Ministry for Primary Industries
Manatū Ahu Matua

Commercial catch sampling for species proportion, sex, length, and age of jack mackerels in JMA 7 in the 2014–15 fishing year, with a summary of all available data sets

New Zealand Fisheries Assessment Report 2017/39

P.L. Horn
C. Ó Maolagáin
D. Hulston
S.L. Ballara

ISSN 1179-5352 (online)
ISBN 978-1-77665-642-4 (online)

July 2017

New Zealand Government

Growing and Protecting New Zealand

Requests for further copies should be directed to:

Publications Logistics Officer
Ministry for Primary Industries
PO Box 2526
WELLINGTON 6140

Email: brand@mpi.govt.nz
Telephone: 0800 00 83 33
Facsimile: 04-894 0300

This publication is also available on the Ministry for Primary Industries websites at:
http://www.mpi.govt.nz/news-and-resources/publications
http://fs.fish.govt.nz go to Document library/Research reports

Table of Contents

EXECUTIVE SUMMARY

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

***New Zealand Fisheries Assessment Report 2017/39*. 29 p.**

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 2014–15 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 80% of the 2014–15 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 2014–15 were similar to those from the eight previous years. The age-frequency distributions for all species in 2014–15 had mean weighted CVs of 19% or less, which bettered the target of 30%. There was clear variation in catch-at-age between years for all species probably because of the progression of year classes with different relative strengths.

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

1. INTRODUCTION

Commercial catches of jack mackerel are recorded as an aggregate of the three species (*Trachurus declivis*, *T. murphyi*, and *T. novaezelandiae*) under the general code JMA, so separate species catch information is not available from 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. Since the mid 2000s the JMA 7 fishery was primarily a trawl fishery with a small proportion of catches made using purse seine or set net. Before then, larger proportions of the catch came from purse seine fishing (Taylor & Julian 2008).

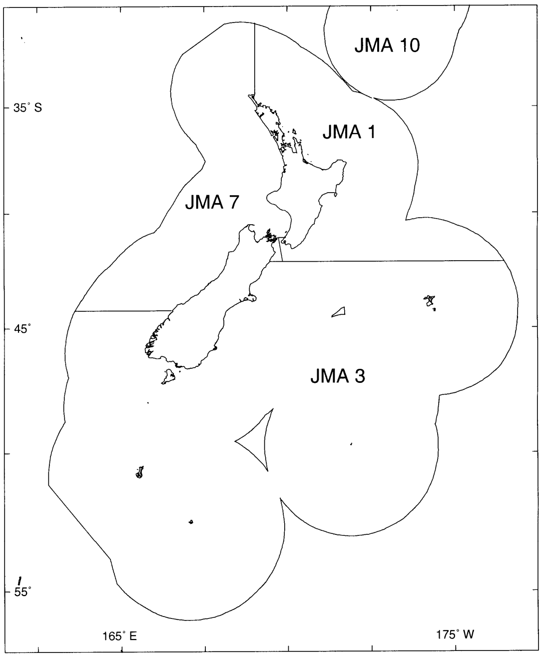


Figure 1: Jack mackerel administrative Fishstocks.

This report provides estimates of relative proportions and catch-at-age for the three *Trachurus* species in the commercial JMA 7 catch for 2014–15 using observer data. Similar data were presented by Taylor et al. (2011) for 2006–07, 2007–08 and 2008–09, Horn et al. (2012a) for 2009–10, Horn et al. (2012b) for 2010–11, Horn et al. (2013) for 2011–12, Horn et al. (2014b) for 2012–13, and Horn et al. (2015) for 2013–14. Summaries of the time series of catch-at-age estimates, sex ratios and species proportions for the JMA 7 catch are also presented. This document fulfils the reporting requirements relating to jack mackerels in objective 1 of Project MID201501 "Routine age determination of hoki and middle depth species from commercial fisheries and trawl surveys", funded by the Ministry for Primary Industries (MPI). That objective is "To determine catch-at-age for commercial catches and resource surveys of specified middle depth and deepwater fishstocks".

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

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

2. METHODS

Catch sampling for length, sex, age, and species composition was carried out by observers primarily working on board large trawl vessels targeting jack mackerels. Sampling was generally carried out according to instructions developed at NIWA and included in the Scientific Observers Manual. Most tows in the observer dataset included estimated total jack mackerel catch and weights by species sampled from the tow. All observer data on jack mackerels sampled from JMA 7 in the 2014–15 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 #10477 on 14 March 2016) 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 2014–15.

Stratification of the data was required because the observer coverage varied with both month and statistical area, the fishery was not consistent throughout the year, and the species composition varied across area and depth (Taylor et al. 2011). The stratification used for years 2006–07 to 2013–14 was derived by Taylor et al. (2011) based on data from the first three years of that series (and shown in appendix A of Horn et al. (2012b)). The Deepwater Working Group questioned whether that stratification was still valid for the current fishery, so a re-analysis was conducted (Appendix A). The resulting stratification differed little to that of Taylor et al. (2011) and is adopted here. Consequently, each fishing event from the catch-effort dataset and the observer dataset was allocated to one of the five strata, i.e.,

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

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

Ageing was completed for all three *Trachurus* species caught by trawl in Statistical Areas 033–047 and 801 of JMA 7 (Figure 2) in the 2014–15 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 380 µm thin transverse section was cut from each block through the primordia using a high speed saw. The thin section was washed, dried, and embedded under a cover slip on a glass microscopic slide. Thin sections were read with a bright field stereomicroscope at up to ×100 magnification. Zone counts were based on the number of complete opaque zones (i.e., opaque zones with translucent material outside them), which were counted to provide data for age estimates. Otoliths of *T. declivis* and *T. novaezelandiae* were read following the validated methods described by Horn (1993) and Lyle et al. (2000). A validated ageing method has not yet been developed for *T. murphyi* in New Zealand waters (Beentjes et al. 2013). Otoliths from this species were interpreted similarly to those of *T. declivis*. However, they are notably harder to read, with presumed annual zones often being diffuse, split, or containing considerable microstructure (Taylor et al. 2002).

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.

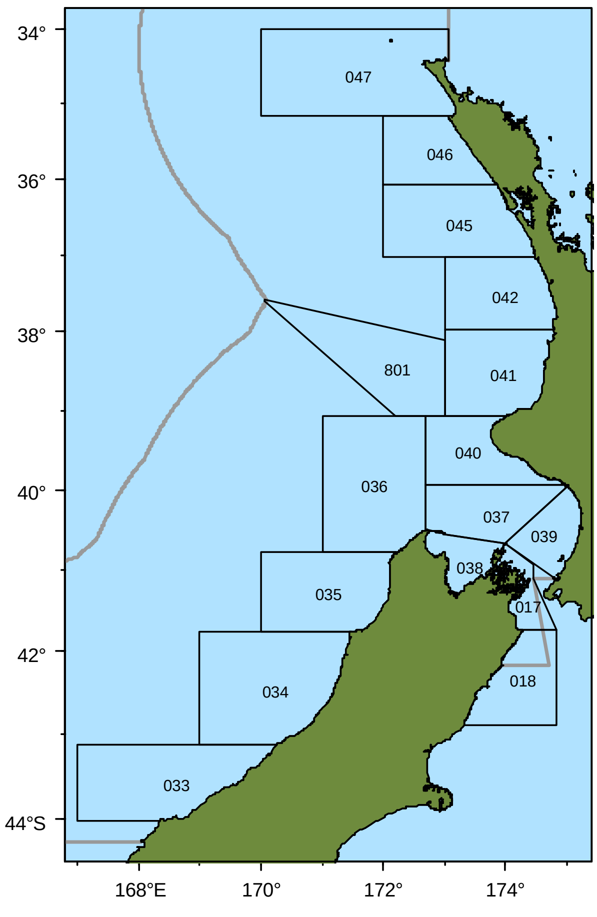


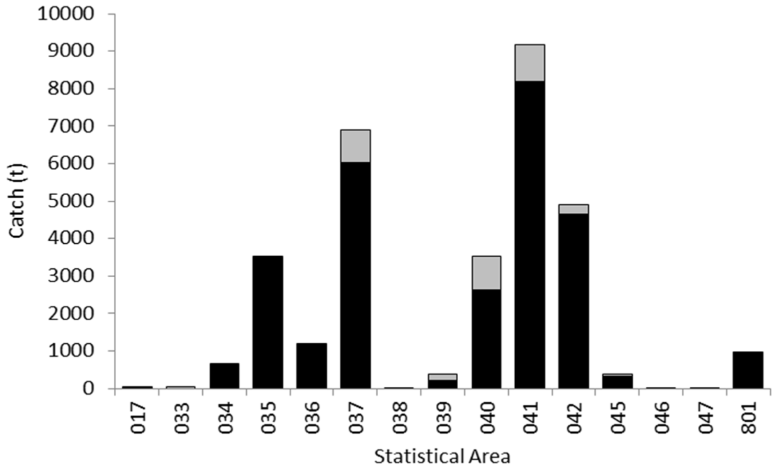
Figure 2: Statistical Areas referred to in the text.

3. RESULTS

3.1 Catch sampling

The landings distribution in 2014–15 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 April–June and concentrated off the northwest South Island (Areas 035–036) in June and in the South Taranaki Bight (Area 037) in April (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 described above.

In 2014–15, about 89% of the landed weight was sampled by observers (Table 1). Most of the estimated landings were derived from four Statistical Areas (035, 037, 040–042), and these were all well sampled (Figure 3). The percentages of the catch sampled in the five most productive months were all greater than 86% (Table 1), and no months could be considered under-sampled. Clearly, the sampling of the whole fishery was satisfactory to estimate the overall catch-at-age. The estimated catch weight sampled in some months and areas was slightly greater than the estimated catch. This can occur if observers and skippers record different estimated catch weights for a tow, or if the recorded location of an individual tow differs in the two databases resulting in it being allocated to different statistical areas.



