CCAMLR Science, Vol. 10 (2003): 113–123

SHORT NOTE

DIET OF THE ANTARCTIC TOOTHFISH (*DISSOSTICHUS MAWSONI*) FROM THE ROSS SEA, ANTARCTICA (SUBAREA 88.1)

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Abstract

The diet of Antarctic toothfish (*Dissostichus mawsoni*) captured by bottom longline in the Ross Sea during the 2001 and 2002 fishing seasons was analysed (3 937 and 5 426 stomachs examined respectively). Fish sampled in 2001 were caught at depths of 317 to 2 154 m and ranged from 58 to 190 cm in total length (TL). Fish sampled in 2002 were caught at depths of 815 to 1 623 m and ranged from 62 to 197 cm TL. A high proportion of stomachs were empty (34% in 2001 and 49% in 2002) and the remaining stomachs often contained prey in advanced stages of digestion, making prey identification difficult. Fish were the most important prey category (%*F* = 86 in 2001 and %*F* = 77 in 2002), in particular icefish (family Channichthyidae) and Whitson's rattail (*Macrourus whitsoni*). Squid, bait and prawns followed in importance in the diet.

Résumé

Une analyse du régime alimentaire de la légine antarctique (*Dissostichus mawsoni*) capturée à la palangre de fond dans la mer de Ross a été effectuée pour les saisons de pêche 2001 et 2002 (examen respectif de 3 937 et 5 426 estomacs). Les poissons de l'échantillon de 2001 avaient été capturés entre 317 et 2 154 m de profondeur; leur longueur totale variait de 58 à 190 cm. Les poissons de l'échantillon de 2002 avaient été capturés entre 815 et 1 623 m de profondeur; leur longueur totale variait de 62 à 197 cm. La proportion d'estomacs vides était élevée (34% en 2001 et 49% en 2002), quant aux autres, ils contenaient souvent des proies à un stade avancé de digestion qui en rendait l'identification difficile. Les poissons représentaient la catégorie la plus importante de proies (%*F* = 86 en 2001 et %*F* = 77 en 2002), le poisson des glaces en particulier (famille des Channichthyidae) et le grenadier de Whitson (*Macrourus whitsoni*). Par ordre d'importance venaient ensuite les calmars, les appâts et les crevettes.

Резюме

Было проведено исследование рациона Антарктического клыкача (*Dissostichus mawsoni*), пойманного на донный ярус в море Росса в течение промысловых сезонов 2001 и 2002 гг. (изучено соответственно 3937 и 5426 желудков). В 2001 г.

рыба была поймана на глубинах 317–2154 м и ее общая длина (TL) колебалась в диапазоне от 58 до 190 см. В 2002 г. рыба была поймана на глубинах 815–1623 м и имела TL от 62 до 197 см. Большая часть желудков была пустой (34% в 2001 г. и 49% в 2002 г.), а в остальных случаях пища в желудках была часто в сильно переваренном состоянии, что затрудняло установление видовой принадлежности добычи. Рыба была основным объектом питания (%F = 86 в 2001 г. и %F = 77 в 2002 г.), особенно ледяная рыба (семейство белокровные рыбы (Channichthyidae)) и макрурус Уитсона (*Macrourus whitsoni*), вслед за ней по важности в рационе шли кальмары, наживка и креветки.

Resumen

Se analizó la dieta de la austromerluza antártica (*Dissostichus mawsoni*) capturada con palangres de fondo en el mar de Ross en las temporadas de pesca de 2001 y 2002 (3 937 y 5 426 estómagos, respectivamente). Los peces muestreados en 2001 fueron extraídos entre los 317 y 2 154 m de profundidad y su intervalo de tallas fue de 58 a 190 cm de longitud total (TL). Los peces muestreados en 2002 fueron extraídos entre los 815 y 1 623 m de profundidad, con un intervalo de tallas de 62 a 197 cm LT. Una alta proporción de los estómagos estaban vacíos (34% en 2001 y 49% en 2002), mientras que los demás estómagos por lo general contenían presas en estado de avanzada digestión, lo que hizo difícil su identificación. Los peces constituyeron el componente principal de la dieta (%F = 86 en 2001 y %F = 77 en 2002); los más abundantes fueron los peces de hielo (familia Channichthyidae) y las colas de rata de Whitson (*Macrourus whitsoni*) seguidos en orden decreciente por calamares, carnada y camarones.

