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Cephalopod diet of the southern elephant seal, *Mirounga leonina*, at King George Island, South Shetland Islands

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Abstract: In the summer of 1995/96, 25 southern elephant seals, *Mirounga leonina*, were stomach lavaged at Stranger Point, King George Island, South Shetland Islands. Cephalopod remains were present in 72% of the individuals sampled (n = 18). Seven species of squid and three of octopus were identified. The squid *Psychroteuthis glacialis* was the most important prey in terms of numbers (77%), biomass (80.8%) and frequency of occurrence (94.4%). Next in importance in terms of mass was the squid *Alluroteuthis antarcticus* (7.8%) in the diet of females and the octopodid *Pareledone ?charcoti* in the diet of males (13.2%). Females preyed on a wider variety of squid taxa than males (7 vs 3) but octopodids occurred only in stomach contents from males. The predominance of *P. glacialis* in the prey of the South Shetland Islands elephant seals can be explained by the southerly location of the foraging areas of this population compared to South Georgia, Heard and Macquarie islands, where the diet of southern elephant seals has previously been analysed. *Psychroteuthis glacialis* is the predominant squid in waters close to the Antarctic continent.

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Introduction

The southern elephant seal, *Mirounga leonina* (Linnaeus, 1758), is an important top predator of the Southern Ocean marine ecosystem. An assessment of the impact of elephant seals on prey resources in the Scotia Sea indicated that they account for nearly 75% of the 3.7×10^6 tonnes of cephalopods and 45% of the 2×10^6 tonnes of fish caught by seabirds and seals (Croxall *et al.* 1985). Detailed information on the diet of subantarctic populations comes from South Georgia (Rodhouse *et al.* 1992), Signy Island (Clarke & MacLeod 1982), Heard Island and Macquarie Island (Green & Burton 1993, Slip 1995). However, little is known about the feeding habits of the more southerly elephant seals from King George Island, South Shetland Islands, where there is a small breeding colony of 500–600 females. This study examined the cephalopod prey of seals at this locality in the moulting season of 1995/96.

Materials and methods

Twenty five recently hauled out southern elephant seals (11 males and 14 females) were immobilised by injection of ketamine hydrochloride at Stranger Point (62°14'S, 58°40'W), King George Island and subjected to stomach lavage (Antonelis *et al.* 1987). Stomach contents were washed through a 1 mm mesh and stored in 70% ethanol. Following Rodhouse *et al.* (1992) the seals were classified in two groups according to their standard length (SL) (1.9–2.15 m, > 2.15 m) which correspond approximately to 2 and 3(+) years respectively. Almost all cephalopod lower beaks (n = 300) were identified by consulting appropriate literature (Clarke 1986, Lipinski & Woyciechoski 1981) and by comparison with voucher collections housed at the British Antarctic Survey, and the Instituto Antártico Argentino. Since knowledge of the octopus fauna of the Antarctic Peninsula is still incomplete, the identification of octopodids in this study should be considered with caution. Lower rostral length (LRL) and lower hood length (LHL) of beaks were measured with vernier callipers to the nearest 0.01 mm for squid and octopus specimens respectively. Allometric equations used to estimate whole wet body mass and dorsal mantle length were taken from Clarke (1986), Rodhouse *et al.* (1990) and Rodhouse *et al.* (1992). The relative importance of each species in terms of biomass, numbers and occurrence was estimated and comparisons were made between sexes using correspondence analysis. To detect changes in the sizes of *P. glacialis* preyed on by seals within the same sex and between sexes a nested ANOVA test was employed.

Results

A total of 588 cephalopod beaks (303 lower and 285 upper) were extracted from 18 (8 males and 10 females) of the 25 individuals sampled. Three seals (two males and one female) were considered to be approximately 2 years old whilst the

Table I. Cephalopod taxa identified from beaks in the stomachs of southern elephant seals at Stranger Point, King George Island expressed as percentage frequency of occurrence (%F), numbers (*n*), percentage of total number (%*n*), mass (M, g) and percentage of total mass (%M).

