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Article *in* New Zealand Journal of Marine and Freshwater Research · September 2000

DOI: 10.1080/00288330.2000.9516946

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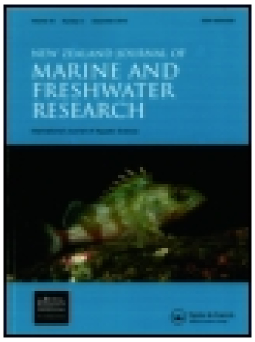

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New Zealand Journal of Marine and Freshwater Research

ISSN: 0028-8330 (Print) 1175-8805 (Online) Journal homepage: https://www.tandfonline.com/loi/tnzm20

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To cite this article: Gavin D. James & Jean-Claude Stahl (2000) Diet of southern Buller's albatross (*Diomedea bulleri bulleri*) and the importance of fishery discards during chick rearing, New Zealand Journal of Marine and Freshwater Research, 34:3, 435-454, DOI: 10.1080/00288330.2000.9516946

To link to this article: https://doi.org/10.1080/00288330.2000.9516946

Published online: 30 Mar 2010.

0028–8330/00/3403–0435 $7.00 © The Royal Society of New Zealand 2000

Diet of southern Buller's albatross (*Diomedea bulleri bulleri*) and the importance of fishery discards during chick rearing

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Abstract Southern Buller's albatrosses (*Diomedea bulleri bulleri* Rothschild) are frequently associated with fishing vessels off southern New Zealand, and may depend substantially on discards from fishing vessels, particularly trawlers, during chick rearing. To test this hypothesis, the diet was determined from 188 chick regurgitations collected at The Snares (May 1996, July 1996 and 1997) and Solander Island (May and July 1997). Fish (mostly discards but also some small species obtained naturally) was the dominant prey category, occurring in 92% of samples, and forming 65% by weight of solid food consumed. Salps (*Pyrosoma* sp. and *Iasis zonaria*) were the most abundant prey items (44% of all items), and second most important by frequency of occurrence (78%) and weight (24%). Cephalopod remains (mostly arrow squid (*Nototodarus* spp.) and *Histioteuthis atlantica*) occurred in 53% of samples, but contributed only 17% by number and 7% by weight. Other dietary items included crustaceans (chiefly *Munida gregaria*, *Nectocarcinus antarctica*, and *Lepas anatifera*), bird feathers, and flotsam. Fishery discards were present in 70% of samples, constituted 60% of the diet by weight, and comprised 91% of the weight of all fish consumed. Discard composition was dominated by Gadiformes (mostly hoki (*Macruronus novaezelandiae*) and macrourids) in 1996, and by jack mackerel (*Trachurus* sp.) in 1997. Breeders at The Snares took more discards in July 1997 (68 g per sample) than May or July 1996 (31 and 28 g respectively), those at Solander Island took more in May (56 g) than July 1997 (29 g). In May 1996, the diet of birds at The Snares tended to be biased towards fish (both discards and natural prey) after long foraging trips, but towards cephalopods after short trips. Sexual differences in diet and discard consumption tended to be more pronounced amongst samples from The Snares. The high, and apparently increased proportion of fish in the diet, strongly suggest that discards from fishing operations have a beneficial effect on the population of southern Buller's albatrosses breeding on The Snares.

Keywords Buller's albatross; *Diomedea bulleri*; diet; discards; fisheries; The Snares; Solander Island; *Trachurus* sp.; *Macruronus novaezelandiae*; *Nototodarus* sp.; *Pyrosoma* sp.; *Iasis zonaria*; *Munida gregaria*

INTRODUCTION

Buller's albatrosses are endemic to New Zealand, where a southern subspecies *Diomedea bulleri bulleri* Rothschild breeds only on The Snares and Solander Island (c. 11500 and 2600 pairs respectively) (Sagar et al. 1999), situated 140 and 40 km respectively to the south of South Island. A northern subspecies *D. b. platei* breeds on the Chatham Islands (16 000 pairs; Robertson 1991), 500 km to the east of New Zealand, and on the Three Kings Islands (8–10 pairs; McCallum et al. 1985), 45 km to the north of New Zealand. Numbers of breeding southern Buller's albatross on The Snares increased by 78% between 1969 and 1992 (Sagar et al. 1994), and increased a further 8% between 1992 and 1997, whereas limited data on the Solander Island population indicated a decline of up to 19% in the number

M99027
Received 10 May 1999; Accepted 7 February 2000

of breeding pairs between 1985 and 1996 (Sagar et al. 1999). Migration is unlikely to have influenced population size as no movement of banded breeding birds between The Snares and Solander Island has been detected (Sagar et al. 2000).

Buller's albatrosses are well known for following fishing vessels and scavenging offal (Gales 1993; Petyt 1995), and consequently are vulnerable to mortality from accidental capture in trawl nets, collision with netsonde monitor cables on trawlers (Robertson 1972; Bartle 1991), and capture on baited longline hooks (Murray et al. 1993; Alexander et al. 1997). It has been estimated that up to 1600 breeding adults were killed annually on Japanese bluefin tuna longlines off southern New Zealand from 1988 to 1992, 30 birds per year died in the subantarctic squid trawl fishery, and "many" more in the hoki trawl fishery to the south-west of New Zealand (Gales 1993).

Current knowledge of the diet of southern Buller's albatrosses is based on a study of 27 food samples from The Snares and Chatham Islands (West & Imber 1986). Although fish items occurred in 48% of samples, only two species could be positively identified—two specimens of red cod (*Pseudophycis bachus*) which were considered fishery discards, and two specimens of southern boarfish (*Pseudopentaceros richardsoni*), a possible discard species. A more detailed study was, therefore, deemed necessary to examine the diet of southern Buller's albatross from the two breeding colonies and to determine the importance of fishery discards in their diet. Recent diet studies of royal albatrosses (*Diomedea epomophora*) (Imber 1999) and Westland petrels (*Procellaria westlandica*) (Freeman 1998), have extended knowledge of prey species found in the diet of procellariiforms feeding in similar latitudes to southern Buller's albatrosses around New Zealand. A recent review of the food of nine albatross species, including data on prey species and locality (Cherel & Klages 1997), has permitted a comparison of Buller's albatross diet with that of other southern ocean albatross species.

Recent satellite tracking studies have revealed an unsuspected complexity of foraging patterns amongst several southern albatross species; for example alternating short and long trips, and differences between males and females for wandering albatrosses at Crozet Islands (Weimerskirch et al. 1997). For southern Buller's albatrosses, analysis of shipborne censuses has shown that the birds forage mostly over shelf and slope areas from The Snares northwards to Banks Peninsula and Westland during the chick-rearing period (Stahl et al. 1998), whereas satellite tracking has revealed distinct foraging strategies for male and female birds breeding on The Snares (Sagar & Weimerskirch 1996; Stahl & Sagar 2000a) and Solander Island (Stahl & Sagar 2000b). During the mid post-guard stage (during our May sampling), both sexes undertook alternate long and short trips from The Snares, but only short trips from Solander Island. At that time, breeders foraged primarily off Fiordland and the south coast of the South Island (birds from Solander Island, short trips), over the Stewart Island shelf (both populations, short trips), and from Otago to Banks Peninsula and the Mernoo Bank (birds from The Snares, long trips). During the late post-guard stage (during our July sampling), breeders from both populations undertook either short trips to the Stewart Island shelf (males), or mostly long trips to the west coast of the South Island (females).

Since albatrosses are surface feeders, they are able to utilise discard material originating from fishing vessel operations, and this frequently includes prey species unavailable to the birds under natural conditions. Although it is difficult to demonstrate clear links between seabird population changes and fisheries, several recent studies have found an increasing dependence on fishery waste. Freeman (1998) documented a major increase in the proportion of fish discards in the diet of Westland petrels following the development of a nearby deepwater fishery, and Jackson (1988) found that trawler offal was the dominant food by mass of the South African population of white-chinned petrel (*Procellaria aequinoctialis*). Gales (1993) highlighted the need to collect data on the contribution of scavenged discards and offal to the diet of southern Buller's albatross, to assess the magnitude of the interaction with the various fisheries. Hence, the principal aims of this study were to determine: (1) the contribution of commercial fisheries to the diet of southern Buller's albatrosses by documenting the relative importance of natural and fisheries-related food items; and (2) variability in diet, by season and sex, of breeders from The Snares and Solander Island.