Keywords: Antarctic toothfish, *Dissostichus mawsoni*, diet, Ross Sea, trophic relationships, CCAMLR

INTRODUCTION

The Antarctic toothfish (*Dissostichus mawsoni*) is a large nototheniid species endemic to the Antarctic continental shelf (Goldsworthy et al., 2002). The other species of the genus, the Patagonian toothfish (*D. eleginoides*), is widespread throughout the Southern Ocean, although it is most common in waters near the Antarctic Convergence (Pilling et al., 2001).

A number of commercially important international longline and trawl fisheries target *D. eleginoides*, and the level of unregulated and illegal fishing of this species is a cause for concern (Brandão et al., 2002). Most fishing effort for *D. mawsoni*, which has a more southern distribution, typically in higher latitudes south of 65ºS, is in Subarea 88.1 and to a lesser extent Subarea 88.2. These subareas encompass the Ross Sea. The longline fishery (trawling is not permitted within these subareas) in these waters is currently managed by CCAMLR as an exploratory fishery. An exploratory fishery only becomes an established fishery when sufficient data and stock information are judged to be available for informed and accurate management. This exploratory status requires a high degree of reporting and research data collection by licensed participants. Catch levels for an exploratory fishery are also managed at a precautionary level to compensate for uncertainties in data available for stock management.

To help manage this developing fishery sustainably, an understanding of the ecological relationships between *Dissostichus* spp. and other key species is required. An awareness of the trophic relationships is important, as removal of a large dominant predator from the environment is likely to affect many other species in the community (Pilling et al., 2001).

D. mawsoni is not only a top fish predator but a source of food for cetaceans (Yukhov, 1971) and seals (Calhaem and Christoffel, 1969; Stirling, 1971; Testa et al., 1985). Some authors consider it to be only second in importance to the Antarctic silverfish (*Pleuragramma antarcticum*) as a key component of the Antarctic pelagic food web (Testa et al., 1985; Eastman, 1993).

Although there have been a number of published observations on the diet of *D. eleginoides* (Duhamel, 1981; Duhamel and Pletikosic, 1983; Goldsworthy et al., 2002), particularly from southwest Atlantic waters (Permitin and Tarverdiyeva, 1972; Tarverdiyeva, 1972; Zhivov and Krivoruchko, 1990; McKenna, 1991; García de la Rosa et al., 1997; Pilling et al., 2001, amongst others), there are few published papers on the diet of *D. mawsoni*. The existing studies range from brief observations of marine mammal feeding (Weddell seals – Wohlschlag, 1968; Calhaem and Christoffel, 1969; sperm whales – Yukhov, 1971) to more comprehensive trophic

studies (Gröhsler, 1992; Pakhomov and Tseytlin, 1992; Takahashi and Iwami, 1997). All these works were based on small sample sizes of fewer than 60 fish, making comparisons difficult.

This study presents dietary observations on *D. mawsoni* from the Ross Sea over the 2001 and 2002 summer fishing seasons, with the aim of increasing our understanding of the trophic relationships of this species within the Antarctic ecosystem.

MATERIALS AND METHODS

D. mawsoni stomach samples were obtained during cruises of the longliner *San Aotea II*, fishing under an exploratory permit in the Ross Sea (Subarea 88.1) during two summer seasons (January–March 2001 and January–March 2002).

Fish were caught by bottom longline at depths of 317–2 154 m in 2001 and 815–1 623 m in 2002, using Mustad autoline hooks baited with arrow squid (*Notodarus* spp.) and jack mackerel (*Trachurus* spp.).

