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Title **REVISED INPUT PARAMETERS AND IMPLICATIONS FOR THE ANTARCTIC TOOTHFISH (*DISSOSTICHUS MAWSONI*) STOCK ASSESSMENT IN SUBAREAS 88.1 & 88.2**

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ABSTRACT

In this paper, we address a number of aspects of the model inputs and parameters of the Antarctic toothfish stock assessment for the Ross Sea fishery. In particular we review catch history, length-weight relationships, catch-at-length and catch-at age. In addition, we report some preliminary model runs that investigate the sensitivity of the 2006 stock assessment to changes in these model inputs and parameters.

Tree-regression methods were used to investigate the areal structure of the length distribution of Antarctic toothfish. While tree-regressions suggested strong evidence of a high degree of small-scale areal complexity, we were unable to provide a stratification that resulted in improved or consistent patterns in length frequencies over the duration of the fishery. Including terms for nation, vessel, or vessel type did not provide any additional information as these tended to be highly correlated with the location variables.

The catch and CPUE indices for the Ross Sea Antarctic toothfish fishery were updated, as are some modelling parameters, and methods for calculating age- and length-frequencies. Most of these changes did not have a significant impact on the assessment results.

We also provide an update of the numbers of fish scanned at length by New Zealand vessels, and the numbers of tagged fish recaptured. Inclusion of observations of the 2006 fish recaptured in 2007 had the greatest impact on the assessment model results. Dunn et al. (2007) noted that the locations of the 2007 recaptures were highly aggregated and were mostly located on four key locations in the Ross Sea, and most had moved only short distances. This confirms the concern that the key uncertainty underlying the current model is the impact of movements and spatial structure in the Antarctic toothfish population. In particular, the level and nature of the bias from non-homogeneous mixing assumptions of tagged fish.

SUMMARY OF FINDINGS AS RELATED TO NOMINATED AGENDA ITEMS

Agenda Item	*Findings*
2.1	We review and update the catch history, length-weight relationships, catch-at-length and catch-at age frequencies. We review alternative methods for the stratification of the Ross Sea length frequencies.
4.3	Preliminary models for the Ross Sea Antarctic toothfish assessment model are presented, including sensitivities that compare outputs from inclusion of revised parameters and model inputs.

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1. INTRODUCTION

The exploratory fishery in the Ross Sea (defined here as Subareas 88.1 and SSRUs 88.2A–B, see Figure 1) was initiated by a New Zealand longline vessel in 1997[1]. Since then, New Zealand vessels, and more recently vessels from other countries, have returned each summer to fish in this area. During that time the fishery for the Ross Sea has increased to about 3000 t per annum, and for 2007 the catch limit for the Ross Sea was set at 3072 t (SC-CAMLR-XXV 2006).

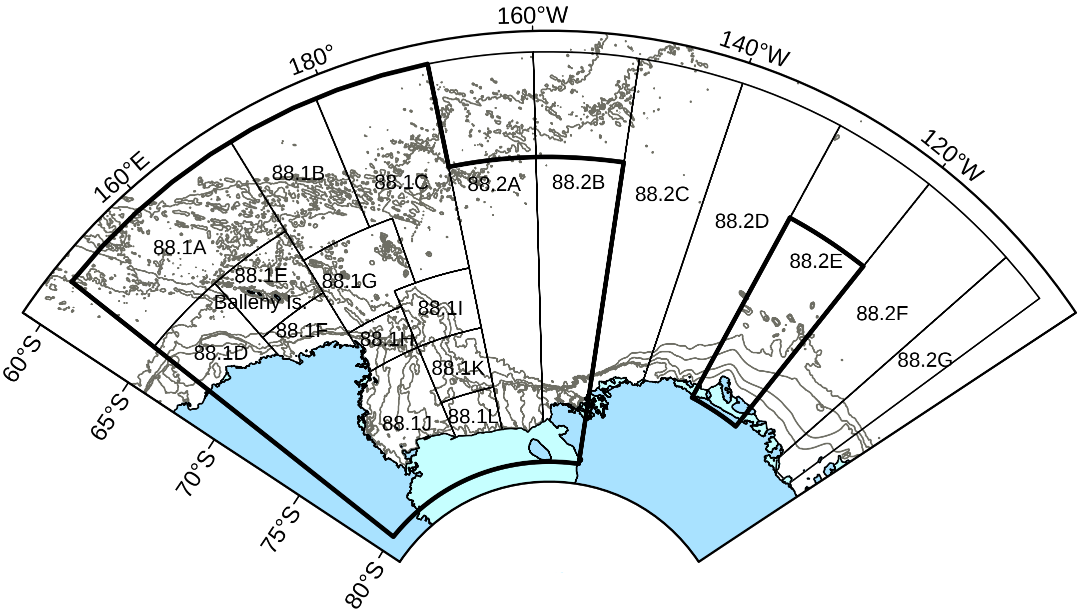

Figure 1: CCAMLR Subareas 88.1 and 88.2 and small scale statistical areas (SSRUs), showing the Ross Sea and SSRU 882E (bounded regions). Depth contours plotted at 500, 1000, 2000, and 3000 m.

The catch limits adopted by CCAMLR for 2006–07 were determined from yield estimates from an integrated stock assessment model of Antarctic toothfish in the Ross Sea (Dunn & Hanchet 2006b). The model of Dunn & Hanchet (2006b) assumed a single homogeneous area with three geographically defined fisheries (shelf, slope and north, see later). Data included within that model were based on total catch (C2 data); catch-at-age frequencies using the tree regression post-stratification method described by Phillips et al. (2005) and reported by Hanchet et al. (2006); CPUE indices including data up to 2006 (Dunn 2006b); and tag-release and recapture data up to the end of 2006 (Dunn & Hanchet 2006d).

At its 2006 annual meeting, WG-FSA agreed that the following items would contribute to the further development of the assessment of *D. mawsoni* in Subareas 88.1 and 88.2 (SC-CAMLR-XXV 2006, Annex 5, para. 12.11);

(i) further investigation and appropriateness of inclusion of the tag and recapture data from all countries fishing in Subareas 88.1 and 88.2,
(ii) consideration of movement and stock structure,
(iii) evaluation of the robustness of the CASAL assessment to recruitment and equilibrium assumptions,
(iv) evaluation of the relative importance of tagging data to the assessments,

[1] Note that this report uses the CCAMLR split year that is defined from 1 December to 30 November. Hence, the term "year" refers to the fishing season in which most fishing occurs, e.g., the period 1 December 2004 to 30 November 2005 is labelled the 2005 year.

(v) evaluation of the relative importance of catch-at-age and CPUE data to the assessments,
(vi) presentation and review of TSVPA to WG-FSA-SAM,
(vii) evaluation of technical aspects and data inputs of TSVPA model. This includes effect of increasing CPUE (with development of fishery) and effect on estimates of spawning stock biomass.

In this paper, we address some of the items noted by the 2006 meeting of WG-FSA and further develop the input parameters to the Antarctic toothfish stock assessment for the Ross Sea fishery. In particular we review catch history, length-weight relationships, catch-at-length and catch-at age, and the tag-release recapture data. In addition, we report some preliminary model runs that investigate the sensitivity of the 2006 stock assessment to changes in these model inputs and parameters.

2. REVISED OBSERVATIONS AND PARAMETERS

2.1 Catch histories

2.1.1 Legal and reported catch

The catch reported (C2 data) for the 2007 season was 3084 t in the Ross Sea (Table 1), 271 t in SSRU 88.2E (Table 2), and 22 t in the remaining SSRUs of 88.2 (Table 3). As in previous years, most of the catch in the Ross sea was taken from the Slope fishery (80%) and in 2007, most of the remainder was taken from the North. In 2007, New Zealand vessels fished on the Ross Sea, with five nations Argentina, UK, Norway, Russia, and Uruguay) fishing in either SSRU 88.2E or SSRUs 88.2DFG.

In general, catches have remained at about 3000 t in the Ross Sea over the last three seasons, while catches for 88.2E have been at approximately 300 t since 2004. SSRUs 88.2DFG have only been fished in the last two years, with the total catch of about 100 t in 2006 falling to about 20 t in 2007.

Weighed mean depths of the catch in the Ross Sea are given in Table 4, and the mean depths fished in 2007 were similar to those recorded in previous seasons.

Table 1: Antarctic toothfish catch (t) in the Ross Sea for New Zealand and other vessels by fishery for the years 1997–2007.

Year	New Zealand			Other			All vessels			Total	Catch Limit[1]
	Shelf	Slope	North	Shelf	Slope	North	Shelf	Slope	North		
1997	0	0	0	0	0	0	0	0	0	0	1 980
1998	8	29	4	0	0	0	8	29	4	41	1 573
1999	14	282	0	0	0	0	14	282	0	296	2 281
2000	64	689	0	0	0	0	64	689	0	752	2 340
2001	112	341	120	1	9	23	113	349	143	604	2 314
2002	10	936	412	0	0	0	10	936	412	1 358	2 758
2003	0	263	691	2	349	469	2	611	1 161	1 774	4 135
2004	46	525	224	97	1 138	147	143	1 663	371	2 177	3 625
2005	8	1179	321	385	1 083	230	393	2 263	551	3 207	3 625
2006	0	1006	333	251	1 367	11	251	2 373	343	2 967	2 964
2007	0	895	265	68	1 549	308	68	2 443	573	3 084	3 072
Total	262	6 145	2 370	804	5 495	1 188	1 066	11 638	3 558	16 260	

1. Catch limit for 88.1 and 88.2 *Dissostichus* spp. combined for the years 1997–2005, and for Subarea 88.1 and SSRUs 88.2A–B for 2006–2007.

Table 2: Total SSRU 88.2E Antarctic toothfish catch (t) for New Zealand and other vessels for the years 2003–2007.

Year	New Zealand	Other	All vessels	Catch limit[1]
2003	106.4	–	106.4	375
2004	362.2	–	362.2	375
2005	266.2	3.5	269.7	375
2006	41.6	276.1	317.7	273
2007	0.0	271.7	271.7	353
Total	776.4	551.3	1 327.7	

1. Catch limit for all 88.2 SSRUs *Dissostichus* spp. combined for the years 2003–2005 and for SSRU 88.2E for 2006–2007.

Table 3: Total SSRU 88.2DFG Antarctic toothfish catch (t) for New Zealand and other vessels for 2006–2007.

Year	New Zealand	Other	All vessels	Catch limit[1]
2006	15.2	91.8	107.0	214
2007	0.0	21.7	21.7	214
Total	15.2	113.5	128.7	

1. Catch limit for all 88.2C, D, F, & G *Dissostichus* spp. combined.

Table 4: Weighted mean depth (m), and the average depth fished by fishery (Shelf, Slope, and North), for the years 1998–2007.

Year	Shelf	Slope	North	All fisheries
1998	697	985	–	908
1999	671	916	–	904
2000	716	974	–	952
2001	654	1 242	1 193	1 121
2002	738	1 118	1 403	1 202
2003	691	1 371	1 477	1 440
2004	662	1 232	1 353	1 215
2005	637	1 200	1 462	1 176
2006	654	1 208	1 379	1 181
2007	658	1 190	1 483	1 233
Average	654	1 186	1 424	1 206

2.1.2 IUU catch

The assessment models of Dunn & Hanchet (2006a, 2006b) ignored any IUU catch in the Ross Sea or SSRU 882E, although it is likely that the inclusion of IUU catch would have resulted in a less conservative assessment (see Dunn 2006a). As at the end of 2006, CCAMLR had reported only small amounts of IUU catch for Subareas 88.1 and 88.2. Here, we update the tables of IUU catch for recent years that may be used within an assessment in 2007 (Table 5). However, we note that data for 2007 are not yet available.

IUU catches reported for the years 2002–2005 were reportedly taken from the northern areas of Subarea 88.1, and are assigned to the North fishery. The IUU catch reported for 2006 was reportedly taken in the southern Ross Sea, in SSRUs 8812A & B, and we assign this catch to the Shelf fishery. We note, however, that the catches reported by CCAMLR are for *Dissostichus* spp. combined, rather than Antarctic toothfish specifically. In the southern Ross Sea, these fish were likely to be entirely Antarctic toothfish. But in the North some proportion of the catch were likely to have been Patagonian toothfish — in particular, those catches from SSRU 88.1A and northern SSRU 88.1B were likely to have caught a significant proportion of Patagonian toothfish. Catches by legal fishing vessels (C2 data) reported that 96% of the *Dissostichus* spp. in SSRU 88.1A was Patagonian toothfish. In SSRUs 88.1B and 88.1C, 14% and 0.2% respectively of the *Dissostichus* spp. catch were reported as Patagonian toothfish.

