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Seasonal and annual changes in Antarctic fur seal (*Arctocephalus gazella*) diet in the area of Admiralty Bay, King George Island, South Shetland Islands

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Abstract: This study describes the seasonal and annual changes in the diet of non-breeding male Antarctic fur seals (*Arctocephalus gazella*) through the analysis of faeces collected on shore during four summer seasons (1993/94–1996/97) in the area of Admiralty Bay (King George Island, South Shetlands). Krill was the most frequent prey, found in 88.3% of the 473 samples. Fish was present in 84.7% of the samples, cephalopods and penguins in 12.5% each. Of the 3832 isolated otoliths, 3737 were identified as belonging to 17 fish species. The most numerous species were: *Gymnoscopelus nicholsi, Electrona antarctica, Chionodraco rastrospinosus, Pleuragramma antarcticum*, and *Notolepis coatsi*. In January, almost exclusively, were taken pelagic Myctophidae constituting up to 90% of the total consumed fish biomass. However, in February and March, the number of bentho-pelagic Channichthyidae and Nototheniidae as well as pelagic Paralepididae increased significantly, up to 45% of the biomass. In April the biomass of Myctophidae increased again. The frequency of squid and penguin occurrence was similar and low, but considering the greater individual body mass of penguins, their role as a food item may be much greater. In March and April, penguins could be as important prey item as fish. The amount of krill in the diet of Antarctic fur seals declined with a concomitant decrease in the mature krill availability. This appears to have been compensated by an increased frequency of the fur seal to eat fish and penguins.

Key words: Antarctica, Admiralty Bay, Antarctic fur seal, diet.

Introduction

Research on the diet of Antarctic fur seals at South Georgia found krill (*Euphausia superba*) to be the main food source for lactating females (Croxall and Pilcher 1984; Doidge and Croxall 1985). However, studies conducted during four summer breeding seasons (Reid and Arnould 1996) and also in winter (Reid 1995;

North 1996) demonstrated that during years of low or reduced krill availability, fish become an important component of Antarctic fur seal diet in this region. At Marion Island (Klages and Bester 1998), at Heard Island (Green *et al.* 1989, 1997), at Kerguelen Islands (Cherel *et al.*1997; Lea *et al.* 2002) and at Macquarie Island (Robinson *et al.* 2002) where large krill concentrations are absent, fish, particularly pelagic Myctophidae, are the main food source of Antarctic fur seals. In comparison, krill and fish were reported to be predominant and equally important food items for Antarctic fur seals in the maritime Antarctic (Antarctic Peninsula and Scotia Sea area) (Daneri 1996; Casaux *et al.* 1998; Casaux *et al.* 2003 a, b, 2004; Daneri and Carlini 1999).

The biomass and spatial distribution of krill concentrations in the South Shetland Islands area are largely dependent on the ice conditions in the Antarctic Peninsula region (Loeb *et al.* 1997) and are further influenced by the circulation of water masses originating from the Bellingshausen and Weddell Seas (Stein and Rakusa-Suszczewski 1983; Priddle *et al.* 1988). Therefore both, circulation patterns and ice conditions, may influence seasonal changes in Antarctic fur seal diet.

Antarctic fur seals (*Arctocephalus gazella*), on the contrary to XIX and the most part of XX century, no longer breed on the southern shores of South Shetland Islands (Aguayo 1978; Bengston *et al.* 1990). However, young and adult males are regularly present in this area between the end of January and the beginning of April. These animals are probably immigrants from the South Georgia area (Salwicka and Rakusa-Suszczewski 2002). During austral summers 1994/95–1996/97, the maximum abundance of Antarctic fur seals hauled out on the western shore of Admiralty Bay varied between 769 to 1709 individuals.

The objective of this study was to examine the diet of non-breeding male Antarctic fur seals, and to explore inter- and intra-annual variations in their diet during the four consecutive summers in Admiralty Bay.

