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Commercial catch sampling for species proportion, sex, length, and age of jack mackerels in JMA 3 in the 2012–13 fishing year

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EXECUTIVE SUMMARY

Horn, P.L.; Hulston, D.; Ó Maolagáin, C. (2014). Commercial catch sampling for species proportion, sex, length, and age of jack mackerels in JMA 3 in the 2012–13 fishing year.

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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 3 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. Landings of jack mackerel by other methods (i.e., setnet and purse seine) were negligible relative to trawl landings.

Each record in the observer data included (estimated) total jack mackerel catch and weights by species sampled from the trawl tow. The sampled weights were scaled to give estimated total catch weights by species for the tow. Stratification of the data was required to account for two distinct areas of relatively high fishing intensity (western Chatham Rise, southern Stewart-Snares shelf). Most of the 2012–13 landed trawl catch was sampled, so sampling was representative of the landings both temporally and spatially.

The landings were almost exclusively two species (*T. declivis* and *T. murphyi*). The overall JMA 3 catch was dominated by *T. murphyi* (57% by weight). Species proportions varied between strata; the northern catch was slightly dominated by *T. declivis* (52%), while southern landings were predominantly *T. murphyi* (78%). The age-frequency distributions for both species in 2012–13 had mean weighted CVs of 23% or less, which more than met the target of 30%. The estimated sex ratios of the sampled catch indicated that populations of both species were dominated by males (63% by number for *T. declivis*, and 56% for *T. murphyi*). Samples of both species comprised few fish younger than about 10 years. The mean lengths of both species were larger in the southern fishery.

An estimate of total instantaneous mortality rate for *T. declivis* of 0.35 yr^{-1} was about double the likely value of natural instantaneous mortality (0.18 yr^{-1}).

A comparison of length distributions of *T. declivis* and *T. murphyi* from JMA 3 and JMA 7 showed little difference for *T. murphyi*, but markedly larger specimens of *T. declivis* in JMA 3 than JMA 7. It is postulated that the *T. declivis* in JMA 3 may be particularly large fish from the JMA 7 population that migrate south during the autumn outside the spawning season.

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 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 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 observer sampling began, which can in turn be used to scale age samples from the various fisheries. Since 2002 the JMA 3 fishery was almost exclusively a trawl fishery, with a small bycatch primarily from setnet fisheries. A purse seine fishery off the north-east coast of South Island produced substantial jack mackerel catches before 2002 (Taylor & Julian 2008), and sporadic catches since then.

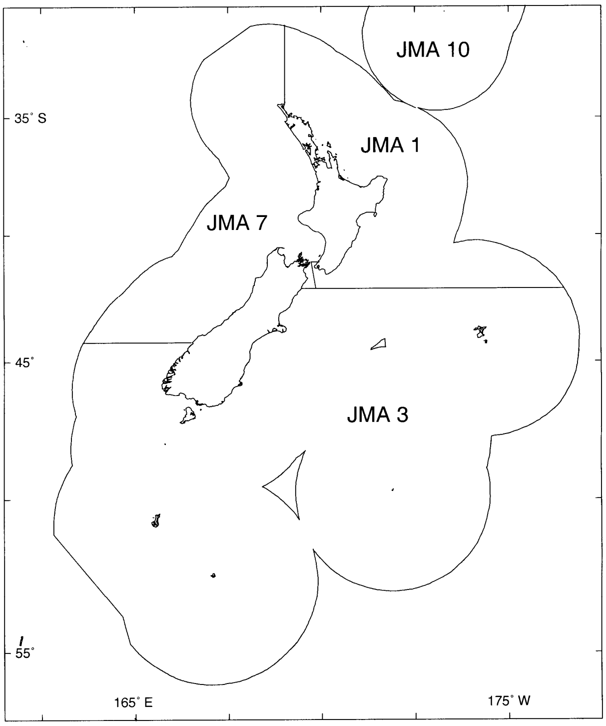

Figure 1: Jack mackerel administrative Fishstocks.

This report provides estimates of relative proportions and catch-at-age for the three *Trachurus* species in the commercial JMA 3 catch for 2012–13 using observer data, and fulfils part of 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 3 and 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. The report on the 2012–13 fishing year, including a summary of previous year's results, was prepared by Horn et al. (2014). The work presented in the current report is 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, as requested by MPI. No previous estimates of JMA 3 age composition are available. However, estimates of species proportions in the JMA 3 catch are available for the observed trawl fishery from 1985–86 to 2004–05 and the purse seine fishery in 1997–98 and 1998–99 (Taylor & Julian 2008).

Age monitoring of the jack mackerels *Trachurus declivis* and *T. novaezelandiae* in New Zealand was investigated by Horn (1993) who tracked strong and weak age classes 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. A validated ageing method was not established for *T. murphyi* in New Zealand waters (Beentjes et al. 2013), however the identification of progressing year classes in catch samples from JMA 7 suggests that the otolith interpretation method used is valid (Horn et al. 2013).

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, barracouta, arrow squid and redbait. Sampling was generally carried out according to instructions developed at NIWA and included in the Scientific Observers Manual. Most records in the observer dataset included estimated total jack mackerel catch and weights by species sampled from each tow. All observer data on jack mackerels sampled from JMA 3 in the 2012–13 fishing year were extracted for the analyses. As for the analyses of the JMA 7 fishery, 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 3 catch.

Commercial catch data extracted from the Ministry for Primary Industries catch-effort database “warehou” (Extract #9336, completed 23 January 2014) 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 3 (i.e., QMAs 3, 4, 5, and 6) in the 2012–13 fishing year.

