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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

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EXECUTIVE SUMMARY

Horn, P.L.; Ó Maolagáin, C.; Hulston, D. (2014). 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.

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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 during the 2012–13 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 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 90% of the 2012–13 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 2012–13 were generally similar to those from the six previous years. The age-frequency distributions for all species in 2012–13 had mean weighted CVs of 21% or less, which more than met the target of 30%. By species, there is clear variation in catch-at-age between years, and it is apparent that for all species this variation is largely a consequence of the progression of year classes with different relative strengths.

Estimated species proportions indicated a predominance of *T. declivis* at 65–71% in the JMA 7 TCEPR catch throughout all statistical areas and the six years of sampling, while *T. novaezelandiae* made up 25–30% and *T. murphyi* 3–8%.

Estimates of total instantaneous mortality rates over the last seven years were 0.25 for *T. novaezelandiae* and 0.20 for *T. declivis*. These values were only slightly higher than the likely value of *M* (0.18), and indicated that both species in JMA 7 were relatively lightly exploited.

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 for the separate jack mackerel quota management areas (Figure 1) from MPI databases. 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 however 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. Recently 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).

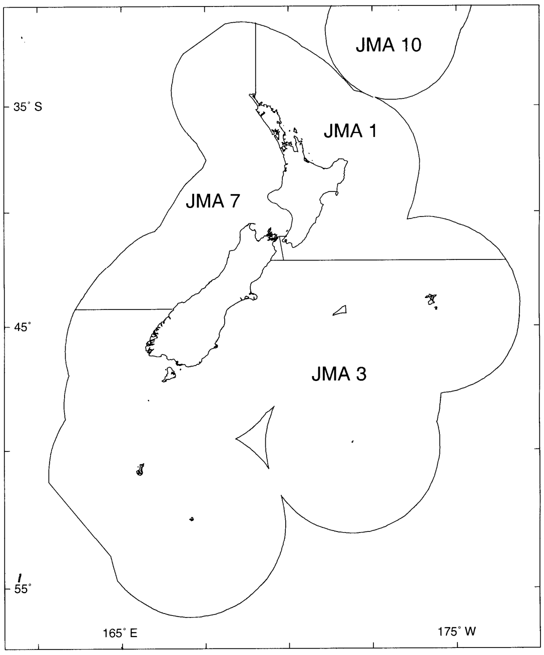

Figure 1: Jack mackerel administrative Fishstocks.

This report provides estimates of relative proportions and catch-at-age using observer data for the three *Trachurus* species in the commercial JMA 7 catch for 2012–13. 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, and Horn et al. (2013) for 2011–12. 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 MID201001D "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 requested by MPI, also under Project MID201001D. The results of this investigation are presented elsewhere (Horn et al. 2014).

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 working primarily 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 tow records in the observer dataset include 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 2012–13 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. All data from one observed trip (trip 3661) were removed from the analysis as many of the mackerel identified as *T. novaezelandiae* were longer than 42 cm and so were most likely *T. declivis*.

Commercial catch data extracted from the Ministry for Primary Industries catch-effort database "warehou" (Extract #9335) were also 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 2012–13.

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 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 033–048 and 801 of JMA 7 (Figure 2) in the 2012–13 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 550 per species. Sets of five otoliths were embedded in blocks of clear epoxy resin and cured at 50°C. Once hardened, a 380 μm thin transverse section was cut from each block through the primordia using a high speed saw. The thin section was washed, dried, and embedded under a cover slip on a glass microscopic slide. Thin sections were read with a bright field stereomicroscope at up to ×100 magnification. Zone counts were based on the number of complete opaque zones (i.e., opaque zones with translucent material outside them), which were counted to provide data for age estimates. Otoliths of *T. declivis* and *T. novaezelandiae* were read following the validated methods described by Horn (1993) and Lyle et al. (2000). A validated ageing method has not yet been developed for *T. murphyi* in New Zealand waters (Beentjes et al. 2013). Otoliths from this species were interpreted similarly to those of *T. declivis*. However, they are notably harder to read, with presumed annual zones often being diffuse, split, or containing considerable microstructure (Taylor et al. 2002).

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.

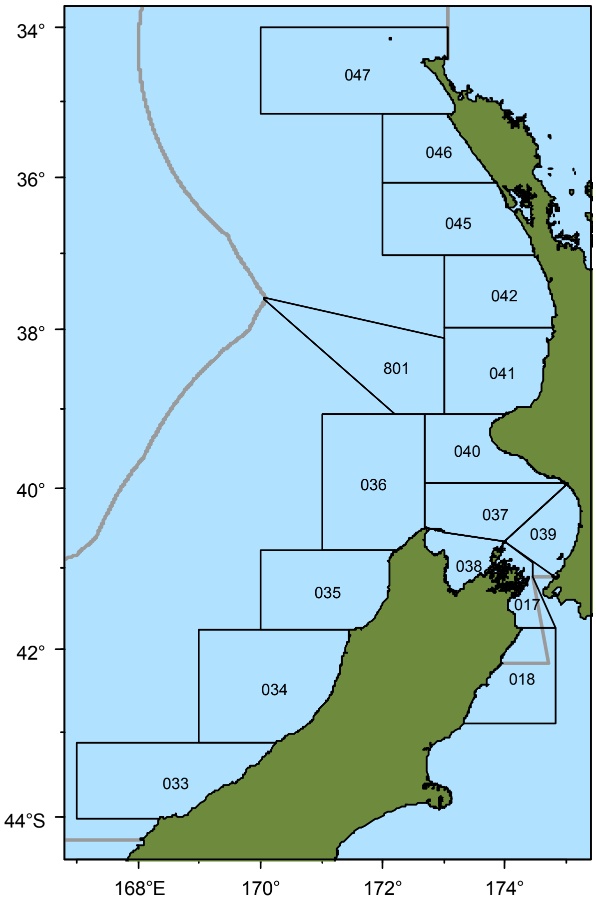

Figure 2: Statistical Areas referred to in the text.

3. RESULTS

3.1 Catch sampling

The landings distribution in 2012–13 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 034–036) (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 2012–13, about 95% 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 percentage of the catch sampled in all but one month was greater than 63% (Figure 3). Only Area 039 and September were under-sampled, although catches from both those strata were low. 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.