Materials and methods

Fur seals feaces were collected at Uchatka Point, on King George Island (62°13'S, 58°26'W) during four austral summers 1993/94–1996/97. In the first half of January of each season the study area was thoroughly cleaned of the previous year remains. Subsequently all the fresh scats of Antarctic fur seals were collected at 7–10 day intervals. Scat collections were made between 16 February – 7 April 1994, 8 February – 5 March 1995, 8 February – 16 March 1996, and 29 January – 26 February 1997. 493 samples were collected. However, 20 scant faeces without any distinguishable remains were not taken into consideration during analysis. All analysed samples (n = 473) were packed individually and stored in 70% ethyl alcohol.

In the laboratory each sample was individually washed through a set of three sieves (Ø 2.5, 1.5 and 0.5 mm). The remains that were caught on the strainers were rinsed in slightly tilted containers, so that the stream of water separated heavier parts from lighter ones (Murie and Lavigne 1985). Prey parts were sorted under the dissecting microscope. Otoliths and cephalopod mandibles were picked out for further identification and measurement. Presence of other prey remains, such as fish vertebrae and eyes, cephalopod eyes, shells, feathers, that did not allow species identification, were also recorded.

Where possible, the otoliths were identified to the species level with the help of the keys by Hecht (1987) and Williams and McEldowney (1990). Partly eroded otoliths of some species, mostly Channichthyidae and Paralepididae, were identified only to the genus or family level. Each of the otoliths was assigned to one of the four groups: (1) good – with well preserved medial relief and intact margins; (2) medium – with slight signs of erosion on the medial relief and margins; (3) poor – with pronounced erosion on the medial relief and margins; (4) bad – with medial relief and margins smoothed by erosion. Otoliths from this latter group were not identified. Differing characteristics of otoliths belonging to different taxa were taken into account during their classification into the above mentioned groups. This was particularly important in case of Myctophidae, which have poorly developed medial relief features. For each sample the identified otoliths of a given species were sorted into left and right ones, and the greater number was considered as a number of fish in a given sample. Otolith length was measured to the nearest 0.01 mm using a microscope with graticule eyepiece. To compensate for loss of length due to erosion of the otoliths during digestion correction factors of: 5, 10 and 15% were added to the measured length of otoliths from groups 1, 2, and 3; respectively.

Standard length and mass of the consumed fish were estimated from the corrected otolith lengths and published regression equations (Hecht 1987, Williams and McEldowney 1990). The importance of each of the fish species in the diet of Antarctic fur seals was expressed, according to Bigg and Perez (1985) as well as to Scharf and Schlicht (2000), by: (1) numerical percentage of a food item (N) *i.e.* the number of prey in a specific prey category as a percentage of the total number of all prey items, (2) proportional frequency of occurrence (F) *i.e.* the percentage of all stomachs that contain a specific prey category and (3) estimated proportion in the biomass (wet weight) of the consumed prey (W).

The presence of skates in the diet of Antarctic fur seals was indicated by dermal denticles and thorns. These do not allow the identification to the species level; thus they were classified as Rajidae spp.

From samples containing krill up to 20 krill eyes were selected and their crystal cones were isolated and measured to estimate the length of the individual krill (Rakusa-Suszczewski 1994). The mass of an individual krill was calculated based on the estimated length and the regression equation for all the development stages (Jażdżewski *et al.* 1978). In order to estimate the total number of individual krill in each sample, all eyes and telsons of krill were sorted and counted. Additionally, the "exoskeleton dry weith" method as described by Casaux *et al.* (1998) was applied to estimate the minimum number of krill individuals per scat. The mean dry mass of each whole exosceletons was calculated (mean 19.87 mg, SD ±0.36; n = 247). The highest value of the above three estimates was accepted as the number of individual krill in the sample.

All of the cephalopod beaks were identified by Dr. M. Lipiński (Sea Fisheries Research Institute, Cape Town, South Africa). Mass and mantle length was estimated using the method developed by Rodhouse *et al.* (1992).

Feathers found in the scats were classified as belonging to penguins of the genus *Pygoscelis* spp.

