Polar Biol (1999) 21: 59–63

SHORT NOTE

G.A. Daneri · U. Piatkowski · N.R. Coria · A.R. Carlini

Predation on cephalopods by Antarctic fur seals, *Arctocephalus gazella*, at two localities of the Scotia Arc, Antarctica

Accepted: 17 July 1998

Abstract The cephalopod remains from 206 Antarctic fur seal (*Arctocephalus gazella*) scats collected at Mossman Peninsula, South Orkney Islands ($n = 105$) and at Stranger Point, South Shetland Islands ($n = 101$) contained 148 beaks (57 lower and 91 upper). The lower beaks were sorted and measured. Identification of 33 of the lower beaks that were collected at Mossman Peninsula revealed two squid species, *Brachioteuthis ?picta* ($n = 26$) and *Psychroteuthis glacialis* ($n = 7$), with lower rostral lengths (LRL) of 2.0–3.5 mm, and 1.0–2.5 mm, respectively. Identification of 15 of the lower beaks collected at Stranger Point revealed the same squid species, with the LRL of *B. ?picta* ranging from 3.0–3.4 mm ($n = 9$), and that of *P. glacialis* from 2.0 to 3.5 mm ($n = 6$). Estimated squid sizes and wet masses indicate that Antarctic fur seals feed on the small subadult squid which inhabit the surface layers. We have compared the squid diet estimated for the seals with that reported for its congeners in lower latitudes and other Antarctic seals, and conclude that cephalopods do not form an important food resource for Antarctic fur seals.

Introduction

The Antarctic fur seal, *Arctocephalus gazella*, is the only eared seal (Family Otariidae) that lives on islands south of the Antarctic Convergence. This species was almost exterminated in the past century due to intense commercial sealing. However, after the collapse of sealing, a substantial recovery of the population has been recorded since the 1930s (Laws 1973; Bonner 1981). At present the population is still increasing in most parts of its distributional range, with the major breeding stock of an approximate all-age population size of 1.6×10^6 animals concentrated at South Georgia (Boyd 1993; SCAR 1994).

The feeding ecology of Antarctic fur seals has been widely studied at South Georgia (Bonner 1968; North et al. 1983; Doidge and Croxall 1985; Reid 1995; North 1996; Reid and Arnould 1996) and Heard Island (Green et al. 1989, 1991). A few studies have been conducted on the diet of fur seals from the South Orkney Islands (Daneri and Coria 1992, 1993) and the South Shetland Islands (Daneri 1996). In addition, the diet of Antarctic fur seals has been recently investigated at Macquarie Island (Goldsworthy et al. 1997) and Kerguelen Island (Cherel et al. 1997). Little information is available on the cephalopod portion of their diet, although it accounts for 33% when the annual biomass consumption is considered, which equals the portions of krill (34%) and fish diet (33%; Laws 1984).

In the Southern Ocean cephalopods constitute an important food resource for apex predators such as birds, seals and whales, with a total annual cephalopod consumption by seals alone of nearly 9×10^6 tonnes (Laws 1984). Doidge and Croxall (1985) calculated that the total annual biomass of prey species taken by Antarctic fur seals (including both sexes and all age classes) at South Georgia in 1983 was nearly 1.5×10^6 tonnes, of which 12% were squid. In the present study we have examined the cephalopod diet of non-breeding male fur seals, mostly juveniles and a few sub-adults. The study is based on scat analysis at two different localities of the Scotia Arc: Mossman Peninsula, Laurie Island (South Orkney Islands) and Stranger Point, King George Island (South Shetland Islands). The importance of cephalopod prey is evaluated and the results are compared with diet studies of other seals from the Southern Ocean.