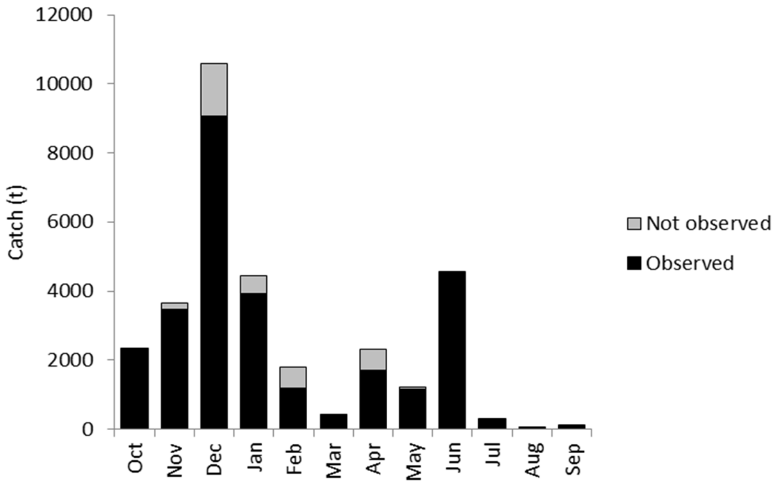


Figure 3: Jack mackerel observed landings and landings that were not observed, by Statistical Area and month, in 2014–15.

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 2014–15 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), 2014–15

Stat													Month
Area	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	All
017	1	2	0	1	3	1	1	3	2	0	0	0	14
033	4	6	5	4	8	7	1	6	1	1	2	4	49
034	2	1	1	1	1	0	2	17	514	68	26	35	667
035	142	0	0	0	0	0	0	38	3 054	225	2	78	3 539
036	102	0	1	0	10	0	2	136	894	0		0	1 145
037	68	289	899	2 070	1 056	50	1 912	496	68			1	6 909
038	1	0	3	0	0	1	0	1	0	0	0	0	7
039	0	0	0	0	19	0	349	8	0	0	1	1	379
040	2	255	728	1 456	716	7	52	273	42	0	2	0	3 532
041	168	2 005	6 712	257	0	1	0	25	0	1	2	0	9 170
042	1 083	1 089	2 226	465	0	49	2	0	0	0	0	0	4 914
43–44	0	0	0	0			0	0	0	0	0	0	0
045	345	0	0	33	0	0	0		0	0	1	1	379
46–47	0	1	0	0	0	0	0	0	0	0	2	1	5
801			15	144		237	12	211	0	0			968
All	2 266	3 649	10 590	4 432	1 813	352	2 332	1 213	4 575	297	38	121	31 678

Sampled landings (t)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	All	%
017					3	0	0	0	0				3	21
033													0	0
034	1							24	495	63	30	26	639	96
035	156							36	2 987	239	1	74	3 493	99
036	106				9		1	134	943		0		1 193	104
037	76	281	837	2 141	643	56	1 488	451	48				6 021	87
038													0	0
039				0	15		168	23					206	54
040	0	210	578	951	516	7	36	270	54				2 622	74
041	181	1 926	5 723	231		90	0	28					8 180	89
042	1 208	1 062	1 908	422	0	52	0	0	0			0	4 653	95
43–44														0
045	280	0		33	0	0	0	0			0		314	83
46–47		0					0	0			0	0	1	20
801	354		13	156		240	13	198					974	101
All	2 362	3 478	9 060	3 935	1 187	446	1 707	1 163	4 527	302	31	102	28 299	89
%	104	95	86	89	65	127	73	96	99	102	82	84	89	

3.2 Species proportions

An examination of estimated species proportions by fishing year (Table 2) indicates that *T. declivis* (JMD) was the dominant species caught from 2006–07 to 2014–15, with 61–71% of landed weight in all years. *T. novaezelandiae* (JMN) was the second most frequently caught species at 24–33%. *T. murphyi* (JMM) was detected at a much lower and quite variable rate of 3–8%. The 2014–15 fishing year produced the lowest proportion of *T. declivis*, and the highest proportion and absolute catch of *T. novaezelandiae*, in the time series presented here.

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

	Species proportions (%)			Estimated catch (t)			Landed catch (t)		
Fishing year	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
2014–15	60.7	33.0	6.3	19 231	10 447	1 999	20 623	11 204	2 144

3.3 Sex ratios

Sex ratios by fishing year since 2006–07 are shown in Table 3. 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% from 2006–07 to 2013–14), although the 2014–15 sample had almost equal proportions.

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

	JMD		JMN		JMM	
Fishing year	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
2014–15	46.2	53.8	44.5	55.5	50.2	49.8

3.4 Catch-at-length

The estimated catch-at-length distributions, by species, for trawl-caught jack mackerel from JMA 7 in 2014–15 are plotted in Figure 4. For *T. novaezelandiae* there was one length mode (i.e., 31–32 cm). For *T. declivis* there was a strong length mode at 43–45 cm, and secondary modes at about 10–20 cm and 30–34 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.

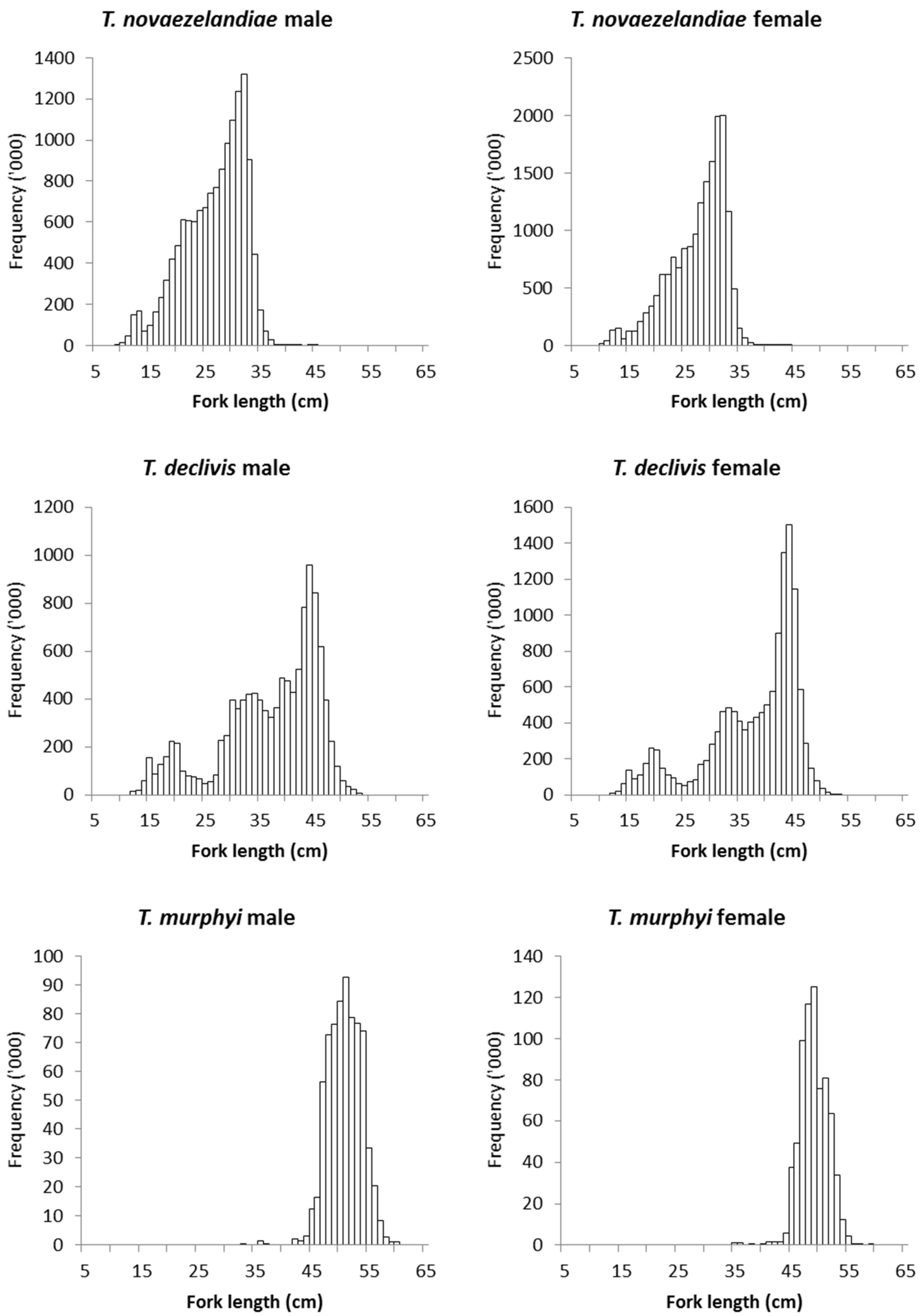


Figure 4: Estimated catch-at-length distributions, by species and sex, from JMA 7 in 2014–15.

3.5 Catch-at-age

The details of the estimated catch-at-age distributions for trawl-caught jack mackerel from JMA 7 in 2014–15 are presented for *T. novaezelandiae* in Table 4, *T. declivis* in Table 5, and *T. murphyi* in Table 6. The mean weighted CVs for *T. novaezelandiae* (15%), *T. declivis* (16%), and *T. murphyi* (19%) 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 2–10 year old fish, with very few fish older than 15 years. The catch of *T. declivis* had abundant fish aged 1 and 4–12 years old, but with a relatively strong drop-off in fish older than 15 years. The catch of *T. murphyi* was dominated by 16–20 year old fish, with very few fish younger than 13 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 2014–15 fishing year. Summary statistics for the sample are also presented.

