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Diet of Antarctic fur seals *Arctocephalus gazella* at the Danco Coast, Antarctic Peninsula

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Abstract The diet of non-breeding male Antarctic fur seals, *Arctocephalus gazella*, was investigated at the Danco Coast, Antarctic Peninsula, by the analysis of 31 and 149 scats collected from January to March 1998 and 2000, respectively. Overall, fish and krill, followed by penguins and squids, were the most frequent prey and constituted the bulk of the diet. The importance of the remaining taxa represented in the samples (octopods, gastropods, bivalves, isopods, polychaetes and poriferans) was negligible. Among fish, channichthyids constituted the bulk of the diet, with *Chionodraco rastrospinosus* and *Chaenodraco wilsoni*, followed by the nototheniid, *Pleuragramma antarcticum*, being the main prey. The myctophid, *Electrona antarctica*, was the most frequent and numerous fish prey. The results are discussed and compared with those reported for the South Shetland Islands, the closest area for which similar information is available.

Introduction

The Antarctic fur seal, *Arctocephalus gazella*, breeds in the Southern Ocean at South Georgia, and the South Sandwich, South Orkney, South Shetland, Bouvet, Marion, Heard, Macdonald and Kerguelen Islands (Fischer and Hureau 1988), but during the post-reproductive dispersal is frequently observed at the Antarctic Peninsula, south to Margarita Bay (J. Bengtson, personal communication, quoted in Whitehouse and Veit 1994).

There exists abundant information on the feeding habits of the Antarctic fur seal. Several studies carried out at Heard Island (Green et al. 1989, 1991), Marion Island (Klages and Bester 1998), Bouvetøya (Kirkman et al. 2000), Kerguelen (Cherel et al. 1997; Guinet et al. 2001), South Georgia (Croxall and Pilcher 1984; Costa et al. 1989; Reid 1995; Reid and Arnould 1996), South Orkney Islands (Daneri and Coria 1992) and South Shetland Islands (Daneri 1996; Casaux et al. 1998a, 2002) indicated that, depending on the study area or season, the Antarctic krill (*Euphausia superba*), fish and/or penguins are the main prey of *A. gazella*. Despite the amount of diet studies carried out and the extent of the area, there is no information on the foraging habits of the Antarctic fur seal at the Antarctic Peninsula. Thus, the aim of this study is to provide information on the diet of the Antarctic fur seal from a previously unstudied area, such as the Danco Coast, Antarctic Peninsula.

Materials and methods

A total of 31 and 149 scats of non-breeding male Antarctic fur seals was found and collected from January to March 1998 and 2000, respectively, at beaches surrounding Cierva Point (64°09′S; 60°57′W), Danco Coast, Antarctic Peninsula (Figs. 1, 2).

The samples were individually washed through sieves (minimum mesh 0.54 mm) and the prey remains were sorted to the lowest taxonomic level possible. In order to estimate the approximate number of individuals of the Antarctic krill (*E. superba*) present in each sample, we considered the number of eyes and telsons or the dry weight of the total of the carapaces present in the sample, according to the technique described by Casaux et al. (1998a). The highest of these three estimates was considered as the minimum number of krill specimens present per sample. The mass of the individuals was estimated by comparison with entire specimens recovered from the study area.

Cephalopods were identified using reference material and the illustrations and descriptions in Clarke (1980), Lipinski and Woyciechowski (1981), Okutani and Clarke (1985) and Fischer and Hureau (1988). The number of individuals represented in the samples was estimated by the number of upper and lower beaks or