G.A. Daneri (✉)
Museo Argentino de Ciencias Naturales "Bernardino Rivadavia" (MACNBR),
División Mastozoología. Av. Angel Gallardo 470,
(1405) Buenos Aires, Argentina
e-mail: gdaneri@mastoz.edu.ar

U. Piatkowski
Institut für Meereskunde, Universität Kiel,
Düsternbrooker Weg 20,
D-24105 Kiel, Germany

N.R. Coria · A.R. Carlini
Instituto Antártico Argentino, Depto de Biología,
Cerrito 1248,
(1010) Buenos Aires, Argentina

Materials and methods

A total of 206 fur seal scats were examined. At Mossman Peninsula, Laurie Island, located at 60°45′S, 44°43′W near Signy Island (South Orkney Islands), 105 scats were collected from mid-January to April 1988. At Stranger Point, located at 62°14′S, 58°40′W on King George Island (South Shetland Islands), 101 scats were collected during three different periods; February 1992 ($n = 34$), October/November 1993 ($n = 36$) and February 1994 ($n = 31$). During sampling only fresh scats were sought and collected. The samples were preserved in 70% ethanol and returned to the laboratory for analysis. They were broken in water and washed through a sieve of 0.5-mm mesh size. Cephalopod remains were represented by beaks and a few eye lenses. A total of 120 squid beaks (41 lower and 79 upper) were removed from the scats collected at Mossman Peninsula, and 28 beaks (16 lower and 12 upper) were removed from the scats collected at Stranger Point. Only lower beaks were identified, and lower rostral lengths (LRL) were measured with vernier calipers to an accuracy of 0.1 mm. Nine lower beaks (eight from Mossman Peninsula samples and one from Stranger Point samples) had to be excluded from the studies due to extensive erosion. Beaks were identified following Clarke (1986) and by comparison with a reference collection kept at the Institut für Meereskunde, Kiel, Germany. Allometric equations were taken from the literature (Clarke 1986; Lu and Williams 1994) to relate LRL to dorsal cephalopod mantle length (ML in mm) and wet mass (in g).

Results

Mossman Peninsula, South Orkney Islands

A total of 120 squid beaks (41 lower and 79 upper beaks) were removed from 34.3% ($n = 34$) of 99 faecal samples which contained prey remains. Of these beaks, 85.8% ($n = 103$) occurred in scats collected in the autumn period (mid-March to April). The percentage frequency of occurrence of squid increased from the mid-January/mid-March period (21.2%) to the mid-March/April period (60.6%).

Identification of the 33 lower beaks that could be measured, revealed that only two squid species, *Brachioteuthis ?picta* ($n = 26$) and *Psychroteuthis glacialis* ($n = 7$), comprised the cephalopod diet. Morphological examination of the *Brachioteuthis* beak revealed that it was identical to the illustrations given by Rodhouse et al. (1992) for *B. ?picta* beaks which the authors had analysed from the southern elephant seal (*Mirounga leonina*) diet at South Georgia. The beaks in our study had no well-defined lateral ridge and were black and strong, which separates them from the *Brachioteuthis ?riseii* type that occurs in the Indian sector of the Southern Ocean (Cherel et al. 1996). Therefore, we identified them tentatively as being the beaks of *B. ?picta*, because the genus *Brachioteuthis* is in need of revision. The LRL of *B. ?picta* ranged from 2.0 to 3.5 mm, representing specimens of 56.9–86.5 mm ML and 4.6–10.1 g wet mass, while those of *P. glacialis* ranged from 1.0 to 2.5 mm, equivalent to a ML of 78.3–107.6 mm and a wet mass of 6.1–26.6 g (Table 1).

Table 1 Relative importance of squid collected from scat samples of *Arctocephalus gazella*, based on the number of lower beaks and estimated size and wet mass of squid. (*ML* Mantle length, *LRL* lower rostral length)

Prey species	Area	Lower beaks		LRL		Range	Estimated			
		Number	(%)	Mean (mm)	(SD)		Mean ML (mm)	Mean mass (g)	Total mass (g)	Total mass (%)
Brachioteuthis ?picta	Mossman Peninsula	26	78.8	2.7	(0.49)	2.0–3.5	70.8	7.0	188.1	64.9
	Stranger Point	9	60.0	3.2	(0.13)	3.0–3.4	80.9	8.9	82.1	29.6
Psychroteuthis glacialis	Mossman Peninsula	7	21.1	1.6	(0.69)	1.0–2.5	90.7	13.4	101.5	35.1
	Stranger Point	6	40.0	2.7	(0.64)	2.0–3.5	112.6	31.1	194.9	70.4

