

DIET OF ADÉLIE PENGUINS *PYGOSCELIS ADELIAE* AT SHIRLEY ISLAND, EAST ANTARCTICA, JANUARY 1992

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SUMMARY

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Stomach samples were collected from 41 Adélie Penguins *Pygoscelis adeliae* attending young chicks at Shirley Island, near Casey Station (66°20'S, 110°25'E) from 8–14 January 1992. The mean mass of stomach samples was 411±115 g, about 10% of mean adult body mass (4.2±0.4 kg). By mass, the diet comprised 48.7% fish (41.9% Antarctic Silverfish *Pleuragramma antarcticum*), 48.3% krill (39.7% Antarctic Krill *Euphausia superba* and 8.5% Crystal Krill *E. crystallorophias*), and 3% amphipods and squid combined.

INTRODUCTION

Adélie Penguins *Pygoscelis adeliae* are small Antarctic penguins (3–4.5 kg) that often breed in very large colonies. The Windmill Islands near Casey Station, East Antarctica, for example, were estimated to hold a total breeding population of approximately 93 000 breeding pairs of Adélie Penguins in 1989/90 (Woehler *et al.* 1991). Little is known about the feeding ecology and diet of Adélie Penguins in this area where commercial krill fishing occurred during the 1980s (Ichii 1990). Comprehensive diet studies conducted at various breeding localities of Adélie Penguins have shown that krill, and the Antarctic Krill *Euphausia superba* in particular, forms part of their diet (Lishman 1985, van Heezik 1988, Ridoux & Offredo 1989). Here we provide for the first time preliminary information on the diet composition of Adélie Penguins near Casey Station. This study formed part of an experiment that monitored the effects of stomach-flushing on adult Adélie Penguins with regard to the growth and survivorship of their chicks (Robertson *et al.* 1994).

METHODS

Study site

Shirley Island lies approximately 550 m off Casey Station (66°20'S, 110°25'E) in East Antarctica. During the austral summer, these islands are the only extensive snow-free areas for some 400 km of coastline east or west of the station (Murray & Luders 1990). Consequently, the islands provide a breeding ground for large numbers of Adélie Penguins and other seabirds. The population of Adélie Penguins on Shirley Island consists of approximately 7600 pairs in 52 colonies (Woehler *et al.* 1991).

Collection and analysis of stomach samples

Stomach samples were collected from 41 breeding adults at a time (8–14 January 1992) during the breeding season when the chicks had just started to group in crèches. The samples were collected using the water-flushing technique (Wilson 1984), stored in 70% ethanol and returned to Australia for analysis.

Whole samples were placed into trays and non-food components, such as pebbles, were removed. The samples were then rinsed with fresh water and strained through a 1-mm sieve. Excess water was expressed with a spoon until all free liquid was removed. Whole samples were subsequently weighed to the nearest gram and were mixed carefully to homogenise the food mass. Squid beaks, relatively large and rare, were removed from the samples. Other prey items were counted in sub-samples of 100 g and the total number of prey items in each sample was extrapolated from the results obtained from the sub-samples.

Fish were in various stages of digestion. Hard parts, such as otoliths and fish jaws, were collected from the 100-g sub-samples for identification and measurements. Measurements of lower jaw bones and uneroded otoliths formed the basis for estimates of standard length (SL) and fish mass (Williams & McEldowney 1990). Because of the harder constitution of otoliths compared to that of jaws the measuring accuracy for these items differed. Left and right lower jaws were considered to be from the same fish if the measurements were within 0.05 mm. Otoliths were assumed to be from the same fish if the width measurements were within 0.2 mm for the Antarctic Silverfish *Pleuragramma antarcticum* and within 0.1 mm for the Dusky Notothen *Trematomus newnesi*. In both cases, the greater measurement was used for calculations of SL and mass.

From the digested material, a further 25 g were taken to count euphausiid eyes to estimate krill numbers. Krill were too highly digested to take measurements from the eye to the tip of the telson to estimate their length. Whole specimens were not found. *E. superba* and *E. crystallorophias* could be distinguished by colour, size and differences in the first antennular segment (Fischer & Hureau 1985). The mean body masses for *E. superba* and *E. crystallorophias* were assumed to be 1 g and 0.25 g, respectively (G. Hosie pers. comm.).

Measurements of lower rostral length of squid beaks were used to calculate the mass for *Psychroteuthis glacialis* (Lu & Williams 1994). A second species, *Mesonychoteuthis*

hamiltoni, was identified but no measurements were possible because the beaks were too eroded. Amphipods in samples were often in good condition and could be identified to species level.