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 2012–13 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), 2012–13

Stat													Month
Area	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	All
017	1	0	1	0	1	1	1	4	1	1	0	0	11
033	2	8	9	9	7	7	8	3	1	1	2	0	57
034	1	4	2	1	1	2	1	1	274	46	27	3	363
035	0	0	0	0	0		0	0	351	137	313	1	803
036	491	1	0	0	0	0	0	288	705	312	75	1	1 873
037	327	113	1 097	1 457	307	1 206	1 880	56	128	89	52	0	6 712
038	6	1	0	3	0	1	0	5	0	0	0	0	17
039	10	0	0	14	0	0	401	2	30	1	1	3	462
040	493	70	1 053	2 021	138	143	493	71	834	176	10	0	5 501
041	675	784	5 197	855	1	79	0	4	274	98	2	0	7 970
042	1 439	419	1 514	480	0	1		0		0	0	1	3 853
045	876	9	0	0	1	0	0	0	0		0	1	887
46-47	0	0		0	0	0	0	0				1	1
801	297							18	286	0		0	601
	4 618	1 410	8 872	4 841	457	1 440	2 784	451	2 885	861	482	11	29 113

Sampled landings (t)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	All	%
017													0	0
033													0	0
034								0	252	47	28	4	331	91.1
035	0						27	2	364	142	325	1	861	107.3
036	339							243	747	319	81		1 730	92.3
037	212	108	1 036	1 466	309	1 173	2 165	0	128	63	56		6 715	100.0
038													0	0
039													0	0
040	435	79	1 247	2 338	176	169	600	16	741	231	9		6 041	109.8
041	447	736	5 337	756		4		4	295	94	1		7 673	96.3
042	1 043	417	1 347	513						0		0	3 321	86.2
045	452	9										1	461	52.0
46-47	0											0	1	46.3
801	77							21	295				393	65.4
	3 006	1 348	8 967	5 074	486	1 345	2 791	286	2 823	896	500	5	27 527	94.6
	65.1	95.6	101.1	104.8	106.2	93.4	100.2	63.4	97.8	104.1	103.6	47.9	94.6	

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 25–30%. *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.

	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

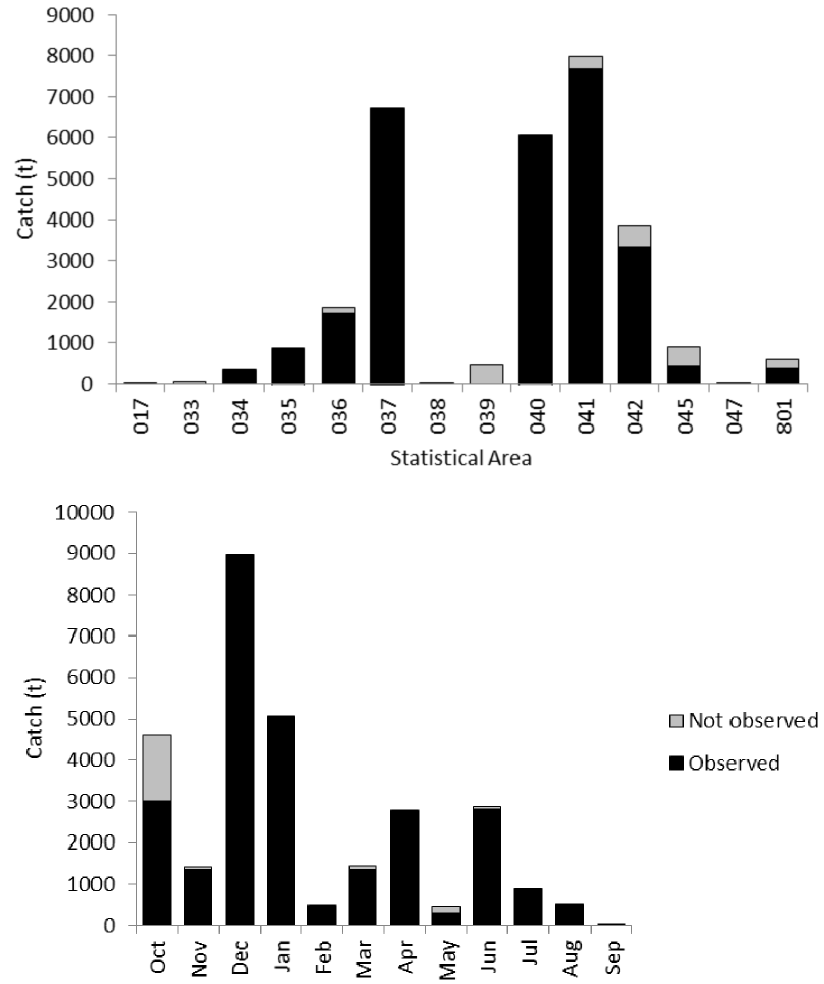

Figure 3: Observed landings and landings that were not observed, by Statistical Area and month, in 2012–13.

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 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.

	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

3.4 Catch-at-length

The estimated catch-at-length distributions, by species, for trawl-caught jack mackerel from JMA 7 in 2012–13 are plotted in Figure 4. For *T. novaezelandiae* there were two length modes (i.e., 16–21 cm, and 29–33 cm). For *T. declivis* there were strong length modes at 28–32 cm and 41–46 cm, and another mode at about 19–21 cm. The length range of *T. murphyi* was very narrow, with most fish 48–54 cm. For all species, there was little between-sex difference in the length distributions.