For the purposes of including IUU catch in sensitivity model runs of Antarctic toothfish in the Ross Sea, we ignore possible impacts of the species composition of the IUU catch, and instead assume that all IUU *Dissostichus* spp. catch was Antarctic toothfish. Further the catch was assigned to either the North or Shelf areas (see above), with a fishing selectivity equal to that of the legal fleet in each respective area.

Table 5: Total IUU catch of *Dissostichus* spp. for Subareas 88.1 & 88.2, for the years 1997–2007 (SC-CAMLR-XXV 2006, Annex 5).

Year	Subarea 88.1	Subarea 88.2	Total
1997	0	0	0
1998	0	0	0
1999	0	0	0
2000	0	0	0
2001	0	0	0
2002	92	0	92
2003	0	0	0
2004	240	0	240
2005	28	0	28
2006	0	15[1]	15
Total			

1. Associated with SSRU 88.2A, and hence included as catch in the Shelf fishery within the Ross Sea assessment model.

2.2 CPUE indices

Before 2005, analysis of toothfish standardised CPUE (catch per set) was restricted to Subarea 88.1 for New Zealand registered vessels fishing in the 1999 to 2003 years (Blackwell & Hanchet 2002, 2003), and extended to all vessels for the 1999 to 2004 years (Phillips et al. 2004) using lognormal models of sets that had a positive catch. Since then CPUE indices have been reported for the Ross Sea (Subarea 88.1 and SSRUs 88.2A & B for the years 1998–2005 (Dunn & Phillips 2005) and 1998–2006 (Dunn 2006b) using both lognormal models of sets that had a positive catch and Tweedie models of all sets (i.e., including sets that had a zero catch). The indices were generally flat until 2003, showed a 30% decline in 2004 followed by a recovery to former levels in 2005.

We update these indices with data for 1997–2007, derived from an extract of the CCAMLR C2 reporting form provided by the CCAMLR secretariat and the New Zealand Ministry of Fisheries on 26th April 2007. For a full description of the models and methods used, see Dunn (2006b). The variables included in the analysis were consistent between the models presented here and CPUE analyses for previous years (Dunn 2006b). Estimates CPUE indices showed a relatively stable trend between 1998 and 2003, with a sharp decline in 2004, an increase in 2005 and 2006, and then a small decline in 2007. Possible explanations for the observed decline in 2004 were gear conflict and competition between vessels to set lines, in addition to extreme ice conditions that limited where lines could be set. None of these factors are believed to have been important since then. See Table 6 and Figure 2 for the lognormal models for core vessels, all vessels, and the Tweedie model based on a single area analysis. Lognormal models of the area-based CPUE indices (Shelf, Slope, and North) are given in Table 7 and Figure 3.

Overall, the CPUE indices for the Ross Sea have generally increased since the beginning of the fishery in 1998, and the trend in indices since 2000, if proportional to vulnerable biomass, would imply an increase in stock size about 20%. However, recent favourable ice conditions, fisher learning and experience since the beginning of the fishery, including improved knowledge of optimum fishing practice, improvements in gear, and changes in regulations (i.e., the relaxation of the by-catch move-on rules and removal of research set requirements) are more likely explanations for the increase in CPUE indices. Hence the CPUE indices developed here are believed to be of limited use as indices of toothfish abundance at the current time (Dunn & Hanchet 2006b). However, we note that CPUE indices may still be useful as a means of detecting large scale changes in catch rates over longer time periods.

Table 6: Ross Sea standardised CPUE indices, 95% confidence intervals, and coefficient of variation (c.v.s) for the lognormal (A), core lognormal (B), and Tweedie models (C), 1999–2007.

	Lognormal model (A)			Core vessels (B)			Tweedie model (C)		
Year	Index	95% C.I.	C.v.	Index	95% C.I.	C.v.	Index	95% C.I.	C.v.
1999	0.76	0.67–0.84	0.06	0.79	0.71–0.89	0.06	0.75	0.66–0.84	0.06
2000	0.98	0.90–1.07	0.04	1.09	0.99–1.20	0.05	1.04	0.95–1.14	0.04
2001	0.76	0.69–0.83	0.04	0.83	0.75–0.91	0.05	0.80	0.73–0.88	0.05
2002	1.18	1.08–1.28	0.04	1.16	1.06–1.27	0.04	1.22	1.13–1.32	0.04
2003	1.00	0.92–1.08	0.04	0.98	0.90–1.07	0.04	0.94	0.87–1.01	0.04
2004	0.67	0.63–0.71	0.03	0.59	0.55–0.64	0.04	0.65	0.61–0.69	0.03
2005	1.25	1.18–1.33	0.03	1.35	1.26–1.44	0.03	1.26	1.19–1.34	0.03
2006	1.49	1.40–1.60	0.03	1.51	1.39–1.64	0.04	1.50	1.41–1.59	0.03
2007	1.22	1.14–1.31	0.03	1.03	0.95–1.11	0.04	1.15	1.08–1.22	0.03

Table 7: Ross Sea standardised CPUE indices, 95% confidence intervals, and coefficient of variation (c.v.s) for the area model (model D), 1999–2007.

	Shelf			Slope			North		
Year	Index	95% CI	C.v.	Index	95% CI	C.v.	Index	95% C.I.	C.v.
1999	0.55	0.38–0.80	0.19	0.73	0.64–0.84	0.07	–	–	–
2000	1.15	0.92–1.43	0.11	1.08	0.97–1.20	0.05	–	–	–
2001	0.66	0.56–0.77	0.08	0.97	0.83–1.14	0.08	0.52	0.43–0.63	0.10
2002	–	–	–	1.65	1.46–1.87	0.06	1.80	1.45–2.23	0.11
2003	–	–	–	1.07	0.94–1.22	0.07	1.11	0.98–1.25	0.06
2004	0.75	0.61–0.92	0.10	0.75	0.68–0.82	0.05	0.47	0.40–0.56	0.09
2005	1.58	1.36–1.83	0.07	1.40	1.29–1.53	0.04	0.67	0.59–0.76	0.07
2006	1.20	1.01–1.42	0.09	1.56	1.42–1.71	0.05	1.15	0.89–1.49	0.13
2007	1.63	1.15–2.31	0.18	1.23	1.12–1.35	0.05	1.01	0.84–1.21	0.09

Table 8: 882E standardised CPUE indices, 95% confidence intervals, and coefficient of variation (c.v.s), 2003–2007.

Year	Index	95% CI	C.v.
2003	0.71	0.46-1.09	0.22
2004	1.07	0.73-1.57	0.19
2005	0.94	0.66-1.33	0.18
2006	1.35	0.82-2.21	0.25
2007	1.04	0.64-1.70	0.25

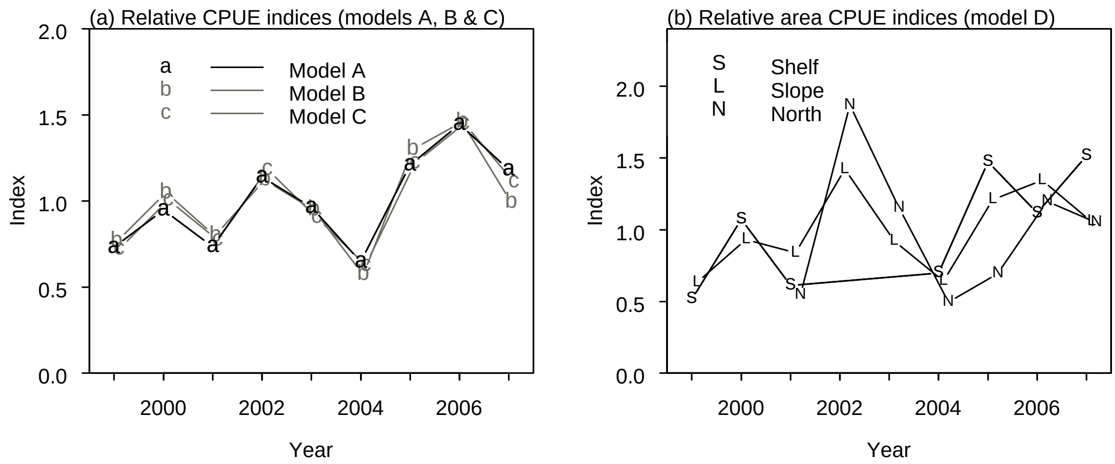

Figure 2: Ross Sea relative CPUE indices (scaled to have mean of one) for (a) the lognormal model (A) and core vessels (B), and (b) the shelf, slope, and north area model (D), 1999–2007.

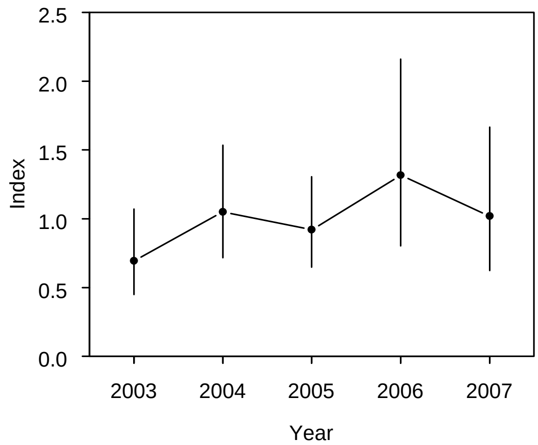

Figure 3: 882E relative CPUE indices (scaled to have mean of one), 2003–2007.

2.3 Length-weight relationship

Dunn et al. (2006) updated length weight parameters for Antarctic toothfish in the Ross Sea based on data for the years 1997–2006. They reported length-weight parameters for males and females, but not for unsexed fish. However, in some years a large proportion of lengths for Antarctic toothfish were recorded as unsexed. We provide an update to these estimates by calculating the length-weight relationship for all fish (i.e., ignoring sex) using the same data as described in Dunn et al. (2006) (i.e., length-weight records from all longline vessels fishing in the Ross Sea up to end of 2005, plus data from all New Zealand vessels fishing in 2006, but excluding data from one vessel, CCAMLR trip number 298). The updated length-weight parameters are provided in Table 9.

In general, Scientific Observer data where a large proportion of toothfish were unsexed were from a small number of vessels. Overall, about 84% of all measured fish were recorded as either male or female. Figure 4 shows the proportion of lengths reported by Scientific Observers from vessels from different nations that were reported as either males or females for the Ross Sea. The vessels that had Scientific Observers that reported sex in less than 50% of cases were the *Volna* and *Yantar* (Russia, 40% and 30% respectively), and the *Mellas* and *Simeiz* (Ukraine, 45% and 47% respectively). All other vessels, except for the *Arnela* (Spain, 55%), *Paloma V* (Uruguay, 61%), and the *Yeon Seong No. 829* (Korea, 83%), had reported at least 85% (i.e., the mean) of fish as sexed. In SSRU 88.2E, none of the Russian or Uruguayan vessel observer reports provided any sexed data, and in SSRUs 882DFG the Russian and Uruguayan vessels observers reported less than 50% of fish as sexed (Figure 5).

Table 9: Updated length-weight parameters for Ross Sea Antarctic toothfish

Group	Parameter (units)	Male	Female	All
Shelf	a (t.cm^{-1})	5.324e-9	5.381e-9	5.479e-9
	b	3.173	3.171	3.167
Slope	a (t.cm^{-1})	4.606e-9	3.923e-9	4.254e-9
	b	3.205	3.238	3.221
North	a (t.cm^{-1})	3.035e-8	1.696e-8	1.289e-8
	b	2.774	2.906	2.953
Ross Sea	a (t.cm^{-1})	1.387e-8	7.154e-9	8.698e-9
	b	2.965	3.108	3.065

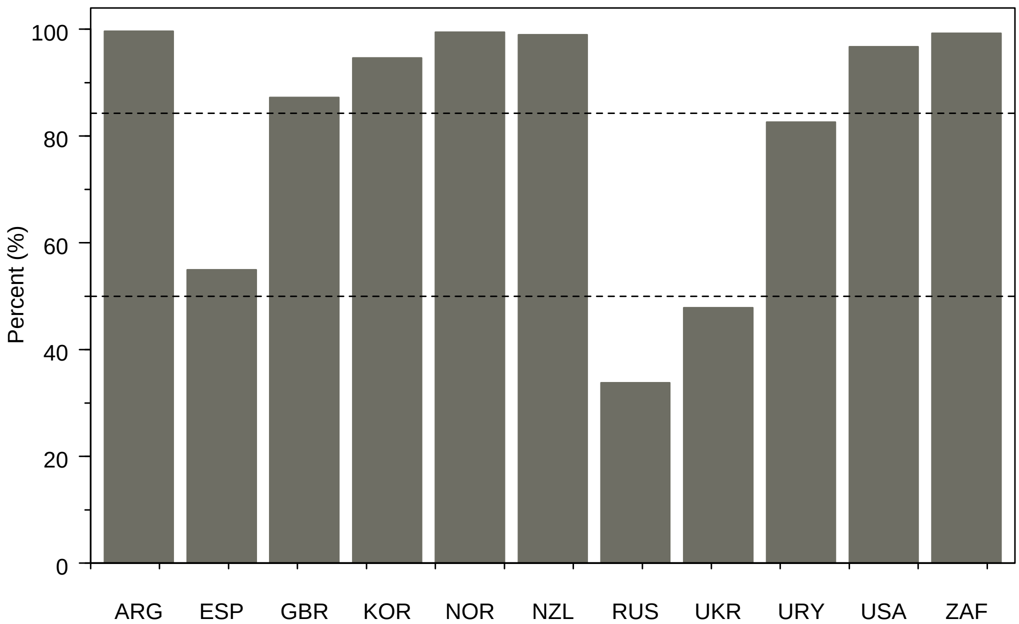

Figure 4: Percent of fish sexed as either male or female in the Ross Sea, as recorded by the CCAMLR Secretariat Observer data, by nation of the vessels for all vessels 1997–2007. Horizontal dashed lines indicate 50% and the mean (85%) coverage.