Results

Krill was the most common prey item found in the scats of non-breeding Antarctic fur seal males (Table 1). It was recorded in 88.3% of all samples (n = 473). Fish were found in 84.7% of the samples; cephalopods and penguins in 12.5% each. The frequency of krill occurrence in the diet samples was above 92% during the first three years of the study (1993–1996). However, in 1997 it dropped to 73%. This decline in the frequency of occurrence of krill coincided with an unusually high frequency of fish (93.1%) and rather high of penguins (10.4%) in the diet

Table 1

Percentage frequency of occurrence of the four main prey items in the scats of Antarctic fur seals. Frequency of otoliths and frequency of dermal denticles and thorns of skates are given separately.

Date	Krill	Fish			Squids	Penguins
		all remains	otoliths only	denticles only		
February 94 (n = 58)	100.0	62.1	55.2	0.0	3.4	3.4
March 94 (n = 78)	88.5	91.0	74.4	7.7	14.1	1.3
April 94 (n = 27)	88.9	100.0	92.6	7.4	44.4	0
1994 mean	**92.5**	**84.4**	**74.1**	**5.0**	**20.7**	**2.4**
February 95 (n = 83)	91.6	77.1	67.5	3.6	13.3	6.0
March 95 (n = 54)	93.9	79.6	72.2	0.0	25.9	18.5
1995 mean	**92.7**	**78.4**	**69.9**	**1.8**	**19.6**	**12.3**
February 96 (n = 61)	98.4	86.9	81.2	6.0	4.9	8.2
March 96 (n = 47)	91.5	78.7	74.5	3.7	4.3	21.3
1996 mean	**94.9**	**82.8**	**77.9**	**4.9**	**4.6**	**14.7**
January 97 (n = 7)	85.7	100.0	100.0	14.3	0	0
February 97 (n = 58)	60.3	86.2	81.0	17.2	10.3	20.7
1997 mean	**73.0**	**93.1**	**90.5**	**15.8**	**5.2**	**10.4**
1994–1997 mean (n = 473)	**88.3**	**84.7**	**77.8**	**6.9**	**12.5**	**12.5**

in that year. There were statistically significant differences in the frequency of occurrence of all prey types among years: krill (χ^2_3 = 39.8; P<0.001), fish (χ^2_3 = 275.9; P <0.003), cephalopods (χ^2_3 = 11.26; P <0.001) and penguins (χ^2_3 = 125,80; P = 0.003). Within the summer seasons 1994, 1995, 1996 there were no significant changes in krill frequency (P >0.05), while in 1997 significant lower krill frequencies were noted (χ^2_4 = 78.42; P = 0.033, range = 36.7 – 100.0%). During the summer season of 1994 statistically significant intra-annual differences in fish frequency were noted, while the remaining seasons were characterized with insignificant changes in fish frequency (1995 – χ^2_5 = 44.5; P = 0.227; 1996 – χ^2_4 = 46.1; P <0.102; 1997 – χ^2_4 = 6.3; P = 0.601). Due to the very long period of retention and accumulation of cephalopod beaks in the predators' stomachs, seasonal changes in the frequency of this prey type were not analyzed. Occurrence of penguin remains in the scats of Antarctic fur seals increased at the end of the season.

The average length of individual krill was 31.7 mm (range 16–52 mm) across all the samples. In 1994 the modal krill length was 30 mm (range 16–45 mm), in

Table 2

The numbers of identified otoliths in Antarctic fur seals diet during the four summers 1994–1997 (the fishes of the family Channichthyidae were not considered as benthic since the individuals caught were of the size corresponding to meso-pelagic juvenile forms, according to Gon and Heemstra 1990).

