



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

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EXECUTIVE SUMMARY

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.

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This report describes the scientific observer sampling programme carried out on trawl landings of jack mackerel (*Trachurus novaezelandiae*, *T. declivis*, and *T. murphyi*) in JMA 7 (central west coast) during the 2013–14 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. Over 88% of the 2013–14 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 2013–14 were similar to those from the six previous years. The age-frequency distributions for all species in 2013–14 had mean weighted CVs of 21% 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 65–71% in the JMA 7 TCEPR catch for all statistical areas and the six years of sampling, while *T. novaezelandiae* was 24–30% and *T. murphyi* was 3–8%.

1. INTRODUCTION

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

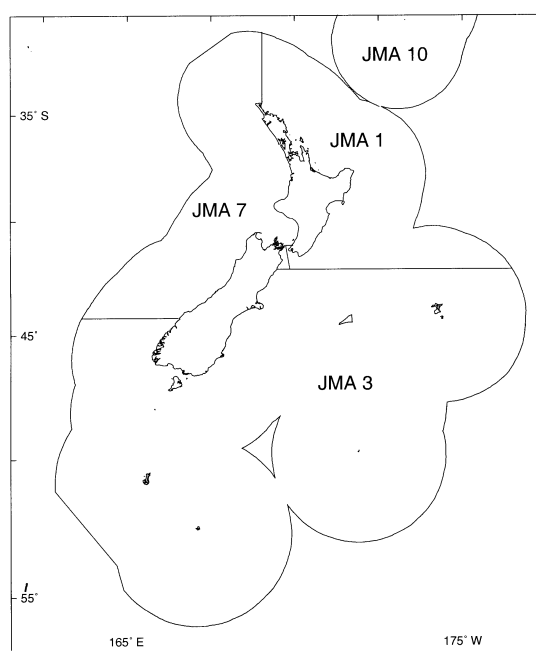


Figure 1: Jack mackerel administrative Fishstocks.

This report provides estimates of relative proportions and catch-at-age for the three *Trachurus* species in the commercial JMA 7 catch for 2013–14 using observer data. Similar data for previous years back to 2006–07 were presented by Taylor et al. (2011), Horn et al. (2012a), Horn et al. (2012b), Horn et al. (2013), and Horn et al. (2014b). 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 Objective 6 of Project MID201001E “Routine age determination of hoki and middle depth species from commercial fisheries and trawl surveys”, funded by the Ministry for Primary Industries (MPI). That objective is “To determine the age and size structure of the commercial catches of jack mackerel (all three species) in the JMA 7 fishery from samples collected at sea by the Observer Programme”.

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

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

2. METHODS

Catch sampling for length, sex, age, and species composition was carried out by observers primarily working on board large trawl vessels targeting jack mackerels. Sampling was generally carried out according to instructions developed at NIWA and included in the Scientific Observers Manual. Most tows in the observer dataset included estimated total jack mackerel catch and weights by species sampled from the tow. All observer data on jack mackerels sampled from JMA 7 in the 2013–14 fishing year were extracted for the analyses. As in previous analyses, estimated species proportions (by weight) in each sampled tow were assumed to be the same as the proportions in a randomly selected sample from the catch (Taylor et al. 2011). The observer data were examined for spatial and temporal variability, and this was compared with the spatial and temporal distribution of the entire commercial JMA 7 catch.

Commercial catch data extracted from the Ministry for Primary Industries catch-effort database “warehou” (Extract #9874 on 10 February 2015) 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 2013–14.

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 derivation of the five strata used in this analysis is shown in Appendix A of Horn et al. (2012b). Each fishing event from the catch-effort dataset and the observer dataset was allocated to one of the five strata, i.e.,

- west coast South Island (Statistical Areas 033 to 036),
- Statistical Areas 037 and 040 from October–January and May–June,
- Statistical Areas 037 and 040 from April and July–September,
- all remaining areas shallower than 124.5 m,
- all remaining areas deeper than 124.5 m.

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 2013–14 fishing year, using data and otoliths collected by observers. For each species, samples of otoliths (for each sex separately) from each 1 cm length class were selected approximately proportionally to their occurrence in the scaled length frequency, with the constraint that the number of otoliths in each length class (where available) was at least one. In addition, otoliths from fish in the extreme right hand tail of the scaled length frequency (constituting about 2% of that length frequency) were over-sampled. Target sample sizes were about 500 per species. Sets of five otoliths were embedded in blocks of clear epoxy resin and cured at 50°C. Once hardened, a 380µm thin transverse section was cut from each block through the primordia using a high speed saw. The thin section was washed, dried, and embedded under a cover slip on a glass microscopic slide. Thin sections were read with a bright field stereomicroscope at up to ×100 magnification. Zone counts were based on the number of complete opaque zones (i.e., opaque zones with translucent material outside them), which were counted to provide data for age estimates. Otoliths of *T. declivis* and *T. novaezelandiae* were read

following the validated methods described by Horn (1993) and Lyle et al. (2000). A validated ageing method has not yet been developed for *T. murphyi* in New Zealand waters (Beentjes et al. 2013). Otoliths from this species were interpreted similarly to those of *T. declivis*. However, they are notably harder to read, with presumed annual zones often being diffuse, split, or containing considerable microstructure (Taylor et al. 2002).

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.

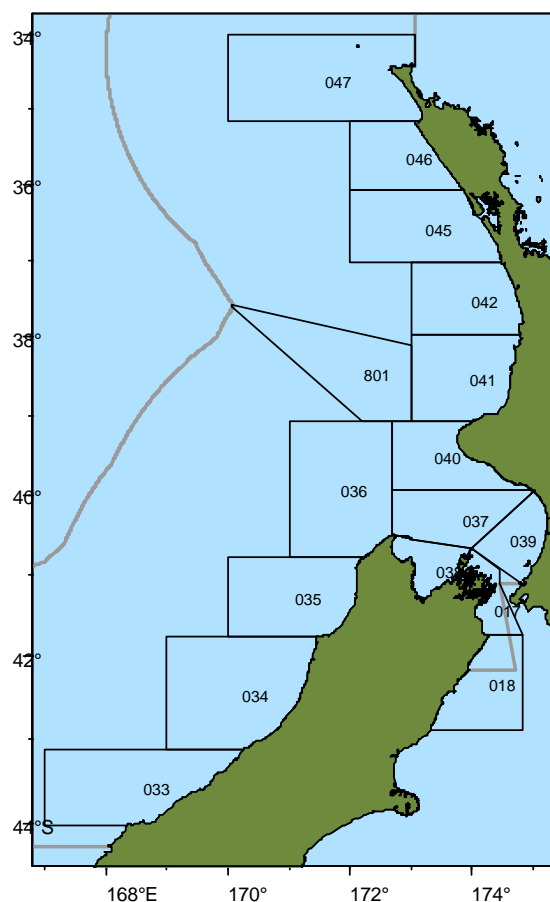


Figure 2: Statistical Areas referred to in the text.

3. RESULTS

3.1 Catch sampling

The landings distribution in 2013–14 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 in the same statistical areas (excluding 042) as well as off the northwest South Island (Areas 035–036) and offshore of the North Taranaki Bight (Area 801) (Table 1). Because the two fishery peaks were quite widely separated in time it was considered desirable to split the year into two equal parts (i.e., a split between March and April), and use separate age-length keys for each part (to account for the growth of fish, particularly of the younger age classes). In each time period, the data were analysed in the five strata determined previously (Taylor et al. 2011, Horn et al. 2012b).

