

Cephalopods in the diets of Emperor and Adelie penguins in Adelie Land, Antarctica

C. Offredo¹, V. Ridoux¹ and M. R. Clarke²

¹ Laboratoire d'Océanographie Biologique, Université de Bretagne Occidentale; F-29283 Brest cédex, France

² The Marine Biological Association of the United Kingdom, The Laboratory; Citadel Hill, Plymouth PL1 2PB, England

Abstract

Cephalopod remains were collected from all of 12 dead Emperor penguin chicks [*Aptenodytes forsteri* (Gray)], from 76% of 29 living adult Emperor penguins, and from 18% of 105 living adult Adelie penguins [*Pygoscelis adeliae* (Hombron & Jacquinot)] from Adelie Land, Antarctica, in 1982. Of the seven species of squids represented by lower beaks, *Psychroteuthis glacialis* comprised 88% of the number in both Emperor chicks and Emperor adults and 100% in Adelie adults. From estimates of the weight of squids represented by lower beaks, *Gonatus antarcticus* and *Kondakovia longimana* contributed 18 and 14%, respectively, of the weight of squids in the diet of Emperor chicks and 27 and 21%, respectively, in the diet of Emperor adults. The data suggest that *Psychroteuthis glacialis* probably hatch in July–September and grow steadily for one year, and then spawn and die.

Introduction

Little is known of the food of the Emperor penguin *Aptenodytes forsteri* (Gray), except that it eats cephalopods (Stonehouse, 1967; Emison, 1968), or of the importance of cephalopods in the diet of the Adelie penguin *Pygoscelis adeliae* (Hombron & Jacquinot). One of the authors (C.O.) was able to collect stomach contents from Emperor penguins and from Adelie penguins in Adelie Land on the Antarctic Continent during a stay from December 1981 to 7 March, 1983. This study presents the first description of the diet of birds living in Adelie Land and the first detailed description of the cephalopod contribution to the diet of Emperor and Adelie penguins. The analysis is of particular interest, since it shows which cephalopods live at high latitudes in the Antarctic (66°S) and in a sector of the Antarctic (near 140°E) in which there has been little collection of cephalopods (Roper, 1969) and no study of

birds' diets. The study of cephalopods in the diet of sea birds in the Antarctic has relevance to studies of the biomass of cephalopods in the region (Clarke, 1983). Penguins have been estimated, on fragmentary evidence, to consume 82% of the total cephalopods eaten by all birds in the Antarctic (Mougin and Prévost, 1980; Prévost, 1981). Adelie penguins are by far the most numerous and widespread of all penguins, and their consumption of cephalopods must be very considerable.

Materials and methods

On 10th September 1982, the stomach contents of twelve Emperor penguin chicks, [*Aptenodytes forsteri* (Gray)], all 5 to 6 wk old and killed during a blizzard the previous night, were collected by dissection. Between 20 September and 15 November 1982, a total of 29 stomach contents of living adult Emperor penguins were collected by washing out the stomachs with 5 litres of fresh water, administered in four doses by funnel and tube, according to the technique of J. C. Stahl and H. Weimerkirch (personal communication).

During January and February 1982, the stomach contents of 105 living adult Adelie penguins [*Pygoscelis adeliae* (Hombron & Jacquinot)] were collected, and 19 of these were subsequently found to contain cephalopod remains. Most of the latter were collected after the end of January.

The cephalopod remains included, besides unidentifiable flesh, some mandibles or "beaks" and a few arm crowns. The lower beaks were identified by methods described elsewhere (Clarke, 1980, 1985). The lower rostral lengths (LRL) of the beaks were measured with vernier calipers to an accuracy of 0.05 mm. LRL distributions of the most numerous genera and the size at which the wings of the beaks become darkened were used in comparison with

