SOME FOODS OF THE WANDERING ALBATROSS (Diomedea exulans)

By M. J. IMBER and R. RUSS

ABSTRACT

Regurgitations or stomach contents of 7 Wandering Albatrosses *(Diomedea exulans)* from the New Zealand region (5 from the Auckland Islands, 50°S, where there is the largest known breeding colony of the species) show that Cephalopoda and fish, in that order, are the main foods. No others were detected. Nearly all the prey are partly or wholly mesopelagic but some are known to migrate towards the surface at night. Hence, this albatross feeds at night. Over 80% of the Cephalopoda were bioluminescent. Though squids of the family Onychoteuthidae, because of their large size, seem most important in the diet, those of the Histioteuthidae were by far the commonest prey.

INTRODUCTION

In 1881 the Danish scientist Japetus Steenstrup reported to a meeting and subsequently published (1882) the following: " . . . First Mate Asm. Corneliussen . . . collected during the last voyage [in the southern seas] remains of cephalopods which he had cut out of the stomachs of albatrosses, *Diomedea exulans* L. These large birds belong, as is well known, to the most voracious cephalopod hunters, and their food consists mainly of the oceanic forms living far from the coasts. As a matter of course the content of their stomachs is of the greatest importance to the scientists whose knowledge of the cephalopod forms from the open sea has hitherto been very scarce. The contents of both the glasses came from the sea a little south of the Cape " (translation from the Danish by Volsoe, Knudsen & Rees 1962; see reference under " Steenstrup 1882 "). Among these remains Steenstrup identified some squids to be of the genus *Gonatus*. But little further progress in elucidating the food of this great albatross had been made 90 years later.

Murphy (1936), citing other workers' findings in addition to his own, reported the food of the albatross to be cephalopods supplemented by fish, with other items obtained by scavenging, but rarely crustaceans. Oliver (1955), possibly heeding Murphy, mentioned pelagic cephalopods, other molluscs, crustaceans and medusae, and commented upon its scavenging habit. McLachlan & Liversidge (1957) stated: " Feeds mainly at night taking small fish and squid which come to the surface." Off eastern Australia the large " cuttlefish " *Amplisepia verreauxi,* (Cephalopoda, Sepiidae), is an important item (Gibson & Sefton 1955, Serventy *et al.* 1971).

An opportunity to investigate, in greater detail, the feeding habits of this albatross was provided by the 1972/73 Auckland Islands expedition. Among its objectives was a survey of the avifauna of these islands which lie about 500 km south of New Zealand (50-51°S, 166°E). A report on the three species of albatross breeding there — Wandering Albatross *Diomedea exulans exulans,* Southern Royal Albatross *D. epomophora epomophora* and White-capped Mollymawk *D. cauta cauta* — is to be published by C. J. R. Robertson. The main colony of *D. exulans* is on Adams I. but a few nest on Disappointment I. and Auckland I. (the main island). Censuses by Russ and Robertson revealed that the total local breeding population of this species represents about 40% of the world's breeding population (Robertson 1975).

During field work on Adams I. in the first week of January 1973, Russ collected two regurgitations from beside the nests of fledglings; both regurgitations seemed fresh, for they were still oily. During banding, adults seldom regurgitated and, though chicks sometimes ejected oil, no useful samples of food were obtained while banding. Between 3 and 5 January 1973 Russ collected a pair of adults at an empty nest and a fully-grown fledgling: these were prepared as study skins at the National Museum, Wellington, and we obtained the stomachs for examination. In addition, Mr F. C. Kinsky, Ornithologist at the Museum, kindly made available from the collection of preserved stomachs, those of Wandering Albatrosses obtained in Wellington Harbour (15 August 1969) and at Opoutama, Hawkes Bay (2 August 1963).

METHODS

Of the seven samples only one (from Wellington Harbour) contained a significant amount of flesh (squid), so no analysis of undigested food was possible. Accordingly, we noted the occurrence of remains of each class of food, then proceeded to identify the beaks of cephalopods and otoliths of fish.