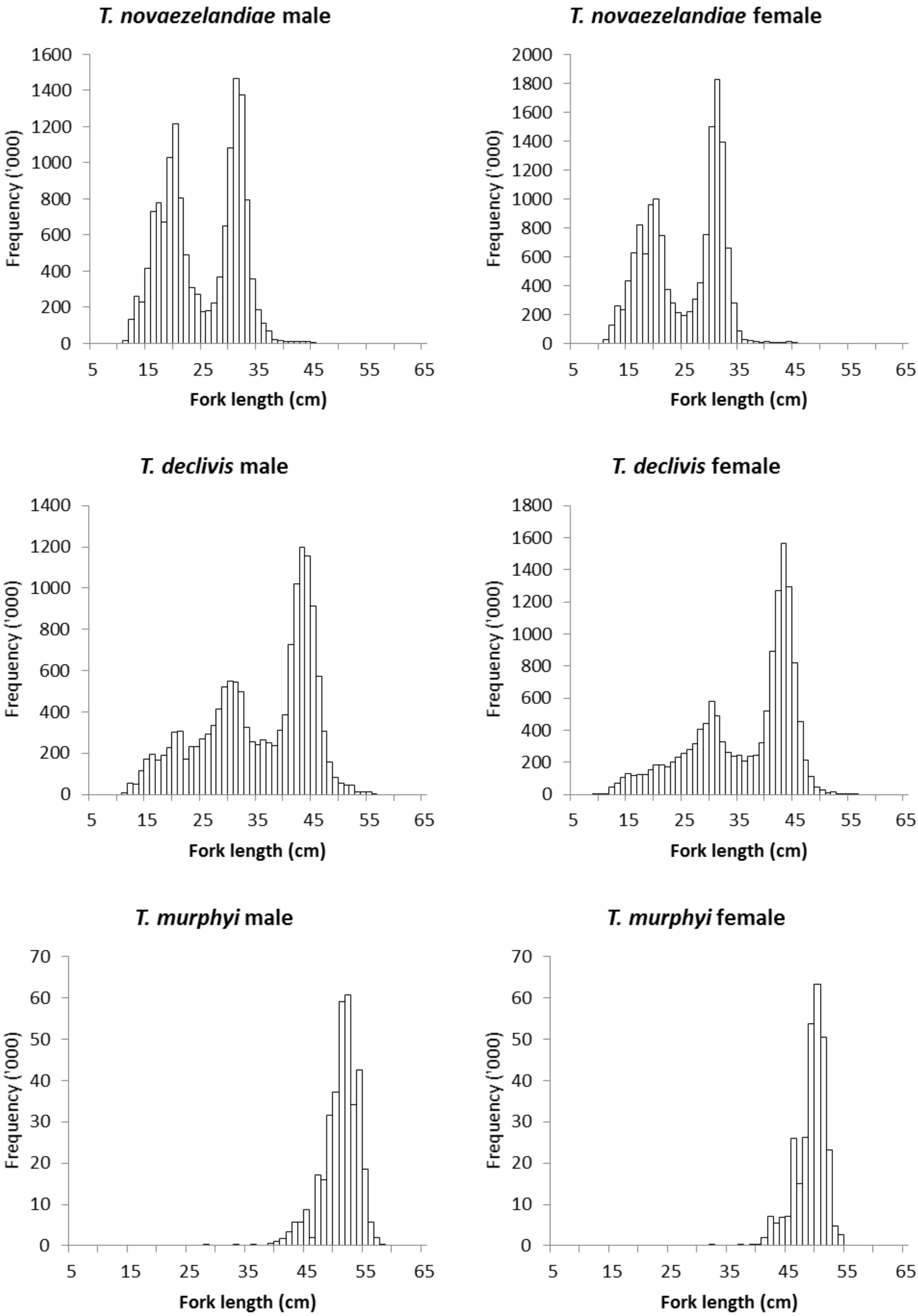

Figure 4: Estimated catch-at-length distributions, by species and sex, from JMA 7 in 2012–13.

3.5 Catch-at-age

The details of the estimated catch-at-age distributions for trawl-caught jack mackerel from JMA 7 in 2012–13 are presented for *T. novaezelandiae* in Table 4, *T. declivis* in Table 5, and *T. murphyi* in Table 6. The mean weighted CVs for *T. novaezelandiae* (19%), *T. declivis* (17%), and *T. murphyi* (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 2–6 year old fish, with very few fish older than 14 years. The catch of *T. declivis* had abundant fish aged 1–15 years old, but with a strong drop-off in fish older than 15 years. The catch of *T. murphyi* was dominated by 14–19 year old fish, with very few fish younger than 14 or older than 21 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 2012–13 fishing year. Summary statistics for the sample are also presented.

Age (years)	Male	CV	Female	CV	Total	CV
0	406 515	0.610	414 613	0.626	821 128	0.524
1	864 212	0.535	668 799	0.662	1 533 011	0.463
2	1 960 220	0.316	2 082 226	0.260	4 042 446	0.244
3	3 754 568	0.171	3 121 434	0.171	6 876 002	0.151
4	1 179 878	0.249	1 029 009	0.242	2 208 889	0.179
5	1 023 793	0.141	1 505 017	0.139	2 528 810	0.101
6	1 303 575	0.112	1 618 629	0.138	2 922 204	0.089
7	410 477	0.231	514 770	0.269	925 247	0.183
8	492 224	0.226	548 194	0.279	1 040 418	0.172
9	457 071	0.217	611 354	0.235	1 068 425	0.159
10	164 872	0.360	410 134	0.281	575 004	0.226
11	496 281	0.200	431 144	0.280	927 425	0.163
12	730 164	0.163	363 794	0.294	1 093 958	0.144
13	450 100	0.226	483 290	0.234	933 390	0.165
14	373 097	0.236	273 902	0.277	646 997	0.179
15	79 625	0.492	73 714	0.510	153 339	0.358
16	61 895	0.480	46 469	0.842	108 364	0.458
17	157 436	0.318	92 518	0.501	249 954	0.280
18	78 455	0.546	101 117	0.393	179 573	0.317
19	0	–	32 947	0.769	32 947	0.769
20	0	–	0	–	0	–
21	0	–	0	–	0	–
22	0	–	0	–	0	–
23	0	–	14 612	0.835	14 612	0.835
24	0	–	6 358	0.903	6 358	0.903
No. measured		11 727		11 153		22 880
No. aged		237		225		462
No. of tows sampled						279
Mean weighted CV (%)		24.2		25.1		19.3

Table 5: Calculated numbers-at-age, separately by sex, with CVs, for *Trachurus declivis* caught during commercial trawl operations in JMA 7 during the 2012–13 fishing year. Summary statistics for the sample are also presented.

Age (years)	Male	CV	Female	CV	Total	CV
0	59 818	1.131	56 582	0.948	116 399	0.793
1	1 399 030	0.251	906 451	0.292	2 305 481	0.238
2	1 649 286	0.299	2 009 531	0.205	3 658 818	0.199
3	1 888 938	0.183	1 282 678	0.227	3 171 616	0.161
4	1 160 448	0.240	1 485 000	0.189	2 645 448	0.161
5	1 229 814	0.195	806 978	0.228	2 036 793	0.153
6	579 602	0.226	387 727	0.248	967 328	0.170
7	647 917	0.178	346 947	0.248	994 863	0.149
8	603 222	0.194	614 664	0.187	1 217 885	0.135
9	516 151	0.210	910 648	0.155	1 426 798	0.125
10	574 818	0.218	755 217	0.185	1 330 036	0.140
11	1 183 403	0.137	1 003 292	0.156	2 186 695	0.099
12	1 056 128	0.145	661 160	0.187	1 717 288	0.113
13	470 456	0.212	466 892	0.216	937 347	0.149
14	521 613	0.203	509 357	0.211	1 030 970	0.143
15	459 425	0.208	596 107	0.199	1 055 532	0.149
16	137 844	0.414	408 196	0.253	546 041	0.211
17	114 497	0.525	373 740	0.264	488 237	0.243
18	0	–	135 411	0.399	135 411	0.399
19	104 859	0.472	162 290	0.369	267 148	0.292
20	0	–	30 372	0.868	30 372	0.868
21	59 128	0.701	0	–	59 128	0.701
22	0	–	37 269	0.801	37 269	0.801
No. measured		16 549		16 673		33 222
No. aged		299		294		593
No. of tows sampled						402
Mean weighted CV (%)		22.2		21.8		16.8

Table 6: Calculated numbers-at-age, separately by sex, with CVs, for *Trachurus murphyi* caught during commercial trawl operations in JMA 7 during the 2012–13 fishing year. Summary statistics for the sample are also presented.

