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Predation on cephalopods by *Pygoscelis papua* and *Arctocephalus gazella* at South Orkney Islands

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ABSTRACT: The cephalopod diet of the gentoo penguin, *Pygoscelis papua* and the Antarctic fur seal, *Arctocephalus gazella* was comparatively analyzed at Laurie Island, South Orkney Islands. A total of 125 stomach samples were collected by the water off-loading method from gentoo penguins during the autumns of 1993, 1995 and 1996, and 39 fur seal scats were collected from mid March to April 1988. Cephalopods preyed upon by gentoo penguins were represented by 1974 beaks (1628 lower, 346 upper) which occurred in 50.4% of the samples. Lower beaks identified belonged exclusively to the squid *Psychroteuthis glacialis*. The mean lower rostral length (LRL) of these beaks was 1.1 mm (range 0.4–1.8 mm). From the Antarctic fur seal scats 103 beaks (41 lower, 62 upper) were removed from 60.6% of scats which contained prey remains. The cephalopod species identified were *Slosarczykovia circumantarctica* and *P. glacialis* which constituted 78.8% and 21.1% in terms of numbers, respectively. The mean lower rostral length for *S. circumantarctica* was 2.7 mm (range 2.0–3.5 mm), while that of *P. glacialis* was 1.6 mm (range 1.0–2.5 mm). The foraging behaviour of the two top predators was analyzed and discussed according to the composition and size of their cephalopod prey.

Key words: Antarctica, South Orkney Islands, gentoo penguin, fur seal, cephalopods.

Introduction

Cephalopods play a key role in the trophic structure of the Southern Ocean ecosystem (Clarke 1996). Their annual consumption of Antarctic krill, *Euphausia superba*, was assessed to be of the order of 100 million tonnes (Fischer and Hureau 1985). In turn, they form an essential prey of Southern Ocean apex marine predators such as seals, seabirds and cetaceans (for recent reviews see: Clarke 1996;

Croxall and Prince 1996; Klages 1996). Clarke (1983) estimated the total annual consumption of cephalopods by these predators to be 34 million tonnes, of which 13.5 millions are taken by seabirds, of which penguins share 82%.

For the gentoo penguin, *Pygoscelis papua* Forster, 1781, an annual consumption of 581 tonnes of cephalopods was estimated in the Southern Ocean (Woehler 1995), and for seals Laws (1984) estimated a total annual cephalopod consumption of nearly 9 million tonnes. The total annual biomass of squid caught by the Antarctic fur seal, *Arctocephalus gazella* Peters, 1875 at South Georgia was calculated to be approximately 180000 tonnes (Doidge and Croxall 1985).

Several studies on the diet of these two predators have been carried out at different localities of their distributional range (Bost *et al.* 1994; Croxall and Prince 1987; Green and Wong 1992; Jabłoński 1985; Volkman *et al.* 1980; Casaux *et al.* 1998; Daneri and Coria 1992; Green *et al*. 1989, 1991; Reid 1995; Reid and Arnould 1996). However, detailed information on the cephalopod portion of their diet is scarce.

The aim of the present study is to analyze and compare the cephalopod prey of *P. papua* and *A. gazella* in terms of taxonomical composition and prey size during the austral autumn at Laurie Island, South Orkneys.

Materials and methods

Our study was carried out at Mossman Peninsula, Laurie Island, South Orkney Islands (60˚46´S, 44˚42´ W), Antarctica. For gentoo penguin we collected 125 samples during the austral autumns (March–May) of 1993 (n = 37), 1995 (n = 46) and 1996 (n = 42). These were obtained from adult specimens by the water off-loading method (Wilson 1984; Gales 1987). Samples were drained, weighed and frozen. In the laboratory they were washed through sieves of 0.10 to 0.25 mm mesh.

On the other hand 39 fur seal scats in fresh condition were collected from mid-March to April 1988 in the same locality. Samples were preserved in 70% ethanol and returned to the laboratory for further analysis. These were broken in water and washed through a sieve of 0.5 mm mesh size. Six faecal samples were considered empty as they passed through the sieve leaving no prey remains and were therefore excluded from the analysis. Cephalopod remains were mainly represented by beaks and a few eye lenses.

Lower beaks extracted from both predator species which presented extensive erosion were not considered for the study (n = 25 for *P. papua* and n = 8 for *A. gazella*).

Lower beaks were identified following Clarke (1986) and by comparison with reference collections kept at the Leibniz-Institut für Meereswissenschaften, Kiel, Germany. Their lower rostral lengths (LRL) were measured with digital callipers

to an accuracy of 0.1 mm. Small beaks (LRL < 2 mm) were measured with a micrometer installed in a stereomicroscope. Allometric equations from the literature were used to relate LRL to dorsal cephalopod mantle length (ML in mm) and animal wet weight (in g). In the case of *Psychroteuthis glacialis* from Gröger *et al.* (2000) and in the case of *Slosarczykovia circumantarctica* equations from Clarke (1986) for a closely related species *Brachioteuthis* sp. were used, *S. circumantarctica* has been recently described by Lipiński (2001) and no equations for this species were available.

