MINISTRY OF FISHERIES
Te Tautiaki i nga tini a Tangaroa

ISSN 1175-1584

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New Zealand Fisheries Assessment Report 2003/43
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Published by Ministry of Fisheries
Wellington
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ISSN 1175-1584

Citation:
Hanchet, S.M.; Stevenson, M.L.; Horn, P.L.; Blackwell, R.G. (2003).
Characterisation of the exploratory fishery for toothfish (*Dissostichus mawsoni* and *D. eleginoides*) in the Ross Sea, and approaches to the assessment of the stocks.
New Zealand Fisheries Assessment Report 2003/43. 27 p.

This series continues the informal
New Zealand Fisheries Assessment Research Document series
which ceased at the end of 1999.

EXECUTIVE SUMMARY

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This report summarises information on the biology and exploratory fishery for toothfish (*Dissostichus mawsoni* and *D. eleginoides*) in the Ross Sea collected between May 1997 and May 2002. The Ross Sea fisheries resources are managed under CCAMLR (Convention for the Conservation of Antarctic Marine Living Resources) jurisdiction, and the area is divided into two main management areas: the western Ross Sea (Subarea 88.1) and the eastern Ross Sea (Subarea 88.2). Fisheries data have been used to delineate the distribution of the two toothfish species. *D. mawsoni* extends from 78° S to the Antarctic Convergence at about 60° S, whilst *D. eleginoides* extends from about 50–55° S (north of the Antarctic Convergence and outside the CCAMLR areas) down to about 75° S. However, the main region of overlap appears to occur in latitudes 62.5–65° S, where catches have been similar and both species are caught on almost every longline set.

The main toothfish species taken in all years in the fishery has been *D. mawsoni*, with *D. eleginoides* contributing at most 5% of the annual catch. Toothfish has formed between 73% and 90% of the total longline catch each year. The main bycatch species is *Macrourus whitsoni*, which has varied from 6 to 17% (mean 10%) by year. The other main bycatch species is *Amblyraja georgiana*, which has varied from 1 to 10% between years. Other species contributed only a minor proportion of the catch. The results of the first standardised CPUE analysis of *D. mawsoni* are presented. The analysis is preliminary and we recommend that subsequent analyses be restricted to the main fishing grounds.

The length and age composition of the catch are presented from 1998 to 2002. The age distribution has varied considerably between years, reflecting the different areas and depths fished each year. For example, in 2002 there was a wider spread of ages and a greater proportion of older fish than in the previous two seasons. In most years the catch comprises fish from age 3 to 35 years of both sexes, although fish aged 5 to 20 are most abundant. Biological parameters are presented for *D. mawsoni*, and, where available, for *D. eleginoides*. Ageing of both species has been at least partially validated, and they have similar growth rates and reach a similar maximum age. Natural mortality for *D. mawsoni* was estimated to be in the range 0.15–0.22. Results of movement (from tag recaptures) are presented and the likely distribution at various life stages is summarised.

No abundance indices have yet been developed for the toothfish fishery. Several options including the use of commercial CPUE data, the use of research sets as a quantitative longline survey, tagging studies, and acoustics are all discussed. It is considered unlikely that any one of the above methods will be able to provide estimates of abundance and yield in the short term. It is therefore recommended that the development of all methods be continued.

The method used by CCAMLR to assess the Subarea 88.1 and 88.2 fisheries at its 2002 meeting is presented. The estimates must be considered very preliminary because they are based on analogy with a different toothfish species in another part of CCAMLR waters. However, several aspects of the assessment suggest that the yields and catch limits can be regarded as precautionary; the area used for the Ross Sea fishery is only the fished area; the lower 95% confidence bound of the ratio of fish densities was used rather than the mean; the estimate of yield calculated for South Georgia (Subarea 48.3) is precautionary; and the resulting yield estimates are further reduced by 50–70%. It is clear, however, that an assessment based on analogy is not an ideal basis on which to manage a fishery in the medium to long term. It is imperative that abundance indices and yield estimates are estimated for the Ross Sea area independently of other areas of the CCAMLR region. Priority therefore needs to be given to the development of abundance indices that can be used to monitor and assess the stock.

1. INTRODUCTION

Toothfish are large endemic Nototheniids living in Antarctic and subAntarctic waters. Three species of toothfish are known to occur: the Antarctic toothfish (*Dissostichus mawsoni*), the Patagonian toothfish (*D. eleginoides*), and *Gvozdarus svetovidovi*, this last species being very rare (Everson 2002). The distribution of the first two species is circumpolar, and, as its common name implies, *D. mawsoni* has a more southern distribution and is found in higher latitudes south of the Antarctic Convergence. *D. eleginoides* is widespread throughout the southern ocean, typically extending north from the Antarctic Convergence into subantarctic waters of the Atlantic, Pacific, and Indian Oceans.

The two main toothfish species support valuable international longline and trawl fisheries. Finfish fisheries in Antarctic waters are largely managed under CCAMLR[1] jurisdiction. 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). Within the Convention area some fisheries are managed by CCAMLR member countries, which have EEZs around their subantarctic Islands. Catches of *D. eleginoides* are taken both inside and outside the Convention area, and catches to the north of the Convention area are taken both within National EEZs and in the High Seas. There is considerable concern with the level of unregulated and illegal fishing of this species (SC-CAMLR-XX 2001). In contrast, *D. mawsoni* appears to be restricted to waters managed solely by CCAMLR. To date, the main fishery for this species has taken place in Subarea 88.1 (the western Ross Sea) and to a lesser extent in Subarea 88.2 (the eastern Ross Sea) (Figure 1).

The Ross Sea fishery was initiated by a New Zealand longline vessel in 1997. The New Zealand vessels have now returned to this area and conducted an exploratory fishery[2] there for the past five seasons. A large amount of research on both toothfish and bycatch species has been carried out in that time. Much of this research has been reported in background documents to the CCAMLR Fish Stock Assessment Working Group (WG-FSA), and little has been published in the scientific literature. Indeed few data that can be used to help derive estimates of productivity, biomass, or yields have been published for *D. mawsoni*. Yukhov (1971, 1982) summarised data derived from specimens taken from the stomachs of sperm whales to the north of the Ross Sea. Limited information on age and growth was provided by Burchett et al. (1984), on feeding (Pakhomov & Pankratov 1992), and on aspects of body size and gonadal histology by Eastman & De Vries (2000). Other results on distribution, growth, and feeding are generally in the grey literature and are not easily accessible.

The aim of the present report is to summarise what is known about the biology and fishery for *D. mawsoni* (and where appropriate *D. eleginoides*) in the Ross Sea, and approaches taken to stock assessment in the region to date. A description of the area is beyond the scope of this report, but a good summary of the Ross Sea environment and ecosystem can be found in Waterhouse (2001).

2. TOOTHFISH DISTRIBUTION

2.1 Geographical distribution

The geographical distribution of the two toothfish species was summarised by Everson (2002). *D. eleginoides* is more typically found in subAntarctic waters, whereas *D. mawsoni* is found in Antarctic waters.

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[1] CCAMLR (Convention for the Conservation of Antarctic Marine Living Resources) has 24 members and was set up in 1982 in response to concern over the exploitation of Antarctic marine living resources (in particular krill and finfish). Data are analysed by the Scientific Committee through its ad hoc working groups on fish stock assessment (WG-FSA) and ecosystem monitoring and management (WG-EMM), and management advice is provided to the Commission. The Commission makes decisions on the management of the fisheries through a series of Conservation Measures. For further details see www.ccamlr.org.

[2] As distinct from an assessed fishery, which an exploratory fishery becomes when sufficient data and stock information are judged to be available for informed and accurate assessment of a fishery.

More specific data on the distribution of *D. mawsoni* in the Pacific Ocean Sector (area 88) was given by Yukhov (1971). From the analysis of sperm whale stomachs he concluded that *D. mawsoni* extended as far north as the Antarctic Convergence (Polar Front). In the vicinity of the Ross Sea (Subareas 88.1 and 88.2) this was at about 58–60° S, whereas further to the east (Subarea 88.3) this was at 60–62° S. *D. eleginoides* is known to occur from 54–55° S in large numbers along the Macquarie Ridge (Everson 2002) and to extend occasionally as far north as the Chatham Rise (MONZ).

Data collected during the exploratory fishery by New Zealand in Subareas 88.1 and 88.2 provide new information on the distribution of the two species in these areas. The number of sets catching *D. mawsoni* and *D. eleginoides* is given by latitude in Table 1. There has been little fishing from 60 to 62.5° S – a single set made by a New Zealand vessel at 60° S caught only *D. eleginoides*. However, from 62.5 to 65° S over 70% of the lines have one or both of the species present. In fact, 72% of the lines set at this latitude caught both species on the same line, whilst a further 10% lines caught only *D. eleginoides*. The total catch of the two species has also been similar in this region (Table 1). This demonstrates clear overlap of the two species in these latitudes. Further south, the number and proportion of lines catching *D. mawsoni* increased, whilst those catching *D. eleginoides* declined. At 65–67.5° S over 95% of the lines contained *D. mawsoni*, whilst only 45% of the lines contained *D. eleginoides*. Furthermore, the proportion of *D. eleginoides* in the catch was only about 1%. *D. mawsoni* continued to be caught on 90–98% of the lines further south to 78° S. In contrast, the proportion of *D. eleginoides* on lines had declined to about 1% by latitudes 70–72.5° S, and the proportion in the catch was less than 1%. The furthest south an individual *D. eleginoides* has been caught is 75.5° S.

