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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

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EXECUTIVE SUMMARY

Horn, P.L.; Hulston, D.; Ó Maolagáin, C. (2012). 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.

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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 2010–11 fishing year, and the subsequent 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 includes (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 varies with both month and statistical area. Just less than 29% of the 2010–11 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 2010–11 were generally similar to those from the four previous years. The age-frequency distributions for all species in 2010–11 had mean weighted c.v.s of 23% or less, which more than met the target of 30%. By species, there is clear variation in catch-at-age between years. For *T. declivis* and *T. murphyi* the variation is largely a consequence of the progression of year classes with different relative strengths. Year class strength progression can also be postulated for *T. novaezelandiae*, but it is not as clear and consistent as for the two other species.

Estimated species proportions indicated a predominance of *T. declivis* at about 65–71% in the JMA 7 TCEPR catch throughout all statistical areas and the five years of sampling; *T. novaezelandiae* was consistently represented at 25–28% and *T. murphyi* at 3% to 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 catch information for each is unavailable from the jack mackerel quota management areas (Figure 1). Consequently, estimates of proportions of the three *Trachurus* species in the catch are essential for assessment of their stocks individually. 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 sampling began, which can in turn be used to scale age structures 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).

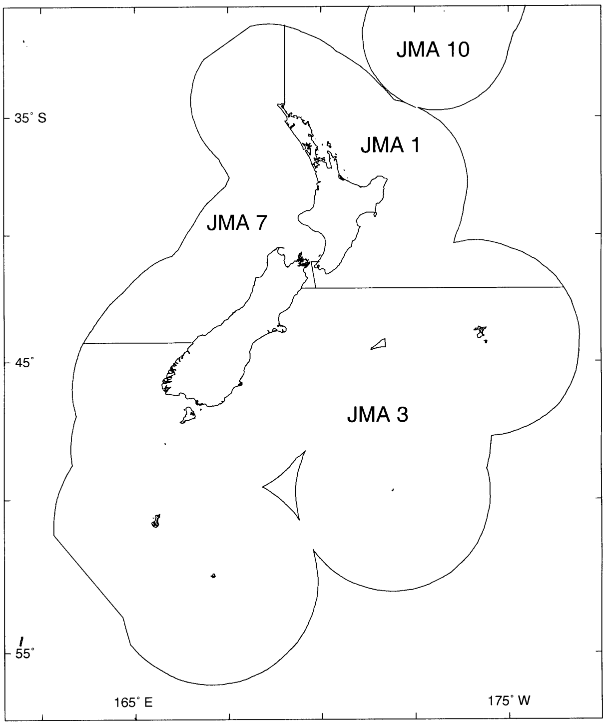

Figure 1: Jack mackerel administrative Fishstocks.

This report provides estimates of relative proportions and catch-at-age for the three *Trachurus* species in the commercial JMA 7 catch for 2010–11 using observer data. Similar data were presented by Taylor et al. (2011) for 2006–07, 2007–08 and 2008–09, and Horn et al. (2012) for 2009–10. 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 MID201001B "Routine age determination of hoki and middle depth species from commercial fisheries and trawl surveys", funded by the Ministry for Primary Industries. 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".

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 carried out according to instructions developed at NIWA and included in the Scientific Observers Manual. Each tow in the observer dataset includes (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 2010–11 fishing year were extracted for the analyses. As in previous analyses, estimated species proportions (by weight) in each sampled landing 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 #8449) 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 2010–11.

Stratification of the data is required because the observer coverage varies with both month and statistical area, the fishery is not consistent throughout the year, and the species composition varies across area and depth (Taylor et al. 2011). The derivation of the five strata used in this analysis is shown in Appendix A. Each fishing event from the catch-effort dataset and the observer dataset was allocated to one of the five strata.

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 defined in Appendix A. 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 (i.e., *T. declivis*, *T. novaezelandiae*, and *T. murphyi*) caught by trawl in JMA 7 (Statistical Areas 033–048, 801 (Figure 2)) in the 2010–11 fishing year, using data and otoliths collected by observers. For each of the three 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 380μm thin transverse section was cut from each block through the primordia using a high speed saw. The thin section was washed, dried, and embedded under a cover slip on a glass microscopic slide. Thin sections were read with a bright field stereomicroscope at up to ×100 magnification. Zone counts were based on the number of complete opaque zones (i.e., opaque zones with translucent material outside them), which were counted to provide data for age estimates. Otoliths of *T. declivis* and *T. novaezelandiae* were read following the validated methods described by Horn (1993) and Lyle et al. (2000). A validated ageing method has not yet been developed for *T. murphyi* in New Zealand waters. 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 scale the weighted length composition of the catch up to catch-at-age by sex using the NIWA catch-at-age software (Bull & Dunn 2002). This software also provides estimates of c.v.s-at-age using a bootstrap procedure. Sex ratios by species were also derived from this process.

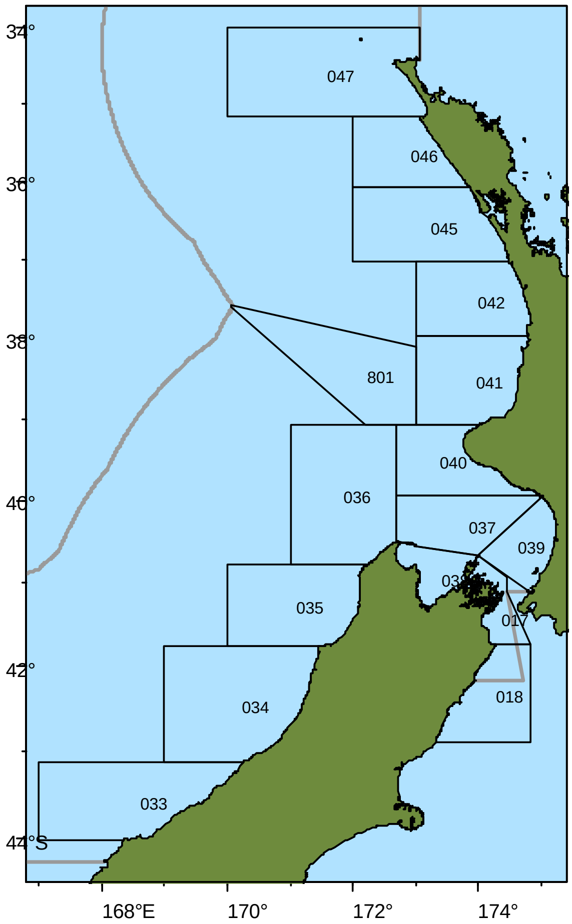

Figure 2: Statistical Areas referred to in the text.

3. RESULTS

3.1 Catch sampling

The landings distribution in 2010–11 shows that there is 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 as well as Area 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 by Taylor et al. (2011).

In 2010–11, about 29% 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). Sampling was concentrated in October–January and June (and these months produced relatively high landings), but February and March were under-sampled (Figure 3). However, it was concluded that sampling of the whole fishery was satisfactory to estimate the overall catch-at-age.

