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OF ANTARCTIC MARINE LIVING RESOURCES

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# Review of the toothfish fishery in SSRU 881K from 1997–98 to 2011–12 and opportunities for fisheries research

Delegation of New Zealand

## Summary

This paper has been prepared to provide science relevant to the joint New Zealand-United States proposal for an MPA in the Ross Sea region. In particular, fisheries data are provided as background to a proposed Special Research Zone in SSRU 88.1K and high-priority fisheries research questions are identified, which could potentially be addressed in the future by managing fishing effort in this area.

We begin by providing a review of previous fishing operations including the timing, depth, and location of fishing together with the catch and CPUE of *Dissostichus* spp. and bycatch species in SSRU 88.1K up to 2011/12. We also provide the size composition of the catch for this same period and results from the tagging programme up to 2010/11. This area is unusual compared to the other slope SSRUs in that it has had very low recapture rates of tagged fish, a relatively high proportion of recaptures which have moved to/from other SSRUs, and strong latitudinal variation in the distribution patterns of toothfish and its two main prey species: macrourids and icefish.

Medium–term research objectives for the Ross Sea fishery, including high priority research questions, were identified in 2008 (New Zealand Delegation 2008). We consider how some of these questions could be addressed by future directed research fishing within the proposed Special Research Zone.

## 1. Background

Conservation Measure 91-04 establishes the requirement for research and monitoring plans to support marine protected areas (MPAs) in the Convention Area. This paper has been prepared to provide science relevant to the joint New Zealand-US proposal for an MPA in the Ross Sea region (Delegations of New Zealand and the US). In particular, we provide fisheries data as background to a proposed Special Research Zone (SRZ) in SSRU 88.1K (Figure 1) and identify research priorities for this zone.

The SRZ comprises roughly equal proportions of continental shelf, continental slope, and abyssal waters in the eastern Ross Sea (Figure 1). The slope is still relatively broad in the north of the SRZ where it joins the Iselin bank. However, it becomes more constricted at around 75ºS to form the Hillary canyon before broadening out again to the southeast. The slope strip, where most of the fishing occurs, is about 440 km long with a depth range of 700–1800 m and a seabed area of 22,000 km$^2$. In the southwest of the SRZ the Glomar Challenger trough provides a relatively deep channel between the Hillary canyon on the slope and the deeper waters adjacent to the Ross Ice Shelf. The slope is bathed by relatively warm, salty Antarctic Bottom Water of the Antarctic Slope Current, which has been entrained by the Ross Gyre, and which flows north west along the continental slope and up around the Iselin bank (Ashford et al. 2012). Bottom waters range from 0.8 to –1.8ºC according to the WOCE Global Hydrographic Climatology (Gouretski & Koltermann 2004).

Although annual summaries of fishing operations in Subareas 88.1 and 88.2 have been reported since 2000 (e.g., Stevenson et al. 2012), they have focused on the wider Ross Sea region. In this paper we review the fishery operations specifically in SSRU 88.1K including the timing, depth, and location of fishing together with the catch of Antarctic toothfish (*Dissostichus mawsoni*) and bycatch species. We also consider other data including the size distribution of Antarctic toothfish and the results of the tag-recapture programme in this area.

A review of the operational management of the fishery, including changes to the SSRU boundaries, review of a 3-year experiment from 2006–2008, and development of medium term research objectives for the fishery was completed in 2008 (New Zealand Delegation 2008). We use this review and additional work carried out since then to identify high-priority research questions which could potentially be addressed by managing fishing effort and data collection in the proposed Special Research Zone.

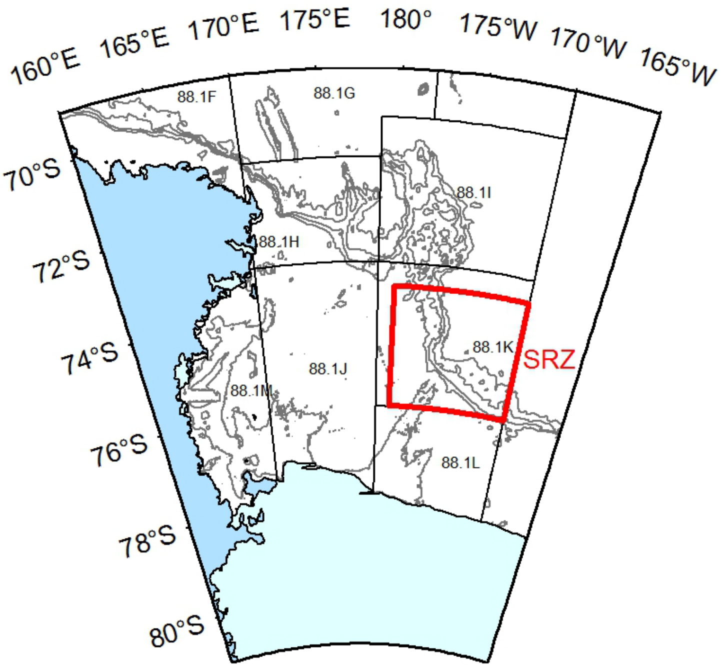


**Figure 1: CCAMLR Subarea 88.1 showing small scale research units (SSRUs) in black, and the proposed Special Research Zone (SRZ) in red. Depth contours plotted at 600, 1000, 1500, and 2000 m.**

## 2. Review of the Antarctic toothfish fishery in 88.1K

### Data sources

Because only limited C2 data and observer data from 2012/13 fishing year were available at the time of writing, we have used C2 and observer data up to and including 2011/12. Details of the extracts, and a description of the checking and grooming carried out on these data are given in Stevenson et al. (2012). Groomed tag-recapture data were only available up until the 2010/11 fishing year (Mormede et al. 2011). The characterisation has been carried out for SSRU 88.1K as a whole because the proposed SRZ encompasses most of this SSRU and there has been little catch and effort in this SSRU outside of the SRZ boundary.

The boundaries for the SSRUs, associated catch limits, and a number of other management measures, changed considerably up until 2004/05 (see New Zealand Delegation 2008 for details). These differences moderated actual catches taken from the area now represented by SSRU 88.1K. Since the 2005/06 season there has been a combined catch limit for the three slope SSRUs (88.1H, 88.1I, and 88.1K), rather than individual catch limits per SSRU. Thus, catches in SSRU 88.1K have been less constrained by a catch limit since 2005/06.

