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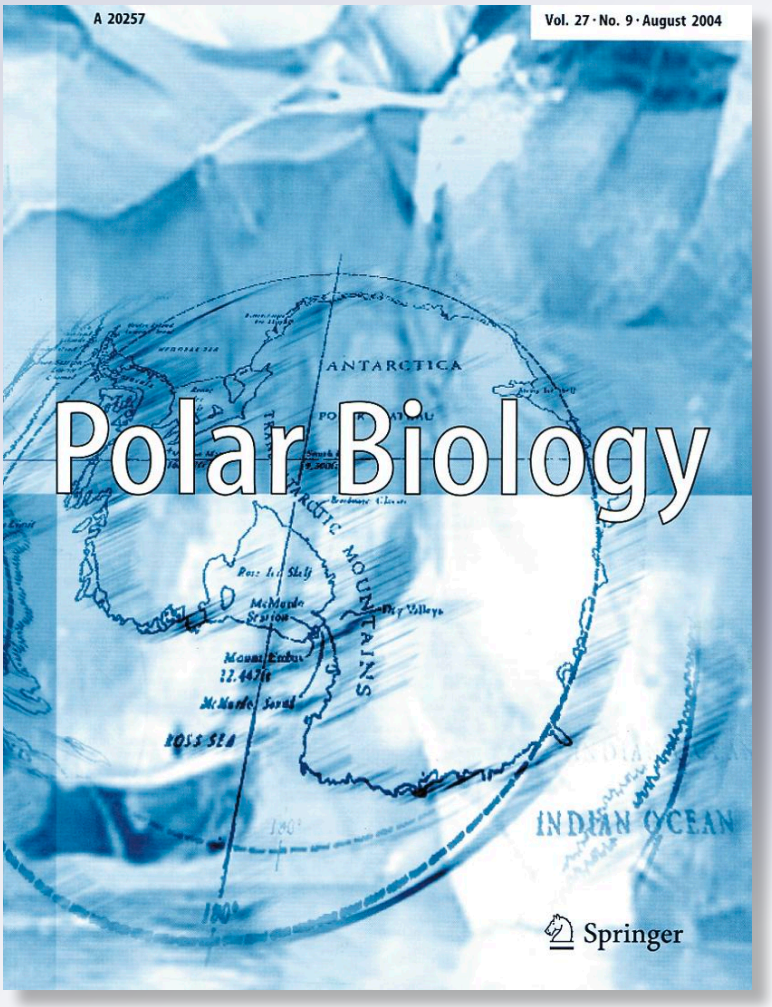

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SHORT NOTE

Feeding habits of three seal species at the Danco Coast, Antarctica: a re-assessment

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Abstract The analysis of prey overlap among Weddell, Antarctic fur and leopard seals was conducted using fecal samples collected at the Danco Coast, Antarctic Peninsula, in 1998 and 2000. The re-occurrence of prey species was moderate in samples collected in 1998, and low in 2000, and reflects resource partitioning among seal species. Prey species that mostly co-occurred in seals' diet were the Antarctic krill *Euphausia superba*, bivalves, and the myctophids *Gymnoscopelus nicholsi* and *Electrona antarctica*. A dietary similarity index of prey overlap has been calculated and demonstrates evident fluctuations in pairwise comparisons between the seal species. The highest and lowest values of prey overlap were observed between Antarctic fur seals and leopard seals, and between Weddell seals and leopard seals, respectively. Prey overlap between Antarctic fur seals and Weddell seals was moderate in both seasons.

Keywords Prey overlap · Antarctic seals · Diet composition · Antarctic Peninsula

Introduction

Investigations on the diet and the foraging behavior of Antarctic top predators are of considerable importance to understand the role they play in the marine ecosystem. Such studies also reveal information on the occurrence of prey species and, under certain conditions, have the potential to be used to monitor trends in prey populations (Casaux et al. 2003a). They furthermore might help in the management of exploited prey stocks by enhancing the accuracy of predictions of yield and in the evaluation of the ecological effects of exploiting particular prey species (Lindstrøm et al. 1998).