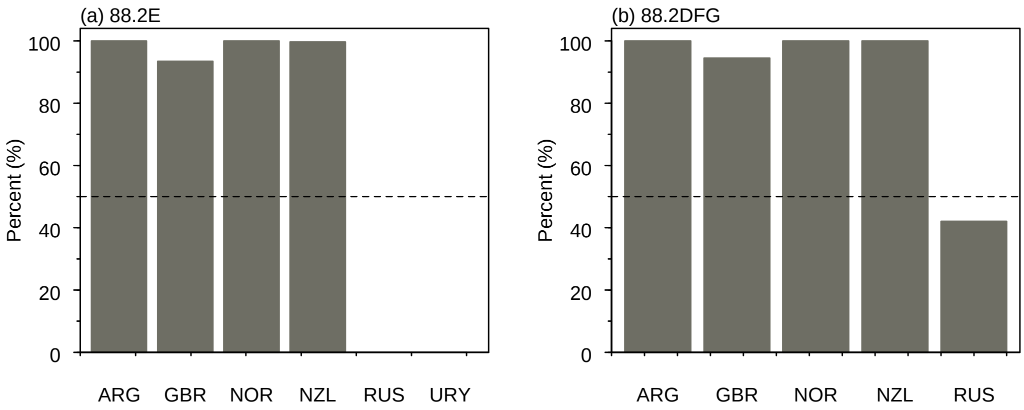

Figure 5: Percent of fish sexed as either male or female in (left) SSRU 882E and (right) 88.2DFG, as recorded by the CCAMLR Secretariat Observer data, by nation of the vessel for all data 2003–2006. (Note, no length data were supplied by Scientific Observers on Russia or Uruguay vessels for sets located in SSRU 882E.) Horizontal dashed lines indicate 50% coverage.

2.4 Catch-at-length and catch-at-age

2.4.1 Update of the catch-at-length data

Catch-at-age estimates of the commercial catch have previously been calculated for Antarctic toothfish in the Ross Sea for (i) New Zealand vessels and (ii) all vessels up to the end of the 2006 season. The catch-at-age estimates were calculated by applying an annual age-length key to the scaled length frequency estimates of the commercial catch within three areas (Shelf, Slope, and North) for the Ross Sea, and for 88.2E separately. The scaled length frequency estimates were calculated by scaling the length frequency samples provided by Scientific Observers to the total set weight, and then scaling to the total landed catch.

We update the estimated catch-at-length frequencies for the Ross Sea in 2007 for New Zealand vessels, and for all vessels where data were available at the time of extract (April 2007). Hence, length-frequencies for all vessels in 2007 are incomplete and the catch proportions-at-length may change as data from the remaining vessels become available. Otolith readings of fish caught in 2007 have not yet been completed, and hence catch-at-age data for 2007 are not yet available. Estimated numbers of fish measured (by sex), and aged are given in Table 10 for the Ross Sea and Table 11 for SSRU 88.2E, and Table 12 for the remaining SSRUs of Subarea 88.2.

In previous analyses the length weight relationship that was applied to the set length frequencies for unsexed fish was assumed to be equal to the length weight relationship for male fish (see Hanchet et al. 2006). While this approximation was likely to be adequate for the New Zealand vessel subset of the data (as the proportion of sexed fish were >99%), this may not be adequate for the all vessels estimates (where the proportion was only 85%).

Here, we compare the length frequencies of the commercial catch for (a) length frequency estimates as presented by Hanchet et al. (2006), i.e., that assumed a length-weight relationship for unsexed fish that was the same as the relationship for males, and (b) length frequencies using the same algorithm, but using the new unsexed length-weight relationship for unsexed fish.

Dunn et al. (2006), when revising the length-weight relationship for Antarctic toothfish in the Ross Sea, reported that different regions of the Ross Sea were found to have slightly different relationships. The length-weight relationships reported by Dunn et al. (2006) for the Shelf, Slope, and North regions are given in Figure 6. These relationship suggest that fish from the

North typically had a different relationship to those in either on the Slope or Shelf, possibly as the proportion of ‘axe handles’ were relatively more abundant in the North (Dunn et al. 2006).

As the length-weight relationship of Antarctic toothfish may vary between regions of the Ross Sea, we compare the length frequencies from (a) and (b) above with the scaled length frequency obtained where the length-weight relationship was ignored. Here, we scale the length measurements using the reported number (C2 data) of Antarctic toothfish landed as the scaling factor for each set and then the reported number within each area (Shelf, Slope, and North). Here, the length weight relationship was ignored as the number of fish were scaled to the total number of fish caught, and not the total weight caught.

The resulting length frequencies (i.e., the 2006 analysis, the 2006 analysis updated with the unsexed length-weight relationship, and the revised analysis using catch of Antarctic toothfish in numbers) are given in Figure 7. While, broadly similar length frequencies were obtained from each of the three algorithms, there were some significant differences. The use of the unsexed length-weight relationship had little impact, and there was almost no change in the estimated length-frequency distributions. However, the use of numbers of fish to scale length-frequencies resulted in a change in the length-frequency distributions at lengths of about 100–120 cm. Here, the later analysis resulted in a small reduction in the estimated proportions in this range when compared with the 2006 analysis.

Table 10 Numbers of measured and aged Antarctic toothfish for New Zealand and all vessels in the Ross Sea, 1998–2007. Note data for 2007 are incomplete, with ‘–’ indicating unavailable at the time of this report.

	Males			Females			Unsexed		Sets	
Year	Measured		Aged	Measured		Aged	NZL	All	NZL	All
	NZL	All		NZL	All					
1998	741	741	227	887	887	268	115	115	65	65
1999	3 098	3 098	215	3 827	3 827	287	24	24	241	241
2000	6 228	6 228	220	7 998	7 998	308	59	59	462	462
2001	3 474	3 896	417	3 977	4 440	473	811	868	342	424
2002	7 085	7 085	267	9 481	9 481	313	74	74	430	430
2003	6 898	9 981	236	6 528	8 673	254	19	7 630	410	728
2004	5 544	18 202	208	7 016	22 662	277	34	6 759	413	1 955
2005	7 724	18 226	198	9 896	22 273	210	18	16 010	454	1 372
2006	5 266	12 346	315	6 559	15 522	431	7	4 040	324	856
2007	5 431	6 183	–	7 340	8 252	–	17	74	382	452

Table 11 Numbers of measured and aged Antarctic toothfish for New Zealand and all vessels in SSRU 88.2E (and including otoliths from SSRUs 882DFG), 2003–2007. ‘–’ indicates no data.

	Males			Females			Unsexed		Sets	
Year	Measured		Aged[1]	Measured		Aged[1]	NZL	All	NZL	All
	NZL	All		NZL	All					
2003	997	997	156	1 078	1 078	119	6	6	74	74
2004	2 788	2 788	156	1 997	1 997	119	14	14	158	158
2005	1 801	1 852	156	1 048	1 105	119	11	12	83	89
2006	482	2 936	156	262	1 439	119	0	33	25	184
2007	0	–	–	0	–	–	0	–	0	–

1. A single age-length key, based on otoliths sampled over all years from SSRUs 882DEFG, was applied to the scaled length frequency in each year.

Table 12 Numbers of measured toothfish for New Zealand and all vessels in SSRUs 88.2DFG, 2006–2007. '–' indicates no data.

Year	Males		Females		Unsexed		Sets	
	Measured		Measured		NZL	All	NZL	All
	NZL	All	NZL	All				
2006	260	706	264	752	0	302	14	49
2007	0	–	0	–	0	–	0	–

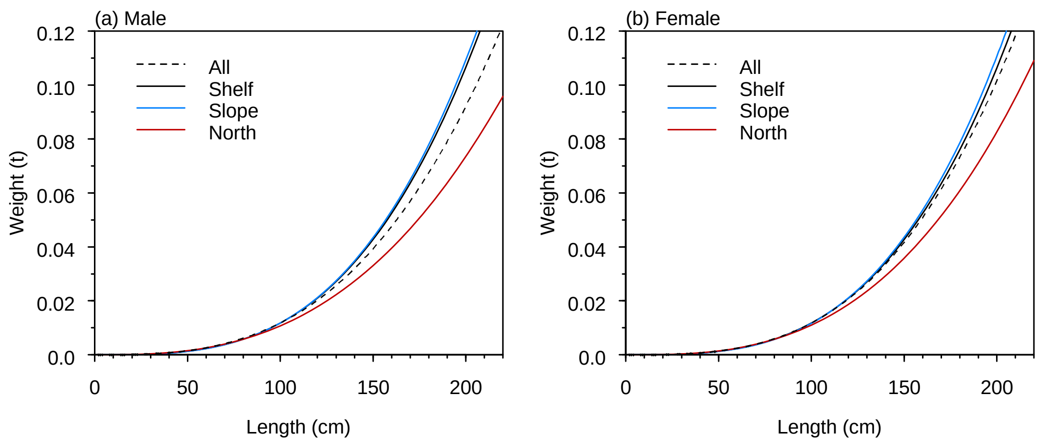

Figure 6: Length-weight curves, by sex, for Ross Sea Antarctic toothfish in the shelf, slope, and north sections of the Ross Sea, with the 'all Ross Sea' curves provided for comparison.

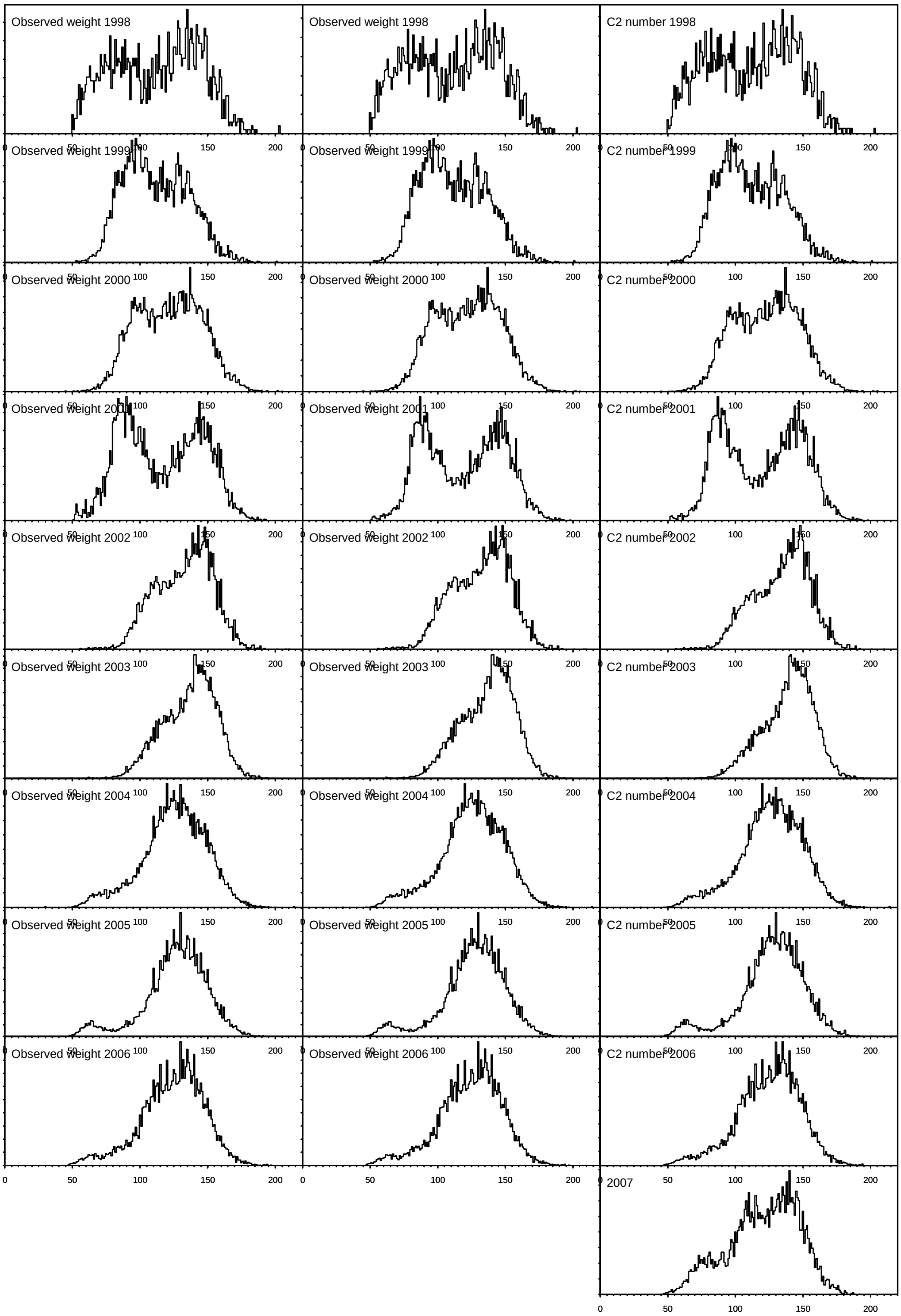

Figure 7: Estimated total length frequencies for all vessels in the Ross Sea, 1998–2007 using (left column) the length frequencies as reported in 2006, (middle column) using the same algorithm as in 2006, but including the revised length-weight relationship for unsexed fish, and (right column), ignoring the length-weight relationship and scaling by the reported (C2 data) number of fish. (Note, data for 2007 are incomplete)

