Diet of the blue petrel at sub-Antarctic Marion Island

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Food samples were collected from 49 blue petrels *Halobaena caerulea* at Marion Island in the sub-Antarctic region. These were analysed and the results compared with previously published data collected at other islands. Crustaceans formed the major prey by mass (59,5%) and frequency (100%), with *Euphausia vallentini* being of particular importance (56,6% by mass of Crustacea). Other prey included fish, cephalopods and two species of insects, a moth (Noctuidae) and an assassin bug *Nabis*.
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Voedselmonsters van 49 bloustormvoëls *Halobaena caerulea* is by Marioneiland in die sub-Antarktiese gebied versamel. Die voedselmonsters is ontleed en die bevindings met reeds gepubliseerde data wat by ander eilande versamel is, vergelyk. Skulpdiere het die hoofprooi volgens massa (59,5%) en frekwensie (100%), gevorm en *Euphausia vallentini* was van besondere belang (56,6% van die massa van die skulpdiere). Ander prooi het vis, koppotiges en twee soorte insekte, 'n mot (Noctuidae) en 'n roofinsek van die genus *Nabis*, ingesluit.
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Blue petrels *Halobaena caerulea* range widely over the Southern Ocean between 30 and 60°S (Harrison 1983). They breed at South Georgia (Croxall & Prince 1980), Crozet and Kerguelen (Jouventin, Stahl, Weimerskirch & Mougin 1984), Macquarie (Brothers 1984), the Prince Edward Islands (Williams 1984) and on Diego Ramirez south of Chile (Schlatter 1984). Only one detailed study of the diet of the blue petrel has been made, at South Georgia (54°55'S/36°38'W) (Prince 1980) although food samples have been collected elsewhere. The summer diet of the blue petrel was studied at Marion Island (46°52'S/37°51'E) in the southern Indian Ocean.

Methods

Blue petrels were trapped in mist nets set up on 12 nights between 16 November 1984 and 8 January 1985. The number of nights on which mist netting was possible was limited by weather conditions. Food samples were obtained using three methods:

(i) During November birds were not feeding chicks and did not have full crops when caught. These birds would not regurgitate spontaneously on handling, therefore it was necessary to use a water off-loading technique (Wilson 1984) to collect stomach contents. Six samples were collected using this method.

(ii) Blue petrels caught in December and January were feeding chicks and often regurgitated their stomach contents on becoming enmeshed in the net; it was possible to collect samples using a 300 mm diameter plastic funnel with a plastic bag attached to the bottom by an elastic band (see Prince 1980). In many cases the birds began to regurgitate as soon as they hit the net and food was lost on the netting or onto the ground. Therefore samples were only collected from birds that had not started regurgitating until they were inverted over the funnel. A total of 34 samples was collected in this manner.

(iii) The third method of obtaining samples was by dissection of nine blue petrel chicks which were collected for another study in December 1984, January and April 1985.

Altogether, 49 birds were sampled. Once collected, the oil was decanted from the samples and its volume measured to the nearest 1 ml. The solid portion of the sample was then sorted further in the laboratory. Gizzard stones and plastic particles were removed and counted. All identifiable prey items were counted, weighed and identified. Unidentified remains of the stomach contents were labelled and weighed separately. Following Ashmole & Ashmole (1967) and Prince (1980), the analysis of the diet involved the three parameters of mass, frequency of occurrence and relative abundance of items.

Results

The mean solid mass of the samples collected was 4,7 ± 5,4 g, (range 0,3 – 19,4 g). For incubating adult blue petrels the mean meal size was 0,7 ± 0,25 g, (range 0,3 – 1,0 g), whereas adults rearing chicks had a mean solid meal size of 7,2 ± 5,43 g, (range 0,5 – 19,4 g). Thus blue petrels that are feeding chicks have roughly 10 times the mass of food in their stomachs as birds which are incubating eggs. The contents of the stomachs were similar throughout the period when samples were collected, except that Cladocera and Ostracoda were only found in birds' stomachs during November. Table 1 sets out the results obtained for the major classes of food items. The most unexpected result was the quantity of insects found in stomach samples. The stomach contents are described below under their main taxonomic groups in order of importance as determined by mass.