In this paper, the word "season" refers to the period from December to May, the months of fishing in the middle of the CCAMLR fishing year (i.e., the 2012 season is part of the 2011/12 split fishing year).

## Results

The historical catch of Antarctic toothfish from the slope SSRU 88.1K has been extremely variable, ranging from no reported catch in 2001, 2003, and 2007 to a peak of 1508 t in 2012 (Table 1). Mean toothfish CPUE has also fluctuated considerably over this time with no clear upward or downward trend. Trends in median catch per hook and catch per set across the fleet have shown no clear patterns but there has been a slight increasing trend in catch per set and a larger proportion of higher catch rates in the past 3–4 years (Table 1 and Figure 2). There were no trends in CPUE when the data were separated out by the three gear types: autoline, Spanish line, and trot line (not shown).

**Table 1: Number of sets, Antarctic toothfish catch (t), mean number of hooks per set, and mean catch per set and catch per hook for SSRU 88.1K, 1999–2012. –, not fished.**

| Season | No. vessels | Sets | Catch (t) | Mean hooks per set | Catch per set (t) | Catch per hook (kg) |
|---|---|---|---|---|---|---|
| 1999 | 2 | 38 | 34 | 5679 | 0.9 | 0.15 |
| 2000 | 3 | 90 | 184 | 4813 | 2.0 | 0.41 |
| 2001 | – | – | – | – | – | – |
| 2002 | 1 | 47 | 121 | 5726 | 2.6 | 0.45 |
| 2003 | – | – | – | – | – | – |
| 2004 | 1 | 16 | 1 | 3600 | 0.1 | 0.01 |
| 2005 | 9 | 365 | 710 | 5769 | 1.9 | 0.35 |
| 2006 | 7 | 165 | 590 | 4984 | 3.6 | 0.56 |
| 2007 | – | – | – | – | – | – |
| 2008 | 4 | 37 | 60 | 6176 | 1.6 | 0.28 |
| 2009 | 7 | 315 | 861 | 5517 | 2.7 | 0.49 |
| 2010 | 6 | 66 | 244 | 5304 | 3.7 | 0.80 |
| 2011 | 6 | 229 | 644 | 7652 | 2.8 | 0.38 |
| 2012 | 12 | 384 | 1549 | 7092 | 4.0 | 0.66 |

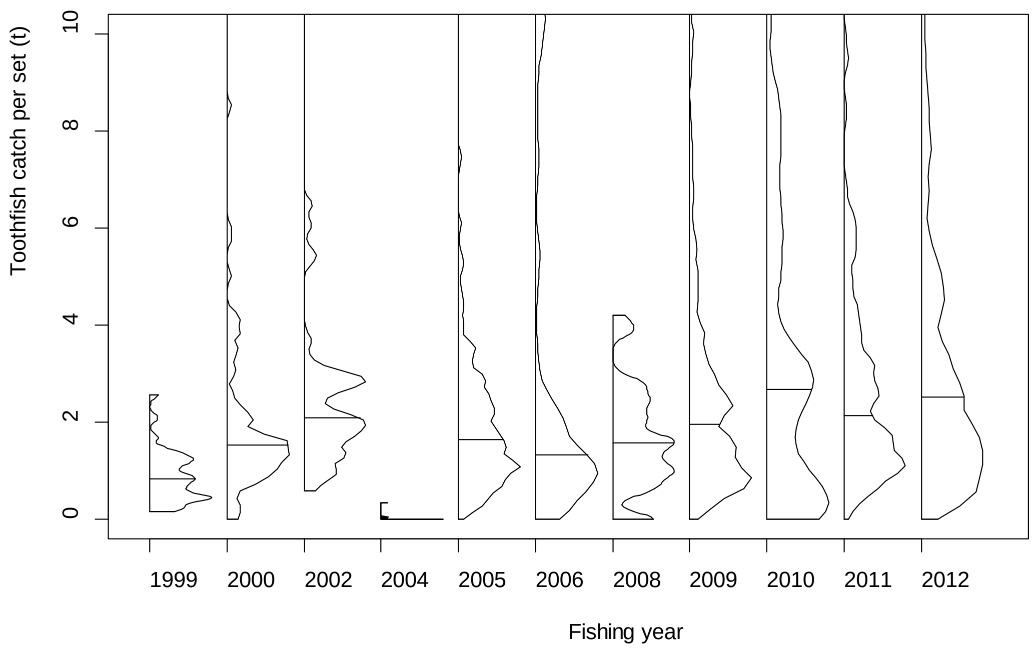


**Figure 2: Distribution of toothfish catch per set in SSRU 88.1K by year. Median catch per set is indicated by the horizontal line. Note there was no fishing in this SSRU in 2001, 2003, or 2007.**

The timing of the fishery has been relatively consistent, with most of the catch taken in January, and a smaller proportion taken in December and February in some seasons. The depth distribution of fishing in SSRU 88.1K has varied considerably through time (Figure 3). In three of the first four years most fishing was in depths less than 900 m. In 2004, a number of required research sets were made in relatively shallow water on the edge of Pennell Bank in the west of the SSRU because ice prohibited fishing deeper. Since 2005 fishing has ranged from 600 to over 1500 m depth and averaged 1000–1100 m. Since 2009 fishing shallower than 550 m has been prohibited.