The identification of cephalopod beaks is based on the lower beaks. We followed Clarke (1962) and made extensive use of the collection of beaks from Grey-faced Petrels *(Pterodroma macroptera gouldi)* (Imber 1973). Additional illustrations and descriptions of beaks were found in Berry (1918), Robson (1924), Akimushkin (1963), Clarke (1965), Filippova (1968, 1972), Young & Roper (1968, 1969) and Voss (1969). Several other references were consulted for species not encountered in this study. Finally, a few rare beaks were sent to Dr J. A. Filippova (All-Union Research Institute of Marine Fisheries and Oceanography, Moscow) and to Dr M. R. Clarke (Marine Biological Association of the U.K., Plymouth).

Otoliths were examined by Mr J. M. Moreland, Ichthyologist at the National Museum. Those he was unable to identify were compared with those illustrated by Fitch & Brownell (1968), Schmidt (1968) and Fitch & Barker (1972).

RESULTS

The digestion-resisting remains comprised beaks of cephalopods and bones and otoliths of fish. There was no indication of other animals, such as Crustacea. The stomach oil of this albatross is nearly colourless (personal observations, Lewis 1969), whereas petrels that feed on crustaceans have reddish stomach oil which is almost certainly coloured by the carotenoid pigments from this food (Lewis 1969). In the 7 samples, remains of Cephalopoda occurred seven times (100%) and the remains of fish four times (57%), but fish remains are probably less resistant to digestion than are cephalopod beaks.

The Cephalopoda among the prey of this albatross are listed in Table 1. Samples were few but no differences were found in the species taken by birds from different localities, so data have been pooled. The Histioteuthidae were commonest, then Cranchiidae, Gonatidae, Chiroteuthidae, Onychoteuthidae and 8 other families of rarer occurrence, in that order. Because of the relatively large size of some species, squids of the Onychoteuthidae seem most important in the diet (on a weight basis). The beaks of *Moroteuthis ingens* and *M. robsoni* are particularly robust, however, and are relatively common among the regurgitated beaks that are often found beside albatross (*Diomedea* spp.) nests (personal observations of material supplied by C. J. R. Robertson). As previously suggested for Grey-faced Petrels (Imber 1973), the accumulation of beaks in albatross stomachs is usually associated with at least one particularly large pair of beaks (usually *Moroteuthis*, occasionally *Taningia*) which are presumed to hinder the fragmentation and onward passage of smaller beaks. In the five stomachs we examined, two contained only two or fewer pairs of beaks which belonged to species of *Histioteuthis*. The other three stomachs (with accumulations of 3, 7 and 19 pairs of beaks) each contained beaks of one or two *Moroteuthis ingens* or *M. robsoni*. Hence, it seems likely that the frequency of occurrence and importance of these two *Moroteuthis* species in the diet is exaggerated in Table 1, but by how much is uncertain.

The four samples containing fish remains comprised one with a pair of otoliths, two with otoliths and bones, and one with only a vertebra. Four pairs of otoliths (representing 4 fish) were found. Two from the specimen collected in Wellington Harbour were identified as belonging to *Macruronus novae-zelandiae* (Hector) of the family Merlucciidae. This mesopelagic fish is also taken by at least two other species of albatross in the New Zealand region (Imber, unpublished). Another pair of otoliths was identified, by reference to Fitch & Brownell (1968), Schmidt (1968) and Fitch & Barker (1972), as belonging to *Halargyreus johnsonii* Gunther of the family Moridae. The fourth pair could not be identified. These fish probably ranged in length from about 25 cm to nearly 1 m.

TABLE 1. Cephalopoda, identified and counted by their beaks, among food of Wandering Albatrosses (*Diomedea exulans*) from Auckland Islands (5 samples) and the east coast of New Zealand (2 specimens)

