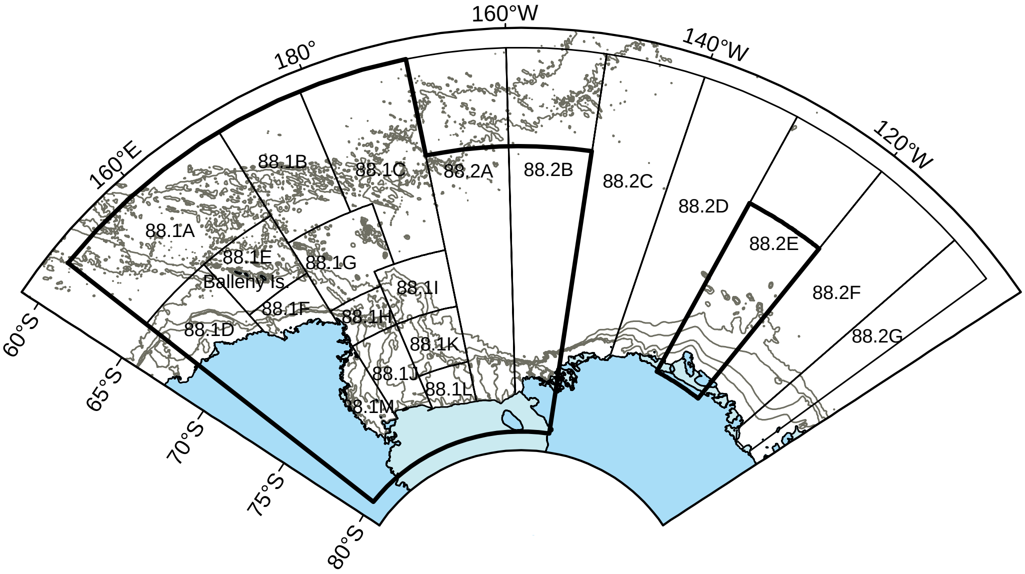
# TOOTHFISH (TOT)

(*Dissostichus mawsoni* and *Dissostichus eleginoides*[1])



**The Ross Sea Region – CCAMLR Subareas 88.1 and 88.2 showing the small-scale research units (SSRUs) used for management, the spatial coverage of the two assessments (the Ross Sea and SSRU 88.2E shown bounded) and with depth contours plotted at 500, 1000, 2000, and 3000 m. From the 2008/09 season, SSRU 88.1J was split into two SSRUs at 170°E, creating a new SSRU 88.1M to the west of that line (which is currently closed to fishing), and reducing the size of 88.1J to the east of that line.**

## 1. FISHERY SUMMARY

This working group report is a summary of the Ross Sea toothfish fishery and it includes the catches of all countries participating in that fishery. The Ross Sea region fisheries occur entirely on the high seas within the Convention for the Conservation of Antarctic Marine Living Resources (CAMLR Convention) area.

Finfish fisheries in Antarctic waters are largely managed under the CAMLR Convention, and in particular its' Article II, paragraph 3. The Convention Area covers roughly the area south of the Antarctic Convergence (varying from 60° S in the Pacific Sector to 45° S in the western Indian Ocean Sector).

### 1.1 Commercial fisheries

Toothfish are large Nototheniids endemic to Antarctic and sub Antarctic waters. There are two main species: Antarctic toothfish (*Dissostichus mawsoni*) and Patagonian toothfish (*Dissostichus eleginoides*). Both have a circumpolar distribution, although *D. mawsoni* has a more southern distribution and is found in higher latitudes. The Ross Sea fishery catches mostly *D. mawsoni*.

Bottom longline and trawl fisheries for Patagonian toothfish occur around many of the subantarctic islands and plateaus south of the Subantarctic Front. To date, the main longline fishery for Antarctic toothfish has taken place in Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) Subarea 88.1 (the western Ross Sea) and to a much lesser extent in CCAMLR Subarea 88.2 (the eastern Ross Sea), as well as in Subarea 48.6 and several CCAMLR divisions in Subarea 58.4 to the west of Subarea 88.1. The western Ross Sea (Subarea 88.1) is divided into three broad ecological regions: a region of seamounts, ridges and banks to the north; a region of shallow water (<800 m) in the extreme south; and a region in between covering the continental slope (800-2000 m),

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[1] Note that this report does not cover the Patagonian toothfish (Dissostichus eleginoides) fishery within the New Zealand Exclusive Economic Zone.

where the main longline fishery occurs.

The exploratory longline fishery for *Dissostichus* spp. in Subarea 88.1 was initiated by a single New Zealand longline vessel in 1996/97 (Table 1). Since then, New Zealand vessels, and more recently vessels from other countries, have returned each summer to fish in this area and the adjacent Subarea 88.2. The catch of toothfish in Subarea 88.1 showed a steady increasing trend during the early period of the fishery, reaching the catch limit and peaking at about 3000 t between 2004/05 and 2006/07, but being under-caught in Subarea 88.1 in 2007/08, and 2008/09. Failure to reach the catch limit in those two years was due to the severe ice conditions in 2007/08 and early closure of the fishery by the CCAMLR Secretariat in 2008/09 due to overestimation of projected catch rates. The catch equalled the TAC in 2009/10.

The catch of toothfish in Subarea 88.2 showed a sharp increase in 2003/04, and exceeded catch limits in 2004/05 and 2005/06 but has since declined slightly. Failure to reach the catch limit in the last four years is primarily due to the lower fishing effort and catch in SSRUs CDFG (Hanchet et al. 2010). Figure 1 shows historical landings and TACs for Subareas 88.1 and 88.2.

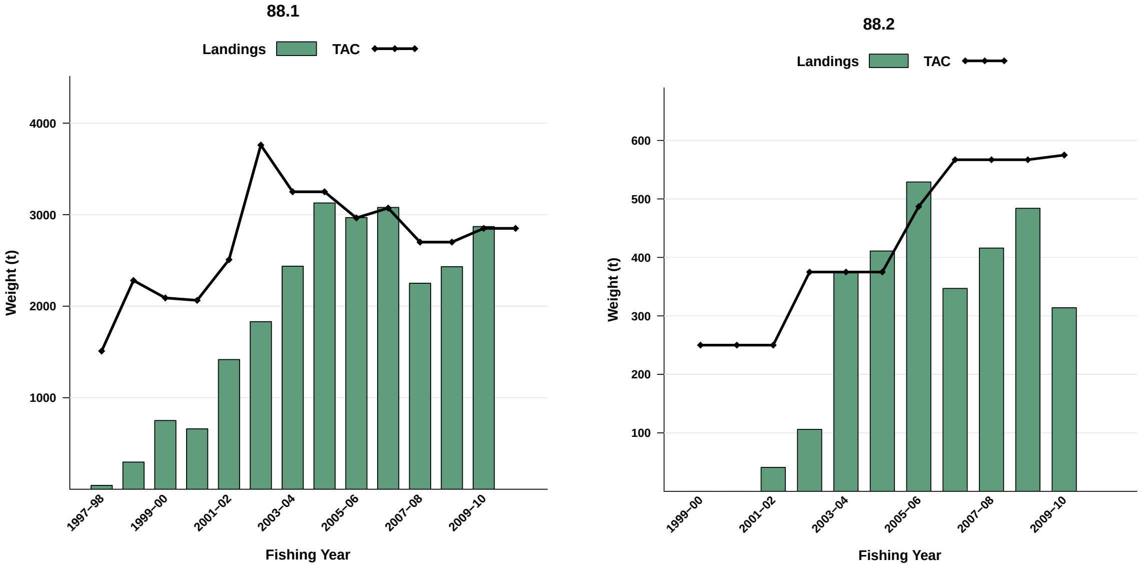

**Figure 1: The landings of toothfish from 1997-98 to 2009-10 in Subarea 88.1, and 1999-00 to 2009-10 in Subarea 88.2. Note the TAC has been plotted for the 2010-11 fishing season which starts 01 December 2010.**

The toothfish catch comprises almost entirely Antarctic toothfish. The multi-year total of ca.125 t of Patagonian toothfish caught in the Ross Sea Region has been taken almost entirely from the north of Subarea 88.1 (SSRUs 88.1A, 88.1B, and 88.1C) (Hanchet et al. 2010). The data in the following tables are collated from CCAMLR reporting requirements, specifically weekly reporting forms (vessel to CCAMLR), monthly reporting (vessel to flag state to CCAMLR) and annual reporting (FAO STATLANT reports to CCAMLR from flag state).

The number, size, and catch limits of the SSRUs in Subarea 88.1 have varied over time. In 1997/98 and 1998/99, Subarea 88.1 was divided into two at 65°S, with separate catch limits in each area. From 1999/2000 to 2002/03, the area south of 65°S was further divided into four SSRUs, with equal catch limits in each SSRU. The number of SSRUs was increased to 12 for the 2003/04 and 2004/05 seasons and the new catch limits were based proportionally on the product of the mean historical CPUE and the fishable seabed area (600–1800 m). The catch limits for the SSRUs were again changed for the 2005/06 and 2006/07 seasons as part of a three-year experiment. To assist administration of the SSRUs, the catch limits for SSRUs 881B, 881C, and 881G were amalgamated into a ‘north’ region and those for SSRUs 881H, 881I, and 881K were amalgamated into a ‘slope’ region. A nominal catch of up to 10 t was permissible in each ‘closed’ SSRU under a research fishing exemption.

**Table 1: Estimated catches (t) of Dissostichus spp. by area for the period 1996–97 to 2009–10 (Source: FAO STATLANT data to 2009/10).**

| | Subarea 88.1 | | | | Subarea 88.2 | | | |
|---|---|---|---|---|---|---|---|---|
| Season | Reported catch | Estimated IUU catch | Total | Catch limit | Reported catch | Estimated IUU catch | Total | Catch limit |
| 1996/97 | <1 | 0 | <1 | 1 980* | 0 | 0 | 0 | 1 980* |
| 1997/98 | 42 | 0 | 42 | 1 510 | 0 | 0 | 0 | 63 |
| 1998/99 | 297 | 0 | 297 | 2 281 | 0 | 0 | 0 | 0 |
| 1999/00 | 751 | 0 | 751 | 2 090 | 0 | 0 | 0 | 250 |
| 2000/01 | 660 | 0 | 660 | 2 064 | 0 | 0 | 0 | 250 |
| 2001/02 | 1 325 | 92 | 1 417 | 2 508 | 41 | 0 | 41 | 250 |
| 2002/03 | 1 831 | 0 | 1 831 | 3 760 | 106 | 0 | 106 | 375 |
| 2003/04 | 2 197 | 240 | 2 437 | 3 250 | 375 | 0 | 375 | 375 |
| 2004/05 | 3 105 | 23 | 3 128 | 3 250 | 411 | 0 | 411 | 375 |
| 2005/06 | 2 969 | 0 | 2 969 | 2 964 | 514 | 15 | 529 | 487 |
| 2006/07 | 3 091 | 0 | 3 091 | 3 072 | 347 | 0 | 347 | 567 |
| 2007/08 | 2 259 | 186 | 2 445 | 2 700 | 416 | 0 | 416 | 567 |
| 2008/09 | 2 448 | 0 | 2 448 | 2 700 | 484 | 0 | 484 | 567 |
| 2009/10 | 2 870 | 0 | 2 870 | 2 850 | 315 | 0 | 315 | 575 |

* A single catch limit in 1996/97 applied to all of Subareas 88.1 and 88.2.