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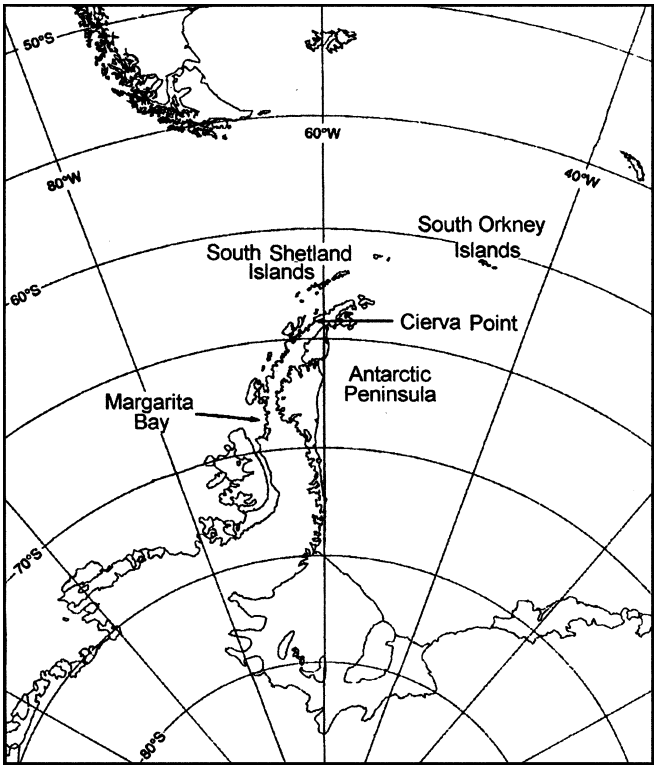

Fig. 1 Map showing the location of Cierva Point at Danco Coast, Antarctic Peninsula

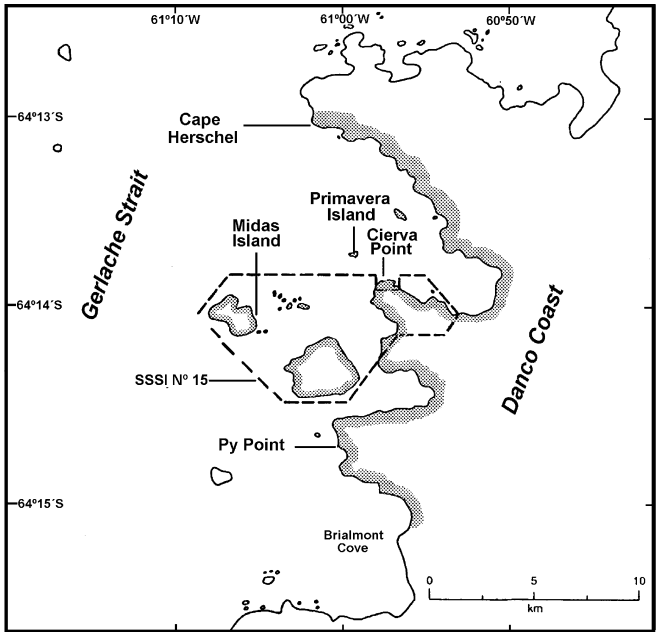

Fig. 2 Map showing the beaches surrounding Cierva Point sampled in this study (*shaded areas*)

eye lenses. The lower hood length of octopod beaks (identified as *Pareledone* sp.) was measured to the nearest 0.01 mm with vernier callipers, and the mass of the individuals estimated using the relationship developed by Rodhouse et al. (1992). The squids were tentatively identified as *Psychroteuthis glacialis* and the mass of the individuals was estimated considering the rostral length of the lower beak and applying the relationship described in Gröger et al. (2000). The number of gastropods and bivalves represented in the scats was estimated considering the number of shells present in the samples, and the mass was estimated by comparison with entire specimens recovered from the study area.

Bones, otoliths and eye lenses indicated the presence of fish in the scat samples. The sagittal otoliths were identified to species level, where possible, using our own reference collection and illustrations and descriptions in Hecht (1987) and Williams and McEldowney (1990). The otoliths belonging to specimens of each species were sorted into right and left; the higher count of right and left otoliths was considered as the number of fish of the corresponding species present in each scat sample. The otolith lengths were measured to the nearest 0.01 mm and the fish body length and mass were estimated using the equations of Hecht (1987), Williams and McEldowney (1990) and Casaux et al. (1998b).

Given that penguins were represented almost exclusively by feathers, the number of individuals represented in the samples was not accurately estimated. Although it will likely result in an underestimation, (Casaux et al. 2002 reported for the South Shetland Islands that a fur seal was seen killing and eating three penguins consecutively), we arbitrarily considered one individual represented per sample. The weight of penguins consumed per scat sample was assumed as the mean mass reported for *Pygoscelis antarctica* fledging chicks (2,910 g, Moreno et al. 1998) minus the mean mass of carcasses of penguins killed by seals (mean = 956.25 g, SD = 233.01, range 550–1,400, $n = 16$; Casaux et al. 2002) found along the shore of Harmony Point (see Casaux et al. 2002). According to the penguin availability at the study area (Favero et al. 2000), the remains represented in the scats might belong to *Pygoscelis antarctica* or *Pygoscelis papua*.