One of the authors (J.M. Fenaughty) and the scientific international and national observers on board the vessel collected biological data (total length (TL), weight, sex, gonad stage and otoliths) from about 40% of all *D. mawsoni* captured during the surveys. *D. mawsoni* were randomly subsampled where catches exceeded 100 fish on targeted line sets, and exceeded 30 fish during exploratory line sets.

Stomachs from 3 937 *D. mawsoni* in 2001 and 5 426 *D. mawsoni* in 2002 were examined and graded according to their fullness and digestive state. These parameters were assessed according to five-point scales. For stomach fullness, these were: empty, trace, part full, nearly full and full; and for state of digestion: fresh, slightly digested, advanced digestion, digested and mixed stages. Often digestion was advanced, making prey identification difficult. Food items present in the stomach contents were identified to the highest possible taxonomic group.

The frequency of occurrence (%*F*) was calculated for each food item, i.e. the number of stomachs in which a food item occurred expressed as a percentage of the total number of stomachs containing food.

RESULTS

During the 2001 fishing season, heavy sea-ice in many areas focused early-season exploratory effort well to the south onto shallower areas within the Ross Sea. *D. mawsoni* at these depths (300–800 m) were typically smaller than those captured in deeper water (800–1 700 m) later in 2001 (mean = 116.2 cm TL) and during the following season (mean = 130.4 cm TL) (Figure 1). The length distribution of the 2001 sample is thus characterised by a broadly defined peak of juvenile fish (at about 85 cm TL), which are largely absent from the 2002 sample.

In 2001, 34% of 3 937 stomachs examined were empty; the remainder were largely partly full (25% held traces of food, 23% held small amounts of food, Figure 2a). Of the 2 583 stomachs that contained food, only 13% contained fresh food items. The remaining stomachs contained food that was mainly in early to advanced stages of digestion (34% and 24% respectively) (Figure 2b).

In 2002, 49% of 5 426 stomachs examined were empty and, as in the previous year, the remainder were largely partly full (15% held traces of food, 20% held small amounts of food, Figure 3a). Of the 2 714 stomachs that contained food, only 8% contained fresh food items. The remaining stomachs contained food that was mainly in advanced stages of digestion or fully digested (29% and 39% respectively) (Figure 3b).

Fish constituted the most important food category in both fishing seasons, occurring in 86% of stomachs in 2001 and 78% in 2002 (Table 1). Most fish were in advanced stages of digestion and could not be identified. In 2002, fish were identified to family or species level in 260 stomachs (8.6% of stomachs containing food items) (Table 2). On occasion, more than one species of fish was present in the same stomach. Icefish (family Channichthyidae) and Whitson's rattail (*Macrourus whitsoni*) were the most important fish prey groups (54% and 37% of stomachs). The taxonomy of Channichthyidae in the Ross Sea region is currently under revision by the Museum of New Zealand. The eel cod (*Muraenolepis microps*) and the deepsea cod (*Antimora rostrata*) were relatively common. Plunderfish (*Pogonophryne permitini*) and barracudina (Paralepididae) were less frequently present. Antarctic starry skates (*Raja georgiana*) or skate egg cases were sometimes present in stomachs from large *D. mawsoni*.

Cephalopods, particularly squid, were the next most important prey group, occurring in 5% of stomachs in 2001 and 14% in 2002. Squid often attacked hooked *D. mawsoni* on the line, leaving deep wounds and obvious sucker marks on the bodies of the fish. Octopus and the mesopelagic

Table 1: Frequency of occurrence (%*F*) of food items in the diet of *Dissostichus mawsoni* sampled in the Ross Sea, 2001 and 2002 fishing seasons: *n* – number of stomachs containing each food item; - – not identifiable to taxonomic level; 0 – absent. (Note: Identification and classification of food items was more rigorous in 2002 than in 2001.)