Table 1: Jack mackerels — distribution of estimated total catch and sampled landings (t, rounded to the nearest tonne), by month and statistical area (Stat Area), in the 2010–11 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), 2010–11

Stat													Month
Area	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	All
033–035	25	9	4	2	8	4	2	1	263	814	75	44	1251
036	267	0	1	0		0	0	4	598	40	5	1	917
037	395	3	118	1778	812	922	867	117	219	35	0	2	5269
038	1	2	1	1	1	0	0	1	2	1	0	1	12
039	1	0	0	0		19	232	2	350	1	1	2	608
040	579	143	270	1197	649	282	93	501	725	0	30	13	4483
041	279	1930	4612	416	2	25	2	177	857	4	84	16	8403
042	0	1073	2770	343	0	0			535		0	0	4721
045–047	4	3	7	2	0	4	1	0	155	1	2	1	180
801			10						598				608
All	1551	3164	7794	3740	1474	1256	1197	803	4302	895	198	80	26451

													Sampled landings (t)	
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	All	%
033–035								2	146	129	1	3	281	22.3
036	75								128				203	22.1
037	389	1	82	383			280	113	114	1		0	1364	25.9
038														
039												1	1	0.2
040	485	58	84	166			13	271	636			14	1728	38.5
041	53	791	562					0	224			17	1647	19.6
042		724	892						211				1828	38.7
045–047									31				31	17.9
801									517				517	85.0
All	1002	1575	1621	548			293	387	2007	131	1	36	7600	28.7
%	64.6	49.8	20.8	14.7			24.4	48.1	46.7	14.5	0.5	44.3	28.7	

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, accounting for 65 to 71% of landed weight in all years. *T. novaezelandiae* (JMN) was the second most frequently caught species at 25 to 28%. By contrast, *T. murphyi* (JMM) was detected at a much lower and quite variable rate of 3 to 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. Data from 2006–07 to 2009–10 are from Taylor et al. (2011) and Horn et al. (2012).

	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

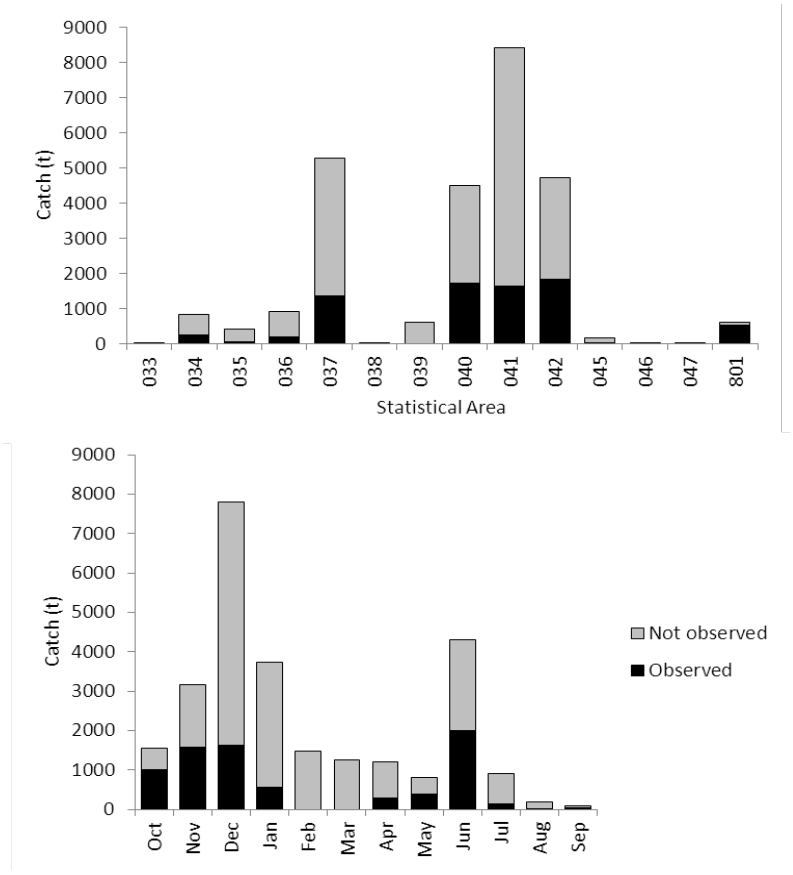

Figure 3: Observed landings and landings that were not observed, by Statistical Area and month, in 2010–11.

3.3 Sex ratios

Sex ratios by fishing year since 2006–07 are shown in Table 3. Generally, ratios are around 50% with the largest digression being *T. murphyi* in 2007–08 with an estimated value for males of 61%. However, some consistent trends are apparent: the *T. declivis* and *T. murphyi* catches usually have a higher proportion of males, while the *T. novaezelandiae* catch is biased towards females.

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

3.4 Catch-at-length

The estimated catch-at-length distributions, by species, for trawl-caught jack mackerel from JMA 7 in 2010–11 are plotted in Figure 4. For *T. novaezelandiae* there are at least three length modes (i.e., 12–13 cm, 17–18 cm, and 29 to 32 cm). For *T. declivis* there is a strong length mode at 41–44 cm, and a secondary mode at about 32–33 cm. The length range of *T. murphyi* is very narrow, with most fish being from 49 to 53 cm. For all species, there is little between-sex difference in the length distributions.