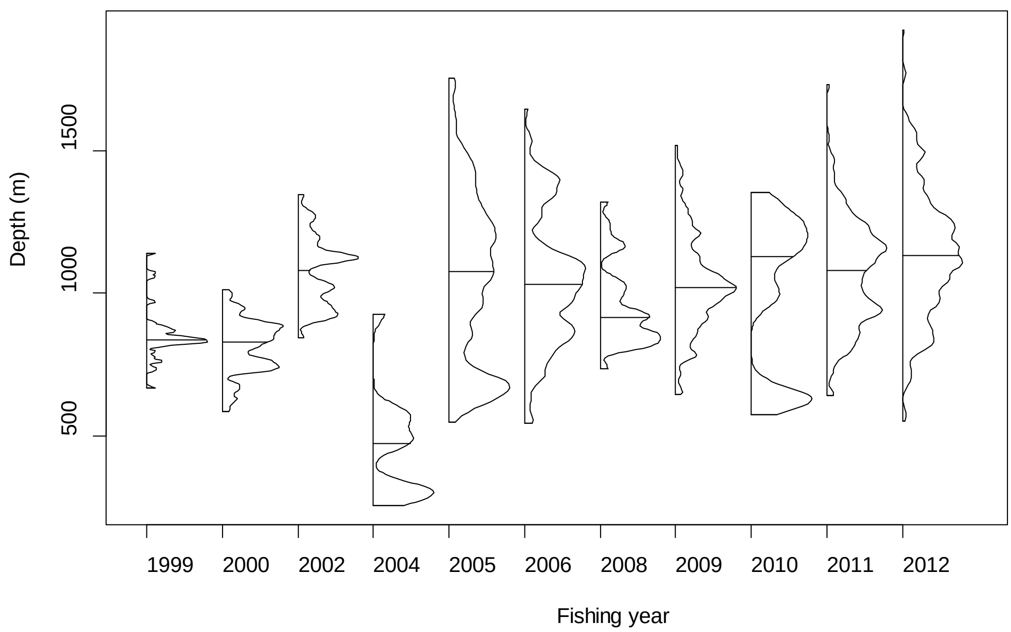


**Figure 3: Depth distribution of longline sets made in SSRU 88.1K by year. Median depth fished indicated by the horizontal line.**

The spatial distribution of fishing in SSRU 88.1K has also been quite variable between years (Figure 4 and Figure 5). Fishing in all years has been concentrated mainly along the 1000 m depth contour with very little fishing on the adjacent shelf. In some years fishing has extended along the depth contour throughout the SSRU, whilst in other years it has been more towards the north or the south. However, the highest catch rates have occurred south of 75°S and between 1200 and 1600 m depth (Figure 5 and Figure 6).

To determine possible reasons for the annual fishing patterns seen in SSRU 88.1K we estimated ice cover using the daily University of Bremen ice analyses for the Ross Sea (available at http://www.iup.uni-bremen.de:8084/amsredata/asi_daygrid_swath/l1a/s3125/). Ice charts were examined at approximately weekly intervals from 17 December through to 25 February from 2004 to 2011. (Note that comparable charts were not available for the earlier years.) Since most of the fishing in this SSRU has been focused on the 1000 m depth contour, we estimated the proportion of the contour which was covered by ≥ 7/10 ice cover for each week and year. In some cases the contour itself was clear enough to be fished but access to these open areas was restricted due to ice barriers blocking vessel entry.

The main driver for the toothfish catch in this SSRU appears to be sea ice (Table 2). In years with favourable sea ice conditions (2005, 2006, 2009, 2011, and 2012) catches have generally been high whilst years with bad sea ice conditions (2004, 2007, 2008, and 2010) catches and CPUE have tended to be very low. The exception was in 2010 when a single vessel obtained access to good fishing grounds and obtained good catch rates despite the bad ice conditions that year.

**Table 2: Estimated percentage ice cover of the 1000 m contour in SSRU 88.1K by week from 17 December to 25 February, 2004–2012. *, indicates vessels may have problems accessing open area due to ice barriers. –, no charts available. Catch and CPUE (t/set) have been copied from Table 1 to make comparison easier.**

| | | | | | | | | | Season |
|---|---|---|---|---|---|---|---|---|---|
| Date | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| 17-Dec | – | 50 | 10 | 90 | 100 | 20* | 75* | 0 | 100 |
| 24-Dec | – | 5 | 5 | 80 | 80 | 5* | 90* | 0 | 60 |
| 31-Dec | – | 0 | 5 | 60 | 100 | 0* | 60 | 0 | 30 |
| 7-Jan | 60 | 0 | 0 | 85 | 95 | 0* | 75 | 0 | 10 |
| 14-Jan | 75 | 0 | 0 | 90 | 85 | 0* | 90 | 0 | 0 |
| 21-Jan | 20 | 0 | 0 | 70* | 95 | 0* | 40 | 0 | 0 |
| 28-Jan | 60 | 0 | 0 | 75 | 50 | 0 | 75 | 0 | 0 |
| 4-Feb | 5 | 0 | 0 | 50* | 60 | 0 | 100 | 0 | 0 |
| 11-Feb | 75 | 0 | 0 | 5 | 95 | 0 | 40 | 0 | 0 |
| 18-Feb | 50* | 0 | 0 | 50 | 90 | 0 | 80 | 0 | 0 |
| 25-Feb | 100 | 0 | 0 | 30 | 60 | 0 | 100 | 0 | 0 |
| | | | | | | | | | |
| Catch (t) | 1 | 710 | 590 | 0 | 60 | 861 | 244 | 644 | 1549 |
| CPUE | 0.1 | 1.9 | 3.6 | – | 1.6 | 2.7 | 3.7 | 2.8 | 4.0 |