2.4.2 Revision of the catch-at-length stratification for the Ross Sea

Estimates of the length and age-frequencies detailed by Hanchet et al. (2006) were calculated for the Ross Sea based on three regional strata (areas). The areas were based on results of a tree based regression analysis of the commercial catch-at-length data used to stratify the commercial catch-at-age data (Phillips et al. 2005). From the tree-based analysis, three strata were defined, Shelf, Slope, and North. The Shelf was defined as the SSRUs 88.1E–F, 88.1H–L, & 88.2A–B at a depth of less than 761 m; Slope was defined as the SSRUs 88.1E–F, 88.1H–L, & 88.2A–B at a depth of greater than or equal to 761 m; and North was defined as SSRUs 88.1A–88.1C, and 88.1G. Note that we refer hereafter to this model as the Phillips model in the discussions below.

Using all available data at the time of extract (including available data for 2007) we investigate potential stratifications based on results from a tree regression algorithm. The method for determining the tree regression was described by Phillips (2005), but we also revise this method by investigating the use of a small area location variable (‘spot’, see below) to allocate observations to strata.

Model runs were carried out on data from all vessels, and from New Zealand vessel separately, using the median length of each set as the response variable. Model terms included ‘spot’, SSRU, month, depth, latitude, longitude, vessel, vessel type, and nation. SSRU, depth, latitude, and longitude were based on the mid-point of each set position. Vessel type was either Spanish longliner or autoliner, and spot was a categorical variable defined as a small area location based on the concatenation of the integer part of the longitude and ½ degree latitude (i.e., all sets with a ½-degree rectangle were assigned to the same ‘spot’). Note that in model runs where spot was offered as a predictor variable (the spot model), no other terms were found to be significant, and hence we also investigated model runs without the spot variable (the revised model).

Model runs that included nation or vessel as a predictor variable were also investigated, but almost always resulted in the same stratifications down to the 3rd level of split. In addition, preliminary investigation of these models suggested that the nation or vessel variable was highly confounded with location. Models runs were also investigated that only included New Zealand data. Here, in locations where coverage from the New Zealand vessels and other vessels was similar, much the same results were obtained. However, locations where New Zealand vessels did not fish or where data were sparse were often poorly allocated, and resulted in allocations to strata that did not appear to fit the data obtained from the rest of the fleet. Hence, for the remainder of the investigation, we used all available data from all vessels.

In general, there was a strong relationship between reported lengths of Antarctic toothfish and location on the Ross Sea. As a general rule, more southern and more shallow regions had shorter fish than both deeper or more northerly locations. The relationship between the observed lengths of Antarctic toothfish and SSRU is given in Figure 8. Fish in the northern SSRUs tended to be longer, except for those fish caught in shallower waters around the Balleny Islands (SSRU 88.2E). More southern SSRUs tended to have shorter fish, although SSRUs 88.1J, 88.1K, 88.1L, and 88.2A (along with fish from 88.2F and 88.2G) appeared to be bimodal in the distribution of lengths.

The relationship between median length in each set and location is given by location for the Ross Sea in Figure 9. In addition, the variability of lengths around the mean length (c.v.) is given in Figure 10. In general, higher c.v.s were associated with shorter median lengths, with lowest variability in the Northern areas. However, in contrast to the overall trend lower variability was found in two areas where mostly shorter fish were found — in the western-most part of SSRU 88.1J (Terra Nova Bay), and in the southern-most part of SSRU 88.1L (Figure 10).

In general, the updated regression tree models typically split the fishery into 4–6 strata (depending on the choice of the cost-complexity parameter, c_p), and generated strata that were broadly were similar to those of the Phillips model. See Figure 11 for a graphical representation of the stratification resulting from the Phillips model.

Figure 12 shows the location of all sets in the Ross Sea, colour coded by strata using the spot variable. As in the case of the Phillips model, the algorithm defined regions that could be broadly grouped as shelf, upper slope, lower slope, and north. However, it was notable that the fish in SSRU 88.2A and on the border of 88.1K and 88.1L were assigned as either north or upper slope. While different from the analysis of Phillips et al. (2005), we note that data from these areas was more limited at the time of that analysis. Areas around the Balleny Islands (SSRU 88.1E) also showed more complex pattern. Here, areas in the immediate vicinity of the islands, and hence a shallower depths, were categorised as shelf , with as sets were located further away (and hence in deeper waters), the classification moved to upper slope, lower slope, and north. The western-most part of SSRU 88.1J (Terra Nova Bay) also had a complex pattern —fish were either classified as shelf or upper slope in a manner that suggested a close relationship with small changes in location or depth.

Model runs based on predictor variables without spot (the revised model) showed a similar pattern, although the model was unable to match the small scale complexity of the spot model (Figure 13). This model allocated set locations in SSRUs 88.1A, 88.1B, 88.1C, 88.1G, and 88.1I at latitudes above 70° 45.5’S to the ‘north’, and below 70° 45.5’S to ‘lower slope’. SSRUs 88.1E, 88.1F, 88.1H, 88.1J, 88.1K, 88.1L, 88.2A, and 88.2B at depths below 838 m were allocated to ‘upper slope’, and locations above 838 m were allocated to ‘shelf’.

For the stratifications resulting from each of the models (i.e., the Phillips model, spot and revised model runs), catch-at-length frequencies were calculated. As described above, we scaled the length measurements using the reported number (C2 data) of Antarctic toothfish landed as the scaling factor for each set and then the reported number within each area (Shelf, Slope, and North), i.e., we ignore the length weight relationship and scale the number of fish to the total number of fish caught, not the total weight caught.

The length-frequency distributions for the Shelf, Slope, and North strata using the Phillips model are given in Figure 14. In general, the shape of the length-frequency distribution of the North remained relatively consistent over all years of the fishery, suggesting that the selectivity pattern had remained constant over this time period. The distribution of lengths of the Slope suggested at least two modes — at about 125 cm and another at 100 cm in the early years, and 60–70 cm in later years. The pattern in the Shelf varied markedly from year to year, with a mode at either 60–70 cm (2007), up to a mode at 120 cm (2005). These changing patterns in the length-frequency distributions between years for the Shelf and Slope areas would suggest a marked change in fishing selectivity between years in each of these regions.

The length frequency distributions using the four strata from the spot model are shown in Figure 12. Here, as with the Phillips model, the length-frequency distribution of the north area remained relatively constant over the duration of the fishery. Similarly, the distribution of the lower slope region also remained very similar. While less variable than the Phillips model, there was some year to year variability in the distribution for the upper slope, and the variability in the shelf area appeared to have a similar pattern to that for the Shelf of the Phillips model.

The length frequency distributions using the four strata from the revised model are shown in Figure 13. Again, the length-frequency distribution of the north and lower slope areas remained relatively constant over the duration of the fishery, although there was a tendency for a small mode at about 60 cm to appear in some years in the lower slope distribution. The upper slope again had some year to year variability in the length frequency distribution, and again, the variability in the shelf area appeared to have a similar pattern to that for the Shelf of the Phillips model.

In general, the results from each of the models suggest a high level of local area complexity ion the length distribution of Antarctic toothfish in the Ross Sea, particularly in shallower areas in the south. In addition, length frequency distributions from locations that were in close proximity to each other can, on occasion, be very different.

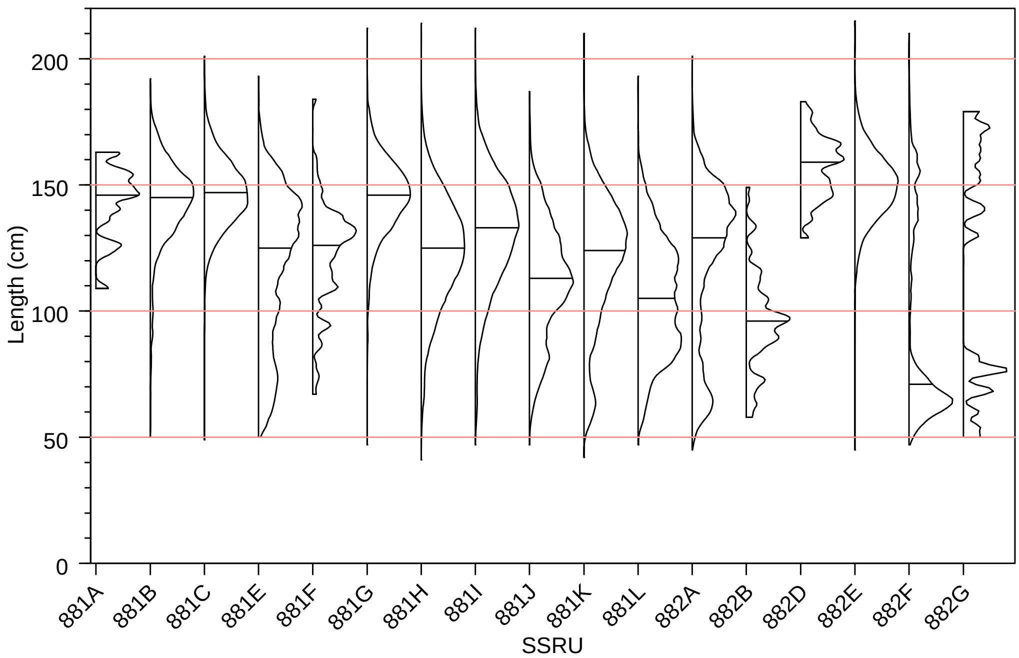

Figure 8: Distribution of sampled lengths by SSRU for all vessels, 1997–2007 (not scaled).

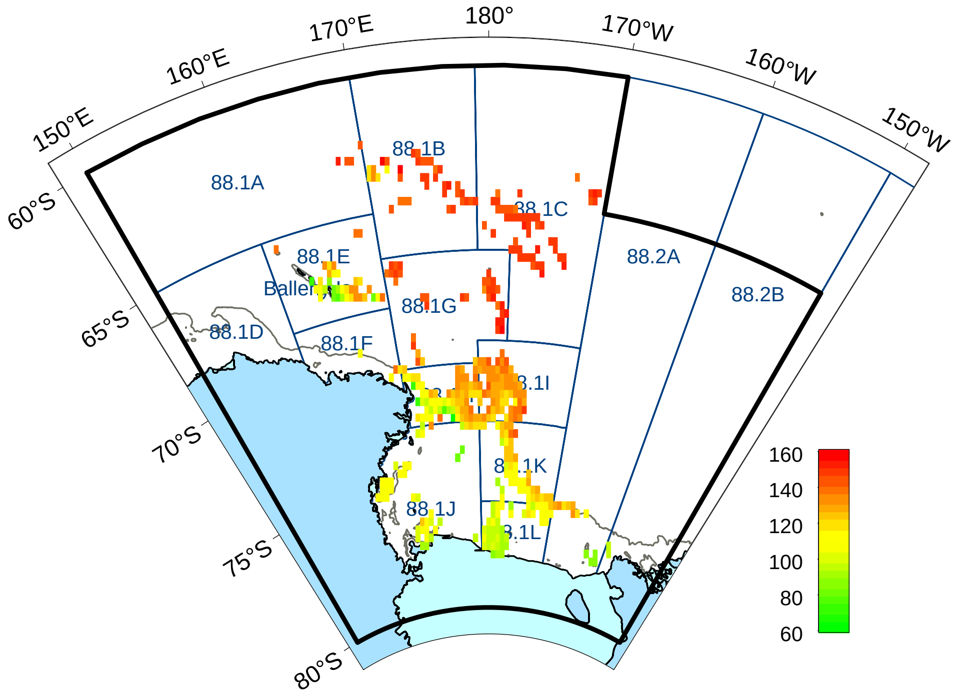

Figure 9: Median length (cm) of Ross Sea Antarctic toothfish by location (not scaled), for all vessels, , 1997–2007. (Gray lines shows the 838 m depth contour.)