Age (years)	Male	CV	Female	CV	Total	CV
1	240 380	0.521	56 766	1.059	297 146	0.545
2	926 366	0.335	793 453	0.405	1 719 817	0.333
3	604 017	0.358	826 766	0.305	1 430 782	0.249
4	1 341 351	0.213	1 582 468	0.202	2 923 819	0.158
5	2 862 402	0.124	2 180 232	0.144	5 042 635	0.100
6	1 510 121	0.164	2 569 447	0.126	4 079 567	0.096
7	1 324 734	0.160	1 641 129	0.154	2 965 863	0.109
8	1 245 011	0.168	1 831 459	0.143	3 076 471	0.113
9	769 105	0.197	1 970 458	0.131	2 739 564	0.108
10	881 072	0.168	1 135 406	0.166	2 016 477	0.115
11	325 680	0.291	755 867	0.216	1 081 548	0.172
12	283 428	0.307	675 382	0.214	958 810	0.175
13	394 087	0.265	314 683	0.304	708 769	0.197
14	457 070	0.230	486 650	0.258	943 720	0.173
15	258 318	0.323	251 638	0.310	509 956	0.232
16	259 062	0.320	185 282	0.365	444 344	0.248
17	90 869	0.519	18 774	0.814	109 643	0.453
18	103 643	0.527	63 699	0.587	167 341	0.401
19	38 955	0.759	67 947	0.749	106 903	0.547
20	10 766	0.606	0	–	10 766	0.606
21	24 635	0.812	0	–	24 635	0.812
No. measured		15 858		20 858		36 716
No. aged		282		325		607
No. of tows sampled						453
Mean weighted CV (%)		21.3		19.1		15.1

Table 5: Calculated numbers-at-age, separately by sex, with CVs, for *Trachurus declivis* caught during commercial trawl operations in JMA 7 during the 2014–15 fishing year. Summary statistics for the sample are also presented.

Age (years)	Male	CV	Female	CV	Total	CV
1	783 986	0.330	896 989	0.314	1680 975	0.298
2	480 560	0.322	469 175	0.326	949 734	0.257
3	388 326	0.362	283 742	0.293	672 068	0.255
4	1 519 368	0.177	1 326 854	0.182	2 846 223	0.141
5	1 329 288	0.186	1 375 770	0.192	2 705 058	0.142
6	938 627	0.180	1 062 353	0.189	2 000 979	0.131
7	982 966	0.171	854 150	0.184	1 837 115	0.127
8	752 753	0.169	824 976	0.171	1 577 729	0.121
9	759 481	0.165	1 206 889	0.136	1 966 371	0.105
10	678 427	0.167	1 063 978	0.147	1 742 404	0.112
11	655 783	0.191	1 142 650	0.142	1 798 433	0.110
12	704 495	0.182	585 519	0.219	1 290 013	0.139
13	272 059	0.277	531 380	0.222	803 440	0.169
14	393 833	0.249	482 708	0.238	876 541	0.172
15	327 702	0.282	483 303	0.228	811 005	0.179
16	98 368	0.480	253 265	0.327	351 634	0.259
17	40 090	0.797	209 864	0.322	249 954	0.290
18	186 579	0.364	108 170	0.503	294 750	0.310
19	50 414	0.711	80 323	0.561	130 737	0.450
20	31 941	0.882	50 118	0.719	82 059	0.559
21	39 321	0.889	0	–	39 321	0.889
No. measured		19 991		23 669		43 660
No. aged		235		271		506
No. of tows sampled						591
Mean weighted CV (%)		22.2		20.8		16.2

Table 6: Calculated numbers-at-age, separately by sex, with CVs, for *Trachurus murphyi* caught during commercial trawl operations in JMA 7 during the 2014–15 fishing year. Summary statistics for the sample are also presented.

Age (years)	Male	CV	Female	CV	Total	CV
6	0	–	1 685	0.848	1 685	0.848
7	3 712	0.912	7 140	0.822	10 852	0.632
8	9 810	0.572	7 219	0.795	17 029	0.452
9	2 102	1.148	11 270	0.645	13 372	0.577
10	0	–	0	–	0	–
11	5 861	0.677	3 339	1.042	9 200	0.593
12	6 270	0.675	10 194	0.619	16 463	0.445
13	16 388	0.458	19 311	0.506	35 699	0.338
14	20 880	0.375	36 456	0.317	57 335	0.245
15	44 076	0.266	40 930	0.287	85 006	0.188
16	76 117	0.211	85 912	0.185	162 029	0.133
17	91 659	0.184	90 790	0.194	182 448	0.133
18	115 306	0.156	124 555	0.154	239 862	0.110
19	143 646	0.136	88 122	0.186	231 768	0.109
20	71 492	0.192	79 291	0.187	150 782	0.128
21	35 188	0.272	36 508	0.302	71 696	0.201
22	34 370	0.307	24 634	0.347	59 004	0.220
23	16 392	0.393	14 246	0.464	30 639	0.301
24	8 573	0.505	6 234	0.719	14 808	0.431
25	5 737	0.720	0	0.000	5 737	0.720
26	3 424	0.876	2 795	1.009	6 218	0.679
27	0	–	8 546	0.644	8 546	0.644
28	0	–	2 795	1.069	2 795	1.069
29	0	–	0	–	0	–
30	4 711	0.741	3 688	1.015	8 399	0.610
31	2 743	0.828	5 397	0.734	8 139	0.539
No. measured		1 656		1 489		3 145
No. aged		260		233		493
No. of tows sampled						347
Mean weighted CV (%)		24.4		28.1		18.9

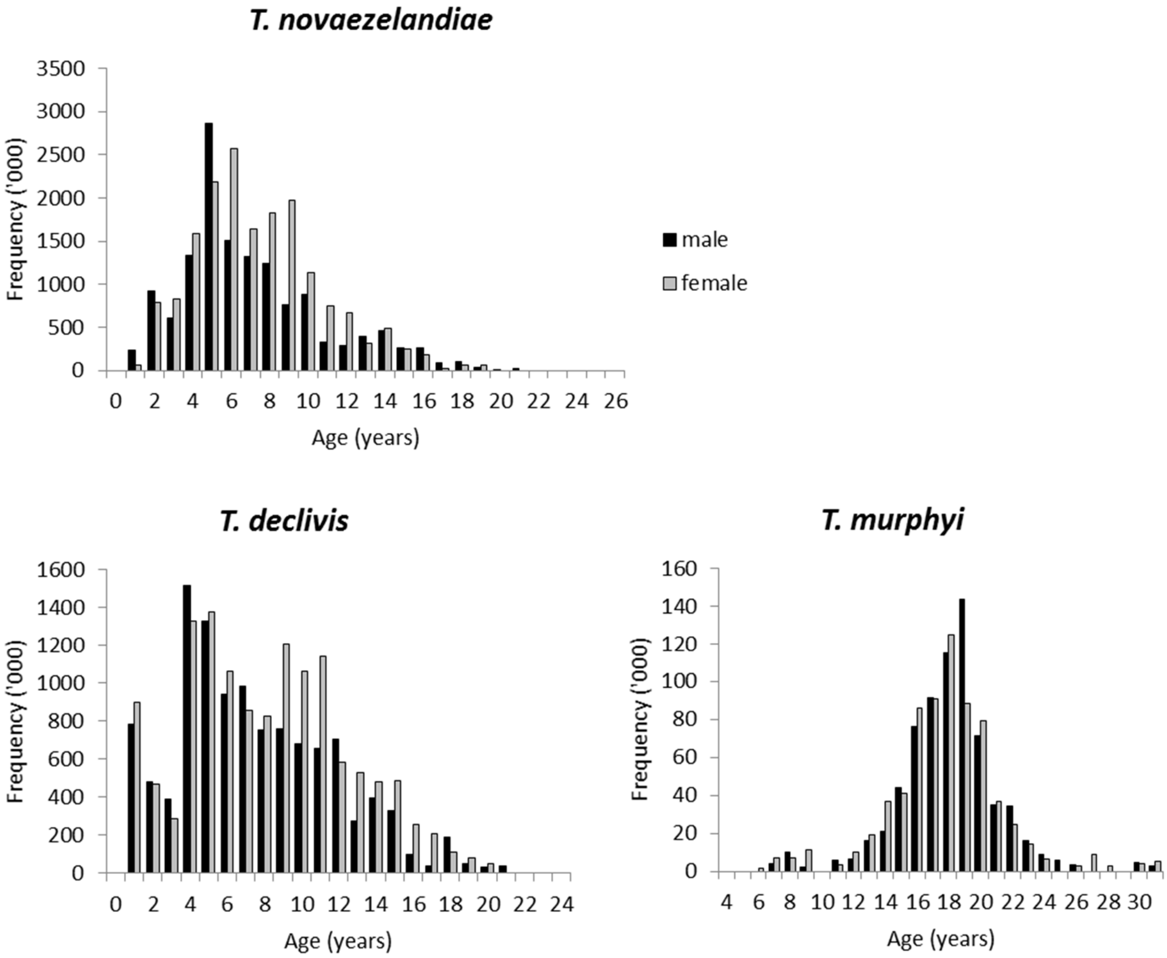


Figure 5: Estimated commercial catch-at-age distributions, by species and sex, from JMA 7 in 2014–15.