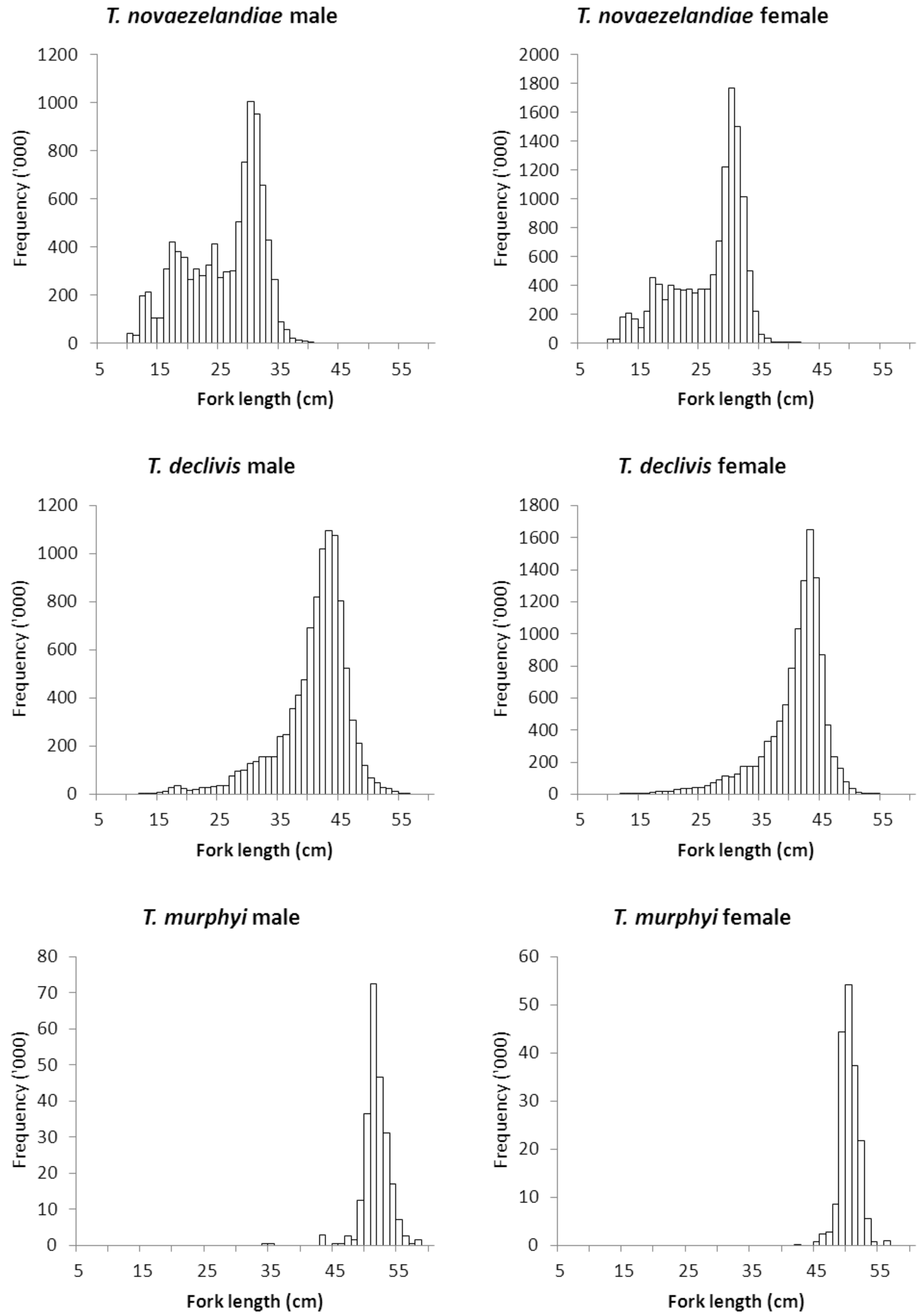

Figure 4: Estimated catch-at-length distributions, by species and sex, from JMA 7 in 2010–11.

3.5 Catch-at-age

The details of the estimated catch-at-age distributions for trawl-caught jack mackerel from JMA 7 in 2010–11 are presented for *T. novaezelandiae* in Table 4, *T. declivis* in Table 5, and *T. murphyi* in Table 6. The mean weighted c.v.s for *T. novaezelandiae* (20%), *T. declivis* (18%), and *T. murphyi* (23%) were all well below the target value of 30%. The estimated distributions are plotted in Figure 5. The catch of *T. novaezelandiae* is dominated by 1–5 year old fish, with very few fish older than 11 years. The catch of *T. declivis* has abundant fish aged 3–10 years old, with fish to 15 years being moderately common. The catch of *T. murphyi* is dominated by 15–20 year old fish, with very few fish younger than 13 or older than 24 years.

Table 4: Calculated numbers-at-age, separately by sex, with c.v.s, for *Trachurus novaezelandiae* caught during commercial trawl operations in JMA 7 during the 2010–11 fishing year. Summary statistics for the sample are also presented.

Age	Male	c.v.	Female	c.v.	Total	c.v.
0	15 621	2.006	0	–	15 621	2.006
1	1 178 195	0.381	1 019 149	0.426	2 197 344	0.378
2	1 225 307	0.284	1 391 187	0.265	2 616 495	0.249
3	1 617 139	0.202	1 411 198	0.224	3 028 337	0.185
4	1 028 706	0.191	1 795 054	0.128	2 823 760	0.114
5	1 008 416	0.184	1 438 412	0.160	2 446 827	0.124
6	212 884	0.436	575 690	0.264	788 574	0.228
7	414 299	0.342	884 724	0.224	1 299 023	0.193
8	418 524	0.286	664 381	0.249	1 082 904	0.189
9	685 553	0.221	867 618	0.193	1 553 170	0.141
10	536 446	0.242	820 286	0.209	1 356 733	0.160
11	500 671	0.296	759 757	0.217	1 260 428	0.170
12	187 222	0.422	156 582	0.533	343 803	0.328
13	122 642	0.494	159 946	0.387	282 588	0.316
14	63 371	0.775	88 833	0.500	152 204	0.429
15	29 208	0.697	80 661	0.446	109 869	0.392
16	83 369	0.609	59 736	0.708	143 105	0.451
17	12 566	1.160	0	–	12 566	1.160
18	0	–	1 648	1.712	1 648	1.712
No. measured		5 950		8 183		14 133
No. aged		271		338		609
No. of tows sampled						199
Mean weighted c.v.		27.8		23.7		20.3

Table 5: Calculated numbers-at-age, separately by sex, with c.v.s, for *Trachurus declivis* caught during commercial trawl operations in JMA 7 during the 2010–11 fishing year. Summary statistics for the sample are also presented.

Age	Male	c.v.	Female	c.v.	Total	c.v.
0	0	–	0	–	0	–
1	123 622	0.379	70 401	0.356	194 023	0.355
2	387 807	0.236	436 792	0.231	824 599	0.191
3	1 157 690	0.162	1 148 983	0.161	2 306 672	0.134
4	1 590 169	0.150	1 162 111	0.170	2 752 281	0.113
5	824 531	0.232	1 183 321	0.180	2 007 852	0.143
6	956 671	0.214	1 079 149	0.221	2 035 819	0.153
7	941 901	0.244	857 240	0.220	1 799 142	0.169
8	916 324	0.238	951 558	0.239	1 867 883	0.175
9	301 104	0.372	1 180 794	0.203	1 481 898	0.176
10	865 243	0.270	719 780	0.245	1 585 021	0.184
11	278 554	0.401	471 031	0.285	749 584	0.230
12	403 029	0.344	564 979	0.281	968 008	0.216
13	244 459	0.413	582 305	0.290	826 764	0.237
14	386 627	0.396	625 270	0.240	1 011 898	0.209
15	447 838	0.344	92 686	0.642	540 524	0.295
16	66 177	0.761	77 724	0.771	143 900	0.545
17	8 623	1.049	0	–	8 623	1.049
18	0	–	42 953	1.091	42 953	1.091
No. measured		10 457		11 700		22 157
No. aged		323		334		657
No. of tows sampled						275
Mean weighted c.v.		25.0		22.9		17.5

Table 6: Calculated numbers-at-age, separately by sex, with c.v.s, for *Trachurus murphyi* caught during commercial trawl operations in JMA 7 during the 2010–11 fishing year. Summary statistics for the sample are also presented.

