THE DIET OF THE WHITECHINNED PETREL *PROCELLARIA AEQUINOCTIALIS* AT SUB-ANTARCTIC MARION ISLAND

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Received 23 January 1992, accepted 21 April 1992

SUMMARY

COOPER, J., FOURIE, A. & KLAGES, N.T.W. 1992. The diet of the Whitechinned Petrel *Procellaria aequinoctialis* at sub-Antarctic Marion Island. *Marine Ornithology* 20: 17-24.

The diet of the Whitechinned Petrel *Procellaria aequinoctialis* was studied at sub-Antarctic Marion Island in 1991. Mean meal size fed to chicks was 31 g. Fish comprised 56.6% by mass of the diet, crustaceans 23.6%, and squid 17.0%. The most abundant prey item was *Euphausia vallentini*. *Themisto gaudichaudii* occurred most frequently. Measurable prey items ranged from 14 to 288 mm in length. The squid diet of the Whitechinned Petrel suggests that scavenging is an important foraging method, although the large numbers of crustaceans in the diet at Marion Island suggest active predation.

INTRODUCTION

In the last decade there has been an upsurge of interest in the diets of the seabirds of the Southern Ocean. Studies have been undertaken at a number of breeding localities in the Antarctic and sub-Antarctic, partially as a requirement for the ecosystem monitoring progamme of the Scientific Committee for the Conservation of Antarctic Marine Living Resources (CCAMLR Ecosystem Monitoring Program 1988). Recent summaries have been published by Croxall & Lishman (1987), Prince & Morgan (1987) and Cooper *et al.* (1990). Most recent studies of the diets of southern seabirds have concentrated on the large surface-nesting species (penguins, albatrosses and the larger petrels). Fewer detailed studies have been carried out on the smaller members of the order Procellariiformes, which group includes the burrowing petrels of the sub-Antarctic islands.

The diets of most of the seabirds breeding at subantarctic Marion Island have now been studied in detail (Cooper & Brown 1990). An exception has been the burrowing Whitechinned Petrel *Procellaria aequinoctialis*, for which up to now, only the squid fraction of its diet at Marion Island has been investigated (Lipinski & Jackson 1989).

Here, we detail the diet of the Whitechinned Petrel at Marion Island, comparing our findings with previous studies at Marion Island and at other breeding localities, and from the wintering range of the species.

METHODS

Thirty occupied burrows of the Whitechinned Petrel were marked by AF with numbered bamboo poles in Prion Valley and above Gentoo Lake in the vicinity

of the Meteorological Station at Marion Island (46 54S, 37 45E) during the first half of February 1991 after hatching was completed. Burrows were provided with removable earth plugs lined with cloth sacking (Sinclair 1981, Schramm 1983).

From mid-February burrows were visited at irregular intervals in the late afternoon or evening and chicks were weighed to the nearest 10 g using 2 and 2.5-Kg Pesola balances. No chicks were weighed at an interval of less than 10 days. Small pieces of vegetation were then placed at the burrow mouths whose disturbance would indicate adult activity. After midnight on the same night, burrows were revisited and chicks reweighed in nests with disturbed vegetation. Chicks found to have increased their mass by at least 30 g were then subjected to multiple stomach flushing (Wilson 1984, Ryan & Jackson 1986, Gales 1987). Stomach contents were taken to an island laboratory, drained through a 1-mm mesh sieve, weighed to the nearest 0.5 g on a 100-g Pesola balance, and labelled and deep frozen after the addition of 96% ethanol.

Three samples collected at Marion Island in 1990 by A.C. Cawrthorn-Blazeby using essentially the same procedure have been included in the analyses.

Collected samples were later taken to South Africa for analysis by NTWK. In the laboratory, the ethanol was drained using a 0.5-mm sieve. The solid portions of the samples were blotted dry, sorted into main prey categories and each component weighed separately to the nearest 0.1 g. Sufficiently intact prey items were measured. Fish and cephalopods were identified from their otoliths and mandibles (beaks), respectively, by comparison with reference specimens held at the Port Elizabeth Museum. Four worn upper beaks were excluded from the analysis. Regressions were used to estimate sizes of fish and squid from measurements of otoliths and beaks (Clarke 1986, Port Elizabeth Museum unpubl. data). Crustaceans were identified from keys (Barnard 1969, Schultz 1969, Kirkwood 1982, 1984).