The commercial catch data were examined to determine if stratification of the data was necessary. Total catches were binned by Statistical Area and month. Total annual catch densities were plotted at the scale of 0.1° of latitude and longitude. Two strata based on area (north and south) were derived (see Results below). Each fishing event from the catch-effort dataset and the observer dataset was allocated to one of the two 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 two 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 *Trachurus declivis* and *T. murphyi* caught by trawl in JMA 3 (Figure 1) in the 2012–13 fishing year, using data and otoliths collected by observers. No specimens of *T. novaezelandiae* were aged; landings of this species were sparse in this area and only two length measurements and otoliths were collected. For each of the two aged 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 (about 2% of the 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* were read following the validated methods described by Horn (1993) and Lyle et al. (2000). Otoliths of *T. murphyi* were interpreted similarly to those of *T. declivis*. However, they were 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.

3. RESULTS

3.1 Stratification of the fishery

The estimated landings from JMA 3 in 2012–13 showed that virtually all the catch was taken by trawl methods (Table 1). Jack mackerels were a minor bycatch of the setnet fishery, primarily when targeting tarakihi, hapuku or rig off the Kaikoura coast. Three landings of jack mackerels were recorded when target fishing for kahawai by purse seine. The available observer data was exclusively from the trawl fishery, and sampling of this fishery was necessary and sufficient to determine the structure of the JMA 3 catch.

Table 1: Estimated total catch of jack mackerels in JMA 3, by fishing method and Statistical Area, in the 2012–13 fishing year. The trawl data combined catch from both midwater and bottom trawl methods.

	Estimated landings (kg)			
Statistical area	Setnet	Purse seine	Trawl	Total
018	2 434		6 359	8 793
019			50	50
020	16	16 000	50 793	66 809
021			1 400 370	1 400 370
022	15		793 831	793 846
023			400	400
024	190		1 303	1 493
025			10 040	10 040
026	3		27 757	27 760
027			23 073	23 073
028			837 665	837 665
029			36 520	36 520
030			988	988
032			685	685
049			38 250	38 250
050			60 455	60 455
407			50	50
504			330	330
Total	2 658	16 000	3 288 924	3 307 582

The distribution of estimated trawl landings showed that there was a fishery from February to June (peaking in March–April) concentrated in Statistical Areas 021–022 and 028 (Table 2, Figure 2). Because less than 5% of landings were taken outside the February–June period, a single time stratum was believed to be adequate to describe the fishery. However, there was a clear north-south split in the distribution of trawling (Table 2, Figure 2). Northern fishing was concentrated on the Mernoo Bank (Area 021) and adjacent to Banks Peninsula (Area 022), with a much lower intensity north of Chatham Islands (Areas 049 and 050). The southern fishery was concentrated on the southern margin of the Stewart-Snares shelf (Area 028). Because there was considerable distance between the northern and southern areas of trawling concentration it was considered desirable to create two area strata. Consequently, JMA 3 was nominally split into northern and southern strata off the eastern coast of South Island at the Otago Peninsula (latitude 45.8° S).