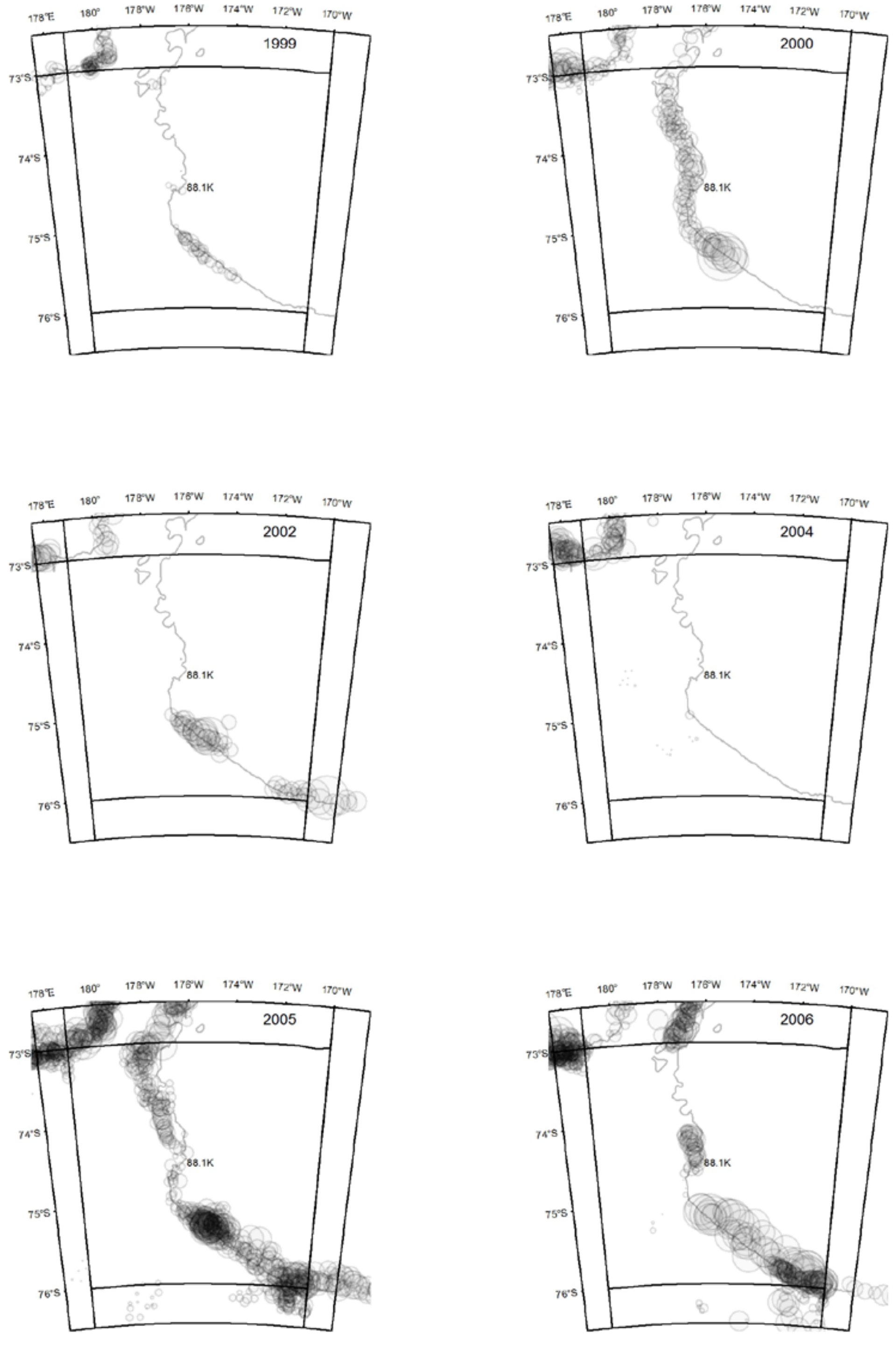


**Figure 4: Catch rates of Antarctic toothfish in SSRU 88.1K and adjacent SSRUs, 1999–2006. Depth contour at 1000 m. Seasons 2001, 2003 and 2007 are not shown as there was no fishing in SSRU 88.1K in those seasons.**

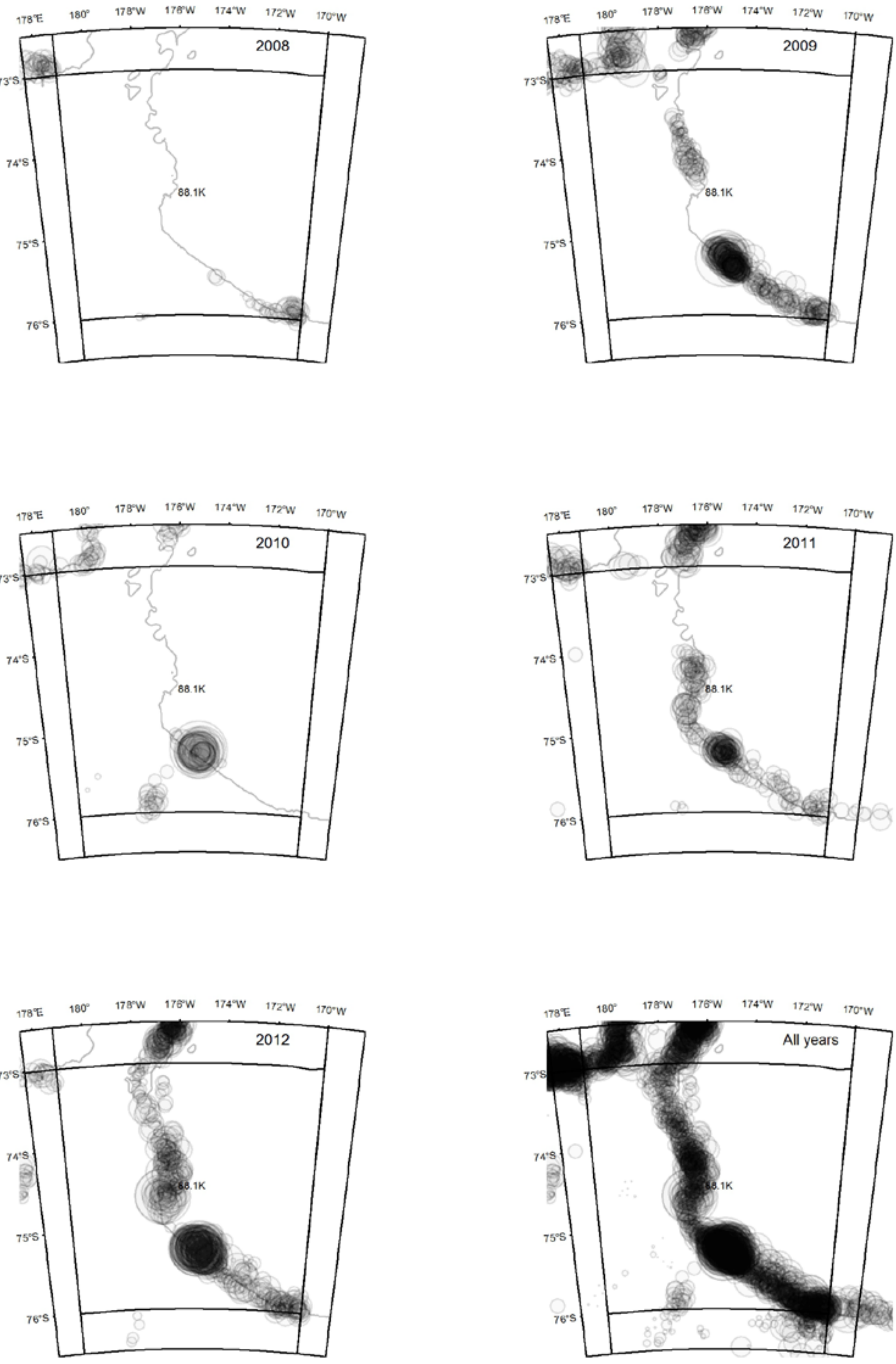


**Figure 5: Catch rates of Antarctic toothfish in SSRU 88.1K and adjacent SSRUs, 2007–2012 and all years combined. Depth contour at 1000 m.**