Results

Pygoscelis papua

A total of 1974 squid beaks (1628 lower and 346 upper) were removed from the stomach contents. All lower beaks that could be identified (n = 1603) belonged to *Psychroteuthis glacialis* Thiele, 1921. In 1993, 218 lower beaks were found in 32.4% of the stomach samples, and 980 lower beaks occurred in 80.4% of the samples obtained in 1995. In 1996, 405 lower beaks were found in 28.6% of the stomach contents.

The mean LRL for the whole study period was 1.1±0.2 mm (range 0.4–1.8 mm) (Table 1). The allometric equations indicated a mean ML of 36.4±5.3 mm and a mean mass of 1.5±0.4 g. There were significant differences between years in the mean size of *P. glacialis* preyed on by gentoo penguins (Nested ANOVA, $F = 10.8251$, $p < 0.0001$).

For the same time periods the frequency of occurrence of fish and krill were respectively 60 and 89% in 1993, 98 and 85% in 1995 and 93 and 50% in 1996.

Table 1

Cephalopod prey taxa of gentoo penguins and Antarctic fur seals from Laurie Island expressed in terms of numbers, beaks sizes (LRL), mean mantle length (ML) and mean weight.

Predator species	Prey species	Year	Lower beaks	LRL (mm)		Range	ML (mm)	Mass (g)
			n	Mean	(SD)			
Pygoscelis papua	*Psychroteuthis glacialis*	1993	218	1.1	(0.14)	0.4–1.5	38.0	1.5
		1995	980	0.98	(0.15)	0.6–1.6	33.7	1.4
		1996	405	1.09	(0.15)	0.7–1.8	37.6	1.7
Arctocephalus gazella	*Slosarczykovia circumantarctica*	1988	26	2.7	(0.49)	2.0–3.5	70.8	7.0
	Psychroteuthis glacialis	1988	7	1.6	(0.69)	1.0–2.5	53.6	5.2

Arctocephalus gazella

A total of 103 beaks (41 lower, 62 upper) occurred in 60.6% of the 39 scats. Of the 33 lower beaks identified, 26 belonged to *Slosarczykovia circumantarctica* Lipiński, 2001 and 7 to *P. glacialis*.

The mean LRL of *S. circumantarctica* beaks was 2.7±0.5 mm (range 2.0–3.5 mm), representing specimens of 56.9–86.5 mm ML and 4.6–10.1 g wet mass, while that of *P. glacialis* beaks was 1.6±0.7 mm (range 1.0–2.5 mm) equivalent to a ML of 34.5–81.2 mm and a wet mass of 1.4–11.8 g (Table 1).

The LRL frequency distributions of *P. glacialis* beaks obtained from gentoo penguins and Antarctic fur seals are shown in Fig. 1.

For the same study period fish and krill occurred in 81.8 and 100% of faecal samples, respectively.

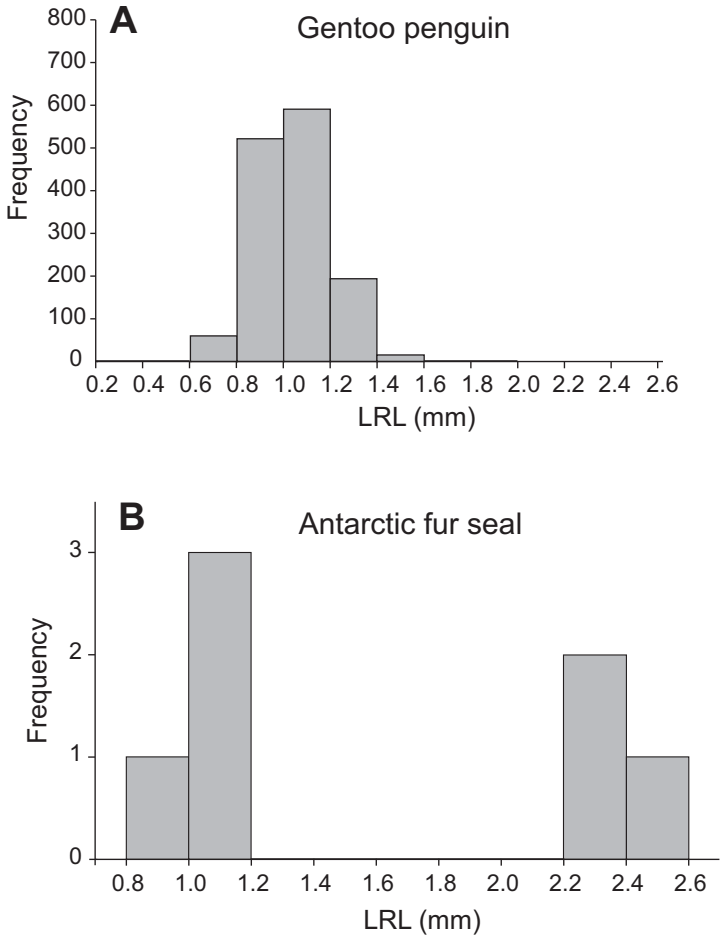

Fig. 1. Lower rostral length frequency distribution of *P. glacialis* eaten by gentoo penguin (**A**) and Antarctic fur seal (**B**).