METHODS

Diet samples ($n = 188$) were collected during the chick-rearing period at The Snares (48°02′S, 166°36′E) in May 1996 ($n = 46$), July 1996 ($n = 43$), and July 1997 ($n = 17$), and at Solander Island (46°35′S, 166°54′E) in May ($n = 41$) and July 1997 ($n = 41$). Regurgitation samples were obtained from chicks immediately following feeding by a marked adult. Chicks were inverted, the sample collected into a bucket and weighed. Samples containing no solid material were discarded. During May and July 1996 (at The Snares), the oil present was decanted and the sample re-weighed to obtain an estimate of the quantity of oil in the chick stomach. The first adult bird returning to each chick from which a sample was collected was dyed on the breast, so that further samples were taken only from that chick when fed by the marked bird. This ensured that the chick received food from the other adult over the c. 10-day sampling period. Adult birds, which were usually captured following feeding of the chick, were checked for band number, weighed, sexed, marked with colour spray, and released. Not all adult birds were able to be captured and sexed; thus only 77 regurgitations were collected from chicks fed by male birds, and 66 from females. Samples were condensed in the field by sieving through a 1 mm sieve, and the solid contents retained and preserved in 70% ethanol upon returning to camp between 1 and 9 h later.

Laboratory analysis involved preliminary sorting of food items into major groups, identification of individual prey where possible, and weighing of individual items if complete, or type of item if in pieces. Only very occasionally were intact fish, cephalopods, or crustaceans found, although moderate numbers of whole salps were present. Fish identification involved comparing body fragments, otoliths, and skull bones against the senior author's reference collection of fish species from southern New Zealand waters. Fish identifications were confirmed where necessary using Ayling & Cox (1982), Paulin & Stewart (1985), Paulin et al. (1989), Cohen et al. (1990), Gon & Heemstra (1990), and McMillan & Paulin (1993), whereas otoliths were checked with reference to Smale et al. (1995) and Schwarzhans (1984). Difficult fish identifications were checked with other experts (YC, PM, NB, PG, PC, DS, and JP—see Acknowledgments). Fish size was estimated, where possible, by comparing skull bones and otoliths against similar-sized reference material, or occasionally by measuring intact or reconstructed skeletons. Cephalopod material (mostly beaks) was identified and assigned a life history stage by MI, although the freshness of beaks was not determined in this study. Crustaceans were examined by SO (mostly), JJ, and BJ, whereas salp identifications were confirmed by JJ and RM.

Only fish material was classified into discard categories; thus all other groups including cephalopods, crustaceans, and salps were classified as natural prey. Fish remains were defined as discards if they were species caught commonly by fishing vessels bottom trawling in waters deeper than the likely maximum diving range for Buller's albatrosses of c. 5 m (based on observations in Fenwick (1978) and Prince et al. (1994)). Fish remains defined as natural prey were those normally likely to be readily available to Buller's albatrosses. Such prey were usually small to moderate-sized surface and mesopelagic species, the latter characteristically undertaking vertical migrations towards the surface at night. Unidentifiable fish flesh and bones were classified as probable discards, with the large size of most of these remains suggesting strongly that they were discards. Although we acknowledge that the vertical distribution of many marine invertebrate groups is poorly known, we are confident that the distribution of most fishes around New Zealand is sufficiently well known to justify the discard classifications adopted here.

Bird sampling and stomach contents data were stored in a relational database ACCESS 7.0, and analysed with EXCEL 7.0 and SYSTAT 6.0. A comparison of total sample weights and total drained prey weights by sampling trip was undertaken using normalised and square root transformed data. However, because the trip variances were not homogeneous, a 2-way ANOVA was inappropriate, and parametric t-tests (incorporating a Bonferroni correction) were employed. Frequencies of occurrence of major prey groups and items were compared between localities, years, and sexes using Chi-squared tests. Multiple samples from the same chick and adult bird were analysed to determine relationships between food items and trip length, after establishing that pseudo-replication was not an issue. This was achieved using the procedure described in the Appendix to test the null hypothesis that, for each sampling trip, diet variability within birds was the same as that between birds. Trips ranged from 1.7 to 7.9 days in length, and were grouped into either short (<3 days) or long (>3 days) based on the tracking results obtained by Stahl & Sagar (2000a).

RESULTS

Weight of food samples

Total sample weights (including liquids) averaged 369.9 g (n = 188, range 25–910 g, SD = 202.4), the oil fraction mean weight 104.4 g (n = 98, range 0–350 g, SD = 97.3), and the drained prey mean weight 64.9 g (n = 188, range 0–348 g, SD = 67.8) or 18%

Table 1 Total sample weights and drained prey weights (mean, ±1 SD, and range) by location, period, sex, and trip duration, for food samples obtained from southern Buller's albatrosses (*Diomedea bulleri bulleri*) breeding at The Snares and Solander Island in 1996 and 1997.

Location and period	Sample groups (*n*)	Total sample weight	Drained prey weight
The Snares, May 1996	All samples (46)	466.8 ± 179.3 (150–875)	69.3 ± 59.6 (0–320)
	Females (14)	433.4 ± 146.3 (170–700)	70.2 ± 57.1 (0–199)
	Males (30)	485.5 ± 184.8 (200–875)	71.4 ± 62.5 (13–320)
	Long trips (16)	473.9 ± 159.3 (170–850)	77.3 ± 79.1 (0–320)
	Short trips (6)	396.0 ± 102.5 (225–525)	53.4 ± 45.0 (12.5–141.6)
The Snares, Jul 1996	All samples (43)	344.1 ± 159.9 (70–910)	45.9 ± 44.0 (1–217)
	Females (15)	354.6 ± 103.5 (90–520)	46.9 ± 53.9 (1–217)
	Males (24)	354.5 ± 194.8 (70–910)	48.3 ± 41.3 (4–167)
The Snares, Jul 1997	All samples (17)	285.7 ± 193.5 (25–400)	85.3 ± 70.8 (4–217)
	Females (6)	290.8 ± 110.7 (125–400)	107.4 ± 51.6 (49–185)
	Males (4)	203.2 ± 137.8 (50–375)	27.1 ± 30.2 (4–69)
Solander Island, May 1997	All samples (41)	507.9 ± 184.7 (150–900)	89.0 ± 86.5 (3–302)
	Females (22)	506.1 ± 185.7 (240–820)	89.7 ± 85.0 (3–273)
	Males (15)	517.3 ± 201.6 (150–900)	91.6 ± 99.6 (4–302)
Solander Island, Jul 1997	All samples (41)	189.5 ± 110.1 (50–450)	47.5 ± 66.8 (4–348)
	Females (9)	243.3 ± 112.0 (100–450)	41.7 ± 37.9 (7–103)
	Males (4)	112.5 ± 62.9 (50–200)	23.6 ± 22.2 (4–46)

Table 2 Species composition (% occurrence/% no./% weight) of food samples obtained from southern Buller's albatrosses (*Diomedea bulleri bulleri*) breeding at The Snares and Solander Island in 1996 and 1997. (Fish species categories: discard (d), or probably discard (pd) from fishing vessels; natural prey (n). + = <0.5%.)

		The Snares			Solander Island	
Prey	All samples *N* = 188	May 1996 *N* = 46	Jul 1996 *N* = 43	Jul 1997 *N* = 17	May 1997 *N* = 41	Jul 1997 *N* = 41
No. prey items	2142	748	418	75	677	224
Total prey weight (g)	12035	3016	1975	1449	3646	1949
FISH	**92/27/65**	**93/16/46**	**93/22/68**	**100/32/81**	**100/37/72**	**78/43/68**
Geotridae						
Southern lamprey (*Geotria australis*) (n)	2/+/+	2/+/1	2/+/+		2/+/+	
Anguilliformes						
Congrid eel (*Bassanago*) sp. (d)	1/+/+	2/+/1	2/+/1			
Unidentified "eel" sp. (d)	2/+/+				2/+/+	5/1/1
Clupeidae						
Sprat (*Sprattus*) sp. (n)	1/2/1					2/15/4
Argentiniidae						
Silverside (*Argentina elongata*) (d)	1/+/+				2/+/+	
Sternoptychidae						
Pearlside (*Maurolicus muelleri*) (n)	1/+/+				2/+/+	2/+/+
Myctophidae						
Common lanternfish (*Lampanyctodes hectoris*) (n)	2/5/+	2/3/+			5/11/1	
Lanternfish (*Symbolophorus* sp.) (n)	2/+/+			6/1/+	2/+/+	2/+/+
Moridae						
Red cod (*Pseudophycis bachus*) (d)	3/+/2			12/3/5	2/+/5	5/1/5
Merlucciidae						
Hoki (*Macruronus novaezelandiae*) (d)	7/1/5	15/1/12	7/1/12		5/+/1	2/+/+
Macrouridae						
Oblique banded rattail (*Caelorinchus aspercephalus*) (d)	1/+/+	2/+/+	2/+/+			
Bollon's rattail (*C. bollonsi*) (d)	1/+/+					2/+/1
Notable rattail (*C. innotablis*) (d)	1/+/+					2/+/+
Oliver's rattail (*C. oliverianus*) (d)	2/+/2	2/+/+			5/+/3	2/+/4