Order Family [1] Species	Lower beaks No.	 Percent	Beak measurement [2] Mean(mm)	 Range	Estimated weight [3] Mean(g)	 Range	Importance of family [4] (Percent)
Octopoda (= Octobrachiata)							
Argonautidae	4	1					<1
Argonauta nodosa Solander	3		13.0	11.0-15.9	160	90- 300	
Argonauta ?*argo* L.	1		(17.0)	-	(350)	-	
Teuthoidea							
Architeuthidae	1	<1					3
Architeuthis sp. (juvenile)	1		8.0	-	3,000	-	
Ommastrephidae	1	<1					1
unidentified sp.	1		9.3	-	1,400	-	
Onychoteuthidae	19	7					37
Onychoteuthis banksi (Leach)	1		3.1	-	54	-	
Moroteuthis ingens (Smith)	10		11.4	10.4-12.3	2,500	1,900-3,100	
Moroteuthis robsoni Adam	3		9.0	7.1-10.1	1,250	620-1,800	
Moroteuthis knipovitchi Filippova	3		6.5	6.2- 6.7	470	400- 520	
?*Kondakovia longimana* Filippova	2		15.5	15.2-15.8	6,300	6,000-6,600	
Gonatidae	29	10					3
Gonatus antarcticus Lönnberg	3		7.7	6.6- 8.9	200	145- 260	
Gonatus sp. (cf. *separata* Akimushkin)	6		5.6	5.3- 5.9	105	94- 115	
Gonatus sp.C	1		6.1	-	125	-	
Gonatus sp.D	4		6.7	4.8- 8.4	150	78- 240	
?*Berryteuthis anonychus* (Pearcy & Voss)	15		4.9	3.8- 5.7	80	48- 110	
?Psychroteuthidae	1	<1					<1
?*Psychroteuthis* sp.	1		8.5	-	(600)	-	
Enoploteuthidae	3	1					<1
?*Enoploteuthis* sp.	3		4.4	4.3- 4.4	55	50- 60	

TABLE 1 (continued)

Octopoteuthidae	9	3					5
Octopoteuthis ?longiptera Akimushkin	7		10.5	6.5-12.7	350	100- 550	
Taonius ?danae Joubin	2		18.5	15.9-21.1	1,425	950-1,900	
Histioteuthidae	149	53					23
Histioteuthis ?eltaninae N. Voss	83		5.0	2.4- 6.6	155	35- 270	
Histioteuthis ?atlantica (Hoyle)	33		5.4	3.6- 6.5	180	78- 260	
Histioteuthis ?miranda (Berry)	17		7.2	6.5- 7.9	330	260- 390	
Histioteuthis ?macrohista N. Voss	13		4.0	3.0- 4.5	98	54- 125	
Histioteuthis ?dofleini (Pfeffer)	2		4.7	2.2- 7.2	135	30- 320	
Histioteuthis sp.G	1		3.0	-	54		
Chiroteuthidae	28	10					9
Chiroteuthis sp.A	20		7.6	6.9- 8.3	430	320- 560	
Chiroteuthis sp.D	2		7.9	7.8- 8.0	475	450- 500	
Mastigoteuthis sp.B	4		6.3	5.1- 9.1	250	140- 720	
Mastigoteuthis sp.D	2		4.2	4.0- 4.5	85	70- 100	
Cycloteuthidae	4	1					5
Cycloteuthis ?akimushkini Filippova	4		12.0	11.0-12.9	(1,500)	-	
Cranchiidae	32	11					13
Taonius ?pavo (Lesueur)	29		9.7	8.9-10.8	500	350- 640	
Megalocranchia richardsoni Dell	2		5.1	4.8- 5.4	110	100- 120	
unidentified sp.	1		5.1	-	110	-	
Unidentified	1	<1	-		-		<1
TOTALS	281	100			400		100

1 Designated species (e.g. Histioteuthis sp.G) correspond to those in Imber (1973), except that Moroteuthis sp.A therein is, here, M. robsoni.

2 Usually length of rostrum, except in Argonautidae where crest length is used (see Clarke 1962). Figure in brackets is an estimate for an incomplete beak.

3 Based on the graphs of Clarke (1962). Figures in brackets are rough estimates based on an incomplete beak, or for families not available to Clarke.

4 Calculated as the sum of the products of No. of lower beaks x estimated mean weight of all species within each family, expressed as a percentage of the total sum of all these products (as in Imber 1973).