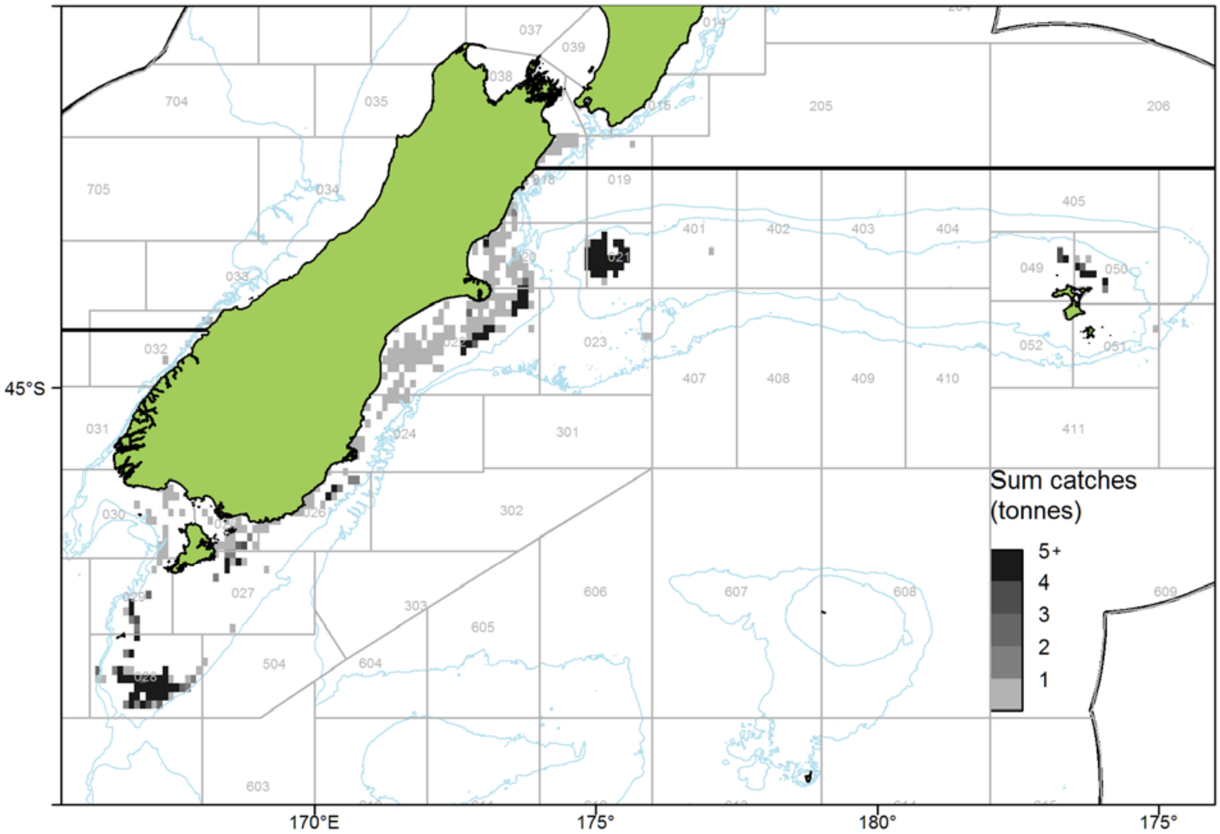

Figure 2: Density plot of estimated total landings of jack mackerel in JMA 3 in 2012–13, by 0.1° quadrants. Statistical area boundaries, and the northern boundaries of the JMA 3 stock are also shown. Depth contours are at 500 and 1000 m.

3.2 Catch sampling

In 2012–13, most of the trawl landed weight was sampled by observers (Table 2). The three Statistical Areas producing over 90% of the catch (021, 022, and 028) were all well sampled (Table 2). The percentage of the catch sampled was greater than 50% in all but one month (Table 2). Only areas or months producing negligible catch amounts (i.e., less than 10 t) 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 was greater (sometimes significantly so) than the estimated catch in some months and areas. 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. One major discrepancy is that landings from an observed trip that caught at least 16 t of jack mackerel north of the Chatham Islands in September 2013 were not recorded for that time-area on the QMS database by the time the data extract was made.

Table 2: Distribution of estimated trawl catch and sampled landings (t, rounded to the nearest 0.1 tonne), by month and statistical area (Stat Area), in the 2012–13 fishing year. Values of 0.0 indicate landings from 1 to 49 kg; blank cells indicate zero landings or samples. %, percentage of estimated total trawl catch 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
018	0.0	0.3	0.2	0.9	0.4	1.8	1.0	1.4	0.1	0.1	0.0	0.2	6.4
019					0.1								0.1
020	0.1	0.2	0.9	1.1	7.2	15.7	24.8	0.4	0.3	0.0	0.0	0.1	50.8
021	47.5				14.3	7.5	904.5	234.2	170.9		21.4		1 400.4
022	0.9	0.1	0.2	0.6	137.0	286.6	360.8	2.9	3.0	0.0	0.0	1.7	793.8
023							0.4						0.4
024		0.0		0.0	0.2	0.4	0.6	0.1				0.1	1.3
025	6.6	1.3	0.4	1.5	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	10.0
026		0.1	0.0	0.0	2.5	24.2	0.2	0.7	0.1				27.8
027	11.9	1.4	0.1		2.3	5.7	1.7						23.1
028				26.6	175.3	565.3	69.9	0.6					837.7
029				1.0	10.0	25.5							36.5
030		0.1	0.1	0.2	0.1	0.2	0.1	0.0	0.0	0.1	0.1	0.1	1.0
032		0.1	0.1	0.2	0.1	0.3			0.0				0.7
049									19.8		18.5		38.3
050									52.4	0.6	7.5		60.5
401-4													0.0
410							0.1						0.1
504							0.0						0.3
All	67.1	3.6	1.9	32.0	349.6	933.3	1 364.2	240.3	246.5	0.8	47.5	2.1	3 288.9

Sampled landings (t)

Stat														
Area	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	All	%
018														0.0
019														0.0
020	0.1	0.0	0.0		18.3	27.8	41.4	0.0	0.5		0.0	0.4	88.4	174.0
021	42.2				18.9	8.9	902.6	216.8	146.0		21.3		1 356.7	96.9
022	0.7	0.2	0.0	0.1	167.0	321.2	279.1	0.9	0.6			0.6	770.4	97.1
023	0.0						0.4		0.1				0.5	125.0
024						1.3	0.0						1.3	100.0
025	5.1	0.2	0.5	1.1	0.4	0.6							7.8	78.0
026	0.0	0.1	0.2	0.1	2.0	24.2	0.0						26.6	95.7
027	10.5	1.2	1.2	0.4	3.3	9.0	1.5	0.0	0.0			0.0	27.1	117.3
028			0.0	33.1	220.7	573.2	85.7	1.1	0.0				913.7	109.1
029		0.0		0.3	5.4	27.4							33.1	90.7
030			0.0			0.0	0.0						0.0	0.0
032														0.0
049	0.0			0.0					24.3		18.0	6.1	48.5	126.6
050	0.2								56.0		10.9	10.1	77.2	127.6
401-4	0.4	0.0	0.0	0.8	0.0				0.0			0.0	1.2	–
410		0.1	0.0	0.0							0.0		0.2	200.0
504			0.0	0.0	0.6	0.0	0.0		0.0				0.7	233.3
All	59.2	1.8	2.1	35.8	436.5	993.4	1 310.8	218.8	227.4	0.0	50.2	17.2	3 353.3	102.0
%	88.2	50.0	110.5	111.9	124.9	106.4	96.1	91.1	92.3	0.0	105.7	819.0	102.0	

3.3 Species proportions and sex ratios

The estimated species proportions for 2012–13 indicated that the overall JMA 3 catch was dominated by *T. murphyi* (57%), with *T. declivis* accounting for virtually all the remainder (Table 3). Catches of *T. novaezelandiae* were negligible. However species proportions varied between strata; the northern catch was slightly dominated by *T. declivis* (52%), while southern landings were predominantly *T. murphyi* (78%).