**Table 2: Estimated catch of Dissostichus spp. in each small-scale research unit (SSRU) by year from fine scale catch and effort (C2) data, and catch limit in place for the 2009/10 season. In the 2007/08 season, a catch of up to 10 t was permissible for SSRUs with zero catch limits under a research fishing exemption.**

| SSRU | 1997/98 | 1998/99 | 1999/00 | 2000/01 | 2001/02 | 2002/03 | 2003/04 | 2004/05 | 2005/06 | 2006/07 | 2007/08 | 2008/09 | 2009/10 | Catch limit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 881A | | | | 1 | | 13 | | | 2 | <1 | | | | 0 |
| 881B | <1 | | | 83 | 45 | 107 | 70 | 70 | 10 | 209 | 94 | 117 | 0 | } |
| 881C | | | | 34 | 363 | 1 001 | 232 | 428 | 333 | 375 | 165 | 292 | 370 | } 372 |
| 881G | 4 | <1 | | 71 | 16 | 65 | 80 | 54 | | | | | | } |
| 881D | | | | | | | | | | | | | | 0 |
| 881E | 5 | <1 | | 10 | | 2 | 40 | 60 | | <1 | | | | 0 |
| 881F | <1 | | | | | <1 | | | | 2 | | | | 0 |
| 881H | 4 | 99 | 181 | 98 | 439 | 481 | 1 114 | 786 | 1 012 | 1 514 | 1 365 | 487 | 1062 | } |
| 881I | 26 | 149 | 376 | 246 | 345 | 131 | 628 | 613 | 373 | 557 | 126 | 633 | 810 | } 2 104 |
| 881K | | 31 | 183 | | 121 | | <1 | 737 | 588 | | 61 | 861 | 244 | } |
| 881J | 2 | 17 | 11 | 12 | | | 1 | 158 | 545 | 438 | 411 | 55 | 328 | } |
| 881L | | | | 97 | | | 12 | 170 | 84 | | 39 | 3 | 56 | } 374 |
| 881M | | | | | | | | | | | | | | 0 |
| 882A | | | | | 41 | | 11 | 137 | 17 | | | | | 0 |
| 882B | | | | | | | 1 | | | | | | | 0 |
| 882E | | | | | | 106 | 362 | 270 | 318 | 325 | 333 | 323 | 283 | 361 |
| 882C | | | | | | | | | | | | | | } |
| 882D | | | | | | | | | 41 | 22 | 38 | 29 | 13 | } 214 |
| 882F | | | | | | | | | 65 | | 45 | 132 | 13 | } |
| 882G | | | | | | | | | 1 | <1 | | | 6 | } |
| Total | 42 | 297 | 752 | 650 | 1 370 | 1 907 | 2 552 | 3 484 | 3 389 | 3 443 | 2 838 | 2 932 | 315 | 3 425 |

Although the overall catch limit in Subarea 88.1 has rarely been exceeded, the catch limit for some SSRUs has been exceeded in some seasons. Ice conditions and bycatch limits are an important factor in the fishery. In 2002/03, 2003/04 and 2007/08 heavy ice conditions meant little catch was taken in SSRUs 88.1J–L. For the 2008/09 season, SSRU 88.1J was split into two at 170ºE, creating a new SSRU 88.1M to the west of that line (which is closed to fishing), and reducing the size of 88.1J to the east of that line. The catch limits for SSRUs 881J and 881L were amalgamated into a ‘shelf’ region. The catch limits for the remaining SSRUs in Subarea 88.1 were adjusted accordingly.

The SSRUs in Subarea 88.2 have also varied over time. In 1997/98 and 1998/99, the Subarea was divided into two at 65°S, with the northern area closed and a catch limit set for the southern area. From 1999/2000 to the present, the area south of 65°S was divided into seven SSRUs, each comprising 20° of longitude. The catch limits for the southern SSRUS in Subarea 88.2 were also changed as part of the three-year experiment. SSRU 882E was treated as a separate SSRU with its own catch limit, whilst SSRUs 882C, 882D, 882F, and 882G were amalgamated with a single catch limit. Fishing has now been carried out in all SSRUs except 88.2C, however, most of the catch has been taken in SSRU 88.2E. In 2005/06, the macrourid bycatch limits were exceeded in SSRUs 88.2CDFG and so Subarea 88.2 was closed before the toothfish catch limit was reached.

Following the revised stock assessments in 2009, the catch limits were revised for the 2009/10 season, but no further changes were made to the SSRU boundaries.

In addition to the catch limits on the target species, many other management measures have been in place over the course of the fishery. These include restrictions on bycatch, measures to minimise local depletion of toothfish, and bycatch mitigation measures (CCAMLR Conservation Measures 33-03 (2010), 41-09 (2010) and 41-10 (2010)).

### 1.2 Recreational fisheries

There is no significant recreational toothfish fishery in Subareas 88.1 and 88.2.

### 1.3 Customary non-commercial fisheries

There is no customary toothfish fishery in Subareas 88.1 and 88.2.

### 1.4 Illegal catches

Based on aerial surveillance and other sources of intelligence, the level of illegal and unreported catch is thought to be low (Table 1). At its 2010 meeting, CCAMLR apportioned the IUU toothfish catch taken in Subarea 88.1 according to the proportions of the toothfish species taken in the commercial catch by SSRU.

### 1.5 Other sources of mortality

A small quantity of toothfish is taken for scientific research purposes in most years, typically in the order of 30-40 kg, although in some years it may be considerably more.

Observers monitor discards, with at least 40% of all hooks hauled being directly observed, and no discarding has been reported to date. Fish are occasionally lost from the line near the surface – if those fish are dead, fishers can usually recover and land them, if alive they generally swim away and are likely to survive (on the basis of the observed tag-recapture data).

Antarctic toothfish are occasionally caught with evidence of squid depredation (i.e., sucker marks and large flesh wounds), but the amount of depredation due to large squid, cetaceans, and pinnipeds is insignificant at the scale of the fishery.

## 2. BIOLOGY

The Antarctic toothfish has a circumpolar distribution south of the Antarctic convergence (60°S). A summary of the biology of Antarctic toothfish, and related references, are given in detail in a species profile (Hanchet 2010). Although it is primarily a demersal species, adults are neutrally buoyant and are known to inhabit the pelagic zone at various locations and times during their life cycle. Early growth has been well documented with fish reaching about 60 cm TL after five years and about 100 cm TL after ten years. Growth slows down after 25 years at a length of about 150 cm. The maximum recorded age is 48 years and maximum length recorded is 250 cm. Ages have been partly validated by following modes in juvenile fish and by tetracycline marking in adult fish. There is a significant difference in growth between sexes with maximum average lengths of 170 cm and 185 cm for males and females respectively.

The age and length at recruitment to the fishery varies between areas and between years. In the northern SSRUs (88.1A–88.1G), toothfish recruit at a length of about 130 cm to the fishery. In the southern SSRUs the length at recruitment depends on the depth of fishing. In some years fish have been fully recruited by about age 7–8, whereas in other years fish have not been fully recruited until at least age 10. During the 2006 season, sub adult fish (with a mode at 60–70 cm) were recorded from the continental slope (1000–1500 m) in Subarea 88.2.

Previous Antarctic toothfish assessments assumed a 50% maturity at 100 cm (with range 85–115 cm) with a logistic relationship by length, and converted the length-based relationship to an age-based relationship via the von Bertalanffy curve for both sexes combined. In 2009, estimates of maturity, based on hindcasting from the presence of post-ovulatory follicles in the ovaries and forecasting from the assessment of oocyte developmental stage, suggested the mean age and length at 50% spawning for females on the Ross Sea slope region were 16.6 y and 133.2 cm and for the mean age and length at 50% maturity for males were 12.8 y and 120.4 cm (Parker & Grimes 2009).

The natural mortality rate *M* was estimated by Dunn et al. (2006) using the methods of Chapman-Robson (1960), Hoenig (1983), and Punt et al. (2005). Estimates of *M* derived from these methods ranged from 0.11 to 0.17 $y^{-1}$. After a consideration of possible biases, Dunn et al. (2006) proposed that a value of 0.13 $y^{-1}$ be used for stock modelling with a range of 0.11–0.15 $y^{-1}$ for sensitivity analyses. They noted that further work is required on values of *M* and in possible changes of *M* with age. Biological parameters relevant to the stock assessment are shown in Table 3.

Antarctic toothfish feeds on a wide range of prey but is primarily piscivorous. The most important prey species of fish caught in the main fishery is Whitson's grenadier (*Macrourus whitsoni*). In continental slope waters, *M. whitsoni*, the icefish *Chionobathyscus dewitti*, eel cods (*Muraenolepis* spp.) and cephalopods predominate in the diet, while on oceanic seamounts *M. whitsoni*, violet cod (*Antimora rostrata*) and cephalopods are important. In the coastal waters around McMurdo Sound, adults feed principally on Antarctic silverfish (*Pleuragramma antarcticum*). In the open oceanic waters in the north of the Ross Sea region, Antarctic toothfish feed on small squid. The diet of Antarctic toothfish also varies with fish size. Crustaceans are more common prey items in smaller toothfish, whereas squid are more common in larger toothfish. Its main predators are likely to be cetaceans (sperm whales, killer whales), pinnipeds (Weddell seals), and colossal squid.

A hypothetical life history for Antarctic toothfish in the Ross Sea was developed by Hanchet al. (2007b). It is believed that they spawn to the north of the Antarctic continental slope, mainly on the ridges and banks of the Pacific-Antarctic Ridge. The spawning appears to take place during winter and spring, and may extend over a period of several months. Depending on the exact location of spawning, eggs and larvae become entrained by the Ross Sea gyres (a small clockwise rotating western gyre located around the Balleny Islands and a larger clockwise rotating eastern gyre covering the rest of 88.1 and 88.2), and may either move west settling out around the Balleny Islands and adjacent Antarctic continental shelf, south onto the Ross Sea shelf, or eastwards with the eastern Ross Sea gyre settling out along the continental slope and shelf to the east of the Ross Sea in Subarea 88.2. As the juveniles grow in size they move west back towards the Ross Sea shelf and then move out into deeper water (greater than 600 m). The fish gradually move northwards as they mature, feeding in the slope region in depths of 1000–1500 m, where they gain condition before moving north onto the Pacific-Antarctic ridge to start the cycle again. Spawning fish may remain in the northern area for up to 2–3 years. They then move southwards back onto the shelf and slope where productivity is higher and food is more plentiful where they regain condition before spawning.

**Table 3: Estimates of biological parameters for Antarctic toothfish.**

Biological parameters

1. Natural mortality (M)

| Males | Females | |
|---|---|---|
| 0.13 | 0.13 | Dunn et al. 2006 |

2. Weight – a(length)$^{b}$ (Weight in kg, length in cm fork length)

| Males | | Females | | |
|---|---|---|---|---|
| a | b | a | b | |
| 0.00001387 | 2.965 | 0.000007153 | 3.108 | Dunn et al. (2006) |

3. vonBertalanffy growth parameters

| Males | | | Females | | | |
|---|---|---|---|---|---|---|
| K | $t_0$ | $L_\infty$ | K | $t_0$ | $L_\infty$ | |
| 0.093 | -0.26 | 169.1 | 0.090 | 0.021 | 180.2 | Dunn et al. (2006) |

4. Maturity

| Males | | Females | | |
|---|---|---|---|---|
| $A_{50}$ | $\pm A_{to95}$ | $A_{50}$ | $\pm A_{to95}$ | |
| 12.8 | 3.5 | 16.6 | 7.3 | Parker & Grimes (2009) |

## 3. STOCKS AND AREAS

The number of stocks or populations of *D. mawsoni* in the Southern Oceans is currently unknown. However, there have been several recent studies looking at genetics, parasites and movements of fish from tag-recapture data which have began to shed some light on stock structure.