Age (years)	Male	CV	Female	CV	Total	CV
8	5 494	0.966	7 564	1.001	13 058	0.710
9	5 531	0.838	79	3.970	5 610	0.869
10	5 843	0.911	4 321	1.014	10 164	0.714
11	0	–	0	–	0	–
12	4 291	0.947	9 951	0.654	14 242	0.499
13	4 530	0.638	11 831	0.549	16 360	0.432
14	28 550	0.265	22 027	0.393	50 577	0.231
15	48 435	0.185	46 692	0.243	95 128	0.142
16	84 291	0.144	43 698	0.255	127 989	0.111
17	68 740	0.146	61 331	0.184	130 072	0.107
18	37 769	0.200	29 966	0.240	67 735	0.145
19	29 526	0.223	26 276	0.274	55 802	0.164
20	16 420	0.302	10 649	0.437	27 069	0.245
21	1 950	0.724	1 632	1.157	3 582	0.664
22	2 883	0.766	5 246	0.638	8 130	0.479
23	2 292	0.757	2 645	0.715	4 937	0.487
24	1 416	1.140	789	1.357	2 205	0.894
25	1 468	1.069	4 483	0.629	5 950	0.532
26	0	–	0	–	0	–
27	1 581	0.915	0	–	1 581	0.915
28	0	–	4 073	0.816	4 073	0.816
29	1 501	1.079	1 667	1.109	3 168	0.785
30	0	–	0	–	0	–
31	1 468	1.045	0	–	1 468	1.045
No. measured		554		443		997
No. aged		277		171		448
No. of tows sampled						165
Mean weighted CV (%)		26.4		35.0		21.2

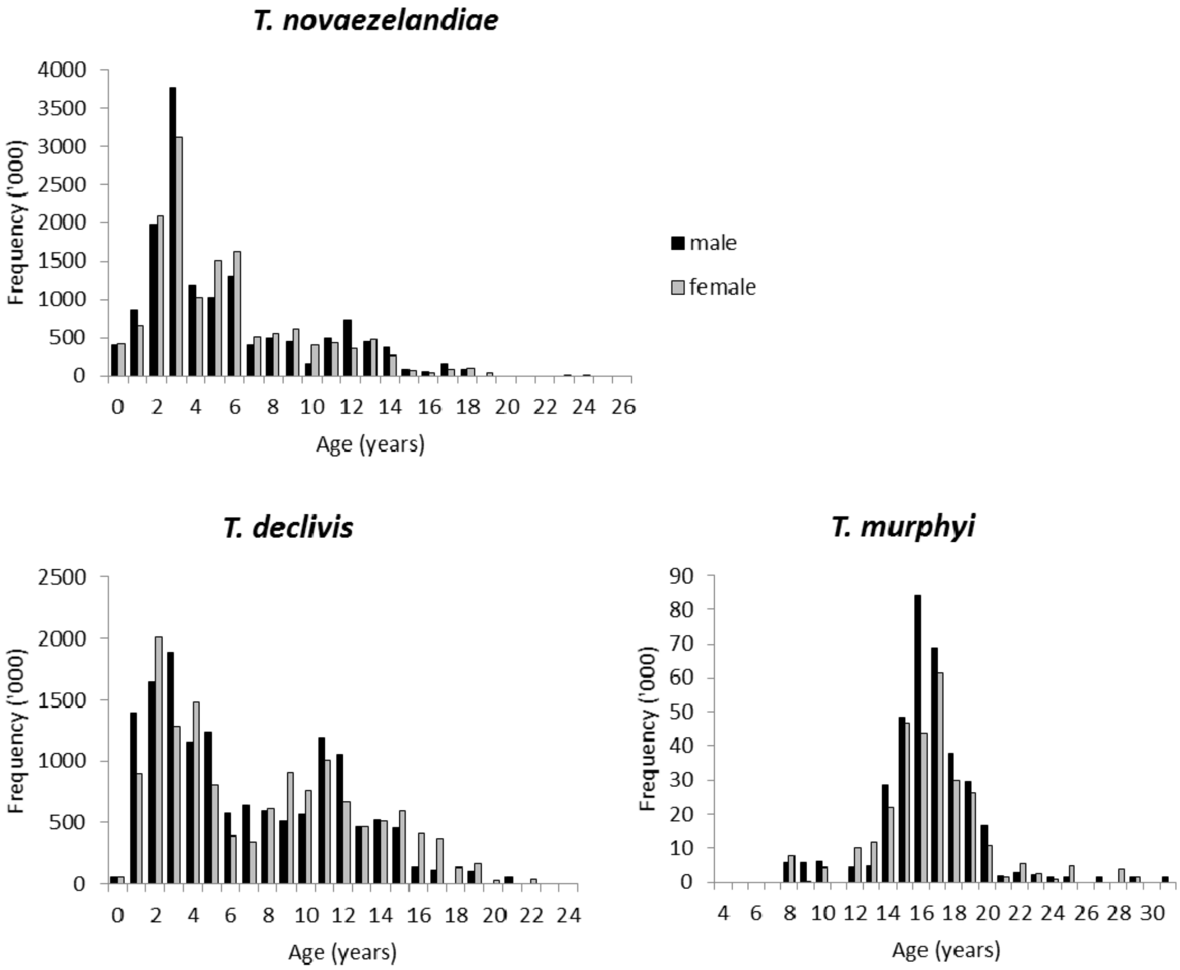

Figure 5: Estimated commercial catch-at-age distributions, by species and sex, from JMA 7 in 2012–13.

3.6 Data summaries

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

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

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

		Catch-at-age mwCV (%)			Catch-at-length mwCV (%)		
Species	Fishing year	Males	Females	Total	Males	Females	Total
T. 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
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
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

Trachurus novaezelandiae

Scaled catch-at-length frequencies by fishing year are shown in Figure 6. They had single modes at 28–31 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 1+ year class in 2008–09 was also relatively strong. 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 3+ year class in 2012–13 was also relatively strong in the two 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. 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 in 2012–13. The 2011–12 1+ year class appeared to be relatively strong.

Trachurus murphyi

Scaled catch-at-length frequencies by fishing year, are shown in Figure 8. All the distributions are unimodal at 49–51 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.