		2001		2002	
		n	%*F*	*n*	%*F*
Coelenterata					
Scyphozoa	medusae	1	0.04	4	0.2
Schleractinia	coral	2	0.08	0	
Crustacea		138	5.3	160	5.3
Decapoda	prawns	-	-	153	5.1
Amphipoda	amphipods	-	-	5	0.2
Isopoda	isopods	-	-	2	0.07
Mollusca		199	7.7	532	17.6
Gastropoda		-	-	2	0.07
Cephalopoda	unidentified squid	137	5.3	433	14.3
	Octopoteuthis rugosa	-	-	37	1.2
	unidentified octopus	62	2.4	60	2.0
Echinodermata	unidentified echinoderms	1	0.04	0	
Pisces					
Chondrichthyes	*Raja (Amblyraja) georgiana*	1	0.04	7	0.2
	skate egg case	0		1	0.03
Osteichthyes	(refer Table 2)	2240	86.4	2355	77.9
Other	bait	310	12.0	332	11.0
	penguin remains	1	0.04	3	0.1
	hooks	0		2	0.07
	rocks	37	1.4	114	3.8
Unidentified prey		3	0.1	5	0.2
Total number of prey items		2930		3515	
Total number of stomachs containing food*		2594		3025	

* The number of stomachs containing food in the 2001 and 2002 fishing seasons was higher than mentioned in the text (and in Tables 1 and 2) as data were not always collected for stomach and digestion state.

Table 2: Frequency of occurrence (%*F*) of fish families and species (Osteichthyes) identified in the diet of *Dissostichus mawsoni* caught in the Ross Sea, 2002 fishing season: *n* – number of stomachs containing each food item.

Family		*n*	%*F*
Muraenolepididae	*Muraenolepis microps*	19	7.3
Artedidraconidae	*Pogonophryne permitini*	3	1.2
Channichthyidae	unidentified icefish	140	53.8
Paralepididae	unidentified barracudina	2	0.8
Macrouridae	*Macrourus whitsoni*	96	36.9
Moridae	*Antimora rostrata*	12	4.6
Total number of prey items		272	
Total number of stomachs containing identifiable fish		260	