Species	Family	Year			
		1994	1995	1996	1997
Mesopelagic species					
*Chionodraco rastrospinosus***	Channichthyidae	66	53	5	13
*Channichthys rhinoceratus***	Channichthyidae	4	0	0	0
*Channichthys wilsoni***	Channichthyidae	1	0	0	0
Channichthyidae gen. sp.	Channichthyidae	9	3	2	0
*Electrona antarctica***	Myctophidae	574	325	345	519
*Gymnoscopelus nicholsi**	Myctophidae	809	186	152	321
*Kreffichthys anderssoni***	Myctophidae	12	3	3	18
*Gymnoscopelus braueri**	Myctophidae	5	4	3	4
Electrona carlsbergi	Myctophidae	0	0	0	4
Protomyctophum normani	Myctophidae	1	1	1	1
*Pleuragramma antarcticum***	Nototheniidae	83	28	24	6
*Notolepis coatsi***	Paralepiddae	34	46	6	4
Notolepis sp.	Paralepiddae	2	1	0	0
Bathypelagic species					
*Protomyctophum bolini***	Myctophidae	13	7	7	22
Lampanyctus achirus	Myctophidae	1	2	0	0
Benthic species					
Trematomus hansoni	Nototheniidae	0	2	0	0
*Lindbergichthys nudifrons***	Nototheniidae	0	0	2	0

* krill eating species; ** species with 50% share of the diet composition.

Table 3

The importance of fish species in the diet of Antarctic fur seals in the area of Uchatka Point during four summer seasons 1994–1997.

Species	Numerical percentage of a food item		Proportional frequency of occurence		Biomass (g)	
	N	%	F	%	W	%
G. nicholsi	1 468	38.3	184	47.4	35555.1	58.2
E. antarctica	1 763	46.0	309	79.6	5979.4	9.8
Ch. rastrospinosus	137	3.6	60	15.5	9192.8	15.0
P. antarcticum	141	3.7	63	16.2	3682.0	6.0
N. coatsi	90	2.3	52	13.4	5534.6	9.1
P. bolini	49	1.3	35	9.0	95.7	0.2
K. anderssoni	36	0.9	25	6.4	103.8	0.2
G. braueri	16	0.4	13	3.4	123.0	0.2
Ch. rhinoceratus	4	0.1	2	0.5	511.1	0.8
T. hansoni	2	0.1	2	0.5	210.0	0.3
L. nudifons	2	0.1	2	0.5	31.2	0.1
E. carlsbergi	4	0.1	1	0.3	26.8	0.0
P. normani	4	0.1	4	1.0	6.5	0.0
L. achirus	3	0.1	2	0.5	6.1	0.0
Ch. wilsoni	1	0.1	1	0.3	53.9	0.1
Channichthyidae sp.	14	0.4	10	2.6	–	–
Notolepis sp.	3	0.1	3	0.8	–	–
Unknown	95	2.5	–	–	–	–
Total	3 832	100.0			61111.9	100.0

1995 – 32 mm (range 22–46 mm), in 1996 – 35 mm (range 20–52 mm). The year of 1997 was characterized by a bimodal krill length distribution: M_a = 30 mm, and M_b = 44 mm (range 20–51). Differences in modal krill lengths were significant between the years ($\chi^2_3 = 127.75$; P <0.005). There were also significant differences in the frequencies of krill length classes within the summer seasons (1994 – χ^2_3 = 15.74; P = 0.001; 1995 – χ^2_5 = 12.17; P = 0.030; 1996 – χ^2_4 = 9.61; P = 0.048; 1997 – χ^2_4 = 12.85; P = 0.012).

A total of 3737 otoliths (found in 388 feaces) were identified as belonging to one of 17 species (Table 2), the remaining 95 otoliths were too eroded to enable proper classification. The vast majority of the identified otoliths (98%) belonged to mesopelagic fish species, mainly Myctophidae, which comprised 90% of the otoliths in the samples. Bathypelagic and benthic fish species were scarcely represented (2%), as were the remains of scates (6.9%) indicating lower reliance of Antarctic fur seals on benthic foraging. The most numerous (46.0%) and the most frequent (79.6%) species overall was *Electrona antarctica* (Table 3). Taking into account the numerical percentage, frequency of occurrence and biomass, the most important fish species were *Gymnoscopelus nicholsi*, *Electrona antarctica*, *Chionodraco rastrospinosus*, *Pleuragramma antarcticum* and *Notolepis coatsi*. The re-