RESULTS

Three food samples were obtained on 15 March 1990 and 31 samples were obtained on 18 nights during the period 15 February to 3 April 1991.

The mean mass of unfed chicks was 1 480 ± 315 g (range 810-1 950 g; n=34), and after feeding was 1 550 ± 260 g (range 850-2 020 g; n=34), resulting in a mean mass gain of 68 ± 41 g (range 30-200 g; n=34). Drained masses of samples ranged from 3 to 110 g, with a mean of 31 ± 29 g. Deduced from mass gains a meal on average represented only 4.6% of prefeeding body mass, with a maximum of 16.3% for a chick that weighed 980 g prior to feeding.

There was no significant linear relationship between initial mass of chicks and mass gained after a meal ($r=0.0734$, $P>0.1$). However, a highly significant linear relationship was found between mass gained as deduced from the two weighings and recovered drained mass of food ($r=0.7480$, $P<0.001$). There was no noticeable trend for mass of stomach contents to increase as the season progressed.

Because a positive significant relationship exists between mass gained and drained meal mass, it may be assumed that the mean difference of 37 g is due mainly to the liquid fraction of the meal being lost during the stomach-flushing process. The liquid content of meals fed to Whitechinned Petrel chicks was therefore roughly estimated to be 54%. A substantial amount of oily liquid was noticed in some samples prior to draining in accord with this estimate. Because of inevitable inaccuracies in weighing in the field in an often windy environment, and because it is likely that some chicks lost mass due to defaecation in between weighings, this figure should be regarded as an approximation only.

All items recovered from stomach contents could be assigned to a prey category, but not all could be identified further. Fish comprised 56.3% of the drained stomach contents by mass, crustaceans 23.6% and squid 17.0%. The balance (2.8%) of the

material was plant fragments (4.2 g), one pteropod *Cleodora sulcata* (0.2 g), two salps (0.6 g) and a piece of bird or mammal flesh weighing 22.0 g. One sample contained 4 g of feathers. In numerical terms, crustaceans dominated due to their small size (98.2%), followed by fish (1.7%) and squid (0.3%). Crustaceans occurred in 25 (73.5%) of the samples, fish in 22 (64.7%) and squid in six (17.7%) (Table 1). The number of prey items per stomach contents varied from one to 504 and was not normally distributed.

A total of 1 947 prey items of 13 taxa was identified, not counting the unidentified bird/mammal flesh, plant and feather material (Table 1). Except for one small piece of pale yellow plastic, no artificial material was recovered.

The most abundant taxon recorded was the euphausiid *Euphausia vallentini* (89.6%, Table 1), with up to 502 being recovered from a single stomach. The most frequently occurring prey was the amphipod *Themisto gaudichaudii* (50.0%), followed by *Euphausia vallentini* (35.3%) and the fish *Protomyctophum normani* (17.6%) (Table 1).

Measurable prey items varied in size from an amphipod with a total length of 14 mm to an ommastrephid squid *Martialia hyadesi* with an estimated dorsal mantle length of 288 mm (Table 1). Most measurable prey were under 25 mm in length.

DISCUSSION

Berruti *et al.* (1985) estimated masses of meals fed to Whitechinned Petrel chicks at Marion Island by repeated weighings. They applied correction factors of 19 and 26 g for different aged chicks to allow for mass losses due to digestion and excretion between six-hourly weighings. Their mean meal mass was estimated to be 190 g, higher than that (68 g) for the present study, even if their correction factors are taken into account. Berruti *et al.* (1985) also found no increase in meal size with increasing age.

Mean drained mass of samples collected from Whitechinned Petrels, primarily chicks, at the Iles Crozet was 44.8 ± 59.8 g; range 0-232 g (Ridoux in press), somewhat heavier than in the Marion Island study. There is no published information on the liquid fraction of the diet.