Estimated species proportions for JMA 3 from 1991–92 to 2004–05 (Taylor & Julian 2008) are included here for comparison (Table 3). The *T. murphyi* proportion of the catch in 2012–13 was lower than in all other years (except for 2002–03) for which data were available.

Table 3: Estimated species proportions (by weight) in JMA 3. Species proportions were rounded to whole numbers. '*N*' is the number of sampled tows that contained a particular species. JMD, *Trachurus declivis*; JMM, *T. murphyi*; JMN, *T. novaezelandiae*. Data from 1992–93 to 2004–05 are from Taylor & Julian (2008).

	Species proportions (%)			*N*		
Fishing year	JMD	JMM	JMN	JMD	JMM	JMN
1991–92	0	100	0	3	14	0
1992–93	14	86	0	18	119	0
1993–94	24	76	0	5	38	0
1994–95	4	96	0	2	15	0
1995–96	2	98	0	49	102	0
1996–97	0	100	0	1	15	0
1997–98	2	98	0	31	60	0
1998–99	15	85	0	29	48	0
1999–2000	29	65	6	20	27	7
2000–01	17	83	0	38	73	1
2001–02	33	66	0	48	70	1
2002–03	68	32	0	6	16	0
2003–04	3	97	0	1	7	0
2004–05	24	76	0	2	27	0
2012–13	43	57	0	69	73	1

Males dominated the sampled populations of both *T. declivis* and *T. murphyi* (i.e., 63% and 56% male, respectively).

3.4 Catch-at-length

The estimated catch-at-length distributions, by species, for trawl-caught jack mackerel from JMA 3 in 2012–13 are plotted in Figure 3. *T. declivis* had a single length mode peak at 44–48 cm. The length range of *T. murphyi* was even narrower, with most 48–52 cm. For both species, there was little between-sex difference in the length distributions.

There were differences in the length distributions of both species between the northern and southern strata (Figure 4). For *T. declivis*, mean fish size was greater in the north than in the south, although the peaks of both distributions occurred at about 47 cm. For *T. murphyi*, mean fish size was markedly smaller in the north, with a modal length of 48 cm, compared with 52 cm in the southern stratum.