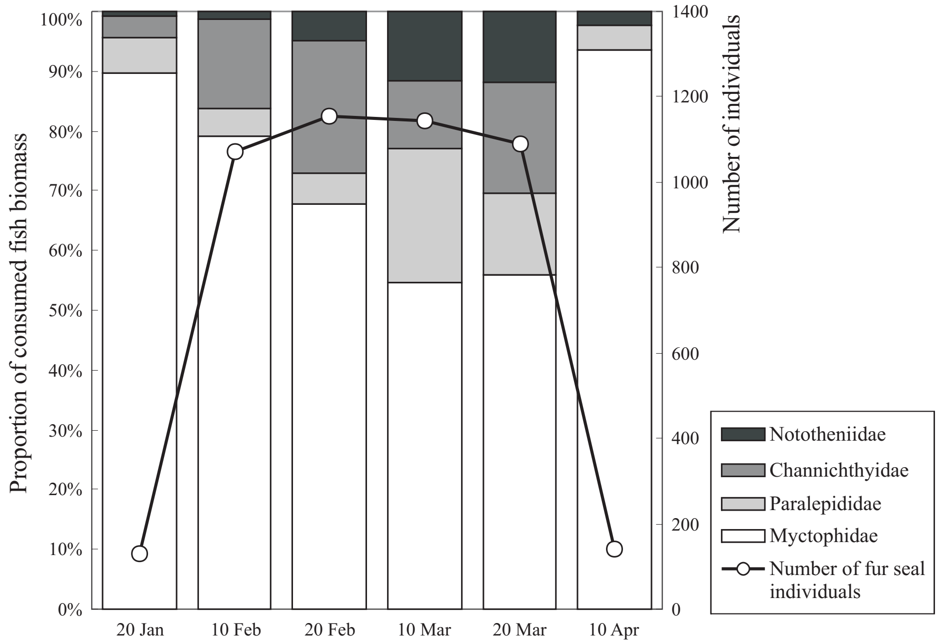

Fig. 1. The biomass percentage composition of four fish families: Channichthyidae, Nototheniidae, Paralepididae and Myctophidae in the diet of Antarctic fur seals. Data from 1994–1997 are combined. A solid line indicates the average number of Antarctic fur seals on the western shore of Admiralty Bay.

maining species were insignificant in the fur seals diet, since their share in the total consumed fish biomass did not exceed 1% (Table 3).

During the months when Antarctic fur seals were more migratory (January and April) they took mostly pelagic fish of the Myctophidae family (Fig. 1). The percent of those fish in terms of total biomass of consumed fish, was nearly 90% in January and 94% in April. Conversely, in months when seals were more sedentary (in the period when the number of Antarctic fur seals in Admiralty Bay was the highest) they fed more on pelagic and bentho-pelagic species (Paralepididae, Channichthyidae and Nototheniidae) which increased to 45% of the biomass of consumed fish.

There were significant differences in the degree of erosion of otoliths between the years (Kruskal-Wallis Test $H_{(3,\, n=2070)} = 95.4$; $P < 0.001$). In the seasons 1994–1996 the erosion was at a similar level, while in 1997 it was considerably higher. When analyzing all years together, the erosion was higher in January and April, than in February and March (Kruskal-Wallis Test $H_{(3,\, n=3789)} = 181.56$; $P < 0.001$).

Of the 75 squid beaks isolated from the samples, 55 were identifiable. Most squid beaks ($n = 53$) belonged to the species *Alluroteuthis antarcticus*. The remaining two represented: *Brachioteuthis ?picta* and ommastrephid species. All of the identified individuals of *A. antarcticus* were juvenile; their mean mantle length, estimated from the measurements of LRL, varied from 15 to 116 mm, which corresponds to 0.4–172.0 g of individual body mass.

Feathers that were found in the scats were recognized as penguin feathers, however, it was not possible to identify the species. They could have belonged to any of the three species of penguins breeding and abundant in the area of Admiralty Bay: Adélie (*Pygoscelis adeliae*), gentoo (*P. papua*), or chinstrap (*P. antarctica*).

