0.16	73 501	0.12
20	30 114	0.18	36 884	0.16	66 998	0.12
21	42 577	0.16	41 530	0.15	84 107	0.11
22	46 790	0.15	33 982	0.17	80 772	0.11
23	28 105	0.21	25 761	0.19	53 867	0.15
24	22 926	0.21	8 531	0.37	31 457	0.19
25	3 367	0.50	5 603	0.39	8 971	0.30
No. measured	1 016		1 015		2 031	
No. aged	252		281		533	
No. of tows sampled					164	
Mean weighted CV (%)	27.7		25.0		20.1	

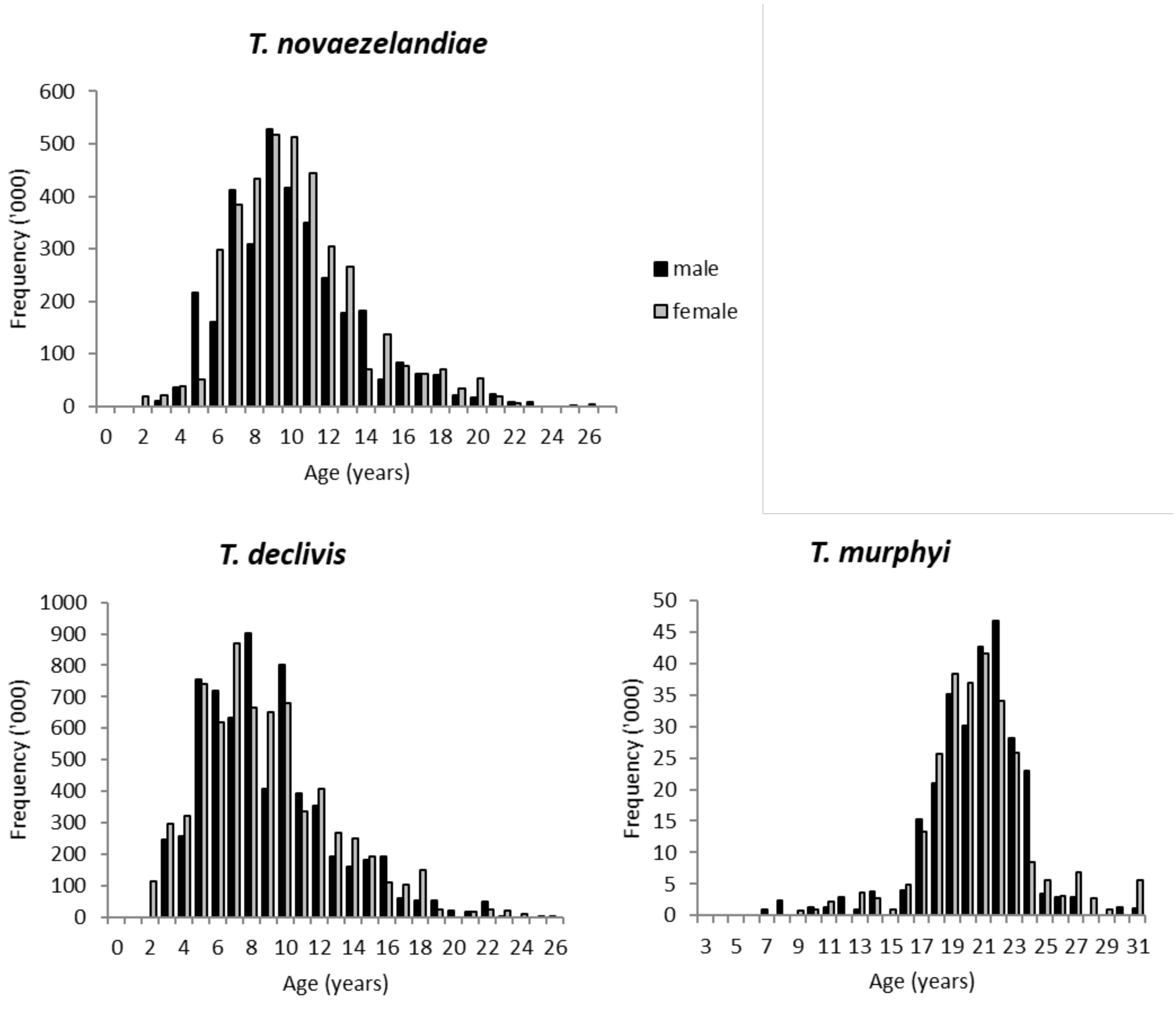

Figure 5: Estimated commercial catch-at-age distributions, by species and sex, from JMA 7 in 2018–19.