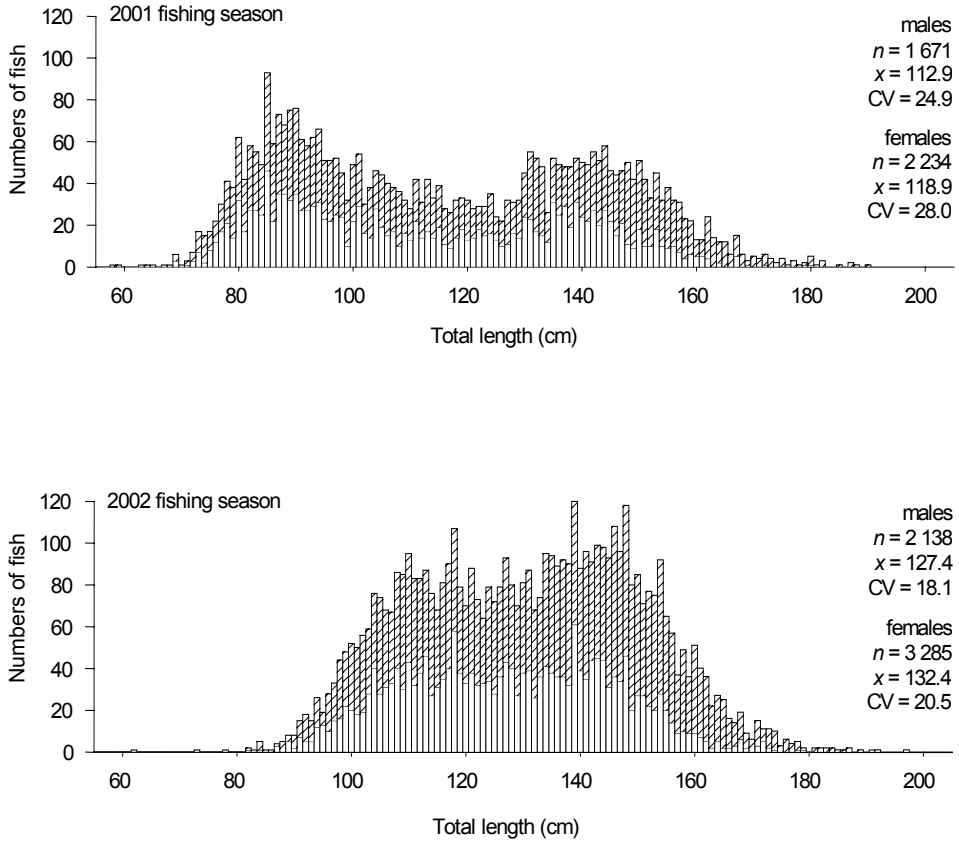

Figure 1: Length frequencies of *Dissostichus mawsoni* sampled for stomach contents during the 2001 and 2002 fishing seasons: *n* – number of fish sampled; *x* – mean length; CV – coefficient of variation.

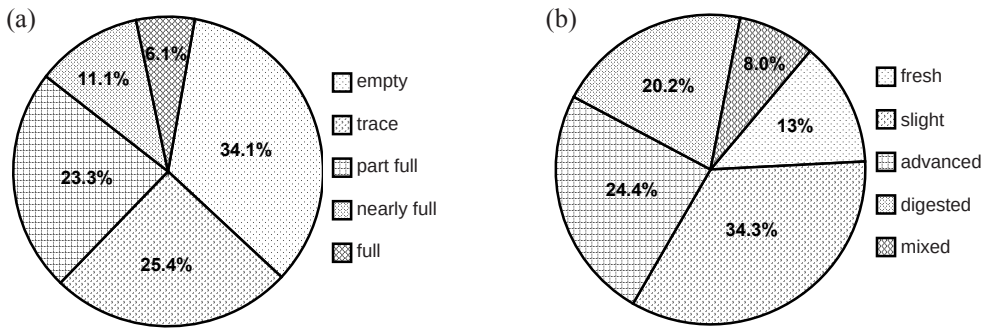

Figure 2: (a) Stomach state (*n* = 3 937) and (b) digestion state (*n* = 2 583) for *Dissostichus mawsoni* captured during the 2001 fishing season.

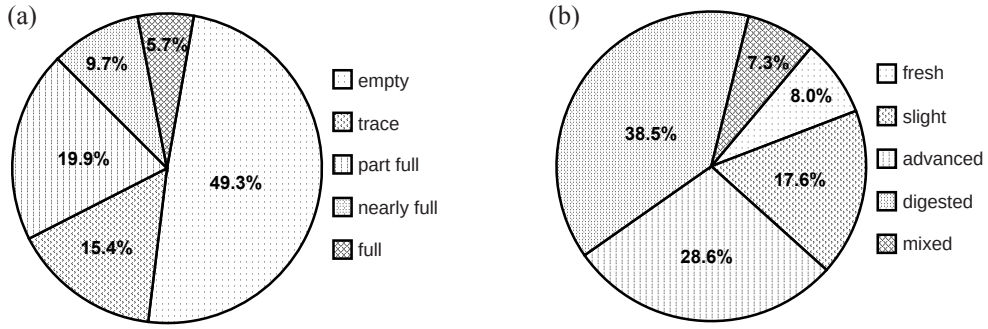

Figure 3: (a) Stomach state (n = 5 426) and (b) digestion state (n = 2 714) for *Dissostichus mawsoni* captured during the 2002 fishing season.

cephalopod *Octopoteuthis rugosa* (only separated from 'squid' in the 2002 survey) were quite common but localised prey items.

Prawns (possibly *Nauticaris* spp.) were a relatively important prey item and were found in about 5% of stomachs in 2002. They were also observed during the 2001 sampling although they were aggregated under the category Crustacea for that year. Live amphipods and isopods were also found in a few stomachs.