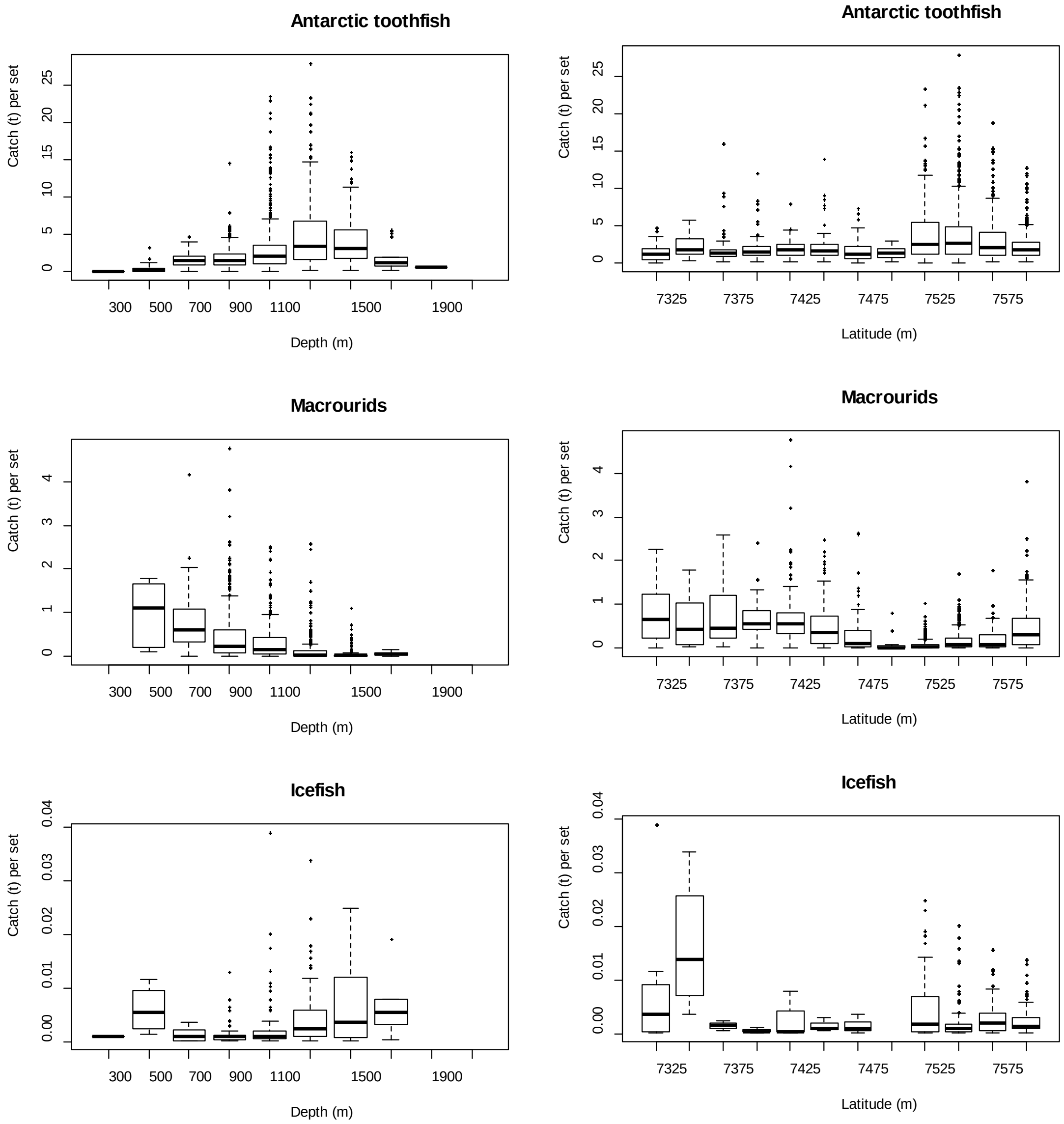


**Figure 6: Boxplots of non-zero catch rates (in tonnes per set) of Antarctic toothfish, macrourids, and icefish in 200 m depth bins (left) and in 0.25° latitude bins (right) in SSRU 88.1K. Each boxplot delineates the 5$^{th}$, 25$^{th}$, 50$^{th}$, 75$^{th}$, and 95$^{th}$ percentiles. Note that the x axes are on different scales.**

## Bycatch

The main bycatch group in this SSRU are macrourids (*Macrourus whitsoni* and *M. caml*), which have formed 11% of the total catch (Table 3). The highest catch rates for macrourids show quite a different pattern to toothfish, occurring mainly to the north of 75ºS and also close to the south east boundary with SSRU 88.2A (Figure 6 and Figure 7). A total of 80 individual macrourids have been examined from SSRU 88.1K, of which 75% were *M. caml* and 25% were *M. whitsoni* (M. Pinkerton, NIWA, pers. comm.), which is similar to that observed elsewhere in Subarea 88.1 (Pinkerton et al. 2012). The catch rates are also strongly driven by fishing depth, being highest in 400–800 m (Figure 6). Other species including skates, icefish, eel cods, and morid cods formed less than 1% of the total catch (Table 3).

**Table 3: Catch (t) by year for the main species/family groups. '0' less than 0.5 t.**

| Year | Antarctic toothfish | Patagonian toothfish | Macrourids | Skates | Other | Total |
|---|---|---|---|---|---|---|
| 1999 | 34 | 0 | 3 | 0 | 0 | 37 |
| 2000 | 184 | 0 | 19 | 3 | 0 | 205 |
| 2002 | 121 | 0 | 17 | 1 | 0 | 139 |
| 2004 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2005 | 710 | 1 | 205 | 7 | 5 | 927 |
| 2006 | 590 | 0 | 72 | 0 | 1 | 663 |
| 2008 | 60 | 0 | 21 | 0 | 1 | 82 |
| 2009 | 861 | 0 | 86 | 0 | 3 | 950 |
| 2010 | 244 | 0 | 4 | 0 | 0 | 248 |
| 2011 | 644 | 0 | 91 | 0 | 2 | 737 |
| 2012 | 1 549 | 0 | 71 | 0 | 4 | 1 624 |
| Total | 4 995 | 1 | 589 | 11 | 16 | 5 612 |
| % | 89 | <1 | 11 | <1 | <1 | |