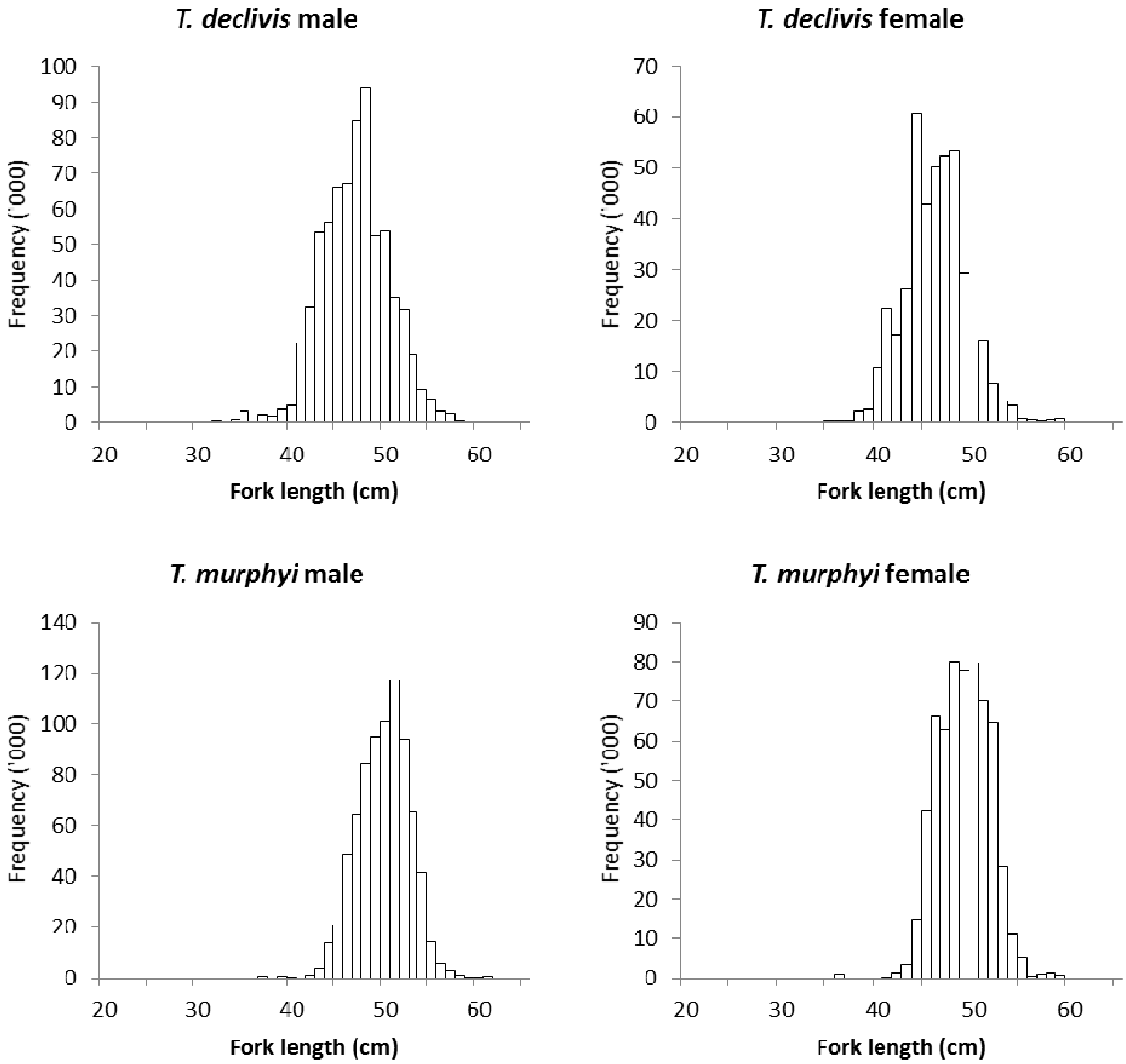

Figure 3: Estimated catch-at-length distributions, by species and sex, from JMA 3 in 2012–13.

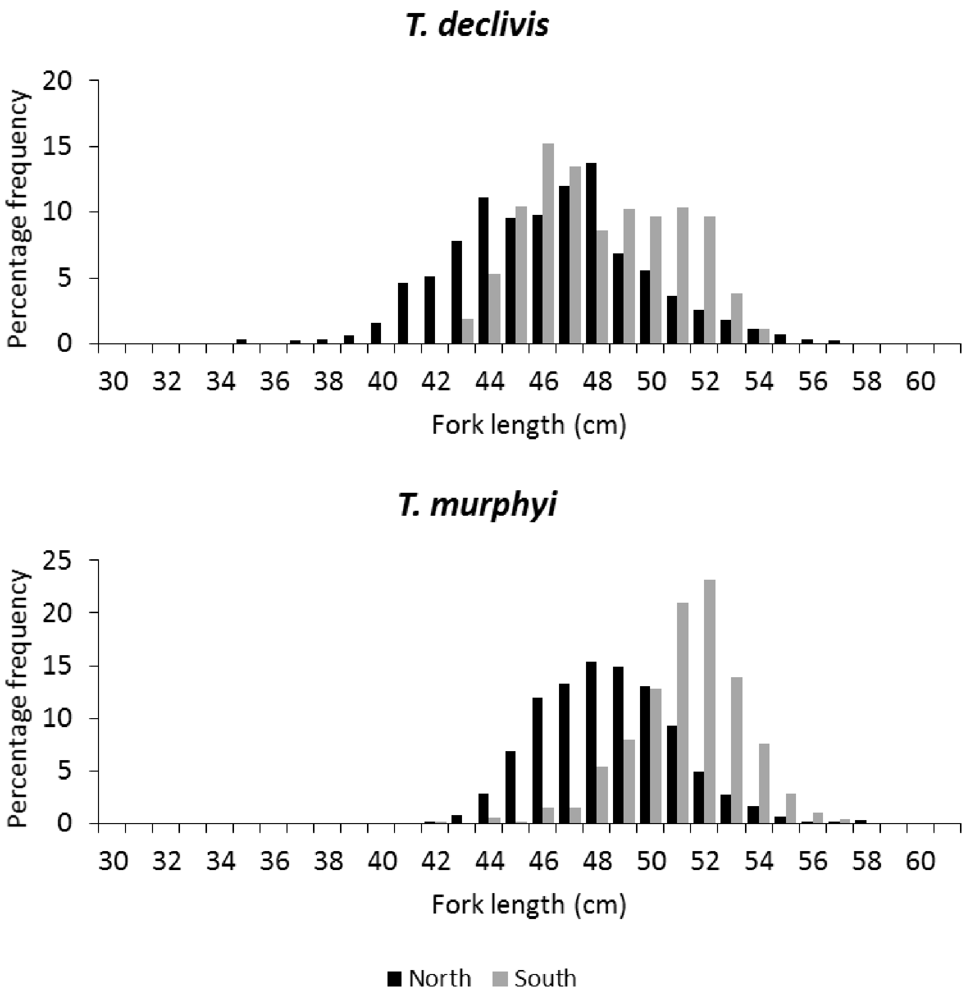

Figure 4: Estimated catch-at-length distributions, by species with sexes combined, from the northern and southern strata in JMA 3 in 2012–13.

3.5 Catch-at-age

The details of the estimated catch-at-age distributions for trawl-caught jack mackerel from JMA 3 in 2012–13 are presented for *T. declivis* in Table 4 and *T. murphyi* in Table 5. The mean weighted CVs for *T. declivis* (21%) and *T. murphyi* (23%) were well below the target value of 30%. The estimated distributions are plotted in Figure 5. The catch of *T. declivis* had a maximum age of 24 years with abundant fish aged 10–19 years old, but virtually none younger than 9 years. The catch of *T. murphyi* was dominated by 14–18 year old fish, with very few fish younger than 11 or older than 22 years.

Table 4: Calculated numbers-at-age, separately by sex, with CVs, for *Trachurus declivis* caught during commercial trawl operations in JMA 3 during the 2012–13 fishing year. Summary statistics for the sample are also presented.

