

## Fish Prey of the Wandering Albatross *Diomedea exulans* at South Georgia

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**Summary.** The fish diet (45% of total diet by weight) of Wandering Albatrosses rearing chicks at South Georgia during the austral winters of 1983 and 1984 was investigated using otoliths retrieved from regurgitations. These provide the first quantitative data for this species and for any albatross. By number of identified otoliths (32% could be identified only as ?Macrouridae and ?Moridae), *Pseudochaenichthys georgianus* (35%), *Muraenolepis microps* (33%) and *Chaenocephalus aceratus* (20%) predominated, with *Notothenia gibberifrons*, *Pagothenia hansonii* and *Champscephalus gunnari* (together 12%) also present. Composition by weight (estimated from otolith length) of the main species was *Pseudochaenichthys* 51%, *Muraenolepis* 14%, *Chaenocephalus* 27%; if digestion and wear had reduced otoliths by 10% the values would be *Pseudochaenichthys* 54%, *Chaenocephalus* 25%, *Muraenolepis* 13%. Composition by weight (actual or corrected values) was almost identical between years but epipelagic fish were significantly more abundant in 1983 than 1984. All identified fish eaten by Wandering Albatrosses are common on the South Georgia continental shelf and most of them are caught in the commercial fishery there. However, two of the three main target species of this fishery in 1983–1984, *Notothenia rossii* and *Champscephalus* were not, or rarely, caught by Wandering Albatrosses. It seems unlikely, therefore, that the albatrosses depend greatly on the fishery for acquisition of fish prey but how they catch several species, including *Muraenolepis*, which are mainly benthic in habit is unknown.

### Introduction

Fish are commonly eaten by all six species of albatrosses which breed at islands in the Southern Ocean (Prince 1980; Thomas 1982; Weimerskirch et al. 1986). However, information on the species taken is either anecdotal or absent. This is mainly because when albatrosses are rearing chicks (the time when food samples are most easily

collected) their foraging trips last at least two days and the material in their stomachs tends to be well digested. Because the keratinous mandibles (beaks) of squid are indigestible, retained in the stomach, resistant to formalin (the usual preservative for predator stomach contents), and can be identified (Clarke 1962, 1986), the cephalopod diet of various albatrosses has been studied in some detail (Imber and Russ 1975; Berruti and Marcus 1978; Clarke and Prince 1981; Clarke et al. 1981; Imber and Berruti 1981; Thomas 1982; Brooke and Klages 1986; Rodhouse et al. 1987).

Although fish otoliths are also relatively indigestible and retained in predator stomachs, they dissolve in formalin. This, and the scarcity of information on the identity of Southern Ocean fish otoliths, is presumably the reason why there have been no studies hitherto on the fish diet of albatrosses in the Antarctic region. This paper presents quantitative data on the identity, size and status of fish taken by the Wandering Albatross *Diomedea exulans*, based on a collection of otoliths present in food samples obtained during the austral winters of 1983 and 1984 at Bird Island, South Georgia (54°00'S, 38°02'W).

The Wandering Albatross is the largest member of the family Diomedidae. Adult males average 10 kg, females 8 kg in weight (Tickell 1968). It breeds at most sub-Antarctic islands, laying eggs in December which hatch in late March. The chick receives food from its parents about every three days from May (when brooding ceases) until about November (when it fledges), both parents sharing these duties (Tickell 1968). The only other seabirds to have dependent offspring during the Antarctic winter are Emperor Penguins *Aptenodytes forsteri* which apparently feed mainly on small notothenioid fish (Ofredo and Ridoux 1986) and King Penguins *A. patagonicus*, which seldom feed their chicks between May and September (Stonehouse 1960). Fish material from Wandering Albatrosses, therefore, provides unique information on the fish available in sub-Antarctic regions in winter to surface foraging seabirds.