The foraging behavior of Weddell *Leptonychotes weddellii*, Antarctic fur *Arctocephalus gazella* and leopard *Hydrurga leptonyx* seals has been well studied at several localities (Green and Williams 1986; Plötz et al. 1991; Daneri and Coria 1992; Green et al. 1995; Klages and Bester 1998; Walker et al. 1998; among others). Previous studies analyzed the diet of breeding and non-breeding individuals (e.g. Reid and Arnould 1996; Casaux et al. 2003b), their individual diving behavior (e.g. Boyd et al. 1994; Sato et al. 2002), regional and seasonal changes in the composition of the diet (e.g. Green et al. 1989; Lake et al. 2003), or analyzed relationships between foraging behavior and prey availability (e.g. Costa et al. 1989; Boyd et al. 1994). The potential of these top-predator studies for investigations in marine ecosystems can be enhanced by multi-species comparisons. Where several predator species with similar foraging behavior co-occur and the availability of feeding resources is limited in quantity or diversity, some degree of food competition might be expected that would shape the foraging behavior and diet composition of top predators. In a multi-species comparison, we therefore re-assess dietary information obtained concurrently from Weddell, Antarctic fur and leopard seals at the Danco Coast, Antarctic Peninsula, in order to elucidate dietary overlap and potential food competition between three species of Antarctic seals.

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Materials and methods

The information on the composition of the diet re-analyzed in this study derived from analyses of fresh scat samples of Weddell (105 and 39 scats, Casaux et al. 2006), Antarctic fur (31 and 149, Casaux et al. 2003b), and leopard seals (14 sampled only in 2000, Casaux et al. 2009). The samples were collected along beaches (20 km long, Weddell and Antarctic fur seals) and on ice floes (leopard seals) close to Cierva Point (64°09′S; 60°57′W), Danco Coast, Antarctic Peninsula, from January to March 1998 and 2000. The slope of the shore around Cierva Point decreases abruptly and the water depth at the surveyed area reaches 300 m deep. The abundance of seals at the study area widely fluctuates between days. The number of Weddell seals and Antarctic fur seals may vary between few individuals and several hundreds. The abundance of leopard seals fluctuated in relation with the concentration of ice floes being this seal only occasionally observed in 1998 and relatively abundant in 2000 (up to few tens).

The degree of dietary overlap among seal species was estimated according to Tyler (1972). The re-occurrence of prey as percentage overlap among seal species is calculated by division of the amount of re-occurrences of a prey species in the respective seal species seals through the number of possible re-occurrences. One re-occurrence means that a prey species occurred in the diet of two predator species, and the total number of re-occurrences possible is the number of predators minus 1, multiplied by the number of prey items. The degree of interspecific prey overlap between pairs of seal species was estimated according to the dietary similarity index "*S*" (Linton et al. 1981) as follows:

$$S = 100\left(1 - 1/2\sum |\mathrm{P}xi - \mathrm{P}yi|\right)$$

where P*xi* and P*yi* are the percentages by mass of prey *i* in the diet of seals *x* and *y*. The dietary similarity index ranges from 0 (when no prey is shared) to 100 (when the diet of two seals is identical).

Results

The composition of the diet of the Weddell seal was diverse and both pelagic and benthic-demersal species were represented in the samples. Fish (mainly Nototheniid and Channichthyid species), followed by mollusks (mainly cephalopods) and crustaceans, were the prey that contributed most to the diet by mass in 1998 and 2000 (Table 1, see details in Casaux et al. 2006). Fish and the Antarctic krill *Euphausia superba* constituted the bulk of the diet by mass in Antarctic fur seals in 1998 and 2000, respectively (Table 1, see details in Casaux et al. 2003b). *Euphausia superba*, followed by penguins, constituted the bulk of the diet by mass of leopard seals (sampled only in 2000), whereas fish contributed only marginally to the diet (Table 1, see details in Casaux et al. 2009).

The prey that most re-occurred among seals were *E. superba*, bivalves (which might be secondary prey coming from the stomachs of targeted prey), *Psychroteutis glacialis* and the myctophids *Gymnoscopelus nicholsi* and *Electrona antarctica*. The re-occurrence of prey among Weddell seals and Antarctic fur seals was 45.2% in 1998 and 32.3% in 2000 by including leopard seals (Table 2). The dietary similarity index "*S*" of prey overlap fluctuated widely between seals of different species in pairwise comparisons. The highest and lowest values of prey overlap were observed between Antarctic fur and leopard seals (67.9) and between Weddell and leopard seals (3.4), respectively; the prey overlap between Antarctic fur and Weddell seals presented intermediate values both in 1998 (47.6) and in 2000 (30.7).