previously described collections of beaks. Previously published (Clarke, 1985) LRL to wet weight of squid relationships were used to calculate the percentage weights of species in the diet, except in the case of *Psychroteuthis glacialis*, for which no curves have been published. Data from seven complete individuals collected from the present samples of *P. glacialis* revealed the relationship between total wet weight and LRL to be $\log \text{wt (g)} = 2.69 \log \text{LRL (mm)} - 0.298$, $r = 0.98$. Although this curve gives only a first approximation of the relationship, it is based upon the only material available of this very rarely caught squid and cannot, at present, be improved. From measurements of six squid from these samples together with two squid reported by Filippova (1972) and three squid referred to by Clarke (1985) the relationship between mantle (body) length (ML) and LRL was calculated to be $\log \text{ML (cm)} = 1.409 \log \text{LRL (mm)} + 0.236$, $r = 0.97$. The relationship between mantle length (ML) and the length of the third arm (A) is $\text{ML (cm)} = 2.195 \text{A (cm)} - 2.518$, $r = 0.989$; this is sometimes of use in determining the size of the squid when only crowns of arms survive digestion.

Results

Emperor penguins (*Aptenodytes forsteri*)

A total of 41 samples were examined, of which all but two contained cephalopod remains. There were some remains

of fish (Offredo, in preparation). Because the food composition of the chicks differed in some ways from that of the adults, we shall consider them separately.

Chicks

The 12 chicks were five or six weeks old, and perished on the night of 9 September 1982. All the stomachs contained small stones, eye lenses and cephalopod beaks. The lower beaks belong to six genera in six families of squids (Table 1). All the samples contained *Psychroteuthis* which at present only embraces the single species *P. glacialis* Thiele, 1920. This genus comprised 88.5% of all beaks and was estimated from the LRLs to contribute 68% of the cephalopod diet by weight.

One small beak was possibly the same species as several beaks collected from adult Emperor penguins; one of these beaks was from a crown which had tentacles with many rows of suckers arranged in a similar way to those of *Brachioteuthis*. However, it does not appear to be the same as *B. picta* Chun, 1910 or *B. riisei* (Steenstrup, 1882) or the other Antarctic genera with multiple rows of suckers on the tentacle, and when more material becomes available it may prove to be a species new to science.

Gonatus antarcticus Lönnerberg, 1898 occurred in 42% of the stomachs and, although it only represented 8.3% of the number of lower beaks, because individuals were larger than most of the other species, it contributed 17.7% of the weight represented by beaks. Similarly, the *Kondakovia*

Table 1. Cephalopods in samples from stomachs of chicks and adults of the Emperor penguin *Aptenodytes forsteri* and of adults of the Adelie penguin *Pygoscelis adeliae*. Values are the number and percentage of samples containing remains of each species/genus of cephalopod, the number and percentage of squid lower beaks of each genus, and the estimated wet weights of each genus represented by lower beaks

Cephalopod species	Sample		Beaks		Estimated wt		
	No.	%	No.	%	Mean (g)	Total (g)	Total (%)
Emperor chicks (n = 12)							
<i>Psychroteuthis glacialis</i>	12	100	170	88.5	68	11 455	68.0
<i>Brachioteuthis?</i>	1	8	1	0.5	5	15	0.1
<i>Gonatus antarcticus</i>	5	42	16	8.3	186	2 980	17.7
<i>Kondakovia longimana</i>	3	25	3	1.6	766	2 297	13.6
<i>Pholidoteuthis?</i>	1	8	1	0.5	71	71	0.4
<i>Galiteuthis glacialis</i>	1	8	1	0.5	22	22	0.1
Totals	12		192	99.9		16 840	99.9
Emperor adults (n = 29)							
<i>Psychroteuthis glacialis</i>	22	76	128	88.3	10	1 316	50.6
<i>Brachioteuthis?</i>	6	21	9	6.2	3	26	1.0
<i>Gonatus antarcticus</i>	3	10	4	2.1	174	694	26.7
<i>Kondakovia longimana</i>	1	3	1	0.7	535	535	20.6
<i>Histioteuthis B</i>	2	7	2	1.4	16	31	1.2
Unidentified	1	3	2	1.4	—	—	—
Totals	27		146	100.1		2 602	100.1
Adelie adults (n = 105)							
<i>Psychroteuthis glacialis</i>	19	18	54	100	13.9	749	100.00