## Methods

The stomach contents of Wandering Albatross chicks ( $n = 80$ ) were sampled at approximately monthly intervals between May and September (inclusive) of 1983 and 1984. Samples were taken by inducing the chick to regurgitate immediately after being fed by a parent. No chick was sampled more than once. Samples were frozen at  $-10^{\circ}\text{C}$  and returned to the UK for analysis. After thawing, otoliths ( $n = 81$ ) were removed from the samples ( $n = 80$ ), retaining in pairs ( $n = 20$ ) those which were extracted from individual fish crania, and stored dry. They were drawn, using a binocular microscope with drawing tube, and maximum length and breadth measured from the drawing and converted into true length (to the nearest 0.01 mm). Thickness was measured, to 0.01 mm, with vernier callipers. Weight was recorded to 0.01 g. Otoliths were identified using reference specimens and illustrations (North et al. 1984; Hecht 1987; British Antarctic Survey (BAS), unpublished data). The degree of digestion of otoliths from the food samples was estimated by comparison with intact specimens. Estimates of fish total length (TL in mm) and weight (TW in g) were derived from otolith length (OL in mm), using least squares linear regression techniques.

$\log_{10}$ -transformed data gave a better fit than untransformed data for all species. The equations used were as follows:

### *Muraenolepis microps*

$$\log_{10}\text{TL} = 1.59 + 1.35 \log_{10}\text{OL} (n = 43, r = 0.92)$$

$$\log_{10}\text{TW} = -0.396 + 4.15 \log_{10}\text{OL} (n = 43, r = 0.98)$$

### *Notothenia gibberifrons*

$$\log_{10}\text{TL} = 1.39 + 1.28 \log_{10}\text{OL} (n = 60, r = 0.98)$$

$$\log_{10}\text{TW} = -1.28 + 4.30 \log_{10}\text{OL} (n = 59, r = 0.98)$$

### *Pagothenia hansonii*

$$\log_{10}\text{TL} = 1.70 + 1.01 \log_{10}\text{OL} (n = 32, r = 0.96)$$

$$\log_{10}\text{TW} = -0.228 + 3.54 \log_{10}\text{OL} (n = 32, r = 0.95)$$

### *Chaenocephalus aceratus*

$$\log_{10}\text{TL} = 1.88 + 1.27 \log_{10}\text{OL} (n = 37, r = 0.90)$$

$$\log_{10}\text{TW} = -0.061 + 4.55 \log_{10}\text{OL} (n = 36, r = 0.89)$$

### *Champscephalus gunnari*

$$\log_{10}\text{TL} = 1.96 + 1.19 \log_{10}\text{OL} (n = 42, r = 0.97)$$

$$\log_{10}\text{TW} = 0.38 + 4.16 \log_{10}\text{OL} (n = 41, r = 0.97)$$

### *Pseudochaenichthys georgianus*

$$\log_{10}\text{TL} = 1.57 + 1.64 \log_{10}\text{OL} (n = 36, r = 0.90)$$

$$\log_{10}\text{TW} = -0.93 + 5.87 \log_{10}\text{OL} (n = 36, r = 0.90).$$

## Results

Fish occurred in 93% of the 80 samples obtained, comprising 56% of prey items (excluding carrion) and contributing 45% of the diet by weight. The samples contained material (flesh, jaw bones, otoliths) from at least 113 fish and contained 81 otoliths from 61 fish. Fifteen samples (13%) contained only traces of fish (flesh or scales), nine (8%) contained fish remains without evidence of heads and 28 (25%) contained jaw bones but no otoliths. Thus otoliths were present in 54% of the samples containing fish and 62.5% of the samples containing more than a trace. Of the 81 otoliths, one was too damaged to be identifiable, 49 (61%) were identified to species and 29 (36%) were identified tentatively to family level.