3.6 Data summaries

Catch-at-length and catch-at-age data from the JMA 7 fishery are available from thirteen 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 target CV of 30% was achieved for all species in all years, except for *T. 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
	2018–19	26	27	19	12	11	9
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
	2018–19	22	24	17	13	14	11
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
	2018–19	28	25	20	23	17	16

Trachurus novaezelandiae

Scaled catch-at-length frequencies by fishing year are shown in Figure 6. 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 classes 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 but is the dominant year class in 2018–19. The two subsequent year classes (age classes 3+ and 4+ in 2014–15) also appeared to be relatively strong in the subsequent three years of sampling but are not evident this year (2018–19). The age frequency for 2018–19 is starkly different in shape from recent years with almost no fish under 5 years observed. No fish 1 year or less were assigned and the CVs for 2, 3, and 4 year old fish were unusually high (see Table A1b). This is likely a result of a higher range of overlapping lengths for these ages than in previous years which in turn may be the result of misidentification (i.e., *T. declivis* rather than *T. novaezelandiae*).

Trachurus declivis

Most variation in abundance has occurred for the fish shorter than 37 cm, presumably related to the relative strengths of juvenile year classes. Scaled catch-at-age-frequency distributions by fishing year are shown in Figure 7. There was a wide range of ages in the catches, and the distributions varied between years. Very few fish 2 years old or less were evident in the most recent distribution. 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 presence through to 2017–18 when they were age 7 and age 4, respectively.

Trachurus murphyi

Scaled catch-at-length frequency distributions 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 has 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. In the most recent age frequency distribution this left-hand tail is still evident but not as strong as the previous year.

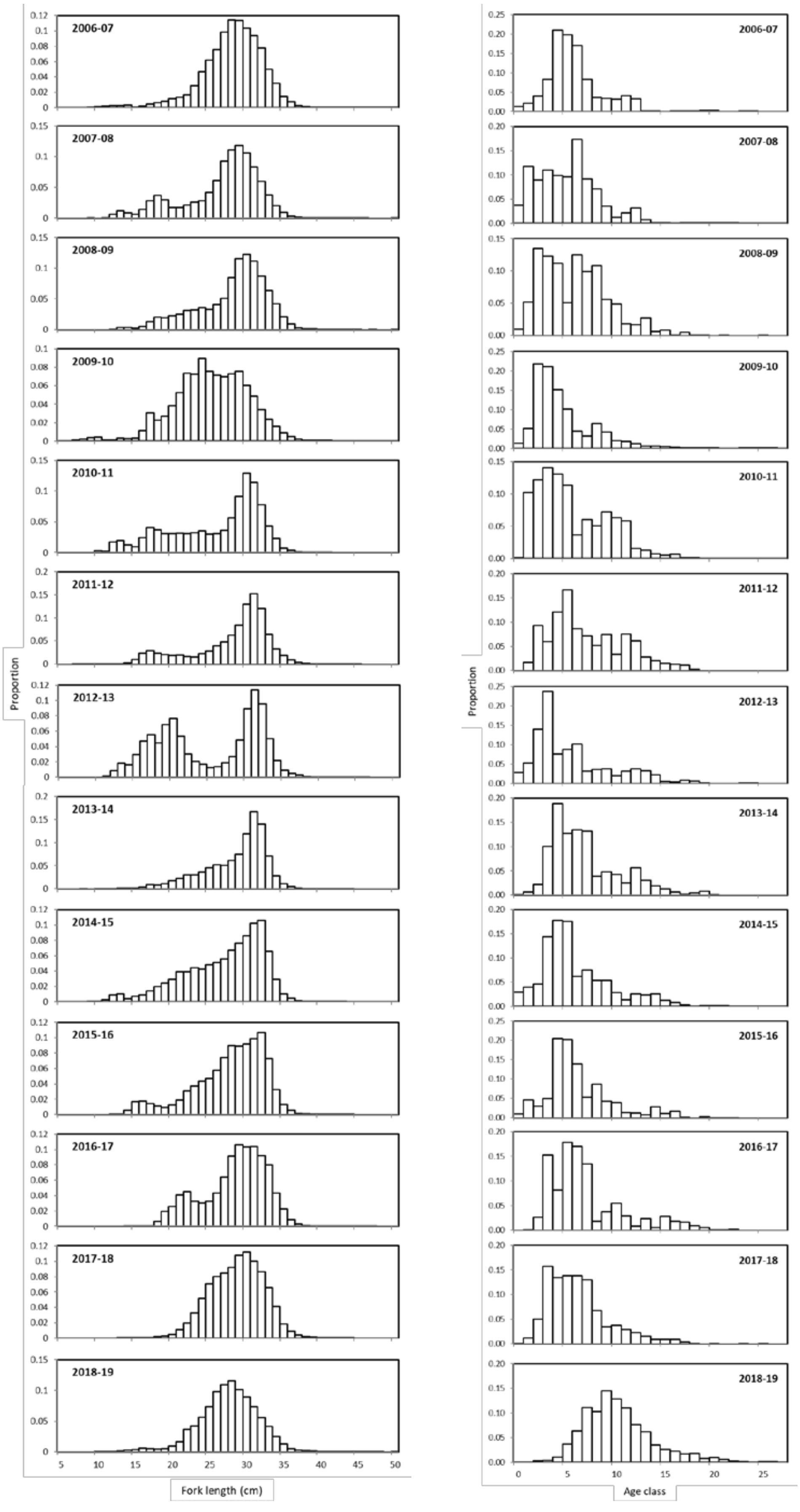

Figure 6: Scaled catch-at-length (left panel) and catch-at-age (right panel, age class in years) proportions for the catch of *Trachurus novaezelandiae* sampled from the 2006–07 to 2018–19 fishing years.