Polychaetes were represented mainly by mandibles, and isopods by exoskeleton remains, and their mass was estimated by comparison with entire specimens collected in the study area.

Since the estimates of the number and mass of prey species represented in scats usually gives biased results (see Clarke and MacLeod 1982; da Silva and Neilson 1985; Green and Burton 1987; Murie 1987; Casaux et al. 1997, among others), the mass estimated of the different dietary items does not necessarily represent their real contribution to the diet. However, these values were included because they provide information not reflected by the frequencies of occurrence.

Results

Overall, fish and krill, followed by penguins and squids, were the most frequent prey and constituted the bulk of the diet of the Antarctic fur seals at Danco Coast (Table 1). The Antarctic krill was the most numerous prey in both seasons and predominated by mass in 2000, whereas fish predominated in 1998. Except for penguins in 1998, the contribution to the diet of the remaining prey was negligible.

The otoliths recovered from the scats represented 2,238 fish (1,026 and 1,212 in 1998 and 2000, respectively); 1,724 of them (769 and 955 in both seasons) were identified as belonging to the families Myctophidae, Bathylagidae, Nototheniidae, Bathydraconidae and Channichthyidae. The otoliths from the remaining 514 specimens were unidentifiable to species because they were broken or greatly eroded (Table 2).

The overall results indicated that, among fish, channichthyids constituted the bulk of the diet (56.4% by mass). *Chionodraco rastrospinosus* and *Chaenodraco wilsoni* were the two most important fish prey by mass in

Table 1 The composition of the diet of non-breeding male Antarctic fur seals at Danco Coast, Antarctic Peninsula, as reflected by the analysis of scats collected during the summers of 1998 and 2000. Percentage frequencies of occurrence (*F%*), number (*N%*) and mass (*M%*); sample sizes in *parentheses*

	1998 ($n=31$)			2000 ($n=149$)			Overall ($n=180$)		
	F%	*N%*	*M%*	*F%*	*N%*	*M%*	*F%*	*N%*	*M%*
Penguins	9.7	0.1	18.4	1.3	0.0	5.2	2.8	0.0	9.2
Fish	100	35.3	72.6	90.6	2.2	30.9	92.2	3.4	43.4
Molluscs									
Cephalopods									
Octopods									
Pareledone sp.	12.9	0.2	1.0	0.7	0.0	0.3	2.8	0.0	0.5
Squids									
Psychroteuthis glacialis	41.9	0.8	4.2	14.1	0.0	3.0	18.9	0.1	3.3
Gastropods									
Nacella concinna	6.5	0.1	0.0	0.7	0.0	0.0	1.7	0.0	0.0
Others	–	–	–	1.3	0.0	0.0	1.1	0.0	0.0
Bivalves	3.2	0.1	0.0	1.3	0.0	0.00	1.7	0.0	0.0
Crustaceans									
Euphausia superba	19.4	63.3	3.8	85.2	97.8	60.6	73.9	96.5	43.7
Isopods				0.7	0.0	0.0	0.6	0.0	0.0
Unidentified	3.2	0.0	0.0	–	–	–	0.6	0.0	0.0
Polychaetes	3.2	0.1	0.0	–	–	–	0.0	0.0	0.0
Porifera	–	–	–	0.7	0.0	0.0	0.6	0.0	0.0

Table 2 Fish represented by the otoliths found in scats of non-breeding male Antarctic fur seals collected at the Danco Coast, Antarctic Peninsula, during the summers of 1998 and 2000. Percentage frequencies of occurrence (*F%*), number (*N%*) and mass (*M%*); sample sizes in *parentheses*