A genetic analysis was carried out by Parker *et al.* (2002) using random amplified polymorphic DNA (RAPD) markers. They concluded that samples taken from McMurdo Sound (Subarea 88.1) and the Bellingshausen Sea (Subarea 88.3) were from two different genetic groups. Smith & Gaffney (2005) detected little genetic diversity in mitochondrial DNA (mtDNA) samples between the Pacific (Subarea 88.1), Indian Ocean (Division 58.4.2), and Atlantic Ocean (Subarea 48.1) sectors. One mtDNA method showed no genetic variation, whilst two other mtDNA methods showed only weak genetic diversity between regions. Smith & Gaffney (2005) also found only weak genetic variation using nuclear DNA introns. They concluded that despite the weak genetic diversity in Antarctic toothfish there was evidence for differentiation between the ocean sectors. Kuhn & Gaffney (2008) expanded the work of Smith & Gaffney (2005) by examining nuclear and mitochondrial single nucleotide polymorphisms (SNPs) on tissue samples collected from Subareas 48.1, 88.1, and 88.2 and Division 58.4.1. They found broadly similar results to those of the earlier studies, with some evidence for significant genetic differentiation between the three ocean sectors but limited evidence for differentiation within ocean sectors.

The occurrence of separate stocks is supported by oceanic gyres, which may act as juvenile retention systems, and by the movement of adult tagged fish. Fish originally caught and tagged on the shelf and slope of the Ross Sea have been recaptured on the northern banks and vice versa. Additionally, one fish tagged at McMurdo Sound was recaptured after 18 years at liberty 1300 n. miles to the northeast in SSRU 88.2E.

For fisheries management purposes, Subareas 88.1 and 88.2 are split into three areas. For stock assessment purposes all of Subarea 88.1 and SSRUs 88.2A and 88.2B are treated as a single ‘Ross Sea’ stock. SSRU 88.2E is treated as a separate stock, ‘SSRU 88.2E’ (CCAMLR 2006). All other parts of Subarea 88.2 (SSRUs 88.2C, 88.2D, 88.2F, 88.2G) are treated as the third management unit and this area is not currently included in a stock assessment. However, it is noted that the stock affinity of the assessed stocks with toothfish in surrounding areas is not well understood, and that assessments in the medium term will consider alternative stock structures including a combined Subarea 88.1 and 88.2 assessment.

## 4. STOCK ASSESSMENT

Updated estimates of biomass and long term yield (using the CCAMLR Decision Rules) were provided in 2009 for Antarctic toothfish for the Ross Sea and SSRU 88.2E stocks based on analyses using catch-at-age from the commercial fishery, tag-recapture data, and estimates of biological parameters as reported below. This is the fourth stock assessment of the Ross Sea fishery, and the second for SSRU 88.E.

### 4.1 Estimates of fishery parameters and abundance indices

### CPUE indices

A standardised CPUE analysis of the Antarctic toothfish fishery in the Ross Sea showed no significant trend from 1998/99 to 2002/03, a large decline in 2003/04 followed by a large increase in 2004/05 to 2006/07, decrease to 2007/08, and increase in 2008/09 (Dunn & Hanchet 2009) (Table 4).

The patterns of increase and declines in the CPUE indices are thought to be reflecting a combination of either good or poor ice conditions, vessel interactions, increasing fisher learning and experience, improved knowledge of optimum fishing practice, improvements in gear, and regulation changes (i.e., move-on rules and research set requirements) rather than toothfish abundance. Indices for the separate shelf, slope, and north fisheries showed a similar variable pattern.

**Table 4: Standardised CPUE indices for the Ross Sea, 95% confidence intervals, and coefficient of variation (c.v.s) for the shelf, slope and north fisheries, and for all areas combined, 1998/99 to 2008/09.**

| | Shelf | | | Slope | | | North | | | All areas | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Index | 95% C.I. | C.V. | Index | 95% CI | C.V. | Index | 95% C.I. | C.V. | Index | 95% C.I. | C.V. |
| 1998/99 | 0.53 | 0.37-0.77 | 0.18 | 0.70 | 0.61-0.80 | 0.07 | – | – | – | 0.62 | 0.55-0.70 | 0.06 |
| 1999/2000 | 1.15 | 0.93-1.43 | 0.11 | 1.07 | 0.96-1.19 | 0.05 | – | – | – | 0.94 | 0.85-1.03 | 0.05 |
| 2000/01 | 0.64 | 0.55-0.75 | 0.08 | 0.96 | 0.82-1.11 | 0.08 | 0.57 | 0.47-0.69 | 0.10 | 0.74 | 0.67-0.81 | 0.05 |
| 2001/02 | – | – | – | 1.64 | 1.46-1.85 | 0.06 | 1.63 | 1.32-2.02 | 0.11 | 1.16 | 1.06-1.26 | 0.04 |
| 2002/03 | – | – | – | 1.03 | 0.91-1.17 | 0.06 | 1.03 | 0.92-1.15 | 0.06 | 0.94 | 0.86-1.02 | 0.04 |
| 2003/04 | 0.74 | 0.61-0.91 | 0.10 | 0.72 | 0.66-0.79 | 0.04 | 0.47 | 0.40-0.56 | 0.08 | 0.62 | 0.58-0.66 | 0.04 |
| 2004/05 | 1.50 | 1.31-1.73 | 0.07 | 1.36 | 1.26-1.47 | 0.04 | 0.67 | 0.60-0.76 | 0.06 | 1.36 | 1.27-1.44 | 0.03 |
| 2005/06 | 1.15 | 0.97-1.36 | 0.08 | 1.52 | 1.40-1.65 | 0.04 | 1.18 | 0.92-1.51 | 0.13 | 1.59 | 1.48-1.72 | 0.04 |
| 2006/07 | 1.46 | 1.13-1.88 | 0.13 | 1.25 | 1.15-1.35 | 0.04 | 0.86 | 0.74-1.01 | 0.08 | 1.25 | 1.16-1.35 | 0.04 |
| 2007/08 | 1.13 | 0.85-1.49 | 0.14 | 1.26 | 1.15-1.38 | 0.05 | 0.57 | 0.47-0.68 | 0.09 | 0.88 | 0.80-0.96 | 0.05 |
| 2008/09 | 1.99 | 1.54-2.57 | 0.13 | 1.41 | 1.28-1.56 | 0.05 | 0.85 | 0.70-1.03 | 0.10 | 1.47 | 1.33-1.61 | 0.05 |

A standardised CPUE analysis of the Antarctic toothfish fishery in SSRU 88.2E shows a modest decline from 2002/03 to 2004/05 followed by an increase to 2005/06, decrease in 2007/08, and increase in 2008/09 (Dunn & Hanchet 2009) (Table 5). The patterns of increase and declines in the CPUE indices are thought to be reflecting a combination of either good or poor ice conditions, vessel interactions, increasing fisher learning and experience, improved knowledge of optimum fishing practice, improvements in gear, and regulation changes (i.e., move-on rules and research set requirements) rather than toothfish abundance.

**Table 5: Standardised CPUE indices for SSRU 88.2E, 95% confidence intervals, and coefficient of variation (c.v.s), 2002/03– 2008/09.**

| Year | Index | 95% C.I. | C.V. |
|---|---|---|---|
| 2002/03 | 1.15 | 0.54–2.46 | 0.39 |
| 2003/04 | 0.85 | 0.56-1.27 | 0.21 |
| 2004/05 | 0.82 | 0.56-1.21 | 0.19 |
| 2005/06 | 1.40 | 0.86-2.26 | 0.24 |
| 2006/07 | 1.05 | 0.65-1.70 | 0.24 |
| 2007/08 | 0.58 | 0.36-0.93 | 0.24 |
| 2008/09 | 1.47 | 0.81-2.67 | 0.31 |

## Tag-recapture data

The tagging program for *Dissostichus* spp. in the Ross Sea was first initiated in the 2000/01 season in Subarea 88.1 by New Zealand vessels participating in the fishery (Dunn et al. 2009). Since then, the toothfish tagging program has been extended to all vessels participating in the fishery and to Subarea 88.2.

As of 2008/09, a total of 8583 Antarctic toothfish have been tagged in Subareas 88.1 and 88.2 by New Zealand vessels, and a total of 18 954 Antarctic toothfish have been tagged by all vessels. Following recommendations from the CCAMLR Scientific Committee (SC-CAMLR), a data set of tag release and recapture for the assessment of Antarctic toothfish was selected on the basis of data quality metrics for individual trips (Middleton 2009). The method first selected an initial informative data set comprising trips with (i) high (above median) rates of recovery of previously released tags, and (ii) where tags released on the trip were subsequently recaptured at a high rate (i.e., above median). The method then used these trips to define the upper and lower bounds of data quality metrics that were informative with respect to tagging data. Other trips with data quality metric values within these ranges were then added to the initial informative data set.

Table 6 gives the number of releases and recaptured Antarctic toothfish for the Ross Sea, and Table 7 for SSRU 88.2E from all trips and the selected trips tag data.

**Table 6: Numbers of Ross Sea Antarctic toothfish with tags released for the years 2001–2009 by all and ‘selected’ trips, and the number recaptured in 2001–2009 by all and ‘selected’ trips. Note 2001 is the 2000/01 season.**

| Data set | Tagged fish released | | | | | | | | | | Recaptures |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Year | Number | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | Total |
| All trips | 2001 | 259 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 4 |
| | 2002 | 684 | 2 | 9 | 4 | 9 | 7 | 13 | 6 | 5 | 55 |
| | 2003 | 861 | – | 9 | 13 | 9 | 2 | 9 | 2 | 2 | 46 |
| | 2004 | 2 031 | – | – | 9 | 22 | 19 | 32 | 26 | 12 | 120 |
| | 2005 | 3 272 | – | – | – | 8 | 26 | 29 | 30 | 11 | 104 |
| | 2006 | 3 025 | – | – | – | – | 11 | 89 | 68 | 15 | 183 |
| | 2007 | 3 533 | – | – | – | – | – | 18 | 62 | 23 | 103 |
| | 2008 | 2 495 | – | – | – | – | – | – | 14 | 19 | 33 |
| | 2009 | 2 794 | – | – | – | – | – | – | – | 9 | 9 |
| | Unknown | – | – | – | 2 | 5 | 2 | – | 1 | – | 10 |
| | Total | 18 954 | 3 | 19 | 28 | 53 | 67 | 191 | 210 | 97 | 668 |
| Selected trips | 2001 | 127 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 4 |
| | 2002 | 684 | 2 | 9 | 3 | 5 | 7 | 13 | 5 | 4 | 48 |
| | 2003 | 808 | – | 5 | 7 | 6 | 2 | 9 | 2 | 2 | 33 |
| | 2004 | 1 811 | – | – | 6 | 21 | 19 | 30 | 22 | 8 | 106 |
| | 2005 | 2 808 | – | – | – | 6 | 25 | 25 | 18 | 8 | 82 |
| | 2006 | 2 443 | – | – | – | – | 11 | 84 | 51 | 14 | 160 |
| | 2007 | 2 871 | – | – | – | – | – | 11 | 42 | 17 | 70 |
| | 2008 | 1 756 | – | – | – | – | – | – | 7 | 12 | 19 |
| | 2009 | 1 874 | – | – | – | – | – | – | – | 7 | 7 |
| | Total | 15 182 | 3 | 15 | 16 | 38 | 64 | 173 | 147 | 73 | 529 |