Age	Male	c.v.	Female	c.v.	Total	c.v.
4	1 080	1.146	0	–	1 080	1.146
5	0	–	0	–	0	–
6	206	2.163	0	–	206	2.163
7	3 028	1.841	0	–	3 028	1.841
8	0	–	0	–	0	–
9	1 351	0.956	139	2.159	1 490	0.873
10	512	1.888	0	–	512	1.888
11	0	–	0	–	0	–
12	0	–	0	–	0	–
13	5 673	0.497	5 728	0.510	11 402	0.363
14	15 004	0.307	8 638	0.452	23 642	0.235
15	35 388	0.205	26 644	0.235	62 032	0.144
16	43 114	0.166	32 887	0.241	76 000	0.130
17	30 990	0.218	20 048	0.313	51 038	0.174
18	17 479	0.265	22 648	0.271	40 127	0.183
19	34 239	0.196	16 912	0.301	51 151	0.155
20	16 422	0.282	16 272	0.349	32 694	0.228
21	5 489	0.438	4 241	0.620	9 730	0.374
22	5 146	0.516	4 154	0.612	9 300	0.392
23	5 545	0.481	5 096	0.553	10 642	0.340
24	8 821	0.424	8 227	0.426	17 048	0.295
25	839	1.099	1 290	1.037	2 129	0.763
26	4 135	0.628	1 432	1.111	5 567	0.543
27	0	0.000	1 290	1.018	1 290	1.018
28	890	1.236	2 951	0.751	3 841	0.630
29	0	–	0	–	0	–
30	1 748	1.313	1 290	1.068	3 038	0.836
No. measured		303		214		517
No. aged		209		132		341
No. of tows sampled						152
Mean weighted c.v.		30.6		35.5		23.1

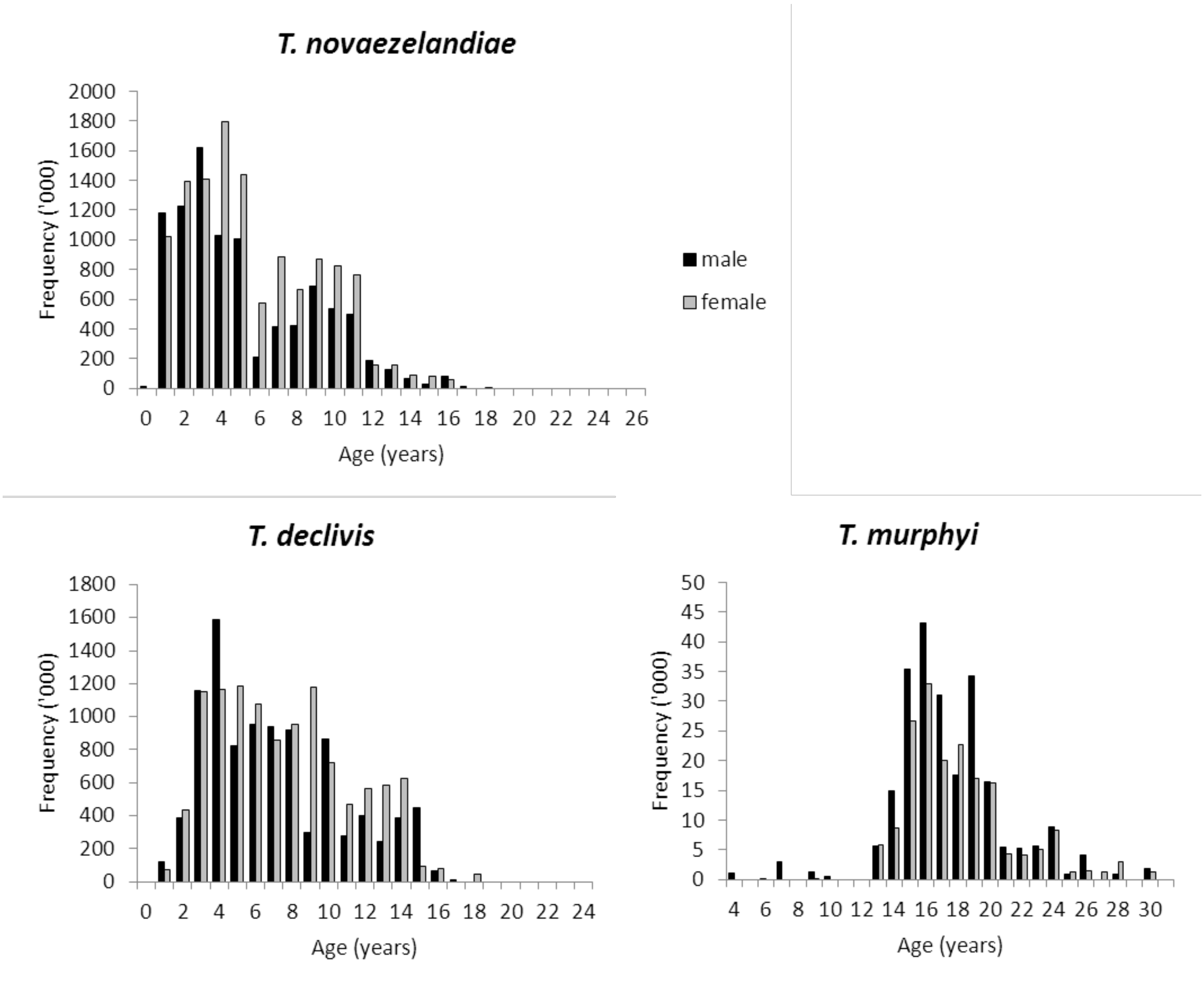

Figure 5: Estimated commercial catch-at-age distributions, by species and sex, from JMA 7 in 2010–11.

3.6 Data summaries

Catch-at-length and catch-at-age data from the JMA 7 fishery are now available from five consecutive years since 2006–07. Mean weighted c.v.s for the length and age distributions, by sex and year, are listed for each species in Table 7. The c.v.s 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 B.

Table 7: Mean weighted c.v.s (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
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
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

Trachurus novaezelandiae

Scaled length-frequencies by fishing year for *T. novaezelandiae* are shown in Figure 6. There are modes at 28–30 cm in all distributions. The distributions are all generally similar, except for a dominant second mode at 24 cm in 2009–10. Scaled age-frequencies for *T. novaezelandiae*, by fishing year, are quite variable between years (Figure 6). However, some possible year class progressions can be postulated. The 1+ year class is strong in 2007–08, and maintains a relatively high abundance in the subsequent years. The 1+ year class in 2008–09 may also be relatively strong. Year classes 4, 5, and 6 in 2006–07 also appear to be relatively strong throughout the series, although there are some inconsistencies (e.g., year class 7 in 2009–10 is weak).

Trachurus declivis

Scaled length-frequencies for *T. declivis*, by fishing year, are often multi-modal (Figure 7). They generally cover similar ranges from about 16 cm to about 50 cm, with a consistent strong mode at 42–43 cm. Most variation in abundance occurs with the fish shorter than 37 cm, presumably relating to the relative strengths of juvenile year classes. Scaled age-frequencies for *T. declivis*, by fishing year, are shown in Figure 7. There is a wide range of ages in the catches, and the distributions are quite variable between years. There is evidence of two relatively strong year classes aged 1 and 2 in 2007–08 that progress to ages 4 and 5 in 2010–11.

Trachurus murphyi

Scaled length-frequencies for *T. murphyi*, by fishing year, are shown in Figure 8. All the distributions are unimodal, peaking at 49–51 cm, and are generally similar with few fish smaller than 45 cm. Scaled age-frequencies for *T. murphyi* by fishing year (Figure 8) exhibit a wide range of ages although few fish younger than 10 years are recorded in any year. There is evidence of a relatively strong year class at age 12 in 2006–07 that progresses to age 16 in 2010–11.