2.2 Depth distribution

The two species show no clear separation by depth (Hanchet et al. 2001, 2002). *D. mawsoni* have been caught in the Ross Sea fishery from about 500 m down to a maximum depth of about 2000 m (Figure 2). Highest catches are from 800 to 1800 m. There is a positive relationship ($P<0.05$) between *D. mawsoni* length and bottom depth (Figure 3). Similar depth preferences and length-depth relationships have been reported for *D. eleginoides* (Everson 2002).

3. THE TOOTHFISH FISHERY

3.1 Commercial catches

Information on catch was extracted from the CCAMLR database and observer electronic logbooks by Hanchet et al. (2002). Catch data used were those reported by the observers, which are the best available estimates of greenweight for the trip, and include fish lost as the longline was being hauled by the ship. In this report, the word fishing "season" refers to the period January–May, the months when the fishery operates in the Ross Sea (i.e., the 2002 season is part of the 1 November 2001 to 31 October 2002 CCAMLR fishing year).

The development of the exploratory toothfish fishery in Subareas 88.1 and 88.2 is summarised in Table 2. Apart from small catches by two South African and two Uruguayan vessels in 2001, New Zealand vessels have developed the exploratory fishery. The New Zealand catch in Subarea 88.1 has steadily increased from under 1 t in 1997 to 1 333 t in 2002. There was a slight decline in catch in 2001 caused by vessels not being able to fish the main grounds because of heavy ice conditions. Subarea 88.2 was fished for the first time by New Zealand in 2002.

For the 1997 season a total catch limit of 1980 t was in place for Subarea 88.1 (Table 2). The catch limits and catches since 1998 are shown by small scale research unit (SSRU) in Table 3. In 1998 and

1999 a separate catch limit was introduced for SSRU 881A. Separate catch limits for the remaining SSRUs were introduced for the first time in 2000. The highest catches have been taken in SSRU 881C. Apart from SSRU 881C in 2002, the catches have not been constrained by the catch limits. All exploratory fishing in Subarea 88.2 has been carried out in SSRU 882A, where the total catch of 41 t was caught against a catch limit of 250 t.

Details of the New Zealand exploratory fishery are summarised in Table 4. Up to 3 vessels per year have been involved in the fishery. From 1998 to 2000 fishing was confined to the period January to March, but in 2001 and 2002 fishing extended into May. The main toothfish species taken in all years has been *D. mawsoni*, with *D. eleginoides* contributing at most 5% of the catch in any one year. *D. mawsoni* has also dominated the catch in all SSRUs except for the northern most area (SSRU 881A) where total catches have been more similar (see also Table 1).

A 100 t catch limit has been set on each fine scale rectangle (FSR) (defined as an area of 0.5° latitude by 1° longitude) in all exploratory fisheries to reduce the possibility of localised depletion and to act as an effort-spreading mechanism. Hanchet et al. (2002) showed that there have been between 28 and 91 FSRs fished each year and that a total of 171 FSRs have been fished over the five years. They concluded that fishing operations to date have had a high exploratory component. Catches from the FSRs were generally low, mainly ranging from 2.5 to 7.5 t. However, there were several instances in 2001 and 2002 when the catch limit of 100 t was almost reached.

Hanchet et al. (2002) provided a comprehensive analysis of the entire catch from the toothfish fishery. They concluded that there were substantial problems with species identification, particularly for rattails (Macrouridae) in the early part of the fishery, and hence reported catch by major species group. Their summary of the reported catch is reproduced in Table 5. Toothfish has formed between 73% and 90% of the total longline catch each year. The main bycatch species group was rattails (Macrouridae), which has varied from 6 to 17% (mean 10%) by year. The main species caught is *Macrourus whitsoni*, but two other species, *M. holotrachys* and *Coryphaenoides armatus*, have also been identified (Marriott & McMillan 2002). The other main bycatch species group is skate, which has varied from 1 to 11% between years. The main species caught is *Amblyraja georgina*, with the larger *Bathyraja eatonii* forming less than 10% of the skate catch. Other species contributed only a minor proportion of the catch (Table 5).

3.2 CPUE Analysis

Blackwell & Hanchet (2002) carried out the first standardised analysis of CPUE for *D. mawsoni* for the 1998 to 2002 fishing seasons. The index of CPUE used was toothfish catch (kg) per baited hook per set. They did not consider the number of hooks lost per set because those data were not available from the database. Vessel, gear, and environmental parameters were plotted against catch (kg) per hook to test whether data transformations were required. The catch data were log transformed to stabilise the variance.

Two analyses were completed. The first (all-ground) analysis found that the variables area, season, length-of-line, soaktime, latitude, and month in season explained 32% of the variation. The second (main-ground) analysis used data only from the two most consistent vessels and the three main fishing grounds (areas) in the fishery. For this analysis, variables area, length of line, season, month, latitude, soaktime, and type of set (research or commercial) explained 34% of the variability.

A total of 1849 sets were available for the all-ground analysis, of which less than 10% had a zero catch of toothfish. For the main-ground analysis, 1225 sets (66% of the total) were used for the analysis. A nominal weight of 1 kg was added to the catch weight to avoid the problems of trying to calculate the log of zero.

The variability in CPUE was analysed using a manual stepwise linear regression analysis (Doonan 1991), using the Proc GLM (General Linear Modelling) procedure of the SAS statistical software

(SAS 1989). Variables were progressively added to the model until less than 1% improvement was seen in R^2 (percentage of variance explained by the model) following the inclusion of each additional variable. Analysis was confined to the main effects because there were insufficient observations available to properly review the effects of first order interactions within the data. Residual plots were examined for evidence of significant departures from model assumptions, and to determine the fit of the regression model to the data. The parameter estimates and standard errors were tabulated for each predictor variable included in the model, and the relationships between these variables and the CPUE indices were examined.

The standardised CPUE indices from both analyses were similar (Table 6). The indices have fluctuated around a level of 1.0 apart from a large drop to 0.4 in 2001. As mentioned above, the heavy ice conditions in 2001 meant that the vessels had to fish different fishing grounds and depths in that year. Because of the unbalanced nature of the distribution of effort among seasons and fishing grounds, the model has problems in identifying the depths and grounds fished in 2001 as being less productive. It is expected that the model performance will be improved as more data become available. The residual plots indicated that the data did not show a reasonable fit to either model, particularly for small and large levels of catch rate.

Blackwell & Hanchet (2002) noted that the analysis was preliminary and recommended that on-going monitoring and subsequent analysis be restricted to the main fishing grounds. They concluded that despite the problems described above, standardised CPUE analysis might be a useful method of monitoring abundance in this fishery in the longer term.

3.3 Length composition of the commercial catch

Observers measure a sample of *D. mawsoni* from each set. Sample sizes from each set in 2002 varied widely ranging from 1 to 186 and averaged about 39 for commercial sets and 67 for research sets (Hanchet et al. 2002). Raw length and sex data were examined by trip, SSRU, and set type (commercial/research) to determine an appropriate stratification for scaling up to commercial catch (Hanchet et al. 2002). Because of the small sample sizes, once the data were broken down to smaller strata there were often too few data to make meaningful comparisons. Strata were therefore only compared where reasonable numbers of fish (over 300 fish) had been caught. In most years either the trip effect or the area effect formed the most important stratum. Therefore, we summed the length frequency data for all sets made on a particular stratum (trip or SSRU), and then scaled that summed length frequency up to the total catch from that stratum, and then combined the different strata to get a scaled length frequency for the year.

The scaled length frequencies for male and female *D. mawsoni* are shown in Figures 4 and 5 respectively. Fish ranged from 52 cm to 210 cm total length. In all years, there is a broad mode of adult fish at about 130–160 cm for males and 130–170 cm for females. The mode for smaller fish varies between years from 80–110 cm in 2001 to 100–120 in 2002. The small fish (below 70 cm) in 1998 were caught mainly in shallow waters around the Balleny Islands. Since 1999 the area within at least 10 n.miles from the Balleny Islands has been closed to fishing. The high numbers of subadult fish (80–100 cm) in 2001 was the result of vessels fishing shallow waters in the south of the Ross Sea because of the extensive sea ice over the deeper fishing grounds.

3.4 Age composition of the commercial catch

About 500 otoliths collected by observers were selected for ageing each year (Hanchet et al. 2002). Otoliths (from each sex separately) from each 1 cm length class were selected proportionally to their occurrence in the scaled length-frequency, with the constraint that at least one otolith from each length class was selected. In addition, all otoliths from fish in the extreme right hand tail of the scaled length-frequency (constituting about 2% of that distribution) were fully selected.

Otoliths were treated and read following the methodology of Horn (2002). Age data from each year were compiled into year-specific age-length keys. These were then applied to the scaled length-frequency distributions to produce catch at age distributions for each year (Figure 6).

The age distribution varies considerably between years, reflecting the different areas and depths fished each year. For example, in 2002 there was a wider spread of ages and a greater proportion of older fish than in the previous two seasons. In most years the catch comprises fish from age 3 to 35 years of both sexes, although fish aged 5 to 20 are most abundant. Despite some apparent variability in age frequency it is not possible to track strong or weak year classes through the fishery.