Lipinski & Jackson (1989) obtained 121 cephalopod beaks from 18 regurgitations of Whitechinned Petrel adults and chicks at Marion Island during the austral summer of 1978. At least 31 were of teuthioid squid, but only 17 were identified further, belonging to the six taxa *Gonatus* sp., *Taonius* sp., *Histioteuthis* sp. *Chiroteuthis* sp., *Pholidoteuthis boschmai* and *Octopoteuthis* sp.. *Gonatus* sp. was the most abundant. Estimated mass of these squid ranged from 25 to 407 g (Lipinski & Jackson 1989). *Martialia hyadesi*, recorded in the present study, has only rarely been recorded from the southern Indian Ocean (Piatkowski *et al.* 1991).

The only other detailed published study of the diet of the Whitechinned Petrel at a breeding locality is that of Ridoux (in press) from the Iles Crozet, some 1 000 km east of Marion Island. Broad prey categories were similar (Table 2). Dietary data from other localities show that Whitechinned Petrels feed on fish, crustaceans, cephalopods and offal in varying proportions. Based on mass terms, cephalopods were more important at South Georgia (Croxall & Prince 1980, Prince & Morgan 1987, Table 2). In the southern Benguela region off South Africa, fishing trawler offal and discards constituted over half the diet of the Whitechinned Petrel (Jackson 1988, Table 2).

At the level of individual taxa, an important difference from Marion Island samples was the presence of Antarctic Krill *Euphausia superba* in the diet of Iles Crozet birds. This species does not occur north of the Antarctic Polar Front (APF) (Miller & Hampton 1989) which is *c.* 400 km south of Marion Island (Lutjeharms & Valentine 1984). A similar situation occurs with sooty albatrosses *Phoebetria* spp., in that Iles Crozet birds take more Antarctic Krill than do Marion birds (Cooper & Klages in

TABLE 1

IDENTIFIED PREY OF THE WHITECHINNED PETREL *PROCELLARIA AEQUINOCTIALIS* AT MARION ISLAND

Taxa	Relative abundance		Frequency of occurrence		Size (mm)*		
	No.	%	No.	%	Mean ± S.D.	Range	n
Crustacea							
Euphausiacea							
Euphausia vallentini (Euphausiidae)	1745	89.6	12	35.3	20.5 ± 1.5	(17-23)	24
Isopoda							
Anuropus sp. (Anuropidae)	1	0.1	1	2.9	100		
Amphipoda							
Themisto gaudichaudii (Hyperiidae)	151	7.8	17	50.0	24.4 ± 1.7	(22-26)	13
Eurythenes gryllus (Lysianassidae)	5	0.3	5	14.7	27.0	(14-48)	5
gammarid amphipod (Gammaridae)	3	0.2	2	5.9	20.2		1
Decapoda							
Pasiphaea scotiae (Pasiphaeidae)	2	0.1	2	5.9	27.0	(16-38)	2
Nematocarinus longirostris (Nematocarcinidae)	1	0.1	1	2.9	34		
Mollusca							
Pteropoda							
Cleodora sulcata	1	0.1	1	2.9	16		1
Cephalopoda							
Histioteuthis sp. (Histioteuthidae)	2	0.1	2	5.9	40.8	(22-60)	2
Martialia hyadesi (Ommastrephidae)	1	0.1	1	2.9	288.0		1
Unidentified fragments	(3)	(0.2)	3	8.8			
Tunicata							
Salpae	2	0.1	1	2.9			
Fish							
Protomyctophum normani (Myctophidae)	32	1.6	6	17.6	75.5 ± 4.0	(71-79)	3
Diretmus argenteus (Diretmidae)	1	0.1	1	2.9	104	1	
Unidentified fragments	(15)	(0.8)	15	44.1			
Carrion							
bird/mammal flesh			1	2.9	(22.0 g)		
Plant material			2	5.9	(0.2, 4.0 g)		
Feathers		1	2.9	(4 g)			

*Euphausiacea, Isopoda, Amphipoda and Pteropoda total length; Decapoda carapace length; Cephalopoda dorsal mantle length; fish total length

TABLE 2

GEOGRAPHICAL VARIATION IN PROPORTIONS OF BROAD PREY CLASSES IN THE DIET OF THE WHITECHINNED PETREL *PROCELLARIA AEQUINOCTIALIS*