Of the 61 fish represented, 40 (66%) were identified to species and 19 (31%) to family (Table 1). Ten species (one unidentified) of fish were represented by otoliths in the samples. Of the six species identified, *Muraenolepis microps*, *Pseudochaenichthys georgianus* and *Chaenocephalus aceratus* were present in both years samples and together comprised 58% of all otoliths and 87% of all identified ones. *Notothenia gibberifrons* and *Pagothenia hansonii* were present only in the 1984 and *Champscephalus* only in the 1983 samples. Together these contributed 12% of identified specimens. The two species of ?Macrouridae (grenadiers) were not uncommon (27% of all otoliths) and occurred in both years. Their otoliths are similar to, but not identical with, those of *Coelorhynchus fasciatus* (common around the Falkland Islands and known from South Georgia); they are different from *Cynomacrus piriei* (a higher latitude species; Fischer and Hureau 1985). The only other species of this family known from the Scotia Sea are *Cynomacrus marinii* and *Macrourus holotrachys* (Fischer and Hureau 1985). No otoliths of these were available for comparison; our material is similar to, but not identical with the illustra-

**Table 1.** Identity and number of fish, identified from otoliths, in food samples from Wandering Albatrosses in 1983 and 1984

Species	1983			1984			Both years		
	No.	% Total	% Identified	No.	% Total	% Identified	No.	% Total	% Identified
<i>Muraenolepidae</i>									
<i>Muraenolepis microps</i>	5	21.7	27.8	8	21.1	36.4	13	21.3	32.5
<i>Nototheniidae</i>									
<i>Notothenia gibberifrons</i>	0	—	—	3	7.9	13.6	3	4.9	7.5
<i>Pagothenia hansonii</i>	0	—	—	1	2.6	4.6	1	1.6	2.5
<i>Channichthyidae</i>									
<i>Chaenocephalus aceratus</i>	2	8.7	11.1	6	15.8	27.3	8	13.1	20.0
<i>Champscephalus gunnari</i>	1	4.4	5.6	0	—	—	1	1.6	2.5
<i>Pseudochaenichthys georgianus</i>	10	43.5	55.6	4	10.5	18.2	14	23.0	35.0
?Macrouridae									
Species B	2	8.7	—	4	10.8	—	6	9.8	—
Species M	2	8.7	—	8	21.6	—	10	16.4	—
?Moridae									
Species S	1	4.3	—	2	5.4	—	3	4.9	—
Unidentified	0	—	—	1	2.7	—	1	1.6	—

tion of the latter in Hecht (1987). The one species of ?Moridae (moras) was less common, although taken in both years. The only species of this family apparently reported for the Scotia Sea (Fischer and Hureau 1985) is *Antimora rostrata*; no otoliths of this species were available but the illustration in Hecht (1987) does not quite match our specimens.<sup>1</sup>

A summary of the measurements of otolith length and derived information is presented in Table 2. Full data for each specimen are available on request. Only specimens identified to species level could be used in estimating the size of the intact fish. The estimates of fish total weight, derived from otolith length, are used to give estimates of age, using the most detailed age-length relationship currently available. The estimates of age are inevitably less precise than those of length, especially when averages of different relationships for male and female fish have had to be used (e.g., with *Chaenocephalus aceratus*). Even in this case, however, estimates are probably accurate to  $\pm$  one year.

The estimation of the size and age of intact fish is affected by the amount of otolith wear (digestion) that has occurred. Otoliths of Channichthyidae (*Chaenocephalus*, *Champscephalus*, *Pseudochaenichthys*) were only slightly affected ( $\leq 5\%$  loss) but some otoliths of the *Muraenolepis* and of ?Macrouridae appeared to have lost c. 10% overall length. Small changes in otolith length have considerably greater effect on estimates of fish weight than of fish length. To give some idea of the potential significance of this we include in Table 2 estimates of fish weight assuming a 10% reduction of otolith length. With our current knowledge of digestion rates of otoliths any more sophisticated treatment is unjustified. Except in the case of very large (>2000 g) individual fish, a 10% increase in otolith length adds about one year to the age, but for some species (e.g., *Pseudochaenichthys* and *Chaenocephalus*) it nearly doubles body weight.