Prey	All samples N = 188	The Snares May 1996 N = 46	The Snares Jul 1996 N = 43	The Snares Jul 1997 N = 17	Solander Island May 1997 N = 41	Solander Island Jul 1997 N = 41
Small banded rattail						
(*C. parvifasciatus*) (d)	1/+/+					2/+/+
Rattail (*Caelorinchus* sp.) (d)	3/+/+	7/+/+	5/+/+			
Four rayed rattail						
(*Coryphaenoides subserrulatus*) (d)	2/+/1	4/+/1		6/1/5		
Javelin fish (*Lepidorhynchus denticulatus*) (d)	5/1/4	7/1/8	5/+/4		2/+/1	10/2/5
Gadiformes						
Unidentified "cod" sp. (d)	11/1/4	20/2/5	2/+/9	30/7/6	5/+/1	10/2/4
Zeidae						
Black oreo dory (*Allocyttus niger*) (d)	1/+/+			6/1/7		
Macrorhamphosidae						
Redbanded bellowsfish						
(*Centriscops obliquus*) (d)	1/+/+	2/1/+				
Unidentified "snipefish" sp. (d)	1/1/+	4/2/1				
Carangidae						
Jack mackerel (*Trachurus* sp.) (d)	15/1/22	4/+/3	2/+/2	36/8/47	37/2/33	12/3/32
Emmelichthyidae						
Redbait (*Emmelichthys nitidus*) (n)	4/2/3		5/4/3		12/2/7	
Rubyfish (*Plageiogenion rubiginosus*) (d)	1/+/+				2/+/+	
Gempylidae						
Barracouta (*Thyrsites atun*) (d)	1/+/+		2/+/1			
Pleuronectiformes						
Unidentified "flatfish" sp. (d)	1/+/+	2/+/+				
Unidentifiable						
Natural fish prey (n)	43/12/2	50/5/1	40/12/4	48/8/1	49/17/2	32/17/4
Probable fish discard (pd)	32/–/17	28/-/13	42/–/31	29/3/10	39/–/20	22/–/9
CEPHALOPODS	**53/17/7**	**48/11/3**	**42/15/4**	**53/32/9**	**68/19/11**	**59/32/10**
Ancistrocheiridae						
Ancistrocheirus lesueuri	1/+/+		2/+/+			
Octopoteuthidae						
Octopoteuthis sp.	2/+/+	2/+/+	2/+/+			2/+/+
Onychoteuthidae						
Moroteuthis robsoni	1/+/+		2/+/+			2/+/+
Moroteuthopsis ingens	2/+/+	2/+/+			2/+/+	5/1/+
Onychoteuthis sp. B	1/+/+			6/1/+		
Cycloteuthidae						
Discoteuthis sp.	1/+/+					2/+/+
Gonatidae						
Gonatus antarcticus	3/+/+	4/+/+	5/+/+			2/+/+
Histioteuthidae						
Histioteuthis atlantica	20/4/+	15/1/+	21/7/2	24/8/+	17/1/+	27/9/+
Histioteuthis macrohista	5/1/+	13/1/+	5/+/+	6/1/+		
Neoteuthidae						
?*Nototeuthis dimegacotyle*	1/+/+	2/+/+			2/+/+	
Ommastrephidae						
Arrow squid (*Nototodarus* sp.)	34/9/1	35/6/1	19/3/1	29/11/+	56/16/+	27/15/+
Martialia hyadesi	1/+/+	2/+/+				
Unidentified sp.	1/+/+				2/+/+	
Chiroteuthidae						
Chiroteuthis sp. A	2/+/+	2/+/+	2/+/+			2/+/+
Chiroteuthis sp. D	1/+/+					5/1/+
Mastigoteuthidae						
Mastigoteuthis cf. *Dentata*	2/+/+	4/+/+		6/1/+	2/+/+	
Cranchiidae						
Galiteuthis glacialis	4/+/+	7/+/+		12/3/+	2/+/+	5/1/+
Taonius sp. B	1/+/+		2/+/+			
Taonius sp. C	1/+/+					2/+/1
Teuthowenia pellucida	4/+/+	2/+/+	5/+/+		5/+/+	5/2/+
Family Spirulidae						

Table 2 (*continued*)

Prey	All samples N = 188	The Snares May 1996 N = 46	The Snares Jul 1996 N = 43	The Snares Jul 1997 N = 17	Solander Island May 1997 N = 41	Solander Island Jul 1997 N = 41
Spirula spirula	1/+/+				5/+/+	
Octopodidae						
Amphitretus thielei	1/+/+	2/+/+				
Benthoctopus tangaroa	1/+/+		2/1/+			
Pinnoctopus cordiformis	5/1//2	2/+/+	7/1/+	6/1/+	10/1/6	2/+/+
Unidentifiable						
Cephalopod remains	20/1/4	9/1/1	9/1/1	29/5/8	32/+/5	30/+/9
CRUSTACEANS	**37/9/2**	**33/5/3**	**40/5/+**	**18/7/2**	**56/19/2**	**27/6/+**
Copepoda						
Lophoura sp. H	1/+/+	2/+/+				
Sphyrion quadricornis	1/+/+					5/1/+
Trifur lottellae	2/+/+		2/+/+	6/1/+	2/+/+	2/+/+
Cirripedia						
Lepas anatifera	5/3/+	4/+/+			17/8/+	
Isopoda						
Unidentified Cirolanid sp.	1/+/+			6/1/+		
Unidentified sp.	1/1/+	4/1/+				
Amphipoda						
Phronima ?sedentaria	1/+/+	2/+/+				
?Eurythenes obesus						
Unidentified sp.	1/+/+				2/+/+	
Decapoda (Natantia)						
Acanthephyra pelagica	1/+/1				2/+/+	
Decapoda (Reptantia)						
?Diacanthurus rubricatus	1/+/+				2/+/+	
Leptomithrax sp.	1/+/+				2/+/+	
Munida gregaria	9/4/+	13/2/+	9/1/+		15/9/1	
Unidentified Galatheid sp.	1/+/+	4/1/+				
Nectocarcinus antarcticus	9/1/+		21/3/+	12/3/+	7/+/+	7/1/+
Nectocarcinus sp.	1/+/+		5/+/+			
Neommatocarcinus huttoni	1/+/+					2/2/+
Ovalipes catharus	2/+/+			6/1/1	5/1/+	2/+/+
Unidentifiable						
Crustacean remains	7/–/+	4/–/+	7/–/+		12/–/+	7/–/+
TUNICATES	**78/44/24**	**89/62/42**	**70/57/25**	**76/29/8**	**88/24/14**	**66/19/21**
Salpidae						
Iasis zonaria	40/15/2	65/14/4	42/32/4	35/15/1	37/7/1	17/7/1
Pyrosoma atlanticum	77/29/22	89/48/38	65/25/21	82/15/8	83/18/13	66/12/21
Unidentifiable	1/+/+	2/+/+				
OTHER						
Bird feathers	3/–/1	11/–/5			2/-/+	
Foraminifera (benthic)	1/+/+	2/+/+				
Unidentifiable animal phylum	1/–/+		5/–/+			
NON-FOOD ITEMS	**23/–/1**	**9/–/2**	**6/–/3**		**6/–/1**	**2/–/+**
Algae	8/–/+	7/–/+			27/–/1	2/–/+
Wood	14/–/1	24/–/1	23/–/3		10/–/+	2/–/+
Pumice	1/–/+	2/–/+				
Plastics	5/–/+	15/–/+	2/–/+			5/–/+

of the total mass. Mean total sample weights and drained prey weights by location, period, sex, and trip duration are presented in Table 1. At both The Snares in 1996 and Solander Island in 1997, mean sample weights were significantly greater in May than July ($P < 0.01$, $t = 4.5$, $t = 9.8$ respectively), as were mean prey weights ($P < 0.05$, $t = 2.6$, $t = 2.1$ respectively). Although average sample and prey weights from The Snares in July 1997 were 50 and 80% greater, respectively, than those from birds from Solander Island, this was not significant owing to the wide variation in weights. Among July samples from The Snares, average prey weights were 86% greater in 1997 than 1996, although the difference was not significant. There were no differences by sex in either sample or prey weights from The Snares in May and July 1996, and Solander Island in May 1997. However, in July 1997, average sample and prey weights from females exceeded those from males both at The Snares (by 43 and 296% respectively) and Solander Island (by 116 and 77% respectively), although the differences were not statistically significant because of small sample sizes.

Individual parents of chicks which were sampled more than once, made trips ranging between 1 and 8 days in length ($n = 29$, mean 4.1 days, SD = 1.91). Drained prey weights from all individuals that were re-sampled were not significantly related to trip length ($r = 0.168$). However, at The Snares in May 1996, mean sample and prey weights were 20 and 45% greater, respectively, on long trips than short trips.