4. BIOLOGY

4.1 Length-weight relationships

Length-weight parameters for *D. mawsoni* were estimated by Hanchet et al. (2001). The data were checked for obvious errors, outliers removed, and the data log-transformed and geometric mean regressions calculated. Length-weight parameters were almost identical for male and females with a power term of about 3.1 (Table 7). Patchell (2002) noted a significant difference in the length-weight relationship of *D. mawsoni* for each sex between summer and late autumn in 2002. The change coincided with the fish maturing sexually before spawning and indicated that *D. mawsoni* loses condition at this time, possibly as a result of an extensive spawning migration. Length-weight parameters for *D. eleginoides* (Hanchet et al. 2001) are also given in Table 7.

4.2 Reproduction

Gonad stages have been recorded for male and female toothfish by observers using the CCAMLR 5-stage system (Patchell 2001). This is similar to the staging system used by New Zealand observers for middle depth species, except that resting fish are classified as stage 2 in the CCAMLR system but stage 1 in the NZ system. Gonad stage data have been analysed for *D. mawsoni* for the past 3 years (e.g., Patchell 2002, Hanchet et al. 2002). They found that the length at 50% maturity based on the macroscopic staging system was about 110 cm for males and 130 cm for females. However, these values are considerably higher than those estimated for *D. eleginoides* which are 75 and 110 cm respectively (Everson 2002). Furthermore, it appears that larger fish mature earlier in the season than smaller fish, so that samples collected between January and March are likely to bias the estimates. They therefore concluded that macroscopic staging data collected between January and March were not useful for estimating the length at maturity.

Microscopic examination of histological sections supported these conclusions (Patchell 2001). He found that ovaries from *D. mawsoni* as small as 90 cm were already undergoing vitellogenesis. Although the work suffered from small sample sizes, his results suggest that 50% of female *D. mawsoni* mature at a size of between 95 and 110 cm. No testes were collected and so the size at maturity for males could not be estimated. For assessment purposes length at maturity is assumed to be 100 cm for both sexes (Hanchet et al. 2002).

In 2001 and 2002 fishing extended into April and May and large numbers of ripe (and some running ripe) fish were found. However, all the fishing in these months took place in the north of Subarea 88.1, and only large toothfish (over 130 cm) of both sexes were caught. (The main fishing grounds to the south are covered in ice and so cannot be fished at this time.) Gonad weights collected in 2002 showed a large increase in GSI from a mean of 2% in January/February to a mean of about 10% in April/May (Patchell 2002). These data provide strong evidence that *D. mawsoni* start spawning in May in the Ross Sea area. Spawning may extend through until early spring (Yukhov 1982, Eastman & De Vries 2000). However, it is believed that spawning is over by October because adult toothfish caught at McMurdo Sound at this time have gonads that are in the resting state (Eastman & De Vries 2000).

4.3 Age and growth

Burchett et al. (1984) read 46 otoliths of *D. mawsoni* caught in McMurdo Sound and provided a preliminary growth curve for both sexes combined. Horn (2002) carried out the first comprehensive analysis of the growth of *D. mawsoni.* He read 1520 *D. mawsoni* otoliths from collections made in Subarea 88.1 between 1998 and 2000 (Figure 7). Von Bertalanffy growth parameters were calculated from the analysis and are given in Table 7. However, Horn (2002) noted that the annual deposition of the growth zones was unvalidated, and that there were few otoliths from juvenile fish and so the growth curve may poorly define juvenile growth. However, since then Horn et al. (2002) examined otoliths from *D. mawsoni* that had been tagged previously with oxy-tetracycline, including one fish that had been at liberty for 7 years. Their analysis showed that the translucent zones in the otolith were formed annually. They also presented data on the growth of juvenile fish from the Shetland Islands, which agreed with his predicted growth of juvenile fish from the Ross Sea. They noted that some uncertainty still existed over the interpretation of multiple banding in sub-adult otoliths (ages 3–10), and that further oxy-tetracycline marking and recapture of fish younger than 10 years (under 100 cm) would be required to complete the full validation for this species.

Tagging studies have also provided estimates of growth rates (De Vries & Eastman 1998, Horn et al. 2002). Estimates of growth rates from tagged fish have been somewhat lower than the mean estimates of growth from the otolith ageing (Horn et al. 2002). It is unclear whether this represents geographical variation in individual growth (the tagged fish were mainly from McMurdo Sound), whether the tagged fish grew more slowly as tagging is known to have an adverse effect on growth rates (Stevens & Kalish 1998), or whether estimates of growth from the otolith ageing are biased.

Growth curves for *D. eleginoides* for the Ross Sea region were partially validated by Horn (2002), and are given in Table 7.

4.4 Natural mortality

An estimate of instantaneous natural mortality (*M*) was derived by Hanchet et al. (2001) using the equation

$$M = -\log_e(p)/A$$

where p is the proportion of the population that reaches age A or older (Hoenig 1983). From the estimated numbers at age in the commercial catch, 1% of males were at least 24 years old, and 1% of females had lived 26 years. The subsequent estimates of M from these ages are 0.19 and 0.18. However, the longline fishery is unlikely to provide an unbiased estimate of population numbers at age, so these estimates must be considered to be very uncertain. Hence, a range of ± 0.03 around these values is recommended, i.e., M = 0.15–0.22.

4.5 Feeding

Although there have been several studies of the diet of *D. eleginoides* (e.g., Pilling et al. 2001, Goldsworthy et al. 2002), there is little published on the diet of *D. mawsoni* (Fenaughty et al. 2002). Most studies have examined few fish and the diet has varied depending on geographical location and fish size. Fenaughty et al. (2002) carried out the first comprehensive feeding study of *D. mawsoni* using the frequency occurrence method. They examined the stomach contents of over 9000 fish captured from the longline fishery in the Ross Sea during the 2001 and 2002 seasons (3937 and 5436 stomachs respectively). A high proportion of the stomachs sampled were empty (34% in 2001 and 49% in 2002). However, Pilling (2001) found that longline fish had a higher proportion of empty stomachs than pot caught fish, and suggested regurgitation might be a problem for line caught fish. Fish were the most important food items occurring in 86% of stomachs in 2001 and 78% of stomachs in 2002. However, fish could be identified to family or species level in less than 10% of the stomachs. Icefish (Channichthyidae) and Whitson's rattail (*Macrourus whitsoni*) were the most common species identified. Squid and prawns were the next most important prey items, whilst rocks and bait were also commonly found in the stomachs.

The diet of adult *D. mawsoni* varies geographically (Eastman & De Vries 2000, Fenaughty et al. 2002). In the coastal waters around McMurdo Sound, adults feed on Antarctic silverfish, on the banks and slopes of the Ross Sea they feed mainly on fish (probably mainly icefish and rattails), whilst in the open oceanic waters they feed on small squid. The diet of *D. mawsoni* also varies with fish size (Pakhomov & Pankratov 1992, Fenaughty et al. 2002). Crustaceans and bait were more common in smaller fish and squid and rocks were more common in larger fish (Fenaughty et al. 2002).

4.6 Movement

Over 5000 *D. mawsoni* have been tagged since 1972 in McMurdo Sound (~77° S) by US researchers (De Vries & Eastman 1998). They reported that between 1972 and 1998 there had been 13 recaptures. One fish originally tagged in McMurdo Sound in 1997 was recaptured 3.3 years later north of 72° S (a distance of almost 800 km) (Horn et al. 2002).

Over 1000 *D. mawsoni* have been tagged during the New Zealand exploratory fishery in the Ross Sea (Smith & Bond 2001, Hanchet et al. 2002): 259 were tagged in the 2001 season and 793 were tagged in the 2002 season. One fish was recaptured in 2001 after only 3 days at liberty. In 2002, three fish were recaptured, one of which had been at liberty for over a year. Distances travelled and days at liberty for these three fish were 11 km (7 days), 27 km (33 days), and 67 km (371 days).

D. eleginoides have also been tagged during the New Zealand exploratory fishery in the Ross Sea (Smith & Bond 2001, Hanchet et al. 2002): 67 were tagged in the 2001 season and 278 were tagged in the 2002 season. Two fish were recaptured in 2002, both of which had been tagged the previous season. One fish had travelled about 80 km, whilst the other had remained in the same location.

Other information on potential movements is considered below (Section 4.7).

4.7 Life history

Eastman & De Vries (2000) drew together unpublished and published material on *D. mawsoni* from the Ross Sea and other parts of the Antarctic to present a likely life history for this species. We have attempted to update their life cycle with new information, mainly derived from the New Zealand exploratory fishery.

Juvenile (4–15 cm long) *D. mawsoni* are believed to be mainly pelagic (Roshchin 1997). They have been caught in large numbers by midwater trawl by Russian vessels fishing for krill and Antarctic silverfish (*Pleuragramma antarcticum*) in surface waters (0–100 m) over bottom depths of 400–2000 m. However, small numbers of juvenile fish (13–14 cm long) have also been caught in March by bottom trawl in shallow waters around the South Orkney and South Shetland Islands by US AMLR surveys (Jones et al. 2001). Juvenile fish feed on adult euphausiids and larval fish (Pakhomov & Pankratov 1992).

After reaching a length of about 15 cm they become more benthopelagic (Roshchin 1997). Immature fish (15–75 cm long) were commonly caught in the Indian Ocean by bottom trawl by Russian vessels fishing for Wilson's mackerel icefish (*Chaenodraco wilsoni*). They were caught in depths of 180–1000 m, but were most common in 200–400 m. In the Ross Sea fishery small fish (under 70 cm long) have mainly been caught in relatively shallow waters (300–800 m) around the Balleny Islands and on the Ross Sea Shelf. They feed primarily on fish (Pakhomov & Pankratov 1992).