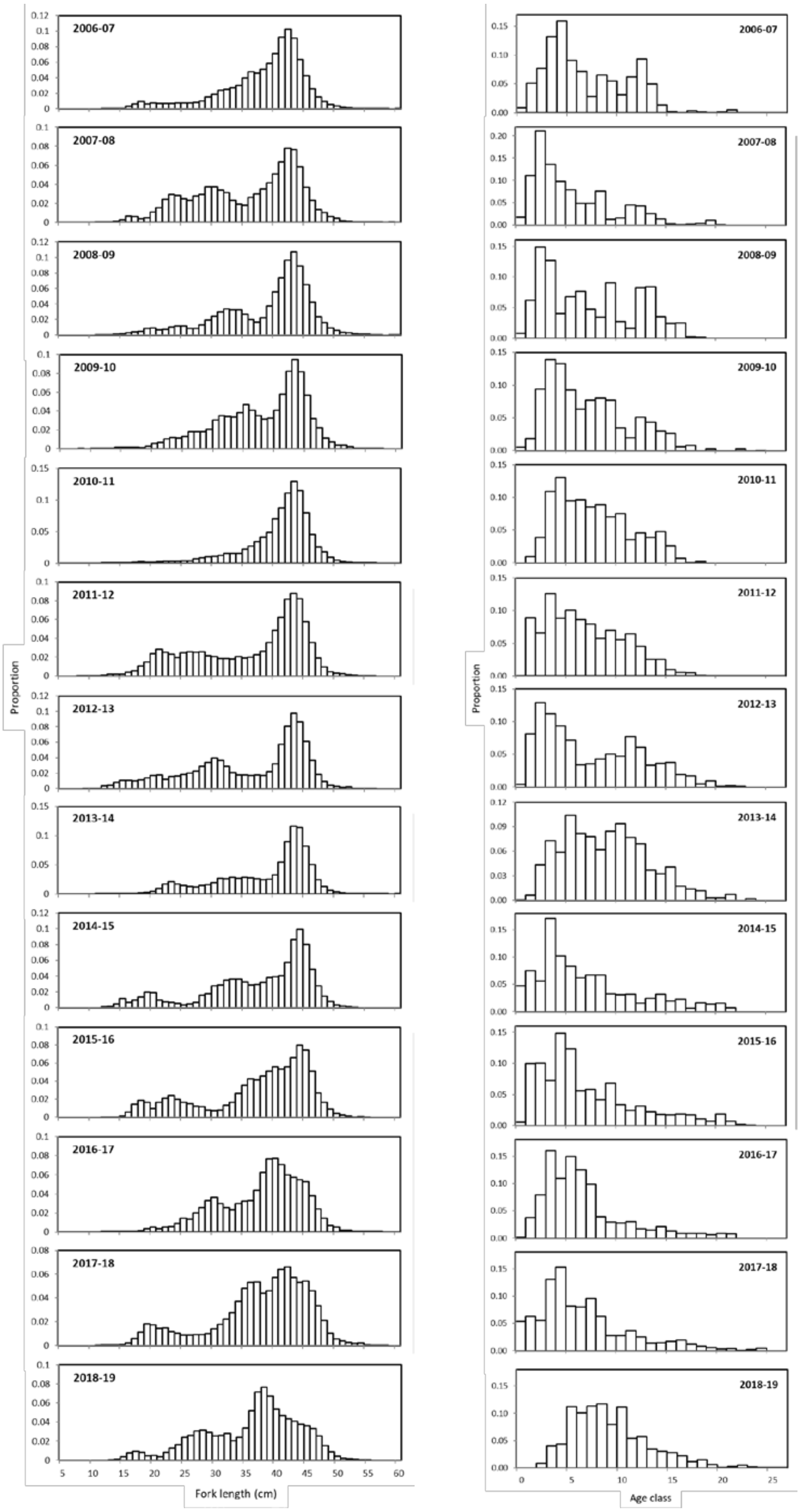

Figure 7: Scaled catch-at-length (left panel) and catch-at-age (right panel, age in years) proportions for the catch of *Trachurus declivis* sampled from the 2006–07 to 2018–19 fishing years.