The digested portions of the diet samples were classified as containing either predominantly fish or predominantly krill and constituted the unidentified portion of the diet (see Table 1). Krill and fish remains were distinguishable because the fish portion was generally grey, indicating that it consisted most likely of *P. antarcticum*, whereas the krill portion was coloured pink.

All means are given ± 1 standard deviation.

RESULTS

Sample mass and body mass of penguins

The mean total sample mass of the 41 stomach samples was 411 ± 151 g (range 128–737 g). Flushed penguins weighed on average 4.2 ± 0.4 kg (range 3.6–4.8 kg). Thus, at the time of sampling, the mean mass of the stomach samples was about

10% of adult body mass. At the same time, the mean body mass of chicks ($n = 50$) averaged 3.5 ± 0.5 kg (range 2.5–4.3 kg).

Diet composition

In total, 17.5 kg of stomach contents were collected of which 12.8 kg (73%) consisted of highly digested material. Only 11 of the samples contained intact prey items (usually amphipods), whereas the other samples ($n = 30$) were either moderately or heavily digested.

Prey species included four major categories: a) fish (three species), b) krill (two species), c) amphipods (two suborders) and d) squid (two species, Table 1). About 48% by mass of the total diet consisted of krill. Two species of euphausiids were identified: *E. superba* and *E. crystallorophias* constituting by mass 39.7% and 8.5%, respectively, of the identified krill portion. The large number of krill eyes collected from the highly digested krill mass allowed inclusion of an estimate for krill numbers but because neither the relative contribution of the two euphausiids nor their length distributions were known, an estimate for the reconstituted mass of krill could not be derived. Hence, the digested krill mass was not included in the reconstructed diet.

TABLE 1

Diet composition of Adélie Penguins at Shirley Island in 1992

Prey taxa	Frequency of occurrence		Relative abundance		Reconstituted mass	
		%	No.	%	(g)	%
FISH	63		128	0.16	2623	48.7
Nototheniidae						
<i>Pleuragramma antarcticum</i>	41		112	0.14	2255	41.9
<i>Trematomus newnesi</i>	10		14	0.02	368	6.8
<i>T. bernacchii</i>	2		?		?	
<i>Trematomus</i> sp.	7		1	< 0.001	?	
unidentified nototheniids	5		1	< 0.001	?	
unidentified fish			?		(1888) ^a	
KRILL	98		77 574	98.26	2598	48.3
<i>Euphausia superba</i>	88		2138	0.03	2138	39.7
<i>E. crystallorophias</i>	76		1838	0.02	460	8.5
unidentified euphausiids	73		73 598 ^b	98.21		
AMPHIPODS	88		1245	1.58	146.3	2.7
Hyperiidia						
<i>Hyperia macrocephala</i>	39		119	0.15	33	0.6
<i>Cylopus lucasii</i>	59		451	0.57	56	1.0
<i>Themisto gaudichaudii</i>	5		7	< 0.01	0.3	< 0.01
<i>Vibilia</i> sp.	54		300	0.38	15	0.3
Gammaridae	59		368	0.47	42	0.8
SQUID	7		4	0.005	17	0.3
Cranchiidae						
<i>Mesonychoteuthis hamiltoni</i>	2		2	< 0.005	?	
Psychroteuthidae						
<i>Psychroteuthis glacialis</i>	5		2	< 0.005	17	0.3
TOTAL			78 951		5384.3	

^a actual wet mass.

^b number of krill estimated from number of eyes.

The unidentified portion of fish was not included in the diet reconstruction because it was impossible to determine the size and number of fish ingested. The grey colour of the fish component implied, however, that most of it consisted of *P. antarcticum*. Fish species that could be identified belonged to the family Nototheniidae among which *P. antarcticum* and *T. newnesi* were the most common species, contributing 41.9% and 6.8% by mass, respectively, to the identified fish portion of the penguins' diet.

Amphipods belonged chiefly to the sub-order Hyperidea, of which *Cylopus lucasii* occurred most frequently (451 of 1245 identified amphipods). Squid and amphipods together made up 3% by mass of the diet.

Estimated standard lengths and mass of *Pleuragramma antarcticum* and *Trematomus* spp.

Length estimates obtained from jaws and otoliths of *P. antarcticum* showed no overlap. Standard length estimates based on otolith measurements ranged from 140–180 mm whereas those obtained from jaw measurements ranged from 90–120 mm. Small otoliths erode faster than large ones and are therefore not often found in stomach samples, especially if foraging trips last more than one day (see van Heezik & Seddon 1989). Similarly, differences were expected in the rate of digestion of jaws. It is, however, not known why large jaws were absent from the samples and only small ones were found. We concluded that jaws and otoliths belonged to different individuals and presented all estimates in Figure 1. The SL estimates based on otolith width varied significantly from those based on jaw length ($t_{20} = 0.8$, $P < 0.5$). The mean SLs were 161.2 ± 14.9 mm (range 140.4–181.9 mm) and 110.2 ± 8.9 mm (range 94.4–115.5 mm) for otolith- and jaw-based estimates, respectively.