Bait, with marks indicating that *D. mawsoni* had been feeding on the line before capture, was present in 11 to 12% of stomachs examined in both seasons. Fish hooks were also found in some stomachs. Other items recovered were a large quantity of rocks, the remains of three penguins, and the occasional jellyfish, echinoderm, coral remnant and gastropod.

To briefly examine the effect of *D. mawsoni* size on the diet, the 2001 and 2002 samples were subdivided into three length classes: a subadult class of less than 100 cm and two arbitrary adult classes, medium-sized adults of 100 to 149 cm and large adults of 150 to 200 cm TL (Figures 4 and 5). The subadult length class was defined based on data on *D. eleginoides,* which reaches sexual maturity at about 100 cm in length (Konforkin and Kozlov, 1992 from Goldsworthy et al., 2002), and on recent work on both *Dissostichus* species (Horn, 2002).

In general, in both fishing seasons bait and crustaceans were more commonly encountered in the stomachs of smaller fish, while squid and rocks were more common in stomachs from larger fish. In 2001, the proportion of fish prey was slightly higher in the stomachs of smaller *D. mawsoni.*

DISCUSSION

Subadult and adult *D. mawsoni* in the Ross Sea (300–2 100 m depths) are primarily piscivorous, although they feed on a wide variety of prey. Icefish and *M. whitsoni* were the most frequently identified fish in the stomachs examined, and *M. microps* and *A. rostrata* were also relatively common. *P. permitini*, Paralepididae and *R. georgiana* were occasionally present. Squid, bait and prawns were also important food items. Octopus was a relatively common but localised prey. *O. rugosa* was also a common prey in some areas, suggesting epibenthic feeding.

A number of fish prey species, in particular *M. whitsoni*, were caught on baited hooks before being eaten in turn by toothfish.

By size category, crustaceans and bait were more commonly encountered in the stomachs of smaller fish, while squid and rocks were more common in stomachs from larger fish. A higher proportion of juvenile *D. mawsoni* were caught in 2001 when fishing was conducted in shallower waters closer to the Antarctic continent than in 2002 when more fishing was conducted in deeper water. During the 2001 season 53% of sets were made in waters less than 1 000 m in depth.

A high proportion of the stomachs contained prey in advanced stages of digestion. This may be due to an efficient digestive system, regurgitation of fresh prey (see below), or the cessation of feeding once the fish has been hooked. Likewise, many stomachs were empty, particularly in 2002 when more fishing was conducted in deeper water (34% of stomachs in 2001 and 49% in 2002). This may be due in part to a lack of food resources or lower feeding intensity (García de la Rosa et al., 1997), particularly in deeper water, or regurgitation of stomach contents prior to landing.