Stranger Point, South Shetland Islands

A total of 28 squid beaks (16 lower and 12 upper) were removed from fur seal scats during the three collection periods. Of these, 19 beaks (9 lower and 10 upper) were removed from 7 (23.3%) of the 30 scats containing the prey remains collected in 1992, 7 beaks (5 lower and 2 upper) from 5 (15.2%) of the 33 scats collected in the spring of 1993, and 2 lower beaks in 6.6% of the 30 scats collected in 1994.

Identification of the 15 lower beaks that could be measured revealed that, as at Mossman Peninsula, *B. ?picta* ($n = 9$) and *P. glacialis* ($n = 6$) were the only squids taken by the fur seals. *P. glacialis* was identified exclusively from the faeces collected in the summer seasons of 1992 and 1994. The LRL of *B. ?picta* ranged from 3.0 to 3.4 mm, which represented squid of 76.9–85.5 mm ML and 8.2–9.9 g wet mass, while the LRL of *P. glacialis* ranged from 2.0 to 3.5 mm, representing specimens of 99.8–128.3 mm ML and 20.1–47 g wet mass (Table 1).

Discussion

There are many shortcomings in the determination of cephalopods in the seal diet. When studying seal diets by means of scat analysis, it is assumed that there is no selective ejection of hard parts orally (i.e. beaks). However, Green et al. (1989), based on literature data and field observations, stated that there was no evidence of this type of regurgitation in *A. gazella*. Furthermore, cephalopod beaks can persist in seal stomachs for a long time after feeding. This results either in an overestimation of these hard parts in the stomachs or in an underrepresentation in the seal faeces (Bigg and Fawcett 1985; Reid 1995).

The analysis of more than 300 stomachs collected from adult female fur seals at South Georgia from 1971 to 1983 showed a low abundance of squid remains, and stomach lavages practised on breeding females in 1993 indicated the exclusive presence of krill (Doidge and Croxall 1985; Reid and Arnould 1996). The examination of a complete stomach of a recently dead young male fur seal found near Stranger Point, King George Island in the spring of 1993 revealed that it was completely empty, and stomach lavages applied to 12 young male individuals at the same location in the austral summers of 1995/1996 and 1996/1997 showed that most of them ($n = 9$) were also empty. The remaining stomachs ($n = 3$) all contained krill remains, and two of them also a few fish otoliths, but there was no evidence of squid (Daneri and Carlini, unpublished data).

Bonner (1968) suggested that cephalopods do not form an important food item of Antarctic fur seals during summer, but they are more common during other seasons when krill becomes scarce. Our data indicate that at Mossman Peninsula the occurrence of squid increases in the fur seal diet at least during the autumn period. This agrees with the observations of Green et al. (1991), who noticed an increase of the frequency of occurrence of squid in the diet of fur seals at Heard Island from summer (7.4% in a total of 144 collected scats) to the late autumn/early winter period (49.3% in a total of 373 collected scats). At King George Island squid remains occurred in an average of 15% of fur seal scats, and at South Georgia the presence of squid never exceeded 5% in the faeces collected during different seasons and years (Reid 1995; North 1996; Reid and Arnould 1996).

B. ?picta and *P. glacialis* also occurred in the diet of Heard Island fur seals in the autumn/winter period of 1990 (Green et al. 1991). However, at that locality the dominant cephalopod prey was *Mastigoteuthis?* which represented 97.4% of all lower beaks ($n = 307$). At South Georgia the only squid prey species in common with the present study was *B. ?picta*. It was represented by three beaks, one removed from a scat collected in the austral winter season and the remaining two from summer collections. Other species identified were *Alluroteuthis antarcticus*, *Martialia hyadesi*, *Moroteuthis knipovitchi* and the octopod *Pareledone turqueti* (Reid 1995; North 1996; Reid and Arnould 1996).