The mass of *P. antarcticum* calculated from standard lengths obtained from otoliths averaged 32.2 ± 9.4 g (range 20.2–46.2 g) whereas those based on jaw measurements averaged 9.5 ± 2.5 g (range 5.7–16.4 g). The standard lengths of *T. newnesi* obtained from otolith widths were 124.0 mm, 145.6 mm and 167.5 mm, with masses of 29.6 g, 49.0 g and 75.4 g, respectively.

DISCUSSION

The pelagic distributions of *E. superba* and *E. crystallophias* do not generally overlap. Antarctic Krill occurs in oceanic waters off the continental slope and in the southerly oceanic waters of the Southern Ocean, whereas Crystal Krill inhabits the relatively shallow waters of the continental shelf (Knox 1994). At Casey, the 1000-m isobath indicating the change from continental shelf to oceanic waters lies at its closest point c. 90 km off the coast. The dominance of *E. superba* in the diet of the Adélie Penguins suggests that most penguins fed along the shelf break during the early crèche stage when stomach samples were collected, although some penguins were assumed to have foraged over the continental shelf, as was indicated by the presence of *E. superba*. *Pleuragramma antarcticum* is a pelagic shoaling fish and reported to be found in similar areas to *E. crystallophias* (Williams 1985). *Trematomus newnesi* is an inshore benthic species and may be common in the intertidal zone (Fischer & Hureau 1985). Of the total number of samples containing fish remains, 38% had intact crania, suggesting that the penguins had recently ingested the fish and hence had foraged inshore, probably on their way back to the colony.

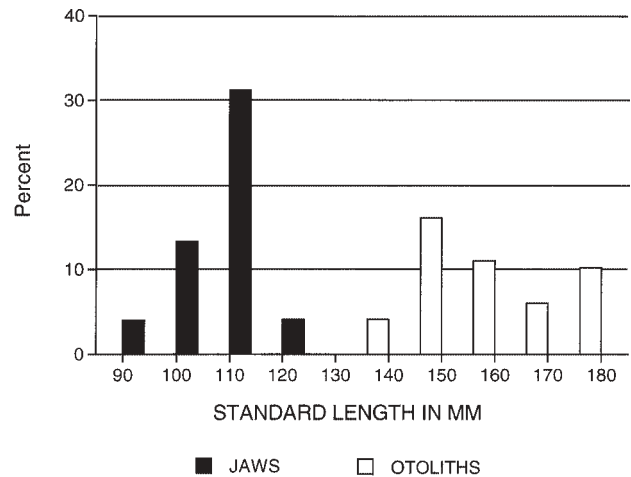


Fig. 1. Estimated standard length frequency distribution of Antarctic Silverfish *Pleuragramma antarcticum* in the diet of Adélie Penguins at Shirley Island, January 1992.

In 1995/96, stomach samples of Adélie Penguins were collected at Shirley Island and *P. antarcticum* and *E. crystallophias* contributed 30% and 51% by mass, respectively, whereas *E. superba* (0.3%) was virtually absent from the penguins' diet during the crèche stage (Wienecke *et al.* in press). In the same breeding season, Adélie Penguins at Dumont D'Urville (66°40'S, 140°00'E) consumed 38% by mass *E. superba*, 22% *E. crystallophias* and 37% *P. antarcticum* during the crèche period, respectively (Wienecke *et al.* in press). Thus, differences in the diet composition occurred at different locations during the same breeding season.

Studies at other locations in East Antarctica have also shown interseasonal and interannual variation in the diet composition of Adélie Penguins (e.g. Lishman 1985, Offredo *et al.* 1985, Green & Johnstone 1988, Puddicombe & Johnstone 1988, van Heezik 1988). In these studies, significant interannual variations were found in the occurrence of *E. superba*, highlighting the importance of multi-year studies when decisions are made about the management of krill fisheries in Antarctic waters. Currently *E. superba*, but not *E. crystallophias*, is commercially exploited but the contribution made by these two krill species to the penguins' diet is not constant and may vary in the same season between localities. Although Adélie Penguins are numerous and often breed in the vicinity of stations, making them a convenient study species, the reasons for the changes in their diets, as well as changes in prey distribution and availability, are still largely unknown.

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