Diet composition

The species composition of food samples by frequency of occurrence, number of prey items, and weight is presented in Table 2. Fish occurred in 92% of samples, salps in 78%, cephalopods in 53%, crustaceans in 37%, non-food items in 23%, bird feathers in 3%, and miscellaneous or unidentified in 1% of samples. In addition, 11% of samples contained only fish. Fish were also the principal prey group by weight (65% of drained weight), followed by salps (24%), cephalopods (7%), crustaceans (2%), bird feathers (1%), and non-food and unidentifiable items (1%).

Salps were the most abundant prey item (44%), and were relatively more common in 1996 at The Snares (60%) than in 1997 at Solander Island and The Snares (24%) (Table 2). Fish were the next most abundant group, forming 27% of all prey items consumed, and were relatively more abundant in 1997 (38%) than in 1996 (18%). Cephalopods formed 17% of all prey items with higher proportions in 1997 (23%) than in 1996 (13%). Crustacean remains comprised 9% of all prey items.

At Solander Island in 1997, most main prey groups (but excluding javelin fish, unidentified gadiformes, and *Histoteuthis atlantica*) occurred more often in May than July; the same trend was observed at The Snares in 1996, except for crustaceans (more frequent in July) and fish (no difference). At The Snares, crustaceans and non-food items occurred more frequently in July 1996 than July 1997, whereas cephalopods and to a lesser degree fish and salps occurred more often in July 1997. During the latter period, fish and salps were taken more frequently by birds from The Snares than by birds from Solander Island.

Amongst samples containing sufficient sexed birds (Table 3), the frequency of occurrence of fish in stomachs was similar for male and female breeders at The Snares. Cephalopods tended to be taken more often by females, whereas salps were taken more often by males at The Snares. Crustaceans were taken more often by males at The Snares, particularly in July, but they appeared to be eaten more frequently by females at Solander Island. At The Snares in May 1996, fish tended to be more frequent in samples from long trips, whereas cephalopods, salps, and non-food items occurred more often after short foraging trips (Table 4).

Fish

Twenty-one definite discard fish taxa, and six species not associated with commercial fishing operations, were identified (Table 2), together with much unidentifiable fish material. Fish discards comprised 91% by weight of all fish remains. Of identified species, the commonest (all discards) were jack mackerel (*Trachurus* sp.), hoki (*Macruronus novaezelandiae*), and javelin fish (*Lepidorhynchus denticulatus*), which occurred in 15, 7, and 5% of samples, respectively.

Jack mackerel were uncommon among 1996 samples from The Snares, but in 1997 samples from both The Snares and Solander Island, they formed between 32 and 47% by weight of prey consumed. Females more often tended to take pieces of large jack mackerel, a definite discard, but numbers were too small to be significant. Hoki were significantly more common in 1996 ($P < 0.05$) than 1997 samples, occurring most frequently in May 1996 samples from The Snares. They were less frequent (1996) or absent (1997) from July samples from this locality, and infrequent among 1997 samples from Solander Island (both months). Javelin fish were most frequent among July 1997 samples from Solander Island, but were present in all other sample groups except the July 1997 samples from The Snares. Notably, hoki, javelin fish, other macrourids, and probable fish discards only occurred in samples from long foraging trips in May 1996 samples from The Snares (Table 4). Six other macrourids besides javelin fish were identified, although none was common. Red cod (*Pseudophycis bachus*), a common inshore species whose offal is often discarded by fishing vessels, was positively identified only 5 times (all in 1997), whereas two other important commercial fish species—black oreo (*Allocyttus niger*) and barracouta (*Thyrsites atun*) were recorded just once.

Of those fish species considered of natural origin, redbait (*Emmelichthys nitidus*), a small to medium-sized non-commercial epipelagic species, were present in July 1996 samples from The Snares (8 individuals in each of 2 samples) and May 1997 samples from Solander Island (2–5 individuals in 5 samples). Two small species of natural origin were the most abundant fish species, but they occurred in only a few samples: 33 sprat (*Sprattus* sp.) in one sample, and 19, 35, and 42 common lanternfish (*Lampanyctodes hectoris*) in three other samples. One of the latter samples also contained a specimen

Table 3 Species composition of main prey items (% occurrence/% no./% weight) from food samples of southern Buller's albatrosses (*Diomedea bulleri bulleri*) breeding at The Snares (May and July 1996) and Solander Island (May 1997), in relation to sex. (Fish species categories: discard (d), or probably discard (pd) from fishing vessels; natural prey (n). + = <0.5%.)

	The Snares, May 1996		The Snares, Jul 1996		Solander Island, May 1997	
	Males N = 30	Females N = 14	Males N = 24	Females N = 15	Males N = 15	Females N = 22
No. prey items	434	247	193	195	249	342
Total prey wt. (g)	2054	900	1158	704	1373	1973
PREY TAXA						
Fish	**97/20/56**	**93/15/33**	**96/25/71**	**87/21/62**	**100/43/69**	**100/20/72**
Common lanternfish (*Lampanyctodes hectoris*) (n)	3/4/+				13/31/2	
Redbait (*Emmelichthys nitidus*) (n)			4/4/6	7/4/+	7/2/1	14/3/7
Hoki (*Macruronus novaezelandiae*) (d)	10/1/17	29/1/2	13/2/20			9/1/2
Javelin fish (*Lepidorhynchus denticulatus*) (d)	7/1/8	7/+/10	4/1/5	7/1/3		5/+/2
Other Macrouridae (d)	13/1/1	21/1/2	8/1/1	7/+/+	7/+/4	5/+/3
Unidentified Gadiformes (d)	17/2/5	29/3/4		7/1/25	7/+/+	5/+/1
Jack mackerel (*Trachurus* sp.) (d)	7/+/5		4/1/3		33/2/38	41/3/33
Unidentified natural fish prey (n)	33/3/+	64/9/1	42/15/1	40/11/8	40/5/2	50/11/2
Unidentified probable fish discard (pd)	37/2/15	14/+/12	46/1/34	33/4/25	53/1/21	32/1/22
Cephalopods	**43/12/2**	**57/11/5**	**42/21/3**	**47/11/6**	**60/22/19**	**77/21/7**
Histioteuthis atlantica	13/1/+	21/1/+	17/11/+	27/4/5	27/2/+	14/1/+
Histioteuthis macrohista	10/1/+	21/2/+	4/1/1	7/1/+		
Nototodarus sp.	33/7/1	36/4/1	25/4/2	13/2/+	53/18/+	59/17/+
Crustacea	**33/7/5**	**29/1/+**	**50/8/+**	**27/2/+**	**47/14/1**	**64/26/2**
Lepas anatifera	7/+/+				20/7/+	14/11/+
Munida gregaria	13/3/+	14/1/+	13/2/+	7/1/+	13/5/+	18/13/1
Nectocarcinus antarcticus			33/5/+	7/1/+	7/+/+	9/1/+
Tunicates	**93/61/37**	**79/72/60**	**79/46/22**	**67/66/29**	**87/21/11**	**86/33/18**
Iasis zonaria	70/16/4	57/12/3	50/19/2	33/42/6	33/2/+	41/12/1
Pyrosoma sp.	93/45/33	79/60/57	79/27/20	53/23/23	80/19/11	86/21/16
Non-food items	**30/–/1**	**43/–/2**	**29/–/3**	**20/–/2**	**13/–/+**	**36/–/1**

of pearlside (*Maurolicus muelleri*), a small vertically-migrating mesopelagic species like the common lanternfish. The substantial numbers of small unidentified natural fish prey may have consisted of these or other species. These small unidentified natural fish prey items occurred commonly (Table 2); more frequently in May than July at both The Snares and Solander Island. They were taken more frequently by females than males in May although there was little difference by sex in July (Table 3). At The Snares in May 1996, they were more frequent after long than short trips (Table 4).

Lengths of several fish prey were estimated from fish remains (Table 5). Large discard prey (mean lengths >400 mm) included specimens of barracouta, hoki, jack mackerel, javelin fish, and red cod. Moderate-sized fish discard prey (200–400 mm) included specimens of the remaining five species of macrourid and black oreo. Small discard prey comprised only the silverside (*Argentina elongata*). Of the fish prey likely to be taken naturally, the eight specimens of redbait whose length could be estimated, ranged from 137 to 190 mm standard length, the four lamprey (*Geotria australis*) ranged from 420 to 452 mm, whereas specimens of the other four species were all small (50–90 mm).