**Table 7: Numbers of 88.2E Antarctic toothfish with tags released for the years 2003–2009 by all and 'selected' trips, and the number recaptured in 2003–2009 by all and 'selected' trips. Note 2003 is the 2002/03 season.**

| Data | Tagged fish released | | | | | | | | | | Recaptures |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Year | Number | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | Total |
| All trips | 2003 | 94 | – | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 4 |
| | 2004 | 397 | – | – | 15 | 10 | 9 | 5 | 1 | 0 | 40 |
| | 2005 | 269 | – | – | – | 5 | 4 | 1 | 1 | 1 | 12 |
| | 2006 | 251 | – | – | – | – | 12 | 20 | 3 | 2 | 37 |
| | 2007 | 254 | – | – | – | – | – | 4 | 4 | 4 | 12 |
| | 2008 | 343 | – | – | – | – | – | – | 21 | 13 | 34 |
| | 2009 | 360 | – | – | – | – | – | – | – | 32 | 32 |
| | Unknown | – | – | – | 0 | – | 1 | – | – | – | 1 |
| | Total | 1 968 | 0 | 0 | 16 | 16 | 28 | 30 | 30 | 52 | 172 |
| Selected trips | 2003 | 94 | | 0 | 0 | – | 2 | 0 | 0 | 0 | 2 |
| | 2004 | 159 | | – | 7 | – | 5 | 2 | 1 | 0 | 15 |
| | 2005 | 0 | | – | – | – | – | – | – | – | 0 |
| | 2006 | 251 | | – | – | – | 12 | 18 | 3 | 2 | 35 |
| | 2007 | 100 | | – | – | – | – | 1 | 4 | 3 | 8 |
| | 2008 | 343 | | – | – | – | – | – | 21 | 7 | 28 |
| | 2009 | 156 | | – | – | – | – | – | – | 8 | 8 |
| | Total | 1103 | | 0 | 7 | – | 19 | 21 | 29 | 20 | 96 |

## Catch-at-age data

Strata for the Antarctic toothfish length and age frequency data were determined using tree-based regression (a post-stratification method) (Hanchet et al. 2009). The analysis used the median length of fish in each longline set, and the explanatory variables SSRU and depth. On average, about 800 Antarctic toothfish otoliths collected by observers were selected for ageing each year, and used to construct annual area-specific age-length keys (ALKs). Age data were available for the 1998/99 to 2007/08 seasons, but were not available for the 2008/09 season. In the Ross Sea, ALKs for each sex were applied to the shelf/slope fisheries and the north fishery separately. The ALKs were applied to the scaled length-frequency distributions for each year to produce catch-at-age distributions (Hanchet et al., 2009). In SSRU 882E, otoliths were only available from the New Zealand fleet, who did not fish SSRU 882E every year. Therefore, for SSRU 882E, a single ALK for each sex using otolith ages from all available years was used to construct annual age frequencies.

## Parameter estimates

A list of parameter values used for the assessments is given in Table 8.

## 4.2 Biomass estimates

## (i) The Ross Sea (Subarea 88.1 and SSRUs 88.2A and 88.2B)

## The stock assessment model

The model was sex- and age-structured, with ages from 1–50, where the last age group was a plus group (Dunn & Hanchet 2009). The annual cycle was broken into three discrete time steps, nominally summer (November–April), winter (May–October), and end-winter (age-incrementation) (Table 9).

**Table 8: Parameter values for *D. mawsoni* in Subarea 88.1 and 88.2.**

| | | | | Value | |
|---|---|---|---|---|---|
| Component | Parameter | Male | Female | All | Units |
| Natural mortality | $M$ | 0.13 | 0.13 | | $y^{-1}$ |
| VBGF | $K$ | 0.093 | 0.090 | | $y^{-1}$ |
| VBGF | $t_0$ | -0.256 | 0.021 | | y |
| VBGF | $L_\infty$ | 169.07 | 180.20 | | cm |
| Length to mass | '*a*' | 0.00001387 | 0.00000715 | | cm, kg |
| Length to mass | '*b*' | 2.965 | 3.108 | | |
| Length to mass variability (CV) | | | | 0.1 | |
| Maturity | $A_{m50}$ | 12.8 | 16.6 | | y |
| Range: 5% to 95% maturity | | 9.3–16.3 | 9.3–23.9 | | y |
| Recruitment variability | $\sigma_R$ | | | 0.6 | |
| Stock recruit steepness (Beverton-Holt) | $h$ | | | 0.75 | |
| Ageing error (CV) | | | | 0.1 | |
| Initial tagging mortality | | | | 10% | |
| Instantaneous tag loss rate (single tagged) | | | | 0.062 | $y^{-1}$ |
| Instantaneous tag loss rate (double tagged) | | | | 0.004 | $y^{-1}$ |
| Tag detection rate | | | | 98.5% | |
| Tagging related growth retardation (TRGR) | | | | 0.5 | y |

**Table 9: Annual cycle of the stock model, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur within a time step occur after all other processes, with half of the natural mortality for that time step occurring before and half after the fishing mortality.**

| Step | Period | Processes | $M^1$ | Age$^2$ | Observations | |
|---|---|---|---|---|---|---|
| | | | | | Description | $M^3$ |
| 1 | Nov–April | Recruitment and fishing mortality | 0.5 | 0.0 | Tag-recapture | 0.5 |
| | | | | | Catch-at-age proportions | 0.5 |
| 2 | May–November | Spawning | 0.5 | 0.0 | | |
| 3 | - | Increment age | 0.0 | 1.0 | | |

[1] *M* is the proportion of natural mortality that was assumed to have occurred in that time step.

[2] Age is the age fraction, used for determining length at age, which was assumed to occur in that time step.

[3] *M* is the proportion of the natural mortality in each time step that was assumed to have taken place at the time each observation was made.

The model was run from 1995 to 2009, and was initialised assuming an equilibrium age structure at an unfished equilibrium biomass, i.e., a constant recruitment assumption. Recruitment was assumed to occur at the beginning of the first (summer) time step. Recruitment was assumed to be 50:50 male to female, and was parameterised as a year class strength multiplier (assumed to have mean equal to one over a defined range of years), multiplied by an average (unfished) recruitment ($R_0$) and a spawning stock-recruitment relationship. In this model, the year class strength multipliers were assumed fixed, and set equal to 1.

The base-case model was implemented as a single-area, three-fishery model. A single area was defined with the catch removed using three concurrent fisheries (slope, shelf and north). Each fishery was parameterised by a sex-based double-normal selectivity ogive (i.e. domed selectivity) and allowed for annual selectivity shifts that shifted left or right (shelf fishery) with changes in the mean depth of the fishery (slope and north fisheries in the Ross Sea). The double-normal selectivity was parameterised using four estimable parameters and allowed for differences in maximum selectivity by sex – the maximum selectivity was fixed at one for males, but estimated for females. The double-normal selectivity ogive was employed as it allowed the estimation of a declining right-hand limb in the selectivity curve.

Fishing mortality was applied only in the first (summer) time step. The process was to remove half of the natural mortality occurring in that time step, then apply the mortality from the fisheries instantaneously, then to remove the remaining half of the natural mortality.

The population model structure includes tag–release and tag–recapture events. Each tagged fish was assigned an age-sex based on its length and the modelled population structure of fish at that age and sex. Tagging from each year was applied as a single tagging event. The usual population processes (natural mortality, fishing mortality etc.) were then applied over the tagged and untagged components of the model simultaneously. Tagged fish were assumed to suffer a retardation of growth from the effect of tagging (TRGR), equal to 0.5 of a year for the year immediately following release.

## Model estimation

The model parameters were estimated using Bayesian analysis, first by maximising an objective function (MPD), which is the combination of the likelihoods from the data, prior expectations of the values of the those parameters, and penalties that constrain the parameterisations; and second, by estimating the Bayesian posterior distributions using Monte Carlo Markov Chains (MCMCs).

Initial model fits were evaluated at the MPD, by investigating model fits and residuals. Parameter uncertainty was estimated using MCMCs. These were estimated using a burn-in length of 4 x $10^5$ iterations, with every 1000th sample taken from the next 1 x $10^6$ iterations (i.e. a final sample of length 1000 was taken).

## Observation assumptions

The catch proportions-at-age data for 1998–2008 were fitted to the modelled proportions-at-age composition using a multinomial likelihood. Following the recommendations of WG-SAM that CPUE indices were not indexing changes in abundance, the CPUE indices were not used. Tag–release events were defined for the 2001–2008 years. Within-season recaptures were ignored. Tag–release event for the years 2002–2009 were assumed to have occurred at the end of the first (summer) time step, following all (summer) natural and fishing mortality.

The estimated number of scanned fish (i.e. those fish that were caught and inspected for a possible tag) was derived from the sum of the scaled length frequencies from the vessel observer records, plus the numbers of fish tagged and released. Tag recapture events were assumed to occur at the end of the first (summer) time step, and were assumed to have a detection probability of 98.5% to account for unlinked tags.

For each year, the recovered tags at length for each release event were fitted, in 10 cm length classes (range 40–230 cm), using a binomial likelihood.

## Process error and data weighting

Additional variance, assumed to arise from differences between model simplifications and real world variation, was added to the sampling variance for all observations. Adding such additional errors to each observation type has two main effects, (i) it alters the relative weighting of each of the data sets (observations) used in the model, and (ii) it typically increases the overall uncertainty of the model, leading to wider credible bounds on the estimated and derived parameters.

The additional variance, termed process error, was estimated for the base-case MPD run, and the total error assumed for each observation was calculated by adding process error and observation error. A single process error was estimated for each of the observation types (i.e. one for the catch-at-age data and one for the tag-recapture data).

## Penalties

Two types of penalties were included within the model. First, the penalty on the catch constrained the model from returning parameter estimates where the population biomass was such that the catch from an individual year would exceed the maximum exploitation rate (see earlier). Second, a tagging penalty discouraged population estimates that were too low to allow the correct number of fish to be tagged.

## Priors

The parameters estimated by the models, their priors, the starting values for the minimisation, and their bounds are given in Table 10. In models presented here, priors were chosen that were relatively non-informative and that also encouraged conservative estimates of $B_0$.