Discussion

As observed at other study sites (Doidge and Croxall 1985; Reid and Arnould 1996; Cherel *et al.* 1997; Casaux *et al.* 1998; Daneri and Carlini 1999; Kirkman *et al*. 2000; Casaux *et al.* 2003 a, b, 2004; Osman *et al.* 2004), Antarctic fur seals in the Admiralty Bay area fed mainly on locally abundant resources, krill and fish.

During the first three years of the study, krill dominated the fur seal diet. However, in 1997 fish became the most frequently consumed prey. This finding is surprising because in 1997 the krill biomass in the South Shetland Islands region was estimated to be the highest since 1992 (Hewitt and Demer 1997). However, the season 1997 was characterized by an atypical spatial distribution of krill swarms. To the north of South Shetlands, krill formed swarms of sexually mature individuals, while to the south of the archipelago a mixture of one-year old and juvenile individuals were found (Hewitt and Demer 1997). The presence of two age-size classes in the diet of Antarctic fur seals in 1997 suggests, that Antarctic fur seals might have ventured to the northern shores of South Shetlands to forage on the larger krill found there. Moreover, the higher degree of erosion of otoliths from 1997 indicates that Antarctic fur seals were foraging in greater distances from Admiralty Bay, which could correspond to trips to the northern side of South Shetlands. It should be also pointed out that Osman *et al.* (2004) have suggested a fur seal preference for larger krill.

The average krill length in the Antarctic fur seal diet in Admiralty Bay during the summer seasons 1994–1997 was only 31.7 mm. Thus it was much less than reported from South Georgia (Reid and Arnould 1996) where during four consecutive summer seasons Antarctic fur seals took krill of an average length of 42 mm as well as from Cape Shirreff, Livingstone Island found by Osman *et al.* 2004, where mean sizes of krill eaten were from 40.9 mm to 51.5 mm. Mean total length of krill preyed at Harmony Point, Nelson Island was 52.7mm with SD + 10.2 mm (Casaux *et al.* 2004). So, particularly striking was the absence of the older krill size classes, of lengths greater than 45 mm in the current study. Since the aggregations of younger krill are found in shelf waters, and the older ones beyond the shelf break and in the open ocean (Jażdżewski *et al.* 1978), we hypothesize that the main feeding grounds of Antarctic fur seals in this study area may be inshore ones.

The frequency of fish remains in the samples was only slightly lower than that of krill. Other studies of Antarctic fur seal diets repeat that fish are a substantial component of their diet in most regions of Antarctica (Green *et al.* 1989, 1991; Daneri and Coria 1992, 1993; Daneri 1996; Cherel *et al.* 1997; Klages and Bester 1998; Casaux *et al.* 1998, 2003 a, b, 2004; Lea *et al.* 2002; Robinson *et al.* 2002; Osman *et al.* 2004,). The only area where the fur seal diet consists nearly entirely of krill is South Georgia (North *et al.* 1983, Croxall and Pilcher 1984, Doidge and Croxall 1985, Boyd *et al.* 1991). However, Reid and Arnould (1996) pointed out that even in this area fish could become an important food item when krill availability is limited.

17 fish species has been identified from otoliths found in the studied material. Five species: *Gymnoscopelus nicholsi*, *Electrona antarctica*, *Chionodraco rastrospinosus*, *Pleuragramma antarcticum* and *Notolepis coatsi* were recognized as the most important. *G. nicholsi* and *E. antarctica* were, similarly as in Antarctic Peninsula and Scotia Sea region (Daneri and Carlini 1999; Casaux *et al.* 2003 a, b; Casaux *et al.* 2004; Osman *et al.* 2004) most frequent and numerous fish prey item of Admiralty Bay Antarctic fur seals. Less frequent and less numerous were *Ch. rastrospinosus* and *P. antarcticum* , fish species reported also as the considerable food item of Antarctic fur seal from Danco Coast, Antarctic Peninsula (Casaux *et al.* 2003a) and from different localities of the Antarctic Peninsula, South Shetland Islands and South Orkney Islands (Casaux *et al.* 2003b). *N. coatsi* were the most frequent and numerous in Antarctic fur seal diet at King George Island in spring (Daneri and Carlini 1999).