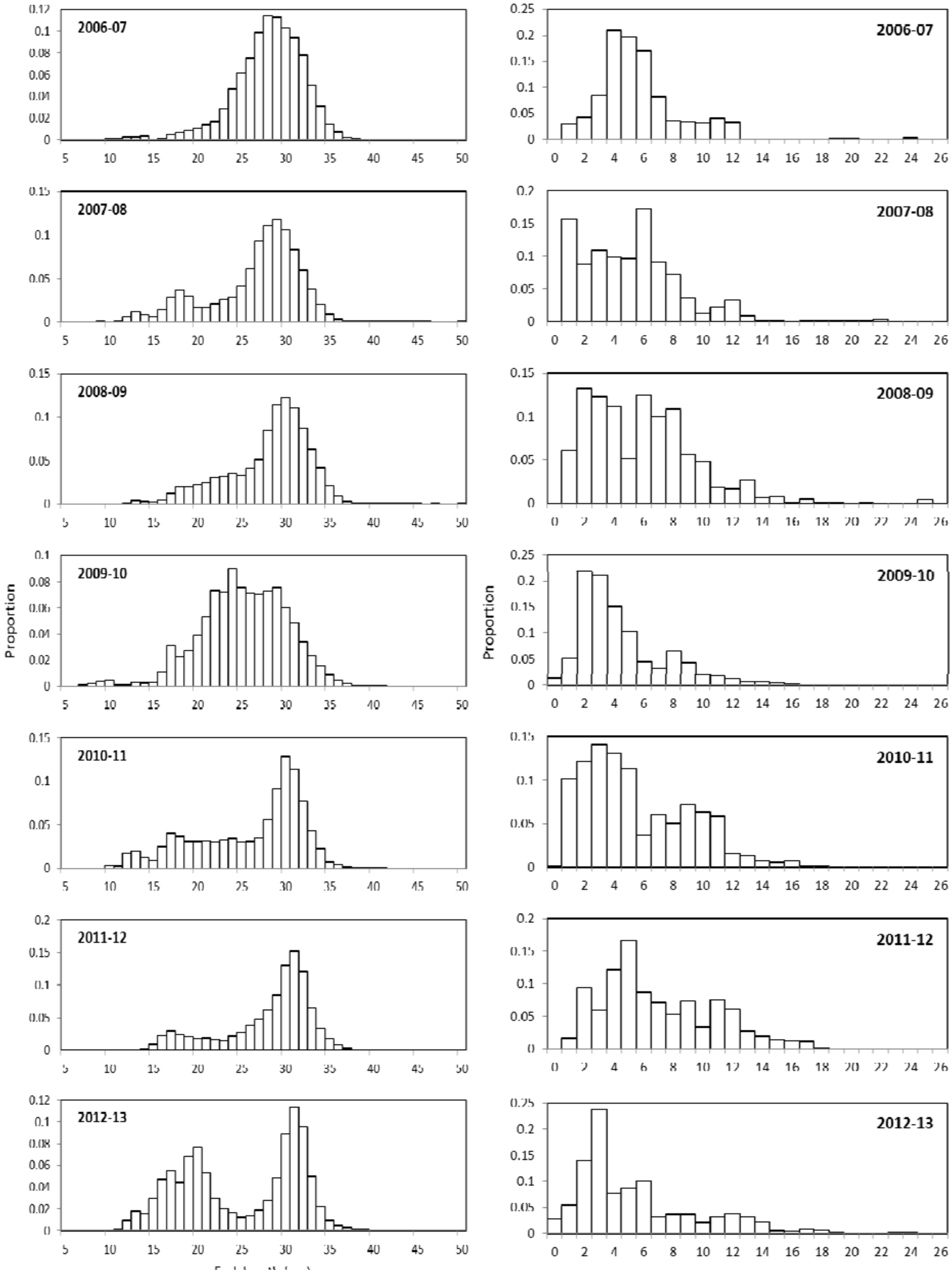

Figure 6: Scaled catch-at-length (left panel) and catch-at-age (right panel) proportions for the catch of *Trachurus novaezelandiae* sampled from the 2006–07 to 2012–13 fishing years.

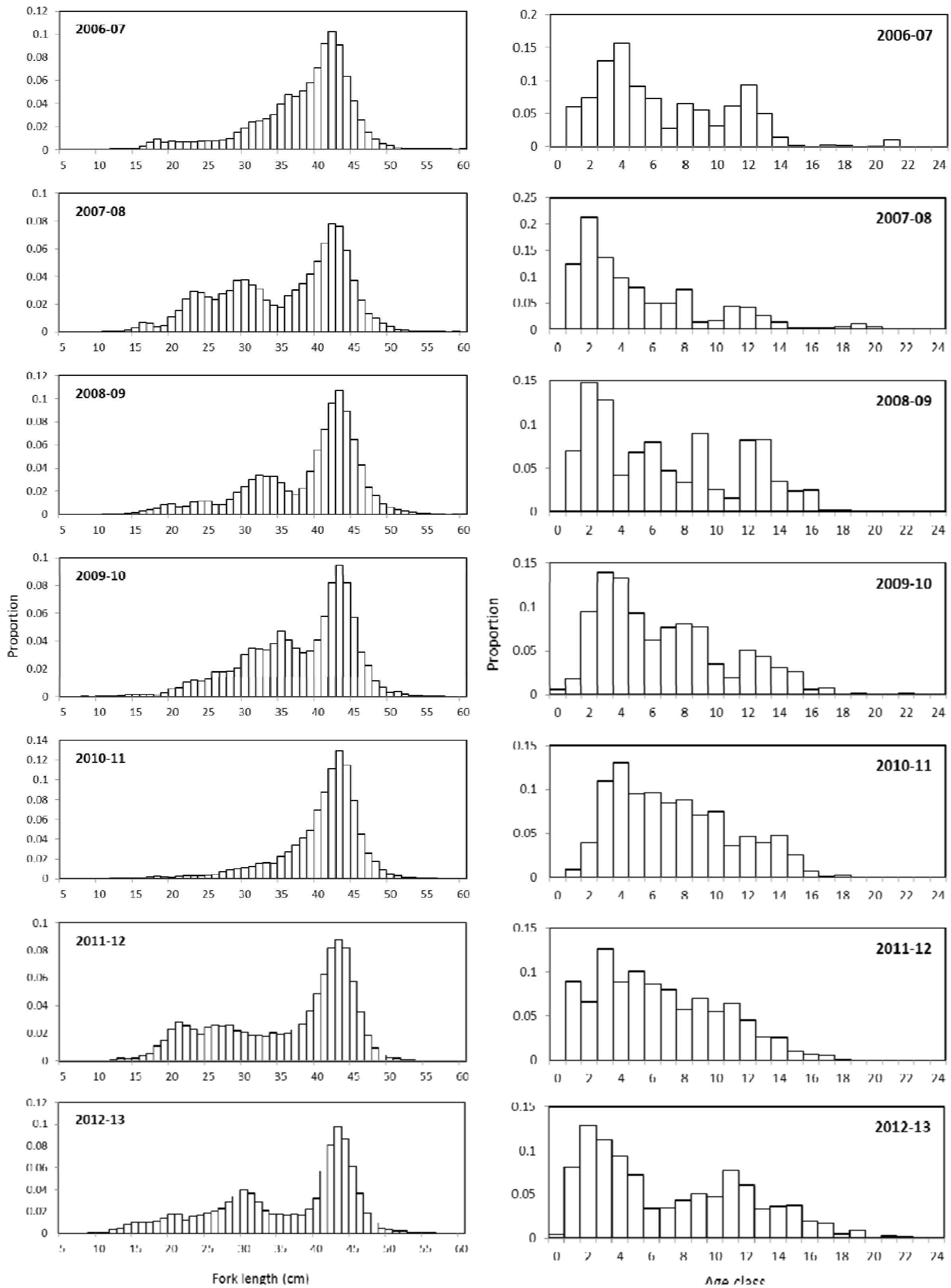

Figure 7: Scaled catch-at-length (left panel) and catch-at-age (right panel) proportions for the catch of *Trachurus declivis* sampled from the 2006–07 to 2012–13 fishing years.