**Table 10: Number (N), start values, priors, and bounds for the free parameters (when estimated) for the Ross Sea base case.**

| Parameter | | N | Start value | Prior | Bounds | |
|---|---|---|---|---|---|---|
| | | | | | Lower | Upper |
| $B_0$ | | 1 | 150 000 | Uniform-log | $1\text{x}10^4$ | $1\text{x}10^6$ |
| Male fishing selectivities | $a_1$ | | 8.0 | Uniform | 1.0 | 50.0 |
| | $s_L$ | | 4.0 | Uniform | 1.0 | 50.0 |
| | $s_R$ | 9 | 10.0 | Uniform | 1.0 | 500.0 |
| Female fishing selectivities | $a_{max}$ | | 1.0 | Uniform | 0.01 | 10.0 |
| | $a_1$ | | 8.0 | Uniform | 1.0 | 50.0 |
| | $s_L$ | | 4.0 | Uniform | 1.0 | 50.0 |
| | $s_R$ | 12 | 10.0 | Uniform | 1.0 | 500.0 |
| Selectivity shift ($ykm^{-1}$) | $E$ | 2 | 0.0 | Uniform | 0.0 | 50.0 |
| Annual selectivity shift[1] | $E_f$ | 12 | Mean depth | Uniform | -10.0 | 10.0 |

### Base case and sensitivity runs

Model runs were conducted for the base case and the sensitivity runs are described in Table 11. The base-case models included tag–release and recapture data from the 'selected' trips, and the proportions-at-age of the catch. Sensitivity runs were determined as modifications to the base-case runs, and were chosen to investigate the effect of alternative data and assumptions within the model.

### Model estimates

MCMC samples from the posterior were estimated. MCMC diagnostics suggested no evidence of poor convergence in the key biomass parameters and between sample autocorrelations were low.

**Table 11: Labels and description of the Ross Sea and 88.2E sensitivity runs.**

| Model | | Description |
|---|---|---|
| R1 | Base case | Selected trips tag data with the revised maturity ogive |
| R2 | New Zealand tag data + 2007 maturity | New Zealand vessels tag data and the 2007 maturity ogive |
| R3 | Selected trips + 2007 maturity | Selected trips tag data with the 2007 maturity ogive |

Key output parameters for the base case are summarised in Table 12 and Figure 2. MCMC estimates of initial (equilibrium) spawning stock abundance ($B_0$) were 62 080 tonnes (95% credible intervals 56 020–70 090 tonnes), and current ($B_{2009}$) biomass was estimated as 80% $B_0$ (95% CIs 78–82%). Results of sensitivity runs are shown in Table 12 and 13. The New Zealand vessels case was less optimistic than models using the 'selected' trips, suggesting a lower initial biomass and current biomass. The inclusion of the revised maturity ogive suggested a lower spawning stock biomass. In all sensitivity cases, current biomass was estimated to be above 76% B0.

**Table 12: Median MCMC estimates (and 95% credible intervals) of B0, B2009, and B2009 as % B0 for the Ross Sea base case and sensitivity models.**

| Model | | $B_0$ | $B_{2009}$ | $B_{2009}$ (%$B_0$) |
|---|---|---|---|---|
| R1 | Base case | 62 080 (56 020–70 090) | 49 580 (43 530–57 670) | 79.9 (77.7–82.2) |
| R2 | New Zealand tag data + 2007 maturity | 64 260 (55 710–74 490) | 48 920 (40 420–59 170) | 76.2 (72.5–79.4) |
| R3 | Selected trips + 2007 maturity | 90 530 (81 270–101 950) | 75 230 (65 890–86 610) | 83.1 (81.1–85.0) |

**Table 13: Selected MPD parameter (B0, B2007, and B2009) values for the 2007 Ross Sea base case model, and the updated Ross Sea base case and sensitivity models.**

| Model | | $B_0$ | $B_{2007}$ | $B_{2007}$ (%$B_0$) | $B_{2009}$ | $B_{2009}$ (%$B_0$) |
|---|---|---|---|---|---|---|
| | Base case from 2007 | 70 740 | 60 010 | 84.8 | – | – |
| R1 | Base case | 62 340 | 53 960 | 86.6 | 52 160 | 83.7 |
| R2 | New Zealand tag data + 2007 maturity | 64 060 | 53 390 | 83.3 | 51 250 | 80.0 |
| R3 | Selected trips + 2007 maturity | 90 340 | 79 660 | 88.2 | 77 510 | 85.8 |

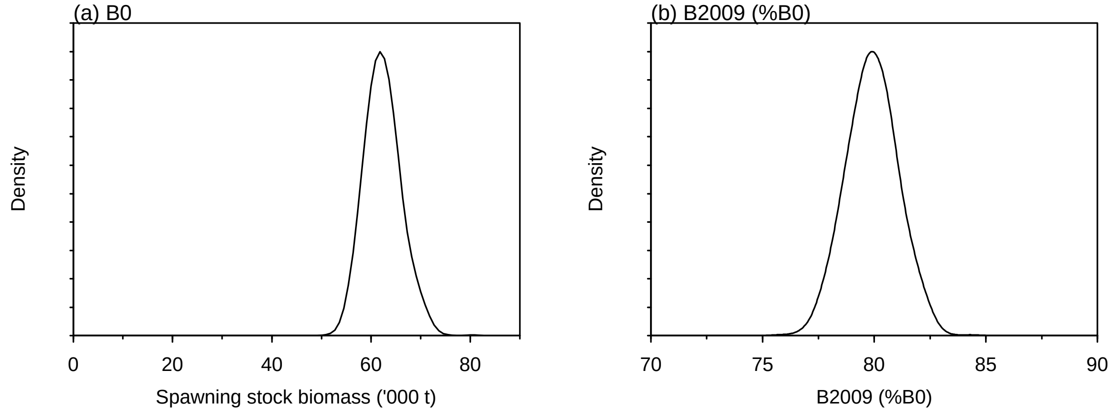

**Figure 2: MCMC posterior distributions for (a) B0 and (b) B2009 as a percent of B0 for the Ross Sea base case model.**

Overall, the results suggested that the decline in biomass due to fishing has been relatively small, and that current biomass is 78–82% $B_0$. Diagnostic plots of the observed proportions-at-age of the catch versus expected values show little evidence of inadequate model fit. Estimated selectivity curves appeared reasonable, with strong evidence of domed shaped selectivity. The tag-recapture data are reasonably well fitted, and were probably the only data that had any real weight within the model.

### (ii) SSRU 88.2E

### The stock assessment model

The stock assessment model for SSRU 88.2E had a very similar structure as that used for the Ross Sea and the previous assessment for SSRU 88.2E was in 2006. The models were run from 2002–2009, using a single-area, single-fishery model with selectivity assumed to be double-normal. The base case model was the same as for the Ross Sea, and used tag data from the 'selected' trip data set. Sensitivity models were run using data from New Zealand vessels only, and applying the 2007 assumed maturity curve with the same base case and sensitivities (see Table 11).

### Model estimates

Estimated initial equilibrium mid-season spawning stock biomass ($B_0$) ranged from 5900–10 000 t, with current biomass at 6090 t (95% C.I.s 4400–8 600 t, Table 14, Figure 3).

**Table 14: Median MCMC estimates (and 95% credible intervals) of B0, B2007, and B2009 for the 2006 882E base case model, and the updated 882E base case and sensitivity models.**

| Model | | $B_0$ | $B_{2009}$ | $B_{2009}$ (%$B_0$) |
|---|---|---|---|---|
| | 2006 base case | 10 300 (5 340–25 210) | – | – |
| R1 | Base case | 7 540 (5 870–10 020) | 6 090 (4 420–8 560) | 80.7 (75.3–85.5) |
| R2 | New Zealand tag data + 2007 maturity | 24 320 (14 500–45 950) | 22 830 (13 010–44 450) | 93.8 (89.7–96.7) |
| R3 | Selected trips + 2007 maturity | 10 970 (8 450–14 660) | 9 470 (6 950–13 160) | 86.3 (82.3–89.8) |

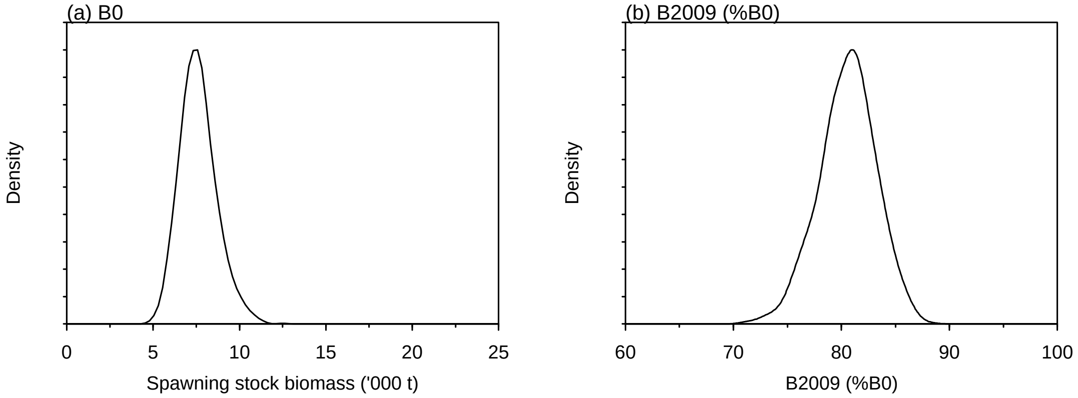

**Figure 3: MCMC posterior distributions for (a) B0 and (b) B2009 for the 882E base case.**

As with the Ross Sea model, the results suggested that the decline in biomass due to fishing has been small, and that current biomass was 75–86% $B_0$. Diagnostic plots of the observed proportions-at-age of the catch versus expected values show little evidence of inadequate model fit. Estimated selectivity curves appeared reasonable, with strong evidence of domed shaped selectivity. The tag-recapture data are reasonably well fitted, but, as for the Ross Sea model, were probably the only data that had any real weight within the model.

The New Zealand vessels case were much more optimistic than models using the ‘selected’ trips, suggesting a much higher initial and current biomass, although this model was relatively imprecise. The inclusion of the revised maturity ogive suggested a lower spawning stock biomass.

### 4.3 Yield estimates

Yields were estimated for the Ross Sea fishery using the methods described in Dunn & Hanchet (2007c). For each sample from the posterior distribution estimated for each model, the stock status was projected forward 35 years under a scenario of a constant annual catch (i.e., for the period 2010–2044). Recruitment from 2003–2043 was assumed to be lognormally distributed with a standard deviation of 0.6 with a Beverton-Holt stock-recruitment steepness $h = 0.75$. Future catch was assumed to follow the same split between fisheries as that in the years 2007–2009 (i.e. 0.5%, 81.2% and 15.3% of the total future catch was allocated to the shelf, slope and north fisheries respectively). The selectivity shift was assumed to be the average of shifts estimated for previous years. The same method was used for SSRU 88.2E, except that with only a single fishery, no catch split assumption was required.

The decision rules are $rule_1 = \max(Pr[\mathrm{SSB}_i < 0.2 \times B_0]) \leq 0.10$, where $i$ is any year in the projection period, and $rule_2 = Pr[\mathrm{SSB}_{+35} < 0.5 \times B_0] \leq 0.50$. They were evaluated by calculating the maximum future catch that meets both decision rule criteria.

#### (i) Ross Sea (Subareas 88.1 and SSRUs 88.2A and 88.2B)

The constant catch for which there was median escapement of 50% of the median pre-exploitation spawning biomass level at the end of the 35-year projection period was 2850 tonnes. At this yield there is a less than 10% chance of spawning biomass dropping to less than 20% of the initial biomass.

#### (ii) SSRU 88.2E

The constant catch for which there was median escapement of 50% of the median pre-exploitation spawning biomass level at the end of the 35-year projection period was 361 tonnes. At this yield there is a less than 10% chance of spawning biomass dropping to less than 20% of the initial biomass.