In 2013–14, about 88% of the landed weight was sampled by observers (Table 1). Most of the estimated landings were derived from four Statistical Areas (037, 040–042), and these were all well sampled (Figure 3). The percentages of the catch sampled in the nine most productive months were all greater than 78% (Table 1). Only February could be considered under-sampled, although less than 3% of the total catch came from that month. 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.

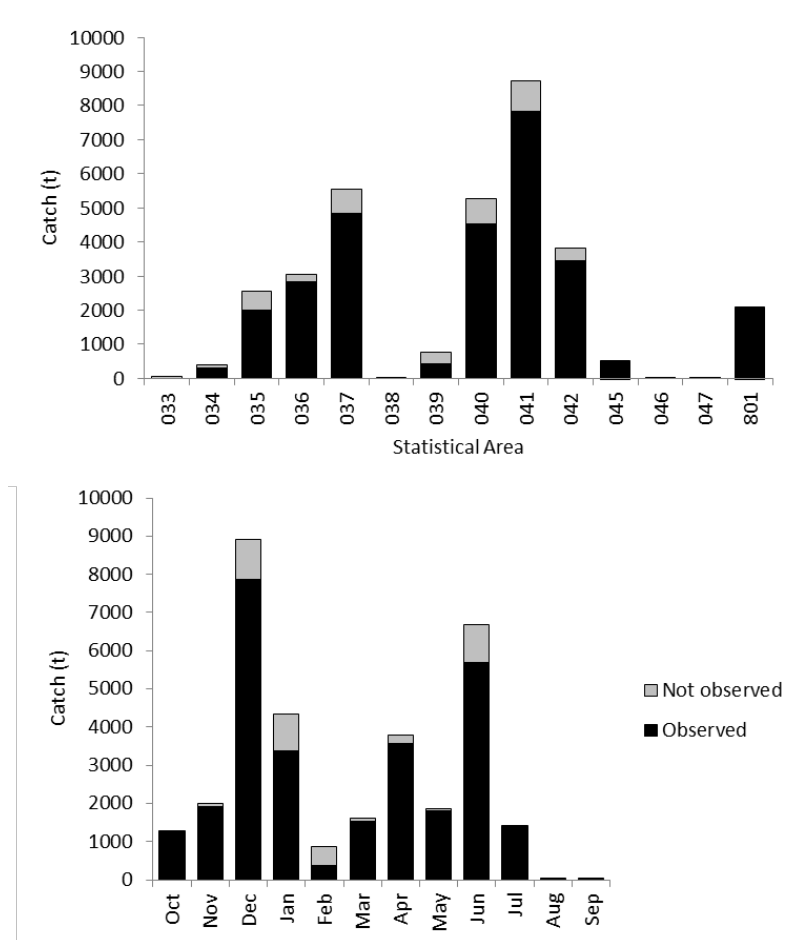


Figure 3: Observed landings and landings that were not observed, by Statistical Area and month, in 2013–14.

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 2013–14 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), 2013–14

Stat Area	Month												All
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
033	2	6	2	10	8	3	2	5	0	0	2	2	43
034	1	2	0	1	2	3	1	1	313	52	9	7	390
035	0	0	0	0	0	0	0	136	1 815	574	25	5	2 557
036	0	0	0	132	39	100	85	381	2 322	0		0	3 058
037	19	81	931	1 384	436	799	1 357	313	226			0	5 547
038	1	1	1	0	1	0	0	1	1	0	0	1	7
039	0	0	0	0	20	88	239	68	336	1	1	3	758
040	25	90	1 047	1 897	311	466	796	292	329	2	0	0	5 256
041	291	745	5 199	578	40	43	420	123	938	343	1	2	8 723
042	419	1 047	1 734	6	9	42	220	0	104	241	0	0	3 823
43–44	0	0	0	0			0	0	0	0	0	0	0
045	441	35	0	0	0	0	0		0	0	1	1	479
46–47	1	0	0	0	0	0	0	0	0	0	2	0	5
801			0	320		59	676	552	296	182			2 085
All	1 202	2 008	8 915	4 329	865	1 604	3 797	1 872	6 681	1 395	41	22	32 731

Sampled landings (t)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	All	%
033								0					0	0
034								0	259	52	4	4	320	82
035						0		126	1 305	554	21	3	2 008	79
036				62	0	87	105	468	2 113	0			2 835	93
037	20	73	839	1 082	229	896	1 158	266	276	0			4 838	87
038													0	0
039				21		18	194	24	169				426	56
040	24	90	1 056	1 428	124	459	844	169	286	49			4 530	86
041	323	752	4 532	470	5	0	395	136	896	317			7 827	90
042	455	964	1 453	0	9	0	224	0	100	247			3 451	90
43–44														0
045	472	43		0		0	0	0	0	0			515	108
46–47				0	0			0	0	0			0	0
801				313		84	634	629	274	172			2 106	101
All	1 293	1 922	7 880	3 375	367	1 543	3 555	1 818	5 680	1 391	25	7	28 857	88
%	108	96	88	78	42	96	94	97	85	100	61	32	88	

3.2 Species proportions

An examination of estimated species proportions by fishing year (Table 2) indicates that *T. declivis* (JMD) was the dominant species during the period examined, with 65–71% of landed weight in all years. *T. novaezelandiae* (JMN) was the second most frequently caught species at 24–30%. *T. murphyi* (JMM) was detected at a much lower and quite variable rate of 3–8%.

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.

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

3.3 Sex ratios

Sex ratios by fishing year since 2006–07 are shown in Table 3. Generally, ratios were around 50% for *T. declivis* and *T. novaezelandiae*, although *T. novaezelandiae* consistently had more females than males. The sex ratios for *T. murphyi* indicate a sampled population quite strongly biased towards males (i.e., 54–62%).

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

Fishing year	JMD		JMN		JMM	
	Males	Females	Males	Females	Males	Females
2006–07	51.6	48.4	49.5	50.5	54.8	45.2
2007–08	51.7	48.3	43.0	57.0	60.7	39.3
2008–09	52.5	47.5	45.7	54.3	56.9	43.1
2009–10	51.5	48.5	49.1	50.9	54.3	45.7
2010–11	46.8	53.2	43.4	56.6	56.9	43.1
2011–12	47.7	52.3	48.0	52.0	61.6	38.4
2012–13	50.8	49.2	50.0	50.0	55.3	44.7
2013–14	51.2	48.8	45.4	54.6	57.6	42.4

3.4 Catch-at-length

The estimated catch-at-length distributions, by species, for trawl-caught jack mackerel from JMA 7 in 2013–14 are plotted in Figure 4. For *T. novaezelandiae* there was one length mode (i.e., 30–32 cm). For *T. declivis* there was a strong length mode at 42–45 cm, and secondary modes at about 22–24 cm and 32–36 cm. The length range of *T. murphyi* was very narrow, with most fish 44–55 cm. For all species, there was little between-sex difference in the length distributions.