Few age-length data are available for *Muraenolepis*. White and North's (1979) data suggest that the fish were about 6–9 years old; Permitin's (1973) information on the length at which sexual maturity is attained (21–27 cm in males, 23–32 cm in females) suggests that all specimens were likely to have been adults. *Notothenia gibberifrons* and *Chaenocephalus aceratus* become sexually mature about age 5–8 years and *Champscephalus gunnari* at age 3–5 years, so the albatross prey of these species are almost entirely adults. The *Pseudochaenichthys* specimens are a mixture of adults and immatures. Permitin (1973) gives lengths at sexual maturity of 40–48 cm for males and 44–50 cm for females. Using uncorrected otolith lengths, 36% of prey would be adults; with lengths corrected for 10% loss, 57% would be adult. The single *Pagothenia* was immature.

There are some differences in the abundance and size of fish between the 1983 and 1984 samples. *Notothenia gibberifrons* and *Pagothenia* were only present in 1984 and *Champscephalus* in 1983. There were fewer *Pseudochaenichthys* in 1984 but these were significantly larger ( $t = 3.6$ ;  $P < 0.01$ ) than in 1983. Size differences between years in *Chaenocephalus*, however, were not significant ( $t = 1.2$ ;  $P > 0.1$ ). The *Muraenolepis* specimens in 1983 and 1984 were almost identical in size.

The otoliths of ?Macrouridae are disproportionately large in comparison to body size. Thus if the otoliths had been from *Coelorhynchus fasciatus* they would have represented fish of 88–190 mm length, weighing probably less than 100 g each. Moras are somewhat larger, averaging ca. 400 mm in length and probably weighing 300–500 g. Therefore, the fish which we could not identify to the species level (ten ?Macrouridae, three ?Moridae) certainly do not make a disproportionate contribution by weight to the composition of the fish prey of Wandering Albatrosses.

Using the species for which full details are available, we assess the contribution they make to the diet of the Wandering Albatross in Table 3. By weight *Notothenia gibberifrons*, *Pagothenia* and *Champscephalus* contribute less than 10% in either season, irrespective of whether weight is calculated on the basis of measured or corrected otolith length. The three main species make almost identical contributions in both seasons, whichever estimate of otolith length is used. Thus, differences in otolith length had little consequence for the relative importance by weight of these three species. In general terms we conclude that the main fish preys of the Wandering Albatross in 1983 and 1984 at South Georgia were *Pseudochaenichthys georgianus* (ca. 53%), *Chaenocephalus aceratus* (ca. 26%) and *Muraenolepis* (ca. 14%). These values will be slight overestimates because of the contribution of the unidentified fish.

## Discussion

The main features of the fish diet of Wandering Albatrosses, based on the material identified to the species level, are summarised in Table 4. Material which could not be identified to the species level comprised 34% by number of fish but, based on rough estimates of likely size, probably contributed no more than about 10% by weight of the complete sample.

In attempting to reconstruct the fish diet of predators from otolith material there are obviously numerous problems and biases; these have been reviewed in detail by Duffy and Jackson (1986), Jobling and Breiby (1986) and Croxall (in press). In relation to our study, the main problem is the difficulty in correcting for any loss of otolith material due to wear and the main bias is likely to be the difficulty in recovering small otoliths from bird stomach samples acquired by regurgitation. We have estimated how the composition of the diet would be affected if all

<sup>1</sup> Otoliths of Moridae species S are a good match for otoliths of *Antimora rostrata* which were kindly supplied by Dr. J. D. M. Gordon from specimens caught in the eastern North Atlantic

Table 2. Otolith length and characteristics of fish derived from this, of fish prey of Wandering Albatrosses at South Georgia