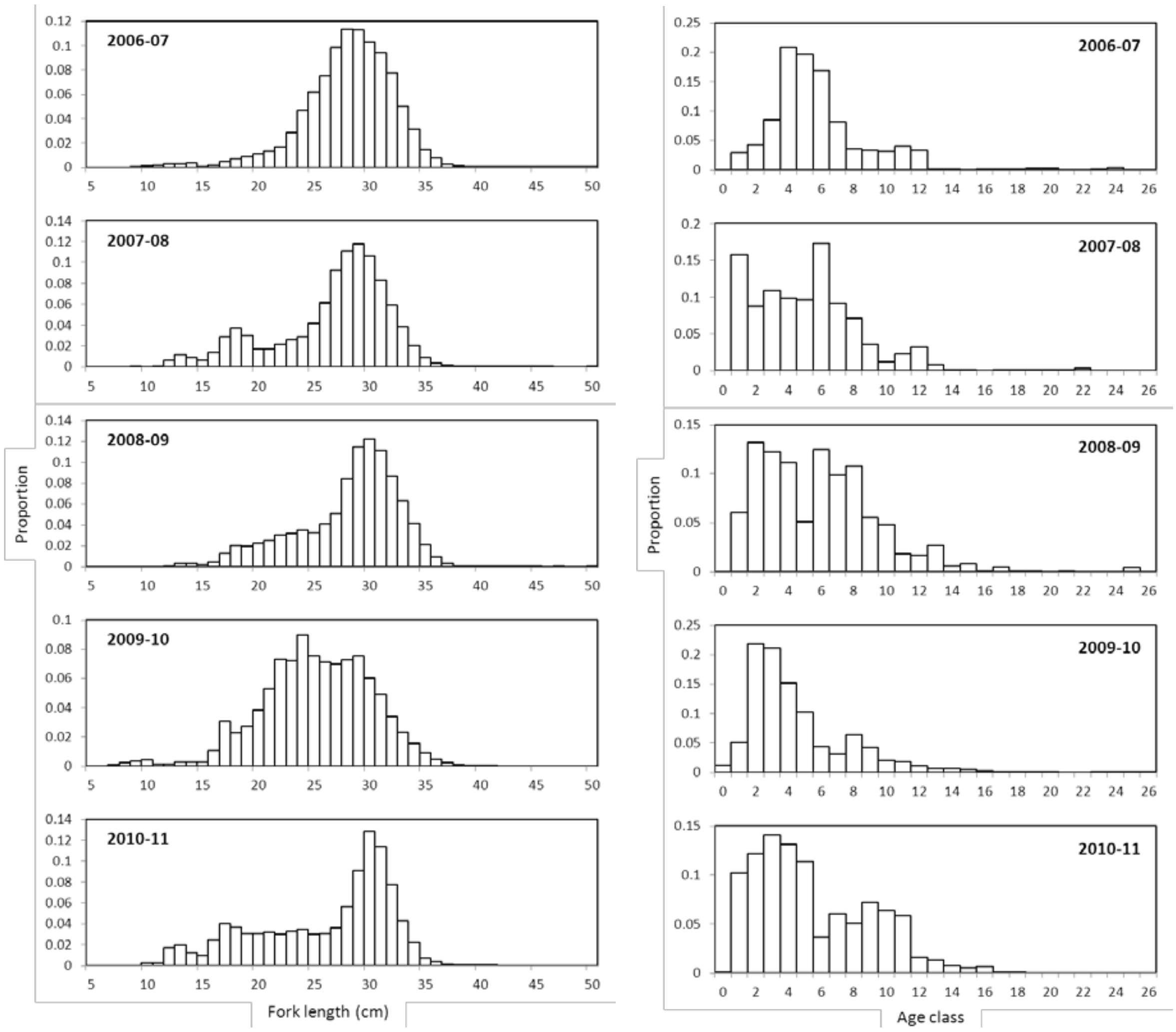

Figure 6: Scaled catch-at-length (left panel) and catch-at-age (right panel) proportions for the catch of *Trachurus novaezelandiae* in fishing years 2006–07 to 2010–11.

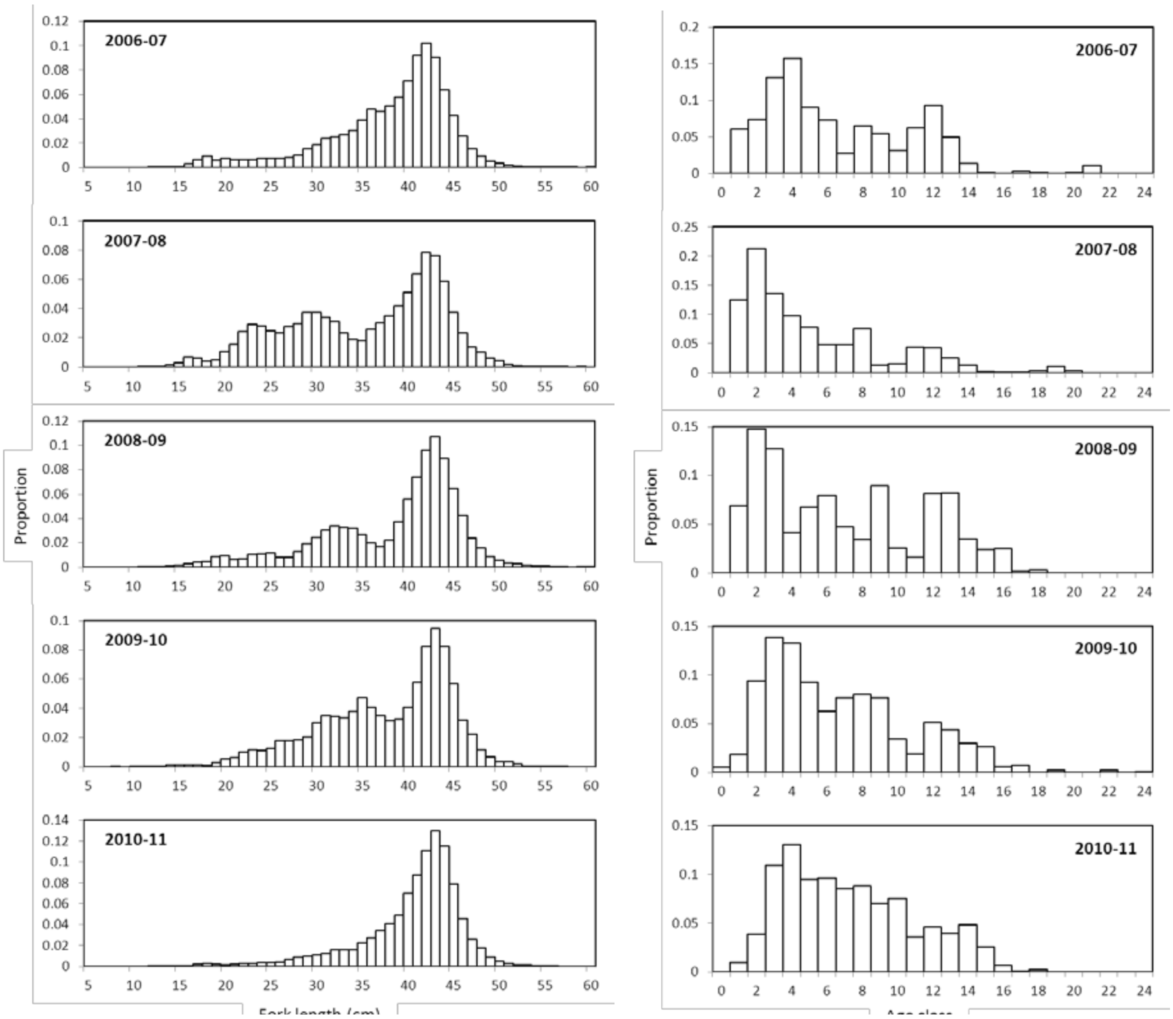

Figure 7: Scaled catch-at-length (left panel) and catch-at-age (right panel) proportions for the catch of *Trachurus declivis* in fishing years 2006–07 to 2010–11.