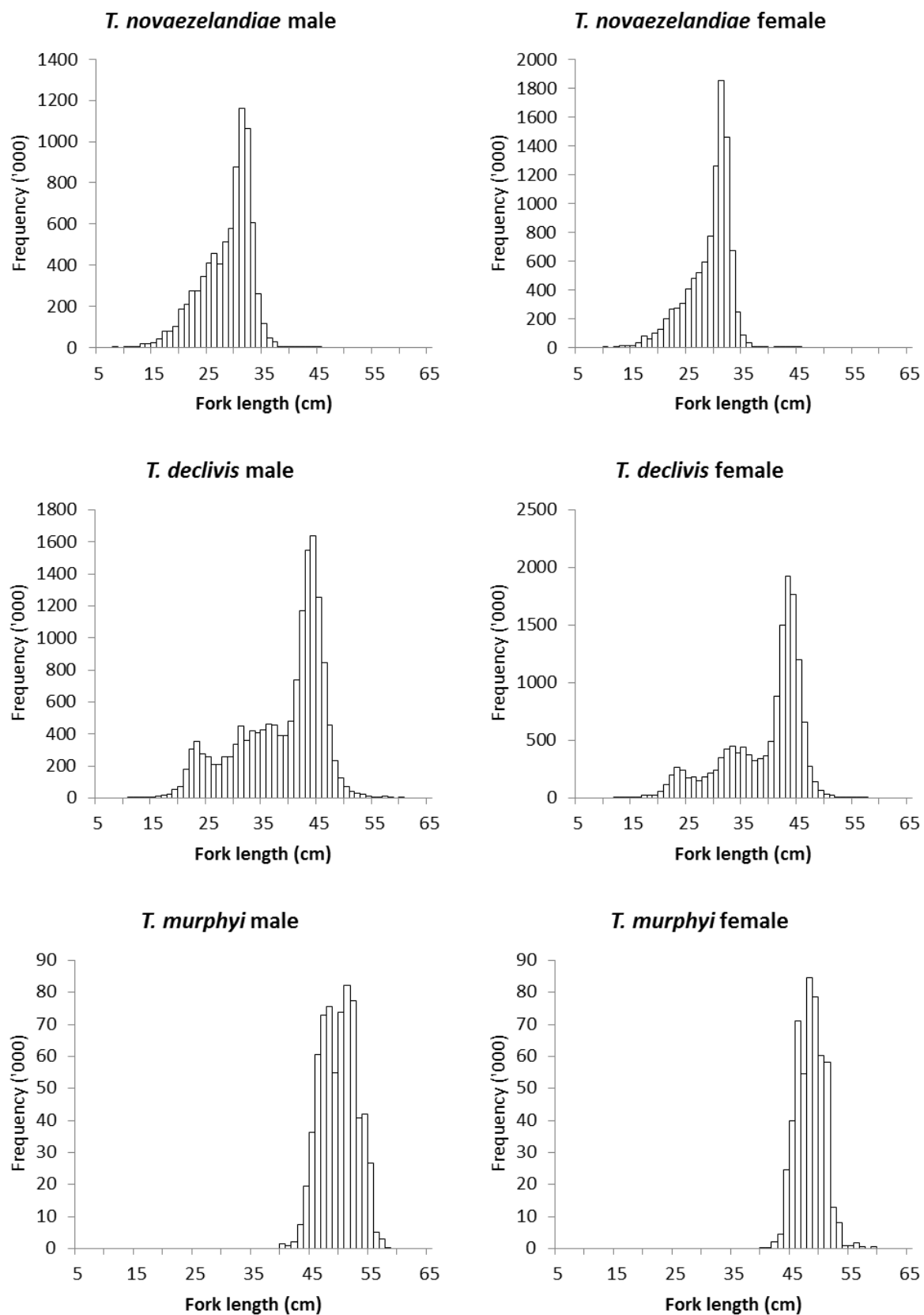


Figure 4: Estimated catch-at-length distributions, by species and sex, from JMA 7 in 2013–14.

3.5 Catch-at-age

The details of the estimated catch-at-age distributions for trawl-caught jack mackerel from JMA 7 in 2013–14 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* (15%), and *T. murphyi* (21%) 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 15 years. The catch of *T. declivis* had abundant fish aged 2–15 years old, but with a strong drop-off in fish older than 15 years. The catch of *T. murphyi* was dominated by 15–20 year old fish, with very few fish younger than 12 or older than 23 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 2013–14 fishing year. Summary statistics for the sample are also presented.

Age (years)	Male	CV	Female	CV	Total	CV
0	452	2.271	123	2.865	574	1.709
1	61 551	0.547	40 134	0.646	101 684	0.516
2	219 418	0.403	170 465	0.448	389 882	0.349
3	997 440	0.227	812 221	0.235	1 809 661	0.201
4	1 506 311	0.158	1 901 524	0.128	3 407 834	0.117
5	1 354 903	0.139	931 057	0.169	2 285 960	0.108
6	1 038 421	0.122	1 380 917	0.119	2 419 337	0.083
7	858 238	0.142	1 510 322	0.126	2 368 560	0.093
8	285 001	0.226	415 401	0.243	700 402	0.167
9	416 988	0.192	445 087	0.257	862 075	0.163
10	250 254	0.254	513 561	0.224	763 815	0.174
11	58 533	0.526	378 771	0.273	437 304	0.247
12	373 002	0.185	642 992	0.201	1 015 994	0.147
13	247 970	0.222	298 011	0.232	545 982	0.163
14	172 405	0.244	169 224	0.315	341 628	0.199
15	115 357	0.300	105 776	0.369	221 133	0.232
16	52 720	0.397	54 964	0.368	107 686	0.275
17	10 974	0.537	15 189	0.800	26 163	0.512
18	43 983	0.521	24 875	0.560	68 858	0.385
19	105 496	0.343	34 174	0.449	139 668	0.287
20	14 910	0.673	0	–	14 910	0.673
No. measured	14 108		16 263		30 371	
No. aged	275		299		574	
No. of tows sampled					397	
Mean weighted CV (%)	19.0		18.6		14.4	

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

Age (years)	Male	CV	Female	CV	Total	CV
0	4 783	1.347	2 059	2.568	6 842	1.197
1	59 500	0.651	136 739	0.469	196 238	0.441
2	705 461	0.425	597 941	0.493	1 303 402	0.409
3	1 503 375	0.233	671 610	0.351	2 174 985	0.222
4	820 150	0.247	937 098	0.267	1 757 250	0.191
5	1 894 178	0.147	1 212 377	0.209	3 106 555	0.129
6	929 140	0.190	1 503 854	0.141	2 432 995	0.114
7	1 339 448	0.171	982 765	0.203	2 322 212	0.136
8	986 123	0.170	870 487	0.183	1 856 610	0.123
9	1 289 779	0.146	1 229 993	0.141	2 519 771	0.099
10	1 363 157	0.134	1 428 046	0.133	2 791 203	0.093
11	996 134	0.174	1 293 464	0.143	2 289 597	0.108
12	1 285 894	0.142	769 080	0.174	2 054 973	0.111
13	568 155	0.200	526 650	0.224	1 094 805	0.142
14	400 923	0.219	567 838	0.206	968 760	0.146
15	569 715	0.203	648 177	0.192	1 217 892	0.138
16	102 881	0.445	412 958	0.257	515 839	0.221
17	216 402	0.314	194 442	0.333	410 844	0.230
18	114 824	0.354	229 367	0.360	344 191	0.254
19	40 440	0.649	44 225	0.625	84 664	0.456
20	25 027	0.781	66 215	0.496	91 243	0.409
21	3 496	0.929	211 838	0.342	215 335	0.335
22	0	–	0	–	0	–
23	53 201	0.690	6 858	1.015	60 060	0.624
No. measured	25 322		24 611		49 933	
No. aged	318		297		615	
No. of tows sampled					645	
Mean weighted CV (%)	19.9		21.4		15.4	

Table 6: Calculated numbers-at-age, separately by sex, with CVs, for *Trachurus murphyi* caught during commercial trawl operations in JMA 7 during the 2013–14 fishing year. Summary statistics for the sample are also presented.