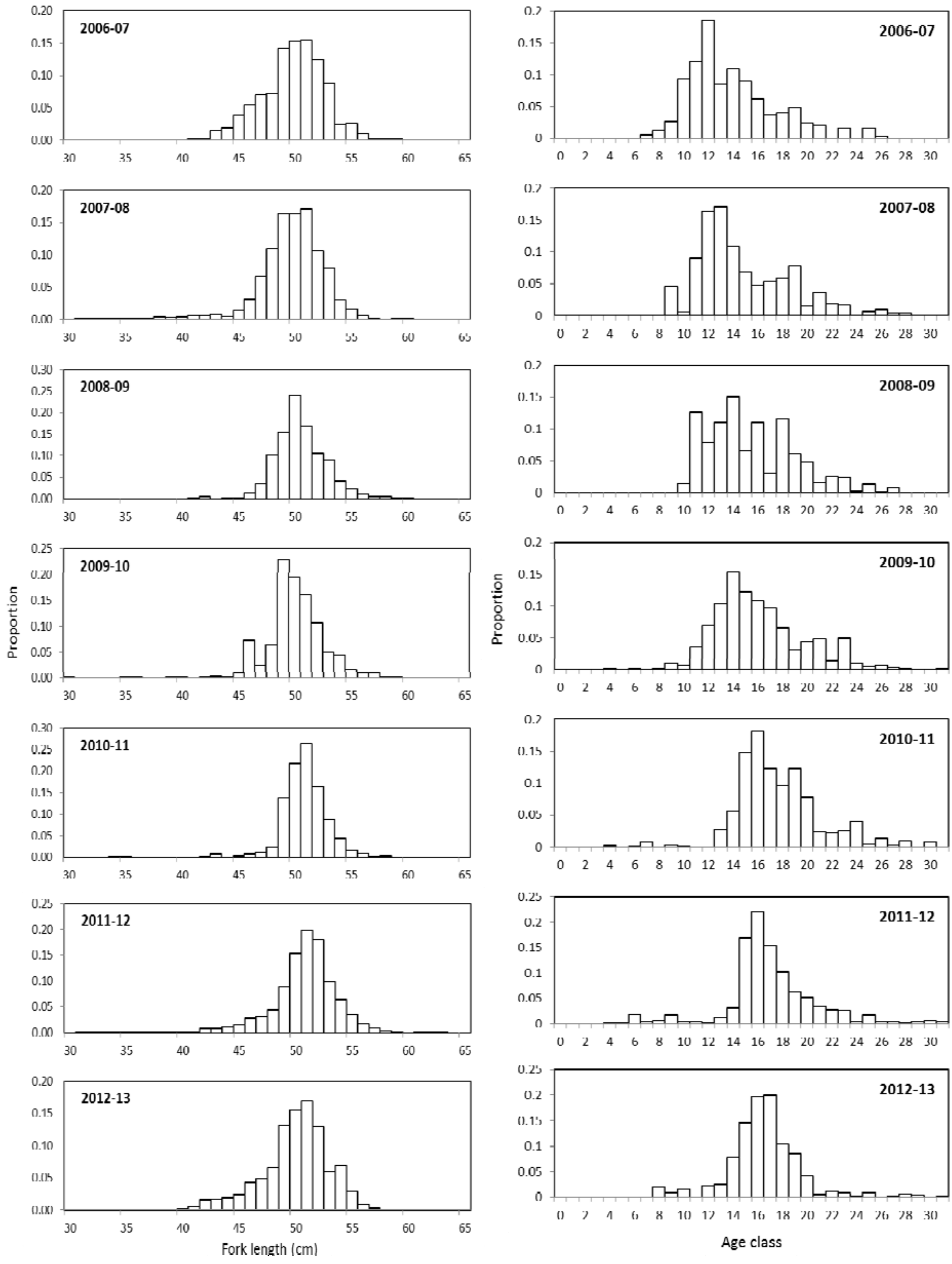

Figure 8: Scaled catch-at-length (left panel) and catch-at-age (right panel) proportions for the catch of *Trachurus murphyi* sampled from the 2006–07 to 2012–13 fishing years.

3.7 Estimation of mortality rates

Estimates of total instantaneous mortality (Z) were made for *T. novaezelandiae* and *T. declivis* in each sampled year, and for all years combined, using the method of Chapman & Robson (1960) as implemented using the R software developed by Ogle (2014), i.e.,

$$Z = \log_e\left(\frac{1+a-1/n}{a}\right)$$

where a is the mean age above recruitment age and n is the sample size. Age at recruitment is the age at which 100% of fish are estimated to be vulnerable to the sampling method, and it varied between years (see Figures 6 and 7). Each sample was standardised so that an effective sample size of 1000 aged fish produced the Z estimate for each year.

Mortality rate estimates with confidence intervals are presented in Table 8. The catch-at-age distributions for the combined samples (i.e., the standardised age distributions summed across the seven sampled years) are shown in Figure 9. Age ranges used to estimate Z were allowed to vary between samples, with the minimum age in the range being essentially the age of the most abundant year class. It was believed that age at full recruitment could vary between years owing to different levels of fishing intensity in different areas and depths, which influences the minimum age of years classes comprehensively sampled. Using this method, for *T. novaezelandiae*, Z estimates were 0.22–0.37, with a value of 0.25 for all years combined. Estimates for *T. declivis* are slightly lower, 0.16–0.23, with a combined value of 0.20. Inflexion points in the catch-curves (Figure 9) indicate that at some time between ages 10 and 15 years, both species (but particularly *T. declivis*) experienced a change in mortality (or some other factor responsible for removals from the population) from a slower to a faster rate.

Table 8: Estimates of total instantaneous mortality (*Z*) with standard errors (s.e.) and 95% confidence intervals (95% CI) for *T. novaezelandiae* and *T. declivis*, by year, and for all years combined. 'Age range' denotes the age classes (years) used to estimate *Z*.