Age	Male	CV	Female	CV	Total	CV
3	0	–	0	–	0	–
4	62	2.939	0	–	62	2.939
5	3 525	1.038	584	1.455	4 109	0.890
6	0	–	170	1.819	170	1.819
7	3 047	0.829	1 972	1.378	5 019	0.784
8	2 424	1.010	4 933	1.118	7 357	0.807
9	19 076	0.398	18 753	0.648	37 829	0.404
10	34 917	0.317	20 466	0.555	55 383	0.309
11	57 762	0.266	22 092	0.393	79 854	0.234
12	51 242	0.235	37 556	0.342	88 798	0.215
13	72 450	0.191	46 893	0.265	119 343	0.158
14	77 909	0.186	57 451	0.202	135 360	0.137
15	86 294	0.180	52 922	0.225	139 216	0.133
16	88 247	0.159	39 488	0.248	127 735	0.134
17	45 554	0.269	20 963	0.310	66 517	0.216
18	52 727	0.237	35 436	0.255	88 163	0.172
19	32 004	0.291	31 996	0.276	64 000	0.191
20	37 346	0.291	3 920	0.719	41 266	0.282
21	14 878	0.397	16 179	0.432	31 057	0.292
22	8 713	0.555	6 415	0.697	15 128	0.431
23	11 361	0.460	1 465	1.113	12 826	0.424
24	4 991	0.687	0	–	4 991	0.687
No. measured		1 659		899		2 558
No. aged		306		200		506
No. of tows sampled						69
Mean weighted CV		25.2		33.5		20.9

Table 5: Calculated numbers-at-age, separately by sex, with CVs, for *Trachurus murphyi* caught during commercial trawl operations in JMA 3 during the 2012–13 fishing year. Summary statistics for the sample are also presented.

Age	Male	CV	Female	CV	Total	CV
7	0	–	0	–	0	–
8	1 458	1.812	2 354	1.090	3 812	0.925
9	446	2.335	0	–	446	2.335
10	6 920	0.827	134	2.062	7 054	0.783
11	0	–	18 541	0.773	18 541	0.773
12	20 529	0.633	11 361	0.812	31 890	0.494
13	15 757	0.687	13 228	1.060	28 984	0.624
14	102 400	0.280	43 061	0.470	145 462	0.247
15	126 151	0.228	103 748	0.233	229 899	0.164
16	133 706	0.202	110 052	0.219	243 758	0.138
17	138 087	0.194	128 750	0.217	266 837	0.139
18	125 399	0.202	57 744	0.290	183 143	0.155
19	35 390	0.362	41 287	0.305	76 677	0.238
20	8 269	0.757	28 073	0.375	36 342	0.319
21	25 021	0.501	30 455	0.400	55 477	0.318
22	22 524	0.460	14 346	0.597	36 871	0.374
23	11 104	0.659	0	–	11 104	0.659
24	0	–	0	–	0	–
25	0	–	3 240	0.973	3 240	0.973
26	0	–	3 240	1.081	3 240	1.081
27	204	1.797	0	–	204	1.797
28	5 625	1.013	3 697	0.897	9 321	0.701
No. measured		2 196		1 648		3 844
No. aged		164		130		294
No. of tows sampled						73
Mean weighted CV		28.9		33.8		22.5