Age (years)	Male	CV	Female	CV	Total	CV
5	4 657	0.766	0	0	4 657	0.766
6	3 245	1.138	105	2.599	3 350	1.105
7	5 754	0.741	0	–	5 754	0.741
8	9 079	0.589	3 648	1.041	12 726	0.519
9	3 319	0.972	0	–	3 319	0.972
10	9 427	0.593	3 739	1.118	13 165	0.531
11	0	–	0	–	0	–
12	26 181	0.347	24 862	0.357	51 043	0.237
13	26 437	0.390	26 682	0.371	53 119	0.261
14	23 075	0.405	28 157	0.338	51 231	0.252
15	45 501	0.264	49 577	0.275	95 077	0.184
16	103 092	0.176	72 295	0.247	175 387	0.145
17	154 270	0.144	86 196	0.224	240 466	0.113
18	97 680	0.192	68 841	0.234	166 521	0.142
19	64 819	0.225	26 011	0.379	90 830	0.183
20	52 660	0.244	38 459	0.309	91 118	0.192
21	14 067	0.487	23 207	0.418	37 274	0.313
22	19 557	0.426	18 893	0.430	38 450	0.312
23	9 004	0.578	18 598	0.477	27 602	0.368
24	6 649	0.726	1 421	1.132	8 070	0.643
25	3 835	0.792	2 743	0.952	6 578	0.607
26	0	–	0	–	0	–
27	0	–	7 101	0.688	7 101	0.688
28	0	–	0	–	0	–
28	0	–	0	–	0	–
30	0	–	2 743	0.997	2 743	0.997
No. measured	1 291		862		2 153	
No. aged	233		169		402	
No. of tows sampled					282	
Mean weighted CV (%)	26.6		32.5		20.7	

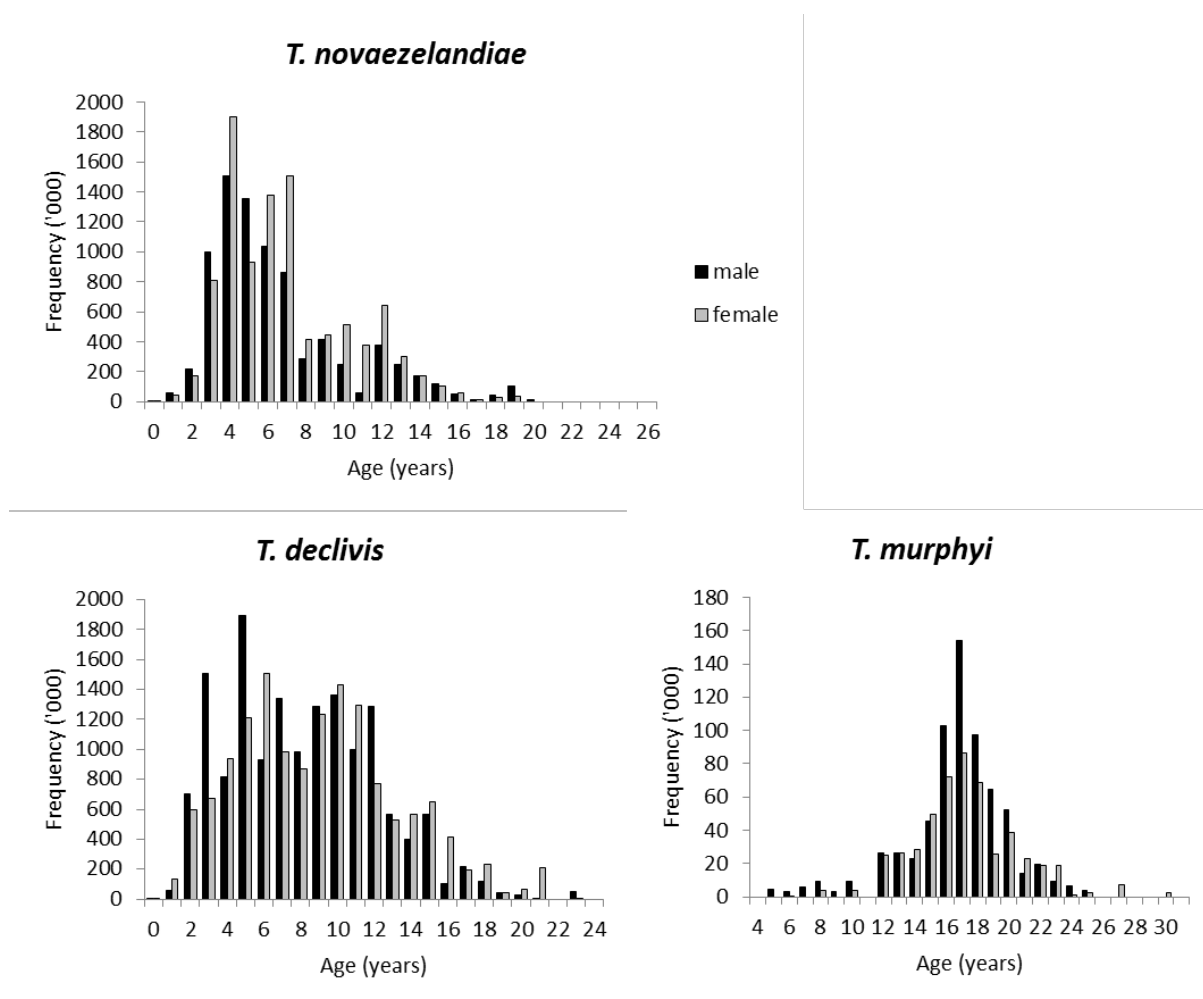


Figure 5: Estimated commercial catch-at-age distributions, by species and sex, from JMA 7 in 2013–14.

3.6 Data summaries

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

Trachurus novaezelandiae

Scaled catch-at-length frequencies by fishing year are shown in Figure 6. Most variation in abundance occurred with the fish shorter than 25 cm, presumably relating to the relative strengths of juvenile year classes. Scaled catch-at-age frequencies by fishing year, varied between years (Figure 6). However, some possible year class progressions can be postulated. The 1+ year class was strong in 2007–08, and maintained a relatively high abundance in all subsequent years. The 2+ year class in 2009–10 was also relatively strong and showed evidence of progression. 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 strong 4+ year class in 2013–14 was also relatively strong in the three previous years.

Trachurus declivis

Scaled catch-at-length frequencies by fishing year are shown in Figure 7 with most of the fish 16–50 cm. Most variation in abundance occurred with the fish shorter than 37 cm, presumably related to the relative strengths of juvenile year classes. Scaled catch-at-age-frequencies by fishing year, are shown in Figure 7. There was a wide range of ages in the catches, and the distributions varied between years. There was evidence of two relatively strong year classes aged 1+ and 2+ years in 2007–08 that maintained a relatively high abundance up to 2011–12, but were relatively weak from 2012–13. The 2011–12 1+ and 3+ year classes appeared to be relatively strong, and both were still strong as 3+ and 5+ in 2013–14.