D. mawsoni move deeper as they get older, and are believed to mature at a length of about 100 cm and an age of about 10 years. The seasonal distribution and abundance of adult toothfish is unclear. The main reference to this is Yukhov (1982), which is written in Russian, but parts are cited by Eastman & De Vries (2000). Yukhov's data were collected from sperm whale stomachs between January and March. On attaining sexual maturity Yukhov asserts that toothfish migrate north to the oceanic waters between the shelf break and the Antarctic Convergence. These northward migrations take place early in the austral summer. While in oceanic waters they apparently occupy the 300–600 m mesopelagic zone, with a preferred depth of 500 m, and feed on squid for 1–2 years. Yukhov also speculated that *D. mawsoni* return to coastal waters for spawning several times during their life, although they may not spawn every year. Eastman & De Vries (2000) found peak catch rates of *D. mawsoni* in McMurdo Sound in October/November, and concluded that they are feeding at this time in shallow waters before the northward migratory phase of their life cycle.

Without having a translation of the original paper it is difficult to determine how much of this is speculation, and how much is backed up by data. For example, how does he know there is a northward migration in early summer? What is the basis for the comments that *D. mawsoni* are in the mesopelagic zone? How does he know that they return to coastal waters for spawning, and that they may not spawn every year?

Data from the exploratory fishery in the Ross Sea shed light on some of these questions. New Zealand vessels have caught adult *D. mawsoni* using bottom longlines from throughout Subarea 88.1 (from 65° S to 78° S) from January to March. This suggests that a large part of the population is spread throughout the region at this time of the year, and at least part of the population is on the bottom. Large adult fish were found at 77° S in February, suggesting that at least part of the population do not move at all. Indeed, the geographic distribution is similar to that shown by Yukhov (1971). The vertical distribution of *D. mawsoni* is more difficult to ascertain, although both they and *D. eleginoides* are known to make forays into midwater – presumably for feeding (Fuiman et al. 2002, Williams & Lamb 2002).

By mid April the Ross Sea itself is covered by ice and fishing is restricted to the north of 70°S. Patchell (2002) noted that adult toothfish caught in April and May in this northern area were close to spawning and had a significantly lower condition than those caught further south in summer. He speculated that this might be the result of an extensive spawning migration. Although the origin of these fish is unknown, it is clear that these data are not consistent with a migration of fish into coastal waters for spawning. *D. eleginoides* are known to spawn at depths of between 800 and 1200 m (Everson 2002). By August the sea ice extends to almost 60° S, so Subarea 88.1 is completely inaccessible to fishing and the location of toothfish at this time is unknown. Between late September and December adult toothfish can be caught under the ice at McMurdo Sound (Eastman & De Vries 2000), but it is unclear whether they are also there for the rest of the year. Adult *D. mawsoni* feed on Antarctic silverfish in the coastal waters around McMurdo Sound, on icefish and rattails on the banks and slopes of the Ross Sea, and on small squid in the open oceanic waters (Fenaughty et al. 2002).

5. STOCK STRUCTURE

The number of populations of *D. eleginoides* and *D. mawsoni* are currently unknown (Everson 2002). No genetic studies have been carried out on *D. mawsoni* and there are too few tagging returns to draw any inferences. However, the movement of a tagged fish from McMurdo to off Cape Adare (a distance of 800 km) suggests that the fish in Subarea 88.1 (and probably also 88.2) can be regarded as a single population.

Evidence from meristic, morphometric, DNA microsatellite markers, and tagging studies indicate that *D. eleginoides* may be composed of several populations (Smith & McVeagh 2000, Everson 2002). Several studies have suggested differences between fish caught in the Atlantic, Indian, and Pacific sectors. However, genetic differences have also been observed at much smaller scales (e.g., in adjacent fishing grounds around Macquarie Island), so the question of stock structure for this species is still very much open to question.

Both toothfish species are readily distinguished by isoelectric focusing of muscle proteins and these protein profiles distinguish *Dissostichus* spp. from other fillets marketed under common trade names such as bass and hake (Smith & Gaffney 2000).

6. ABUNDANCE INDICES

No abundance indices have yet been developed for the toothfish fishery. Hanchet (2000) identified several possible options including the use of commercial CPUE data, the use of research sets as a quantitative longline survey, and tagging. A further option using acoustic methods has also recently been proposed by O'Driscoll (2002).

6.1 *Tagging*

Tagging has been carried out on Antarctic toothfish during the 2001 and 2002 seasons with the primary aim of determining movements and growth rates, but with a secondary aim of potentially determining abundance (Smith & Bond 2001). About 1100 toothfish have now been tagged (Hanchet et al. 2002). A project to look at the feasibility of tagging toothfish to estimate abundance is currently underway (J. McKenzie, NIWA, pers. comm.).

6.2 CPUE analysis

A preliminary standardised CPUE analysis was carried out on the 5 years of data from 1998 to 2002 (Blackwell & Hanchet 2002). One analysis was carried out using the entire data set, and a second using only data from the *Janas* and *San Aotea* and the main fishing grounds. The analysis currently suffers from an unbalanced design with different grounds being fished in different years. However, as data from more years become available and the fishing pattern becomes more consistent between years the technique might be useful for monitoring abundance.

6.3 Research set simulation

As a condition on their permit, all vessels fishing in a new or exploratory fishery must carry out 20 research sets in each small-scale research unit (SSRU) before commercial fishing can take place. Each research set must have a minimum number of hooks and be separated from its neighbours by at least 5 n. miles. Using simulation studies, Ball & Constable (2001) showed that there were certain advantages to be gained by carrying out research sets in a consistent manner between years. A project is currently underway to continue this simulation study by making it more applicable to the Ross Sea area (Hanchet unpubl. data.). It is planned to simulate the Ross Sea area based on known fishing grounds and recruitment areas, and test various research set strategies to determine which approaches are optimal for the Ross Sea fishery.

6.4 Acoustic study

Another potential method for monitoring abundance is acoustics (O'Driscoll 2002). Australian scientists carried out a trial acoustic survey for *D. eleginoides* around Macquarie Island (Kloser et al. 1999). They concluded that acoustic estimation methods using echo integration were of limited use because of the low densities of toothfish in the survey area and the co-occurrence of toothfish with swimbladder species such as morids and rattails. However, acoustic echograms collected during the exploratory fishery in 2001 suggest that toothfish in the Ross Sea may be distinguishable on the echosounder (G. Patchell, Sealord Group Ltd, pers. comm.).

Although there are several potential problems with acoustics, O'Driscoll (2002) concluded that collection of acoustic data from vessels participating in the exploratory fishery during the 2003 season is worthwhile. The cost of data collection and analysis is low, and the potential benefits if acoustics could be used successfully to estimate toothfish abundance are great. He also proposed assessing the feasibility of echo counting as an alternative to the more conventional technique of echo integration (which was the method attempted by the Australians). Echo counting may have advantages over echo integration if toothfish are sparsely distributed. Toothfish are also being collected for target strength modelling.

It is considered unlikely that any one of the above methods will be able to provide estimates of abundance and yield in the short term. It is therefore recommended that all methods be explored further.

7. STOCK ASSESSMENT

There was a large increase in interest in developing new and exploratory fisheries for toothfish in CCAMLR waters in the mid 1990s. Initial estimates of yield for these new and exploratory fisheries were based on analogy with yields from South Georgia (Subarea 48.3) (SC-CAMLR-XVII 1998). They were based on the idea of relating the biological parameters for the toothfish species in the new area to the biological parameters and yield estimate for *D. eleginoides* in Subarea 48.3. This was then corrected by the ratio of the seabed area between the two areas. Furthermore, a discount factor (0.3-0.5) was applied to reflect the uncertainty in the approach.

Because of uncertainties over the productivity, distribution, and abundance of toothfish in these new areas this approach was discontinued for most of those fisheries in 2000. However, for Subarea 88.1, where some exploratory fishing had been carried out, the method was refined to include this new information. The method used by CCAMLR to assess the Subarea 88.1 fishery at the 2002 WG-FSA meeting is given below.

Methods

The formula used for estimating the precautionary long-term yield is

$$\text{Yield} = \gamma B_0. \qquad (1)$$

CPUE is assumed to be an index of biomass density. These can be combined to give the formula relating yields in Subareas 48.3 and 88.1:

$$Y_{881} = \frac{\gamma_{881} f_{881} A_{881}}{\gamma_{483} f_{483} A_{483}} Y_{483}. \qquad (2)$$

Here γ is the precautionary pre-exploitation harvest level for each area, f is the relative fish density (a function of CPUE and fishing selectivity), A is the seabed area, and Y is the long-term precautionary yield. This assumes that the catchability and the relationship between CPUE and actual density is the same for the species/fisheries in Subareas 48.3 and 88.1. Separate yield estimates are calculated for each SSRU.

Determination of γ

The γ is the maximum pre-exploitation harvest rate subject to the following two conditions: (i) that the probability that the stock will go below 20%B is less than 10%; and (ii) that the median spawning stock escapement is greater than 50% (Constable & de la Mare 1996).