	Trachurus novaezelandiae				*Trachurus declivis*			
Year	Age range	*Z*	s.e.	95% CI	Age range	*Z*	s.e.	95% CI
2006–07	4–14	0.372	0.012	0.349–0.396	4–15	0.227	0.007	0.213–0.241
2007–08	1–14	0.223	0.007	0.210–0.237	2–20	0.233	0.007	0.219–0.248
2008–09	2–19	0.219	0.007	0.206–0.233	2–18	0.169	0.005	0.159–0.180
2009–10	2–19	0.314	0.010	0.295–0.334	3–17	0.208	0.007	0.195–0.221
2010–11	3–18	0.243	0.008	0.228–0.258	4–18	0.213	0.007	0.200–0.227
2011–12	5–18	0.243	0.008	0.228–0.258	3–18	0.206	0.007	0.193–0.219
2012–13	3–19	0.250	0.008	0.234–0.265	2–22	0.161	0.005	0.151–0.171
All years	3–23	0.248	0.003	0.242–0.254	3–22	0.197	0.002	0.192–0.202

The Working Group recommended that a single age at full recruitment be used for each species. Consequently, Z values were also estimated using a minimum age of 6 years for *T. novaezelandiae* and 4 years for *T. declivis* (Table 9), ages believed to be very likely fully recruited, based on the sets of distributions in Figures 6 and 7. For *T. novaezelandiae*, Z estimates were 0.24–0.46, with a value of 0.30 for all years combined. Estimates for *T. declivis* are lower, 0.16–0.23, with a combined value of 0.20.

Table 9: Estimates of total instantaneous mortality (*Z*) with standard errors (s.e.) and 95% confidence intervals (95% CI) for *T. novaezelandiae* and *T. declivis*, by year, and for all years combined. 'Age range' denotes the age classes (years) used to estimate *Z*.

	Trachurus novaezelandiae				*Trachurus declivis*			
Year	Age range	*Z*	s.e.	95% CI	Age range	*Z*	s.e.	95% CI
2006–07	6–14	0.430	0.019	0.392–0.467	4–15	0.227	0.007	0.213–0.241
2007–08	6–14	0.463	0.022	0.420–0.507	4–20	0.220	0.009	0.203–0.238
2008–09	6–19	0.348	0.015	0.318–0.377	4–18	0.167	0.006	0.155–0.179
2009–10	6–19	0.308	0.019	0.271–0.345	4–17	0.217	0.007	0.202–0.231
2010–11	6–18	0.264	0.012	0.241–0.287	4–18	0.213	0.007	0.200–0.227
2011–12	6–18	0.236	0.009	0.219–0.253	4–18	0.216	0.007	0.202–0.231
2012–13	6–19	0.244	0.011	0.222–0.266	4–22	0.164	0.006	0.152–0.176
All years	6–23	0.296	0.005	0.287–0.306	4–22	0.200	0.003	0.195–0.206

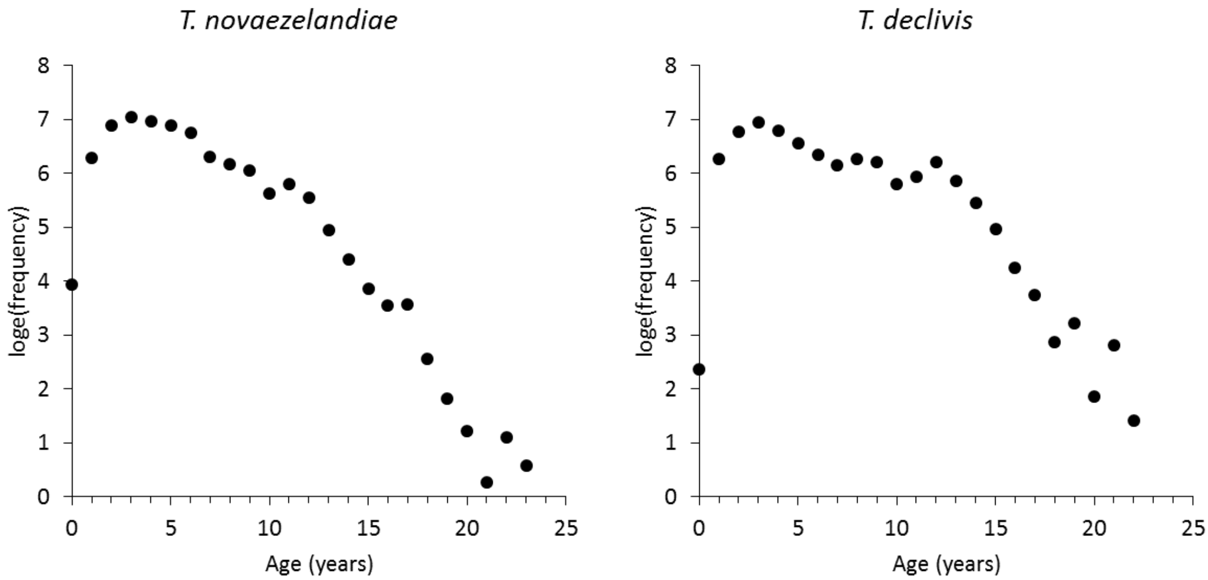

Figure 9: Estimated catch-at-age for *T. novaezelandiae* and *T. declivis* in JMA 7, for the years 2006–07 to 2012–13 combined.

4. DISCUSSION

The 2012–13 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, with more than 60% of the catch sampled in all months with substantial landings. Spatially, there was very good coverage of catch in the heavily fished Statistical Areas (037, 040–042); only Area 039 was under-sampled, but it produced less than 2% of the catch. Estimates of the 2012–13 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. One entire trip was removed from the analysis because the *T. novaezelandiae* data from it included a large mode of fish with lengths of 40–50 cm, almost certainly misidentified *T. declivis*. It was also likely that some fish from other observed trips were misidentified. When the raw age data were plotted against length, 1.8% of the aged *T. declivis* appeared as outliers that fitted well on the growth curve for *T. novaezelandiae*, and 4.7% 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 seven fishing years from which data were available. The percentage of *T. novaezelandiae* was also consistent temporally at 25–30%. 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. (2014) 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 six 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 collected data on sex of *T. murphyi* indicated a population consistently biased towards males (i.e., 54–62% of sampled fish). It is known (author's unpublished data) that *T. murphyi* can, at times, be quite difficult to sex, with deposits of fat in the body cavity often appearing like male gonads when the gonads are in a regressed state. However, it is interesting to note that 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 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.

Rates of instantaneous natural mortality (M) for *T. novaezelandiae* and *T. declivis* were previously estimated to be 0.17–0.20, with the best point estimate for both species being 0.18 yr^{-1} (Horn 1993). Estimates of instantaneous total mortality (Z) from commercial trawl fishery samples in JMA 7 in 1989–1991 were 0.22–0.23 for both species (Horn 1993). The Z estimates from the current work are slightly higher for *T. novaezelandiae* (0.30) and lower for *T. declivis* (0.2) than those determined previously. 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, suggest that *T. novaezelandiae* and *T. declivis* in JMA 7 are not over-exploited. The inflexion in the catch-curve for *T. declivis* (see Figure 9) suggesting a change in mortality from a slower to a faster rate at around age 13 years may not be related to mortality at all, but instead may be a consequence of migration of larger (older) fish from the JMA 7 area to the JMA 3 area (Horn et al. 2014).

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.