3.6 Data summaries

Catch-at-length and catch-at-age data from the JMA 7 fishery are now available from nine 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 bettered the target of 30% for all species in all years, except for *Trachurus murphyi* in 2006–07.

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

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

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

Trachurus novaezelandiae

Scaled catch-at-length frequencies by fishing year are shown in Figure 6. They had single modes at 28–32 cm in all distributions except 2009–10, and 2012–13 when there were second modes at 24 and 20 cm respectively. Most variation in abundance occurred with the fish shorter than 25 cm, presumably relating to the relative strengths of juvenile year classes. Scaled catch-at-age frequencies by fishing year, varied between years (Figure 6). However, some possible year class progressions can be postulated. The 1+ year class was strong in 2007–08, and maintained a relatively high abundance in all subsequent years. The 2+ year class in 2011–12 was also relatively strong, and it progressed as the dominant year class in the subsequent three years. Year classes 4, 5, and 6 in 2006–07 also appeared to be relatively strong throughout the series, although there were some inconsistencies e.g., year classes 7 in 2009–10 and 10 in 2011–12 were weak.

Trachurus declivis

Scaled catch-at-length frequencies by fishing year are shown in Figure 7 with most of the fish 16–50 cm. There was a strong mode at 42–44 cm, with lesser modes for smaller fish in the distributions for some years, e.g., 30 cm in 2012–13. 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 (with the 4+ class in 2014–15 still maintaining its strength).

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 broad 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. Since about 2012–13, the older of these two year classes appears to be losing much of its dominance.

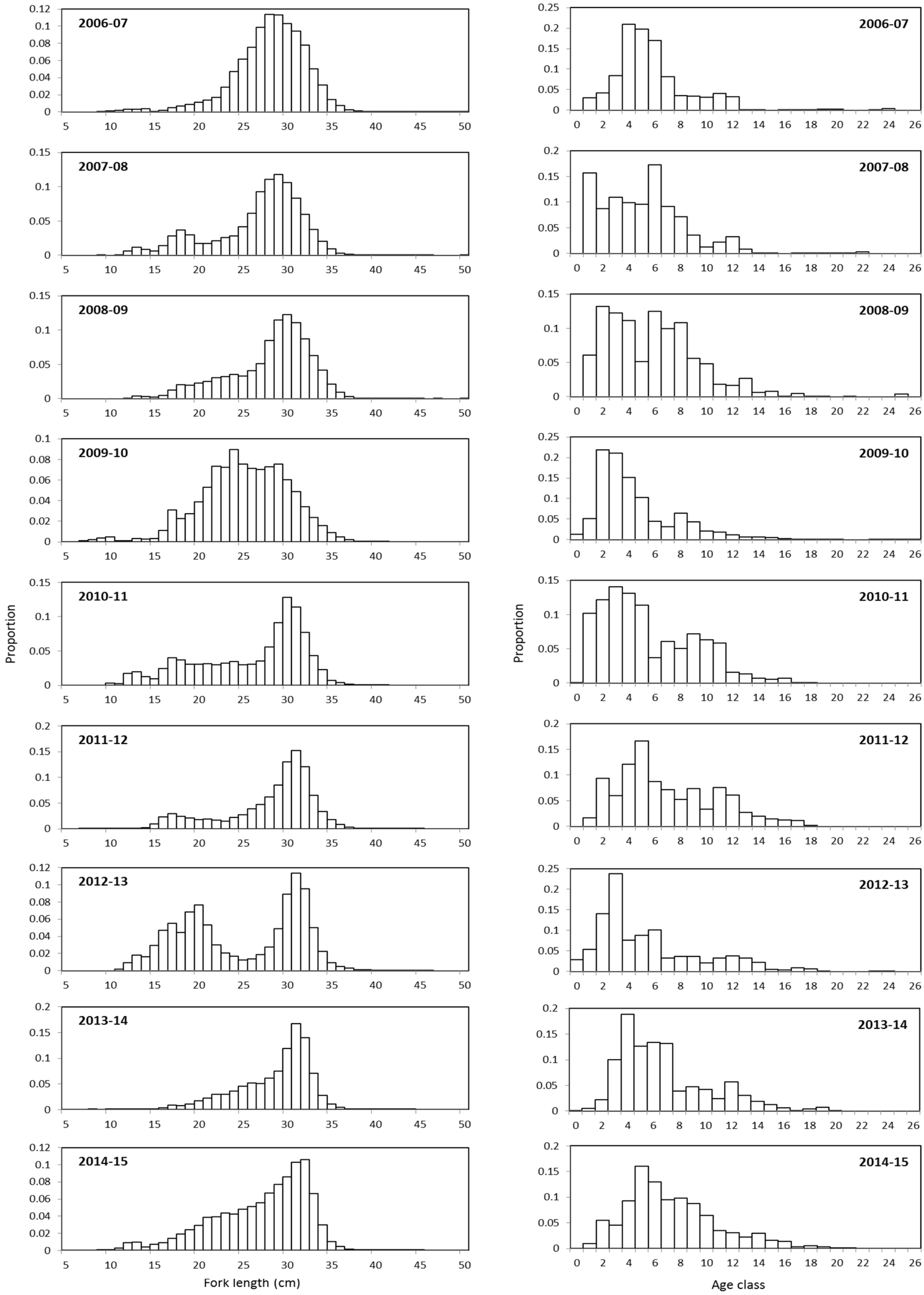


Figure 6: Scaled catch-at-length (left panel) and catch-at-age (right panel) proportions for the catch of *Trachurus novaezelandiae* sampled from the 2006–07 to 2014–15 fishing years.

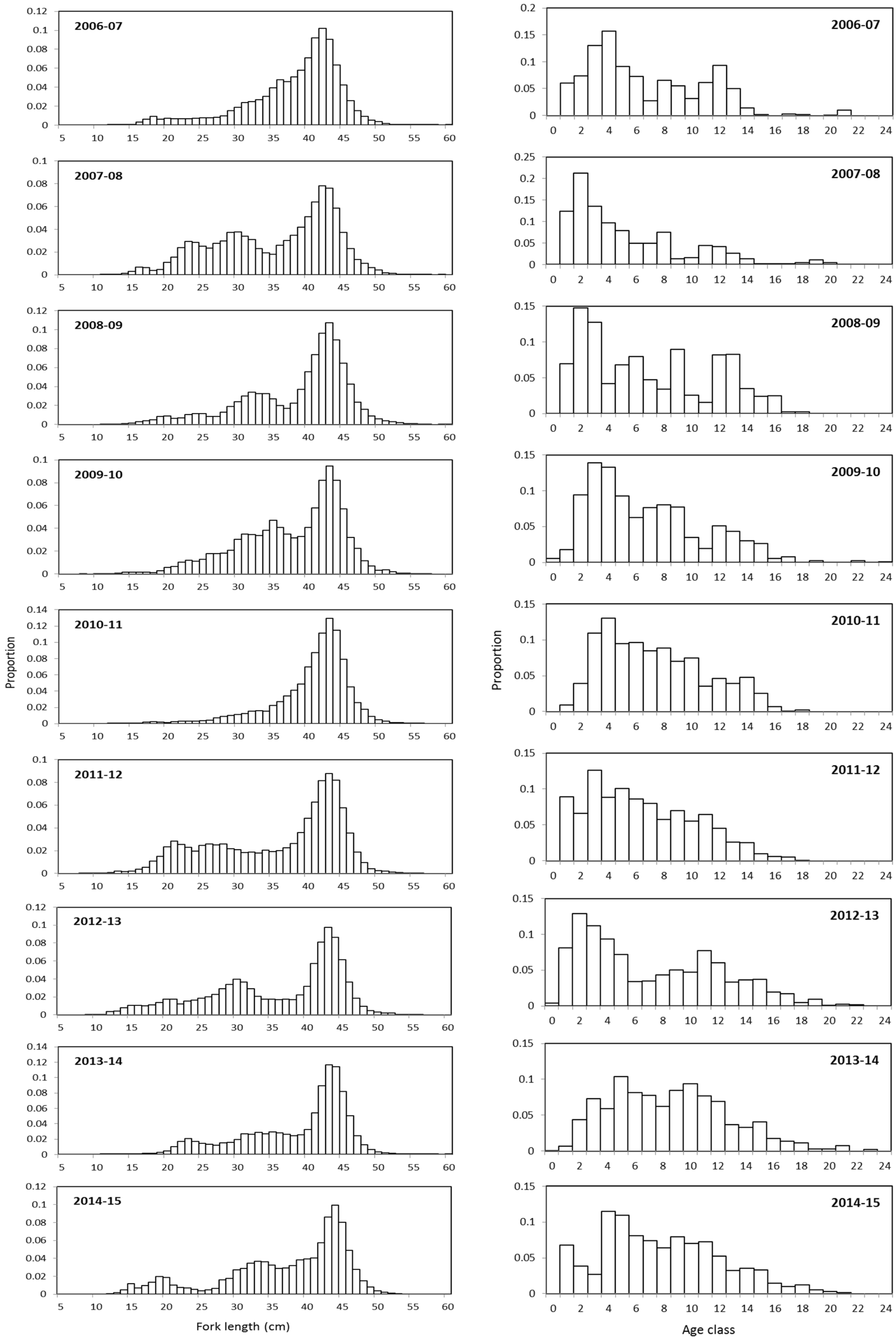


Figure 7: Scaled catch-at-length (left panel) and catch-at-age (right panel) proportions for the catch of *Trachurus declivis* sampled from the 2006–07 to 2014–15 fishing years.