Species	Year	Fish no.	Otolith length (mm)		Fish length (mm)		Fish wt (g)		Corrected fish wt (g <sup>1</sup> )		Age (years) <sup>2</sup>		Reference <sup>3</sup>					
			Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean		Range				
<i>Muraenolepis microps</i>	1983	5	8	4.45	0.54	3.9-5.3	299	49	244-389	230	126	114-475	341	188	169-705	76-9	1	
	1984	8	13	4.48	0.40	3.9-5.5	295	36	241-389	214	91	109-475	318	134	162-705	76-9		
	Both	13	21	4.50	0.48	3.9-5.5	297	40	241-389	220	103	109-475	327	153	162-705	76-9		
	1984	3	4	7.47	0.48	7.0-8.1	322	27	294-358	305	87	219-425	460	131	330-641	6	5-7	2,3
<i>Notothenia gibberifrons</i>	1984	1	1	3.0			154			30			42				2	3
	1983	2	2	3.70	0.85	3.1-4.3	401	116	319-484	401	359	148-655	619	553	228-1011	5	3-7	4
<i>Chaenocephalus aceratus</i>	1984	6	8	4.35	0.53	3.6-5.1	492	76	383-604	759	407	285-1449	1172	628	439-2236	8	5-12+	4
	Both	8	10	4.19	0.63	3.1-5.1	469	88	319-604	670	405	148-1449	1033	625	228-2236	7	3-12+	4
<i>Chaenopscephalus gunnari</i>	1983	1	1	3.80			447			614			912				7	4
	1983	10	10	3.72	0.63	3.0-4.8	325	91	225-487	375	381	74-1175	657	666	130-2055	4	2-10	5,6
<i>Pseudochaenichthys georgianus</i>	1984	4	4	4.90	0.68	4.1-5.6	507	113	376-634	1597	1135	466-3027	2794	1985	815-5796	8	4-12+	5,6
	Both	14	14	4.06	0.83	3.0-5.6	377	127	225-634	724	852	74-3027	1267	1490	130-529	5	2-12+	5,6
? <i>Macrouridae</i> sp. B	1983	2	3	4.45	0.07	4.4-4.5												
1984	4	6	6	3.33	1.51	1.1-4.4												
Both	6	9	9	3.7	1.3	1.1-4.5												
? <i>Macrouridae</i> sp. M	1983	2	4	12.57	0.46	12.2-12.9												
1984	8	11	11	11.53	2.82	6.8-14.4												
Both	10	15	15	11.74	2.53	6.8-14.4												
? <i>Moridae</i> sp. S	1983	1	2	15.85														
1984	2	3	3	11.50	2.8	9.5-13.5												
Both	3	5	5	12.95	3.2	9.5-15.8												

<sup>1</sup> Corrected for 10% loss of otolith length; <sup>2</sup> Based on uncorrected lengths; <sup>3</sup> References: 1 = Permittin 1973, White and North 1979, 2 = Hoffman 1982, 3 = Shust and Pinskaya 1978, 4 = Kock 1981, 5 = Chojnacki and Palczewski 1981, 6 = Mucha 1980

Table 3. Composition by estimated weight (g), on the basis of measured and corrected (allowing for 10% loss in length) otolith length, of fish diet of Wandering Albatrosses at South Georgia in 1983 and 1984

	<i>Muraenolepis microps</i>		<i>Notothenia gibberifrons</i>		<i>Pagothenia hansonii</i>		<i>Chaenocephalus aceratus</i>		<i>Champsocephalus gunnari</i>		<i>Pseudochaenichthys georgianus</i>		Total													
	Measured	Corrected	Measured	Corrected	Measured	Corrected	Measured	Corrected	Measured	Corrected	Measured	Corrected	Measured	Corrected												
Wt	%	Wt	%	Wt	%	Wt	%	Wt	%	Wt	%	Wt	%	Wt	%											
1983	1150	18.2	1705	16.4	802	12.7	1239	11.9	614	9.7	912	8.8	3750	59.4	6570	63.0	6316	10426								
1984	1712	12.6	2544	11.5	915	6.7	1380	6.2	30	0.2	42	0.2	4554	33.5	7032	31.7	—	6388	47.0	11176	50.4	13599	22174			
Combined	2860	14.4	4251	13.0	915	4.6	1380	4.2	30	0.15	42	0.1	5360	26.9	8264	25.3	614	3.1	912	2.8	10136	50.9	17738	54.4	19915	32587

**Table 4.** Summary of the identified fish diet of Wandering Albatrosses at South Georgia in terms of dietary composition, size, weight and status of prey