Trachurus murphyi

Scaled catch-at-length frequencies by fishing year, are shown in Figure 8. All the distributions are unimodal at 49–51 cm (except for the 2013–14 distribution which has a broader mode from 46–51 cm), and are generally similar with few fish smaller than 45 cm. Scaled catch-at-age frequencies by fishing year (Figure 8) exhibit 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.

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

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

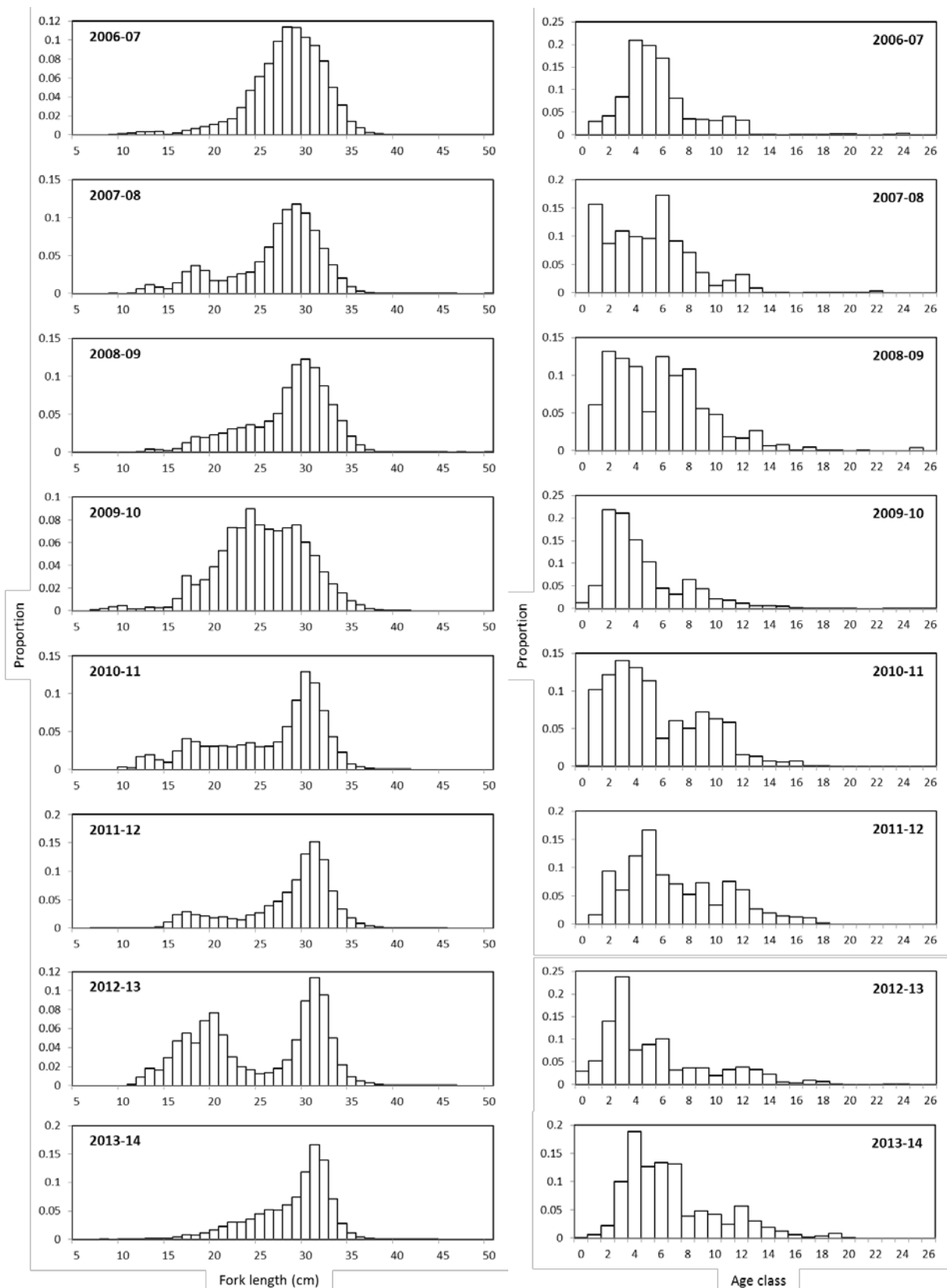


Figure 6: Scaled catch-at-length (left panel) and catch-at-age (right panel) proportions for the catch of *Trachurus novaezelandiae* sampled from the 2006–07 to 2013–14 fishing years.