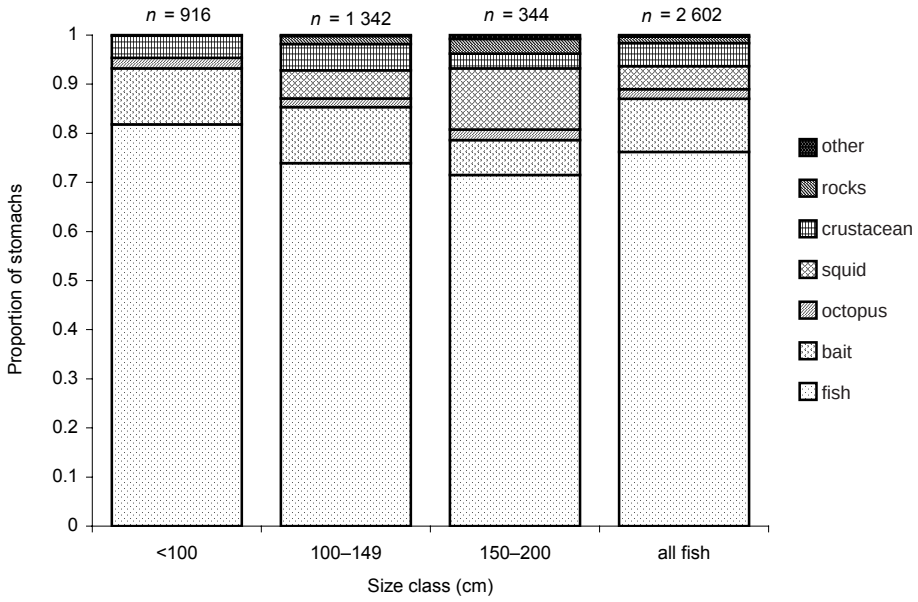

Figure 4: Proportion of *Dissostichus mawsoni* stomachs from the 2001 fishing season containing each food category by size class. *n* – number of stomachs.

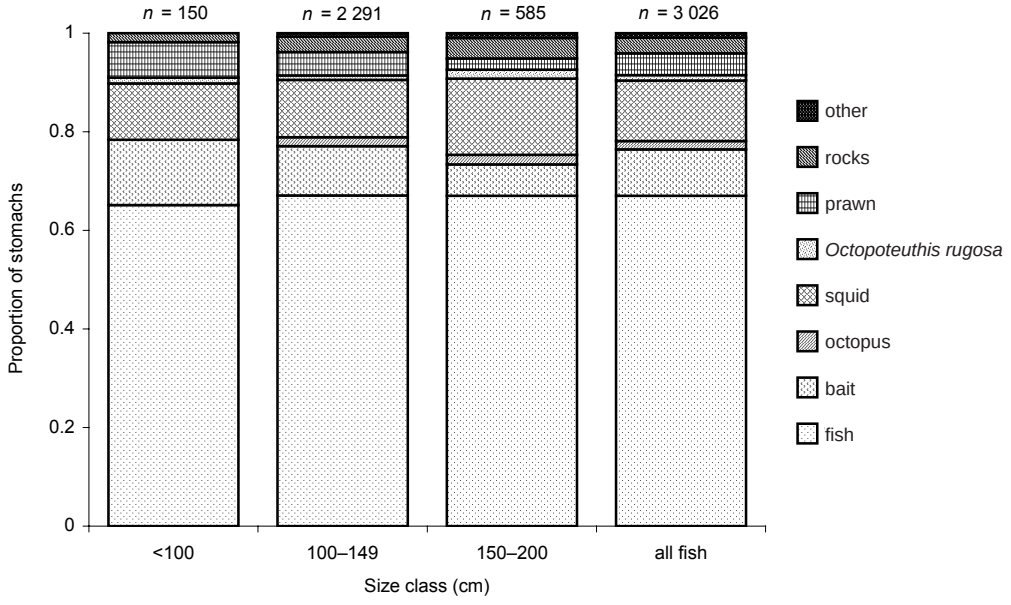

Figure 5: Proportion of *Dissostichus mawsoni* stomachs from the 2002 fishing season containing each food category by size class. *n* – number of stomachs.

Although like all nototheniids, *Dissostichus* spp. lack a swim bladder, stomach contents from longline-caught fish may be affected by regurgitation. Pilling et al. (2001) compared the diet of *D. eleginoides* caught by longlining and by potting from east Shag Rocks (South Georgia) in 300 to 600 m depths, and found that only 28% of pot-caught fish exhibited empty stomachs, in comparison to 91% of fish captured by longline. They suggested that feeding studies based on longline-caught fish might be biased as regurgitation rates may vary with prey species.

However, the current study observed similar percentages of empty stomachs (34% in 2001) to those observed in pot-caught fish when fishing was carried out over a wide range of depths (300–2 100 m). In a study of trawl-caught *D. eleginoides* from the waters around Macquarie Island (500–1 290 m) over three summer seasons, the percentage of empty stomachs varied significantly (15–62%), although no evidence of regurgitation was found in the stomachs examined (Goldsworthy et al., 2002).