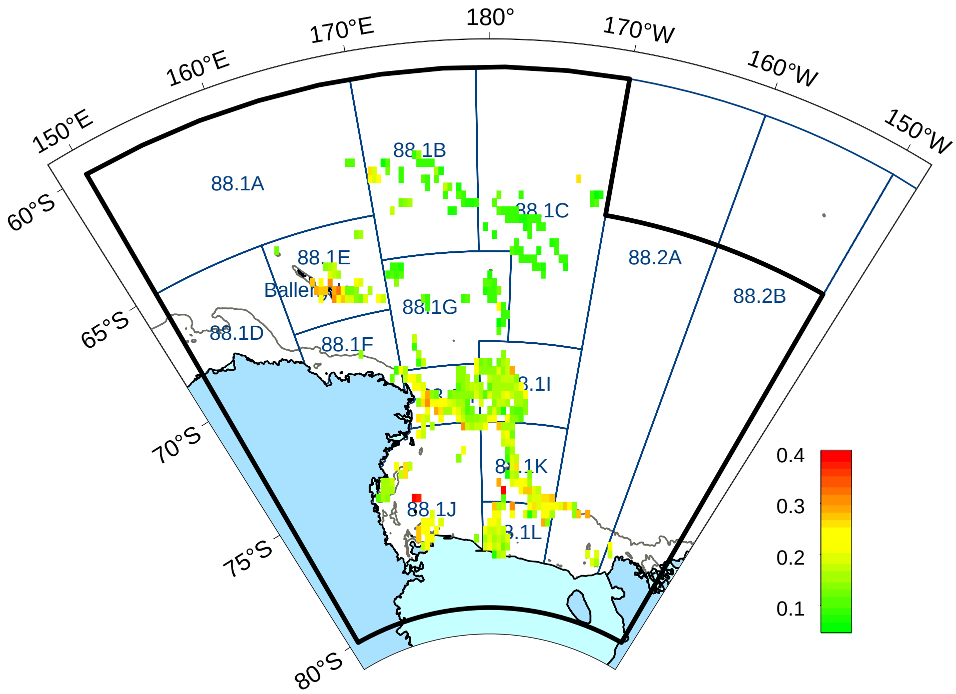

Figure 10: C.v. of the length of Antarctic toothfish by location (not scaled) for all vessels, , 1997–2007. (Gray lines shows the 838 m depth contour.)

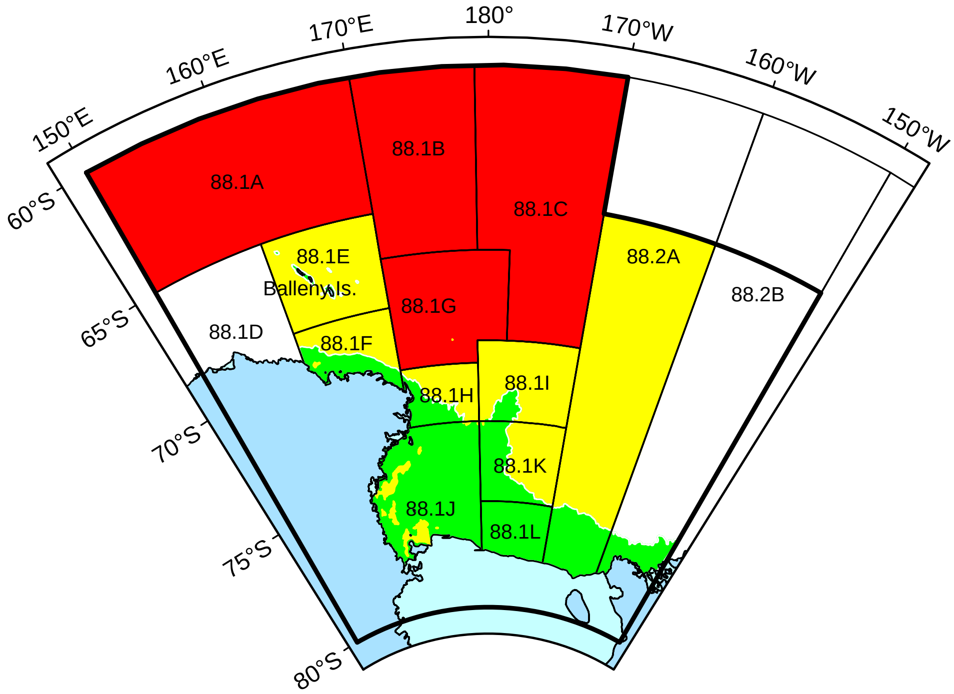

Figure 11: Allocation of C2 locations in the Ross Sea to 3 areas (Shelf, Slope, and North) using the 2006 algorithm (depth=760m) for all vessels, 1997–2007. (Division between shelf and slope occurs at the 760 m depth contour)

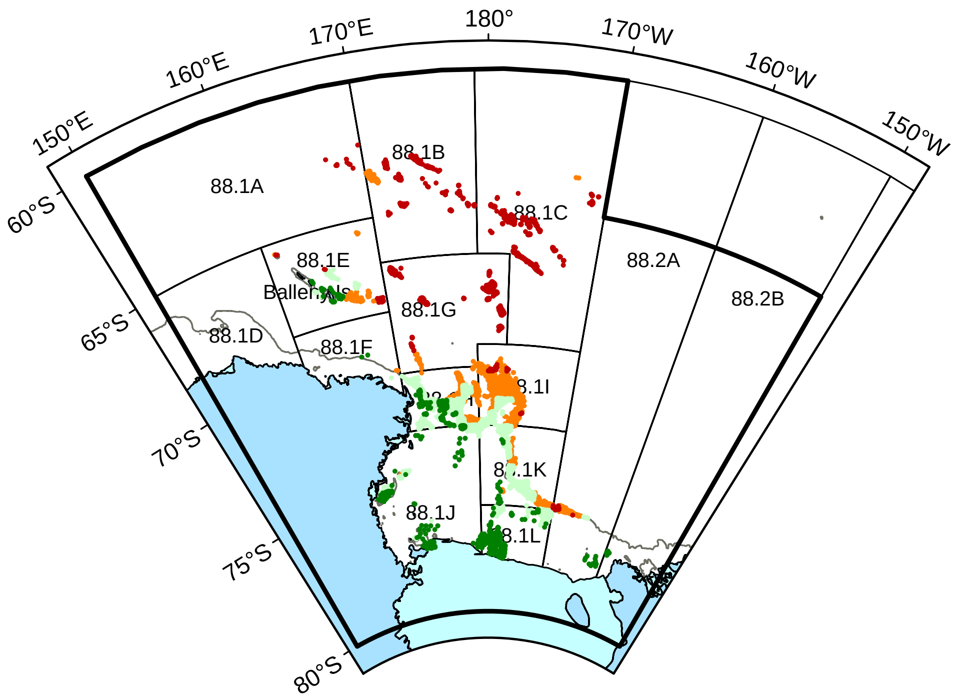

Figure 12: Allocation of C2 sets in the Ross Sea to strata using the spot algorithm for all vessels, 1997–2007. Key: dark green = shelf, light green = upper slope, orange = lower slope, and red = north. (Gray lines shows the 838 m depth contour.)

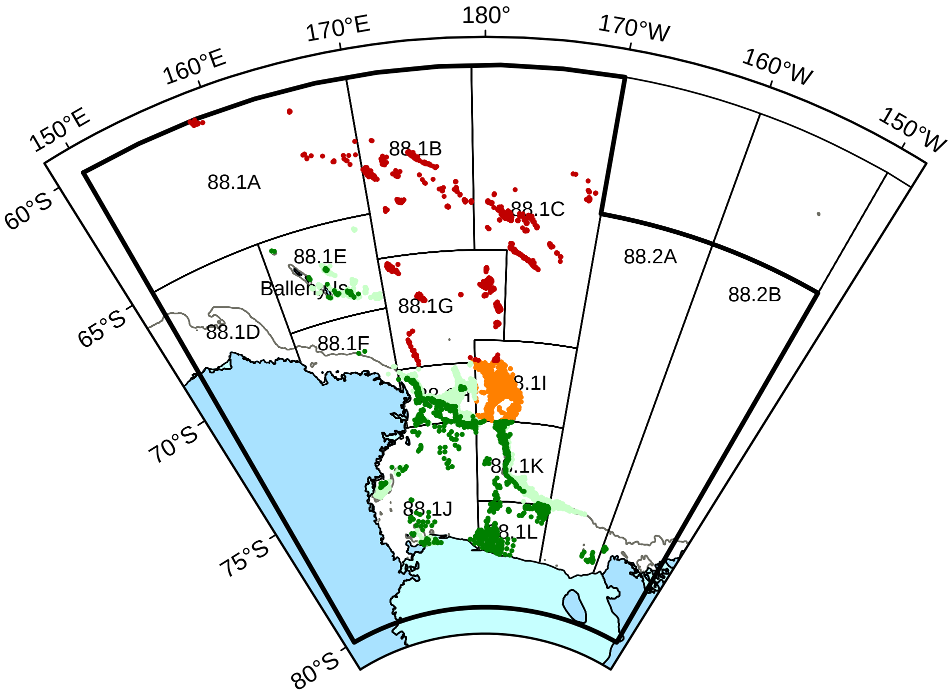

Figure 13: Allocation of C2 sets in the Ross Sea to strata using the revised algorithm for all vessels, 1997–2007. Key: dark green = shelf, light green = upper slope, orange = lower slope, and red = north. (Gray lines shows the 838 m depth contour.)

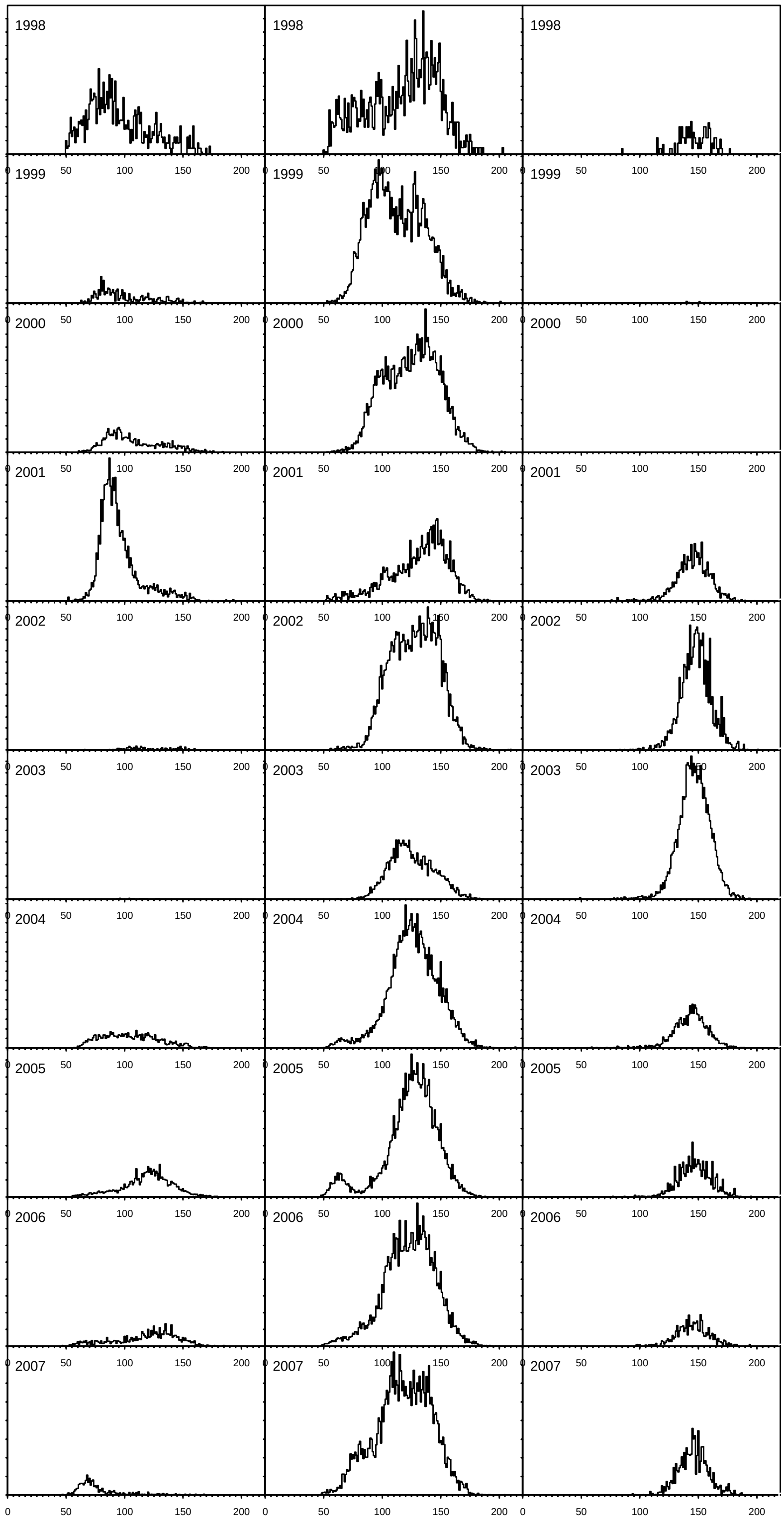

Figure 14: Estimated total length frequencies for all vessels in the Ross Sea, 1998–2007 for (columns) Shelf, Slope, and North using the Phillips model.