Species	Proportion (%) of diet		Fish length (mm)		Fish weight <sup>1</sup> (g)		Fish status <sup>1</sup>
	By no.	By weight <sup>2</sup>	Mean	Range	Mean	Range	
<i>Muraenolepis microps</i>	32.5	12–18	297	241–389	220	109–475	Adult
<i>Notothenia gibberifrons</i>	7.5	4–7	322	294–358	305	219–425	late Juvenile/Adult
<i>Pagothenia hansonii</i>	2.5	1	154		30		Juvenile
<i>Chaenocephalus aceratus</i>	20.0	12–34	469	319–604	670	148–1449	75% Adult 25% Juvenile
<i>Champocephalus gunnari</i>	2.5	3–8	447		614		Adult
<i>Pseudochaenichthys georgianus</i>	35.0	47–63	377	225–634	724	74–3027	60% Juvenile 40% Adult

<sup>1</sup>Estimated from uncorrected otolith measurements; <sup>2</sup>Range from corrected and uncorrected measurements

otoliths had lost 10% of their length, but have no indication of whether there are fish species or sizes taken by Wandering Albatrosses which are not represented in the regurgitated samples. It is logical that seabirds as large as the Wandering Albatross should take relatively large prey, so the absence of 0–1 year-old juvenile fish from the samples may be real and not an artefact of the way in which they were obtained.

#### Characteristics of Fish Eaten by Wandering Albatrosses

The six species identified in this sample are all at least fairly common around South Georgia. *Muraenolepis* is a bottom-dwelling eel-cod of fjords and the continental shelf which eats benthic organisms; it spawns in winter (Permitin 1973; Burchett et al. 1983). *Notothenia gibberifrons* and *Pagothenia* are benthic rock-cods, the former eating mainly sedentary prey (bivalves, worms), the latter also taking more active animals (amphipods, mysids, decapods) (Targett 1981; Burchett et al. 1983). They spawn in late winter and summer, respectively (Fischer and Hureau 1985; BAS, unpublished data). *Chaenocephalus* is a sluggish benthic-demersal ice-fish eating mainly nektonic organisms, chiefly mysids and fish, but also some krill (Targett 1981; Burchett et al. 1983). Burchett (1983) found adults to be present in shallow water (less than 90 m deep) from November to February, when they spawn near the coast and in fjords, but absent after May when they were presumably feeding in deeper water. *Champocephalus* is a pelagic species chiefly eating krill (Permitin and Tarverdieva 1978; Targett 1981) and spawning in autumn. *Pseudochaenichthys* is somewhat intermediate ecologically between the benthic-demersal species and *Champocephalus*. It is commonly benthic on the shelf but is also a pelagic planktivore (eating krill and mysids); it is rare in shallow inshore waters (Burchett et al. 1983). It spawns in autumn (Permitin and Tarverdieva 1978).

#### Comparison Between Years

In a detailed analysis of the squid material from the same Wandering Albatross samples, Rodhouse et al. (1987)

identified significant differences between the two years. This mainly involved an increase in the contribution of species characteristic of waters north of the Antarctic Polar Front. Rodhouse (in press) was unable to link this to an incursion of warmer water in 1984. He suggested that the scarcity of krill in the South Georgia region in 1983 (Heywood et al. 1985; Croxall et al., in press, Pridle et al., in press) resulted in sufficient disruption of the food web – many of the squid eat krill – to cause Wandering Albatrosses to have to extend their foraging range in 1984.

Differences between years in the fish samples were less pronounced. *Pseudochaenichthys* was less common in 1984 than 1983 (11% versus 53% of all fish); *Notothenia gibberifrons* and *Pagothenia* were reported only in 1984. *Champocephalus* was taken only in 1983. The ?Macrouridae fish were more common in 1984 than 1983 (33% versus 17% of fish). Because the ?Macrouridae are unlikely to be common around South Georgia (otherwise we would have material from which their otoliths could have been identified), they provide the only evidence of a tendency for Wandering Albatrosses to have foraged further a field in 1984. Pelagic fish (*Pseudochaenichthys* and *Champocephalus*) which feed mainly on krill, in contrast to the benthic-demersal species (the rest), form 61% of the identified material in 1983 but only 18% of the 1984 sample. This significant difference ( $\chi^2 = 11.8$ ;  $P = 0.01$ ) is perhaps suggestive of a shift either in the fish taken by, or available to, Wandering Albatrosses. The shift away from krill-eating species would be in line with changes in the food web consequent on the scarcity of krill after the 1983 winter. However, the sample of fish is very small and this can only be regarded as a tentative conclusion.