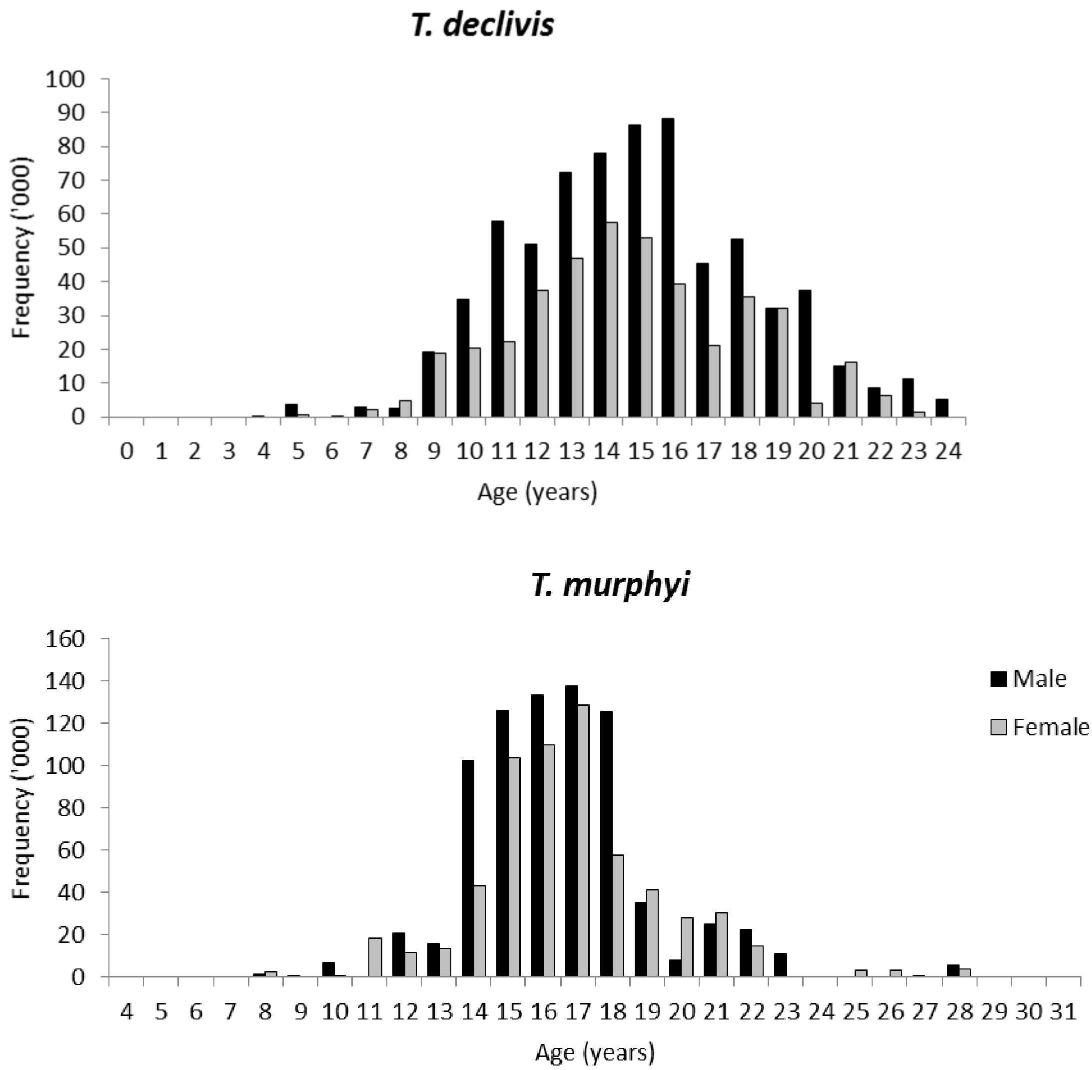

Figure 5: Estimated commercial catch-at-age distributions, by species and sex, from JMA 3 in 2012–13.

3.6 Estimation of mortality rate for *T. declivis*

An estimate of total instantaneous mortality (Z) was made for *T. declivis* in 2012–13 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.

Z was estimated to be 0.35 y^{-1}, with a 95% confidence interval of 0.32–0.38, when age at recruitment was set at 15 years.

4. DISCUSSION

The jack mackerel trawl fishery in JMA 3 in 2012–13 was comprehensively sampled by observers. Sampling intensity was high in all months and all areas where substantial catches were taken. In particular, there was very good coverage of catch in the heavily fished Statistical Areas (021, 022 and 028). The sampled catch almost exclusively comprised the species *T. declivis* and *T. murphyi*; a negligible catch of *T. novaezelandiae* was recorded in one sampled tow. Estimates of the 2012–13 catch-at-age for *T. declivis* and *T. murphyi* had mean weighted CVs over all age classes of 23% or less, well below the target of 30%.

There were two distinct areas of relatively high fishing intensity for jack mackerels in the JMA 3 Fishstock area, i.e., the western Chatham Rise, and the southern edge of the Stewart-Snares shelf. Based on the 2012–13 observer data, *T. declivis* were slightly more common in the northern region, but *T. murphyi* strongly dominated catches in the southern region.

Most of the sampled *T. declivis* and *T. murphyi* catch comprised adult fish. This was expected for *T. murphyi*, as analyses of catch composition in JMA 7 (Horn et al. 2013) indicated that the species had experienced 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 large new immigration or recruitment through spawning success. In contrast, catches of *T. declivis* in JMA 7 had always comprised, and were sometimes dominated by, fish 5 years or younger (Horn et al. 2013). In the JMA 3 catch, *T. declivis* younger than 9 years old were rare. It is not known if the lack of young fish in the catch is a consequence of very low fishing selectivity on these age classes, or because young fish do not generally occur in the area. Specimens of *T. declivis* have seldom been recorded in research trawl surveys of the Chatham Rise, Sub-Antarctic, or inshore east coast South Island (author's unpublished data), so these surveys provided no information on the presence or absence of young fish in JMA 3. This may be because research bottom trawls towed at relatively slow speeds (3–4 knots) are unlikely to adequately sample jack mackerels.

The dominance in the 2012–13 JMA 3 catch of *T. murphyi* aged 14–19 years was similar to the results for the JMA 7 catch in the same year (Horn et al. 2014). This supports the hypothesis of a single strong recruitment pulse into the New Zealand EEZ some years ago, possibly from international waters. There is evidence (Taylor & Julian 2008, and anecdotal information from commercial fishers) that the relative abundance of *T. murphyi* has declined in recent years, as would be expected as the recruitment pulse experienced mortality. The proportion of the JMA 3 catch made up by *T. murphyi* in 2012–13 was notably lower than all but one of the estimates from 2004–05 and earlier (Taylor & Julian 2008).

Although the overall length distribution of *T. murphyi* for JMA 3 was very similar to that estimated from the JMA 7 fishery, there were distributional differences in the length distribution within JMA 3 (see Figure 4). It is not known what caused this difference, or whether it occurs consistently between years.

The collected data on the sex of *T. murphyi* indicated a population dominated by males (i.e., 56% of fish by number). 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, ranging from 62 to 71% of the sexed mackerels (Hurst & Bagley 1997).

The dominance of males (i.e., 63% by number) in the estimated catch of *T. declivis* from JMA 3 is in strong contrast to the sex ratios derived for JMA 7 landings over seven years (i.e., 47–52% male, Horn et al. 2013). No other estimates of *T. declivis* sex ratios from other years in JMA 3 are available, so it is not known if the 2012–13 value is an aberration or the norm.

A rate of instantaneous natural mortality (*M*) for *T. declivis* was previously estimated to be 0.17–0.20, with the best point estimate of 0.18 yr^{-1} (Horn 1993). The *Z* estimate from the current work (0.35 yr^{-1}) is about double the *M* value. This could be interpreted as meaning that in JMA 3 the rate of fishing mortality was approximately equal to the rate of natural mortality, so the stock has been moderately exploited. However, the probable lack of young fish in the JMA 3 population (as noted above) suggests that the adult *T. declivis* in JMA 3 may derive from other areas, and not be a distinct stock. The estimate of *Z* could, therefore, be influenced by migration to or from the JMA 3 area, and may not be a good estimate of the total mortality rate.