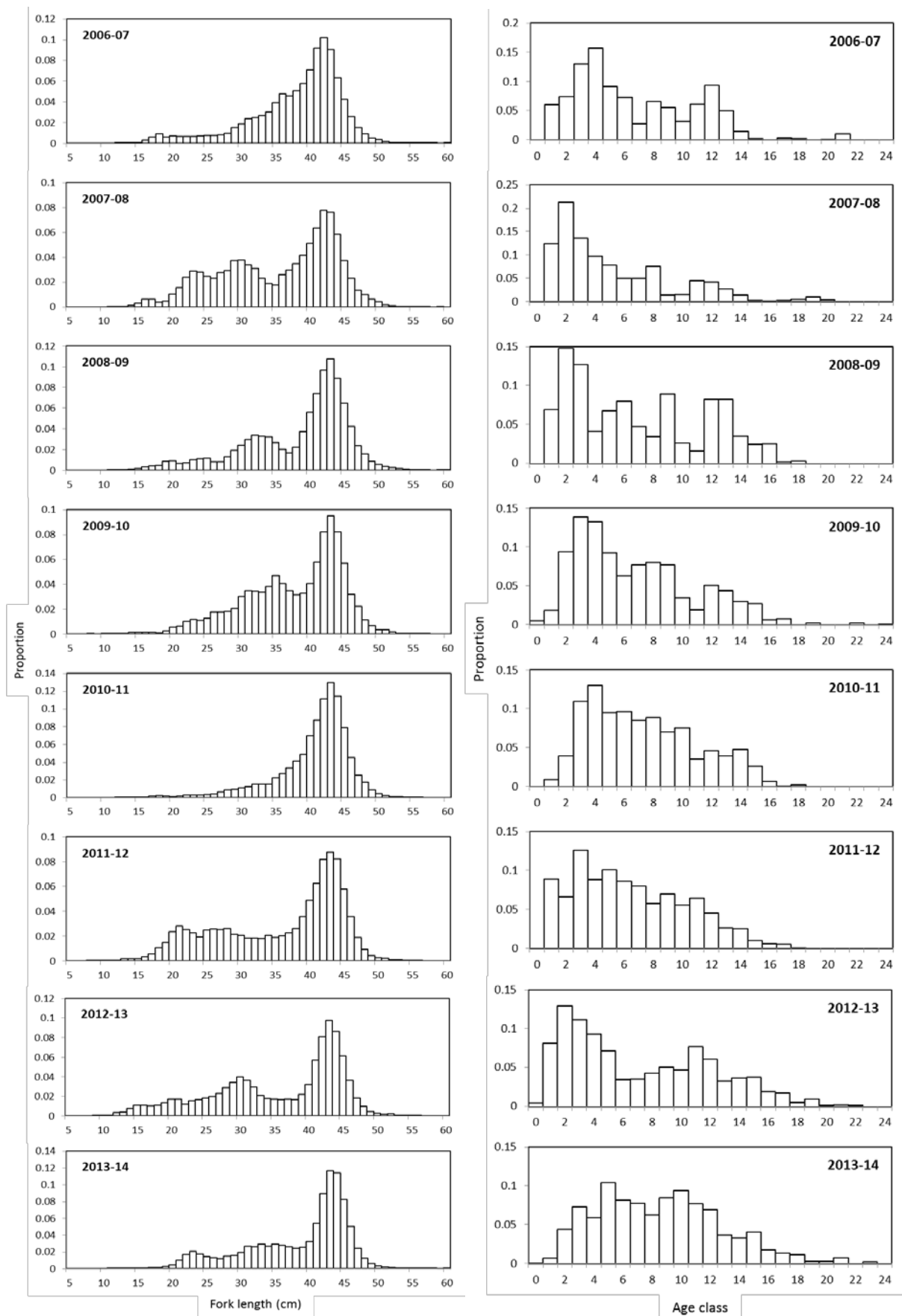


Figure 7: Scaled catch-at-length (left panel) and catch-at-age (right panel) proportions for the catch of *Trachurus declivis* sampled from the 2006–07 to 2013–14 fishing years.

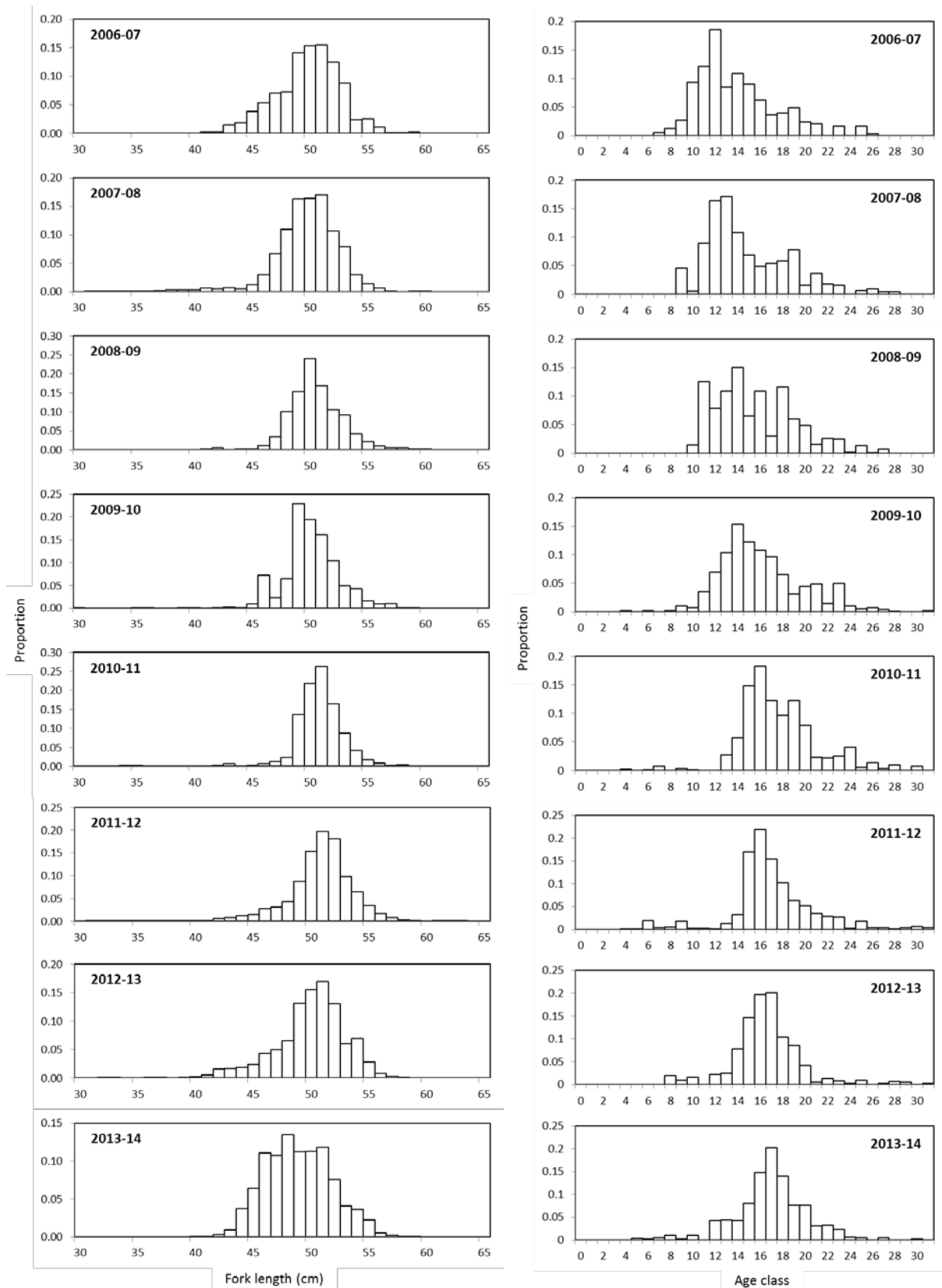


Figure 8: Scaled catch-at-length (left panel) and catch-at-age (right panel) proportions for the catch of *Trachurus murphyi* sampled from the 2006-07 to 2013-14 fishing years.

4. DISCUSSION

The 2013–14 jack mackerel trawl fishery was comprehensively sampled (as it was in all years since at least 2006–07). Sampling intensity was high in all months, and more than 78% of the catch was sampled in all months producing substantial landings. Spatially, there was very good coverage of catch in the heavily fished Statistical Areas (037, 040–042). Estimates of the 2013–14 catch-at-age for all three jack mackerel species had mean weighted CVs over all age classes of 21% or less, well below the target of 30%.

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, 4.0% of the aged *T. declivis* appeared as outliers that fitted well on the growth curve for *T. novaezelandiae*, and 6.5% of aged *T. novaezelandiae* were outliers that fitted well on the *T. declivis* growth curve. Such misidentifications are apparent only for the older and larger fish of both these species because the length-at-age ranges of both species overlapped significantly for the small, young fish. 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 significantly it was not possible to estimate any percentages.

Estimates of species proportions indicated a consistent predominance of *T. declivis* at 65–71% of total catch weight in the eight fishing years from which data were available. The percentage of *T. novaezelandiae* was also consistent temporally at 24–30%. The predominance of *T. declivis* overall is expected given that this species generally occurs deeper and further offshore than *T. novaezelandiae* and that most of the vessels targeting jack mackerels are restricted to fishing at least 12 n. miles, and often 25 n. miles off the coast.

Most of the *T. declivis* catch in all years comprised adult fish at least 37 cm long. Differences between years in the length distributions were primarily in the abundance of fish shorter than 37 cm, and was a consequence of variation in year class strengths. The position of the mode of large *T. declivis* in JMA 7 (centred on 43 cm) differs 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 mean age of *T. murphyi* in the catch generally increased over the eight sampled years. In 2006–07, most fish were 10–15 years old, compared with 15–20 years old in 2010–11 and 2011–12. This is indicative of a strong recruitment pulse, comprising several year classes, possibly as a result of immigration from international waters. These year classes are now growing through, with no evidence of any substantial new immigration or recruitment through spawning success. The 2013–14 length distribution contained more smaller fish (i.e. 45–48 cm) than in any other sampled year, but the age distribution mode continued its shift to the right in accordance with the hypothesis of a single migration pulse. The collected data on sex of *T. murphyi* indicated a population consistently biased towards males (i.e., 54–62% of sampled fish). *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, 62–71% of the sexed fish (Hurst & Bagley 1997).