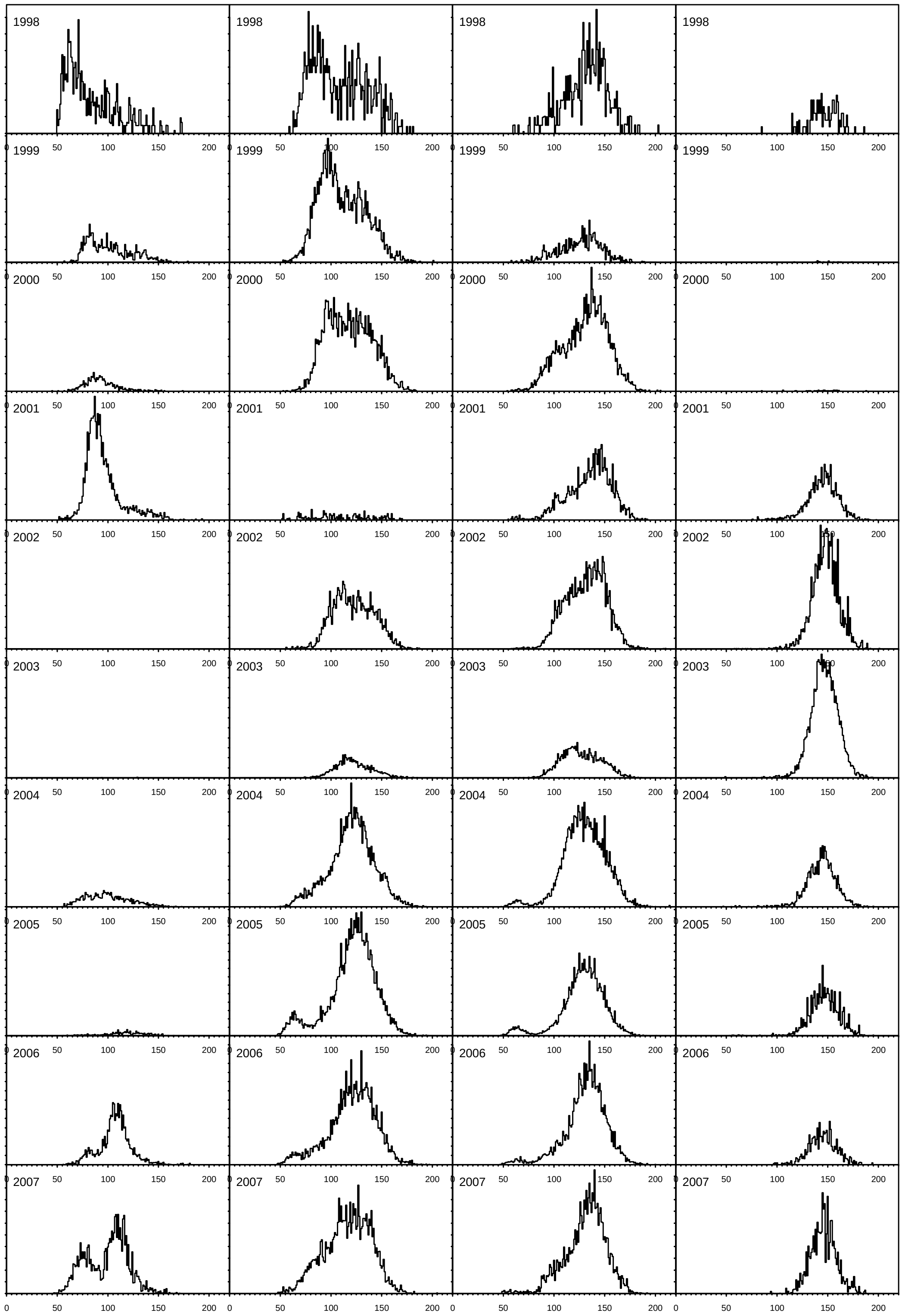

Figure 15: Estimated total length frequencies for all vessels in the Ross Sea, 1998–2007 for (columns) Shelf, Slope, Slope/North, and North using the spot model.

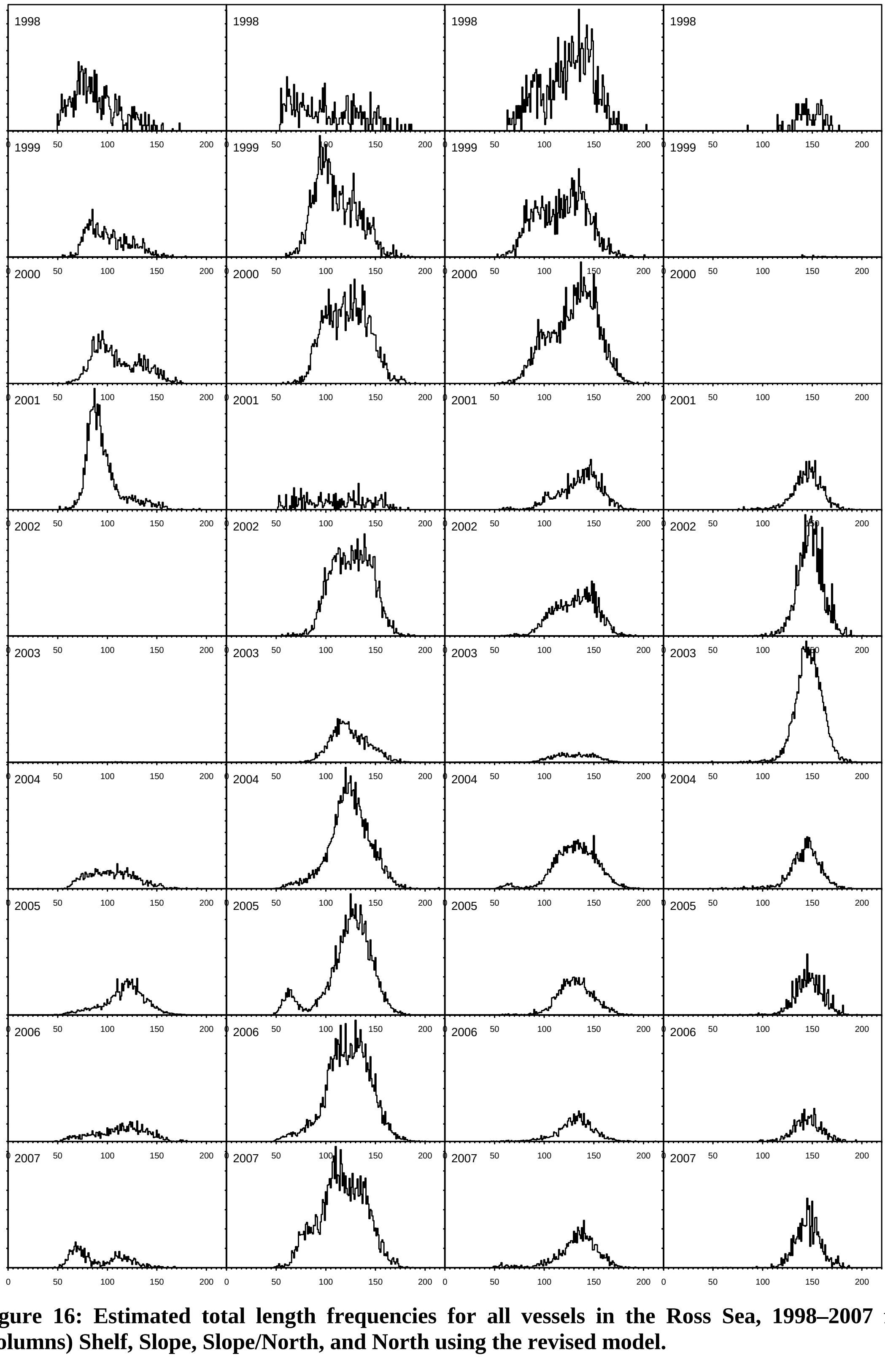

Figure 16: Estimated total length frequencies for all vessels in the Ross Sea, 1998–2007 for (columns) Shelf, Slope, Slope/North, and North using the revised model.

2.5 Age-length key

Dunn et al. (2006) recommended that separate age-length keys be used for the north and the shelf/slope areas of the Ross Sea to estimate catch-at-age frequencies for Antarctic toothfish. They reported that different areas appears to have different mean ages at length, with the northern areas of the Ross Sea having a higher mean age at length than either the Shelf or Slope. They suggested that the apparent differences between areas in mean age at length may be related to a trade-off between somatic growth and reproductive productivity, and noted that fish in the north are generally more sexually mature than those on the shelf and slope (Patchell 2002, Fenaughty 2006). Dunn et al. (2006) reported that there were no apparent between-area differences for males up to about 110 cm or for females up to about 120 cm. But for longer fish, median age at length was greater in the North area, i.e., large fish in the north have, on average, experienced a slower growth rate than similar sized fish in the slope.

We investigated the impact of the use of area-specific age-length keys on the distribution of age frequencies by applying separate age-length keys to length-frequency data for the Shelf/Slope and North areas separately. Here, we combined the length data into a sex specific length frequency for all years combined for New Zealand vessels in the Ross Sea. Further, all Antarctic toothfish age-length data from New Zealand vessels in the Ross Sea were combined to generate area-specific age-length keys. For the purposes of this investigation, data over all years were combined as insufficient otoliths have been aged to generate complete annual age-length keys for each area separately.

The effects of area-specific age-length keys on the cumulative age-frequency curve are plotted in Figure 17. Estimated reduction in mean age of fish on the Slope/Shelf when using the Shelf/Slope specific age-length key was about 1 year at ages over 10 years. The change in mean age was -0.70 y and -0.60 y for males and females respectively. For fish in the North, the effect was to increase the average age by about 2 years over the entire age distribution. The change in mean age was 1.68 y and 2.27 y for males and females respectively.

A simple randomisation test was carried out using the same data. Here, the difference in mean age was compared with the same test statistic where the labels of Shelf/Slope and North were randomly allocated among the age-length data. Results from a test using 200 randomisations suggested a highly significant difference between the Shelf/Slope and the North in the mean age of the resulting age-frequency distributions ($p<0.01$).