An important component of Equation (2) is the ratio of the precautionary pre-exploitation harvest levels (γ) between the areas. These are calculated using the biological and fishery parameters for each of the areas. Biological and fishery parameters for *D. eleginoides* are the same as that used for the Subarea 48.3 assessment (SC-CAMLR-XXI).

The fishing selectivity pattern for Subarea 48.3 is based on the left side of the 1995 scaled commercial length frequency (this is the earliest reliable data for this area). When graphed, fish are considered to have 100% selection at the peak of the length frequency distribution (and at all greater lengths) and have zero selection where the distribution meets the x-axis (and at all smaller lengths). The mean selectivity is taken as the length corresponding to 50% of the vertical height of the mode.

The fishing selectivity pattern for Subarea 88.1 is divided into separate fishing selectivity patterns for each of the SSRUs. The fishing selectivity pattern is based on the left side of the scaled commercial length frequency for all years combined for each SSRU. The method used to do this is described above.

These biological parameters and the fishing selectivity pattern are used within the Generalised Yield Model (GYM) to calculate γ. The Generalised Yield Model was described by Constable & de la Mare (1996), and is currently used for assessing *D. eleginoides*.

Estimation of relative fish density

The relative fish densities are calculated from a combination of the CPUE of Subareas 88.1 and 48.3 and the fishing selectivities from those areas.

Catch is taken as the weight of the fish taken from the longline set and effort is taken as the number of hooks used in that set. The CPUE for that set is taken to be the catch divided by the effort.

Catch-per-unit-effort (CPUE) data are available from both commercial and research data sets. CPUE data from 1998 to 2002 were used for Subarea 88.1, whilst CPUE data from the beginning of the fishery (years 1987–92) were used for Subarea 48.3. The data sets were combined and then a subset of data was taken from them. The subset of data consists of a number of sets which are all mutually separated by a distance of not less than 5 nautical miles. This restriction on the data was introduced to gain a sufficient spatial coverage without giving undue weight to samples of the population density, which were close enough that the correlation between samples was too high. The subsets were derived randomly using a software program called Data Loser (I. Ball, Australian Antarctic Division, pers. comm.).

The CPUE estimates from the subsets were averaged and the ratio of CPUE between the SSRU and Subarea 48.3 calculated. This was repeated 10 000 times and the one-sided lower 95% confidence bound of this ratio was calculated.

The ratio of relative fishing densities (f_{881}/f_{483}) is the ratio of the CPUE from each area adjusted for the fishing selectivity. The ratio of total biomass to recruited biomass was calculated for each of the areas using the appropriate biological parameters. The fishing selectivity used to estimate the recruited biomass is the same as those used to calculate γ.

Estimation of area

A_{881} and A_{483} are the seabed areas that have been fished within these subareas. A_{483} is all the seabed area in the depth range of 600 to 1 800 m in Subarea 48.3.

The area fished in Subarea 88.1 (A_{881}) was derived by inputting all the available catch and effort data into a GIS system to determine polygons of fished area, and applying a bathymetric grid using Lambert Azimuthal equal area projection, to calculate the amount of seabed area over which *Dissostichus* spp. were located. Preliminary analysis of the data showed that catches of *Dissostichus* spp. outside the 600–1800 m depth range were minimal. Therefore, the area fished outside those depths is excluded. The CPUE analysis (above) is also restricted to data from this depth range.

Estimation of yield for area 48.3

The pre-exploitation precautionary yield for Subarea 48.3 is calculated using estimates of recruitment from trawl surveys, together with the other biological parameters used for the calculations of γ, using zero catches. This yield is then adjusted by the ratio of γs, densities (a function of CPUE and fishing selectivity), and seabed areas to give estimates of precautionary yield for *D. mawsoni* in Subarea 88.1.

Results

The values for each of the parameters in equation 2 are summarised in Table 8. Estimated yields ranged from 1772 to 5129 t for the various SSRUs in Subarea 88.1. The yield for Subarea 88.2 was calculated using the same approach and equalled 602 t.

A summary of the catches and catch limits for *Dissostichus* spp. in Subareas 88.1 and 88.2 are given in Table 9. As a precautionary measure a discount factor (ranging from 0.3 to 0.5) has been applied in the past to the estimates of yield from this method to reflect the uncertainty of this approach (SC-CAMLR XXI).

8. MANAGEMENT IMPLICATIONS

Estimates of yield based on the stock assessment given above are being used by CCAMLR to manage the Subarea 88.1 and 88.2 fisheries (SC-CCAMLR-XX 2001). These estimates must be considered very preliminary because they are based on analogy with a different toothfish species and in another part of the Antarctic. However, several aspects of the assessment suggest that the yields can still be regarded as precautionary – and that they can probably be regarded as minimum yield estimates from this region. Firstly, the area used to assess the Ross Sea fishery is only the fished area, whereas the area used for Subarea 48.3 is the entire area of seabed between 600 and 1800 m (the fished area in Subarea 88.1 is about 30% of the total seabed area within these depths). Secondly, when the ratio of the fish densities between the two areas was calculated, the lower 95% confidence bound of the ratio was used rather than the mean. Thirdly, the estimate of yield calculated for Subarea 48.3 itself is considered to be precautionary. Lastly, the discount factor applied to the yield estimates provides a further precautionary element.

It is clear, however, that an assessment based on analogy is not an ideal basis on which to manage a fishery in the medium to long term. It is imperative that abundance indices and yield estimates are estimated for the Ross Sea area independently of other areas of the CCAMLR region. Priority therefore needs to be given to the development of abundance indices that can be used to monitor and assess the stock.

9. ACKNOWLEDGMENTS

We thank the observers from New Zealand and South Africa for collecting the large amount of data used in this report. We also acknowledge the help and support of the New Zealand companies involved in the fishery, in particular Sealord Group Ltd and Sanford Ltd for the provision of data and information on the fishery. We also thank the CCAMLR Secretariat for the extraction of the data, and members of the WG-FSA for many helpful discussions. Lastly, we thank Brent Wood for drafting Figure 1, and Don Robertson, Neville Smith, and Kevin Sullivan for making many helpful comments on an earlier draft of the manuscript. This work was funded by the Ministry of Fisheries under Project PAT2000/01 (Objective 7).

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Table 1: The percentage of sets catching *D. eleginoides* (TOP) and *D. mawsoni* (TOA) and the percentage of TOP in the catch by 2.5° latitude in Subareas 88.1 and 88.2 for New Zealand vessels only.

Latitude	% of sets catching each species		% TOP in the catch
	TOP	TOA	
62.5–65.0°	82	72	36.7
65.0–67.5°	45	96	0.8
67.5–70.0°	18	91	1.2
70.0–72.5°	1	98	<0.1
72.5–75.0°	<1	95	<0.1
75.0–78.0°	1	98	<0.1

Table 2: Total catch and catch limit of *Dissostichus* spp in Subareas 88.1 and 88.2 by nationality and Subarea. –, no permit to fish; 0, permit available but no fishing took place.

Year	New Zealand		South Africa		Uruguay		Total catch		Total catch limit	
	88.1	88.2	88.1	88.2	88.1	88.2	88.1	88.2	88.1	88.2
1997	<1	0	–	–	–	–	<1	0	1 980	–
1998	41	0	–	–	–	–	42	0	1 510	63
1999	297	–	–	–	–	–	297	–	2 281	–
2000	751	–	–	–	–	–	751	–	2 090	250
2001	590	–	25	0	23	0	658	0	2 064	250
2002	1 333	41	0	0	–	–	1 333	41	2 508	250

Table 3: Catch and catch limits (t) of *Dissostichus* spp by SSRU and year in Subarea 88.1 in the Ross Sea.

Year	881A		881B		881C		881D		881E		881 B-E	
	Catch	Limit	Catch	Limit	Catch	Limit	Catch	Limit	Catch	Limit	Catch	Limit
1998	<1	338	14	–	9	–	13	–	5	–	41	1 172
1999	0	271	41	–	61	–	101	–	94	–	297	2 010
2000	0	175	48	479	239	479	160	479	306	479	751	1 915
2001	126	175	232	472	186	472	43	472	74	472	535	1 889
2002	58	171	333	584	567	584	195	584	179	584	1 274	2 337

Table 4: Summary of the exploratory fishery for *D. mawsoni* (TOA) and *D. eleginoides* (TOP) by year in Subareas 88.1 and 88.2 for New Zealand vessels only.

Year	Number of vessels	Number of LF samples	TOA catch (t)	TOP catch (t)	Period fished
1997	1	2	0	0.1	May 1997
1998	2	65	41	0.5	Feb-Mar 1998
1999	3	341	296	0.5	Jan-Feb 1999
2000	3	463	753	0.3	Jan-Mar 2000
2001	3	505	580	30.3	Jan-May 2001
2002	2	429	1 358	12.0	Jan-May 2002

Table 5: Total catch and % catch by year for the main fish species/family groups. For species codes, see Appendix 1.