## 5. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

### 5.1 Incidental catch (fish and invertebrates)

The main bycatch species in this fishery is the Whitson’s rattail, *M. whitsoni*, which contributed about

4–16% of the total toothfish catch by weight from 1997/98 to 2008/09. The other major bycatch group is skates (mainly *Amblyraja georgiana* and *Bathyraja eatonii*). Skates (rajids) made up 9–10% of the total toothfish landings in 1997/98 and 1998/99, but the reported landings of skates has decreased in more recent years due to a tag release programme and the live release of untagged skates. In both programmes, only live skates are returned to the water and as a result are not included in landing data. Other fish bycatch species, including moray cods (*Muraenolepis* spp.), morid cods (mainly *Antimora rostrata*), icefish, and rock cods each contributed 1% or less of the overall catch.

**Table 15: Landings of managed by-catch species (macrourids, rajids and other species) in Subarea 88.1. Rajids cut from the longlines and released are not included in these estimates. Source: fine-scale data.**

| Season | Macrourids | | Rajids | | | Other species | |
|---|---|---|---|---|---|---|---|
| | Catch limit (t) | Reported landings (t) | Catch limit (t) | Reported landings (t) | Number released | Catch limit (t) | Reported landings (t) |
| 1996/97 | - | 0 | - | 0 | - | - | 0 |
| 1997/98 | - | 9 | - | 5 | - | 50 | 1 |
| 1998/99 | - | 22 | - | 39 | - | 50 | 5 |
| 1999/00 | - | 74 | - | 41 | - | 50 | 7 |
| 2000/01 | - | 61 | - | 9 | - | 50 | 14 |
| 2001/02 | 100 | 154 | - | 25 | - | 50 | 10 |
| 2002/03 | 610 | 66 | 250 | 11 | 966 | 100 | 12 |
| 2003/04 | 520 | 319 | 163 | 23 | 1 744 | 180 | 23 |
| 2004/05 | 520 | 462 | 163 | 69 | 4 996 | 180 | 24 |
| 2005/06 | 474 | 258 | 148 | 5 | 14 640 | 160 | 18 |
| 2006/07 | 485 | 153 | 152 | 38 | 7 352 | 160 | 43 |
| 2007/08 | 426 | 112 | 133 | 4 | 7 190 | 160 | 20 |
| 2008/09 | 430 | 183 | 135 | 7 | 7 088 | 160 | 16 |
| 2009/10 | 430 | 120 | 142 | 8 | 6 748 | 160 | # |

# Data not yet available.

Current catch limits for macrourids were derived from biomass estimates of the IPY-2008 trawl survey for the slope of the Ross Sea (see below). In each of the 2003/04, 2004/05, and 2005/06 seasons, the bycatch limit for *Macrourus* spp. was exceeded in at least one of the SSRUs leading to the closure of the fishery in those areas. No bycatch limit was exceeded in the last three seasons.

Current catch limits for Rajids and other species in Subarea 88.1 and Subarea 88.2 are proportional to the catch limit of *Dissostichus* species in each small-scale research unit (SSRU) based on the following rules:

- Rajids: 5% of the catch limit of *Dissostichus* spp. or 50 tonnes per SSRU whichever is greater;
- Other species combined: 20 tonnes per SSRU.

Catch limits for Rajids or for other species have never been exceeded.

**Table 16: Landings of managed by-catch species (macrourids, rajids and other species) in Subarea 88.2. Rajids cut from the longlines and released are not included in these estimates. Source: fine-scale data.**

| Season | Macrourids | | Rajids | | | Other species | |
|---|---|---|---|---|---|---|---|
| | Catch limit (t) | Reported landings (t) | Catch limit (t) | Reported landings (t) | Number released | Catch limit (t) | Reported landings (t) |
| 1996/97 | - | 0 | - | 0 | - | - | 0 |
| 1997/98 | - | 0 | - | 0 | - | - | 0 |
| 1998/99 | - | 0 | - | 0 | - | - | 0 |
| 1999/00 | - | 0 | - | 0 | - | - | 0 |
| 2000/01 | - | 0 | - | 0 | - | - | 0 |
| 2001/02 | 40 | 4 | - | 0 | - | 20 | 0 |
| 2002/03 | 60 | 18 | - | 0 | - | 140 | 8 |
| 2003/04 | 60 | 37 | 50 | 0 | 107 | 140 | 8 |
| 2004/05 | 60 | 21 | 50 | 0 | - | 140 | 3 |
| 2005/06 | 78 | 92 | 50 | 0 | 923 | 100 | 12 |
| 2006/07 | 88 | 54 | 50 | 0 | - | 100 | 13 |
| 2007/08 | 88 | 17 | 50 | 0 | – | 100 | 4 |
| 2008/09 | 90 | 58 | 50 | 0 | 265 | 100 | 14 |
| 2009/10 | 90 | 50 | 50 | 0 | # | 100 | # |

# Data not yet available.

## 5.2 Population assessments for rajids and macrourids

O'Driscoll et al. (2005) considered approaches to monitoring and assessing macrourids and rajids in Subarea 88.1 and recommended that a random bottom trawl survey would be the best approach to obtaining estimates of standing stock. Tag-recapture experiments for rajids, catch-curve analysis for macrourids and experimental manipulation of fishing effort are alternative methods that could be used to monitor abundance. An experimental tagging programme in the Ross Sea fishery was started in 2000, and a preliminary assessment of skates completed by Dunn et al. (2007). The IPY trawl survey of the Ross Sea slope was carried out in 2008 leading to an assessment of macrourids for the first time.

### Rajids

Preliminary estimates of the age and growth of *Amblyraja georgiana* in the Ross Sea suggested that these skates initially grow very rapidly for about five years, after which growth almost ceases (Francis and Ó Maolagáin, 2005). However, Francis & Gallagher (2008) presented an alternative interpretation of age and growth in *A. georgiana* that is radically different from the published interpretation. By counting fine growth bands in the caudal thorns instead of broad diffuse bands, they generated growth curves that suggest much slower growth, greater ages at maturity (about 20 years compared with 6–11 years) and greater maximum ages (28–37 years compared with 14 years). Several pieces of circumstantial evidence support the new interpretation, but a validation study is required to determine which growth scenario is correct. Updated length-weight relationships for skates were provided by Francis (2010).

Dunn et al. (2007) presented the data and a preliminary developmental model for Antarctic skates in SSRUs 881H, I, J and K of the Ross Sea. The developmental model attempted to create a catch history of all skates and rays in the Ross Sea, and integrate these data with the available observational data (including tag–recapture data) into a single integrated stock assessment model.

Dunn et al. (2007) concluded that aspects of the catch history were very uncertain, including the species composition, the weight and number of skates caught, the proportion discarded, and the survival of those tagged or discarded. The size composition of the commercial catch was also very uncertain because of the low numbers sampled each year. Most aspects of the tagging data were also uncertain including the actual numbers of skates released, the initial mortality of tagged skates, the tag-loss rate, and the numbers of skates scanned for tags. While updated summaries of the numbers of skate tag releases and recaptures have been reported, these data are still preliminary, and further work is required. Lastly, there is great uncertainty over the biological parameters including age and growth, natural mortality, steepness and size and age at maturity. However, the paper noted that whilst many aspects of this uncertainty remain, changes to the C2 data form since 2005 have led to substantial improvements in the landings and release data.

A fishery-wide tagging programme and sampling programme for skates was instituted by CCAMLR in 2008/09. It was anticipated that this initiative would lead to more Antarctic skates being tagged in Subareas 88.1 and 88.2. However, only 1907 and 99 skates were tagged in Subareas 88.1 and 88.2 respectively in 2008/09. SC-CAMLR agreed to continue this programme in the 2009/10 season.

### Macrourids

Biological data show that *M. whitsoni* is a relatively slow-growing, long-lived species with an estimated mean age-at-maturity of 10.6 years for males and 13.6 years for females (Marriott et al. 2005). The estimate of the precautionary pre-exploitation yield level ($\gamma$) for *M. whitsoni* in Subarea 88.1 was 0.01439 for a CV (on the estimate of virgin biomass) of 2.0 and 0.01814 for a CV of 0.5 (SC-CAMLR-XXII, Annex 5, paragraph 2). The low $\gamma$ indicates that this species has relatively low productivity. However, catch rates in the toothfish fishery have not declined, juveniles are not selected by the fishery, and comparison of long-line and trawl catch rates with other Antarctic areas suggest that the population in the Ross Sea may be large. A risk categorisation table was prepared for this species by O'Driscoll (2005). Recent genetic studies have shown that specimens originally identified in the Ross Sea region as *M. whitsoni* do in fact comprise two sympatric species: *M. whitsoni* and a new undescribed cryptic species referred to as *Macrourus* sp A. (Smith et al. 2010). Work is underway to determine the degree of overlap of these two species both within the Ross Sea region and circum-Antarctic.

Biomass and yield estimates of *M. whitsoni* for the Ross Sea fishery (Subareas 88.1 and SSRUs 88.2A and 88.2B) based on extrapolations under three different density assumptions from a trawl survey were given by Hanchet et al. (2008) (Table 17). The resulting biomass estimates had a CV of about 0.3. CCAMLR welcomed the concept of decoupling by-catch limits from those of target species and agreed to use estimates of biomass for Subarea 88.1, noting that SSRUs 88.2A and 88.2B are currently closed.

Yield estimates were calculated using the constant density assumption when extrapolating the biomass estimate across the slope region, noting that this would provide a more precautionary estimate of yield than one based on extrapolations using longline CPUE data. The resulting biomass estimate for SSRUs 88.1HIK was 21 410 t which gave a yield estimate of 388 t. This yield estimate was then apportioned across the 5 SSRUs taking into account maximum historical catches (Table 18). The catch limits per SSRU detailed in Table 18 were agreed by CCAMLR for the 2009/10 season.

**Table 17: Biomass estimates from the trawl surveys for the BioRoss 400–600 and 600–800 m and IPY-CAML 600–1200 and 1200–2000 m strata and extrapolated biomass estimates (with c.v.s) for the remaining strata based on three methods of extrapolation.**

| Survey | Depth range (m) | Biomass (t) | Extrapolated biomass (t) | | |
|---|---|---|---|---|---|
| | | | constant density | CPUE (all vessels) | CPUE (NZ vessels) |
| BioRoss – 88.1H | 400–600 | 230 | 230 (49) | 230 (49) | 230 (49) |
| BioRoss – 88.1H | 600–800 | 3 531 | 3 531 (38) | 3 531 (38) | 3 531 (49) |
| SSRU 88.1H west | 800–1200 | | 92 (50) | 83 (54) | 103 (55) |
| SSRU 88.1H west | 1200–2000 | | 713 (40) | 1 114 (49) | 1 038 (47) |
| IPY - 88.1H | 600–1200 | 975 | 975 (50) | 975 (50) | 975 (50) |
| IPY - 88.1H | 1200–2000 | 3 356 | 3 356 (40) | 3 356 (40) | 3 356 (40) |
| SSRU 88.1 I | 600–1200 | | 3 297 (50) | 7 883 (51) | 5 992 (50) |
| SSRU 88.1 I | 1200–2000 | | 4 670 (40) | 11 168 (42) | 8 576 (41) |
| SSRU 88.1 K | 600–1200 | | 1 539 (50) | 5 027 (51) | 2 774 (51) |
| SSRU 88.1 K | 1200–2000 | | 2 998 (40) | 5 995 (45) | 9 111 (43) |
| HIK Sub-total | | | 21 410 | | |
| SSRU 88.2 A+B | 600–1200 | | 1 404 (50) | 1 396 (58) | 857 (60) |
| SSRU 88.2 A+B | 1200–2000 | | 4 087 (40) | 525 (70) | — |
| 88.2 A, B Sub-total | | | 5 491 | | |
| Total | | | 26 892 (29) | 41 823(28) | 36 542(30) |

**Table 18: Estimate yield, maximum historic catch, and revised catch limit of Macrourus spp for the Ross Sea fishery.**

| Region | Estimated yield | Maximum historic catch | Revised catch limit |
|---|---|---|---|
| 881BCG | - | 34 | 40 |
| 881HIK | 388 | 390 | 320 |
| 881JL | | 52 | 70 |
| 881M | 0 | 0 | 0 |
| 882AB | 100 | 8 | 0 |
| Total | 488 | | 430 |

## Mitigation measures

Since the start of the 2000/01 season, rajids likely to survive have been cut free and released at the surface as a measure to reduce rajid mortality. The survival of at least some of these skates has been demonstrated by the recapture of some 47 tagged skates (Ballara et al. 2006), and by the results of survivorship experiment in tanks carried out by the UK.