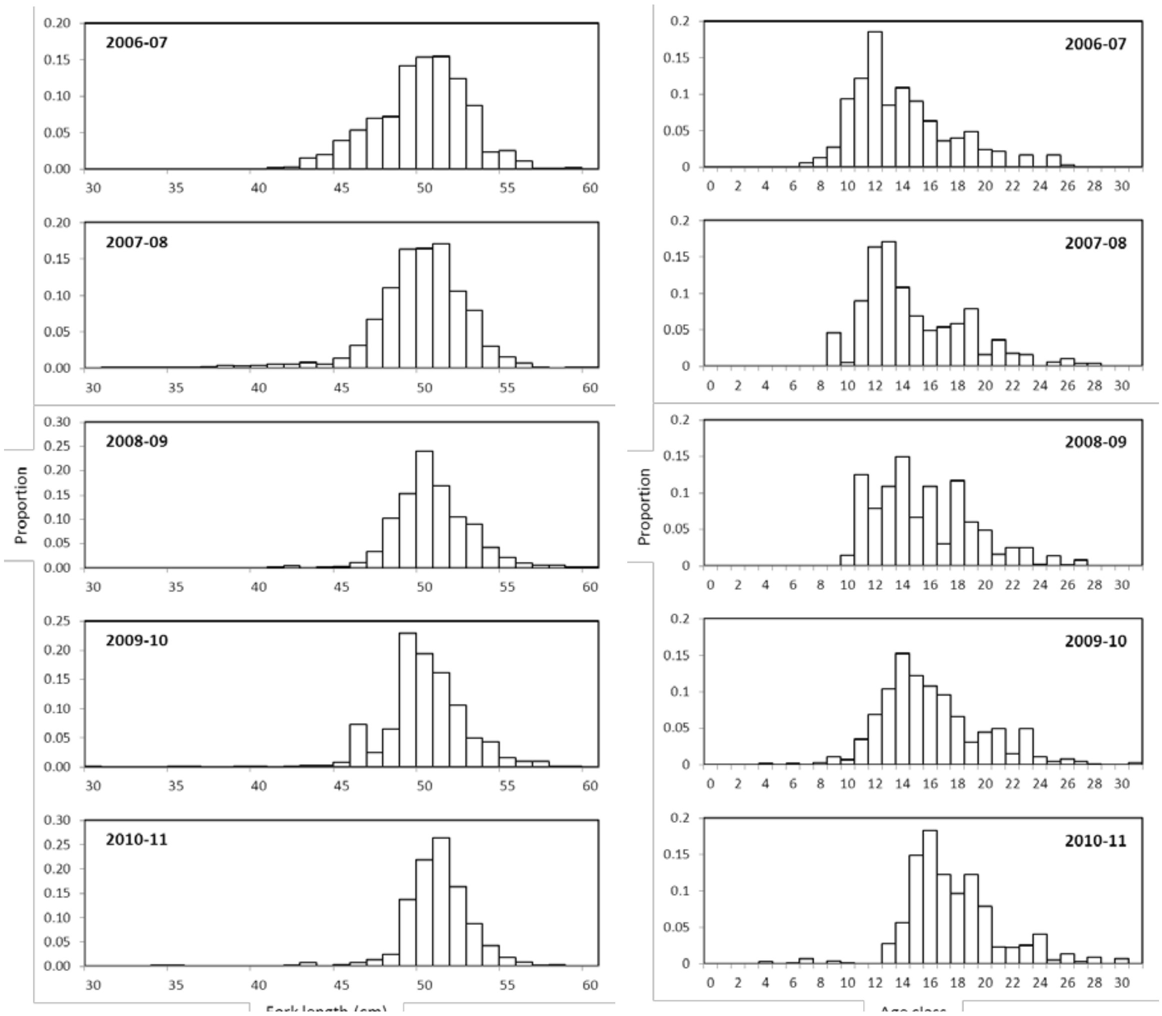

Figure 8: Scaled catch-at-length (left panel) and catch-at-age (right panel) proportions for the catch of *Trachurus murphyi* in fishing years 2006–07 to 2010–11.

4. DISCUSSION

Sampling of the jack mackerel trawl fishery in 2010–11 appeared to be generally representative of the fishery, although there were two months (February and March) when landings were moderate but no sampling occurred. Spatially, there was good coverage of catch in the heavily fished Statistical Areas (037, 040–042). Estimates of the 2010–11 catch-at-age for all three jack mackerel species had mean weighted c.v.s over all age classes of 23% or less, well below the target of 30%.

Estimates of species proportions indicate a consistent predominance of *T. declivis* at around 65–71% of total catch weight in the five fishing years from which data are available. The percentage of *T. novaezelandiae* is also consistent temporally at 25–28%. 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 comprises adult fish at least 37 cm long. Differences between years in the length distributions occur primarily in the abundance of fish shorter than 37 cm. There is some indication that this is a consequence of the progression of two reasonably strong year classes (aged 2 and 3 in 2008–09).

The mean age of *T. murphyi* in the catch has steadily increased over the five sampled years. In 2006–07, most fish were 10–15 years old, compared with 15–20 years old in 2010–11. 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 significant new immigration or recruitment through spawning success.

The *T. novaezelandiae* catch also has a consistent strong adult length mode (at about 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) outweighs the adult mode. The progression of some relatively strong year classes through the time series can be postulated. However, they are not as clear as progressions apparent in the age distributions for *T. declivis* and *T. murphyi*. 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.

5. ACKNOWLEDGMENTS

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Appendix A: Fishery stratification

This section outlines the method used by Taylor et al. (2011) to obtain a stratification of the fishery using data from three heavily sampled fishing years, i.e., 2006–07 to 2008–09.

The stratification was developed from the observer data using variables that were also generally available in the catch effort data. The classification tree method (Breiman et al. 1984) was used to derive a classification tree that is defined by suitable splitting variables and whose leaves have similar proportions within each stratum and diverse proportions between strata. The same tree was used for each of the three fishing years.

A classification tree was fitted to the observer sampled catch data for the three species and the three fishing years 2006–07 to 2008–09 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:

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

To ensure that the Gini index used the correct catch weighted species proportions at each node, a special data frame was required for the `rpart` function. Because in the initial dataset each row contained the catch details of the catch weights of all three species, three copies of the dataset were generated, one for each species, containing a `species` factor variable and a `weight` variable. For the first copy, the species variable was set to JMD and the weight variable was set to the scaled JMD catch weights, and similarly for the other two species. The three copies were then row combined to give the data frame used in the `rpart` function.

The use of this data frame and the setting of the `weights` argument in `rpart` equal to the weight variable ensures that the correct tow catch weighted proportions are used in node splitting. Because there were three exact copies of the covariates used to generate the tree, all three copies were transferred to the same split.

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
stat 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 reasons why this is not the best measure of the stratification from our point of view. Firstly, the prediction performance is not directly related to the impurity species proportions of the terminal nodes because it only depends 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.