	1998 ($n=31$)			2000 ($n=149$)			Overall ($n=180$)		
	F%	*N%*	*M%*	*F%*	*N%*	*M%*	*F%*	*N%*	*M%*
Bathylagidae									
Bathylagus antarcticus	–	–	–	0.7	0.1	0.0	0.6	0.0	0.0
Myctophidae									
Electrona antarctica	64.5	15.4	1.9	61.1	33.3	5.3	61.7	25.1	3.6
Electrona carlsbergi	–	–	–	2.7	0.6	0.3	2.2	0.3	0.1
Gymnoscopelus braueri	3.2	0.2	0.0	5.4	0.7	0.2	5.0	0.5	0.1
Gymnoscopelus nicholsi	25.8	14.6	16.4	19.5	14.2	15.5	20.6	14.4	16.0
Krefftichthys anderssoni	3.2	0.1	0.1	–	–	–	0.6	0.0	0.0
Protomyctophum sp.	–	–	–	1.3	0.3	0.1	1.1	0.1	0.0
Nototheniidae									
Lepidonotothen larseni	–	–	–	1.3	0.2	0.1	1.1	0.1	0.1
Lepidonotothen nudifrons	–	–	–	0.7	0.1	0.1	0.6	0.0	0.0
Notothenia coriiceps	3.2	0.1	0.2	–	–	–	0.6	0.0	0.1
Pagothenia bernacchii	6.5	0.2	0.1	0.7	0.1	0.0	1.7	0.1	0.1
Pagothenia borchgrevinki	6.5	0.2	0.1	–	–	–	1.1	0.1	0.1
Pleuragramma antarcticum	48.4	20.9	18.1	48.3	17.6	27.6	48.3	19.1	22.8
Trematomus newnesi	3.2	0.1	0.1	4.0	0.7	0.7	3.9	0.5	0.4
Bathydraconidae									
Parachaenichthys charcoti	–	–	–	0.7	0.1	0.4	0.6	0.0	0.2
Channichthyidae									
Chaenodraco wilsoni	19.4	7.8	26.3	12.1	3.6	20.5	13.3	5.5	23.4
Chionodraco myersi	3.2	0.5	0.7	–	–	–	0.6	0.2	0.4
Chionodraco rastrospinosus	38.7	10.5	28.1	15.4	4.9	22.3	19.4	7.5	25.2
Cryodraco antarcticus	12.9	4.4	7.9	8.7	2.2	5.8	9.4	3.2	6.8
Pagetopsis macropterus	–	–	–	2.7	0.3	1.2	2.2	0.2	0.6
Unidentified	71.0	25.1	–	43.6	21.2	–	48.3	23.0	–

1998 whereas the nototheniid, *Pleuragramma antarcticum*, followed by those two species, were most important in 2000 (Table 2). *Gymnoscopelus nicholsi* was the myctophid that contributed most to the diet by mass. *Electrona antarctica* was the most frequent and numerous fish prey, followed by Pleuragramma antarcticum.

Table 3 Mean length (cm), standard deviation (SD) and size range of the fish represented by the otoliths found in scats of non-breeding male Antarctic fur seals collected at the Danco Coast, Antarctic Peninsula, during the summers of 1998 and 2000. Sample sizes in parentheses (*standard length; **total length)

	1998			2000		
	Mean	SD	Range	Mean	SD	Range
Bathylagidae						
*Bathylagus antarcticus**	–	–	–	9.4	–	–
Myctophidae						
*Electrona antarctica**	5.8	1.00	3.2–7.9	6.0	0.92	3.5–8.2
*Electrona carlsbergi***	–	–-	–	7.9	1.05	5.7–8.9
*Gymnoscopelus braueri**	4.8	0.45	4.5–5.2	8.3	1.21	5.6–9.2
*Gymnoscopelus nicholsi***	15.7	1.55	11.2–21.2	14.6	1.99	7.8–19.2
*Krefftichthys anderssoni***	9.8	–	–	–	–	–
Protomyctophum sp.*	–	–	–	7.6	0.10	7.5–7.7
Nototheniidae						
*Lepidonotothen larseni***	–	–	–	10.8	0.65	10.4–11.3
*Lepidonotothen nudifrons***	–	–	–	10.6	–	–
*Notothenia coriiceps***	13.3	–	–	–	–	–
*Pagothenia bernacchii***	10.4	4.53	7.2–13.6	8.8	–	–
*Pagothenia borchgrevinki***	10.1	0.38	9.9–10.4	–	–	–
*Pleuragramma antarcticum***	14.2	1.93	3.7–19.1	16.5	1.97	9.0–20.6
*Trematomus newnesi***	10.4	–	–	9.7	0.85	8.3–10.7
Bathydraconidae						
*Parachaenichthys charcoti***	–	–	–	17.1	–	–
Channichthyidae						
*Chaenodraco wilsoni***	18.6	4.58	10.8–30.3	21.2	4.07	13.4–33.1
*Chionodraco myersi***	16.1	3.14	13.1–19.5	–	–	–
*Chionodraco rastrospinosus**	16.7	2.71	12.7–24.5	19.4	2.55	12.6–25.2
*Cryodraco antarcticus***	19.5	3.48	11.2–25.9	20.8	3.73	12.8–27.6
*Pagetopsis macropterus***	–	–	–	22.3	4.86	17.1–28.7