Table 1 The frequency of occurrence, relative abundance and mass of the major classes of prey in the diet of blue petrels at Marion Island

Class	No. of samples containing class	Frequency of occurrence	No. of items	Relative abundance	Mass (g)	% by mass identified
Crustaceans	49	100,0	1 393	92,1	64,3	59,5
Fish	26	53,1	51	3,4	22,9	21,2
Insects	13	26,5	43	2,9	3,9	3,6
Cephalopods	17	34,7	22	1,5	17,0	15,7
Gastropods	1	2,0	1	0,1	trace only	
Unidentified	35	71,4	–	–	124,9	–

Crustaceans

Crustacea were found in all 49 stomach samples, and formed the most important element in the diet by all three measured parameters: mass (59,5%), relative abundance (92,1%) and frequency of occurence (100%). A wide variety of crustaceans was found in the stomach samples (Table 2).

The major prey group was the Euphausiacea which formed 75,3% of the identified crustacean mass. *Euphausia vallentini* was by far the single most important species constituting 56,6% by mass of the identified crustacean material. One sample contained an estimated 250 euphausiid eyes attributed to *E. vallentini*, besides several whole but unmeasured specimens.

Amphipods were the next most important group of crustaceans in the blue petrel diet and accounted for 22,9% by mass. *Cyllopus* was the most numerous and frequently occurring genus. The Gammaridae were as important as *Cyllopus* in terms of mass, with each contributing 7,3%. Cladocera and Ostracoda were not a major component in the diet, only occurring in two samples collected on 16 and 26 November 1984.

Fish

Fish formed 22,9% of the diet by mass and approximately 51 fish (3,4% of prey items by number) were estimated from counts of eye lenses and otoliths. From the otoliths only one species, the lantern fish *Electrona carlsbergi* was positively identified. One *Protomyctophum* sp. and one *Gymnoscopelus* sp. were tentatively identified. All three species are myctophid fish. In general, fish were too well digested for identification.

Table 2 Composition of the crustacean element of the diet of the blue petrel at Marion Island

Species	No. of samples	Frequency of occurrence (%)	No. of items	Relative abundance (%)	Mass (g)	% mass
Cladocera	1	2,0	2	0,1	0,1	0,2
Ostracoda	2	4,1	165	11,8	1,1	1,6
Decapoda						
Nauplius larvae	1	2,0	1	0,1	trace only	
Euphausiacea	17	34,7	21	1,5	12,0	18,7
E. vallentini	31	63,3	964	69,1	36,4	56,6
Fish lice	1	2,0	1	0,1	trace only	
Amphipoda						
Cyllopus	11	22,4	124	8,9	4,7	7,3
Gammaridae	4	8,2	4	0,3	4,7	7,3
Hyperiella	1	2,0	1	0,1	1,0	1,6
Vibilia	11	22,4	39	2,8	1,2	1,9
Themisto gaudichaudi	6	12,2	67	4,8	2,9	4,5
Unidentified amphipods	1	6,1	4	0,4	0,2	0,3
Total	49		1 393		64,3	

Insects

The presence of terrestrial insects in the diet of the blue petrels was unexpected. Assassin bugs of the genus *Nabis* and unidentified moths (Noctuidae) were found in samples collected on three specific days: 7 and 8 January and 28 April 1985. On those days 13 out of 25 of the samples collected contained these insects. The mean number of insects per sample was 2,1 moths and/or 6,7 assassin bugs. The two species of insect were found both together and separately in stomach contents.

Cephalopods

It was only possible to identify four of the 22 cephalopods collected. One was *Bathyteuthis abyssicola*, and this is the first published record of this species being found in a bird's stomach. The other three were all unidentified species of the Onychoteuthidae. The mean lower rostral length of the beaks collected was 1,8 ± 0,5 mm.

Cephalopods comprised 17,0 g (15,7%) of the total identified mass, and constituted only 1,5% of identified prey items.

Gastropods

The only gastropod found during the study was the pelagic larva of an unidentifiable species in one stomach.

Proventricular oil

Oil was found in 23 out of 40 samples (58%). The average volume was 1,0 ± 1,2 ml, and it ranged from 5 ml to mere traces. Colour and consistency varied between a thin, bright red and a thick yellow oil; the red oil, typical of euphausiids was the most commonly found (17 out of 23 cases).

Gizzard stones

Stones were found in 12,5% of the stomach contents. The mean number of stones was 1,8 per sample containing stones. Of the stones collected 66,7% were pumice, the remainder being lava gravel.

Plastic particles

A total of six plastic pellets and discs occurred in five out of 40 samples (12,5%). The mass of these particles was negligible.