Details of the fitting procedure and the subsequently selected five strata are shown in Figure A1 and Table A1.

Species proportions by area in JMA 7 could be categorised into several groupings (Figure A2). In the southernmost and offshore areas (034, 035, 036, 801), *T. declivis* is predominant with a small fraction of *T. murphyi*. *T. novaezelandiae* seldom featured here but appeared consistently in the more northerly and inshore areas (037, 040, 041, 042, 045), and was most represented in the three northernmost areas (041, 042, 045). *T. murphyi* appeared in all areas, but rarely. *T. declivis* was the most highly represented in all areas.

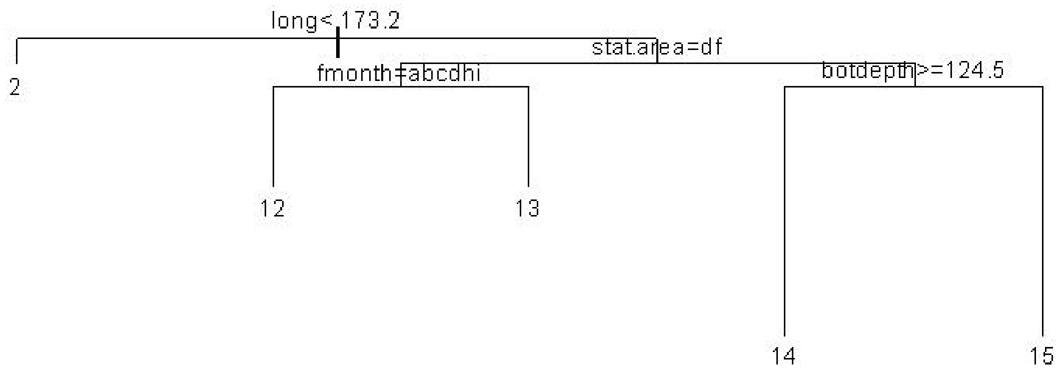

Figure A1: Dendrogram of classification tree used in the stratification of JMA 7; the length of the branches reflect the improvement in the Gini index.

Table A1: Node details for the classification tree. Split, stratum definition; Node count, number of data rows in the node; Proportions, species proportions (JMD, JMN, JMM). Rows in bold with * indicate a leaf.

Node number	Split	Node count	Proportions
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 in 037,040	388	(0.699 0.239 0.062)
12*	**fmonth in Oct-Jan,May-Jun**	**353**	**(0.754 0.176 0.070)**
13*	**fmonth in Apr,Jul-Sep**	**35**	**(0.302 0.690 0.008)**
7	stat.area in 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)**

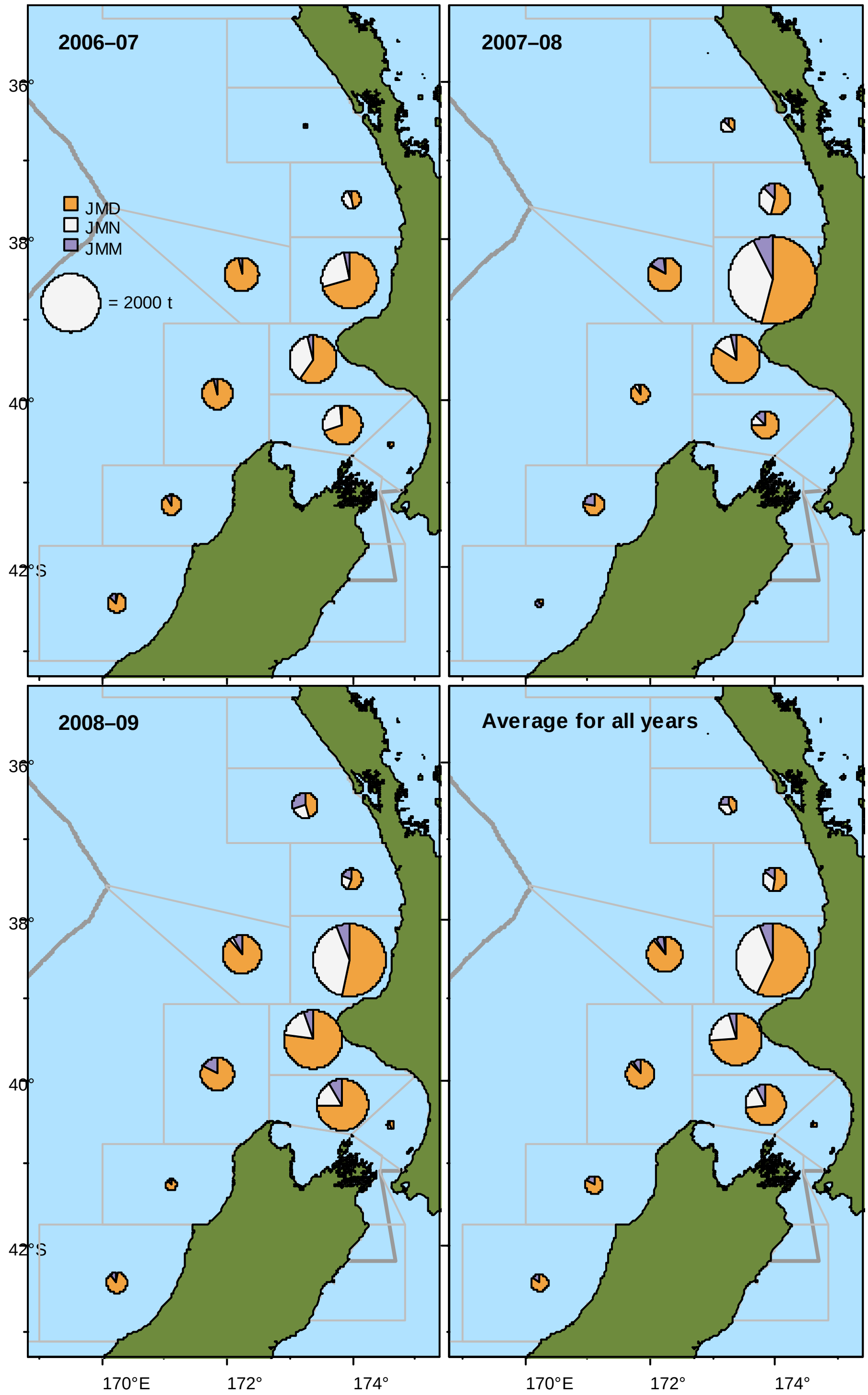

Figure A2: Catch weighted species proportions by statistical area.

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 c.v.s, for *T. novaezelandiae*, by fishing year.