Species	1998		1999		2000		2001		2002	
TOA	40 973	72%	296 292	81%	752 580	86%	579 918	86%	1 357 991	87%
TOP	546	1%	511	<1%	264	<1%	30 305	4%	12 192	1%
GRV	9 487	17%	22 431	6%	69 904	8%	48 507	7%	158 387	10%
SRX	4 877	9%	39 849	11%	41 103	5%	7 647	1%	25 123	2%
MRL	387	1%	4 320	1%	6 649	1%	3 168	<1%	5 355	<1%
ICX	71	<1%	184	<1%	326	<1%	2 476	<1%	1 685	<1%
NOX	133	<1%	44	<1%	9	<1%	1 022	<1%	44	<1%
POG	2	<1%	0	0%	31	<1%	39	<1%	24	<1%
MOR*	161	<1%	50	<1%	281	<1%	3 019	<1%	3 239	<1%
Others	0	0%	12	<1%	0	0%	0	0%	50	<1%
Total (kg)	56 637		363 693		871 147		676 101		1 564 090	

Table 6: Results of preliminary standardised CPUE analysis for *D. mawsoni* (TOA) for New Zealand vessels in the Ross Sea fishery for the two analyses undertaken.

	All vessels/areas		Main vessels/areas	
Year	Year effect	s.e.	Year effect	s.e.
1998	1.21	1.29	–	–
1999	0.84	1.13	0.75	1.16
2000	1.14	1.12	1.05	1.15
2001	0.40	1.12	0.37	1.15
2002	1.00	–	1.00	–

Table 7: Summary of biological parameter estimates for *D. mawsoni* and *D. eleginoides* from Hanchet et al. (2001) and Horn (2002). Von B., von Bertalanffy growth parameters; LW, length weight parameters (length in cm, weight in kg).

		D. mawsoni			*D. eleginoides*		
		Males	Females	Total	Males	Females	Total
Natural mortality		0.19	0.18	0.15-0.22	–	–	–
Von B	t_0 (yr)	0.31	0.50	0.04	0.08	-0.35	-0.05
Von B.	k (yr^{-1})	0.102	0.095	0.095	0.118	0.085	0.086
Von B.	L_∞ (cm)	170.3	184.5	180.2	134.3	158.7	149.6
LW	a	0.00000986	0.00000617	0.00000744	0.00000367	0.00000375	0.00000382
LW	b	3.0335	3.1383	3.0965	3.2563	3.2480	3.2448

Table 8: Assessment of long-term annual yield for the exploratory fishery by SSRU for *Dissostichus* spp. in Subarea 88.1 and for all SSRUs combined in Subarea 88.2 based on fished seabed area.

	88.1					88.2	48.3
	A	B	C	D	E		
Fished seabed area (km²)	3 407	10 484	13 041	11 668	28 074	2 384	32 035
Fishing selectivity (mean)	135	115	120	80	80	115	75
Fishing selectivity (range)	30	70	60	20	20	50	20
Ratio total: recruited biomass	2.551	1.683	1.818	1.131	1.131	1.651	1.158
γ	0.048	0.040	0.041	0.037	0.037	0.041	0.034
CPUE ratio	0.578	0.391	0.823	0.495	0.525	0.587	1.0
Estimated yield (t)	1 536	1 772	5 129	1 533	3 912	602	(7 970)

Table 9: Summary of catch limits and catches for *Dissostichus* spp. in Subareas 88.1 and 88.2 for the 2000/01 and 2001/02 seasons and precautionary yields for 2002/03.

	2000-01		2001-02		2002-03		
	Catch limit	Catch	Catch limit	Catch	Yield	Yield *0.3	Yield *0.5
Subarea 88.1							
SSRU A	175	67	171	57	1 536	461	768
SSRU B	472	287	584	333	1 772	532	886
SSRU C	472	184	584	565	5 129	1 539	2 564
SSRU D	472	46	584	195	1 533	460	766
SSRU E	472	75	584	179	3 912	1 174	1 956
Total	2 063	659	2 508	1 319	13 882	4 164	6 941
Subarea 88.2[1]	-	-	250	41	602	181	301

[1]Note Subarea 88.2 is divided into 7 longitudinal sections each 10° apart.

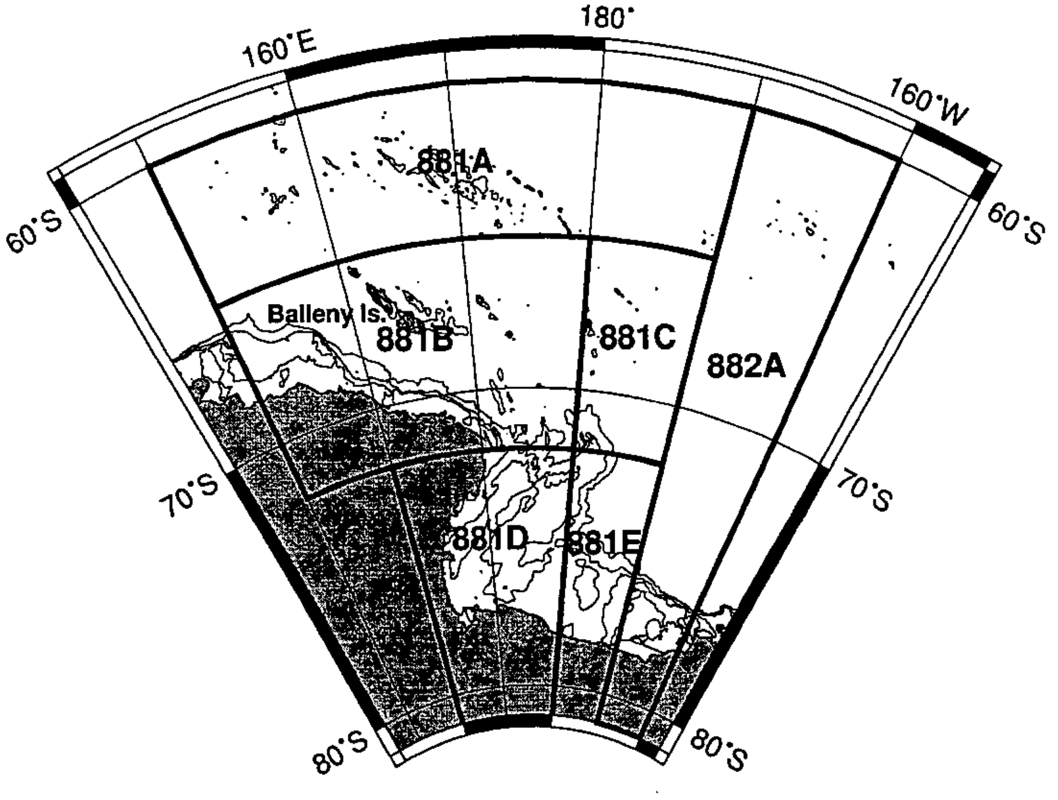

Figure 1: Polar stereographic map showing the Ross Sea and small scale research units fished by New Zealand longline vessels from 1998 to 2002. Depth contours at 1000 m intervals.

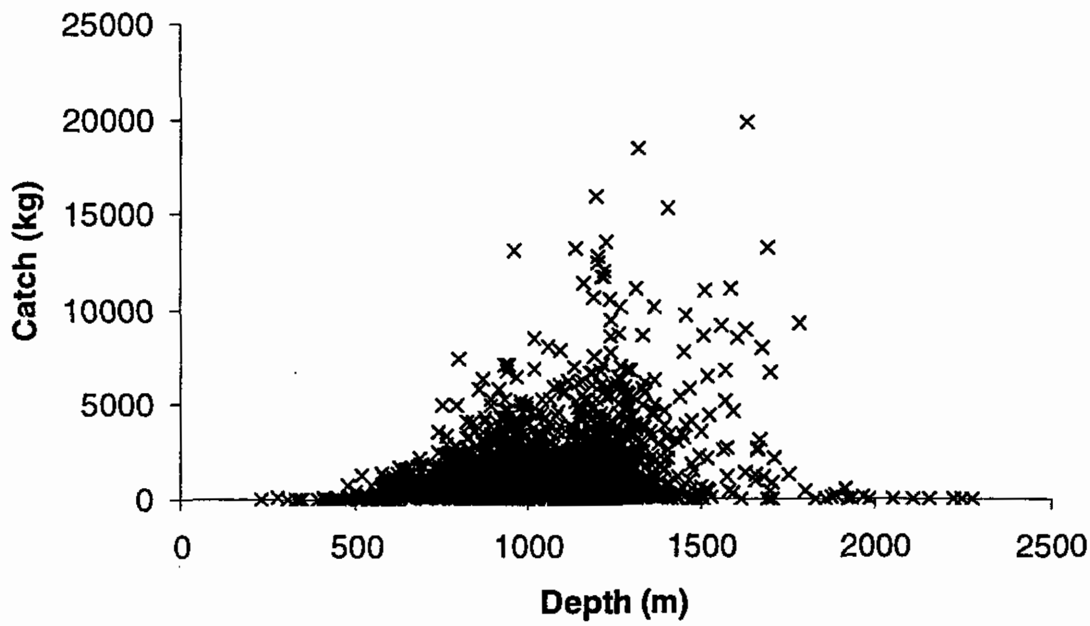

Figure 2: Catch of Antarctic toothfish by depth in the Ross Sea fishery.