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

Table A2: 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	2007	2008	2009	2010	2011	2012	2013
0	0	0	0	0.0054	0	0	0.0041				0.428			0.793
1	0.0605	0.1245	0.0693	0.0180	0.0092	0.0889	0.0813	0.220	0.175	0.170	0.326	0.355	0.267	0.238
2	0.0737	0.2125	0.1478	0.0942	0.0390	0.0659	0.1290	0.172	0.145	0.134	0.207	0.191	0.229	0.199
3	0.1307	0.1357	0.1273	0.1387	0.1091	0.1261	0.1118	0.141	0.119	0.144	0.141	0.134	0.162	0.161
4	0.1574	0.0972	0.0416	0.1327	0.1301	0.0886	0.0933	0.118	0.176	0.311	0.130	0.113	0.182	0.161
5	0.0907	0.0784	0.0678	0.0923	0.0949	0.1004	0.0718	0.244	0.227	0.299	0.160	0.143	0.115	0.153
6	0.0728	0.0492	0.0798	0.0629	0.0963	0.0859	0.0341	0.303	0.325	0.322	0.190	0.153	0.114	0.170
7	0.0270	0.0491	0.0475	0.0767	0.0851	0.0796	0.0351	0.503	0.256	0.385	0.168	0.169	0.117	0.149
8	0.0654	0.0755	0.0343	0.0801	0.0883	0.0575	0.0429	0.310	0.371	0.437	0.186	0.175	0.140	0.135
9	0.0549	0.0131	0.0894	0.0768	0.0701	0.0700	0.0503	0.309	0.503	0.260	0.177	0.176	0.124	0.125
10	0.0315	0.0154	0.0257	0.0345	0.0750	0.0556	0.0469	0.486	0.482	0.463	0.300	0.184	0.137	0.140
11	0.0618	0.0443	0.0160	0.0192	0.0354	0.0642	0.0771	0.272	0.329	0.635	0.367	0.230	0.127	0.099
12	0.0934	0.0422	0.0819	0.0507	0.0458	0.0454	0.0605	0.254	0.301	0.286	0.214	0.216	0.158	0.113
13	0.0496	0.0260	0.0823	0.0435	0.0391	0.0256	0.0330	0.363	0.454	0.281	0.236	0.237	0.208	0.149
14	0.0137	0.0138	0.0352	0.0299	0.0478	0.0254	0.0363	0.537	0.456	0.476	0.268	0.209	0.183	0.143
15	0.0015	0.0024	0.0240	0.0264	0.0256	0.0099	0.0372	0.858	0.912	0.400	0.273	0.295	0.339	0.149
16	0	0.0005	0.0251	0.0057	0.0068	0.0055	0.0193		0.686	0.335	0.469	0.545	0.472	0.211
17	0.0031	0.0017	0.0023	0.0075	0.0004	0.0051	0.0172	0.973	0.966	0.581	0.647	1.049	0.438	0.243
18	0.0013	0.0042	0.0028	0	0.0020	0.0005	0.0048	1.050	0.395	0.633		1.091	0.690	0.399
19	0	0.0104	0	0.0023	0	0	0.0094		0.762		1.020			0.292
20	0.0006	0.0038	0	0	0	0	0.0011	1.101	0.975					0.868
21	0.0104	0	0	0	0	0	0.0021	0.430						0.701
22	0	0	0	0.0023	0	0	0.0013				0.963			0.801
23	0	0	0	0	0	0	0							
24	0	0	0	0.0003	0	0	0				1.254			

Table A3: 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	2007	2008	2009	2010	2011	2012	2013
4	0	0	0	0.0020	0.0026	0.0018	0				2.236	1.146	1.047	
5	0	0	0	0	0	0.0021	0						0.747	
6	0	0	0	0.0021	0.0005	0.0193	0				1.423	2.163	0.420	
7	0.0055	0	0	0	0.0073	0.0044	0	1.041				1.841	1.093	
8	0.0126	0	0	0.0026	0	0.0059	0.0201	0.625			1.481		0.891	0.710
9	0.0272	0.0458	0	0.0105	0.0036	0.0180	0.0086	0.413	0.333		0.948	0.873	0.596	0.869
10	0.0935	0.0053	0.0144	0.0071	0.0012	0.0030	0.0157	0.335	0.594	0.615	0.803	1.888	1.225	0.714
11	0.1216	0.0895	0.1258	0.0350	0	0.0030	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	0.201	0.190	0.304	0.584		1.043	0.499
13	0.0847	0.1708	0.1092	0.1040	0.0273	0.0128	0.0252	0.282	0.172	0.241	0.178	0.363	0.511	0.432
14	0.1092	0.1083	0.1499	0.1530	0.0567	0.0320	0.0779	0.231	0.248	0.208	0.233	0.235	0.322	0.231
15	0.0900	0.0687	0.0657	0.1227	0.1488	0.1694	0.1466	0.300	0.323	0.318	0.271	0.144	0.119	0.142
16	0.0628	0.0484	0.1092	0.1080	0.1823	0.2194	0.1972	0.410	0.309	0.235	0.192	0.130	0.102	0.111
17	0.0363	0.0538	0.0305	0.0965	0.1224	0.1544	0.2004	0.514	0.318	0.299	0.178	0.174	0.119	0.107
18	0.0395	0.0580	0.1163	0.0658	0.0962	0.1019	0.1044	0.476	0.380	0.243	0.222	0.183	0.165	0.145
19	0.0489	0.0783	0.0606	0.0308	0.1227	0.0633	0.0860	0.639	0.306	0.334	0.304	0.155	0.182	0.164
20	0.0244	0.0154	0.0486	0.0450	0.0784	0.0514	0.0417	0.722	0.521	0.371	0.235	0.228	0.198	0.245
21	0.0211	0.0364	0.0159	0.0492	0.0233	0.0349	0.0055	0.647	0.436	0.821	0.269	0.374	0.231	0.664
22	0	0.0180	0.0256	0.0151	0.0223	0.0288	0.0125		0.770	0.406	0.433	0.392	0.267	0.479
23	0.0168	0.0160	0.0251	0.0501	0.0255	0.0270	0.0076	1.119	0.755	0.541	0.273	0.340	0.298	0.487
24	0	0	0.0024	0.0103	0.0409	0.0030	0.0034			0.778	0.576	0.295	0.831	0.894
25	0.0168	0.0063	0.0138	0.0048	0.0051	0.0177	0.0092	1.093	1.019	0.854	0.655	0.763	0.336	0.532
26	0.0033	0.0097	0.0009	0.0076	0.0134	0.0041	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		0.980	0.643	0.791	1.018	0.673	0.915
28	0	0.0039	0	0.0011	0.0092	0.0007	0.0063		0.933		1.060	0.630	1.301	0.816
29	0	0	0	0	0	0.0046	0.0049						0.780	0.785
30	0	0	0	0	0.0073	0.0066	0					0.836	0.645	
31	0	0	0	0.0027	0	0.0039	0.0023				1.014		0.693	1.045