The *T. novaezelandiae* catch also had a consistent strong adult length mode (at 28–31 cm) in all sampled years, although in 2009–10 the relative abundance of 2–4 year old fish (i.e., lengths of about 20–27 cm) outweighed the adult mode. The progression of some relatively strong year classes through the time series is apparent. Taylor (2008) noted that there was a preference in the JMA 7 trawl fishery for larger jack mackerel (i.e., *T. declivis*). Vessels attempting to maximise their catch of *T. declivis* may consequently not comprehensively sample the *T. novaezelandiae* population in the area, resulting in a greater degree of between-year variation in the *T. novaezelandiae* length and age distributions, so it is pleasing that year class progressions are still apparent under this sampling regime.

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

5. ACKNOWLEDGMENTS

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

This appendix lists the estimated proportions-at-age in the JMA 7 trawl fishery, by species and fishing year. The columns in each table are headed so that, for example, the year 2007 refers to the 2006–07 fishing year. Data are presented with sexes combined, in a format that can easily be converted to a CASAL input file in a single-sex model.

Table A1: Proportions-at-age (male, female, and unsexed combined), with CVs, for *T. novaezelandiae*, by fishing year.

Age	Proportion								CV							
	2007	2008	2009	2010	2011	2012	2013	2014	2007	2008	2009	2010	2011	2012	2013	2014
0	0	0	0	0.0127	0.0007	0	0.0284	0.0001				0.913	2.006		0.524	1.709
1	0.0294	0.1574	0.0605	0.0510	0.1021	0.0168	0.0531	0.0056	0.419	0.416	0.327	0.389	0.378	0.487	0.463	0.516
2	0.0422	0.0871	0.1319	0.2183	0.1216	0.0934	0.1399	0.0216	0.349	0.138	0.162	0.213	0.249	0.209	0.244	0.349
3	0.0846	0.1091	0.1225	0.2108	0.1408	0.0598	0.2380	0.1004	0.224	0.144	0.188	0.186	0.185	0.219	0.151	0.201
4	0.2088	0.0985	0.1116	0.1517	0.1312	0.1210	0.0765	0.1890	0.124	0.171	0.309	0.172	0.114	0.109	0.179	0.117
5	0.1970	0.0959	0.0509	0.1020	0.1137	0.1668	0.0875	0.1268	0.106	0.176	0.399	0.209	0.124	0.097	0.101	0.108
6	0.1693	0.1727	0.1244	0.0443	0.0367	0.0868	0.1012	0.1342	0.126	0.131	0.277	0.281	0.228	0.133	0.089	0.083
7	0.0819	0.0911	0.0992	0.0319	0.0604	0.0712	0.0320	0.1314	0.193	0.203	0.330	0.227	0.193	0.176	0.183	0.093
8	0.0358	0.0712	0.1079	0.0639	0.0503	0.0523	0.0360	0.0388	0.276	0.216	0.293	0.211	0.189	0.187	0.172	0.167
9	0.0334	0.0357	0.0557	0.0426	0.0722	0.0739	0.0370	0.0478	0.301	0.243	0.314	0.204	0.141	0.157	0.159	0.163
10	0.0316	0.0121	0.0485	0.0206	0.0631	0.0334	0.0199	0.0424	0.319	0.463	0.356	0.230	0.160	0.252	0.226	0.174
11	0.0404	0.0220	0.0180	0.0181	0.0586	0.0757	0.0321	0.0243	0.281	0.328	0.459	0.274	0.170	0.145	0.163	0.247
12	0.0324	0.0321	0.0167	0.0115	0.0160	0.0609	0.0379	0.0564	0.311	0.302	0.518	0.252	0.328	0.166	0.144	0.147
13	0.0010	0.0080	0.0270	0.0058	0.0131	0.0277	0.0323	0.0303	1.040	0.341	0.313	0.327	0.316	0.222	0.165	0.163
14	0.0012	0.0006	0.0062	0.0066	0.0071	0.0200	0.0224	0.0189	0.944	1.193	0.454	0.367	0.429	0.272	0.179	0.199
15	0	0.0002	0.0081	0.0046	0.0051	0.0143	0.0053	0.0123		1.358	0.655	0.336	0.392	0.305	0.358	0.232
16	0.0004	0	0.0003	0.0027	0.0067	0.0127	0.0038	0.0060	1.203		1.060	0.494	0.451	0.311	0.458	0.275
17	0.0008	0.0012	0.0048	0.0005	0.0006	0.0110	0.0087	0.0015	0.643	1.028	1.002	0.594	1.160	0.374	0.280	0.512
18	0.0006	0.0004	0.0004	0.0001	0.0001	0.0024	0.0062	0.0038	0.864	1.021	1.251	2.105	1.712	0.565	0.317	0.385
19	0.0026	0.0011	0.0003	0.0001	0	0	0.0011	0.0077	0.671	0.949	0.884	1.916			0.769	0.287
20	0.0025	0.0003	0	0.0000	0	0	0	0.0008	0.898	0.895		1.253				0.673
21	0	0.0003	0.0009	0	0	0	0	0		0.835	0.769					
22	0	0.0029	0	0	0	0	0	0		0.572						
23	0.0010	0	0	0.0000	0	0	0.0005	0	1.022			1.134			0.835	
24	0.0034	0	0	0.0001	0	0	0.0002	0	0.544			0.887			0.903	
25	0	0	0.0042	0.0000	0	0	0	0			0.518	2.166				
26	0	0	0	0.0002	0	0	0	0				1.049				

Table A2: Proportions-at-age (male, female, and unsexed combined), with CVs, for *T. declivis*, by fishing year.