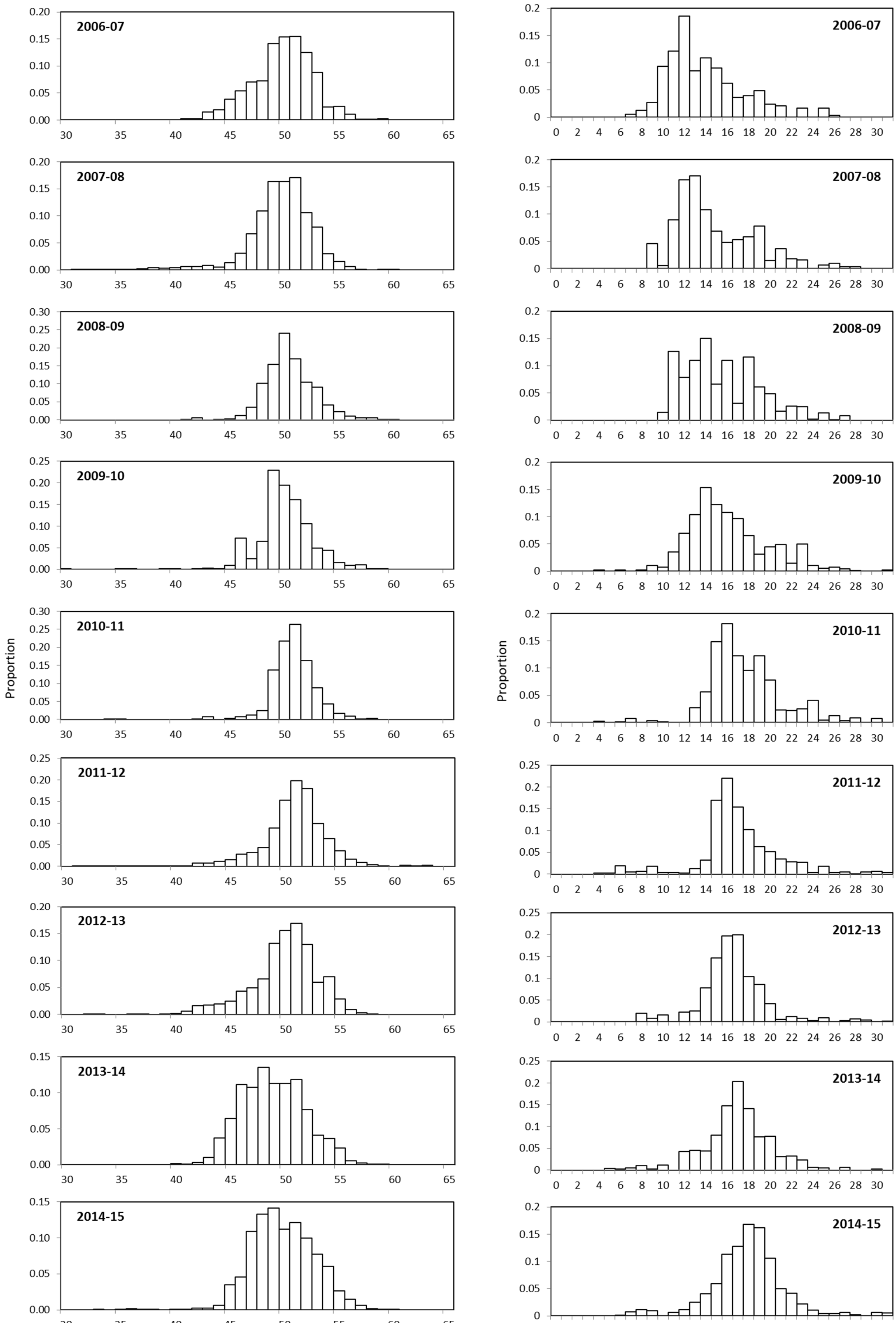


Figure 8: Scaled catch-at-length (left panel) and catch-at-age (right panel) proportions for the catch of *Trachurus murphyi* sampled from the 2006–07 to 2014–15 fishing years.

4. DISCUSSION

The 2014–15 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 86% 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 (035, 037, 040–042). Estimates of the 2014–15 catch-at-age for all three jack mackerel species had mean weighted CVs over all age classes of 19% 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, 6% of the aged *T. declivis* appeared as outliers that fitted well on the growth curve for *T. novaezelandiae*, and 3% of aged *T. novaezelandiae* were outliers that fitted well on the *T. declivis* growth curve. Such misidentifications are particularly apparent for the older and larger fish of both these species (for which the growth curves are clearly divergent), but less so for smaller and younger fish because the length-at-age ranges of both species overlapped substantially for fish aged 4 years or less. So the actual misidentification percentages of *T. declivis* and *T. novaezelandiae* are likely to be higher than the values noted above. It is 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 61–71% of total catch weight in the nine fishing years from which data were available. The percentage of *T. novaezelandiae* was also consistent temporally at 24–33%. The predominance of *T. declivis* overall is expected given that this species generally occurs deeper and further offshore than *T. novaezelandiae* and because most of the vessels targeting jack mackerels are restricted to fishing at least 12 n. miles, and often 25 n. miles off the coast. The lowest proportion of *T. declivis* and highest proportion of *T. novaezelandiae* in the time series were reported in 2014–15. This probably relates to relatively low catches in the autumn–winter fishery, which is usually strongly dominated by landings of *T. declivis* off the west coast of South Island.

Most of the *T. declivis* catch in all years comprised adult fish at least 37 cm long. Differences between years in the length distributions were primarily in the abundance of fish shorter than 37 cm, and was a consequence of variation in year class strengths. The position of the mode of large *T. declivis* in JMA 7 (centred on 43–44 cm in most years) 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 age distribution in 2014–15 comprised fish mainly 16–20 years old, but the age distribution mode continued its shift to the right in accordance with the hypothesis of a single migration pulse. This modal shift in the age distributions has occurred despite the 2013–14 and 2014–15 length distributions having relatively more smaller fish (i.e. 45–48 cm) than in other sampled years. The collected data on sex of *T. murphyi* indicated a population consistently biased towards males (i.e., 50–62% of sampled fish, average 56.5% over 9 years). *T. murphyi* can, at times, be quite difficult to sex (author's unpublished data), with deposits of fat in the body cavity often appearing like male gonads when the gonads are in a regressed state. However, in four research surveys conducted on the Stewart-Snares shelf in February each year from 1993 to 1996 males were also dominant, comprising 62–71% of the sexed fish (Hurst & Bagley 1997).

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

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

We thank the MPI Observer Programme for achieving good sampling coverage of the TCEPR fleet, and Peter McMillan for reviewing the manuscript. This work was funded by the Ministry for Primary Industries under project MID2015-01.

6. REFERENCES

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

Breiman, L.; Friedman, J.H.; Olshen, R.A.; Stone, C.J. (1984). *Classification and Regression Trees*. Belmont, CA: Wadsworth. 358 p.

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

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

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

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

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

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

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

Horn, P.; Sutton, C.; Hulston, D.; Marriott, P. (2012a). Catch-at-age for jack mackerels (*Trachurus* spp.) in the 2009–10 fishing year, and barracouta (*Thyrsites atun*) and silver warehou (*Seriolella punctata*) in the 2004–05 and 2009–10 fishing years. Final Research Report for Ministry of Fisheries Project

MID2010-01A, Objectives 6 & 8. 19 p. (Unpublished report available from Ministry for Primary Industries, Wellington.)

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

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

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

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

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

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

Appendix A: Stratification of observer data

This appendix outlines the method used to obtain a stratification procedure for the available observer data from the five most recent years (2010–11 to 2014–15). Any trawl catch of jack mackerel can comprise from one to three species. The stratification of trawl tows was developed based on the proportions of each species occurring in each observed tow, using effort and location variables that are also available. The classification tree method (Breiman et al. 1984) was used to obtain a tree defined by suitable splitting variables that is grown, with leaves that have similar proportions within each stratum and diverse proportions between strata. A single tree was developed for all five fishing years combined, and for the 2014–15 year only.

A classification tree was fitted to the observer sampled catch data using the `rpart` package in `R`. The splitting criterion (impurity measure) at any node of the tree was the Gini index, which is the default setting for fitting a classification tree. The Gini index at a node with the three species proportions $\left(p^{\mathrm{D}}, p^{\mathrm{N}}, p^{\mathrm{M}}\right)$ is given by

$$1-\sum_{s\in\{\mathrm{D,N,M}\}}\left(p^{s}\right)^{2}.$$

The Gini index uses the catch weighted species proportions at each node. Each data row represents a single tow and contained the tow details and the catch weights and proportions of all three species. The use of this data frame and the setting of `weights` argument in `rpart` equal to the weight variable ensured that the correct tow catch weighted proportions are used in node splitting. The `species` factor was the response variable in the `rpart` formula and the following covariates, which needed to be available in the catch effort data, were offered for tree generation:

month	a `factor` variable
fishing year	a `factor` variable
statistical area	a `factor` variable
latitude	
longitude	
net depth	
bottom depth	

The cross validation measure was based on the error rate from the prediction of the species with largest proportion for each terminal node. There are two reason why this is not the best measure of the stratification. Firstly, the prediction performance is not directly related to the impurity species proportions of the terminal nodes because it only depends only on which proportion is largest for each node. Secondly, in the random partitioning of the data frame the three species rows corresponding to a single row in the observer data will not be assigned to the same partition. This will distort the cross validation statistic. Therefore the cross validation output from `rpart` should only be taken as an indication of where to prune the tree when choosing the tree that defines the stratification.

The resulting tree and stratification details that used data from 2006–07 to 2008–09, derived by Taylor et al. (2011) and used to stratify observer data from years 2006–07 to 2013–14, are shown below (Figure A1, Table A1). They can be compared with the results of the updated analysis.