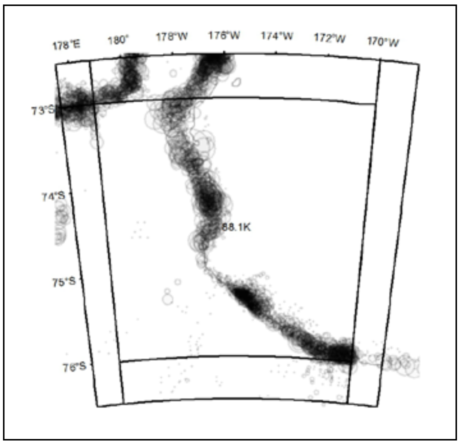


**Figure 7: Macrourid catch rates in SSRU 88.1K and adjacent SSRUs, all years combined.**

## Size distribution of catch

The size distribution of caught toothfish has ranged from 50 to 180 cm (Figure 8). During the first two years slightly smaller fish were caught with a mode at around 100–120 cm. consistent with fishing at slightly shallower depths. Since 2005, the catch has been dominated by slightly larger fish, with a mode at 125–135 cm depending on year and sex, although in some years there was a secondary mode of smaller fish again at around 100–120 cm. In 2005, there was a third mode of very small fish at about 65 cm probably reflecting the shallower depths fished in that year.

## Tag recaptures

Despite the release of almost 4000 tagged toothfish in this SSRU, there have been only 41 recaptures, of which 17 (41%) were recaptured in other SSRUs (Table 4). There have also been only 32 tagged fish recaptured from this SSRU, of which 24 (75%) were originally released in this SSRU and the remaining 8 of which were originally released in other mainly slope SSRUs. The high proportion of recaptured fish either released or recaptured in SSRU K having undergone long-distance movements to or from other SSRUs, compared to other slope SSRUs (88.1H and 88.1I) where a very high proportion of recaptured fish are in the same SSRU where they were released, suggests that toothfish could be more mobile in this area. However, this pattern might also reflect the higher catches and more consistent scanning rates in other slope SSRUs, or variable tagging performance between vessels operating in different SSRUs. With the increased scanning rates arising from high catches from SSRU 88.1K in 2012 and 2013, we expect improved data to investigate these patterns further, and this pattern might change.

**Table 4: Numbers of Antarctic toothfish with tags released for 2001–2011 and the number recaptured in 2001–2011 by slope SSRU and other SSRUs from all vessels (from Mormede et al. 2011).**

| Released fish | | Recaptured fish | | | | |
|---|---|---|---|---|---|---|
| Area | Number | 88.1H | 88.1I | 88.1K | Other SSRUs | Total |
| 88.1H | 8 882 | 606 | 9 | 4 | 14 | 633 |
| 88.1I | 5 315 | 18 | 196 | 2 | 7 | 223 |
| 88.1K | 3 937 | 7 | 7 | 24 | 3 | 41 |
| Other SSRUs | 10 292 | 14 | 9 | 2 | 472 | 497 |
| Total | 28 426 | 645 | 221 | 32 | 496 | 1 394 |

## Diet

Although there have been a number of feeding studies of Antarctic toothfish, most of these have examined stomachs from toothfish collected from the northern seamounts and the Mawson and Iselin banks (e.g., Fenaughty et al. 2003, Stevens et al. 2012) and the Ross Sea shelf (Hanchet et al. 2012). We are unaware of any feeding studies from 88.1K, and in particular the two locations of high catch rates to the north and south of Hillary Canyon. Stomach contents of Antarctic toothfish collected on FV *San Aotea II* in 2012 from the southeast corner of SSRU 88.1K were reported by observers. A preliminary analysis of these data showed that fish comprised 62% of toothfish diet in this area based on frequency of occurrence: these included icefish (8%), macrourids (6%), eel cods (5%), and plunderfishes and notothens (3%), plus 39% which could not be accurately identified. Cephalopods comprised 38% of total diet, mainly squid (36%) and deepwater octopus (2%). Collection of diet data from 88.1K is clearly a priority to better understand toothfish ecology in this area and as a means of investigating possible ecosystem effects of fishing on the demersal fish community (see Discussion, below).