Potential mitigation measures for macrourids were examined by Ballara & O’Driscoll (2005). They used a standardised CPUE analysis to determine factors affecting by-catch rates of macrourids in the Ross Sea. The analysis was based on fine-scale haul-by-haul data and observer data from all vessels in the fishery from 1997/98 to 2004/05. The major factors influencing macrourid bycatch were vessel, area, and depth. Catch rates of *M. whitsoni* were highest along the shelf edge (SSRUs 88.1E, 88.1I, 88.1K and 88.2E) in depths from 600 to 1000 m, and there was an order of magnitude difference in reported macrourid catch rates between different vessels. Examination of vessel characteristics showed that catch rates of macrourids were lower with the Spanish line system than with the autoline system. This effect was confounded by the bait type, as Spanish line vessels tended to use the South American pilchard as bait, whereas autoline vessels used varying species of squid and/or mackerel.

However, the difference in macrourid catch rates between the few Spanish line vessels that used squid and mackerel for bait and the majority that used pilchards was much less than the overall difference between Spanish line and autoline vessels. Russian and Korean vessels reported extremely low catch rates compared to other vessels fishing in the same location.

There is a 'move-on' rule in place to help prevent localised depletion of bycatch species. This rule requires a vessel to move to another location at least 5 n. miles distant if the bycatch of any one species is equal to or greater than 1 tonne in any one set. The vessel is not allowed to return to within 5 n. miles of the location where the bycatch exceeded 1 tonne for a period of at least five days (Conservation Measure 33-03 (2010)).

## 5.3 Incidental catch (seabirds and marine mammals)

Seabirds have not been caught in this toothfish fishery with the exception of one Southern giant petrel (*Macronectes giganteus*) caught in 2003/04 (Table 19). Considerable effort has been put into mitigation of seabird captures in the fishery, through implementation of CCAMLR Conservation Measures regarding line sink rate, use of streamer lines, seasonal restrictions on fishing, prohibition of offal dumping, line weighting and only allowing daytime setting under strict conditions.

**Table 19: Seabird incidental mortality limit, reported seabird incidental mortality, incidental mortality rate, and estimated incidental mortality for the years 1997/98 to 2009/10 in Subareas 88.1 and 88.2.**

| Season | Incidental mortality limit | Incidental mortality rate (seabirds/thousand hooks) | Estimated incidental mortality |
|---|---|---|---|
| 1997/98 | | 0 | 0 |
| 1998/99 | | 0 | 0 |
| 1999/00 | | 0 | 0 |
| 2000/01 | | 0 | 0 |
| 2001/02 | 3* | 0 | 0 |
| 2002/03 | 3* | 0 | 0 |
| 2003/04 | 3* | 0.0001 | 1 |
| 2004/05 | 3* | 0 | 0 |
| 2005/06 | 3* | 0 | 0 |
| 2006/07 | 3* | 0 | 0 |
| 2007/08 | 3* | 0 | 0 |
| 2008/09 | 3* | 0 | 0 |
| 2009/10 | 3* | 0 | 0 |

* Per vessel during daytime setting.

### Mitigation measures

Mitigation measures were implemented in line with recommendations from the CCAMLR *ad hoc* Working Group on Incidental Mortality Associated with Fishing (WG-IMAF). This group again in 2008 assessed the risk level of seabirds in the fishery in Subarea 88.1 as low (category 1, lowest risk, with highest risk being category 5) south of 65°S, medium (category 3) north of 65°S and overall as medium (category 3) and CCAMLR applied:

- Conservation Measure 25-02 (2009). This Conservation Measure concerns line-weighting, night setting, use of streamer lines and prohibition of offal dumping. Under the risk category for these Subareas, there is an exemption to paragraph 4 to allow for daytime setting subject to line sink rate requirements and seabird incidental mortality limits.

- No restriction to the longline fishing season south of 65°S, but longline fishing north of 65°S is restricted to the period outside the breeding season of at risk species (where known or relevant).

WG-IMAF assessed the risk level of seabirds in the longline toothfish fishery in Subarea 88.2 as low (category 1) and CCAMLR applied:

- Conservation Measure 25-02 (2009) (with exemption to paragraph 4 to allow for daytime setting) and no need to restrict the longline fishing season.

Conservation Measure 25-02 applies and in recent years has been linked to an exemption for night setting in Conservation Measure 24-02 subject to a seabird incidental mortality limit. Vessels catching three birds are required to stop fishing in the sub-area concerned. Offal and other discharges are regulated under annual CCAMLR conservation measures (Conservation Measures 41-09 and 41-10).

Near full implementation of the required CCAMLR Conservation Measures has meant that seabird captures have been successfully avoided during this toothfish longline fishery. There is a high degree of certainty in the estimates provided of seabird captures, given the high level of observer coverage (100% of vessels covered by two observers, greater than 40% of all hooks hauled directly observed).

### 5.4 Maintenance of ecological relationships

Developments in evaluating ecosystem effects of the Antarctic toothfish fishery were discussed at the FEMA and FEMA II workshops (SC-CAMLR-XXVI/BG/6, paragraphs 45 to 48 and SC-CAMLR-XXVIII/3). The FEMA and FEMA II workshops noted that the fishery for Antarctic toothfish may affect ecological relationships in the Ross Sea region by interaction between toothfish and its predators and interactions between toothfish and its prey.

The predators of toothfish include Type C killer whales, sperm whales and Weddell seals. A mass-balance food-web model suggested that toothfish formed about 6–7% of the diet of its predators at the scale of the Ross Sea (Pinkerton et al. 2010a etc), but provided no support for the hypothesis that depletion of toothfish stocks would greatly change the diet of toothfish predators at the population scale (Pinkerton et al. 2010a). However, the consumption of toothfish in particular locations at particular times of the year, or by particular parts of predator populations may be especially important to some predators, even though the total consumption of toothfish by all individuals of a predator species is relatively low. With respect to Weddell seals, Pinkerton et al. (2008b) reviewed information on interactions with toothfish from habitat overlap, diver observations, animal-mounted cameras, observations from field scientists in McMurdo Sound, stomach contents, vomit and scats analysis, stable isotopes of carbon and nitrogen, and also compared natural mortality rates of Antarctic toothfish in McMurdo Sound with potential consumption by Weddell seals. Pinkerton et al. (2008b) concluded that while toothfish were a prey item for Weddell seals in McMurdo Sound between October and January, the extent of the relationship was not known.

The mass-balance food-web model also suggested that toothfish consumed 70% of the annual production of demersal species as prey items (Pinkerton et al. 2009), and so a reduction of the toothfish population might have a large impact on the mortality of these species. The FEMA workshop noted that there was an additional interaction with the fishery, whereby demersal fish are taken as by-catch so that a reduction in natural mortality may be partially offset by an increase in fishing mortality.

Changes to the abundance of toothfish prey species may have effects on other species in the food-web through second-order effects (e.g. a “keystone” predator trophic effect[2] or trophic cascades[3]), however, these are likely to be dependent on the particular ecosystem and may be difficult to predict. As toothfish are a species that is a large and mobile predator, their prey species are long-lived, the functional predator diversity is low, and the predator intra-guild predation is weak or absent, then the potential for a trophic cascades in marine systems may be higher (Shurin et al. 2002, Heithaus et al. 2008).

The FEMA II workshop also noted that the escapement level of 50% is the proportion of spawning biomass permitted to escape the fishery over the long term, and that as a consequence, the sub-mature fish would have a much higher escapement (e.g., >90% for fish <100 cm) (SC-CAMLR-XXVIII, Annex 3, Figure 1). However, the FEMA II workshop noted that the escapement level in the decision rule for the spawning biomass may need to be modified upwards if the size/age classes of *Dissostichus* spp. that are important prey for predators are reduced below the level needed to safeguard predators. Preliminary work towards developing a Minimum Realistic Model of the toothfish fishery was discussed by Pinkerton et al. (2010b).

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[2] Keystone predators maintain biodiversity by preferentially consuming competitively dominant prey species. If keystone predators are removed or their biomass reduced, abundance of some prey species can increase to levels where they start to exclude subordinate competitors.

[3] Trophic cascade: reorganisation of the lower trophic levels of an ecosystem due to the change in abundance of a predator.

### 5.5 Ecosystem indicators

At present we cannot predict the effects of the toothfish fishery on ecosystem relationships in the Ross Sea region. There is a need to establish appropriate monitoring in the Ross Sea to ascertain how species and ecological relationships are affected by the fishery. Monitoring should focus on species most likely to be affected by the toothfish fishery in the first instance.

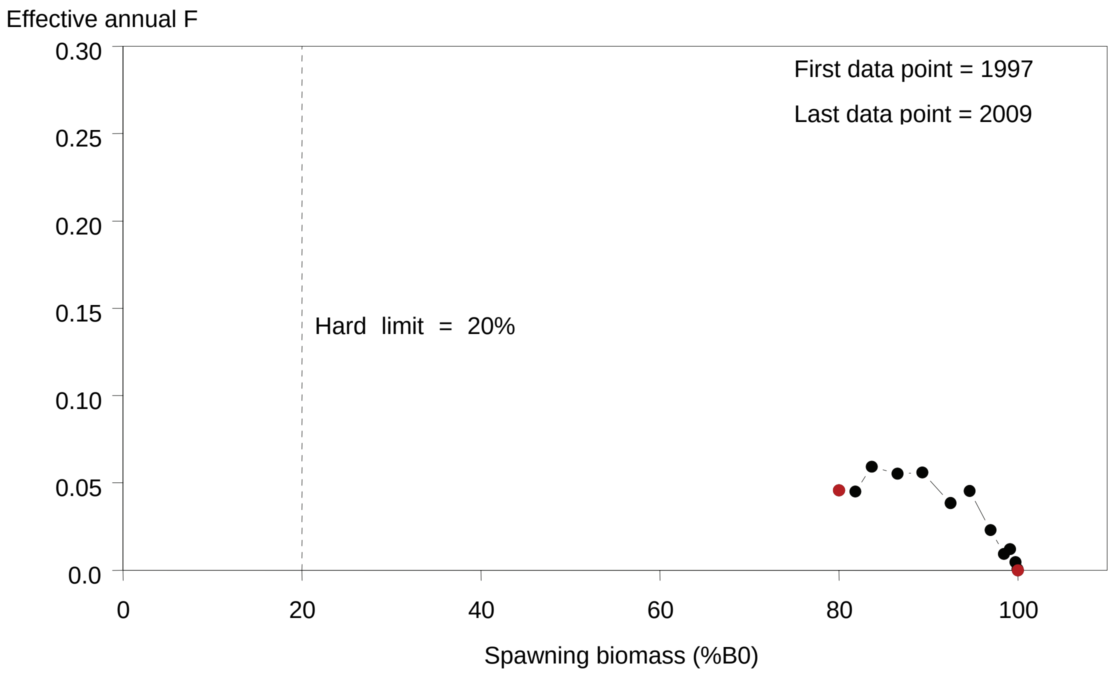
## 6. STATUS OF THE STOCKS

### Stock structure assumptions

Uncertainty remains over spawning dynamics and early life history of Antarctic toothfish. The present hypothesis is that Antarctic toothfish in Subareas 88.1 and 88.2 spawn to the north of the Antarctic continental slope, mainly on the ridges and banks of the Pacific-Antarctic Ridge. It has been recommended that for stock assessment purposes Subareas 88.1 and SSRUs 88.2A and 88.2B be treated as a 'Ross Sea' stock, whilst SSRU 88.2E be treated as a separate 'SSRU 88.2E' stock (CCAMLR 2006). However, it is noted that the stock affinity of the assessed stocks with toothfish in surrounding areas is not well understood.