The remaining 12 species recognized in the material from Admiralty Bay were not frequent in the fur seals' diet, and none of them exceeded 1% of total consumed fish biomass (Table 3). Most of the identified species are krill-eating fish inhabiting the pelagic zone over the continental shelf (Fischer and Hureau 1985; Gon and Heemstra 1990). Rembiszewski *et al.* (1978) reported similar results from 115 krill trawls hauled in the region of Antarctic Peninsula, South Orkneys, South Georgia and South Sandwich Islands. They found that young individuals of the family Channichthyidae, adults of the family Myctophidae, and *N. coatsi* together with krill make up a trophic community that travels long distances. We conclude that in the areas of Antarctica where krill is present, Antarctic fur seals search mainly for krill swarms and supplement their diets with krill-eating fishes that accompany them. Fishes of the family Channichthyidae (Reid 1995, North 1996, Reid and Arnould 1996) were found in fur seal scats from the South Georgia area, whereas in other regions of Antarctica more Myctophidae were found (Daneri 1996, Casaux *et al*. 1998, Daneri *et al*. 1999). Antarctic fur seals did not prey upon benthic fish species, which according to Kock *et al*. (2000) constitute nearly 97% of fish biomass in the South Shetlands area. The probable cause of this absence is that benthic species inhabit depths that are beyond diving capabilities of Antarctic fur seals. Even those benthic fish species that live at depths available to the seals, like some representatives of the family Nototheniidae (*Notothenia coriiceps*, *Trematomus hansoni*, *Lindbergichthys nudifrons*) and rays (Rajidae) were taken only sporadically. It is also probable that these species are more difficult to hunt, because they live in a kelp canopy.

The composition of fish species varied seasonally (Fig. 1). Pelagic Myctophidae dominated the diet of Antarctic fur seals when they were migratory and active (January and April), while bentho-pelagic Channichthyidae and Nototheniidae prevailed when the seals stayed in Admiralty Bay (February and March). Species diversity was lower in January and April (6 and 7 species respectively), and greater in February and March (14 and 11 species respectively). We suppose that the diet switch we found in the January–April period reflects consecutive phases of the non-breeding male Antarctic fur seal migration. Individuals that arrive in January and at the beginning of February come from the open ocean waters of Bransfield Strait, where they primarily forage on pelagic fish, particularly *Electrona antarctica*. In February and March when the Antarctic fur seals are moulting, they search for food closer to the shore. This explains the increase of bentho-pelagic fishes in their diet. At the end of March – early April, after completing their molt, Antarctic fur seals are leaving Admiralty Bay and returning to an offshore habitat where they feed. This period was characterized by the return of pelagic Myctophidae to the diet.

Seasonal shifts in the fish species composition in the diet of Antarctic fur seals were also reported from South Georgia (Reid and Arnould 1996) and from Heard Island (Green *et al.* 1989). In the first case the changes were related to oceanographic variations, mainly in the location of the Antarctic Polar Front, which brought large swarms of Myctophidae into the foraging areas of fur seals. Whereas, at Heard Island the shift was explained by changes of Antarctic fur seal population structure. From September to mid-November the population consists almost exclusively of males. In mid-November females, and at the end of December subadult males arrive. In this study the mechanism driving changes in fish species composition may be similar to those from Heard Island.

Cephalopods were regularly taken by fur seals, but in small numbers. Their remains were found in 12.5% of the samples. Similar frequencies of cephalopod remains were noted from other localities of the Scotia Sea (Daneri *et al*. 1999). The comparatively low frequency and importance of cephalopods in Antarctic fur seals diet is evidently different from diets of its congeners from lower latitudes. For the sub-Antarctic fur seal (*Arctocephalus tropicalis*), the South African fur seal (*A. pusillus pusillus*), and for the Australian fur seal (*A. pusillus doriferus*) cephalopods are an important dietary item (Bester and Laycock 1985; Gales *et al*. 1993; Klages and Bester 1998).