Cephalopods

A total of 24 cephalopod taxa was identified, with the species composition by locality and period presented in Table 2, and the age class composition in Table 5. Two species were dominant in both frequency and abundance: the arrow squid *Nototodarus* sp. which was found mostly as younger stages (83% as immatures, juveniles, and subadults combined), and *Histoteuthis atlantica*, taken mainly as adults (93%). At both The Snares in 1996 and Solander Island in 1997, arrow squid occurred significantly

Table 4 Species composition of main prey items (% occurrence/% no./% weight) from food samples of southern Buller's albatrosses (*Diomedea bulleri bulleri*) in relation to long and short foraging trips made from The Snares, May 1996. (Fish species categories: discard (d), or probably discard (pd) from fishing vessels; natural prey (n). + = <0.5%.)

	The Snares, May 1996	
	Long trips *N*=16	Short trips *N*=6
No. prey items	279	63
Total prey wt. (g)	1237	320
PREY TAXA		
Fish	**94/16/64**	**83/16/26**
Southern lamprey (*Geotria australis*) (n)		17/3/6
Hoki (*Macruronus novaezelandiae*) (d)	13/1/26	
Javelin fish (*Lepidorhynchus denticulatus*) (d)	19/2/21	
Other Macrouridae (d)	25/1/+	
Unidentified Gadiformes (d)	31/3/7	33/3/17
Unidentified natural fish prey (n)	69/8/+	33/1/+
Unidentified probable fish discard (pd)	19/1/6	
Cephalopods	**31/4/1**	**67/25/17**
Histioteuthis atlantica	6/+/+	
Histioteuthis macrohista	6/1/+	33/6/+
Nototodarus sp.	38/2/1	83/16/6
Pinnoctopus cordiformis	6/+/+	
Crustacea	**31/2/+**	**33/27/+**
Munida gregaria	13/1/+	33/11/+
Tunicates	**81/78/33**	**100/32/40**
Iasis zonaria	56/15/5	50/5/2
Pyrosoma sp.	81/62/29	100/27/38
Non-food items	**25/–/1**	**33/–/16**

Table 5 Fish length (mean, range, *n*) and age composition of cephalopods identified in food samples obtained from southern Buller's albatrosses (*Diomedea bulleri bulleri*) breeding at The Snares and Solander Island in 1996 and 1997. (Measurements: total length (TL), fork length (FL), standard length (SL). Age categories: immature (i), juvenile (j), subadult (s), adult (a).)

Fish	Length (mm)	Cephalopods	Age composition
Southern lamprey (*Geotria australis*)	TL 434 (420–452) (*n* = 3)	*Ancistrocheirus lesueuri*	1s
Sprat (*Sprattus* sp.)	SL 90 (*n* = 1)	*Octopoteuthis* sp.	2s 1a
Silverside (*Argentina elongata*)	FL 120 (*n* = 1)	*Moroteuthis robsoni*	2a
Pearlside (*Maurolicus muelleri*)	SL 45 (*n* = 1)	*Moroteuthopsis ingens*	5a
Common lanternfish (*Lampancytodes hectoris*)	SL 56 (52–60) (*n* = 4)	*Onychoteuthis* sp. B	1a
Lanternfish (*Symbolophorus* sp.)	SL 88 (80–95) (*n* = 3)	*Discoteuthis* sp.	1a
Red cod (*Pseudophycis bachus*)	TL 400 (*n* = 1)	*Gonatus antarcticus*	5a
Hoki (*Macruronus novaezelandiae*)	TL 517 (350–650) (*n* = 12)	*Histioteuthis atlantica*	1i 2s 72a
Notable rattail (*Caelorinchus innotablis*)	TL 200 (*n* = 1)	*Histioteuthis macrohista*	13a
Oblique banded rattail (*C. aspercephalus*)	TL 300 (250–350) (*n* = 2)	?*Nototeuthis dimegacotyle*	2a
Oliver's rattail (*C. oliverianus*)	TL 275 (200–350) (*n* = 2)	Arrow squid *Nototodarus* sp.	83i 40j 55s 27a
Small banded rattail (*C. parvifasciatus*)	TL 250 (*n* = 1)	*Martialia hyadesi*	1j
Rattail (*Caelorinchus* sp.)	TL 240 (*n* = 1)	Unidentified Ommastrephid	1i
Four rayed rattail (*Coryphaenoides subserrulatus*)	TL 257 (250–270) (*n* = 3)	*Chiroteuthis* sp. A	3a
Javelin fish (*Lepidorhynchus denticulatus*)	TL 416 (340–500) (*n* = 11)	*Chiroteuthis* sp. D	1i 1s
Black oreo dory (*Allocyttus niger*)	TL 280 (*n* = 1)	*Mastigoteuthis* cf. *dentata*	1s 3a
Jack mackerel (*Trachurus* sp.)	FL 490 (430–540) (*n* = 10)	*Galiteuthis glacialis*	9a
Redbait (*Emmelichthys nitidus*)	SL 167 (137–190) (*n* = 8)	*Taonius* sp. B	1a
Barracouta (*Thyrsites atun*)	FL 750 (*n* = 1)	*Teuthowenia pellucida*	9a
		Spirula spirula	2a
		Amphitretus thielei	1a
		Benthoctopus tangaroa	1j 2s
		Pinnoctopus cordiformis	12a

($P < 0.01$) more often in May than July, whereas the opposite was true for *H. atlantica*. Arrow squid were more common than *H. atlantica* in May, but both species were equally common in July. Arrow squid and unidentified cephalopods were more common in 1997 than 1996 with frequencies of occurrence of 29 and 19% respectively at The Snares in July, and 56 and 35% in May 1997 (Solander Island) and May 1996 (The Snares). Arrow squid comprised 53%, and *H. atlantica* 24%, of the cephalopod prey items in this study.

Neither frequency of occurrence nor abundance of arrow squids differed between sexes in May (The Snares 1996 and Solander Island 1997), although at The Snares they tended to occur more frequently among samples from males in July 1996 (Table 3). At The Snares, *H. atlantica* were taken more frequently by females in May and July 1996, and were only present among female samples in July 1997 (two of six birds). However, on Solander Island they were taken more frequently by males in May 1997 (Table 3). At The Snares in May 1996, arrow squid were more frequent among samples of birds returning from a short trip (Table 4).

Three other cephalopods—*Galiteuthis glacialis*, *Histoteuthis macrohista*, and *Pinnoctopus cordiformis*, were sometimes present in small numbers (10–13% of samples) (Table 2). The octopod *P. cordiformis* was present in all, and the cranchid squid *G. glacialis* in most sample groups, whereas the histioteuthid squid *H. macrohista* was only present amongst samples from The Snares but from all three periods. *H. macrohista* was taken more frequently by females and during short trips (Tables 3 and 4).

Crustaceans

Of the 14 crustacean species identified (Table 2), lobster-krill (*Munida gregaria*), swimming crabs (*Nectocarcinus antarcticus*), and goose barnacles (*Lepas anatifera*) were the most common, occurring in 9, 9, and 5% of samples respectively. Goose barnacles are likely to have been taken naturally at the surface, but the lobster krill and swimming crabs may have been secondarily ingested when feeding on fish discards. Lobster-krill were notably more common in May than July at both The Snares and Solander Island, and were taken in similar proportions by both sexes, but were more common following short foraging trips than long (Table 4). At The Snares, swimming crabs were only present in July samples (when they were taken more frequently by males), whereas at Solander Island occurrence was similar in May and July (Table 3). Goose barnacles were only recorded from May samples, where they tended to occur more often at Solander Island (1997) than at The Snares (1996), and to be taken more often by males (Table 3). Other crab species identified were *Ovalipes catharus* (only present among 1997 samples), *Neommatocarcinus huttoni*, and *Leptomithrax* sp. All other crustacean items occurred infrequently; pelagic amphipods and prawns; three copepod species—*Lophura* sp. H, and *Sphyrion quadricornus*, parasites on deepwater fish, and *Trifur lotellae*, parasitic on a variety of midwater and deepwater fish species, including red cod; and cirolanid isopods which are also parasitic on fish. Euphausiids were notably absent. All crustaceans, except the parasitic isopods, were classified as naturally-obtained prey.

Salps and other prey

Only two salps, *Pyrosoma* sp. (probably mostly or entirely *P. atlanticum*) and *Iasis zonaria*, were present. Both were abundant and occurred frequently; *Pyrosoma* in 77% and *I. zonaria* in 40% of samples (Table 2). Although *Pyrosoma* were frequently broken into pieces, the largest number of intact specimens in a stomach was 69, and the largest individual was 143 mm in length. *I. zonaria* were smaller (up to 70 mm long) and were usually intact, with up to 71 animals present in one sample. Both *Pyrosoma* and *I. zonaria* occurred more frequently in May than July. In July, both species were more abundant in 1996 than 1997 (Table 2), although *Pyrosoma* sp. tended to occur more frequently in 1997. In July 1997, birds from The Snares took both salp species more frequently than birds from Solander Island. At The Snares, males took *Pyrosoma* and *Iasis* more frequently than females (May and July 1996), although not necessarily in greater numbers, whereas at Solander Island there was little difference by sex. There was no difference between short and long trips in frequency of occurrence or abundance of these two species. Bird feathers of non-penguin origin were present in eight May samples, sometimes in large numbers, and suggested scavenging on carcasses. The frequency of other miscellaneous floating items—algae, wood fragments, pumice, and plastics, suggested indiscriminate surface feeding at times.