The stratification of Taylor et al. (2011) first split off tows off west coast South Island plus relatively deep tows off west coast North Island — all these having a very high proportion of *T. declivis*. Most remaining tows in the south Taranaki Bight were stratified by month, while those north of Cape Egmont were stratified by depth (tows shallower than 125 m were dominated by *T. novaezelandiae*).

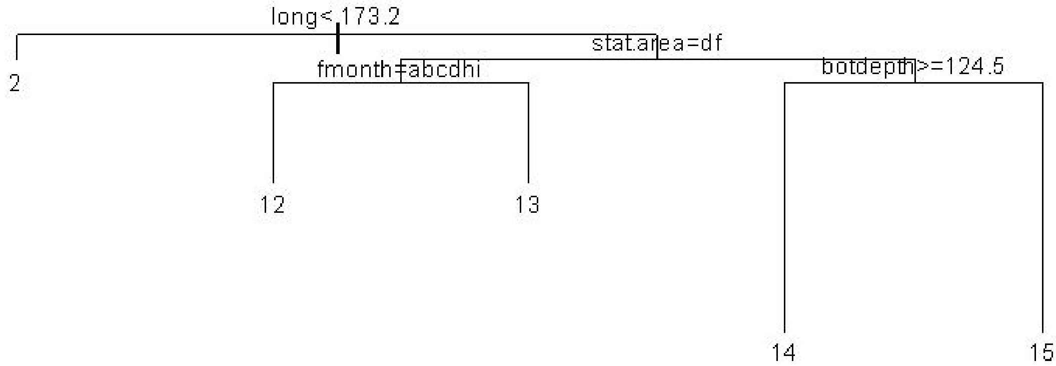


Figure A1: Dendrogram of classification tree derived using data from 2006–07 to 2008–09 by Taylor et al. (2011).

Table A1: Node details of classification tree derived using data from 2006–07 to 2008–09 by Taylor et al. (2011): split definition, number of data points in node, and species proportions. Bold type and * indicate a leaf.

Node number	Split	Node count	Proportions (JMD, JMN, JMM)
1	root	1556	(0.686, 0.241, 0.073)
2*	**long < 173.25**	**568**	**(0.876, 0.044, 0.080)**
3	long ≥ 173.25	988	(0.587, 0.343, 0.070)
6	stat.area = 037, 040	388	(0.699, 0.239, 0.062)
12*	**fmonth = Oct–Jan, May–Jun**	**353**	**(0.754, 0.176, 0.070)**
13*	**fmonth = Feb–Apr, Jul–Sep**	**35**	**(0.302, 0.690, 0.008)**
7	stat.area = 039, 041, 042, 045, 046	600	(0.522, 0.405, 0.074)
14*	**botdepth > 124.5**	**364**	**(0.606, 0.296, 0.098)**
15*	**botdepth ≤ 124.5**	**236**	**(0.393, 0.570, 0.038)**

The stratification tree and its descriptors derived in the updated analysis using data from 2010–11 to 2014–15 are shown below (Figure A2, Table A2). The first split grouped tows west of longitude 173.1° (i.e., west coast South Island and deeper west coast North Island), almost identically to Taylor et al. (2011). The remaining area was then split into two groups of statistical areas. Area 041 (comprising a large proportion of the north Taranaki Bight fishery) was further split at a bottom depth of 120 m, with *T. novaezelandiae* dominating the shallower stratum. All other statistical areas were split by month with *T. declivis* dominating catches throughout the year except for March and April when *T. novaezelandiae* dominated.

The stratification using data from 2010–11 to 2014–15 was very similar to that derived previously using data from 2006–07 to 2008–09. The east-west boundary was virtually identical between stratifications, and off west coast North Island the northern catches were depth stratified (split at about 120 m) and the southern catches were month stratified.

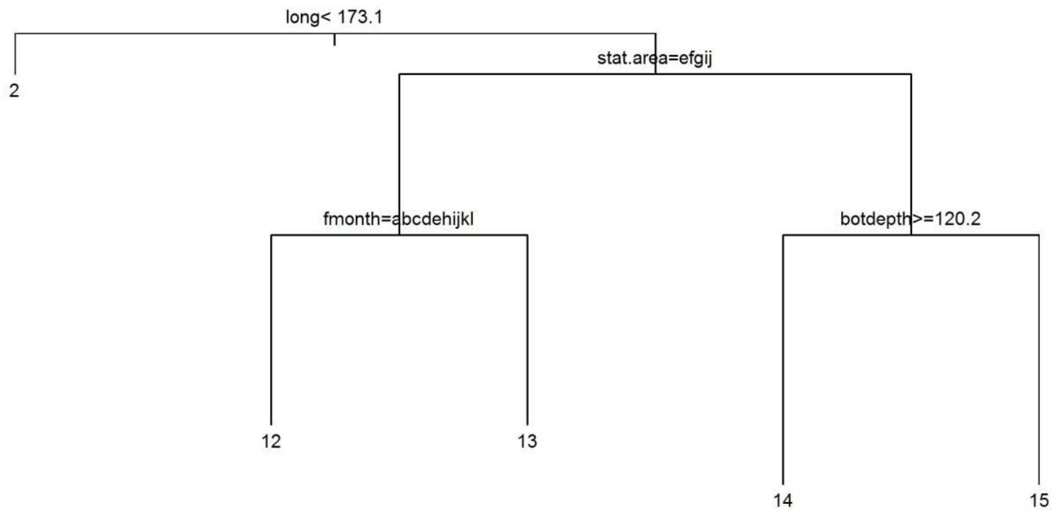


Figure A2: Dendrogram of classification tree derived using data from 2010–11 to 2014–15.

Table A2: Node details of classification tree derived using data from 2010–11 to 2014–15: split definition, number of data points in node, and species proportions. Bold type and * indicate a leaf.

Node number	Split	Node count	Proportions (JMD, JMN, JMM)
1	root	11655	(0.661, 0.302, 0.037)
2*	**long < 173.15**	**2946**	**(0.930, 0.034, 0.035)**
3	long ≥ 173.15	8709	(0.575, 0.387, 0.038)
6	stat.area = 037, 039, 040, 042, 045	5586	(0.649, 0.303, 0.048)
12*	**fmonth = Oct–Feb, May–Sep**	**4377**	**(0.704, 0.238, 0.058)**
13*	**fmonth = Mar–Apr**	**1209**	**(0.375, 0.623, 0.002)**
7	stat.area = 041	3123	(0.462, 0.516, 0.022)
14*	**botdepth ≥ 120.25**	**1440**	**(0.582, 0.392, 0.026)**
15*	**botdepth < 120.25**	**1683**	**(0.366, 0.615, 0.019)**

A stratification was also completed for data from only the most recent fishing year (2014–15). The tree had only three branches (Figure A3) and its descriptors are shown in Table A3. The first split was based on month and it essentially produced six groups (October, January–March, and May–July were dominated strongly by *T. declivis*, whereas in the residual months proportions of *T. novaezelandiae* and *T. declivis* in the catches were relatively even). A second split was only marginally justified; with catches from the residual months split into two groups of statistical areas.

The stratification of this single year of data was quite different to the results from the two multi-year analyses. Although the fishery occurs over a very similar broad area each year, there can be differences between years in the intensity of fishing (or observing) in some areas and times (Figure A4). For example, in 2014–15, there were few observed tows in Statistical Area 036 relative to the previous two years. Consequently, a stratification based on several years is likely to better define any areal and temporal differences in the species mix because the fishery area and seasons will be more comprehensively covered. It was also pleasing to note that the stratification based on data from 2006–07 to 2008–09 was very similar to that using data from 2010–11 to 2014–15. The updated stratification is, therefore, considered to be suitable for use in determining the catch-at-age distribution and species proportions of the JMA 7 jack mackerel catch.

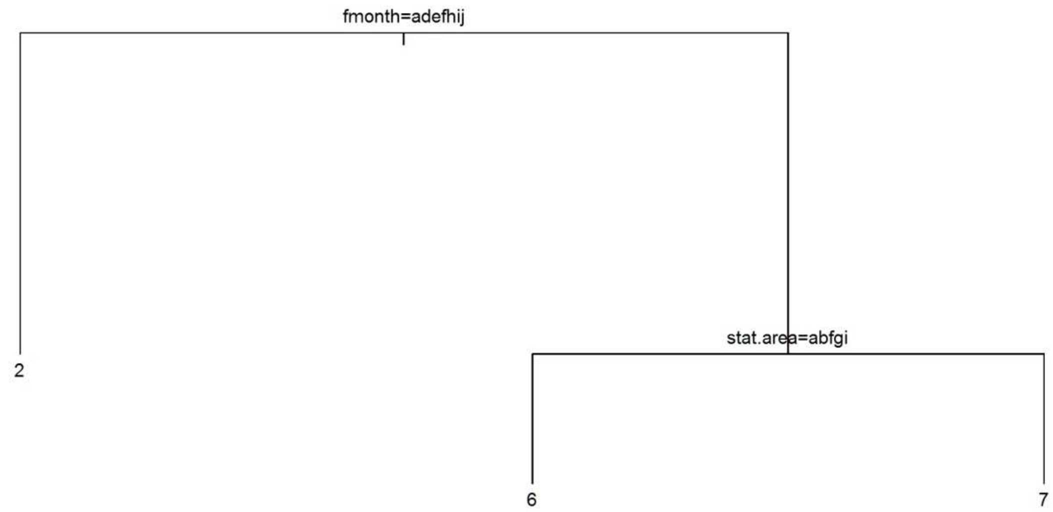


Figure A3: Dendrogram of classification tree derived using data from 2014–15 only.