Discussion

The three seal species investigated in this study shared the consumption of *E. superba*, *P. glacialis* and the myctophids *G. nicholsi* and *E. antarctica*. Generally, the three seal species showed only moderate or low re-occurrences of prey species in a comparison of their dietary spectrum. When the dietary spectrum was pairwise compared between seal species, a high degree of prey overlap was observed between leopard seals and Antarctic fur seals for the year for which data are available. This was related to the fact that *E. superba* and penguins were important components in the diet of both seal species. The contribution of *E. superba* to the diet could potentially be overestimated given that both seal species could have been indirect krill consumers by preying upon krill-feeding penguins. Studies focused on marine fish assemblages of the Northern hemisphere indicated that although prey overlap between species pairs was high, the competition among predators was low due to the high abundance of their main prey (Høines and Bergstad 1999, 2002). In this sense, Barrera-Oro (2003) suggested that an analogous phenomenon may occur in Antarctica among important krill predators, principally in summer. However, in our data, fishes were an important component in the samples of Antarctic fur seals but not in those of leopard seals, which might reflect different food preferences or otherwise the exploitation of alternative resources or feeding grounds to reduce food competition or predation risks. The Weddell seal preyed predominantly on fish, whereas *E. superba* and penguins were scarcely represented or even absent from the Weddell seals dietary spectrum. This explains the low prey

Table 1 Composition of the diet (as mass percent) of three species of seals at the Danco Coast, Antarctic Peninsula in 1998 and 2000

	Weddell seal 1998	Antarctic fur seal 1998	Weddell seal 2000	Antarctic fur seal 2000	Leopard seal 2000
Crustaceans					
Euphausia superba	0.0	3.8	0.0	60.6	83.1
Decapods	0.1	–	–	–	–
Amphipods					
Gammarids	0.0	–	0.0	–	–
Isopods					
Glyptonotus antarcticus	0.0	–	0.1	–	–
Serolis sp.	0.0	–	–	0.0	–
Others	0.0	0.0	0.0	–	–
Molluscs					
Cephalopods					
Octopods					
Pareledone sp.	3.5	1.0	2.8	0.3	–
Teuthoids					
Psychroteutis glacialis	5.7	4.2	3.0	3.0	0.4
Gastropods					
Nacella concinna	0.0	0.0	0.0	0.0	–
Others	0.0	–	–	0.0	–
Bivalves	0.0	0.0	0.1	0.0	0.0
Polychaetes	0.0	0.0	–	–	–
Porifera	–	–	–	0.0	–
Fish					
Bathydraconidae					
Parachaenichthys charcoti	–	–	–	0.1	–
Channichthyidae					
Chaenodraco wilsoni	27.7	19.1	23.5	6.3	–
Chionodraco myersi	–	0.5	–	–	–
Chionodraco rastrospinosus	3.6	20.4	31.4	6.9	–
Cryodraco antarcticus	–	5.7	3.6	1.8	–
Pagetopsis macropterus	–	–	1.5	0.4	–
Pseudochaenichthys georgianus	–	–	1.0	–	–
Nototheniidae					
Gobionotothen gibberifrons	14.1	–	1.3	–	2.0
Lepidonotothen nudifrons	1.2	–	–	0.0	–
Notothenia coriiceps	–	0.1	–	–	–
Nototheniops larseni	–	–	–	0.0	–
Pagothenia borchgrevinki	–	0.1	–	–	–
Pleuragramma antarcticum	28.5	13.2	27.9	8.5	–
Trematomus bernacchii	4.3	0.1	0.2	0.0	–
Trematomus newnesi	–	0.1	–	0.2	–
Trematomus scotti	3.6	–	–	–	–
Myctophidae					
Electrona antarctica	2.3	1.4	1.2	1.7	0.1
Electrona carlsbergi	–	–	–	0.1	–
Gymnoscopelus braueri	0.1	0.0	–	0.1	–
Gymnoscopelus nicholsi	5.0	11.9	2.3	4.8	1.6
Krefftichthys anderssoni	–	0.0	–	–	–
Protomyctophum normani	0.1	–	–	0.0	–

Table 1 continued

	Weddell seal 1998	Antarctic fur seal 1998	Weddell seal 2000	Antarctic fur seal 2000	Leopard seal 2000
Paralipididae					
Notolepis coatsi	0.1	–	0.1	–	–
Bathylagidae					
Bathylagus antarcticus	–	–	–	0.0	–
Birds					
Penguins	–	18.4	–	5.2	12.8