The seals from Admiralty Bay ate almost exclusively juvenile specimens of squids; the maximum mantle length was estimated to be 128 mm. The absence of adult cephalopods is probably a result of the preference of older squids to greater depths (Lu and Williams 1994). *Alluroteuthis antarcticus* was the dominant squid species found in the diet of Admiralty Bay fur seals. Curiously, another squid species – *Psychroteuthis glacialis* has been recently reported from scats of Antarctic fur seals from Antarctic Peninsula, South Shetlands and South Orkneys area (Casaux *et al.* 2003 a, b).

Penguins were often preyed upon by Antarctic fur seals at South Georgia (Doidge and Croxall 1985) and Marion Island (Hofmeyr and Bester 1993). Penguin remains were also found, but in smaller numbers, in Antarctic fur seal scats at Heard Island (Green *et al*. 1989, 1991). At Nelson Island (South Shetlands) penguin remains, skin and feathers, were found in 27.8% and 54.6% of scats of non-breeding male Antarctic fur seals in February of 1996 and 1997, respectively (Casaux *et al.* 1998). Penguins have been constant and sometimes very important (in term of biomass) prey item of fur seals from the northern Antarctic Peninsula surrounding areas (Casaux *et al.* 2003 a, b, 2004). According to Kirkman *et al*. (2000) adult male fur seals are the main predators of penguins. Among the samples they examined only the faeces of dominant males contained penguin feathers. The males hunted at the edge of land killing the birds that were leaving the sea. In Admiralty Bay, Antarctic fur seals were also observed hunting penguins in shallow water, 15–30 m off shore. After catching a bird they were seen tossing and killing it, however they were not seen to be actually eating penguins. Taking into account the large individual body mass of pygoscelid penguins, on average more than 4.5 kg (Jabłoński 1986) we suggest that they can be an important dietary item for non-breeding male Antarctic fur seals. There are three species of penguins breeding in Admiralty Bay: Adélie (*Pygoscelis adeliae*), gentoo (*P. papua*), and chinstrap (*P. antarctica*). Adélie penguins are the most numerous of the three above species, with a population ranging from 14000 to 33000 pairs (Myrcha 1993). Despite their numbers this species is unlikely to become prey of Antarctic fur seals, since Adélie penguins (both adult and chicks) depart from Admiralty Bay at the beginning of February. However the remaining two species could be important prey for seals. These two species are an order of magnitude less abundant than Adélie but they start egg laying 2–4 weeks later (Trivelpiece *et al.* 1987), so the penguins fledging periods of their chicks coincides with the maximum abundance of Antarctic fur seals. Most probably the remains of gentoo and chinstrap penguin chicks were found in this study. This hypothesis is confirmed by the fact that the frequency of feathers in the scats increased towards the end of each of the summer seasons, when chinstrap (mid to late February) and gentoo (end of February beginning of March) chicks fledge (Trivelpiece *et al.* 1987).

Conclusions

In this study krill and fish were recorded in almost identical proportions in Antarctic fur seal scats. This agrees with other results from the South Shetland Islands region, but is significantly different from South Georgia and Heard Island data, where either krill or fish are the main prey, respectively. The Antarctic fur seal diet at

South Georgia is also distinguished by the species composition, which is dominated by Channichthyidae, while at South Shetlands and at Heard Island pelagic Myctophidae prevail. In the Admiralty Bay area, the frequencies of cephalopod and penguin remains in the samples were equal, but considering the much greater individual body mass of penguins, they may have been a more important food source.

The seasonal pattern of diet changes was consistent in consecutive years of this study. There were seasonal changes in the frequency of occurrence of penguin remains and seasonal shifts in the type of fish consumed.

The results of this four year study suggest that the share of krill in Antarctic fur seal diet was dependent not only on it's availability but also on the age-size structure of the krill population. The portion of krill in the diet decreased with the decrease of its size, which was compensated for by an increase in the frequency of fish.

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