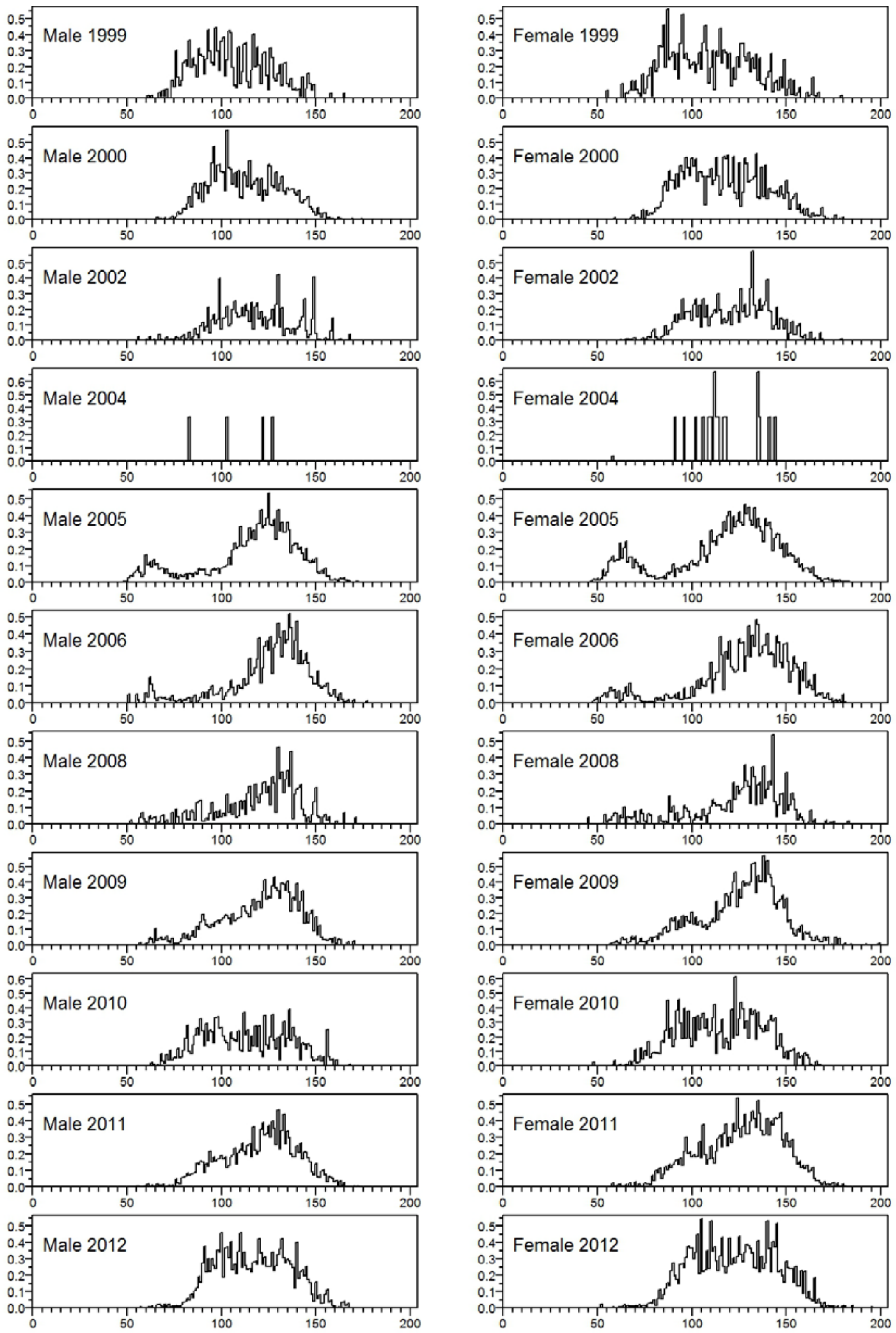


**Figure 8: Estimated proportion of fish at length by sex for all vessels in SSRU 88.1K, for the years 1999–2012.**

## 3. Review of medium-term research priorities

A review of the operational management of the fishery, including changes to the SSRU boundaries, review of a 3-year experiment from 2006–2008, and development of medium term research objectives for the fishery was completed in 2008 (New Zealand Delegation 2008). The research objectives were developed to address CCAMLR's goals with respect to article II of the Convention: (i) maintenance of the toothfish population at or above target levels; and (ii) ecological relationships between harvested, dependent and related populations are maintained. These are summarized below.

### Maintenance of the toothfish population in Subareas 88.1 and 88.2 at or above target levels

One of the key research priorities identified in 2008 was to reduce uncertainty in the stock assessment relating to stock structure, biological and model parameters, and data quality issues. Considerable work has been carried out since then to develop a more robust tagging data set for input to the stock assessment (e.g., Middleton 2009, Mormede & Dunn 2012). More recently, an approach has been developed which uses a case-control method to develop a vessel-specific performance index of tag detection, and selection criteria to identify vessels which have very low reported recapture rates, and to exclude these from the assessment (Mormede 2013).

One of the main issues identified in 88.1K is the unusual tagging results from this area. Using tag data up to and including the 2011 fishing season, only a total of 41 tags have been recaptured there, compared with 633 in SSRU 88.1H and 223 in SSRU 88.1I (Table 3). Although toothfish catches have been higher in these other SSRUs, if we adjust these recaptures by the total catch up to 2010–11, then recapture rates per tonne of catch are nonetheless 3 times higher in 88.1I and 6 times higher in 88.1H. The reason for this lower recapture rate in 88.1K is unknown and needs to be investigated. Secondly, fish released in 88.1K appeared to have less fidelity to that SSRU than fish released in other SSRUs. Thus, a relatively high proportion of fish released in 88.1K were recaptured in other SSRUs whilst a relatively high proportion of the recaptures of fish in 88.1K were of fish released in other (mainly slope) SSRUs. Although these results suggest fish in 88.1K may be quite transient relative to toothfish elsewhere on the slope, these data may also reflect potential biases arising from variable tagging performance (i.e. affecting rates of tagging survival, recapture, and/or detection) between vessels historically operating in 88.1K relative to those operating elsewhere. With the recent increased catches and associated increased number of scanned fish in 881.K, and the recent increased size of fish tagged to meet the minimum tag overlap statistic, these patterns might be expected to change when the 2012 and 2013 tag data are analysed.

There is a clear need to understand (i) the relatively low recapture rates in 88.1K and (ii) toothfish movement rates both within 88.1K and between 88.1K and adjacent slope SSRUs. These questions can be addressed in part by the continuation of the existing toothfish tagging programme, with an increased tagging rate per tonne of fish caught in the new SRZ to compensate for reduced catch in this area. Improved science outcomes from tag-recapture data will be more readily achieved by well-designed research fishing than by Olympic fishing alone, and the Scientific Committee should be encouraged to review and approve research designs under CM 24-01 pursuant of research priorities for this zone. If the main aim of this research was to improve recapture rates to improve the estimation of abundance for toothfish in this area then research designs with a high spatial overlap between years should be a priority and fishing and associated tagging effort would ideally be carried out in areas where tags have previously been released. However, if examining fish movement is judged to be a higher priority, then research effort should be spread more widely through the SRZ and also in adjacent SSRUs.

A secondary aspect of research fishing in the proposed SRZ will be to monitor changes in the size distribution of Antarctic toothfish or changes in other physiological parameters related to growth and maturity as affected by fishing intensity. It is expected that as the Antarctic toothfish spawning stock biomass is fished down towards the target of 50% $B_0$ over a period of 35 years consistent with CCAMLR Decision Rules, there will be a truncation in the average maximum length and age of the population. Some fished populations also experience a change in growth rates or age at maturity as a plastic response to reduced intra-specific competition. At present there is little evidence for such changes in any SSRU (Stevenson et al. 2012). However, with a shift of effort from the proposed SRZ into the other two slope SSRUs (H and I) and a corresponding increase in localised exploitation rates, we might see a difference in the size and age distribution or other population parameters of toothfish between the SRZ and the adjacent slope SSRUs. Monitoring changes to these parameters between the Special Research Zone and other un-fished areas inside the MPA vs. comparable slope areas outside the MPA may enable scientists to distinguish between the effects of fishing and broader environmental influences. These parameters could be estimated more precisely within the SRZ by an increased sampling of toothfish biological data in the research catch.