The glacial squid, *P. glacialis*, is the most abundant squid found in the diet of other Antarctic seals such as southern elephant seals (*Mirounga leonina*), Weddell seals (*Leptonychotes weddellii*), and Ross seals (*Ommatophoca rossii*), whereas *B. ?picta* occurs only in relatively small numbers, or is absent (e.g. Plötz et al. 1991; Rodhouse et al. 1992; Green and Burton 1993; Skinner and Klages 1994; Slip 1995; Casaux et al. 1997). A comparison of the LRL of *B. ?picta* and *P. glacialis* measured in this study with those presented for other Antarctic seals demonstrates that other seals prey on similarly sized specimens of *B. ?picta*, but that fur seals take smaller (younger) specimens of *P. glacialis* than do the others (Table 2).

The wider variety of squid species taken by Weddell seals and southern elephant seals might be due to their greater vertical foraging range compared with that of fur seals, as shown in studies on the diving behaviour of these three seal species (e.g. Kooyman 1981; Boyd and Arnbom 1991; McConnell et al. 1992). These Antarctic seals commonly dive to depths exceeding 300 m, whereas Antarctic fur seals forage mostly at night during shallow dives which rarely exceed the upper 50 m of the water column (Laws 1984; Croxall et al. 1985). The high abundance of *B. ?picta* in the diet of Antarctic fur seals is not surprising since this squid is often found at or near the surface (Rodhouse et al. 1992). Specimens of *P. glacialis*, preyed upon by deep-diving Weddell and southern elephant seals are larger than those taken by fur seals, which is in accordance with the bathymetric distribution of the squid. Filipova and Pakhomov (1994) found that at Prydz Bay, young *P. glacialis* were concentrated in the upper 100 m of the water column, and in hauls sampling depths of less than 45 m they repre-

Table 2 *Brachioteuthis ?picta* and *Psychroteuthis glacialis*. Number of lower beaks (*n*) and size ranges of LRL found in scat samples of *Arctocephalus gazella* at Mossman Peninsula (South Orkney Islands) and Stranger Point (South Shetland Islands) compared with beak sizes reported for the prey of other Antarctic seals

Prey species	Antarctic fur seal		Weddell seal[a]		Southern elephant seal[b]		Ross seal[c]	
	LRL (mm)		LRL (mm)		LRL (mm)		LRL (mm)	
	n	Range	*n*	Range	*n*	Range	*n*	Range
Brachioteuthis ?picta	35	2.0–3.5	5	3.3–3.5	192	1.7–4.3	–	–
Psychroteuthis glacialis	13	1.0–3.5	105	2.7–7.1	361	1.7–4.9	97	2.6–7.0

[a] Data from Deception Island, South Shetland Islands (Clarke and MacLeod 1982)
[b] Data from South Georgia (Rodhouse et al. 1992)
[c] Data from King Haakon II Sea (Skinner and Klages 1994)

sented the only squid species present. Evidence of a strong ontogenetic descent of this species, with small individuals living at shallow depths and sub-adults/adults living closer to the seafloor, was suggested by Lu and Williams (1994). Therefore, larger specimens of *P. glacialis* are hardly ever in the depth range of shallow-diving Antarctic fur seals.

The relatively low abundance of cephalopods in the diet of Antarctic fur seals is in contrast to its congeners in lower latitudes like the sub-Antarctic fur seal (*Arctocephalus tropicalis*), the South African fur seal (*Arctocephalus pusillus pusillus*), and the Australian fur seal (*Arctocephalus pusillus doriferus*), which all take considerable amounts of cephalopod prey (Bester and Laycock 1985; Lipinski and David 1990; Gales et al. 1993, Klages and Bester 1998). However, at Kerguelen Islands cephalopods are of minor importance in the diet of Antarctic fur seals (Cherel et al. 1997), although they form the bulk of the diet of southern elephant seals at that location (Guinet et al. 1996).