The estimated size of the ingested fish ranged from 3.2 cm (*Electrona antarctica*) to 33.1 cm (*Chaenodraco wilsoni*) (Table 3). There were significant differences between seasons in the size of the specimens of *Chaenodraco wilsoni* (Mann-Whitney *U*-test, $P < 0.05$), *Chionodraco rastrospinosus* (Mann-Whitney *U*-test, $P < 0.0001$), *G. nicholsi* (Mann-Whitney *U*-test, $P < 0.0001$), and *Pleuragramma antarcticum* (Mann-Whitney *U*-test, $P < 0.0001$) represented in the diet. The size of the specimens of *Cryodraco antarcticus* (Mann-Whitney *U*-test, ns) and *Electrona antarctica* (Mann-Whitney *U*-test, ns) ingested in both seasons did not differ statistically. The remaining species were not tested because they were scarcely represented or absent in one of both seasons.

Discussion

As also observed at other localities of the South Atlantic sector (Daneri and Coria 1992; Reid 1995; Daneri 1996; Casaux et al. 1998a), the analysis of the scats collected at the Danco Coast indicated that fish and krill were the main components in the diet of non-breeding male Antarctic fur seals. Fish (72.6% by mass) were largely the dominant prey in 1998 whereas krill (60.6%), followed by fish (30.9%), were the dominant prey in 2000. These findings suggest differences between years in prey availability and/or in the foraging strategy used by seals. Given that the food preferences of male *A. gazella* during the non-breeding period remain unknown (see Casaux et al. 1998a), it is not possible to assess if the high consumption of fish in 1998 is related to a poor krill abundance within the foraging areas or, in contrast, to appropriate fish availability.

As observed by Reid (1995), Reid and Arnould (1996) and Casaux et al. (1998a) in the diet of Antarctic fur seals during summer, cephalopods were scarcely represented in our samples. Daneri and Coria (1992) suggested that cephalopods might be an important component of the diet during autumn, which seems to be supported by the results reported by Green et al. (1991).

Based on the analysis of scats collected at the South Shetland Islands, Casaux et al. (1998a) suggested that penguins should be considered as a dietary item of the Antarctic fur seal (but see Fischer and Hureau 1988). Their suggestion is supported by the findings of Casaux et al. (2002) who observed that at Harmony Point, Nelson Island, South Shetland Islands, penguins were the prey that most contributed to the diet of seals by mass during the summers of 2001 and 2002. The low occurrence of penguin remains in the scats analysed in this study might be explained by the low availability of these birds at the study area (Favero et al. 2000) compared to the reported availability for that locality (Silva et al. 1998).

The dominant fish in the diet are krill-feeding species (see Gon and Heemstra 1990), and many of them (*Parachaenichthys charcoti*, *Bathylagus antarcticus*, *Chionodraco myersi*, *Pagetopsis macropterus*, *Lepidonotothen nudifrons*, *Pagothenia borchgrevinki*, *Trematomus newnesi*) had not been previously reported as prey of *A. gazella*. Previous studies indicated that the channichthyid *Champsocephalus gunnari* was the most important fish prey of Antarctic fur seals at South Georgia (North et al. 1983; Reid 1995; North 1996; Reid and Arnould 1996), whereas myctophids predominated at Heard Island (Green et al. 1989, 1991), Marion Island (Klages and Bester 1998), Bouvetøya (Kirkman et al. 2000), Kerguelen (Cherel et al. 1997; Guinet et al. 2001), South Orkney Islands (Daneri and Coria 1993) and at King George (Daneri 1996; Daneri and Carlini 1999) and Nelson (Casaux et al. 1998a, 2002) Islands, both at the South Shetland Islands. By contrast, our overall results indicate that the channichthyids *Chionodraco rastrospinosus* and *Chaenodraco wilsoni*, and the notothenid *Pleuragramma antarcticum*, were the dominant fish prey of the Antarctic fur seals at Danco Coast, Antarctic Peninsula. The remaining channichthyids and notothenids, as well as bathydraconids, bathylagids and myctophids (except *G. nicholsi*), contributed little to the diet.