Relative importance of fish discards

Fish discards were present in 70% of all samples (definite and probable discards in 44 and 35% respectively), and accounted for 60% of the diet by weight (42% definite and 18% probable discards)

(Table 6). Non-discard prey items (including naturally-obtained fish prey) were taken more frequently (present in 97% of all samples) and in much greater numbers (91% of prey items), but accounted for a lesser proportion of the diet by weight (40%) than discards (Table 6). Mean total prey weight was greater in May than July, and was a result of an increase in natural prey rather than discard prey (Table 6).

In 1996, breeders from The Snares took proportionately more discards (by weight) in July than May, although the mean weight of discards was similar in both months (Table 6); the reduction in total prey weight in July primarily resulting from a lesser quantity of salps (Table 2). Discard material in stomachs from these birds was markedly greater in July 1997 than July 1996, with the mean weight of natural prey similar in both months (Table 6). The composition of discards from samples from The Snares also differed between the 2 years, with gadiformes (mostly hoki and javelin fish) dominant in 1996, and jack mackerels in 1997 (Table 2). Large jack mackerel body pieces were significantly more abundant ($P < 0.01$) in 1997 (22.1 g per stomach) than in 1996 (1.6 g).

Jack mackerel was also the dominant discard species among 1997 samples from Solander Island. Breeders from this locality took over double the weight of discards in May compared with July 1997 (Table 6), and during the latter month, lesser amounts both proportionately and in absolute terms than birds from The Snares.

Birds from Solander Island showed no sex bias in discard consumption in May 1997 (Table 3), whereas at The Snares males took a greater amount of discards than females in May 1996.

The influence of long (3–8 days) and short (<3 days) trips on prey composition, including discards, is shown in Table 4 for samples from breeders from The Snares in May 1996 (the only month for which there was sufficient data). Samples from long trips contained more fishery discards as well as larger quantities (47 g per sample, 61% by weight), than samples from short trips (9 g, 17% by weight). Natural fish prey were also more important in samples from long trips, except for lampreys, which only occurred in samples from short trips. Natural prey such as cephalopods, and to a lesser extent crustaceans, were more important in samples from short trips.

DISCUSSION

Importance of fish discards

The most notable feature of the diet of southern Buller's albatrosses was the predominance of fish, particularly discards, which comprised 91% by weight of all fish consumed. Fish remains occurred in 92% of samples and formed 65% of the total drained weight of samples. This is in contrast to the limited results from the 1970s (West & Imber 1986), where cephalopods were the preferred food, with fish, crustaceans, and salps successively less common. Fish remains were also more common and comprised a higher proportion by weight in this study of southern Buller's albatross, than for virtually all other albatrosses studied (Cherel & Klages

Table 6 Prey weights (g) of all food samples collected from southern Buller's albatrosses (*Diomedea bulleri bulleri*) breeding at The Snares and Solander Island in 1996 and 1997, by discard status and trip.

		Total prey	Discard prey		Probable discard		Natural prey	
Trip(s)	*N*	Mean	Mean	%	Mean	%	Mean	%
The Snares, May 1996	46	69.3	21.1	32	9.5	15	35.0	53
The Snares, Jul 1996	43	45.9	13.3	29	14.5	32	18.1	39
The Snares, Jul 1997	17	85.3	59.7	70	8.7	10	16.8	20
Solander Island, May 1997	41	89.0	37.5	42	18.1	20	33.3	38
Solander Island, Jul 1997	41	47.5	24.5	52	4.2	9	18.8	39
The Snares, 1996 (May and Jul)	89	58.0	17.3	30	11.9	22	26.8	48
Solander Island, 1997 (May and Jul)	82	68.3	31.0	45	11.1	17	26.0	38
All May samples	87	78.6	28.8	37	13.6	18	34.2	45
All Jul samples	101	53.2	25.7	48	9.4	18	18.1	34
All samples	188	64.9	27.2	42	11.3	18	25.6	40

1997). The relative importance of fish (as determined from otoliths and other bones) and cephalopods (using beaks), may be biased in favour of the latter because beaks are more resistant to digestion (Imber & Ross 1975; Cherel & Klages 1997). If so, this would only serve to make fish even more important in the diet of southern Buller's albatrosses than this study has demonstrated.

Of equal interest is evidence that the importance of fish in the diet may have increased over time. Fish were present in 92% of samples examined in this study, compared with 64% in 14 samples collected from The Snares during the 1970s (West & Imber 1986). Five of the latter samples were collected during February and March, with collection date of the remaining nine not reported. Therefore, it remains a possibility that different sampling seasons may be responsible in part for the apparent changes in the proportion of fish present over time. Freeman (1998) also observed a large increase in the proportion of fish in the diet of Westland petrels compared with samples collected two decades earlier, although she attributed this partly to different sampling methods employed in the two studies. It seems highly probable that these apparent increases in the fish component of southern Buller's albatross and Westland petrel diets are related to the growth of deepwater fisheries around New Zealand over this period, and the increased availability of discard material. Although some European studies have suggested increases in seabird populations resulting from associations with fishing activities (Furness 1982), it has proved difficult to link these directly with increased utilisation of discards from fishing activities (Oro 1996). However, this study and that of Freeman (1998) have provided strong evidence in the form of major increases in the proportion of discard fish consumed, that these two New Zealand procellariiforms are now utilising discards much more frequently as a new source of food.

Fish and crustaceans have a higher calorific value than squids (Clarke & Prince 1980). The high, and apparently increased proportion of fish now present in the diet, provide a plausible explanation for the increased numbers of breeding birds (Sagar et al. 1994), and the reduced time to fledging (P. M. Sagar pers. comm.) that have been observed for southern Buller's albatrosses breeding on The Snares, and suggest strongly that discards from fishing operations are having a beneficial effect on this population.

There is some indication that cephalopod remains were less common (53% of samples) in this study, than during the 1970s (79% of samples) (West & Imber 1986), although they only had 14 samples available which limits the comparison. Further, 77% of the cephalopods present in the 1970s samples were arrow squid, with 70 individuals in one regurgitation, whereas in our study the figure was 53%. Also supporting this view is the observed reduction in the proportion of arrow squid in the diet of royal albatrosses foraging off the south east coast after 1980 (Imber 1999). This trend, if true, should not be surprising as it is the natural corollary of fish becoming more important. Whether this trend is real or not, it is apparent arrow squid were, and still are, a key prey item for southern Buller's albatross.

Characteristics of prey items taken by Buller's albatrosses

One of the striking and unexpected features of the fish discard material in the samples, was the large number of large pieces of adult jack mackerel consumed, especially in 1997. About one third of the 31 samples containing jack mackerel contained large pieces, often the head, occasionally the rear half of the body, suggesting they had been torn apart by feeding birds. Length was estimated for 10 specimens, and all were near maximum size (430–540 mm fork length). Although the vertebrae at the back of the heads were intact, suggesting they had not been processed by heading machines on fishing vessels, given their size the specimens were almost certainly discards from fishing operations. External features still present precluded identification to species level, but based on a detailed examination of the otoliths, it is most likely that they were *Trachurus murphyi* (D. Stevens, NIWA pers. comm.). The predominantly southern distribution of this species and the size of the specimens supports this view. This pelagic species was first found in New Zealand waters in the mid 1980s (Annala et al. 1998), apparently having arrived from the eastern southern Pacific Ocean. Although pre- and post-spawning fish have been located off the east coast, no fish smaller than 38 cm have been found, despite examination of baitfish catches and gut contents of a range of pelagic predators (Annala et al. 1998). It seems feasible that albatrosses would have found and consumed juveniles if they had been present at the surface in numbers consistent with adult abundance, but none was found.

Specimens of the next most commonly taken fish discard species, hoki, and javelin fish, were also large, indicating they probably originated from vessels fishing in depths of 200–600 m on the shelf and slope (Annala et al. 1998). The considerable numbers of macrourids and unidentified gadiforms, although somewhat smaller in size, probably originated as bycatch from the same fisheries. No orange roughy remains were found, but the one specimen of black oreo present must have originated from deepwater vessels fishing on the continental slope in depths of 600–1300 m (Annala et al. 1998). One large specimen of barracouta, a target species of coastal fisheries, was also present. Several other mostly smaller deepwater benthic species are also likely to have originated as discards from deepwater trawl fisheries, notably eels, silverside, redbanded bellowsfish, snipefishes, and rubyfish.