The proposed SRZ in particular may be an ideal location for a large-scale deployment of acoustic tags and an acoustic array to examine toothfish movement and behavioural hypotheses. As described, the toothfish population may be particularly transient in this location, and the steep and roughly linear configuration of the slope in this area makes electronic monitoring via an acoustic array particularly tractable to establish movement and mixing rates between the proposed SRZ and adjacent SSRUs. Understanding fish movement has important implications for stock assessment (Mormede et al. 2013) and for assessing the extent to which the MPA may be achieving its objectives. Furthermore knowledge of the vertical distribution, abundance, and behaviour of Antarctic toothfish in the water column in the slope region would provide important information on the potential for interactions on the Ross Sea slope between toothfish and two of its potential predators: Weddell seals and Type C killer whales.

## Ecological relationships between harvested, dependent and related populations are maintained.

One of the key research priorities has been to quantify the relationships between Antarctic toothfish, its predators, and its prey. Trophic modelling at the level of the Ross Sea shelf and slope ecosystem has suggested that reduction in the toothfish abundance is likely to have the largest impact on the abundance of the 'medium-sized demersal fish group (i.e., macrourids and icefish) through predation release" (Pinkerton et al. 2010). However, Pinkerton & Bradford-Grieve (2012) note that the analysis does not take into account the fact that the fishery also takes medium-sized demersal fish as bycatch. A spatially explicit Minimum Realistic Model is currently being developed to better understand the nature of the relationships among and between the fishery, Antarctic toothfish, macrourids, and icefish on the slope. Preliminary modelling suggests that as the Antarctic toothfish population declines then macrourid abundance would be expected to only show a minor increase whilst the icefish population may show a substantial increase. Increased collection of length and age data for bycatch species, as well as increased toothfish stomach sampling in matched strata in the proposed SRZ and in more heavily fished areas could potentially detect these effects.

One of the main characteristics of the 88.1K fishery is the different distribution patterns of Antarctic toothfish, macrourids and icefish. The highest catch rates of toothfish tended to be deeper than 1000 m and in the south, whereas the highest catch rates of macrourids tended to be shallower than 1000 m and in the more northern portions of the slope. Catch rates of icefish were two orders of magnitude lower than catch rates of macrourids, and showed more overlap with toothfish both in terms of depth and latitude. Given the different distributions between toothfish and two of its main prey species we would expect toothfish diet, and potential effects of fishing, to vary latitudinally along the slope of the proposed SRZ.

In the future, directed research fishing in the proposed SRZ and in the slope area immediately to the north and east (i.e., SSRUs 88.1I and 88.2A) would provide a unique opportunity to provide data to determine the effects of fishing on toothfish and its main prey species. This type of research fishing would be best carried out as a standardised stratified quantitative longline survey – as has been developed for surveying sub-adult toothfish on the Ross Sea shelf (Hanchet et al. 2012). An important aspect of the survey design would be to identify appropriate fished, lightly fished, and unfished strata (to the north of the proposed SRZ, within the proposed SRZ, and to the east of the proposed SRZ respectively), preferably separated latitudinally by distances of 20–30 km to lessen the effects of mixing. The adjacent pairs of strata should have similar catch rates of toothfish and bycatch species with similar size structures, and would need to be depth stratified. In addition to the usual data collection for exploratory fisheries, vessels undertaking this research would need to collect length frequency data on macrourids and icefish, and toothfish stomach contents data. To investigate these effects the Scientific Committee could be encouraged in future to request and evaluate research plans submitted by Members identifying appropriate survey strata, sample sizes, catch limits, and data collection plans to carry out this research.

## Conclusions

At its 2010 meeting the Scientific Committee noted that the research and assessment work in Subarea 88.1 on the distribution, abundance and demography of Antarctic toothfish (*D. mawsoni*) has led to an estimate of the fisheries potential yield and allowed the CCAMLR Scientific Committee to formulate and provide advice to the Commission on appropriate harvest levels and other aspects of conservation over the last eight years (SC-CAMLR-XXIX, para. 3.129). Although reasonably robust stock assessments are now available, there is still some uncertainty over aspects of the Antarctic toothfish tagging programme and in particular the low recapture rates and high implied movement rates of fish tagged in SSRU 88.1K (Mormede et al. 2011). There is also uncertainty over potential ecosystem effects of fishing – particularly on the Ross Sea slope (Pinkerton et al. 2010).

The establishment of a Special Research Zone in 88.1K as part of the MPA proposal provides a unique opportunity to address some of these uncertainties. The most important fisheries research question is to understand the reasons for the low recapture rates of toothfish tags in this region, and the relatively high movement rates of fish in this area. The ability to address these questions in the context of reduced catches in this area under the MPA proposal is partly addressed by increasing the tagging rate to 3 tags per tonne. It is also important that vessels carrying out research fishing in the area adhere closely to the tagging protocols and ensure high tagging performance so that the initial mortality rate of tagged fish is minimised and detection rates of tagged fish are maximised. This could be examined using the case-control methodology being developed by Mormede (2013)

Other key research questions to understand effects of fishing, which could be addressed by research in the proposed SRZ, depend to a large extent on the degree of mixing of toothfish (and bycatch) between the proposed SRZ and other adjacent SSRUs. Toothfish tag-recapture studies have suggested that in general Antarctic toothfish move only short distances between release and recapture (Mormede et al. 2011). However, results up to the 2011 season suggest that Antarctic toothfish within 88.1K may be more transient than Antarctic toothfish elsewhere on the Ross Sea slope and may be moving to areas that are not currently fished. Furthermore, the consistently high catch rates from vessels fishing at a single location in the proposed SRZ over a period of 2–3 weeks (particularly in the 2012 season) suggests a very high local population or a high turnover of toothfish through the area, at least during that particular time of year. It is important to understand fish movement and mixing rates in 88.1K and if possible the ecological explanation for observed high abundances so that the results of other proposed research in this area can be properly interpreted.

Another key research question which could be addressed in the future in the area of the proposed SRZ regards the potential effects of fishing on the main prey species of toothfish: macrourids and icefish. This could be addressed using an annual or semi-annual standardised stratified quantitative longline survey – as has been developed for surveying sub-adult toothfish on the Ross Sea shelf (Hanchet et al. 2012). An important aspect of the survey design would be to identify appropriate pairs of strata, preferably separated latitudinally by distances of 20–30 km to lessen the effects of mixing. The adjacent pairs of strata should have similar catch rates of toothfish and bycatch species with similar size structures, and would need to be depth stratified. The Scientific Committee should be encouraged to review and approve research designs submitted under CM 24-01 pursuant of this and other research priorities in the proposed SRZ.

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