#### Comparison with Other Data on Fish Prey of Albatrosses

The only attempt at a quantitative estimation of fish in the diet of Wandering Albatrosses was by Voisin (1969) who found fish in two (18%) of 11 samples and Mougín (1970), who found fish in nine (45%) of 20 samples (both

**Table 5.** Fish identified in food samples from diet studies of albatrosses

Species of albatross	Identification of fish			Proportion (%) of fish in diet	Reference
	Species	Genus	Family		
Blackbrowed Albatross <i>Diomedea melanophrys</i>	<i>Pseudochaenichthys georgianus</i> (Channichthyidae) <i>Geotria australis</i> (Petromyzonidae)		Myctophidae	40 <sup>1</sup>	Prince 1980
Greyheaded Albatross <i>D. chrysostoma</i>	<i>Geotria australis</i>		Myctophidae	35 <sup>1</sup>	Prince 1980
Buller's Albatross <i>D. bulleri</i>	<i>Pseudophycis bacchus</i> (Moridae) <i>Pentaceros richardsoni</i> (Pentacero- tidae)			50 <sup>2</sup>	West and Imber 1986
Waved Albatross <i>D. irrorata</i>	<i>Decapterus scombrinus</i> (Carangidae) <i>Etrumeus acuminatus</i> (Clupeidae) <i>Priacanthus cruentatus</i> (Priacanthidae)	<i>Antennarius</i>	Exocoetidae	39 <sup>2</sup>	Harris 1973
Black-footed Albatross <i>D. nigripes</i>		<i>Decapterus</i> (Carangidae)	Exocoetidae Gempylidae Sternoptychidae	50 <sup>3</sup>	Harrison et al. 1983
Laysan Albatross <i>D. immutabilis</i>	<i>Cololabis saira</i> (Scomberesocidae) <i>Euleptorhamphus viridis</i> (Hemiramphidae)	<i>Cypselurus</i> (Exo- coetidae) <i>Argyropelecus</i> (Sternoptychidae) <i>Vinciguerria</i> (Gonostoma- matidae)	Exocoetidae Mullidae Myctophidae	9 <sup>3</sup>	Harrison et al. 1983
Light-mantled Sooty Albatross <i>Phoebastria palpebrata</i>			Nototheniidae Myctophidae	11 <sup>1</sup>	Thomas 1982

<sup>1</sup>By weight; <sup>2</sup>By frequency of occurrence; <sup>3</sup>By volume

sets of data from the Crozet Islands). None of the fish material was identified. Imber and Russ (1975) reported fish in four (57%) of seven Wandering Albatross samples and identified two *Macruronus novaezelandiae* (Merlucidae) in a sample obtained from Wellington Harbour, New Zealand and one *Halargyreus johnsonii* (Moridae) in a sample of unspecified provenance.

Information on the identity of fish taken by any species of albatross is very scarce; identifications of fish from the five main quantitative studies of albatross diet are summarised in Table 5. Considering the importance of fish in albatross food samples, this paucity of information emphasises the need for more detailed studies. The absence of Myctophidae, common in the upper 50 m around South Georgia, in the Wandering Albatross diet is surprising.

#### *Fish Prey and Wandering Albatross Foraging*

The fish taken by Wandering Albatrosses are a mixture of pelagic and benthic-demersal species but all are characteristic of the South Georgia continental shelf. Wandering Albatrosses have the potential, even during chick-rearing, to fly long distances because each partner only returns to feed its chick about every six days on average (Tickell 1968; Croxall and Prince, in press), which allows

a maximum foraging radius of about 1100 km (Penycuik et al. 1984). The squid diet typically contains some species characteristic of temperate and sub-tropical waters (Clarke et al. 1981; Rodhouse et al. 1987). Also, birds known to be feeding chicks at South Georgia have been seen as far away as off the Falkland Islands and the coast of Argentina (Croxall and Prince, in press). However, apart from the ?Macrouridae, there is no evidence from their fish prey that Wandering Albatrosses forage away from the South Georgia shelf.