Table A3: Node details of classification tree derived using data from 2014–15 only: split definition, number of data points in node, and species proportions. Bold type and * indicate a leaf.

Node number	Split	Node count	Proportions (JMD, JMN, JMM)
1	root	2463	(0.584, 0.366, 0.050)
2*	**fmonth = Oct, Jan–Mar, May–Jul**	**1044**	**(0.809, 0.135, 0.056)**
3	fmonth = Nov, Dec, Apr, Aug, Sep	1419	(0.410, 0.544, 0.046)
6*	**stat.area = 034, 035, 037, 040, 042**	**726**	**(0.524, 0.399, 0.077)**
7*	**stat.area = 039, 041**	**693**	**(0.324, 0.654, 0.022)**

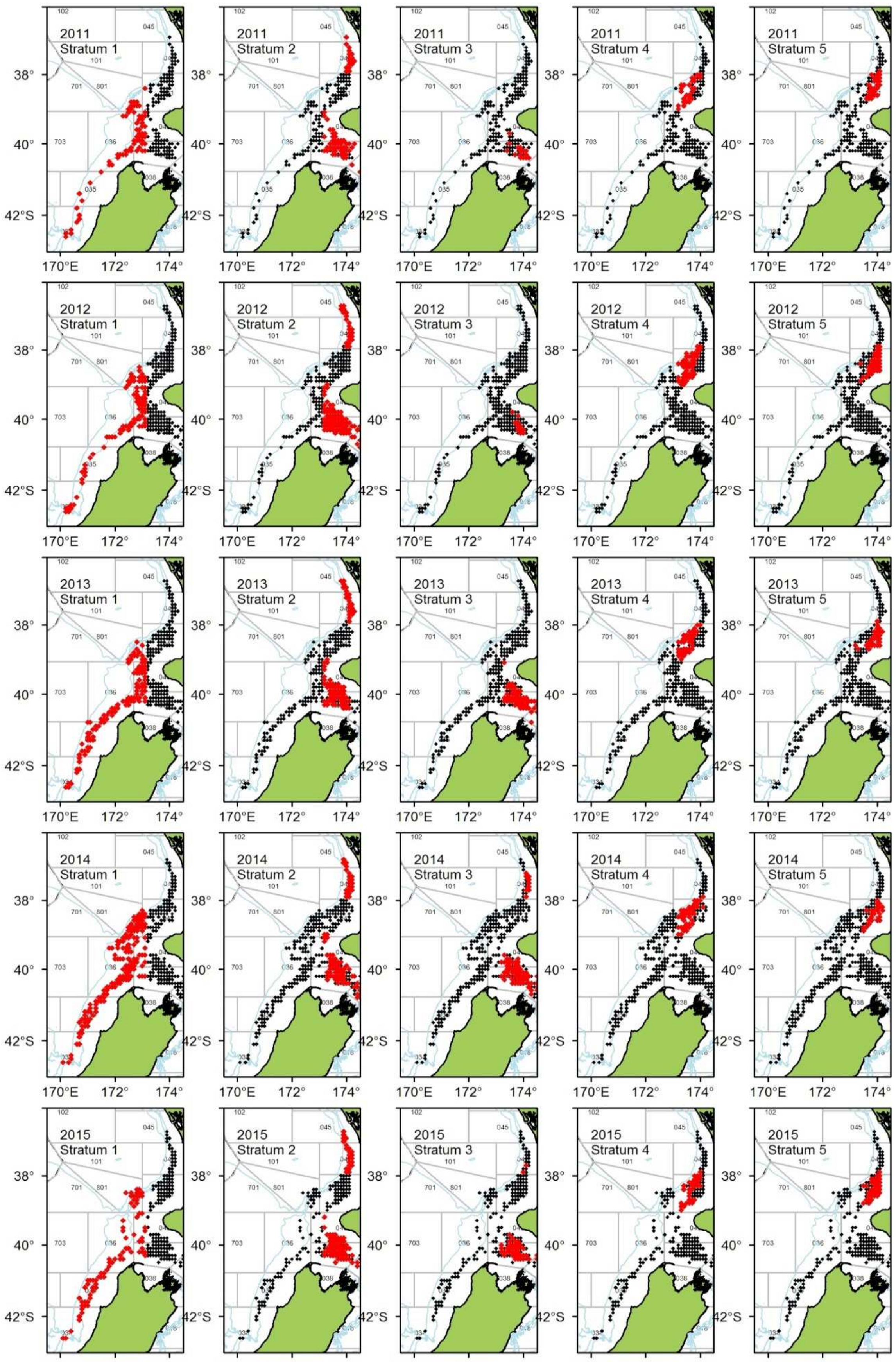


Figure A4: Start locations of all observed tows by year for 2011–12 to 2014–15 (black dots in each row of plots) overlaid with start positions of tows by stratum in each year (red dots).

Appendix B: 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 B1: Proportions-at-age (male, female, and unsexed combined), with CVs, for *T. novaezelandiae*, by fishing year.

	Proportion									CV								
Age	2007	2008	2009	2010	2011	2012	2013	2014	2015	2007	2008	2009	2010	2011	2012	2013	2014	2015
0	0	0	0	0.0127	0.0007	0	0.0284	0.0001	0				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	0.0095	0.419	0.416	0.327	0.389	0.378	0.487	0.463	0.516	0.545
2	0.0422	0.0871	0.1319	0.2183	0.1216	0.0934	0.1399	0.0216	0.0548	0.349	0.138	0.162	0.213	0.249	0.209	0.244	0.349	0.333
3	0.0846	0.1091	0.1225	0.2108	0.1408	0.0598	0.2380	0.1004	0.0456	0.224	0.144	0.188	0.186	0.185	0.219	0.151	0.201	0.249
4	0.2088	0.0985	0.1116	0.1517	0.1312	0.1210	0.0765	0.1890	0.0932	0.124	0.171	0.309	0.172	0.114	0.109	0.179	0.117	0.158
5	0.1970	0.0959	0.0509	0.1020	0.1137	0.1668	0.0875	0.1268	0.1608	0.106	0.176	0.399	0.209	0.124	0.097	0.101	0.108	0.100
6	0.1693	0.1727	0.1244	0.0443	0.0367	0.0868	0.1012	0.1342	0.1301	0.126	0.131	0.277	0.281	0.228	0.133	0.089	0.083	0.096
7	0.0819	0.0911	0.0992	0.0319	0.0604	0.0712	0.0320	0.1314	0.0946	0.193	0.203	0.330	0.227	0.193	0.176	0.183	0.093	0.109
8	0.0358	0.0712	0.1079	0.0639	0.0503	0.0523	0.0360	0.0388	0.0981	0.276	0.216	0.293	0.211	0.189	0.187	0.172	0.167	0.113
9	0.0334	0.0357	0.0557	0.0426	0.0722	0.0739	0.0370	0.0478	0.0874	0.301	0.243	0.314	0.204	0.141	0.157	0.159	0.163	0.108
10	0.0316	0.0121	0.0485	0.0206	0.0631	0.0334	0.0199	0.0424	0.0643	0.319	0.463	0.356	0.230	0.160	0.252	0.226	0.174	0.115
11	0.0404	0.0220	0.0180	0.0181	0.0586	0.0757	0.0321	0.0243	0.0345	0.281	0.328	0.459	0.274	0.170	0.145	0.163	0.247	0.172
12	0.0324	0.0321	0.0167	0.0115	0.0160	0.0609	0.0379	0.0564	0.0306	0.311	0.302	0.518	0.252	0.328	0.166	0.144	0.147	0.175
13	0.0010	0.0080	0.0270	0.0058	0.0131	0.0277	0.0323	0.0303	0.0226	1.040	0.341	0.313	0.327	0.316	0.222	0.165	0.163	0.197
14	0.0012	0.0006	0.0062	0.0066	0.0071	0.0200	0.0224	0.0189	0.0301	0.944	1.193	0.454	0.367	0.429	0.272	0.179	0.199	0.173
15	0	0.0002	0.0081	0.0046	0.0051	0.0143	0.0053	0.0123	0.0163		1.358	0.655	0.336	0.392	0.305	0.358	0.232	0.232
16	0.0004	0	0.0003	0.0027	0.0067	0.0127	0.0038	0.0060	0.0142	1.203		1.060	0.494	0.451	0.311	0.458	0.275	0.248
17	0.0008	0.0012	0.0048	0.0005	0.0006	0.0110	0.0087	0.0015	0.0035	0.643	1.028	1.002	0.594	1.160	0.374	0.280	0.512	0.453
18	0.0006	0.0004	0.0004	0.0001	0.0001	0.0024	0.0062	0.0038	0.0053	0.864	1.021	1.251	2.105	1.712	0.565	0.317	0.385	0.401
19	0.0026	0.0011	0.0003	0.0001	0	0	0.0011	0.0077	0.0034	0.671	0.949	0.884	1.916			0.769	0.287	0.547
20	0.0025	0.0003	0	0.0000	0	0	0	0.0008	0.0003	0.898	0.895		1.253				0.673	0.606
21	0	0.0003	0.0009	0	0	0	0	0	0.0008		0.835	0.769						0.812
22	0	0.0029	0	0	0	0	0	0	0		0.572							
23	0.0010	0	0	0.0000	0	0	0.0005	0	0	1.022			1.134			0.835		
24	0.0034	0	0	0.0001	0	0	0.0002	0	0	0.544			0.887			0.903		
25	0	0	0.0042	0.0000	0	0	0	0	0			0.518	2.166					
26	0	0	0	0.0002	0	0	0	0	0				1.049					

Table B2: Proportions-at-age (male, female, and unsexed combined), with CVs, for *T. declivis*, by fishing year.