Cursory observations of the diet of *D. mawsoni* were reported by Calhaem and Christoffel (1969) while studying the feeding habits of a Weddell seal (*Leptonychotes weddelli*) from an ice hole in McMurdo Sound. The seal preyed only on *D. mawsoni,* the stomachs of which contained numerous *P. antarcticum*, a small abundant pelagic notothenid of the Antarctic shelf. Yukhov (1971) examined 59 intact, fresh *D. mawsoni* (97–174 cm TL) taken from the stomachs of sperm whales captured largely in open oceanic waters of the Pacific sector of Antarctica. The *D. mawsoni* stomachs were dominated by squid (20–33 cm mantle length), with remnants of small fishes in one stomach and stones in others.

Pakhomov and Tseytlin (1992) analysed the diet of 52 *D. mawsoni* (214–4 450 g, length data unavailable) along with that of six other fish species in the Cosmonaut Sea (East Antarctica). The main prey of *D. mawsoni* were small notothenids (*Trematomus eulepidotus, T. hansoni* and young *P. antarcticum*), spiny icefish (*Chaenodraco wilsoni*) and myctophids.

Gröhsler (1992) conducted a comprehensive study of the feeding ecology of 27 species of Antarctic fish around Elephant Island (South Shetland Islands). The 38 samples of *D. mawsoni* (11–119 cm TL) examined over the austral winter showed a high proportion of empty stomachs (39%). Mysids and amphipods were the most abundant prey items, but fish, in particular *Gobionotothen gibberifrons* (three individuals) and *Champsocephalus gunnari* (two individuals), were the only important prey category by dry and wet weight.

Takahashi and Iwami (1997) examined the diets of 38 taxa of demersal fish from the South Shetland Islands. They recorded the stomach contents of four *D. mawsoni*, in which *G. gibberifrons* constituted 85% of the dry weight of the sample.

CONCLUSIONS

Based on these studies it appears that the diet of *D. mawsoni* varies considerably between areas, even within the Ross Sea area. Under shore fast-ice and heavy pack-ice, *D. mawsoni* feeds largely on *P. antarcticum* (Calhaem and Christoffel, 1969; Fuiman et al., 2002), while in deeper waters, away from the shore fast-ice, common benthic species (icefish and *M. whitsoni*) form the bulk of the diet (this study). In open oceanic waters, squid may dominate the diet (Yukhov, 1971). The diet of *D. eleginoides* also varies between areas and years (see Goldsworthy et al., 2002) although it is dominated by locally abundant fish species, particularly nototheniids and icefish. Therefore it appears that both *Dissostichus* species are largely piscivorous opportunists, preying mainly on locally abundant benthic and, on occasion, pelagic species.

In the absence of sharks, which are rare in Antarctic waters (Fischer and Hureau, 1985), both *Dissostichus* species are presumably the dominant fish predator. However, they do compete with marine mammals and penguins in some areas (Wohlschlag, 1968; Calhaem and Christoffel, 1969; Yukhov, 1970, 1971; Testa et al., 1985; Goldsworthy et al., 2001).

The method of frequency of occurrence of prey categories used in this study may have biased the results, since 'such analyses tend to overestimate the importance of prey items with small biomass and underestimate the importance of prey items with large biomass' (Goldsworthy et al., 2002). The advanced stages of digestion found in most stomachs made prey identification difficult, and delicate species may have been underrepresented in the results. Partial regurgitation of stomach contents may have also caused some underestimates.

ACKNOWLEDGEMENTS

The authors thank the CCAMLR and New Zealand Ministry of Fisheries scientific observers, namely Simon Beatson, Mark Dixon, Cathy Morrish and Hennie Crous, who helped collect

the feeding data used in this study. The assistance and cooperation of Sanford Limited in supporting the study as part of its research involvement in the exploratory fishery in the Ross Sea is gratefully acknowledged. Esteban Barrera-Oro, Konstantin Shust and Mary Livingston provided constructive comments on an earlier draft of the manuscript. This work was partially funded by the New Zealand Ministry of Fisheries under research project PAT2000/01.

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