In common with other studies (Cherel & Klages 1997), natural fish prey formed a minor part of the diet, and, with the possible exception of the lampreys (*Geotria australis*), were all small pelagic species, common over the shelf and slope where these albatrosses commonly forage (Stahl & Sagar 2000a). It is likely that the "light fishes" (Myctophidae and *Maurolicus* sp.) were taken mostly at night when these species typically migrate towards the surface to feed on plankton (Ringelberg 1995), although it is possible that some may have been secondarily ingested as the prey of hoki (Clark 1985). The abundance of these fishes was probably underestimated as their small bodies and otoliths are likely to be digested rapidly. The large number of sprat remains in one stomach suggests that these fish were taken naturally, presumably near the surface, and perhaps close to The Snares, as Hardy (1986) recorded schools of sprat in Hoho Bay at The Snares. The four lamprey were present in three samples, and their lengths (range 420–452, mean 434 mm) were similar to the 41 specimens measuring 459 ± 090 mm collected from grey-headed and black-browed albatross regurgitations from South Georgia (Prince 1980). This lamprey has a circum-polar distribution (Gon & Heemstra 1990), and Potter et al. (1979) suggested that they are probably found in large groups at sea where they swim near the surface during their adult marine life cycle. Support for this comes from one sample which contained two lampreys. Of interest is that this sample was obtained from a male from The Snares in May 1996 that had made a short foraging trip (<2 days), suggesting these lampreys were taken from The Snares shelf region. The redbait (*Emmelichthys nitidus*), is a small to medium-sized pelagic fish present in surprising numbers in the samples. Although they are taken occasionally by trawlers, they are likely to also be available to albatrosses naturally (Hedd 1999). Given the relatively small size of the specimens taken, it is considered unlikely these fish were obtained as discards, and they were classified as natural prey in this study.

Several fish species were recorded for the first time from albatross regurgitations (see Cherel & Klages 1997 for a list of previously known species). Natural prey species included redbait (*Emmelichthys nitidus*); sprat (*Sprattus* sp.), also recorded recently from Westland petrel regurgitations (Freeman 1998); pearlside (*Maurolicus muelleri*), and the lanternfishes *Lampanyctodes hectoris* and *Symbolophorus* sp., all common mesopelagic species around New Zealand. Amongst those newly recorded species which are considered definite fisheries discards were two eels *Bassanago* sp. and *Diastobranchus capensis* (the latter only recorded near a nest and not included in analyses); black oreo (*Allocyttus niger*); several species of macrourid including *Caelorinchus aspercephalus*, *C. bollonsi*, *C. innotablis*, *C. oliverianus*, *C. parvifasciatus*, and *Coryphaenoides subserrulatus*; silverside (*Argentina elongata*); redbanded bellowsfish (*Centriscops obliquus*); and rubyfish (*Plageiogenion rubiginosus*). West & Imber (1986) recorded only two species of fish in their study of southern Buller's albatross—two specimens of red cod (*Pseudophycis bachus*) which are considered fishery discards, and two specimens of southern boarfish (*Pseudopentaceros richardsoni*), a possible discard species. The latter was not recorded in this study.

The cephalopods eaten by southern Buller's albatrosses indicate that foraging extends little, if at all, into oceanic waters. Ommastrephids and histioteuthids, which frequent the continental shelves, were the commonest families, with the ommastrephid arrow squid the most common cephalopod in the samples. Although two species of arrow squid occur in New Zealand waters, it is likely that most, if not all, specimens found in this study were *N. sloani*, as it is found only in and to the south of the subtropical convergence zone (Annala et al. 1998), where southern Buller's albatross are known to forage (Stahl & Sagar 2000a,b). *N. sloani* occurs over the continental shelf in water up to 500 m deep, and forms the basis of a large fishery around southern New Zealand (Annala et al. 1998). It has been found frequently in the diet of royal albatross (Imber 1999) and Buller's albatross (West & Imber 1986). This species was the dominant cephalopod in the diet of Fiordland (*Eudyptes pachyrhynchus*) and yellow-eyed penguins (*Megadyptes antipodes*) around southern New Zealand (Van Heezik 1990a,b).

Although Imber (1976) recorded arrow squid in the diet of Westland petrels, Freeman (1998) did not. The large numbers of immature, juvenile, and subadult stages of arrow squid recorded here are not likely to be taken in association with fishing vessels, and were presumably taken as natural prey.

Remains of adult histioteuthid squids *Histioteuthis atlantica* were also commonly found. This species, and *H. macrohista*, are mainly found close to land (Voss 1969), and were common in the diet of royal albatross (Imber 1999), wandering albatross (*Diomedea exulans*) (Imber 1992), and present in samples from Buller's albatross (West & Imber 1986) and Westland petrels (Freeman 1998). Histioteuthids, which migrate vertically, are bioluminescent, and relatively slow-moving, and may be actively selected as prey (Imber 1999). Smaller numbers of the cranchiid squids *Galiteuthis glacialis* and *Teuthowenia pellucida* were eaten, but adults of these are not known to migrate towards the surface at night and may have been scavenged. The presence of *G. glacialis* is surprising in that this species is usually found near, and to the south of, the Antarctic convergence, well to the south of the known feeding grounds of southern Buller's albatrosses.

The inshore benthic octopod *Pinnoctopus cordiformis* (= *Octopus maorum*, O'Shea 1999) occurred surprisingly often. This species has also been recorded not infrequently in the diet of royal albatross (Imber 1999), and Fiordland and yellow-eyed penguins (Van Heezik 1990a,b), and occasionally in the diet of Buller's albatross (West & Imber 1986), and Westland petrels (Freeman 1998). How these benthic octopuses are obtained in quantity by albatrosses is conjectural, although (Imber 1999) suggests they could be obtained from post-spawning mortality and associated floating, as discards from the rock lobster (*Jasus edwardsii*) fishery, and from the prey of New Zealand fur seals (*Arctocephalus forsteri*). O'Shea (1999) gives the distribution of this octopus as New Zealand-wide (except for the Auckland, Campbell, or Bounty Islands), and the depth range as 0–300 m although they are usually captured in less than 100 m. Juvenile stages of another benthic octopod *Benthoctopus tangaroa*, found naturally in deep water (500–1500 m) around central and southern New Zealand (O'Shea 1999) were present occasionally, and may have been obtained directly as bycatch from deepwater fisheries or indirectly from the stomachs of deepwater fish taken by this fishery (O'Shea 1999). One adult specimen of a pelagic octopod *Amphitretus thielei* was also present. Juveniles of this species are pelagic, whereas adults are bathypelagic, usually in depths greater than 800 m (O'Shea 1999). Of the cephalopods recorded, only the single record of *A. lesueuri* and two instances of *Spirula spirula* appear to be new.

Weimerskirch et al. (1986) suggested that albatrosses may scavenge dead or dying squids near the surface, and this could provide a substantial food source during post-spawning periods as squids are typically short-lived; arrow squids being annual species (Annala et al. 1998). Although albatrosses can also scavenge discards from fishing vessels, we chose not to classify any cephalopods as discards in this study principally because of the uncertainties over their origin. Some cephalopod taxa float after death, making them available to albatrosses, whereas others sink (Lipinski & Jackson 1989). Croxall & Prince (1994) suggested that some albatross species may be able to dive and seize live prey more often than has previously been accepted, possibly taking advantage of the bioluminescence of some squid taxa (Imber & Russ 1975).

Crustaceans were relatively unimportant in the diet of southern Buller's albatrosses, a conclusion also reached by West & Imber (1986), and typical of albatrosses generally (Cherel & Klages 1997). Of the commoner crustacean prey items consumed by southern Buller's albatrosses (lobster-krill, swimming crabs, and goose barnacles), all could be available naturally as food, at or near the surface. Lobster-krill sometimes swarm at the surface in large numbers along the south-east coast of New Zealand, particularly during the warmer months (Zeldis 1985), and this concurs with their more frequent occurrence in the May (rather than July) samples. The "swimming" crab (*Nectocarcinus antarcticus*) is widespread around New Zealand in depths of 0–550 m, but is more common south of Cook Strait (Main 1974), and has been described as "agile, often at the surface, and active at night" (Bennett 1964). It is also possible that the specimens originated as secondary prey from scavenged fish viscera (S. O'Shea, NIWA pers. comm.). At least two other (probably benthic) crab species were present. Goose barnacles were probably scavenged from floating objects such as wood or algae, both of which were also present in samples. Amongst the crustaceans which were first records for albatross diets were two parasitic copepods, *Lophura* sp. H found on slender cod *Halagyreus johnsoni*, and *Sphyrion quadricornus*, known to be parasitic on the macrourids *Caelorinchus biclonozonalis* and *Coryphaenoides* sp. B. These and cymothoid isopods which live in the mouth cavities of fish, are regularly ingested with their hosts (Cherel & Klages 1997). Also, new prey records for albatrosses were the crabs *Nectocarcinus antarcticus*, *Neomatocarcinus huttoni*, *Ovalipes catharus*, and *Leptomithrax* sp. Although no euphausiids were found in this study, this is not surprising as the diet sampling was undertaken during winter. However, the presence of large numbers in some southern Buller's albatross stomachs examined by West & Imber (1986), and in Westland petrel stomachs (Freeman 1998), together with reports that euphausiids can be found near the surface in considerable numbers (Fenwick 1978), apparently apply to warmer periods of the year.