We conclude that, at least during the period studied, cephalopods did not constitute an important food item in the diet of Antarctic fur seals in our study areas.

Acknowledgements We wish to thank the members of Orcadas Station for logistic help and Lic. L. Cáceres for field assistance at Laurie Island. We are also grateful to Ricardo Montiel and Aldo Corbálan for field assistance at King George Island. The advice of three anonymous reviewers is gratefully acknowledged.

References

Bester MN, Laycock PA (1985) Cephalopod prey of the sub-Antarctic fur seal, *Arctocephalus tropicalis*, at Gough Island. In: Siegfried WR, Condy PR, Laws RM (eds) Antarctic nutrient cycles and food webs. Springer, Berlin Heidelberg New York, pp 551–554

Bigg MA, Fawcett I (1985) Two biases in diet determination of northern fur seals (*Callorhinus ursinus*). In: Beddington JR, Beverton RJH, Lavigne DM (eds) Marine mammals and fisheries. George, Allen and Unwin, London, pp 284–291

Bonner WN (1968) The fur seal of South Georgia. Sci Rep Br Antarct Surv 56:1–81

Bonner WN (1981) Southern fur seals – *Arctocephalus*. In: Ridgway SH, Harrison RJ (eds) Handbook of marine mammals, vol 1. The walrus, sea lions, fur seals, and sea otters. Academic Press, London, pp 161–208

Boyd IL (1993) Pup production and distribution of breeding Antarctic fur seals (*Arctocephalus gazella*) at South Georgia. Antarct Sci 5:17–24

Boyd IL, Arnbom TR (1991) Diving behaviour in relation to water temperature in the southern elephant seal: foraging implications. Polar Biol 11:259–266

Casaux R, Baroni A, Carlini A (1997) The diet of the Weddell seal *Leptonychotes weddellii* at Harmony Point, South Shetland Islands. Polar Biol 18:371–375

Cherel Y, Ridoux V, Rodhouse PG (1996) Fish and squid in the diet of king penguin chicks, *Aptenodytes patagonicus*, during winter at sub-antarctic Crozet Islands. Mar Biol 126:559–570

Cherel Y, Guinet C, Tremblay Y (1997) Fish prey of Antarctic fur seals *Arctocephalus gazella* at Ile de Croy, Kerguelen. Polar Biol 17:87–90

Clarke MR (1986) A handbook for the identification of cephalopod beaks. Clarendon Press, Oxford

Clarke MR, MacLeod N (1982) Cephalopod remains in the stomachs of eight Weddell seals. Br Antarct Surv Bull 57:33–40

Croxall JP, Everson I, Kooyman GL, Ricketts C, Davis RW (1985) Fur seal diving behaviour in relation to vertical distribution of krill. J Anim Ecol 54:1–8

Daneri GA (1996) Fish diet of the Antarctic fur seal, *Arctocephalus gazella*, in summer, at Stranger Point, King George Island, South Shetland Islands. Polar Biol 16:353–355

Daneri GA, Coria NR (1992) The diet of Antarctic fur seals, *Arctocephalus gazella*, during the summer-autumn period at Mossman Peninsula, Laurie Island (South Orkneys). Polar Biol 11:565–566

Daneri GA, Coria NR (1993) Fish prey of Antarctic fur seals, *Arctocephalus gazella*, during the summer-autumn period at Laurie Island, South Orkney Islands. Polar Biol 13:287–289

Doidge DW, Croxall JP (1985) Diet and energy budget of the Antarctic fur seal, *Arctocephalus gazella*, at South Georgia. In: Siegfried WR, Condy PR, Laws RM (eds) Antarctic nutrient cycles and food webs, Springer, Berlin Heidelberg New York, pp 543–550

Filippova JA, Pakhomov EA (1994) Young squid in the plankton of Prydz Bay, Antarctica. Antarct Sci 6:171–173