The comparison of our results with those from the closest localities for which information on the diet of the Antarctic fur seal is available, Nelson Island (see Casaux et al. 1998a, 2002) and King George Island (see Daneri 1996; Daneri and Carlini 1999), showed two main differences: the relative contribution of penguins and the different fish species to the diet of seals at both localities. The lower occurrence of penguins in the samples collected at the Danco Coast compared to that reported for the South Shetland Islands might be explained by the relatively low availability of these birds at the Danco Coast (see above). As previously stated, whereas myctophids predominated at the South Shetland Islands (see Daneri 1996; Casaux et al. 1998a, 2002; Daneri and Carlini 1999), channichthyids and *Pleuragramma antarcticum* constituted the bulk of the diet at the Danco Coast. The absence of recent comparative studies on the abundance of these fish at both areas prevents further analysis.

Daneri (1996) reported that during the 1991/1992 summer season, the myctophids *G. nicholsi* and *Electrona antarctica* and the notothenid *Pleuragramma antarcticum* (which occurred in the samples analysed with frequencies of 60%, 60% and 63%, respectively) contributed 33%, 12% and 31% of the total number of otoliths found in scats of the Antarctic fur seal collected at Potter Peninsula, King George Island, South Shetland Islands. Daneri and Carlini (1999) reported that those three species were also the most frequent and numerous prey at Potter Peninsula during the 1992/1993 and 1993/1994 summer seasons. Casaux et al. (1998a) observed that myctophid species (mainly *G. nicholsi*, *Electrona antarctica* and *Electrona carlsbergi*) contributed 85.2% of the fish mass to the diet of *A. gazella* at a close locality such as Harmony Point, Nelson Island, during the 1995/1996 and 1996/1997 summer seasons. In contrast to the reports of Daneri (1996) and Daneri and Carlini (1999), Casaux et al. (1998a) observed that *Pleuragramma antarcticum* was scarcely represented in samples from 1996/1997, and absent in those from 1995/1996, as well as in the diet of two *Pleuragramma antarcticum*-feeders such as cape petrels (*Daption capense*) (see Casaux et al. 1998c) and Weddell seals (*Leptonychotes weddelli*) (see Casaux et al. 1997) at Nelson and King George Islands, also during the 1995/1996 summer season. Casaux et al. (1998a) suggested that such a pattern could be related to a low availability of this fish in the area during those two seasons. Recently, Casaux et al. (2002) also observed that myctophids contributed to the diet of *A. gazella* with 86.5% of the fish mass and that *Pleuragramma antarcticum* was scarcely represented in the samples collected at Harmony Point during the 2000/2001 and 2001/2002 summer seasons. During the last five summer seasons, *Pleuragramma antarcticum* remained absent or scarcely represented in the diet of potential *Pleuragramma antarcticum*-feeders such as Antarctic fur seals, Weddell seals and Antarctic terns (*Sterna vittata*), at several localities of the South Shetland Islands, myctophids being the main fish prey (R. Casaux, unpublished data). This information seems to be reflecting changes in the availability of *Pleuragramma antarcticum* at this archipelago during the last decade.

The general biology, and particularly the population dynamics and distribution of myctophids and *Pleuragramma antarcticum* in the Southern Ocean, are poorly known (but see Linkowski 1985; Kellermann 1986; Lee et al. 1996; Greely et al. 1999, among others). In view of the current or potential interest in these fish as target species for commercial fisheries (see Kock 1992), information on population and distribution is required for proper resource management. Given their widespread distribution, once the relative preferences of the Antarctic fur seal for myctophids and *Pleuragramma antarcticum* are elucidated by considering simultaneously information on seals' diet, the foraging areas and depths dived by seals, and prey availability, the long-term study of concurrent information on the diet of this seal at different localities may help to produce advice on the distribution/abundance patterns of these fish.

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