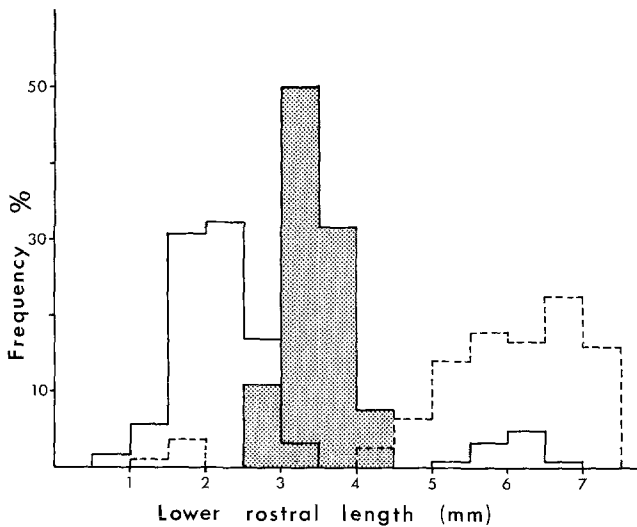


Fig. 1. *Psychroteuthis glacialis*. Percentage frequency distributions of the lower rostral length of squid beaks collected from Emperor penguin chicks, *Aptenodytes forsteri* (dashed line), in September and adults in September to November (continuous line), and from adult Adelle penguins, *Pygoscelis adeliae*, in January and February (stippled)

longimana Filippova, 1972 eaten were large and contributed 13.6% of the weight but only 1.6% of the number of beaks. A small beak closely resembling a small *Pholidoteuthis* of more temperate seas may represent another as yet undescribed species.

The largest squids taken were estimated to have a total wet weight of 766 g and the smallest only 1.5 g.

The LRL distribution for *Psychroteuthis glacialis* from the chicks shows a small peak at 1.0 to 2.0 mm and a second much larger peak at 4.0 to 7.5 mm (Fig. 1).

Adults

Of 29 living adult samples, 27 contained cephalopod remains (Table 1); 76% of these contained *Psychroteuthis glacialis*, which comprised 88.3% of the beaks, and estimates show that the species contributed 50.6% of the wet weight of cephalopods represented by lower beaks. *Gonatus antarcticus* only comprised 2.1% of the beaks present but, because they were large, they contributed 26.7% to the weight, and the squid which provided the single *Kondakovia longimana* beak contributed 20.6% to the weight of cephalopods represented by beaks.

The estimated mean weight of the *Psychroteuthis glacialis* was much less (10 g) in the adult penguins than in the chicks (68 g), reflecting the very different LRL distributions of the beaks (Fig. 1). In the adults, most of the beaks were between LRLs of 0.5 and 3.5 mm, with a much smaller number at 5.0 to 7.0 mm.

Four squid species were common to both chicks and adults but, in addition, the chicks contained *Pholidoteuthis?* and *Galiteuthis glacialis* and the adults contained *Histioteuthis* B beaks, which are probably *H. eltaninae* Voss, 1969.

A tentacle club of a squid identified as belonging to *Psychroteuthis glacialis* Thiele, 1921 was found on the ground in the rookery.

Adelle penguins (*Pygoscelis adeliae*)

Of 105 living Adelle penguins sampled, only 19 contained the remains of cephalopods. By weight, 79% of the food was euphausiid, 18% was fish and 3% was cephalopod (Offredo, in preparation). Two samples were taken every day from 2 January 1982 to 25 February 1982 except in bad weather conditions. No cephalopods were present in the stomachs until 25 January, and, after that 19 of 54 samples (35.2%) contained cephalopods. All the cephalopods present were *Psychroteuthis glacialis*; the estimated mean weight of squids represented by beaks was 13.9 g and the maximum weight was 25 g.

The LRL distribution falls between the distribution of beaks from the Emperor penguin stomachs (Fig. 1).

Cephalopod growth

Psychroteuthis glacialis lower beaks with undarkened wings had LRLs of 1.9 to 4.2 mm and beaks with darkened wings had LRLs of 3.2 to 7.3 mm. One beak was in the intermediate stage, an isolated dark spot on the wing, at a LRL of 3.9 mm. Thus, darkening of the wing takes place at 3.2 to 4.2 mm. This stage takes place prior to sexual maturity in many species, and beaks which have undarkened wings are immature in nearly all species. From Fig. 1 it will be seen that most of the squids in the adult Emperor penguins were immature, while most of the squids in the chicks were mature or nearly so. This surprising difference may be explained by the time of year in which the collections were made.