### Ross Sea stock

| **Stock Status** | |
|---|---|
| Year of Most Recent Assessment | 2009 |
| Assessment Runs Presented | A single base case model run was accepted by CCAMLR, model run R1. |
| Reference Points | CCAMLR decision rule[4]: 50% $B_0$ after 35 years with Pr(SSB > 20% $B_0$) > 0.9 for a constant catch harvest strategy<br>Hard Limit: 20% $B_0$ with Pr(SSB > 20% $B_0$) ≥ 0.1 |
| Status in relation to CCAMLR decision rule | $B_{2009}$ was estimated to be 80% $B_0$. Virtually Certain (> 99% probability) to be above the long term target (50% $B_0$) |
| Status in relation to Hard Limit | $B_{2009}$ is Virtually Certain (> 99% probability) to be above the Hard Limit |
| Historical Stock Status Trajectory and Current Status | |



| **Fishery and Stock Trends** | |
|---|---|
| Recent Trend in Biomass or Proxy | Estimates of biomass have never been below 50% $B_0$, and the fishery is still in a fish-down phase. |
| Recent Trend in Fishing Mortality or Proxy | Fishing pressure has increased early in the fishery and has stabilised at about target levels. |
| Other Abundance Indices | – |
| Trends in Other Relevant Indicators or Variables | The CPUE indices and the catch-at-age data are relatively short time series, and are not informative for determining current or initial stock size. For assessments, the tag-recapture data provide the best information on stock size, but the total number of fish recaptured in both areas is small and may introduce bias into the model. Although the absolute stock size is uncertain, the available evidence (tag recapture data, catch rates, length frequency data) suggests that the stock has been lightly exploited to date. |

| **Projections and Prognosis** | |
|---|---|
| Stock Projections or Prognosis | The biomass of the stock is expected to decline slowly over the 35 year projection period |
| Probability of Current Catch or TACC causing decline below Decision rile/Limit | Decision rule: As likely as not at the end of a 35 year projection period<br>Hard Limit: Exceptionally unlikely |

| **Assessment Methodology** | | |
|---|---|---|
| Assessment Type | Level 1 – Quantitative stock assessment | |
| Assessment Method | Age-structured CASAL model with Bayesian estimation of posterior distributions | |
| Main data inputs | Multi-year tag-recapture data<br>Commercial catch-at-age proportions<br>New data in 2009 included updated tag-release and recapture data and catch-at-age data for 2008 | |
| Period of Assessment | Latest assessment: 2009 | Next assessment: 2011 |

| | |
|---|---|
| Changes to Model Structure and Assumptions | Revised maturity ogive |
| Major Sources of Uncertainty | The models assume homogenous mixing of tags within the population. Other major sources of uncertainty include estimates of the natural mortality rate, stock structure and migration patterns, stock-recruit steepness and natal fidelity assumptions with respect to other areas. Uncertainty about the size and variability of year classes affects the reliability of short-term stock projections. |

| **Qualifying Comments** |
|---|
| For the base case model and for sensitivity runs, current biomass is estimated to be between 80% and 83% $B_0$. Estimates of long term yield based on the CCAMLR decision rules[4] were 2850 t. At its 2009 meeting CCAMLR agreed to set the catch limit in 2009/10 to 2850 t for the Ross Sea (CCAMLR 2009). |

| **Fishery Interactions** |
|---|
| Main bycatch species are macrourids and rajids |

**SSRU 88.2E**

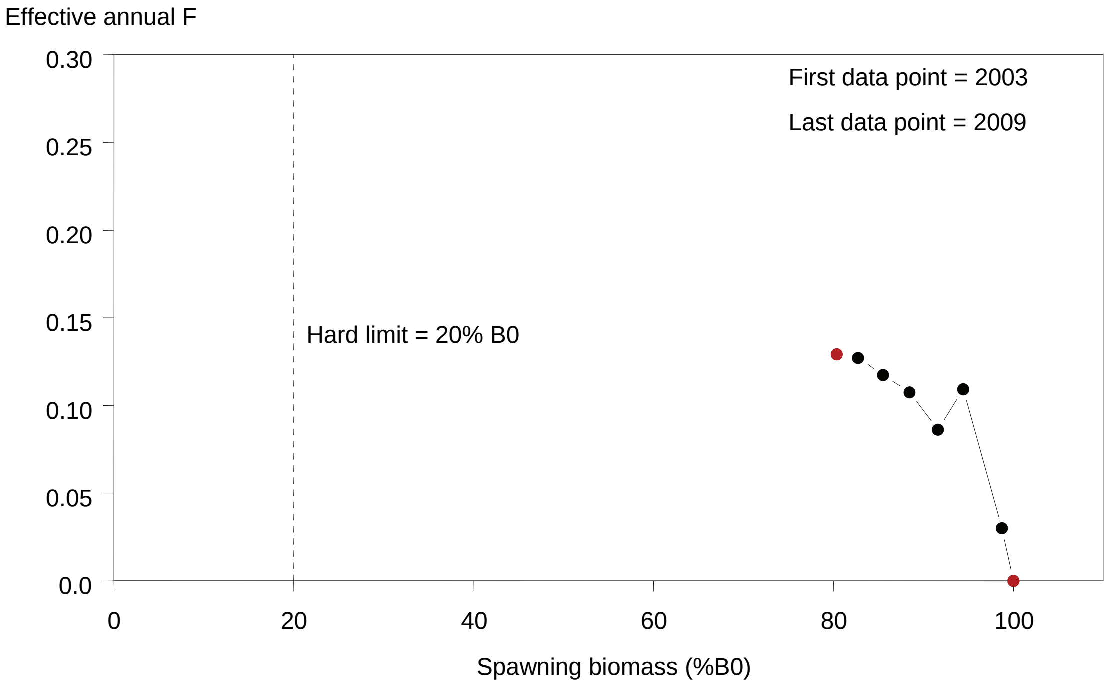
| **Stock Status** | |
|---|---|
| Year of Most Recent Assessment | 2009 |
| Assessment Runs Presented | A single base case model run was accepted by CCAMLR, model run R1. |
| Reference Points | CCCAMLR decision rule[4]: 50% $B_0$ after 35 years with Pr(SSB > 20% $B_0$) > 0.9 for a constant catch harvest strategy<br>Hard Limit: 20% $B_0$ with Pr(SSB > 20% $B_0$) ≥ 0.1 |
| Status in relation to CCAMLR decision rule | $B_{2009}$ was estimated to be 81% $B_0$. Virtually certain (> 99% probability) to be above the long term target (50% $B_0$) |
| Status in relation to Hard Limit | $B_{2009}$ is Virtually Certain (> 99% probability) to be above the Hard Limit |

---

[4] Yield estimates are calculated by projecting the estimated current status under a constant catch assumption, using the decision rules:

1. Choose a yield, $\gamma_1$, so that the probability of the spawning biomass dropping below 20% of its median pre-exploitation level over a 35-year harvesting period is 10% (the depletion probability);
2. Choose a yield, $\gamma_2$, so that the median escapement in the SSB at the end of a 35 year period is 50% of the median pre-exploitation level (the level of escapement); and
3. Select the lower of $\gamma_1$ and $\gamma_2$ as the yield.

In the models, the depletion probability was calculated as the proportion of samples from the Bayesian posterior where the predicted future spawning stock biomass (SSB) was below 20% of $B_0$ in that respective sample in any one year, for each year over a 35-year projected period. The level of escapement was calculated as the proportion of samples from the Bayesian posterior where the predicted future status of the SSB was below 50% of $B_0$ in that respective sample at the end of a 35-year projected period.

| Historical Stock Status Trajectory and Current Status |
|---|
|  |

| **Fishery and Stock Trends** | |
|---|---|
| Recent Trend in Biomass or Proxy[7] | Estimates of biomass have never been below 50% $B_0$, and the fishery is still in a fish-down phase. |
| Recent Trend in Fishing Mortality or Proxy | Fishing pressure has increased early in the fishery and has stabilised at about target levels. |
| Other Abundance Indices | – |
| Trends in Other Relevant Indicators or Variables | The CPUE indices and the catch-at-age data are relatively short time series, and are not informative for determining current or initial stock size. For assessments, the tag-recapture data provide the best information on stock size, but the total number of fish recaptured in both areas is small and may introduce bias into the model. Although the absolute stock size is uncertain, the available evidence (tag recapture data, catch rates, length frequency data) suggests that the stock has been lightly exploited to date. |

| **Projections and Prognosis** | | |
|---|---|---|
| Stock Projections or Prognosis | The biomass of the stock is expected to decline slowly over the 35 year projection period until the stock meets the target level | |
| Probability of Current Catch or TACC causing decline below Decision rule/Limit | Decision rule: As likely as not at the end of a 35 year projection period<br>Hard Limit: Exceptionally unlikely | |
| **Assessment Methodology** | | |
| Assessment Type | Level 1 – Quantitative stock assessment | |
| Assessment Method | Age-structured CASAL model with Bayesian estimation of posterior distributions | |
| Main data inputs | Multi-year tag-recapture data<br>Commercial catch-at-age proportions<br>New data in 2009 included updated tag-release and recapture data and catch-at-age data for 2007–2008 | |
| Period of Assessment | Latest assessment: 2009 | Next assessment: 2011 |
| Changes to Model Structure and | Revised maturity ogive | |

| Assumptions | |
|---|---|
| Major Sources of Uncertainty | The models assume homogenous mixing of tags within the population. Other major sources of uncertainty include estimates of the natural mortality rate, stock structure and migration patterns, stock-recruit steepness and natal fidelity assumptions with respect to other areas. Uncertainty about the size and variability of year classes affects the reliability of short term stock projections. |

| **Qualifying Comments** |
|---|
| For the base case model and for sensitivity runs, current biomass is estimated to be between 81% and 94% $B_0$. Estimates of long term yield based on the CCAMLR decision rules[2] were 361 tonnes. At its 2009 meeting CCAMLR agreed to set the catch limit in 2009/10 to 361 t (CCAMLR 2009). |

| **Fishery Interactions** |
|---|
| Main bycatch species are macrourids and rajids |

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