	Proportion									CV								
Age	2007	2008	2009	2010	2011	2012	2013	2014	2015	2007	2008	2009	2010	2011	2012	2013	2014	2015
0	0	0	0	0.0054	0	0	0.0041	0.0002	0				0.428			0.793	1.197	
1	0.0605	0.1245	0.0693	0.0180	0.0092	0.0889	0.0813	0.0066	0.0680	0.220	0.175	0.170	0.326	0.355	0.267	0.238	0.441	0.298
2	0.0737	0.2125	0.1478	0.0942	0.0390	0.0659	0.1290	0.0437	0.0384	0.172	0.145	0.134	0.207	0.191	0.229	0.199	0.409	0.257
3	0.1307	0.1357	0.1273	0.1387	0.1091	0.1261	0.1118	0.0729	0.0272	0.141	0.119	0.144	0.141	0.134	0.162	0.161	0.222	0.255
4	0.1574	0.0972	0.0416	0.1327	0.1301	0.0886	0.0933	0.0589	0.1152	0.118	0.176	0.311	0.130	0.113	0.182	0.161	0.191	0.141
5	0.0907	0.0784	0.0678	0.0923	0.0949	0.1004	0.0718	0.1042	0.1095	0.244	0.227	0.299	0.160	0.143	0.115	0.153	0.129	0.142
6	0.0728	0.0492	0.0798	0.0629	0.0963	0.0859	0.0341	0.0816	0.0810	0.303	0.325	0.322	0.190	0.153	0.114	0.170	0.114	0.131
7	0.0270	0.0491	0.0475	0.0767	0.0851	0.0796	0.0351	0.0779	0.0744	0.503	0.256	0.385	0.168	0.169	0.117	0.149	0.136	0.127
8	0.0654	0.0755	0.0343	0.0801	0.0883	0.0575	0.0429	0.0623	0.0639	0.310	0.371	0.437	0.186	0.175	0.140	0.135	0.123	0.121
9	0.0549	0.0131	0.0894	0.0768	0.0701	0.0700	0.0503	0.0845	0.0796	0.309	0.503	0.260	0.177	0.176	0.124	0.125	0.099	0.105
10	0.0315	0.0154	0.0257	0.0345	0.0750	0.0556	0.0469	0.0936	0.0705	0.486	0.482	0.463	0.300	0.184	0.137	0.140	0.093	0.112
11	0.0618	0.0443	0.0160	0.0192	0.0354	0.0642	0.0771	0.0768	0.0728	0.272	0.329	0.635	0.367	0.230	0.127	0.099	0.108	0.110
12	0.0934	0.0422	0.0819	0.0507	0.0458	0.0454	0.0605	0.0689	0.0522	0.254	0.301	0.286	0.214	0.216	0.158	0.113	0.111	0.139
13	0.0496	0.0260	0.0823	0.0435	0.0391	0.0256	0.0330	0.0367	0.0325	0.363	0.454	0.281	0.236	0.237	0.208	0.149	0.142	0.169
14	0.0137	0.0138	0.0352	0.0299	0.0478	0.0254	0.0363	0.0325	0.0355	0.537	0.456	0.476	0.268	0.209	0.183	0.143	0.146	0.172
15	0.0015	0.0024	0.0240	0.0264	0.0256	0.0099	0.0372	0.0408	0.0328	0.858	0.912	0.400	0.273	0.295	0.339	0.149	0.138	0.179
16	0	0.0005	0.0251	0.0057	0.0068	0.0055	0.0193	0.0173	0.0142		0.686	0.335	0.469	0.545	0.472	0.211	0.221	0.259
17	0.0031	0.0017	0.0023	0.0075	0.0004	0.0051	0.0172	0.0138	0.0101	0.973	0.966	0.581	0.647	1.049	0.438	0.243	0.230	0.290
18	0.0013	0.0042	0.0028	0	0.0020	0.0005	0.0048	0.0115	0.0119	1.050	0.395	0.633		1.091	0.690	0.399	0.254	0.310
19	0	0.0104	0	0.0023	0	0	0.0094	0.0028	0.0053		0.762		1.020			0.292	0.456	0.450
20	0.0006	0.0038	0	0	0	0	0.0011	0.0031	0.0033	1.101	0.975					0.868	0.409	0.559
21	0.0104	0	0	0	0	0	0.0021	0.0072	0.0016	0.430						0.701	0.335	0.889
22	0	0	0	0.0023	0	0	0.0013	0	0				0.963			0.801		
23	0	0	0	0	0	0	0	0.0020	0								0.624	
24	0	0	0	0.0003	0	0	0	0	0				1.254					

Table B3: Proportions-at-age (male, female, and unsexed combined), with CVs, for *T. murphyi*, by fishing year.

	Proportion									CV								
Age	2007	2008	2009	2010	2011	2012	2013	2014	2015	2007	2008	2009	2010	2011	2012	2013	2014	2015
4	0	0	0	0.0020	0.0026	0.0018	0	0	0				2.236	1.146	1.047			
5	0	0	0	0	0	0.0021	0	0.0039	0						0.747		0.766	
6	0	0	0	0.0021	0.0005	0.0193	0	0.0028	0.0012				1.423	2.163	0.420		1.105	0.848
7	0.0055	0	0	0	0.0073	0.0044	0	0.0049	0.0076	1.041				1.841	1.093		0.741	0.632
8	0.0126	0	0	0.0026	0	0.0059	0.0201	0.0107	0.0119	0.625			1.481		0.891	0.710	0.519	0.452
9	0.0272	0.0458	0	0.0105	0.0036	0.0180	0.0086	0.0028	0.0094	0.413	0.333		0.948	0.873	0.596	0.869	0.972	0.577
10	0.0935	0.0053	0.0144	0.0071	0.0012	0.0030	0.0157	0.0111	0	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	0.0064	0.301	0.263	0.222	0.383		1.119			0.593
12	0.1857	0.1634	0.0784	0.0692	0	0.0021	0.0219	0.0431	0.0115	0.201	0.190	0.304	0.584		1.043	0.499	0.237	0.445
13	0.0847	0.1708	0.1092	0.1040	0.0273	0.0128	0.0252	0.0448	0.0250	0.282	0.172	0.241	0.178	0.363	0.511	0.432	0.261	0.338
14	0.1092	0.1083	0.1499	0.1530	0.0567	0.0320	0.0779	0.0432	0.0401	0.231	0.248	0.208	0.233	0.235	0.322	0.231	0.252	0.245
15	0.0900	0.0687	0.0657	0.1227	0.1488	0.1694	0.1466	0.0802	0.0595	0.300	0.323	0.318	0.271	0.144	0.119	0.142	0.184	0.188
16	0.0628	0.0484	0.1092	0.1080	0.1823	0.2194	0.1972	0.1479	0.1133	0.410	0.309	0.235	0.192	0.130	0.102	0.111	0.145	0.133
17	0.0363	0.0538	0.0305	0.0965	0.1224	0.1544	0.2004	0.2028	0.1276	0.514	0.318	0.299	0.178	0.174	0.119	0.107	0.113	0.133
18	0.0395	0.0580	0.1163	0.0658	0.0962	0.1019	0.1044	0.1405	0.1678	0.476	0.380	0.243	0.222	0.183	0.165	0.145	0.142	0.110
19	0.0489	0.0783	0.0606	0.0308	0.1227	0.0633	0.0860	0.0766	0.1621	0.639	0.306	0.334	0.304	0.155	0.182	0.164	0.183	0.109
20	0.0244	0.0154	0.0486	0.0450	0.0784	0.0514	0.0417	0.0769	0.1055	0.722	0.521	0.371	0.235	0.228	0.198	0.245	0.192	0.128
21	0.0211	0.0364	0.0159	0.0492	0.0233	0.0349	0.0055	0.0314	0.0502	0.647	0.436	0.821	0.269	0.374	0.231	0.664	0.313	0.201
22	0	0.0180	0.0256	0.0151	0.0223	0.0288	0.0125	0.0324	0.0413		0.770	0.406	0.433	0.392	0.267	0.479	0.312	0.220
23	0.0168	0.0160	0.0251	0.0501	0.0255	0.0270	0.0076	0.0233	0.0214	1.119	0.755	0.541	0.273	0.340	0.298	0.487	0.368	0.301
24	0	0	0.0024	0.0103	0.0409	0.0030	0.0034	0.0068	0.0104			0.778	0.576	0.295	0.831	0.894	0.643	0.431
25	0.0168	0.0063	0.0138	0.0048	0.0051	0.0177	0.0092	0.0055	0.0040	1.093	1.019	0.854	0.655	0.763	0.336	0.532	0.607	0.720
26	0.0033	0.0097	0.0009	0.0076	0.0134	0.0041	0	0	0.0044	1.247	1.032	1.217	0.564	0.543	0.788			0.679
27	0	0.0041	0.0078	0.0046	0.0031	0.0047	0.0024	0.0060	0.0060		0.980	0.643	0.791	1.018	0.673	0.915	0.688	0.644
28	0	0.0039	0	0.0011	0.0092	0.0007	0.0063	0	0.0020		0.933		1.060	0.630	1.301	0.816		1.069
29	0	0	0	0	0	0.0046	0.0049	0	0						0.780	0.785		
30	0	0	0	0	0.0073	0.0066	0	0.0023	0.0059					0.836	0.645		0.997	0.610
31	0	0	0	0.0027	0	0.0039	0.0023	0	0.0057				1.014		0.693	1.045		0.539