The 2012–13 length-frequency distributions for *T. declivis* and *T. murphyi* in JMA 3 and JMA 7 are compared in Figure 6. The *T. murphyi* distributions are very similar between areas, both peaking at 52 cm and with most fish 46–54 cm long. The two *T. declivis* distributions differ markedly, however. The lack of small fish (i.e., less than about 40 cm) in JMD 3 was noted above, but it is also apparent that the mean length of the adult size mode also differs between areas. In JMA 7 the modal adult length was 43 cm, with few fish larger than 47 cm. IN JMA 3 the modal adult length was 48 cm, with many fish larger than 50 cm.

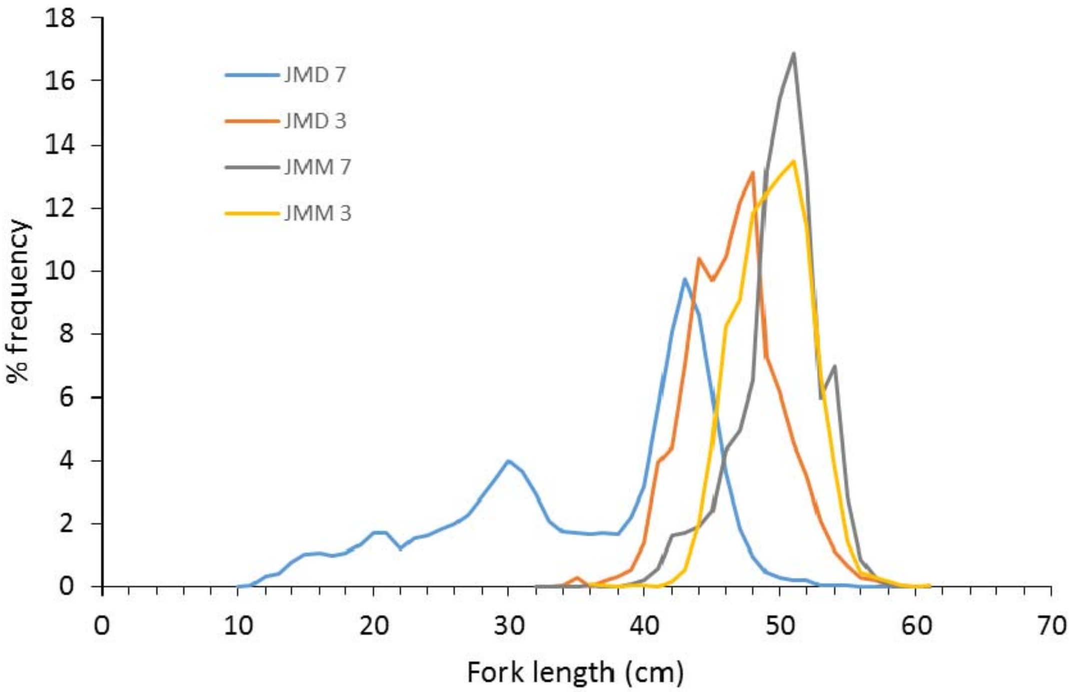

Figure 6: Estimated commercial catch-at-length distributions, for *T. declivis* (JMD) and *T. murphyi* (JMM) from Fishstocks JMA 3 and JMA 7 in 2012–13. The JMA 7 distributions are from Horn et al. (2014).

There are several possible reasons for the difference between the two *T. declivis* distributions. First, some of the fish identified as *T. declivis* may actually have been the (generally larger) *T. murphyi*. While some mis-identification of the three *Trachurus* species does occur (Horn et al. 2014), about two-thirds of the *T. declivis* identifications would need to be wrong to enable the two *T. declivis* adult modes to match in Figure 6. When reading the *T. declivis* otoliths from JMA 3, the otolith reader (DH) concluded that, based on the otolith structure, fewer than 2% of them were likely to be from *T. murphyi*, and fewer than 15% were classified as 'very hard to read' and so possibly may have been from *T. murphyi*. Consequently, species mis-identification is an unlikely explanation for the difference. Second, *T. declivis* in JMA 3 may be a biological stock distinct from JMA 7, with a growth rate producing fish with a larger maximum size. However, small mackerel are scarce in JMA 3 (*T. declivis* younger than 2 years old have occasionally been recorded in the South Canterbury Bight (Hurst et al. 2000)), and there are no known mackerel spawning grounds in JMA 3, although a few spent fish have been observed off Otago and Southland in February (Hurst at al. (2000). Consequently, a distinct biological stock in JMA 3 is unlikely. Third, *T. declivis* in JMA 3 may be a biological stock distinct from JMA 7, and the JMA 7 population has experienced much heavier levels of exploitation than JMA 3 fish. However, as noted for the previous reason, there is no evidence of a distinct spawning population in JMA 3. Fourth, the *T. declivis* in JMA 3 may be particularly large (and older) fish from the JMA 7 population that migrate south during the autumn (outside the spring-summer spawning season off the western coast of North Island). The catch of *T. declivis* in JMA 7 had abundant fish aged 1–15 years old, but with a strong drop-off in fish older than 15 years (Horn et al. 2013). The age distribution estimated for *T. declivis* in JMA 3 from the current work showed few fish younger than 9 years, age at full selectivity of 15 years, and over half the fish were that age or older. Of the four possible reasons presented for the difference between the two *T. declivis* distributions, the fourth appears to be the most plausible.

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