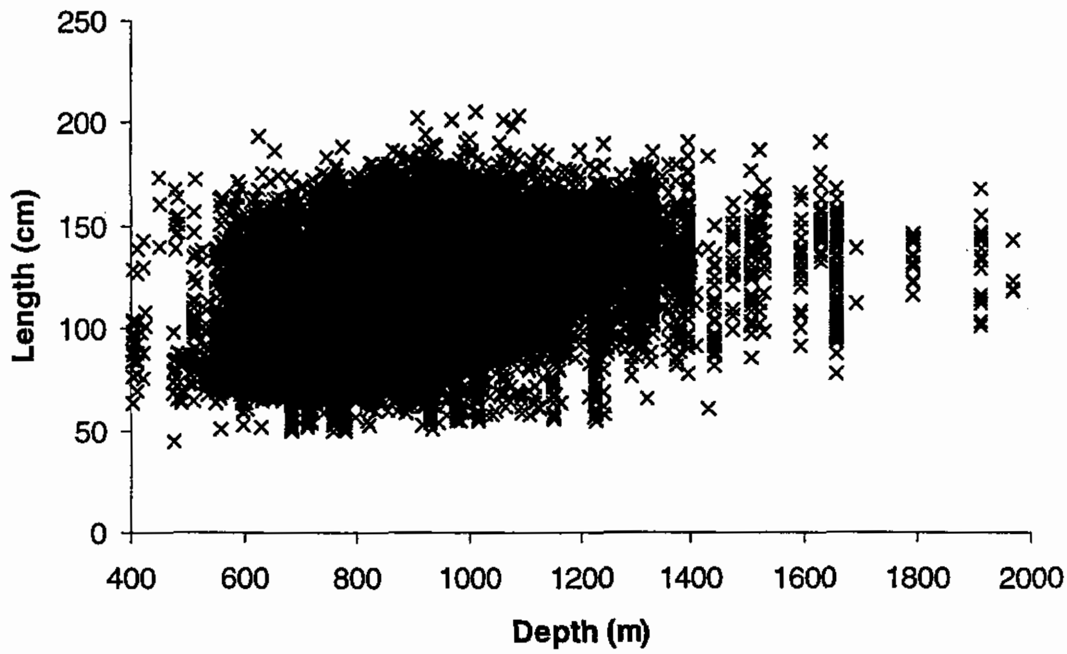

Figure 3: Antarctic toothfish length versus depth in the Ross Sea.

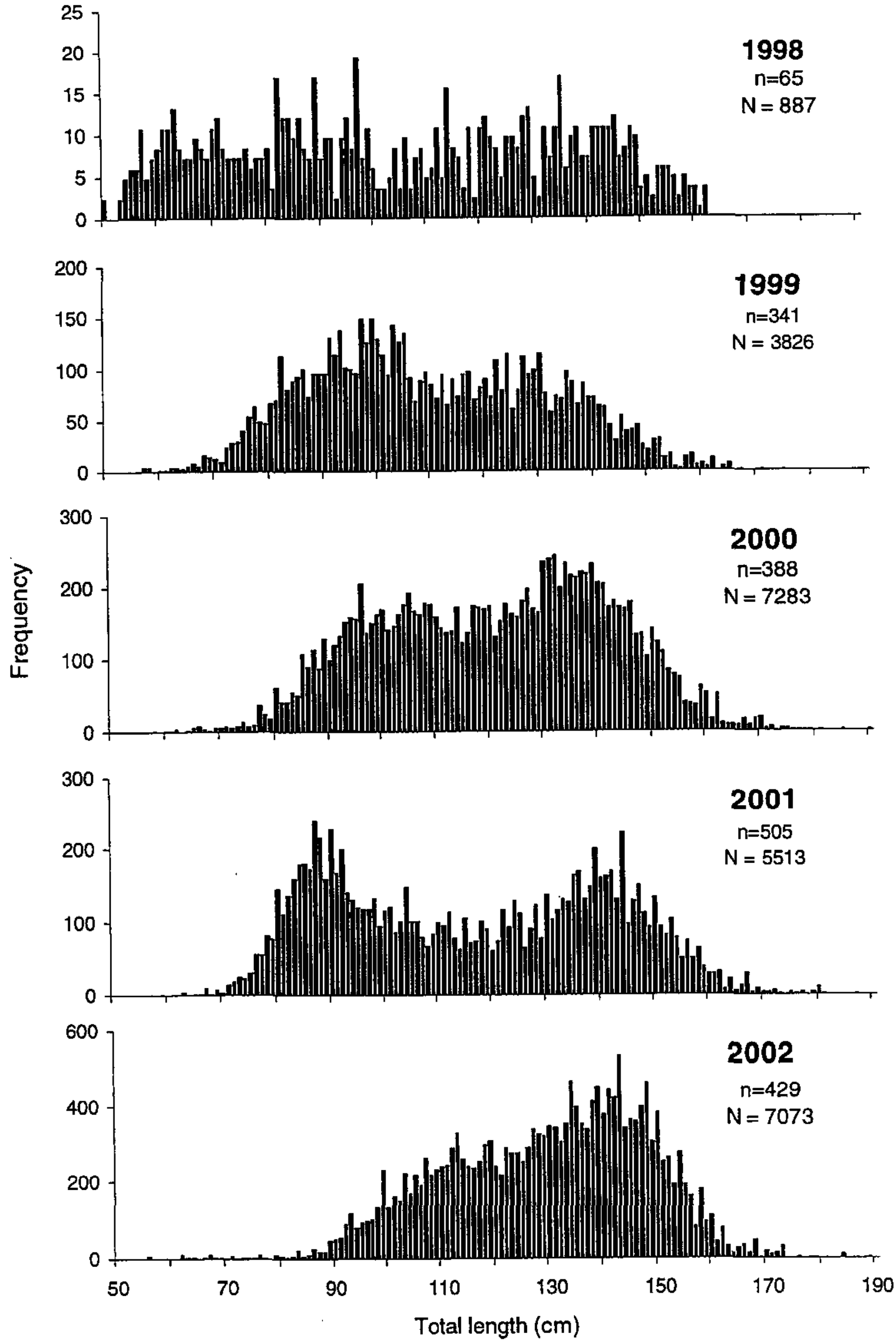

Figure 4: Weighted length frequency distribution of male toothfish by year. n, number of sets sampled, N, number of fish measured.

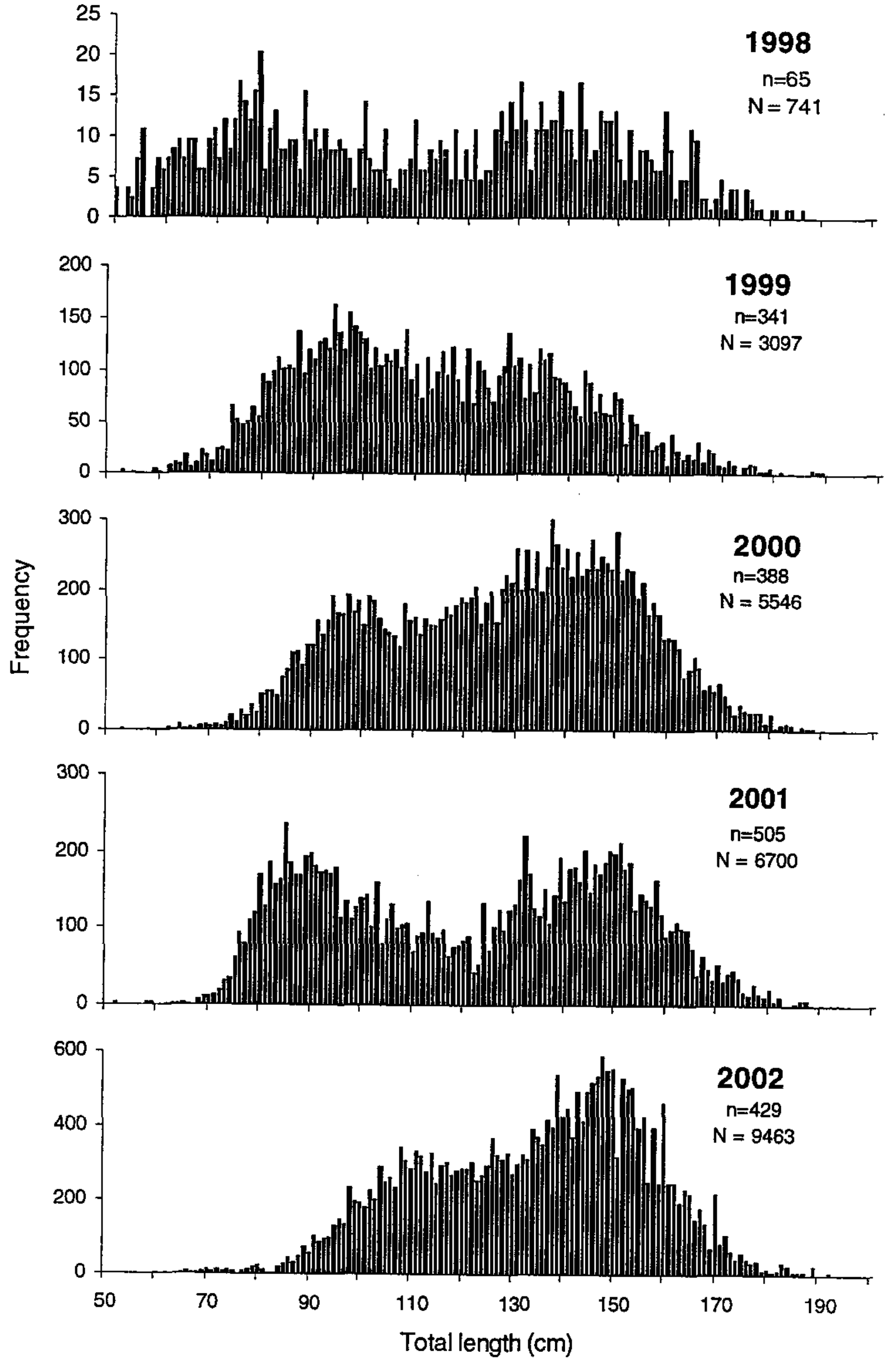

Figure 5: Weighted length frequency distribution of female toothfish by year. (n, number of sets sampled, N, number of fish measured.)