	Males					Females					Sexes combined				
	%F	*n*	%*n*	M,g	%M	%F	*n*	%*n*	M,g	%M	%F	*n*	%*n*	M,g	%M
Psychroteuthis glacialis Thiele, 1921	87.5	17	50.0	4098	76.2	100.0	214	80.5	38964	81.4	94.4	231	77.0	43062	80.8
Gonatus antarcticus Lönnberg, 1898	12.5	2	5.9	209	3.9	30.0	10	3.8	1643	3.4	22.2	12	4.0	1851	3.5
Moroteuthis knipovitchi Filippova, 1972						10.0	3	1.1	1874	3.9	5.6	3	1.0	1874	3.5
Kondakovia longimana Filippova, 1971						20.0	7	2.6	1422	3.0	11.1	7	2.3	1422	2.7
Alluroteuthis antarcticus Odhner, 1923						50.0	13	4.9	3740	7.8	27.8	13	4.3	3740	7.0
Chiroteuthis veranyi Férussac, 1835						10.0	1	0.4	115	0.2	5.6	1	0.3	115	0.2
Brachioteuthis ?picta	25.0	8	23.5	64	1.2	50.0	18	6.8	130	0.3	38.9	26	8.7	193	0.4
Pareledone polymorpha (Robson, 1930)	12.5	1	2.9	70	1.3						5.6	1	0.3	70	0.1
Pareledone charcoti (Joubin, 1905)	37.5	5	14.7	711	13.2						16.7	5	1.7	711	1.3
Pareledone turqueti (Joubin, 1905)	12.5	1	2.9	227	4.2						5.6	1	0.3	227	0.4
		34	100	5378	100		266	100	47887	100		300	100	53265	100

rest corresponded to 3 years old or more. In addition to the beaks, nematode worms were found in all stomach samples, amphipods in two, and decapod crustaceans, tunicates and bivalves each in one. Lower beaks found in any stomach ranged from 1–107 (mean = 16.8). The average number of cephalopod species in any stomach was 2.3 (range 1–6).

Nine cephalopod taxa were identified from 300 of the 303 lower beaks. The squid *Psycroteuthis glacialis* was by far the dominant prey in terms of numbers (77%), biomass (80.8%) and frequency of occurrence (94.4%). Of the remaining taxa, *Brachioteuthis ?picta*, *Gonatus antarcticus*, *Alluroteuthis antarcticus* and the octopodid *Pareledone ?charcoti* occurred in more than 15% of seal stomachs. However, these four species combined accounted for only 12.2% of the total estimated biomass consumed. Female elephant seals preyed upon a greater diversity of squid species than did males (7 vs 3). However, 37.5% of males sampled ($n = 3$) had fed on octopodids which in turn did not occur in the diet of females (Table I). The beak size (LRL or LHL), mean estimated dorsal mantle length (ML) and mean estimated mass of the species taken by seals are shown in Table II.

A Correspondence Analysis showed that sex is not significantly associated with the principal sources of variability in the composition of stomach contents. The total number of prey items differed significantly between male and female elephant seals ($H = 4.93$, df: 1, $P = 0.025$, Kruskal Wallis test). A nested ANOVA design (individual elephant seals nested within sex), showed a significant component of variance attributed to differences between individuals ($F = 8.378$, df: 15,214; $P < 0.00001$) accounting for 41% of total variability in the size of the *P. glacialis* beaks but no differences were found between males and females ($F = 0.123$, df: 1,15; $P = 0.73$).

Discussion

The Antarctic glacial squid, *P. glacialis* is predominant in the diet of elephant seals at King George Island (Table I). This squid has also been reported as a common, but less important prey of southern elephant seals at Signy Island, South Orkney Islands (Clarke & MacLeod 1982). A more recent dietary study based on 51 elephant seals at South Georgia (Rodhouse *et al.* 1992) in the moulting seasons of 1986 and 1988/89, showed that *P. glacialis* was also the most frequent (frequency of occurrence 80%) and important prey species in terms of numbers (33.7% of 1070 lower beaks), but its contribution in

Table II. Beak size (LRL/LHL, mm) estimated mantle length (ML, mm), and estimated mass (M, g) of cephalopods preyed on by male and female southern elephant seals at Stranger Point, King George Island.