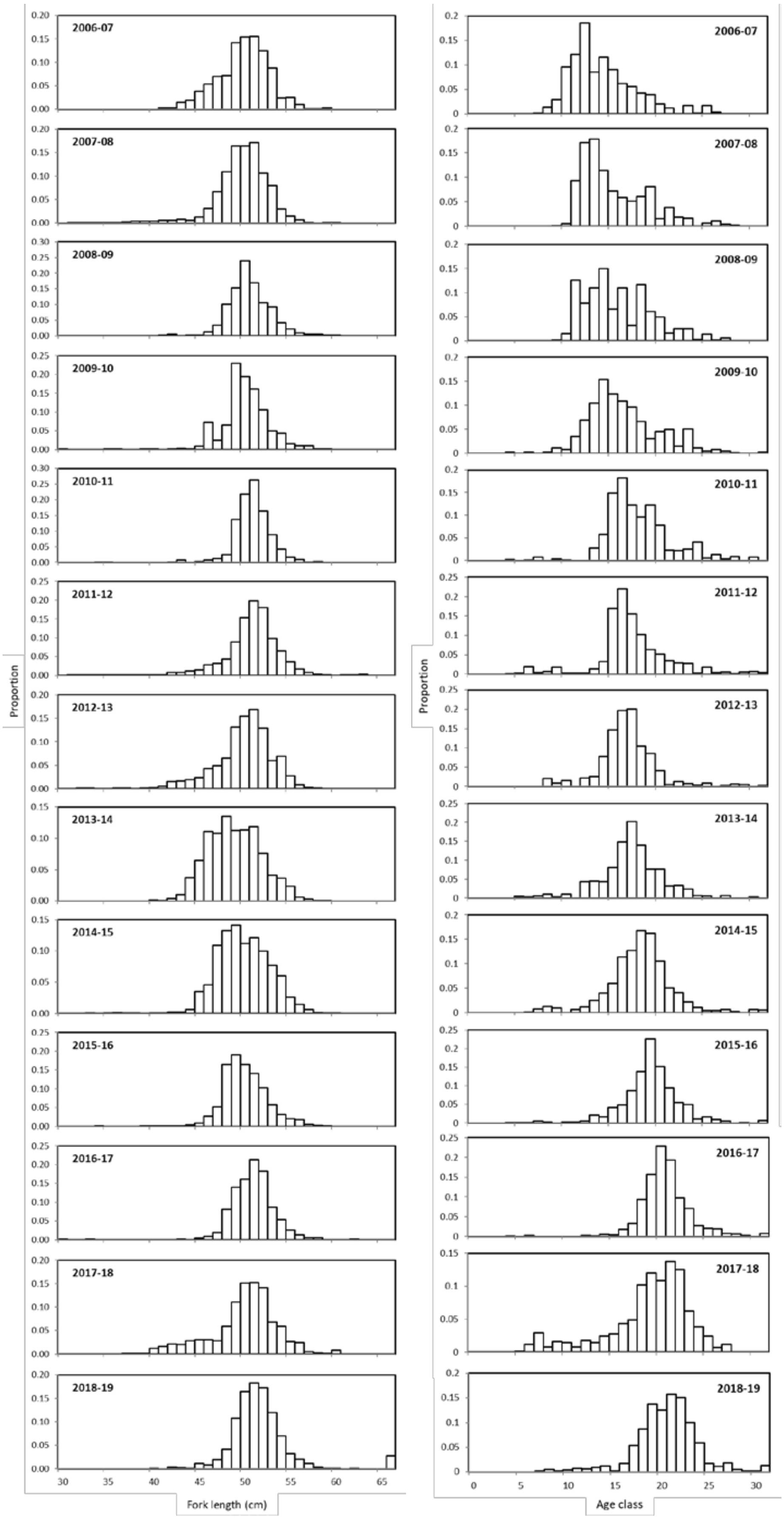

Figure 8: Scaled catch-at-length (left panel) and catch-at-age (right panel, age in years) proportions for the catch of *Trachurus murphyi* sampled from the 2006–07 to 2018–19 fishing year.

3.7 Observer species identification accuracy assessment

To investigate the ongoing issue with jack mackerel species identifications (see Horn et al. 2019) age-at-length plots for the 2017–18 and 2018–19 fishing years for all species were contrasted (Figures 9 & 10). It was clear that when these raw age data were plotted against length, 4% of the aged *T. declivis* appeared as obvious outliers that fitted well on the growth curve for *T. novaezelandiae*, and 8% of aged *T. novaezelandiae* were outliers that fitted well on the *T. declivis* growth curve (Figures 9 & 10). Misidentification is 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 (i.e., 4 years and under) due to the substantial overlap in length-at-age of these individuals. Thus, the misidentification rates of *T. declivis* and *T. novaezelandiae* are likely to have been substantially higher than the values noted above. Further evidence of this is in the starkly different shape of the *T. novaezelandiae* age frequency observed for 2018–19 relative to other years, with an almost total absence of young fish (4 years and under) (Figure 6). This was likely the result of a significant change in mean age for small fish between 2017–18 and 2018–19 (Figures 9 & 10). For example, a 20-cm *T. novaezelandiae* in 2017–18 was on average under 2 years but in 2018–19 was over 6 years (Figures 9 & 10). On noting this difference, all otoliths from small fish (under 23 cm) were re-examined and the original age estimates were confirmed. Thus, it does not appear to be a change in interpretation of otoliths. Furthermore, the difference is too large to be a genuine difference in growth rate and we surmise that is a result of mis-identification rates differing between years. It is also likely that some misidentification has occurred between *T. declivis* and *T. murphyi*, but because the length-at-age ranges for these species overlap substantially (Figure 9) it is not possible to estimate any error rates. It is possible the left-hand tail of young fish in the *T. murphyi* age frequency distribution observed in the most recent two years (Figure 8) is the result of misidentification rather than recruitment.