	Proportion					c.v.				
Age	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
0	0	0	0	0.0127	0.0007				0.913	2.006
1	0.0294	0.1574	0.0605	0.0510	0.1021	0.419	0.416	0.327	0.389	0.378
2	0.0422	0.0871	0.1319	0.2183	0.1216	0.349	0.138	0.162	0.213	0.249
3	0.0846	0.1091	0.1225	0.2108	0.1408	0.224	0.144	0.188	0.186	0.185
4	0.2088	0.0985	0.1116	0.1517	0.1312	0.124	0.171	0.309	0.172	0.114
5	0.1970	0.0959	0.0509	0.1020	0.1137	0.106	0.176	0.399	0.209	0.124
6	0.1693	0.1727	0.1244	0.0443	0.0367	0.126	0.131	0.277	0.281	0.228
7	0.0819	0.0911	0.0992	0.0319	0.0604	0.193	0.203	0.330	0.227	0.193
8	0.0358	0.0712	0.1079	0.0639	0.0503	0.276	0.216	0.293	0.211	0.189
9	0.0334	0.0357	0.0557	0.0426	0.0722	0.301	0.243	0.314	0.204	0.141
10	0.0316	0.0121	0.0485	0.0206	0.0631	0.319	0.463	0.356	0.230	0.160
11	0.0404	0.0220	0.0180	0.0181	0.0586	0.281	0.328	0.459	0.274	0.170
12	0.0324	0.0321	0.0167	0.0115	0.0160	0.311	0.302	0.518	0.252	0.328
13	0.0010	0.0080	0.0270	0.0058	0.0131	1.040	0.341	0.313	0.327	0.316
14	0.0012	0.0006	0.0062	0.0066	0.0071	0.944	1.193	0.454	0.367	0.429
15	0	0.0002	0.0081	0.0046	0.0051		1.358	0.655	0.336	0.392
16	0.0004	0	0.0003	0.0027	0.0067	1.203		1.060	0.494	0.451
17	0.0008	0.0012	0.0048	0.0005	0.0006	0.643	1.028	1.002	0.594	1.160
18	0.0006	0.0004	0.0004	0.0001	0.0001	0.864	1.021	1.251	2.105	1.712
19	0.0026	0.0011	0.0003	0.0001	0	0.671	0.949	0.884	1.916	
20	0.0025	0.0003	0	0.0000	0	0.898	0.895		1.253	
21	0	0.0003	0.0009	0	0		0.835	0.769		
22	0	0.0029	0	0	0		0.572			
23	0.0010	0	0	0.0000	0	1.022			1.134	
24	0.0034	0	0	0.0001	0	0.544			0.887	
25	0	0	0.0042	0.0000	0			0.518	2.166	
26	0	0	0	0.0002	0				1.049	

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

	Proportion					c.v.				
Age	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
0	0	0	0	0.0054	0				0.428	
1	0.0605	0.1245	0.0693	0.0180	0.0092	0.220	0.175	0.170	0.326	0.355
2	0.0737	0.2125	0.1478	0.0942	0.0390	0.172	0.145	0.134	0.207	0.191
3	0.1307	0.1357	0.1273	0.1387	0.1091	0.141	0.119	0.144	0.141	0.134
4	0.1574	0.0972	0.0416	0.1327	0.1301	0.118	0.176	0.311	0.130	0.113
5	0.0907	0.0784	0.0678	0.0923	0.0949	0.244	0.227	0.299	0.160	0.143
6	0.0728	0.0492	0.0798	0.0629	0.0963	0.303	0.325	0.322	0.190	0.153
7	0.0270	0.0491	0.0475	0.0767	0.0851	0.503	0.256	0.385	0.168	0.169
8	0.0654	0.0755	0.0343	0.0801	0.0883	0.310	0.371	0.437	0.186	0.175
9	0.0549	0.0131	0.0894	0.0768	0.0701	0.309	0.503	0.260	0.177	0.176
10	0.0315	0.0154	0.0257	0.0345	0.0750	0.486	0.482	0.463	0.300	0.184
11	0.0618	0.0443	0.0160	0.0192	0.0354	0.272	0.329	0.635	0.367	0.230
12	0.0934	0.0422	0.0819	0.0507	0.0458	0.254	0.301	0.286	0.214	0.216
13	0.0496	0.0260	0.0823	0.0435	0.0391	0.363	0.454	0.281	0.236	0.237
14	0.0137	0.0138	0.0352	0.0299	0.0478	0.537	0.456	0.476	0.268	0.209
15	0.0015	0.0024	0.0240	0.0264	0.0256	0.858	0.912	0.400	0.273	0.295
16	0	0.0005	0.0251	0.0057	0.0068		0.686	0.335	0.469	0.545
17	0.0031	0.0017	0.0023	0.0075	0.0004	0.973	0.966	0.581	0.647	1.049
18	0.0013	0.0042	0.0028	0	0.0020	1.050	0.395	0.633		1.091
19	0	0.0104	0	0.0023	0		0.762		1.020	
20	0.0006	0.0038	0	0	0	1.101	0.975			
21	0.0104	0	0	0	0	0.430				
22	0	0	0	0.0023	0				0.963	
23	0	0	0	0	0					
24	0	0	0	0.0003	0				1.254	

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

	Proportion					c.v.				
Age	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
4	0	0	0	0.0020	0.0026				2.236	1.146
5	0	0	0	0	0					
6	0	0	0	0.0021	0.0005				1.423	2.163
7	0.0055	0	0	0	0.0073	1.041				1.841
8	0.0126	0	0	0.0026	0	0.625			1.481	
9	0.0272	0.0458	0	0.0105	0.0036	0.413	0.333		0.948	0.873
10	0.0935	0.0053	0.0144	0.0071	0.0012	0.335	0.594	0.615	0.803	1.888
11	0.1216	0.0895	0.1258	0.0350	0	0.301	0.263	0.222	0.383	
12	0.1857	0.1634	0.0784	0.0692	0	0.201	0.190	0.304	0.584	
13	0.0847	0.1708	0.1092	0.1040	0.0273	0.282	0.172	0.241	0.178	0.363
14	0.1092	0.1083	0.1499	0.1530	0.0567	0.231	0.248	0.208	0.233	0.235
15	0.0900	0.0687	0.0657	0.1227	0.1488	0.300	0.323	0.318	0.271	0.144
16	0.0628	0.0484	0.1092	0.1080	0.1823	0.410	0.309	0.235	0.192	0.130
17	0.0363	0.0538	0.0305	0.0965	0.1224	0.514	0.318	0.299	0.178	0.174
18	0.0395	0.0580	0.1163	0.0658	0.0962	0.476	0.380	0.243	0.222	0.183
19	0.0489	0.0783	0.0606	0.0308	0.1227	0.639	0.306	0.334	0.304	0.155
20	0.0244	0.0154	0.0486	0.0450	0.0784	0.722	0.521	0.371	0.235	0.228
21	0.0211	0.0364	0.0159	0.0492	0.0233	0.647	0.436	0.821	0.269	0.374
22	0	0.0180	0.0256	0.0151	0.0223		0.770	0.406	0.433	0.392
23	0.0168	0.0160	0.0251	0.0501	0.0255	1.119	0.755	0.541	0.273	0.340
24	0	0	0.0024	0.0103	0.0409			0.778	0.576	0.295
25	0.0168	0.0063	0.0138	0.0048	0.0051	1.093	1.019	0.854	0.655	0.763
26	0.0033	0.0097	0.0009	0.0076	0.0134	1.247	1.032	1.217	0.564	0.543
27	0	0.0041	0.0078	0.0046	0.0031		0.980	0.643	0.791	1.018
28	0	0.0039	0	0.0011	0.0092		0.933		1.060	0.630
29	0	0	0	0	0					
30	0	0	0	0	0.0073					0.836
31	0	0	0	0.0027	0				1.014	