DISCUSSION

There have been few critical studies of the foods of any albatross. The most thorough and most recent is that by Harris (1973) on the Waved Albatross *(D. irrorata)*. The similarity of the diet of the Waved and Wandering Albatrosses, especially insofar as cephalopods are concerned, is very marked: the differences seem mainly caused by dissimilarities in the cephalopod faunas of the two regions. Reports in the literature of identified Cephalopoda eaten by albatrosses (Table 2) are more frequent than reports of other classes of prey, thus indicating their general importance to the Diomedeidae. Tickell (1964) found that Black-browed *(D. melanophris)* and Grey-headed *(D. chrysostoma)* Albatrosses feed extensively on cephalopods. Fish are next in importance as food of albatrosses generally and have been reported in most studies (Tickell 1964, Harris 1973, this paper). However, Crustacea seem important only in the food of the smaller species (Tickell 1964, Harris 1973, C. J. R. Robertson pers comm.).

The prey of Wandering Albatrosses are mostly typical mesopelagic animals, some of which are known to undertake diurnal vertical migrations, upwards at dusk and downwards at dawn (cf. Table 8 in Imber 1973). Others no doubt do so, at least to some extent, for albatrosses feed at the surface whilst some prey have been recorded only from deep water. The typical daytime depth of most of these prey is between 50 and 500 m, though many individuals of some species occur deeper still — frequently to 1000 m but some to 5000 m (Clarke 1966). Hence, apart from daytime scavenging, the Wandering Albatross is a nocturnal feeder as McLachlan & Liversidge (1957) stated. This conclusion is mainly derived from what is known about the cephalopods but is also supported by our knowledge of the fish prey.

Lewis (1969) made a biochemical analysis of the stomach oils of four procellariiform birds, including one Wandering Albatross collected in Cook Strait. He found that wax esters constituted 77% of the latter's oil. As discussed by Lewis, wax esters are rare or absent in zooplankton and other epipelagic animals, and their discovery in the stomach oils of Sooty Shearwater *(Puffinus griseus)* and Fulmar *(Fulmarus glacialis)* (see also Cheah & Hansen 1970) led to the hypothesis, never proven, of a secretory origin. However, within the last decade wax esters have been discovered as prominent lipids in numerous mesopelagic and bathypelagic fish, crustaceans and squids (Lewis 1967, 1969, Lee & Hirota 1973). Lee & Hirota state: "In general, of the pelagic fauna, only the deep-living temperate and polar zooplankton and nekton store wax esters." These include many animals that undertake diurnal vertical migrations. Here is further strong evidence linking oceanic birds and mesopelagic prey, and of nocturnal feeding by Wandering Albatrosses. Conversely, results presented in this paper support Lewis' contention (1969) that stomach oil is of dietary origin.

TABLE 2 — Cephalopoda in the food of albatrosses other than Wandering Albatrosses **(Diomedea exulans)**

Species	Locality	Cephalopoda (family, species) identified	Reference
Light-mantled Sooty Albatross (Phoebetria palpebrata)	South Indian Ocean	Cranchiidae - Taonius pavo	Chun 1910
Laysan Albatross (Diomedea immutabilis)	North Pacific Ocean	Onychoteuthidae - Onychoteuthis banksi	Clarke 1966 citing S.S. Berry
Black-footed Albatross (D. nigripes)	North-west Pacific Ocean	Amphitretidae - Amphitretus ?pelagicus; Histioteuthidae - 2 species; Gonatidae - 2 species; Chiroteuthidae - Chiroteuthis veranyi; Cranchiidae - Taonius pavo; Octopoteuthidae - 1 species	Akimushkin 1954 a, b, 1963
Albatrosses (unidentified)	South Georgia	Gonatidae - Gonatus antarcticus	Clarke 1966
Waved Albatross (D. irrorata)	Galapagos Islands	Ommastrephidae, Histioteuthidae, Octopoteuthidae, Chiroteuthidae, Enoploteuthidae, Onychoteuthidae, Pholidoteuthidae	Harris 1973

As with Grey-faced Petrels (Imber 1973), detection of prey seems to be mainly through their bioluminescence. This applies to the cephalopods eaten by the Wandering Albatross though apparently not to the fish. Over 80% of the cephalopods enumerated in Table 1 are bioluminescent. Most of the species listed in Table 2 are bioluminescent, as are at least 96% of the squids taken by Waved Albatrosses (Harris 1973). In particular, the importance of the highly bioluminescent squids of the family Histioteuthidae in the food of oceanic vertebrates — Procellariiformes (Akimushkin 1963, Harris 1973, Imber 1973, this paper, Imber unpublished) and Cetacea (Akimushkin 1963, Clarke 1966, Gaskin & Cawthorn 1967) — is becoming increasingly evident. However, bioluminescence is prevalent among mesopelagic animals so this factor might merely be a coincidence.