Discussion and conclusion

The squid, *Psychroteuthis glacialis*, was a relatively frequent prey of gentoo penguins for the total period of our study, being particularly abundant in the second sample period (1995). This suggests a common presence of this prey in their diet as reported by Coria *et al.* (2000). *P. glacialis* has also been reported to be the major diet of Adélie penguins in Marguerite Bay (Antarctic Peninsula) (McDaniel and Emslie 2002). It was remarkable that the increase in the frequency of occurrence and abundance of this squid species observed in 1995 coincided with a decrease in the occurrence and abundance of krill (the authors personal observation). This would suggest a differential prey availability in the foraging areas of gentoo penguins between the years studied. In contrast, several studies reported the absence of cephalopods in the diet of gentoo penguins (Kato *et al.* 1991; Williams 1991; Jabłoński 1985) or that they occur only in small amounts as prey (Croxall and Prince 1980; Adams and Klages 1989; Hindell 1989; Ridoux 1994). However, the fact that the only cephalopod species found in the diet of gentoo penguins in our samples was *P. glacialis* is not surprising, since this species is widely distributed and endemic in the Southern Ocean (Fischer and Hureau 1985; Gröger *et al.* 2000).

The cephalopod prey of the Antarctic fur seal was represented by two squid taxa, *S. circumantarctica* and *P. glacialis*, the former being more abundant (Table 1).

Bonner (1968) suggested that cephalopods were not an important item of the diet of Antarctic fur seals in the summer months, but that it was possible that they were taken in greater amounts in other seasons when krill became scarce. In support of this, several dietary studies of fur seals carried out during the summer seasons at different localities of the Scotia Arc [e.g. South Georgia, Isla 25 de Mayo (= King George Island) and Nelson Island], have shown that the occurrence of cephalopods in their diet is relatively low (range 5–23%) (Reid and Arnould 1996; Casaux *et al.* 1998; Daneri *et al.* 1999). According to Bonner's (1968) explanation, the occurrence of squid in the autumn diet of fur seals in our study seemed to be relatively high (60.6%). However, krill was also present in all faecal samples (100%).

In regard to the foraging behaviour *P. papua* is considered a "diurnal and inshore feeder" (Trivelpiece *et al.* 1986; Robinson and Hindell 1996). Croxall and Lishman (1987) stated that their dives rarely exceeded 20 meters in depth. Croxall et. al. (1988), however, reported that when gentoo penguins foraged on krill, aproximately 75% of their dives did not surpass 54 m depth, whereas when fish constituted the target prey, nearly 60% of their dives ranged between 54 and 136 m depth and were generally performed in inshore areas (Adams and Wilson 1987). But feeding activity during the night is not frequent (Wilson *et al.* 1993; Robinson and Hindell 1996).

On the other hand, in relation to the foraging behavior of *A. gazella*, the distance travelled offshore may range from nearly 15 km to more than 200 km, and this depends on the seasonal prey availability. Mean dive depths generally do not

exceed 40 m and shallow dives are usually frequent at night in relation to the vertical migration of krill to the surface. However, maximum dive depths of up to 130 m have been reported in concordance with the vertical descent of krill to deeper layers of the water column during the day (Croxall et. al. 1985; Bengston et. al. 1991; Boyd *et al.* 1994; Goebel *et al.* 2000).

The estimated size of the squid *P. glacialis* preyed on by both, gentoo penguins and fur seals, indicated that the specimens belonged to early stages of the species. According to Lu and Williams (1994) there is evidence of a strong ontogenetic descent of this squid species with small individuals living in shallow depths and larger ones living closer to the sea floor. Therefore, the larger specimens of *P. glacialis* would be out of the dive depth range of these two predator species. Additionally, there was a partial overlap in the size range of *P. glacialis* specimens caught by penguins and fur seals, with the larger sizes being predated more efficiciently by the seals as indicated by Fig. 1. This might be explained by a differential buccal aperture diameter between the two predator species and the more offshore foraging behaviour of the seals, which enables them to prey upon larger squid.

From the present study we suggest that cephalopods might constitute a common and frequent prey item during the autumn season in the diet of both, *P. papua* and *A. gazella* at least at the South Orkney Islands area.

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