	Males							Females						
	LRL/LHL		ML		M		*n*	LRL		ML		M		*n*
	Mean	sd	Mean	sd	Mean	sd		Mean	sd	Mean	sd	Mean	sd	
Psychroteuthis glacialis	4.6	1.4	186.9	90.2	241.0	338.3	17	4.8	0.8	198.7	52.3	182.1	133.2	214
Gonatus antarcticus	4.9	0.4	166.7	18.2	104.2	29.7	2	5.4	1.1	189.0	46.9	164.3	103.6	10
Moroteuthis knipovitchi								5.6	0.2	221.3	21.1	388.9	48.5	3
Kondakovia longimana								7.4	1.9	261.9	82.3	203.2	212.0	7
Alluroteuthis antarcticus								4.3	1.1	131.3	32.7	287.7	171.6	13
Chiroteuthis veranyi								5.3		141.0		114.9		1
Brachioteuthis ?picta	2.9	0.5	75.6	9.1	8.0	1.7	8	2.7	0.3	71.6	5.1	7.2	0.9	18
Pareledone ?polymorpha	3.0		45.1		69.8		1							
Pareledone ?charcoti	5.7	0.8	57.1	6.7	142.2	33.3	5							
Pareledone ?turqueti	7.5		72.5		227.2		1							

n = the number of lower beaks found of each taxon.

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mass was lower in comparison with our study (15.4% vs 80.8%). However, the importance of this species in the diet of South Georgia elephant seals varied between seasons. In 1986 *P. glacialis* was not abundant, occurring in 61% of stomachs and representing only 3.5% in mass of cephalopods consumed, whereas *Moroteuthis knipovitchi* was the main prey, contributing 40.3% of the biomass and occurring in 72% of seals sampled. In 1988/89 a decline in the importance of the latter species was observed coupled with an increase of *P. glacialis*, which by that year was the most frequent (frequency occurrence 93%) and abundant prey, contributing 26.6% in mass. At Heard Island, the cephalopod prey of southern elephant seals was numerically dominated by the squid *Moroteuthis ingens* (Smith, 1881) which, together with *M. knipovitchi*, *A. antarcticus* and *Kondakovia longimana*, totalled 90% of the estimated mass of cephalopods consumed (Green & Burton 1993). The same study revealed that at Macquarie Island the most abundant cephalopod prey was the subantarctic squid, *Histioteuthis eltaninae* which, combined with *M. knipovitchi*, *A. antarcticus* and *K. longimana*, accounted for almost 80% of the squid mass estimated. At both islands, *P. glacialis* was then of minor importance in the seals' diet. Nevertheless, a more recent study at Heard Island (Slip 1995) showed that *P. glacialis* was the most abundant species comprising 21% of the 1492 lower beaks found. However, in mass (5.3%) and frequency of occurrence (31%) this species was largely surpassed by *K. longimana* (40.1%) and *G. antarcticus* (51%) respectively.

Rodhouse *et al.* (1992) and Slip (1995) have both suggested that changes in the relative importance of *P. glacialis* in the diet of seals are linked to foraging in higher latitude areas. This is supported by observations of elephant seal females travelling south from South Georgia to sites off the Antarctic continental shelf (Boyd & Arnbom 1991, McConnell *et al.* 1992).

Therefore, the dominance of *P. glacialis* in the diet of seals from King George Island suggests that they forage on the local continental shelf where this squid is abundant. Furthermore, the shorter postbreeding aquatic phase of female elephant seals at King George Island would also suggest that foraging may be less distant there than at South Georgia (Carlini *et al.* 1997).

The presence of octopods, only found in the diet of males, might be explained by the observation made by Hindell *et al.* (1991) on diving patterns of southern elephant seals from Macquarie Island. They stated that there were five characteristic types of dive in elephant seals of which two were the most common. Type 1 dives were interpreted as pelagic foraging dives and were mainly undertaken by females. Type 2 dives were considered as benthic foraging dives and were common in males but rarely seen in females. Similarly, Le Boeuf *et al.* (1993, 1996) found sex differences in the foraging and diving patterns of the northern elephant seals, *Mirounga angustirostris* (Gill, 1866), with female foraging exclusively pelagic and males also showing benthic dives. If the diving patterns for the South Shetland Islands population were similar, it would be more likely that males would forage on the bottom and prey on benthic octopods than females.

In terms of prey diversity in relation to seal size, our data differ from those of Rodhouse *et al.* (1992) who found that larger elephant seals, especially males, preyed on a wider variety than smaller ones. However, only three of our seals were <2.16 m (two males and one female), and thus no general conclusions can be drawn.