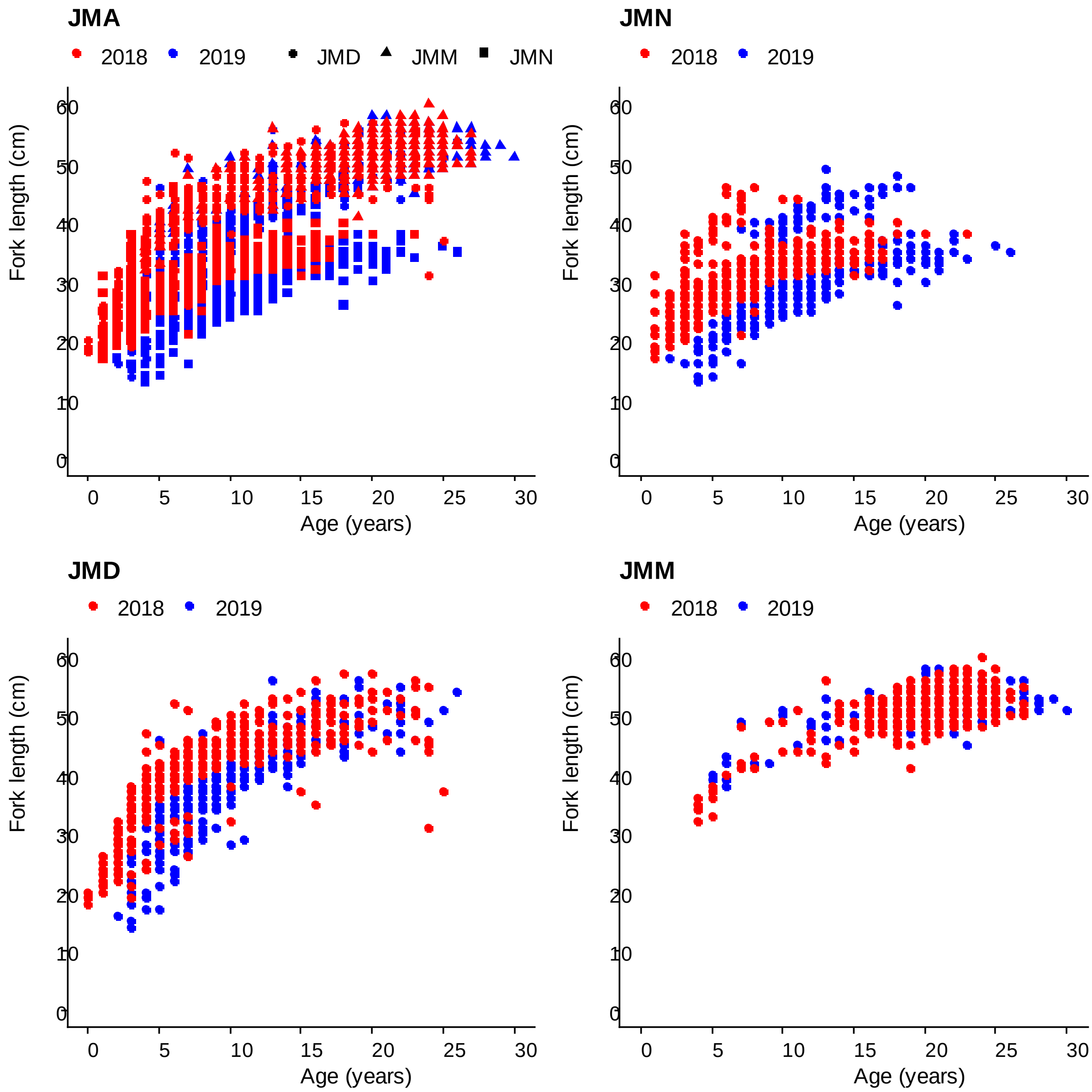

Figure 9: Length-at-age for all *Trachurus* spp (JMA), *T. novaezelandiae* (JMN), *T. declivis* (JMD), and *T. murphyi* for 2017–18 and 2018–19 fishing years based on observer identifications. 2018 = 2017–18 fishing year, 2019 = 2018–19 fishing year.