Gales R, Pemberton D, Lu CC, Clarke MR (1993) Cephalopod diet of the Australian fur seal: variation due to location, season and sample type. Aust J Mar Freshwater Res 44:657–671

Goldsworthy SD, Hindell MA, Crowley HM (1997) Diet and diving behavior of sympathric fur seals (*Arctocephalus gazella* and *A. tropicalis*) at Macquarie Island. In: Hindell MA, Kemper C (eds) Marine mammal research in the southern hemisphere. Surrey Beatty, Chipping Norton, pp 151–163

Green K, Burton HR (1993) Comparison of the stomach contents of southern elephant seals, *Mirounga leonina*, at Macquarie and Heard Islands. Mar Mammal Sci 9:10–22

Green K, Burton HR, Williams R (1989) The diet of Antarctic fur seals *Arctocephalus gazella* (Peters) during the breeding season at Heard Island. Antarct Sci 1:317–324

Green K, Williams R, Burton HR (1991) The diet of Antarctic fur seals during the late autumn and early winter around Heard Island. Antarct Sci 3:359–361

Guinet C, Cherel Y, Ridoux V, Jouventin P (1996) Consumption of marine resources by seabirds and seals in Crozet and Kerguelen waters: changes in relation to consumer biomass 1962–85. Antarct Sci 8:23–30

Klages NTW, Bester MN (1998) Fish prey of fur seals *Arctocephalus* spp. at subantarctic Marion Island. Mar Biol 131:559–566

Kooyman GL (1981) Weddell seal *Leptonychotes weddellii*. In: Ridgway SH, Harrison RJ (eds) Handbook of marine mammals, vol 2. Seals. Academic Press, London, pp 275–296

Laws RM (1973) Population increase of fur seals at South Georgia. Polar Rec 16:856–858

Laws RM (1984) Seals. In: Laws RM (ed) Antarctic ecology, vol. 2. Academic Press, London, pp 621–715

Lipinski MR, David JHM (1990) Cephalopods in the diet of the South African fur seal (*Arctocephalus pusillus pusillus*). J Zool Lond 221:359–374

Lu CC, Williams R (1994) Contribution to the biology of squid in the Prydz Bay region, Antarctica. Antarct Sci 6:223–229

McConnell BJ, Chambers C, Fedak MA (1992) Foraging ecology of southern elephant seals in relation to the bathymetry and productivity of the Southern Ocean. Antarct Sci 4:393–398

North AW (1996) Fish in the diet of Antarctic fur seals (*Arctocephalus gazella*) at South Georgia during winter and spring. Antarct Sci 8:155–160

North AW, Croxall JP, Doidge DW (1983) Fish prey of the Antarctic fur seal, *Arctocephalus gazella*, at South Georgia. Br Antarct Surv Bull 61:27–37

Plötz J, Ekau W, Reijnders PJH (1991) Diet of Weddell seals *Leptonychotes weddellii* at Vestkapp, eastern Weddell Sea (Antarctica), in relation to local food supply. Mar Mammal Sci 7:136–144

Reid K (1995) The diet of Antarctic fur seals *Arctocephalus gazella* during winter at South Georgia. Antarct Sci 7:241–249

Reid K, Arnould JPY (1996) The diet of Antarctic fur seals *Arctocephalus gazella* during the breeding season at South Georgia. Polar Biol 16:105–114

Rodhouse PG, Arnbom TR, Fedak MA, Yeatman J, Murray AWA (1992) Cephalopod prey of the southern elephant seal, *Mirounga leonina* L. Can J Zool 70:1007–1015

SCAR (1994) Report of the 23rd meeting of the SCAR group of specialists on seals. Padova, Italy

Skinner JD, Klages NTW (1994) On some aspects of the biology of the Ross seal *Ommatophoca rossii* from King Haakon VII Sea, Antarctica. Polar Biol 14:467–472

Slip DJ (1995) The diet of southern elephant seals (*Mirounga leonina*) from Heard Island. Can J Zool 73:1519–1528