Discussion

Diet

Previously published data on the diet of blue petrels show quite marked differences. Fourteen blue petrels at Kerguelen and one at the Crozet Islands all contained only cephalopods (Paulian 1953; Despin, Mougin & Segonzac 1972). Similarly, of 27 beached specimens in New Zealand, 93% contained cephalopod beaks (Reed 1981). However, at Bird Island, South Georgia, crustaceans were the most important element, by mass, relative abundance and frequency of occurrence, followed by fish with cephalopods only ranking third in importance (Prince 1980). Bierman & Voous (1950) sampled seven birds at sea near the South Sandwich Islands, and found 71% to contain crustaceans and the remaining 29% contained cephalopods.

Cephalopod beaks remain in the stomachs of seabirds for some time, whereas crustaceans and fish, and even otoliths are digested relatively rapidly (Furness, Laugksch & Duffy 1984). This may explain why both Prince (1980) and this study found crustaceans and fish to constitute the major portion of the birds' diet, while the other work has possibly overemphasized the cephalopod component, owing to the fact that samples were collected entirely by dissection as opposed to regurgitation.

The order of importance by mass of the major groups of prey of the blue petrel at Marion Island is crustaceans, fish and cephalopods, which corresponds to the order of these prey classes in the diet of blue petrels at South Georgia (Prince 1980) though there are proportionally less crustaceans and more fish and cephalopods in the Marion Island samples. Since South Georgia is south of the Antarctic Polar Front, whereas Marion Island is north of it, the closer proximity of Antarctic krill *Euphausia superba* may account for the total preponderance of crustaceans, and Antarctic krill in particular, in the diet of the South Georgian population (Prince 1980). In contrast, the most important single prey species for the Marion Island population was the euphausiid *E. vallentini*, which is distributed between the Antarctic Polar Front and the Subtropical Convergence, normally between 50°S and 40°S (Mauchline & Fisher 1969).

Ostracods only occurred in two of the Marion Island samples, and Cladocera in one collected during November. However, there were insufficient samples taken over too short a period of time to determine any seasonal variation in the diet. The amphipods *Vibilia, Cyllopus* and *Hyperiella* were taken as a food source by both the South Georgia (Prince 1980) and Marion populations of blue petrels.

The most obvious difference between the results of this study and previous data is the presence of moths and assassin bugs in the stomach contents. It is most unlikely that these insects are a regular food source for the blue petrels (J.E. Crafford & W.K. Steele unpubl. data). The insects are not found on Marion or Prince Edward Island, and must have been collected while floating on the sea surface in a moribund state.

Feeding behaviour

Previously published reports on blue petrels feeding show similar behaviour patterns. Bierman & Voous (1950) saw flocks of 'up to some hundreds' of birds, swimming on the surface and picking oil droplets and euphausiids from near the surface. Dives were also observed for up to 6 s. This behaviour corresponds to the 'surface seizing' and 'surface diving' methods of foraging (Harper, Croxall & Cooper 1985). The flocks were often associated with whales, which stir up crustaceans, or with large swarms of Antarctic krill (Bierman & Voous 1950).

It is probable that most feeding by seabirds in the Southern Ocean takes place at night when many marine organisms migrate to the top few metres of the water column. The bioluminescence of some species will aid in their detection by predatory birds (Imber 1973). The euphausiid *E. vallentini* usually occurs at depths of between 100 m and 250 m, but it does rise to the surface at night, and it has five pairs of light-producing photophores on the thorax, abdomen and eye stalks (Mauchline & Fisher 1969).

Foraging range

Croxall, Ricketts & Prince (1984) estimated a potential foraging range of 670 km for breeding blue petrels. The Antarctic Polar Front has been located at roughly 50°S between Africa and Antarctica, during January/February (Lutjeharms & Emery 1983). This would place the Front approximately 330 km south of Marion Island during this period, which was when the samples were collected. *Euphausia vallentini*, the most important prey species of the blue petrel at Marion Island (Table 2), occurs north of this Front (Mauchline & Fisher 1969). So it would seem the birds are predominantly feeding north of the Antarctic Polar Front. However the presence of prey species that are typically regarded as being Antarctic in distribution, e.g. the amphipod *Cyllopus*, suggests that blue petrels from Marion Island are indeed capable of foraging south of the Antarctic Polar Front while breeding.

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