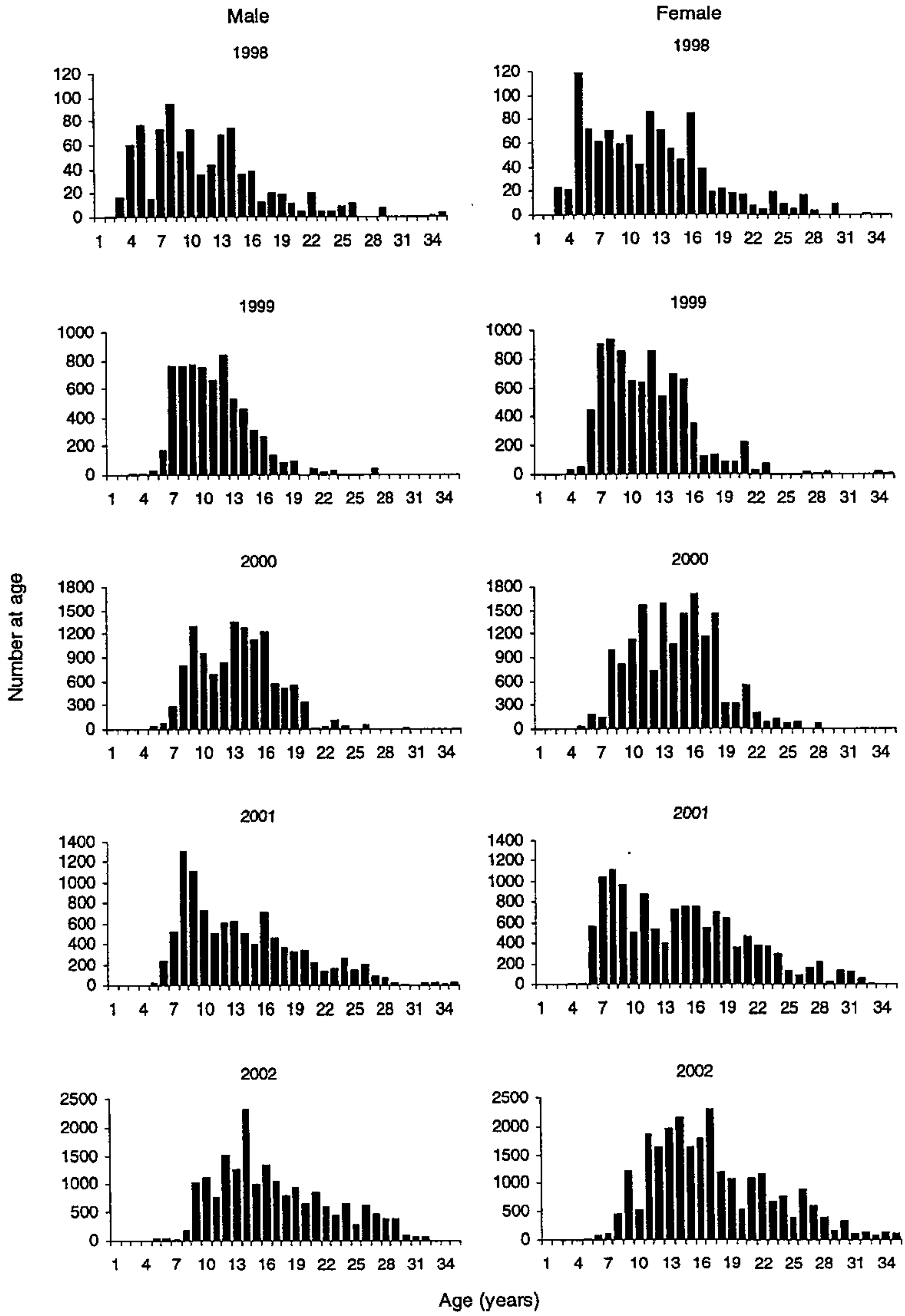

Figure 6: Estimated numbers at age, by sex and year, for *D. mawsoni* in the commercial longline catch from the Ross Sea.

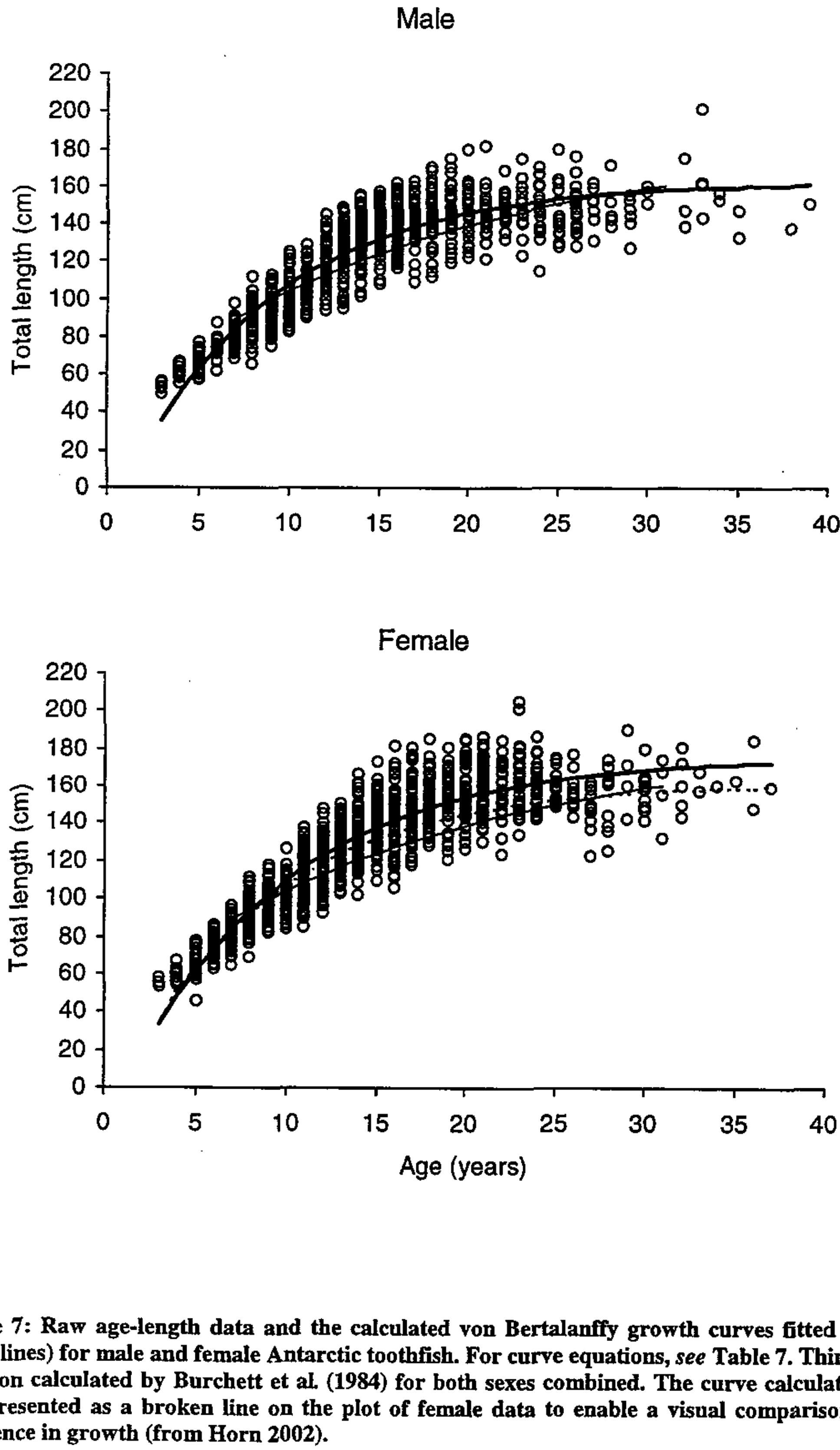

Figure 7: Raw age-length data and the calculated von Bertalanffy growth curves fitted to all the data (thick lines) for male and female Antarctic toothfish. For curve equations, *see* Table 7. Thin line shows the equation calculated by Burchett et al. (1984) for both sexes combined. The curve calculated for males is also presented as a broken line on the plot of female data to enable a visual comparison of the sexual difference in growth (from Horn 2002).

APPENDIX 1

List of species codes, scientific and common names used in the document. Note this is not a complete list of species recorded from the fishery (e.g., *see* Stewart & Roberts 2001).

Species code	Scientific name	Common name
GRV	*Macrourus* spp.	Rattails, grenadiers
ICX	Channichthyidae	Icefish spp.
MOR	Moridae.	Morid cods
MRL	*Muraenolepis* spp.	Moray cods
NOX	Nototheniidae	Rockcods
POG	*Pogonophryne* spp.	Plunderfish
SRX	*Rajiformes* spp	Skates and rays
TOA	*Dissostichus mawsoni*	Antarctic toothfish
TOP	*Dissostichus eleginoides*	Patagonian toothfish