Age	Proportion								CV							
	2007	2008	2009	2010	2011	2012	2013	2014	2007	2008	2009	2010	2011	2012	2013	2014
0	0	0	0	0.0054	0	0	0.0041	0.0002				0.428			0.793	1.197
1	0.0605	0.1245	0.0693	0.0180	0.0092	0.0889	0.0813	0.0066	0.220	0.175	0.170	0.326	0.355	0.267	0.238	0.441
2	0.0737	0.2125	0.1478	0.0942	0.0390	0.0659	0.1290	0.0437	0.172	0.145	0.134	0.207	0.191	0.229	0.199	0.409
3	0.1307	0.1357	0.1273	0.1387	0.1091	0.1261	0.1118	0.0729	0.141	0.119	0.144	0.141	0.134	0.162	0.161	0.222
4	0.1574	0.0972	0.0416	0.1327	0.1301	0.0886	0.0933	0.0589	0.118	0.176	0.311	0.130	0.113	0.182	0.161	0.191
5	0.0907	0.0784	0.0678	0.0923	0.0949	0.1004	0.0718	0.1042	0.244	0.227	0.299	0.160	0.143	0.115	0.153	0.129
6	0.0728	0.0492	0.0798	0.0629	0.0963	0.0859	0.0341	0.0816	0.303	0.325	0.322	0.190	0.153	0.114	0.170	0.114
7	0.0270	0.0491	0.0475	0.0767	0.0851	0.0796	0.0351	0.0779	0.503	0.256	0.385	0.168	0.169	0.117	0.149	0.136
8	0.0654	0.0755	0.0343	0.0801	0.0883	0.0575	0.0429	0.0623	0.310	0.371	0.437	0.186	0.175	0.140	0.135	0.123
9	0.0549	0.0131	0.0894	0.0768	0.0701	0.0700	0.0503	0.0845	0.309	0.503	0.260	0.177	0.176	0.124	0.125	0.099
10	0.0315	0.0154	0.0257	0.0345	0.0750	0.0556	0.0469	0.0936	0.486	0.482	0.463	0.300	0.184	0.137	0.140	0.093
11	0.0618	0.0443	0.0160	0.0192	0.0354	0.0642	0.0771	0.0768	0.272	0.329	0.635	0.367	0.230	0.127	0.099	0.108
12	0.0934	0.0422	0.0819	0.0507	0.0458	0.0454	0.0605	0.0689	0.254	0.301	0.286	0.214	0.216	0.158	0.113	0.111
13	0.0496	0.0260	0.0823	0.0435	0.0391	0.0256	0.0330	0.0367	0.363	0.454	0.281	0.236	0.237	0.208	0.149	0.142
14	0.0137	0.0138	0.0352	0.0299	0.0478	0.0254	0.0363	0.0325	0.537	0.456	0.476	0.268	0.209	0.183	0.143	0.146
15	0.0015	0.0024	0.0240	0.0264	0.0256	0.0099	0.0372	0.0408	0.858	0.912	0.400	0.273	0.295	0.339	0.149	0.138
16	0	0.0005	0.0251	0.0057	0.0068	0.0055	0.0193	0.0173		0.686	0.335	0.469	0.545	0.472	0.211	0.221
17	0.0031	0.0017	0.0023	0.0075	0.0004	0.0051	0.0172	0.0138	0.973	0.966	0.581	0.647	1.049	0.438	0.243	0.230
18	0.0013	0.0042	0.0028	0	0.0020	0.0005	0.0048	0.0115	1.050	0.395	0.633		1.091	0.690	0.399	0.254
19	0	0.0104	0	0.0023	0	0	0.0094	0.0028		0.762		1.020			0.292	0.456
20	0.0006	0.0038	0	0	0	0	0.0011	0.0031	1.101	0.975					0.868	0.409
21	0.0104	0	0	0	0	0	0.0021	0.0072	0.430						0.701	0.335
22	0	0	0	0.0023	0	0	0.0013	0				0.963			0.801	
23	0	0	0	0	0	0	0	0.0020								0.624
24	0	0	0	0.0003	0	0	0	0				1.254				

Table A3: Proportions-at-age (male, female, and unsexed combined), with CVs, for *T. murphyi*, by fishing year.

Age	Proportion								CV							
	2007	2008	2009	2010	2011	2012	2013	2014	2007	2008	2009	2010	2011	2012	2013	2014
4	0	0	0	0.0020	0.0026	0.0018	0	0				2.236	1.146	1.047		
5	0	0	0	0	0	0.0021	0	0.0039						0.747		0.766
6	0	0	0	0.0021	0.0005	0.0193	0	0.0028				1.423	2.163	0.420		1.105
7	0.0055	0	0	0	0.0073	0.0044	0	0.0049	1.041				1.841	1.093		0.741
8	0.0126	0	0	0.0026	0	0.0059	0.0201	0.0107	0.625			1.481		0.891	0.710	0.519
9	0.0272	0.0458	0	0.0105	0.0036	0.0180	0.0086	0.0028	0.413	0.333		0.948	0.873	0.596	0.869	0.972
10	0.0935	0.0053	0.0144	0.0071	0.0012	0.0030	0.0157	0.0111	0.335	0.594	0.615	0.803	1.888	1.225	0.714	0.531
11	0.1216	0.0895	0.1258	0.0350	0	0.0030	0	0	0.301	0.263	0.222	0.383		1.119		
12	0.1857	0.1634	0.0784	0.0692	0	0.0021	0.0219	0.0431	0.201	0.190	0.304	0.584		1.043	0.499	0.237
13	0.0847	0.1708	0.1092	0.1040	0.0273	0.0128	0.0252	0.0448	0.282	0.172	0.241	0.178	0.363	0.511	0.432	0.261
14	0.1092	0.1083	0.1499	0.1530	0.0567	0.0320	0.0779	0.0432	0.231	0.248	0.208	0.233	0.235	0.322	0.231	0.252
15	0.0900	0.0687	0.0657	0.1227	0.1488	0.1694	0.1466	0.0802	0.300	0.323	0.318	0.271	0.144	0.119	0.142	0.184
16	0.0628	0.0484	0.1092	0.1080	0.1823	0.2194	0.1972	0.1479	0.410	0.309	0.235	0.192	0.130	0.102	0.111	0.145
17	0.0363	0.0538	0.0305	0.0965	0.1224	0.1544	0.2004	0.2028	0.514	0.318	0.299	0.178	0.174	0.119	0.107	0.113
18	0.0395	0.0580	0.1163	0.0658	0.0962	0.1019	0.1044	0.1405	0.476	0.380	0.243	0.222	0.183	0.165	0.145	0.142
19	0.0489	0.0783	0.0606	0.0308	0.1227	0.0633	0.0860	0.0766	0.639	0.306	0.334	0.304	0.155	0.182	0.164	0.183
20	0.0244	0.0154	0.0486	0.0450	0.0784	0.0514	0.0417	0.0769	0.722	0.521	0.371	0.235	0.228	0.198	0.245	0.192
21	0.0211	0.0364	0.0159	0.0492	0.0233	0.0349	0.0055	0.0314	0.647	0.436	0.821	0.269	0.374	0.231	0.664	0.313
22	0	0.0180	0.0256	0.0151	0.0223	0.0288	0.0125	0.0324		0.770	0.406	0.433	0.392	0.267	0.479	0.312
23	0.0168	0.0160	0.0251	0.0501	0.0255	0.0270	0.0076	0.0233	1.119	0.755	0.541	0.273	0.340	0.298	0.487	0.368
24	0	0	0.0024	0.0103	0.0409	0.0030	0.0034	0.0068			0.778	0.576	0.295	0.831	0.894	0.643
25	0.0168	0.0063	0.0138	0.0048	0.0051	0.0177	0.0092	0.0055	1.093	1.019	0.854	0.655	0.763	0.336	0.532	0.607
26	0.0033	0.0097	0.0009	0.0076	0.0134	0.0041	0	0	1.247	1.032	1.217	0.564	0.543	0.788		
27	0	0.0041	0.0078	0.0046	0.0031	0.0047	0.0024	0.0060		0.980	0.643	0.791	1.018	0.673	0.915	0.688
28	0	0.0039	0	0.0011	0.0092	0.0007	0.0063	0		0.933		1.060	0.630	1.301	0.816	
29	0	0	0	0	0	0.0046	0.0049	0						0.780	0.785	
30	0	0	0	0	0.0073	0.0066	0	0.0023					0.836	0.645		0.997
31	0	0	0	0.0027	0	0.0039	0.0023	0				1.014		0.693	1.045	