Taken from Casaux et al. (2003b, 2006, 2009)

Table 2 Re-occurrence of prey among three species of seals at the Danco Coast, Antarctic Peninsula, in 1998 and 2000

	Weddell seal 1998	Antarctic fur seal 1998	No of re-occ.	Weddell seal 2000	Antarctic fur seal 2000	Leopard seal 2000	No of re-occ.
Crustaceans							
Euphausia superba	+	+	1	+	+	+	2
Decapods	+		0				0
Amphipods							
Gammarids	+		0	+			0
Isopods							
Glyptonotus antarcticus	+		0	+			0
Serolis sp.	+		0		+		0
Others	+	+	1	+			0
Molluscs							
Cephalopods							
Octopods							
Pareledone sp.	+	+	1	+	+		1
Teuthoids							
Psychroteutis glacialis	+	+	1	+	+	+	2
Gastropods							
Nacella concinna	+	+	1	+	+		1
Others	+	0			+		0
Bivalves	+	+	1	+	+	+	2
Polychaetes	+	+	1				0
Porifera			0		+		0
Fish							
Bathydraconidae							
Parachaenichthys charcoti			0		+		0
Channichthyidae							
Chaenodraco wilsoni	+	+	1	+	+		1
Chionodraco myersi		+	0				
Chionodraco rastrospinosus	+	+	1	+	+		1
Cryodraco antarcticus		+	0	+	+		1
Pagetopsis macropterus			0	+	+		1
Pseudochaenichthys georgianus			0	+			0
Nototheniidae							
Gobionotothen gibberifrons	+		0	+		+	1
Lepidonotothen nudifrons	+		0		+		0
Notothenia coriiceps		+	0				

Table 2 continued

	Weddell seal 1998	Antarctic fur seal 1998	No of re-occ.	Weddell seal 2000	Antarctic fur seal 2000	Leopard seal 2000	No of re-occ.
Nototheniops larseni			0		+		0
Pagothenia borchgrevinki		+	0				
Pleuragramma antarcticum	+	+	1	+	+		1
Trematomus bernacchii	+	+	1	+	+		1
Trematomus newnesi		+	0		+		0
Trematomus scotti	+		0				
Myctophidae							
Electrona antarctica	+	+	1	+	+	+	2
Electrona carlsbergi			0		+		0
Gymnoscopelus braueri	+	+	1		+		0
Gymnoscopelus nicholsi	+	+	1	+	+	+	2
Krefftichthys anderssoni		+	0				
Protomyctophum normani	+		0		+		0
Paralipididae							
Notolepis coatsi	+		0	+			0
Bathylagidae							
Bathylagus antarcticus			0		+		0
Birds							
Penguins		+	0		+	+	1
Total re-occurrences			14				20
Maximum possible			31				62
% Of re-occurrences			45.2				32.3

overlap between Weddell seals and leopard seals. For both seasons, the magnitude of prey overlap between Weddell seals and Antarctic fur seals was mainly determined by the degree of fish consumption by the latter seal species. As observed, the three seal species preyed on fish to a different degree. Thus, fish might be important to buffer interspecific resource competition, particularly in years of low krill availability.

It can therefore be concluded that the three seal species are capable of foraging on all of the prey represented in the total of the number of samples considered here, and it was expected that some degree of food specialization would occur. Leopard seals preyed predominantly on *E. superba*, Antarctic fur seals consumed comparatively less *E. superba* and more fish, and Weddell seals were markedly more ichthyophagous than the other two species. Based on the assumption of an adequate diversity of prey species, our observations indicate some degree of resource partitioning that might have been driven by food competition. Other studies highlighted the capacity of Weddell seals to switch between pelagic and benthic resources (Plötz et al. 1991; Casaux et al. 1997), whereas Casaux et al. (2004) reported an unusual consumption of penguins by Antarctic fur seals in two consecutive seasons at Nelson Island. Such findings were fully or partially explained in terms of changes in prey availability. However, according to our interpretations, these varying preferences might also be explained by changes in the diet due to food competition. Future studies should consider multi-species diet analyzes in order to interpret interspecific foraging relationships between seals to improve our knowledge on their foraging behavior and to consider their potential as indicator species in light of changes in marine ecosystems.

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