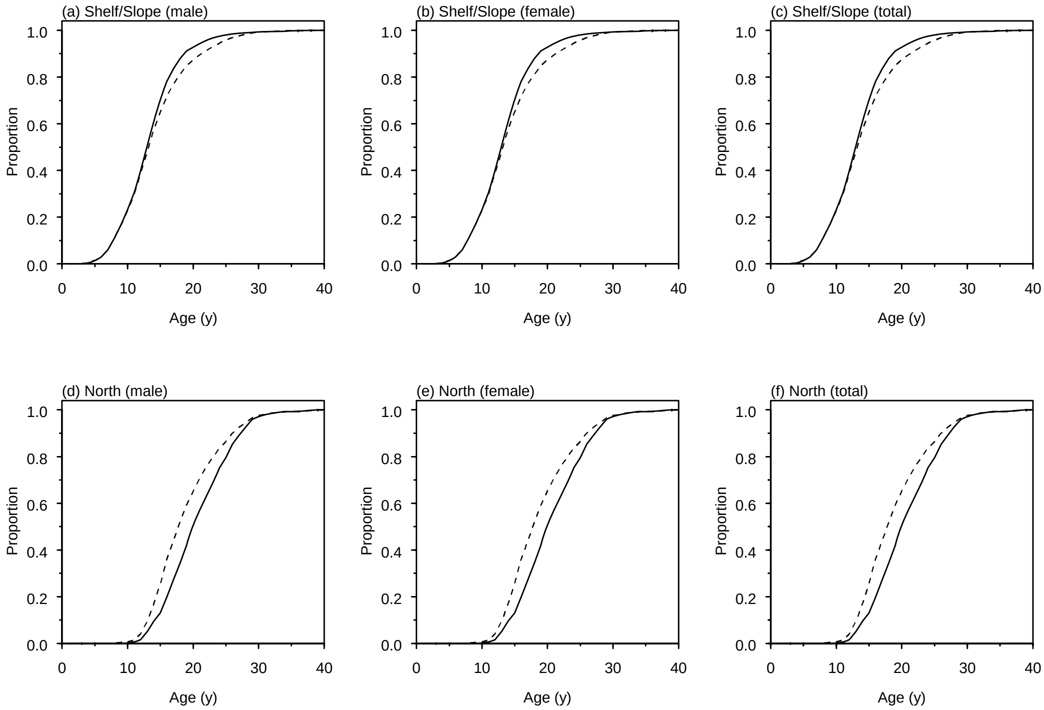

Figure 17: Estimated cumulative age frequencies over all years combined for males, females, and all Antarctic Toothfish in the Shelf/Slope and North areas of the Ross Sea on New Zealand vessels, assuming (solid lines) area specific age-length keys, and (dashed lines) the overall age-length key applied to each area separately.

2.6 Updated tag-release and recapture data

Tag-release and tag-recapture data for New Zealand vessels are reported in Dunn et al. (2007). At the time of the tag data were extracted by the CCAMLR Secretariat for this report, data for all vessels were incomplete. The updated numbers of tags released and recaptured by New Zealand vessels, and ignoring within-season recaptures are given in Table 13. The tags recaptured by New Zealand vessels in 2007 were at a higher rate than in previous years, with most of these being recaptures from 2006 releases (Dunn et al. 2007).

Table 13: Numbers of Antarctic toothfish with tags released for the years 2001–2006 by (a) New Zealand vessels and the number recaptured in 2002–2007 (excluding within season recaptures).

Data source	Tagged fish released								Tagged fish recaptured
	Year	Number	2002	2003	2004	2005	2006	2007	Total
New Zealand	2001	259	1	1	0	0	0	1	3
Vessels	2002	684	–	5	3	5	5	3	21
	2003	858	–	–	7	7	0	4	18
	2004	865	–	–	–	16	11	7	34
	2005	1 518	–	–	–	–	12	8	20
	2006	1 495	–	–	–	–	–	48	48
	Total	4 183	1	6	10	28	28	71	144

2.7 Revised scanned numbers

Dunn & Hanchet (2006b) used the estimated numbers at length for New Zealand vessels as the source data of number of fish scanned at length. These estimates were based on the reported observer weights in each set. We revised the numbers of fish scanned at length by New Zealand vessels using the updated proportions-at-length data based on the number of Antarctic toothfish caught, i.e., we ignore the length-weight relationship in weighting of length-frequencies within sets and instead weight using the number of fish caught. Note that the effect of the change in methodology was to alter the relative proportions within each length class, while the total number scanned remains unchanged.

The revised numbers of fish scanned at length by New Zealand vessels is given in Table 14. In general, only slight differences between the two methods was discernable. A comparison of the proportions reported by Dunn & Hanchet (2006b) and the revised estimates is shown in Figure 18.

Table 14: Estimated number of New Zealand vessel Antarctic toothfish scanned by 10 cm length class for the years 2002–2007 using the revised methodology for determining the numbers of scanned fish at length.

Length class						Revised estimate
	2002	2003	2004	2005	2006	2007
30	0	0	0	0	0	0
40	6	12	2	32	6	22
50	67	19	62	759	63	177
60	233	35	350	1 661	277	512
70	201	36	569	760	1 062	1 828
80	522	103	658	815	2 022	2 418
90	2 351	394	1 077	1 984	3 202	3 018
100	4 196	980	1 782	3 546	8 245	5 405
110	5 249	1 736	3 264	6 690	9 211	6 269
120	5 737	2 675	4 502	9 922	7 590	6 155
130	8 027	5 406	4 784	10 632	8 478	7 344
140	10 073	8 111	4 871	8 392	7 307	7 082
150	7 135	6 889	3 312	5 415	4 465	4 167
160	2 978	3 320	1 524	2 244	1 895	1 556
170	966	878	402	758	526	468
180	200	202	73	228	125	81
190	15	14	5	16	30	3
200	5	3	0	2	3	1
210	3	1	10	0	0	0
220	0	0	0	0	6	0

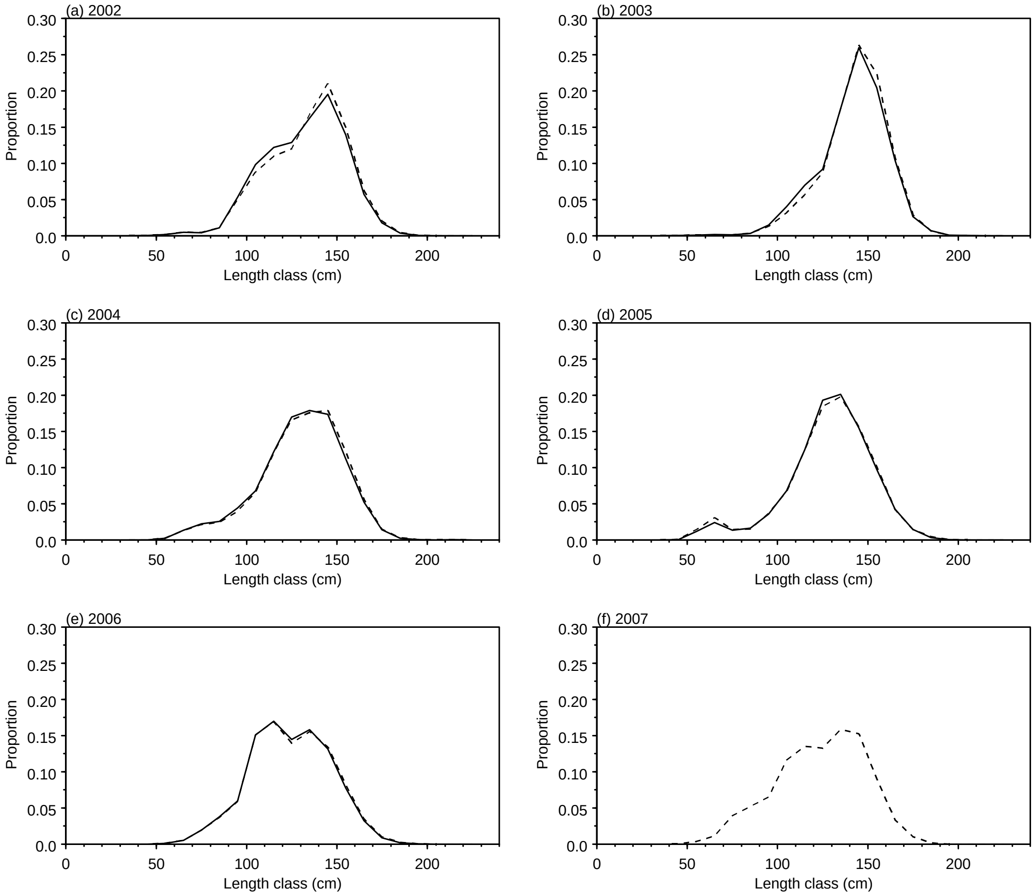

Figure 18: Estimated proportions of scanned fish (New Zealand vessels) for the years 2002–2007, using (solid lines) reported numbers by Dunn & Hanchet (2006b) and (dashed lines) using the revised methodology for determining the numbers of scanned fish at length.

2.8 Revised tag parameters

2.8.1 Tag growth check

Dunn & Hanchet (2006b) assumed a check on growth of individual fish (g_i), where growth for tagged fish was adjusted by assuming that the value of the t_0 von Bertalanffy growth parameter was modified by -0.75 years, i.e., the mean size at age for a tagged fish was modelled as,

$$\bar{s}\left(age\right) = L_{\mathrm{inf}}\left(1-\exp\left(-k\left(age-t_0-g_i\right)\right)\right),$$

where g_i=0.75.

Dunn & Hanchet (2006b) did not describe the basis for the assumption of g_i=0.75, nor has the value of this parameter been estimated for Antarctic toothfish. We revise this value and assume that g_i=0.5. Note that this is equivalent to the value assumed by Agnew et al. (2006) for the assessment of Patagonian toothfish in 48.3, and was based on the analysis of Patagonian toothfish tag-growth data in 48.3 by Agnew et al. (2005).

2.8.2 Selectivity on tag-release

The model of Dunn & Hanchet (2006b) applied to Antarctic toothfish in the Ross Sea applied tagging to the modelled population were deterministically calculated from the observations of numbers of fish at length, i.e., the numbers of fish tagged at age were calculated within the model using the length frequency of the tagged and untagged fish, and the population state and growth parameters in the given year and time step of the release event. This method assumes that all fish within the modelled untagged population were equally likely to be tagged, conditional on their length.

However, as discussed in the 2006 meeting of the WG-FSA, fish that are tagged are selected from the subset of the available fish in the part of the population vulnerable to fishing, and that the conversion of tagged numbers-at-length to numbers-at-age within the model could take into account the selectivity process by which they were selected.

As the facility to model this process was recently added to the modelling software (CASAL version 2.09, Bull et al. 2005)[2], Dunn & Hanchet (2006b) did not have the ability to investigate the impact of ignoring it. Dunn & Hanchet (2006c) did investigate an alternative method for including the tag-release data by including the proportions at length as observations, and hence allowing the model to estimate the tagged proportions at age. Here, the tagged proportions-at-length data were fitted to the modelled proportions-at-length composition using a multinomial likelihood. They found that this approach, while in theory providing a better method for including the tag-release data, resulted in fits that were not entirely satisfactory. The model fits were comparable to the 2006 base case and the additional uncertainty associated with the length-frequency observations contributed to an overall increase in uncertainty in key parameter estimates. However, estimated tagged age frequencies were much 'spikier', the model showed some evidence of non-ideal minimisation, and the MCMC trace plots indicated a lack of MCMC convergence.

Here, we revise the model of Dunn & Hanchet (2006b) to include a selectivity that was applied to the conversion of tagged fish at length to fish at age within each fishery. Hence, for each of the Shelf, Slope, and North fisheries, the fishing selectivities estimated within the model were applied to the untagged population to determine the age frequency of tagged fish for release events defined for each of the fisheries separately, and hence for each annual cohort collectively.

2.9 Modifications to the model

As there are a number of possible revisions and updates that could be applied to the base case model presented by Dunn & Hanchet (2006b) to assess Antarctic toothfish in the Ross Sea, we summarise these as additive changes to the 2006 base case. Table 15 provides a summary of the revised model runs. Key output parameters from each of these models are given in Table 16.

Model 1 reproduces the 2006 base case (labelled the free shift case in Dunn & Hanchet 2006b) that was used to formulate the advice of SC-CAMLR-XXV (2006) for the Ross Sea in 2006, and hence gives the same estimate of initial and current biomass as reported in 2006 (Table 16). Models 2a and 2b updates this for the 2007 year, and adds in the updated catches (model 2a) and IUU catches (model 2b) for the 2007 fishing season. Adding an additional year to the model, but no new observations, results in the same estimate of initial biomass as Model 1. The inclusion of IUU catch resulted in a very similar estimate of initial biomass (<1% change). As the impact of IUU catch on model outputs was negligible and the estimated

[2] This modification to CASAL was based on a suggestion at the 2006 meeting of WG-FSA by A. Constable, Australian Government Antarctic Division.

of IUU catch may not be accurate for Antarctic toothfish, we ignore any IUU catch in subsequent models.

The remaining models (3–8b) investigate the impact of new or revised observations. Typically, when adding new observations to the model, the estimates of process error included within the model may change. We do not revise the estimates of process errors here, so that the impact of each change or additional observation can be more easily assessed (but note that these would need to be updated before being used to inform management advice).

Model 3 includes the updated CPUE indices, and resulted in much the same estimates of the key biomass parameters, as did the use of the revised catch-at-age frequencies (Model 4), revised proportions of fish scanned at length (Model 5), and modifying the value of the tag-growth check.

Including the selectivity on the length frequency of tagged fish (Model 7) resulted in a larger estimate of the initial biomass, although the estimated current state was similar. Inclusion of the 2007 tag-recapture data (Model 8a) reduced the biomass to a lower level than that reported for 2006 (B_0=73 100 t). And, removing the CPUE indices also resulted in a small decline in initial biomass (Model 8b, B_0=70 600 t).