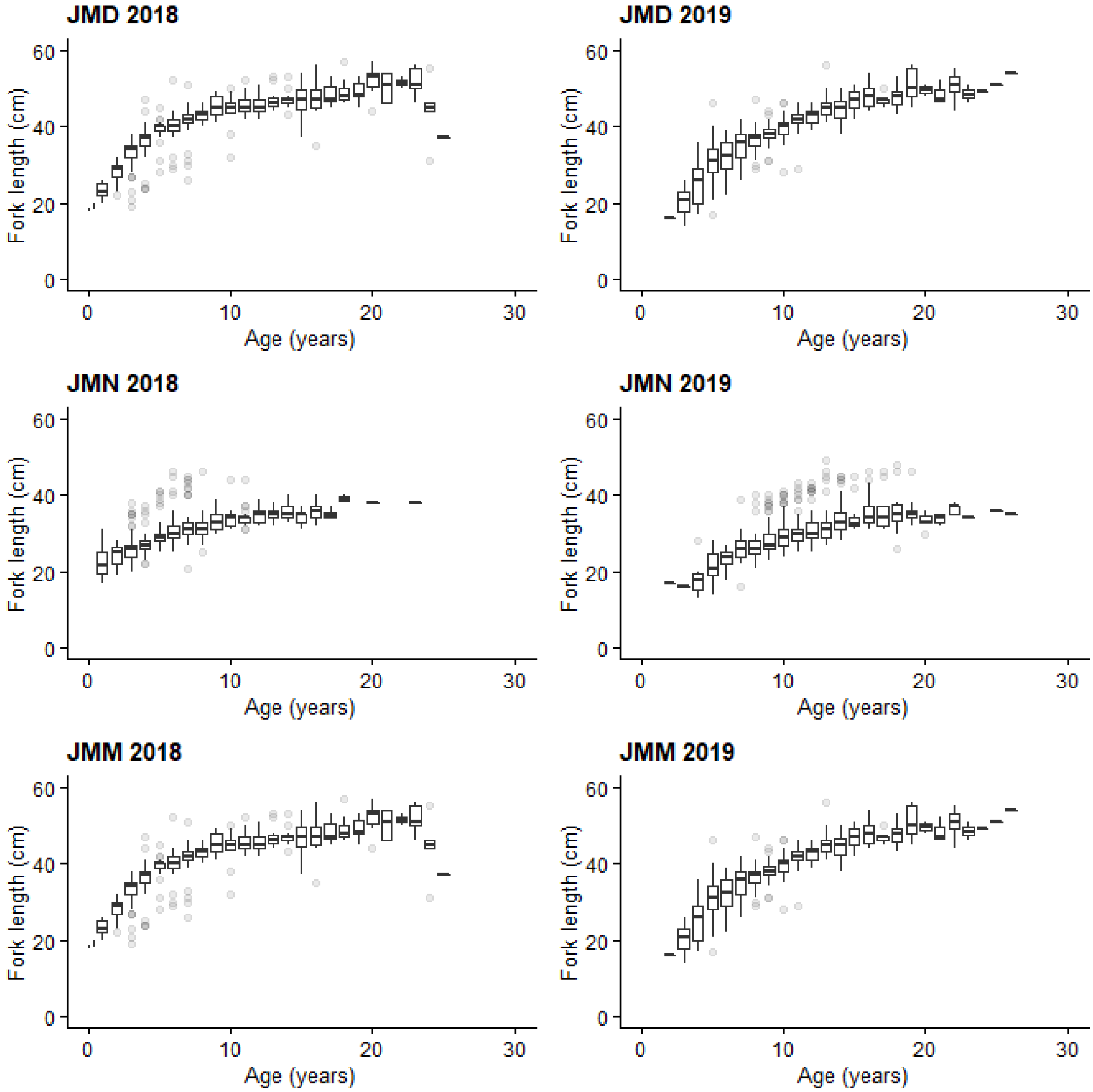

Figure 10: Length-at-age for all *Trachurus* spp (JMA), *T. novaezelandiae* (JMN), *T. declivis* (JMD), and *T. murphyi* for 2017–18 and 2018–19 fishing years based on observer identification represented as boxplots. Differences in mean length-at-age for *T. novaezelandiae* are evident between the two fishing years. 2018 = 2017–18 fishing year, 2019 = 2018–19 fishing year.

4. DISCUSSION

The 2017–18 jack mackerel trawl fishery was comprehensively sampled (as it has been in all years since at least 2006–07). Sampling intensity was high overall, and at least 72% of the catch was sampled in seven of the eight months 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 2018–19 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%.

Estimates of species proportions, based on observer identifications, indicated a consistent predominance of *T. declivis* at 61–73% of total catch weight in the thirteen fishing years from which data were available. The percentage of *T. novaezelandiae* was also consistent temporally at 21–33%. 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* from off the west coast of the South Island.

Species identification has been an ongoing problem in the JMA fishery (Horn et al. 2019). The errors in identification of larger fish can be readily groomed out of the age-length key but the errors for smaller and mid-sized fish are not readily identifiable. The identification problems evident this year suggest that the CAA results should be interpreted with caution, particularly for *T. novaezelandiae* which has exhibited a sudden change in CAA. The CAA could be recalculated by incorporating mean age fish for a given length for small size classes, based on the species aggregate growth curve or could be re-analysed by ageing additional small fish. The former fixes the CAA to current expectations of the growth of juvenile *T. novaezelandiae,* but the latter again relies on observer identifications. Neither approach is ideal, and neither may solve the current problem.