If *Psychroteuthis glacialis* is similar to many other squids in living for one year from hatching to spawning followed immediately by death, the LRL distributions seen in Fig. 1 would be expected. During the spring months of October–November, the immature growing squids which were preyed on by adult Emperors and had hatched between the previous July and September would grow almost linearly to become the population consumed in February by the Adelle penguins. These, if they continued linear growth, would become mature for the following September, when they would form the bulk of the food for the Emperor chicks at the time they spawned and died. The last to die would show in the diet of adult Emperors in late September and October to give rise to the small secondary peak of large squid in Fig. 1. In fact, all beaks in the large group were collected before October. On the other hand, in September some of the fastest growing or earliest to hatch of the recently hatched squids would be large enough to be included in the chicks' diet and would give rise to the small secondary peak of LRL in Fig. 1.

Of the other species, most or all of the *Gonatus antarcticus* and the single *Brachioteuthis?* had darkened wings, while *Kondakovia longimana*, *Galiteuthis glacialis* and the *Pholidoteuthis?* had undarkened wings and were therefore immature.

Discussion

Compared with krill and fish, cephalopods are of minor importance in the diet of Emperor (*Aptenodytes forsteri*) and Adelie (*Pygoscelis adeliae*) penguins near Adelie Land during the breeding season. However, in view of the very large number of Adelie penguins in the Antarctic, the cephalopods in their diet could be of importance in estimates of cephalopod biomass. In 207 samples collected from the Ross Sea from 5 December to 5 February, Emison (1968) only found two squid beaks (*Nototodarus sloani*), and did not assess the weight contribution of the squid from which they came. At King George Island, South Shetlands, no squid at all was recorded in 48 samples from 1 November 1977 to 21 February 1978 (Volkman *et al.*, 1980).

Clearly, *Psychroteuthis glacialis* is taken by Emperor and Adelie penguins in far greater numbers than the other squid in this region, but the larger squid *Gonatus antarcticus* and *Kondakovia longimana* may together also be important by weight (31 to 47%) in the diet of Emperor penguins.

The samples provide evidence that, near Adelie Land, *Psychroteuthis glacialis* probably hatches from July to September after its eggs have presumably lain dormant since the previous September. Growth is approximately linear between October and February and probably continues at a constant rate to the following September when the squids spawn and die.

The regular occurrence of *Psychroteuthis glacialis* in Adelie penguins from Adelie Land only after the 25 January is interesting. In February, these squids were present in 35% of the samples and contributed to 6% of the weight of the diet of *Pygoscelis adeliae*. These squids always occurred in samples containing numerous euphausiids. Adelie penguins did not show any major discontinuity in their diet (mainly euphausiids – Offredo, in preparation) during the collection period. Even at the end of the breeding season, their feeding behaviour changed little, so that the sudden appearance of squids in their diet may have resulted from an important change in the life of the squids themselves.

One explanation for the sudden appearance of *Psychroteuthis glacialis* in the Adelie diet could be that, in January, in the stronger daylight of midsummer, squids probably migrate to greater depths out of reach of the penguins; in February, their appearance in the diet of Adelies could be due to their subsequent movement to shallower depths as the autumn approaches.

On the other hand we might expect *Psychroteuthis glacialis* to feed on krill. The youngest stages would be

unable to feed on adult krill until they grew to a sufficient body size, which they perhaps reach in February. They might then “migrate” into adult krill swarms, where they are then caught by Adelie penguins.

In February, squid predation by Adelie penguins may be locally important; data for the Indian sector of the Antarctic coast is necessary to assess the overall effects on cephalopod biomass.

Although Emperor penguins individually eat much more squid than do Adelie penguins, their wider foraging range and their smaller number (3 000 pairs at Pointe Géologie in 1982) probably make their predation on the squid biomass in this area relatively minor. The deeper diving range of the Emperor penguin (down to 265 m: Kooyman, 1975), may explain the greater diversity of cephalopods in its diet.

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