Locality/parameter	Fish	Crustaceans	Cephalopods	Other	No.	Source
Marion Island, Prince Edward Islands						
Relative mass (%)	56.3	23.6	17.0	3.1	34	This study
Relative abundance (%)	2.4	96.9	0.3	0.4	34	This study
Frequency of occurrence (%)	64.7	73.5	17.7	14.7	34	This study
Ile de la Possession, Iles Crozet						
Frequency of occurrence (%)	14.3	19.0	90.5	*	21	Mougin (1970)
Iles Crozet						
Relative mass (%)	54.7	16.3	24.7	4.3	30	Ridoux (in press)
Relative abundance (%)	3.5	88.2	3.1	5.2	30	Ridoux (in press)
Frequency of occurrence (%)	66.7	70.4	51.9	37.0	30	Ridoux (in press)
South Georgia						
Relative mass (%)	24	29	47	0	?	Croxall & Prince (1980), Prince & Morgan (1987)
Auckland and Campbell Islands						
Frequency of occurrence (%)	33	33	100	?	3	Imber (1976)
Southern Benguela region, South Africa						
Frequency of occurrence (%)	31.7	19.4	9.7	39.4***	106	Jackson (1988)
Relative dry mass (%)	21.2	13.2	11.4	51.2***	106	Jackson (1988)
Relative abundance (%)	38.0	23.0	24.7	14.4***	106	Jackson (1988)

* vegetation and feathers recorded
** estimated from pie diagram
*** fish offal derived from trawlers

press, Ridoux in press). At South Georgia, south of the APF, Antarctic Krill forms 96% of the crustacean portion of the diet of the Whitechinned Petrel (Croxall & Prince 1980, Prince & Morgan 1987).

Ryan (1987) recorded plastic particles in 57% (n=201) of the stomach contents of Whitechinned Petrels. Most of his samples came from the southern Benguela region, suggesting a higher incidence of plastic pollution at this lower latitude in comparison to the Southern Ocean.

All the identified squid taken by Whitechinned Petrels at Marion Island are deemed to belong to taxa that float after death (Lipinski & Jackson 1989, M.R. Lipinski *in litt.*), suggesting that they may have been predominantly scavenged (see also Prince & Morgan 1987). Of 545 identified cephalopods taken by Whitechinned Petrels (Imber 1976, Lipinski & Jackson 1989, Ridoux in press, this study) 90% are deemed to be "floaters". All but three "sinker" squid were taken in the southern Benguela region. "Sinker" squid taken in the southern Benguela included species known to occur as by-catches in the trawler fishery such as *Loligo vulgaris* and *Octopus* sp. (Lipinski & Jackson 1989). Therefore their presence does not refute the hypothesis that much of the cephalopod diet of procellariiform seabirds is based on "floater" species that rise to the sea surface after death (Lipinski & Jackson 1989, Cooper & Klages in press, Cooper *et al.* in press).

Whitechinned Petrels feed primarily by surface seizing, but are able to undertake plunges to shallow depths (Harper *et al.* 1985, Harper 1987, Jackson 1988). They are known to associate with cetaceans and ships from which they scavenge (e.g. Enticott 1986, Ridoux 1987, Jackson 1988). The species has a relatively heavy bill (Croxall & Prince 1980) and is aggressive, in keeping with its ability to compete for and scavenge large prey items at feeding associations (Harper 1985, Jackson 1988). In contrast to this, the non-cephalopod portion of the (and at Iles Crozet, Ridoux in press) suggests that much of the diet is obtained by active predation because euphausiid and amphipod crustaceans and myctophid fish occur regularly at the sea surface. These three groups formed 98.2% by numbers of the species' diet at Marion Island.

ACKNOWLEDGEMENTS

Avian reseach at Marion Island forms part of the South African National Antarctic Programme, and receives financial and logistic support from the South African Department of Environment Affairs. We thank A.C. Cawthorn-Blazeby and all the Marion 47 Team Members for help with diet sampling under sometimes foul weather conditions. We thank N.J. Adams, M.R. Lipinski and V. Ridoux for their comments on draft texts.

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