Ongoing training in species identification should be provided to observers to ensure best-quality data are returned. Jack mackerel species misidentification is likely to be pervasive throughout the entire historical JMA 7 CAA series, but the degree to which the stock assessment utility of this series is compromised by such errors is currently unknown. Approaches to retrospectively identify and resolve species misidentification in historical data, such as through DNA sequencing of adhering tissue on collected otoliths, or through an examination of the shape of otoliths themselves, should be explored. The former requires residual DNA to be extracted from the dried otolith, which can be achieved (e.g., Bonanomi et al. 2015) but is expensive and may be subject to contamination problems. The latter (shape analysis) has been proven to work effectively for some genera (e.g., *Scomberomorus* spp. by Zischke et al. 2016) but has not been developed for *Trachurus* spp. in New Zealand waters. We recommend developing and testing this approach for *Trachurus* spp. in New Zealand. If found to successfully discriminate between species, it may be possible to re-evaluate species proportions in historical catch data based on otolith shape.

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 column headings represent each fishing year, and, for example, 2007 refers to the 2006–07 1 October to 30 September 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 they comprised less than $5e^{-4}$ % of the sample.

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	2019
0	0.01321	0.03725	0.00935	0.01267	0.00073	0	0.02842	0.00003	0.02970	0.01028	0	0.00071	0
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	0
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	0.00258
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	0.00435
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	0.01040
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	0.03713
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	0.06348
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	0.11065
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	0.10307
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	0.14495
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	0.12892
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	0.11030
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	0.07612
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	0.06178
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	0.03490
15	0	0.00019	0.00808	0.00463	0.00511	0.01431	0.00531	0.01227	0.01266	0.01120	0.02835	0.00934	0.02605
16	0.00037	0	0.00026	0.00266	0.00665	0.01266	0.00375	0.00597	0.00809	0.01647	0.01822	0.00936	0.02231
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	0.01713
18	0.00058	0.00045	0.00040	0.00005	0.00008	0.00236	0.00622	0.00382	0	0	0.00876	0.00023	0.01806
19	0.00260	0.00114	0.00024	0.00006	0	0	0.00114	0.00775	0.00088	0.00322	0.00554	0	0.00789
20	0.00235	0.00063	0	0.00000	0	0	0	0.00083	0.00092	0.00095	0.00077	0.00016	0.00984
21	0	0.00029	0.00082	0	0	0	0	0	0.00143	0.00013	0.00013	0	0.00595
22	0	0.00016	0	0	0	0	0	0	0	0.00030	0.00113	0	0.00199
23	0.00097	0	0	0.00000	0	0	0.00051	0	0	0	0	0.00016	0.00118
24	0.00056	0	0	0.00012	0	0	0.00022	0	0	0	0	0	0
25	0	0	0.00026	0.00000	0	0	0	0	0	0	0	0.00026	0.00031
26	0	0	0	0.00024	0	0	0	0	0	0	0	0	0.00066

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	2019
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	1.011
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	0.886
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	0.525
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	0.283
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	0.228
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	0.148
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	0.177
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	0.132
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	0.144
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	0.141
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	0.172
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	0.176
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	0.213
15		1.348	0.625	0.336	0.392	0.305	0.358	0.232	0.180	0.349	0.184	0.288	0.250
16	1.059		1.035	0.494	0.451	0.311	0.458	0.275	0.296	0.291	0.238	0.261	0.237
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	0.295
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	0.340
19	0.702	1.023	0.972	1.916			0.769	0.287	0.000	0.611	0.349		0.383
20	0.896	0.940		1.253				0.673	0.434	0.645	0.581	0.978	0.406
21		0.869	0.832						0.862	1.155	1.016		0.457
22		1.138								0.773	0.550		0.590
23	1.079			1.134			0.835					0.941	0.974
24	1.065			0.887			0.903						0.000
25			1.037	2.166								1.041	1.086
26				1.049									1.053

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	2019
0	0.00893	0.01782	0.00806	0.00539	0	0	0.00410	0.00023	0.04777	0.00583	0.00119	0.05380	0
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	0
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	0.00868
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	0.04076
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	0.04344
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	0.11226
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	0.10042
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	0.11282
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	0.11749
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	0.07927
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	0.11112
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	0.05443
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	0.05714
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	0.03465
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	0.03088
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	0.02812
16	0	0.00042	0.02509	0.00566	0.00680	0.00554	0.01925	0.01730	0.02311	0.01852	0.00863	0.01920	0.02277
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	0.01220
18	0.00127	0.00417	0.00163	0	0.00203	0.00050	0.00477	0.01154	0.01641	0.01050	0.00913	0.00854	0.01513
19	0	0.01041	0	0.00234	0	0	0.00942	0.00284	0.01405	0.00711	0.00609	0.00539	0.00575
20	0.00048	0.00083	0	0	0	0	0.00107	0.00306	0.01535	0.01846	0.00863	0.00355	0.00160
21	0.00459	0	0	0	0	0	0.00208	0.00722	0.00693	0.00715	0.00820	0.00417	0.00251
22	0	0	0	0.00234	0	0	0.00131	0	0	0.00170	0	0.00072	0.00565
23	0	0	0	0	0	0	0	0.00201	0	0.00038	0	0.00255	0.00177
24	0	0	0	0.00028	0	0	0	0	0	0	0	0.00463	0.00067
25	0	0	0	0	0	0	0	0	0	0	0	0	0.00031
26	0	0	0	0	0	0	0	0	0	0	0	0	0.00015