Research in the Southern Ocean indicates that three species of squid are relatively common (Roper 1969). Two of these are smaller than any represented by beaks in our albatross samples, and one of these is apparently restricted to a vertical range well below the surface. The third commonest "species" he found was *Gonatus antarcticus* (but we suspect this was more than one species) which is much larger than the other two, attaining a mantle length of at least 17 cm (Clarke 1966). It was common in the upper layers, 55% being taken in the upper 250 m (Roper 1969). Whereas 141 specimens of this "species" were captured, Roper recorded that: "Deeper dwelling forms, e.g., species of *Mastigoteuthis, Chiroteuthis,* and *Histioteuthis,* are represented by fewer than two dozen specimens each" in this collection from the Southern Ocean. We, therefore, have the apparent anomaly that Wandering Albatrosses select rarer, deeper-living animals in preference to a common "species" living nearer the surface. But, unlike the Chiroteuthidae and Histioteuthidae, *Gonatus antarcticus* and most other species of this family do not possess light organs. This seems to us the strongest evidence that albatrosses detect many of their prey by its bioluminescence. Apparently some non-bioluminescent prey can be detected at night, since most of these are also mesopelagic. However, unlike most of the bioluminescent squids, these may be detectable because they are relatively large and/or active species (especially the Onychoteuthidae and the fish). Some shallower-living forms may be available during twilight (e.g. Argonautidae and Gonatidae).

In Table 3 the preferred sizes of cephalopods taken by some marine vertebrates of differing body weight are compared. Comparison of Tables 1 and 3 reveals that the range of sizes of cephalopods taken by Wandering Albatrosses overlaps that of all the other species. Sperm Whales captured in Cook Strait had been feeding mainly on onychoteuthid squids (especially *Moroteuthis),* the Histioteuthidae coming second in frequency of occurrence (Gaskin & Cawthorn 1967). Hence, the diet of this albatross comes close to that of Sperm Whales. The largest cephalopods are the *Architeuthis* species, of which the beaks of a juvenile were found in one of the regurgitations of a fledgling on Auckland Is. These squids may attain 1,000 kg and are

regularly taken by Sperm Whales (Clarke 1966). However, they are probably relatively uncommon so that these whales mainly take more abundant squids, few of which exceed 10 kg (Clarke 1962). Hence, these whales, considering their size, take disproportionately small squid when compared with petrels and albatrosses.

TABLE 3. Comparison of the preferred sizes of Cephalopoda eaten by animals of different bodyweight

Species	Weight (kg)	Mean weight of cephalopod eaten (g)	Reference
Grey-faced Petrel (*Pterodroma macroptera gouldi*)	0.55	<75	Imber 1973
Waved Albatross (*Diomedea irrorata*)	3.29	<260	Harris 1973
Wandering Albatross (*Diomedea exulans*)	8.70	<400	this paper
Sperm Whale (*Physeter catodon*)	15,000±	500-3,000	Gaskin & Cawthorn 1967

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Postscript: In Table 1 the 3 squids tentatively identified as **Enoploteuthis** (family Enoploteuthidae) should be placed in the family Cranchiidae, probably as another **Megalocranchia** sp. Cohen (1973, **Journal of the Royal Society of New Zealand** 3: 629-634) considers that the name of the fish family Moridae should be Eretmophoridae.

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RESIGNATION OF PRESIDENT

At its November meeting, Council regretfully accepted the President's resignation which became inevitable due to increased pressure of work and more overseas trips for him in the near future. Mr Kinsky will remain on Council, however, and the positions of President and Vice-President will be handled by Mr B. D. Bell and Mrs G. Hamel, respectively, until May.