Wandering Albatrosses feed mainly by surface-seizing, occasionally making surface dives or even pursuit plunges (Voisin 1981; Prince and Morgan 1987). Thus they are almost entirely reliant on prey at the surface. Epipelagic fish may be available to albatrosses when exploiting concentrations of krill which tend to occur at the surface at night (Prince 1980). However, the commonest epipelagic fish in South Georgia waters, *Champscephalus gunnari*, was rare in the present food samples. In any case, how do Wandering Albatrosses capture fish of essentially benthic habit?

One potential source of fish prey for Wandering Albatrosses might be from fishing operations, particularly as the species is readily attracted to ships. Commercial fishing is nowadays conducted year-round at South Georgia; the main target species in recent years have been

**Table 6.** Fishery catches (tonnes, with percentage of total catch in parenthesis) in the South Georgia region in 1983–1984 and 1984–1985 of species forming the prey of Wandering Albatrosses breeding at Bird Island. Data from CCAMLR (1986)

Species	1983–1984	1984–1985
<i>Notothenia rossii</i>	3022 (2.9)	1891 (4.9)
<i>N. gibberifrons</i>	3304 (3.2)	2081 (5.4)
<i>Chaenocephalus aceratus</i>	161 (0.2)	1042 (2.7)
<i>Champscephalus gunnari</i>	79997 (76.3)	14148 (36.7)
<i>Pseudochaenichthys georgianus</i>	888 (0.8)	1097 (2.8)
Other species	13277 (12.7)	14568 (37.7)
Unidentified fishes	4227 (4.0)	3775 (9.8)
Total	104876	38602

*Notothenia rossii* and *Champscephalus gunnari* (Kock 1985) but a variety of other species are caught (Table 6), including all those eaten by Wandering Albatrosses except *Pagothenia hansonii* and *Muraenolepis microps*. Even these might form part of the “unidentified fishes” category. However, although *Champscephalus* was the main species caught by the fishery in 1983 and 1984 and *Notothenia rossii* the next commonest species, the former was rare and the latter absent in the Wandering Albatross food samples in these years. Clearly, therefore, Wandering Albatrosses derive little direct benefit from the main fishing operation. It is possible, however, that the other species were made available to them in the form of offal or rejected by-catch. However, for some years now, offal from target species and entire fish which form the non-commercial by-catch have been converted on board into fish meal and no waste has been thrown overboard (R. Coggan, T. Lubimova, personal communication). It seems unlikely, therefore, that benthic-demersal fish are made available to Wandering Albatrosses via the commercial fishing operations.

It is possible that such species may appear at the surface as a result of post-spawning mortality of adults, as Clarke et al. (1981) suggested for squid. However, most Antarctic fish (not *Muraenolepis*) are negatively buoyant and only *Muraenolepis* and *Notothenia gibberifrons* spawn in winter (Permitin 1973; Fischer and Hureau 1985). Considering how little is known about the ecology of sub-Antarctic fish in winter it is, of course, possible that even species like *Muraenolepis* and *Notothenia gibberifrons* which are regarded as specialist benthic feeders, may spend some time at higher levels in the water column including at the surface. Unlike the situation with the squid prey of Wandering Albatrosses (Clarke et al. 1981; Rodhouse et al. 1987), where some of the squid ingested were too large to have been swallowed whole (and were, therefore, presumably scavenged), none of the fish prey, with the possible exception of two *Pseudochaenichthys* and one *Chaenocephalus*, could conceivably have been too large for Wandering Albatrosses to swallow whole.

On the basis of the present information, therefore, we cannot account for how Wandering Albatrosses are able to acquire specimens of benthic fish. It seems unlikely

that they do so through the commercial fishery but direct observations of the foraging behaviour of birds which are associated with these fishing boats in winter would be highly desirable.

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