The two salps, *Pyrosoma* sp. and *Iasis zonaria*, occurred frequently and were abundant in the diet. Salps are generally considered to have little nutritive value, and are probably quickly digested and thus likely to be underestimated in samples (Cherel & Klages 1997). Imber (1999) observed large numbers of salps in royal albatross samples from off the southeast coast of New Zealand, and *Pyrosoma* sp. have also been recorded from wandering albatrosses breeding at the Antipodes Islands (Imber 1992).

Other miscellaneous floating items—wood fragments, marine algae, pumice, and plastics—were infrequent and small, and were likely to have been ingested incidentally whilst feeding on the surface. Plastic particles have been found in the stomach contents of all species of albatrosses investigated (Cherel & Klages (1997). Ryan (1987) suggested that as the particles are picked up at sea, their size and colour may be such that they are taken in mistake for small natural prey, such as small crustaceans. Cherel & Klages (1997) noted that accumulated items in albatross stomachs include cephalopod beaks, cephalopod and fish lenses, cephalopod gladii and spermatophores, fish bones (including otoliths), feathers, crustacean exoskeletons, stones, pebbles and pumice, and vegetable and soil matter. All of these (except spermatophores), as well as plastics, algae, and wood fragments were recorded in this study.

Neither the composition by weight of the major prey groups, nor the frequency of occurrence of most prey items, were able to be linked at any acceptable level of statistical significance to the sex of the parent birds. This was a surprising result as foraging studies had indicated likely differences in foraging areas by sex. However, our relatively small sample sizes for most prey items, and the presence at times of a few large pieces of individual items may have biased the results. Cherel & Klages (1997) suggested caution when interpreting diet data, as biases can arise because prey items may be few in number but large in size. Despite these results, there was an indication that males more often fed on some smaller, naturally occurring prey items such as common lanternfish and salps, which are likely to be available closer to the breeding colonies. This is consistent with the foraging studies (Stahl & Sagar 2000a), where males made shorter trips more often than did females. We also found limited evidence that meal weights were greater for birds undertaking long, rather than short trips, as has been found for several other procellariform species (e.g., Weimerskirch & Cherel 1998).

In their review of albatross feeding, Cherel & Klages (1997) reported that the means of the total sample mass in the diet of four smaller southern ocean albatross species varied between 340 and 640 g, the liquid fraction constituted 50–80% of the sample mass, and the solid (or drained) mass the remaining 20–50%, although they noted proportions varied greatly within species. Equivalent mean values from this study for southern Buller's albatrosses were at the lower end of these ranges; 385 g for total sample mass, and 18% for solid mass.

Foraging behaviour and interactions with fisheries

Contact between this albatross and fisheries around New Zealand is mostly confined to shelf and slope areas between 41 and 43°S and the southern Snares shelf, to the breeding season, and to adult birds (Stahl et al. 1998).

In telemetry studies of foraging behaviour, Stahl & Sagar (2000a) found that male and female southern Buller's albatrosses breeding on The Snares made alternating short and long foraging trips in an easterly direction during May, on short trips dispersing onto the Stewart Island shelf, and on long trips up the east coast of the South Island. In July, the males made short trips only, to the same area as before, whereas a female changed to make mostly long trips to the West Coast of the South Island. By contrast Stahl & Sagar (2000b), found that breeders on Solander Island made only short trips in May, again mostly in an easterly direction. In July, the males continued making trips eastwards—extended short trips to the south of The Snares, and long trips to the east coast of the South Island. However, females usually dispersed westwards—on shorter trips towards and west of the Puysegur Bank, and on longer trips to the west coast of the South Island.

Thus, there are often differences in the foraging areas used by males and females, and some difference between the relative frequency of short and long trips by sex, but mostly amongst birds from The Snares in July. This complexity would explain why very few comparisons of the frequency of occurrence of items showed any relationship by sex. There was some evidence that males took more naturally occurring food items (salps, goose barnacles, and lobster-krill), which could indicate more feeding on these smaller, but more readily available prey items closer to the colony.

Stahl & Sagar (2000a) identified a major shift in the foraging pattern of breeders from The Snares in mid June, probably triggered by external factors unrelated to the breeding cycle. They suggested it might be the result of a marked decrease in abundance of arrow squid. This squid has been shown to be a major prey item, and occurs off Banks Peninsula and in the Canterbury Bight (Mattlin et al. 1985). It is possible that the significantly greater number of arrow squid in the May diet samples could be associated with the ready availability of arrow squid during this period when jig vessels are also targeting arrow squid before spawning begins, although as noted above, only a small proportion (13%) of the arrow squid in the samples were adults. This is an annual species with most individuals dying after spawning in June and July (Annala et al. 1998), and so the reduction in numbers in July is likely the consequence of post-spawning mortality. Arrow squid, particularly juveniles, may have become more available to southern Buller's albatrosses following the advent of the squid jigging fishery off the South Island east coast, perhaps because the squid are attracted to the powerful lights used at night during fishing operations.

Based on satellite telemetry studies, Stahl & Sagar (2000a) concluded that southern Buller's albatrosses do not actively search out fishing fleets, but will feed near them if they are encountered on their natural foraging routes. This behaviour could be partly responsible (in addition to the limited sample size for many prey items) for the relatively few significant relationships observed in this study between the occurrence of most discard prey items and the sex of the parent bird, colony of origin, and time of year.

As there is no indication that birds from Solander Island feed less on fishery discards than birds from The Snares, the contrasting trends of the two breeding populations over the past 20 years or so (an increase at The Snares and a decrease at Solander Island) are unlikely to have been caused by differing discard consumption and possible associated benefits.

In conclusion, this study has shown that fish discards, apparently from deepwater trawl fisheries around and to the south of the South Island of New Zealand, form a very substantial portion of the diet of southern Buller's albatrosses breeding on The Snares and Solander Island, and that although the results suggest some relationships between the observed diet and foraging strategies as determined from satellite telemetry, further more intensive studies on diet and movements of adult birds would be required to firmly establish these links.

ACKNOWLEDGMENTS

The following assisted with identification of prey items—Cephalopods: Mike Imber, Department of Conservation, Wellington. Fish: Yves Cherel, CEBC, CNRS, Villiers-en-Bois, France; Peter McMillan, NIWA, Wellington; and Neil Bagley, NIWA, Wellington. Mesopelagic fishes: Paul Grimes, NIWA, Wellington. *Trachurus* spp.: Darren Stevens, NIWA, Wellington. Eels: Peter Castle, Victoria University of Wellington. Myctophid fishes: John Paxton, Australian Museum, Sydney. Invertebrates: Steve O'Shea, NIWA, Wellington; and John Jillett, University of Otago, Dunedin. Parasitic copepods: Brian Jones, Fisheries, Western Australia, Perth. Salps: Rob Murdoch, NIWA, Wellington. Lindsay Hawke undertook the unpleasant task of sorting regurgitation samples. Peter McMillan, Neil Bagley, Michael Stevenson, and other staff from NIWA collected many fish specimens for an otolith and bone reference collection, which was invaluable in the identification of many of the fish remains found in this study. Paul Sagar and two anonymous referees reviewed the manuscript; and Martin Unwin, Mark Taylor, and Chris Francis provided database or statistical assistance. This research was funded by the Public Good Science Fund, Contract No. CO 1507.

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Appendix 1

The following procedure tests the null hypothesis that, at a given location and time, diet variability within birds is the same as that between birds.

The observations were divided into 10 groups, each of which contained all the observations from birds of the same sex from the same trip. Suppose, for a given prey type, that in group i: p_i is the proportion of observations in which that prey was present; m_i is the number of birds with replicate observations; and n_i is the number of these birds for which the two observations were the same.

Under the null hypothesis, n ($= \Sigma_i n_i$) is approximately normal with expected value $\mu_n = \Sigma_i m_i P_i$ and standard deviation $\sigma_n = \Sigma_i m_i P_i(1-P_i)$, where $P_i = p_i^2 + (1-p_i)^2$ is the probability that any two observations from group i are the same. The null hypothesis is rejected if $|(n-\mu_n)/\sigma_n|>1.96$.

The test was found to be not significant for each of the 12 most important prey types. Thus we found no evidence to reject the null hypothesis.