Fish have been reported as both absent and present in the diets of other elephant seal populations. In the present study, the absence of fish remains might be due to low fish prey availability in the 1995/96 season. This is supported by diet samples from 1996/97 and 1997/98 which showed that at least 10% of stomachs samples contained fish remains, including otoliths which were preliminary identified as myctophid fish (Daneri & Carlini unpublished data).

The present study constitutes a first step in the understanding of the feeding habits of one of the southernmost populations of southern elephant seals. Monitoring their diet over an extended period will be necessary to gain adequate knowledge of their feeding ecology. This, coupled with studies of diving behaviour and movements at sea by means of time depth recorders and satellite telemetry, will contribute to a better understanding of various aspects of their aquatic phase.

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References

ANTONELIS, G.A., LOWRY, M.S., DEMASTER, D.P. & FISCUS, C.H. 1987. Assessing northern elephant seal feeding habits by stomach lavage. *Marine Mammal Science*, **3**, 308–322.

BOYD, I.L. & ARNBOM, T. 1991. Diving behaviour in relation to water temperature in the southern elephant seal: foraging implications. *Polar Biology*, **11**, 259–266.

CARLINI, A.R., DANERI, G.A., MARQUEZ, M.E.I., SOAVE, G.E. & POLJAK, S. 1997. Mass Transfer from mothers to pups and mass recovery by mothers during the post-breeding foraging period in southern elephant seals (*Mirounga leonina*) at King George Island. *Polar Biology*, **18**, 305–310.

CLARKE, M.R. & MACLEOD, N. 1982. Cephalopods in the diet of elephant seals at Signy Island, South Orkney Islands. *British Antarctic Survey Bulletin*, No. 57, 27–31.

CLARKE, M.R. 1986. *A handbook for the identification of cephalopod beaks*. Oxford: Clarendon Press, 273 pp.

CROXALL, J.P., PRINCE, P.A. & RICKETTS, C. 1985. Relationships between prey life-cycles and the extent, nature and timing of seal and seabird predation in the Scotia Sea. *In* SIEGFRIED, W.R., CONDY, P.R. & LAWS, R.M., *eds. Antarctic nutrient cycles and food webs.* Berlin: Springer Verlag, 516–533.

GREEN, K. & BURTON, H.R. 1993. Comparison of the stomach contents of the southern elephant seal, *Mirounga leonina*, at Macquarie and Heard islands. *Marine Mammal Science*, **9**, 10–22.

HINDELL, M.A., SLIP, D.J. & BURTON, H.R. 1991. The diving behaviour of adult male and female southern elephant seals, *Mirounga leonina* (Pinnipedia: Phocidae). *Australian Journal of Zoology*, **39**, 595–619.

LE BOEUF, B.J., CROCKER, D.E., BLACKWELL, S.B., MORRIS, P.A. & THORSON, P.H. 1993. Sex differences in diving and foraging behaviour of northern elephant seals. *In* BOYD, I., *ed. Marine mammals: advances in behavioural and population biology Symposium Zoological Society of London*, **66**, 149–178.

LE BOEUF, B.J., MORRIS, P.A., BLACKWELL, S.B., CROCKER, D.E. & COSTA, D.P. 1996. Diving behavior of juvenile northern elephant seals. *Canadian Journal of Zoology*, **74**, 1632–1644.

LIPINSKI, M. & WOYCIECHOWSKI, M. 1981. Cephalopods in the food of Weddell seals from Admiralty Bay (King George Island, South Shetland Islands). *Polish Polar Research* **2**, 163–167.

MCCONNELL, B.J., CHAMBERS, J.C. & FEDAK, M.A. 1992. Foraging ecology of southern elephant seals in relation to the bathimetry and productivity of the Southern Ocean. *Antarctic Science*, **4**, 393–398.

RODHOUSE, P.G., PRINCE, P.A., CLARKE, M.R. & MURRAY, A.W.A. 1990. Cephalopod prey of the grey-headed albatross, *Diomedea chrysostoma*. *Marine Biology*, **104**, 353–362.

RODHOUSE, P.G., ARNBOM, T.R., FEDAK, M.A., YEATMAN, J. & MURRAY, A.W.A. 1992. Cephalopod prey of the southern elephant seal, *Mirounga leonina* L. *Canadian Journal of Zoology*, **70**, 1007–1015.

SLIP, D.J. 1995. The diet of southern elephant seals (*Mirounga leonina*) from Heard Island. *Canadian Journal of Zoology*, **73**, 1519–1528.

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