Overall, most of the modifications to the model structure and revised inputs had little impact when compared with the addition of new observations, or the exclusion of 1-season recaptures. The improved method of converting tag-release length-frequencies to age-frequencies resulted in an slightly more optimistic assessment, while the inclusion of 2007 tag-recapture data and removal of CPUE indices as indices of abundance resulted in lower estimates of initial biomass.

Table 15: Labels and description of the model runs.

Model run		Description
1	2006 base case	The 2006 base case
2a	2007 catch	Model (1) updated for 2007 with the 2007 catch data & mean depths
2b	IUU catch	Model (1) updated with the IUU catch estimates
3	Update CPUE	Model (2a) updated with the 2007 CPUE indices
4	C@A	Model (3) updated with revised catch-at-length method
5	Scanned LFs	Model (4) with the revised scanned numbers
6	Revised growth check	Model (5) with the revised growth check value
7	Tag release selectivity	Model (6) but with selectivity on tag-releases
8a	2007 tag recapture	Model (7) updated with the 2007 tag-recapture data
8b	Exclude CPUE	Model (8a) but excluding CPUE indices

Table 16: Selected MPD parameter values for all model runs.

Model run		B_0	B_{2006}	B_{2006} (%B_0)	B_{2007}	B_{2007} (%B_0)
1	2006 base case	77 200	66 500	86.1	–	–
2a	2007 catch	77 200	66 500	86.1	66 100	85.6
2b	IUU catch	77 800	66 800	85.8	66 500	85.5
3	Update CPUE	78 000	67 300	86.3	67 000	85.9
4	C@A	76 200	65 500	86.0	65 100	85.4
5	Scanned LFs	75 700	64 900	85.7	64 600	85.3
6	Revised growth check	78 100	67 400	86.3	67 100	85.9
7	Tag release selectivity	90 900	80 100	88.2	79 800	87.9
8a	2007 tag recapture	73 100	62 400	85.4	62 100	85.0
8b	Exclude CPUE	70 600	59 800	84.8	59 500	84.4

2.9.1 Likelihood profiles

Likelihood profiles for the model 1 and 8a (2006 base case, 2007 tag recapture cases respectively) using New Zealand tag data are given below (Figure 19–Figure 20). In each case, likelihood profiles were carried out by fixing B_0 at values across a range of plausible values (i.e., 30 000–190 000 t), with the remaining parameters (e.g., selectivities) estimated.

The likelihood profiles for the 2006 base case from Dunn & Hanchet (2006b) are reproduced in Figure 19. Here, the catch-at-age data and tag recaptures from 2003 and 2005 suggested low biomass levels were unlikely, whilst tag recaptures from 2004 and 2002 suggested high biomass estimates were unlikely. The likelihood profiles for data in both model 1 (2006 base case) and model 8a (2007 tag-recapture, see Figure 20) were mostly similar, although the likelihoods from the recapture data from the 2003 and 2005 cohorts more strongly suggested that low biomass values were unlikely. In contrast, the addition of the 2006 release cohort data with recaptures in 2007 in model 8a gave much higher weight to lower initial biomass values (Figure 20). Overall, there was a reasonable degree of consistency between relative contribution to the over likelihood in the likelihood profiles. Most of the sets of observations had a likelihood that reflected a minimum biomass of between about 40 000–60 000 t to about 80 000–150 000 t.

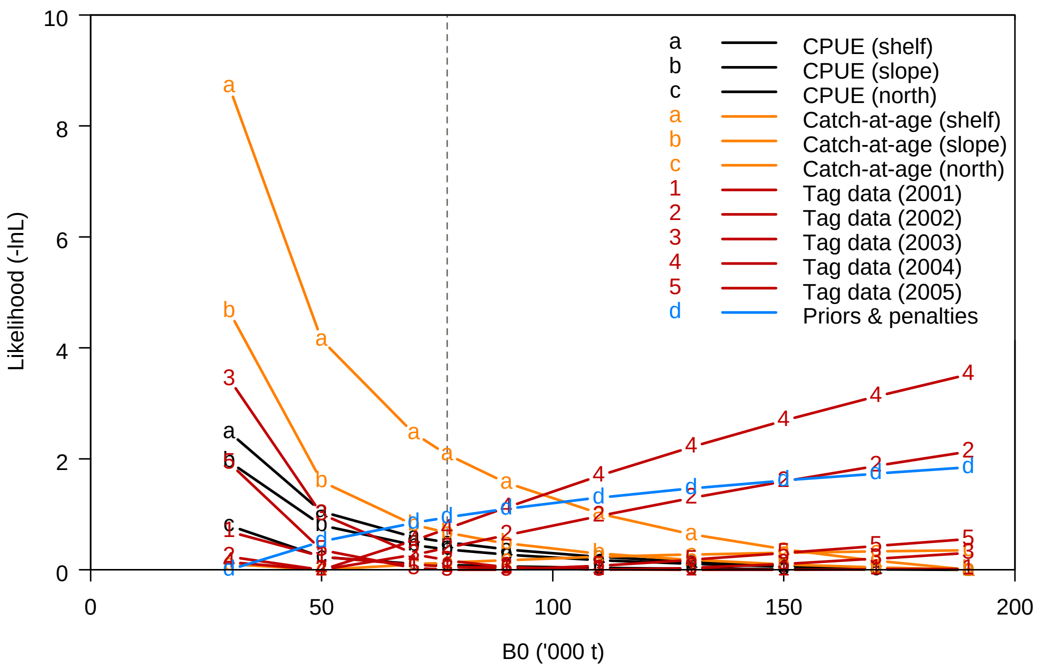

Figure 19: Likelihood profiles for the 2006 base case model for values of B_0. Negative log likelihood values rescaled to have minimum 0 for each data set. The dashed vertical line indicates the MPD.

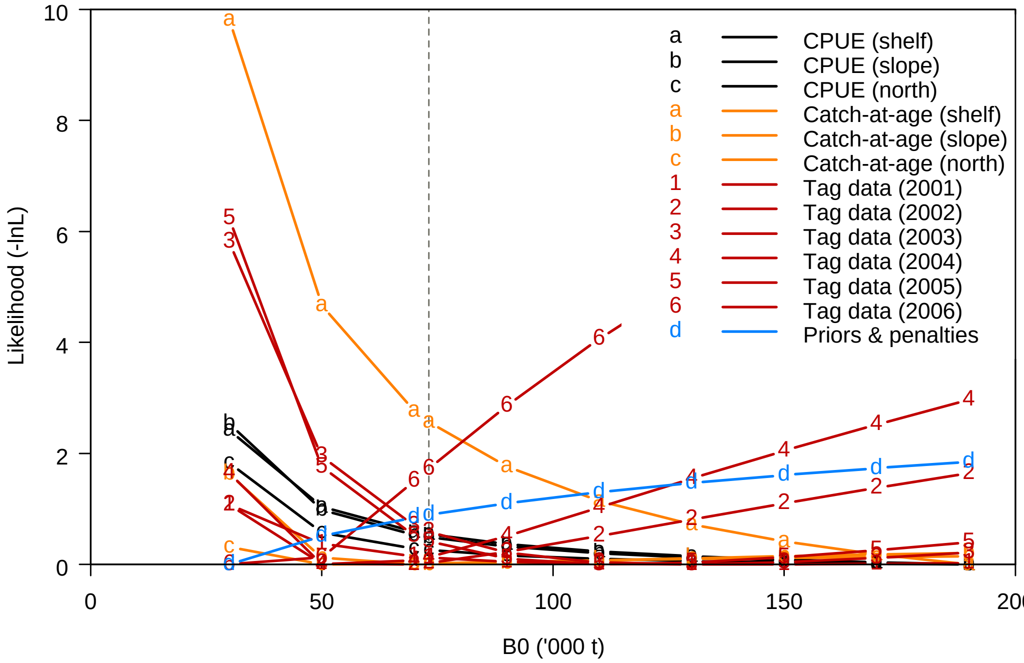

Figure 20: Likelihood profiles for the model 8a (2007 tag recapture) for values of B_0. Negative log likelihood values rescaled to have minimum 0 for each data set. The dashed vertical line indicates the MPD.

3. DISCUSSION

In this paper, we address a number of aspects of the model inputs and parameters of the Antarctic toothfish stock assessment for the Ross Sea fishery. In particular we review catch history, length-weight relationships, catch-at-length and catch-at age, and the tag-release recapture data. In addition, we report some preliminary model runs that investigate the sensitivity of the 2006 stock assessment to changes in these model inputs and parameters.

Tree regressions of the median length of length-frequencies within sets were used to investigate alternative areal stratification of the Ross Sea fishery. Regressions using small scale locations (spot) provided the best fits to the data, but also suggested that the length-frequencies of Antarctic toothfish had a high degree of both large and small scale areal complexity. Surprisingly, locations in parts of SSRU 88.2A and on the border of 88.1K and 88.1L were found to contain larger fish, with median lengths similar to fish found in the northern seamounts or on the deeper parts of the slope. The western-most part of SSRU 88.1J (Terra Nova Bay) also had a complex pattern —fish were either classified as either shelf or upper slope in a manner that suggested a close relationship with very small changes in location or depth.

Tree regressions that attempted to define areal strata based on SSRU, longitude, latitude, or depth results in a similar pattern, but were not able to replicate the small scale complexity as well as the spot algorithm. And, including terms for nation, vessel, or vessel type did not provide any additional information — these tended to be highly correlated with the location variables.

In general, the regression tree models typically split the fishery into 4–6 strata and generated strata that were broadly were similar to the current Shelf, Slope, and North classifications. The results from the tree regression models suggested a high level of local area complexity ion the length distribution of Antarctic toothfish in the Ross Sea, particularly in shallower waters in the southern Ross Sea. The resulting stratifications did not produce length-frequencies that suggested consistent selectivity patterns over the duration of the fishery in, in particular, the slope or shelf regions. While the current stratification (Shelf, Slope, and North) of Phillips et al. (2005) have some deficiencies, particularly when used within the Antarctic toothfish assessment model (Dunn & Hanchet 2006b), revised stratifications did not appear to offer much improvement. Stratification using nation, vessel or other similar variables did not appear to offer any improvements to the models. Hence, we recommend that the current stratifications be maintained until a more complete investigation of the length and age structure of Ross Sea Antarctic toothfish, perhaps within a spatial movement model, has been conducted.

Catches reported for 2007 and the inclusion of the IUU catch history had little effect on model estimates of key parameters. The later result was also in line with the results of a simulation experiment by Dunn (2006a), suggesting that the inclusion of IUU catch in such models would result in less conservative model outputs. The update of the length weight parameters for unsexed fish had little impact on either the scaled length frequencies or the assessment model outputs. However, we note that the number of sampled fish that were sexed by Scientific Observers from some vessels was unusually low. The change of method of rescaling observed lengths to using the number of fish caught resulted in only a small change in the estimated length frequencies. We recommend that the total number of fish caught be used to scale the length-, and hence age-frequencies, rather than using the total weight of fish caught. We also revise the assumed value of the tag growth check. The inclusion of revised length-frequencies and the revised growth check parameter both had a negligible effect on the assessment model outputs.

CPUE indices continue to be of limited use as indices of abundance. Overall, the CPUE indices for the Ross Sea have generally increased since the beginning of the fishery in 1998. Changes in annual ice conditions, fisher learning and experience, and changes in gear and regulations provide the most likely explanations for changes in the CPUE indices. Excluding CPUE indices from the assessments resulted in a slightly lower estimate of initial biomass.

The 2006 base case model assumed that tagged fish, at the time of release, have an age distribution that was determined from the age-length relationship of the entire population multiplied by the length-frequency of the releases. This assumption may lead to a bias in model outputs, as it is unlikely to reflect the true age-frequency of tagged fish released. By applying a selectivity to the population in the calculation of the age distribution of tagged fish, we instead assumed that the age distribution of released fish can be determined from the age-length relationship of the vulnerable population. Here, the use of a selectivity on tag-release events within the model resulted in a higher estimate of initial biomass. It seems appropriate to include this process within the assessment model, but we recommend that this be further investigated.

The most significant impact on the assessment model results was the inclusion of the 2007 tag-recapture data, and in particular, the recaptures of 2006 releases in 2007. The tags recaptured by New Zealand vessels in 2007 were at a higher rate than in previous years, with most of these being recaptures from 2006 releases (Dunn et al. 2007). They noted that the locations of the recaptures were highly aggregated and were mostly located on four key locations in the Ross Sea, and most had moved only short distances. This confirms the concern that the key uncertainty underlying the current model is the impact of movements and spatial structure in the Antarctic toothfish population. In particular, the level and nature of the bias from non-homogeneous mixing assumptions of tagged fish.

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