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	2019
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	0.714
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	0.388
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	0.329
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	0.170
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	0.178
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	0.154
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	0.116
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	0.133
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	0.095
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	0.112
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	0.117
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	0.153
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	0.160
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	0.166
16		0.747	0.312	0.469	0.545	0.472	0.211	0.221	0.200	0.259	0.328	0.209	0.193
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	0.273
18	1.056	0.376	0.841		1.091	0.690	0.399	0.254	0.251	0.310	0.324	0.335	0.216
19		0.784		1.020			0.292	0.456	0.254	0.365	0.373	0.388	0.373
20	1.052	1.018					0.868	0.409	0.277	0.255	0.329	0.406	0.704
21	1.006						0.701	0.335	0.369	0.336	0.355	0.415	0.556
22				0.963			0.801			0.487		0.769	0.346
23								0.624		0.827		0.472	0.735
24				1.254								0.425	0.996
25													0.915
26													1.192

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	2019
4	0	0	0	0.00205	0.00259	0.00176	0	0	0	0.00134	0.00029	0	0
5	0	0	0	0	0	0.00211	0	0.00393	0	0.00144	0	0.00101	0
6	0	0	0	0.00209	0.00049	0.01934	0	0.00283	0.00118	0.00162	0.00271	0.01186	0
7	0.00018	0	0	0	0.00726	0.00436	0	0.00485	0.00759	0.00459	0	0.02866	0.00180
8	0.01384	0	0	0.00264	0	0.00587	0.02012	0.01073	0.01191	0.00247	0	0.00761	0.00440
9	0.02858	0.00161	0.00036	0.01051	0.00357	0.01798	0.00865	0.00280	0.00935	0	0	0.01643	0.00158
10	0.09570	0.00555	0.01443	0.00710	0.00123	0.00300	0.01566	0.01110	0	0.00216	0	0.01434	0.00415
11	0.12119	0.09376	0.12603	0.03502	0	0.00300	0	0	0.00644	0.00241	0	0.00750	0.00645
12	0.18510	0.17118	0.07832	0.06924	0	0.00209	0.02195	0.04305	0.01152	0.00484	0.00264	0.01769	0.00538
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	0.00856
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	0.01235
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	0.00185
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	0.01661
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	0.05332
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	0.08697
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	0.13711
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	0.12498
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	0.15690
22	0	0.01883	0.02495	0.01512	0.02230	0.02878	0.01253	0.03243	0.04128	0.05464	0.09776	0.12516	0.15068
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	0.10048
24	0.00038	0	0.00215	0.01035	0.04088	0.00300	0.00340	0.00681	0.01036	0.01056	0.02829	0.03814	0.05868
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	0.01673
26	0.00327	0.01014	0.00133	0.00757	0.01335	0.00414	0	0	0.00435	0.00944	0.01927	0.00672	0.01119
27	0	0.00425	0.00554	0.00460	0.00309	0.00466	0.00244	0.00599	0.00598	0.00481	0.00812	0.01124	0.01806
28	0	0.00218	0	0.00113	0.00921	0.00066	0.00628	0	0.00196	0	0.00589	0	0.00526
29	0	0	0	0	0	0.00457	0.00488	0	0	0.00180	0.00312	0	0.00175
30	0	0	0	0	0.00729	0.00655	0	0.00231	0.00588	0	0	0	0.00230
31	0	0	0	0.00268	0	0.00394	0.00226	0	0.00569	0.00676	0.00727	0	0.01247

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	2019
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	0.991
8	0.605			1.481		0.891	0.710	0.519	0.452	1.021		0.910	1.256
9	0.420	1.054	1.736	0.948	0.873	0.596	0.869	0.972	0.577			0.705	0.956
10	0.322	0.581	0.663	0.803	1.888	1.225	0.714	0.531		1.479		0.589	0.788
11	0.301	0.251	0.227	0.383		1.119			0.593	1.200		0.945	0.689
12	0.189	0.178	0.291	0.584		1.043	0.499	0.237	0.445	0.761	1.057	0.734	0.899
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	0.507
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	0.513
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	1.016
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	0.314
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	0.207
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	0.149
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	0.122
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	0.121
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	0.113
22		0.767	0.451	0.433	0.392	0.267	0.479	0.312	0.220	0.183	0.180	0.130	0.111
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	0.147
24	4.020		0.823	0.576	0.295	0.831	0.894	0.643	0.431	0.469	0.332	0.305	0.187
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	0.304
26		1.083	0.869	0.564	0.543	0.788			0.679	0.498	0.502	0.439	0.410
27		1.018	0.654	0.791	1.018	0.673	0.915	0.688	0.644	0.600	0.528	0.435	0.355
28		1.070		1.060	0.630	1.301	0.816		1.069		0.700		0.585
29						0.780	0.785			0.988	1.109		1.022
30					0.836	0.645		0.997	0.610				0.980
31				1.014		0.693	1.045		0.539	0.464	0.604		0.380