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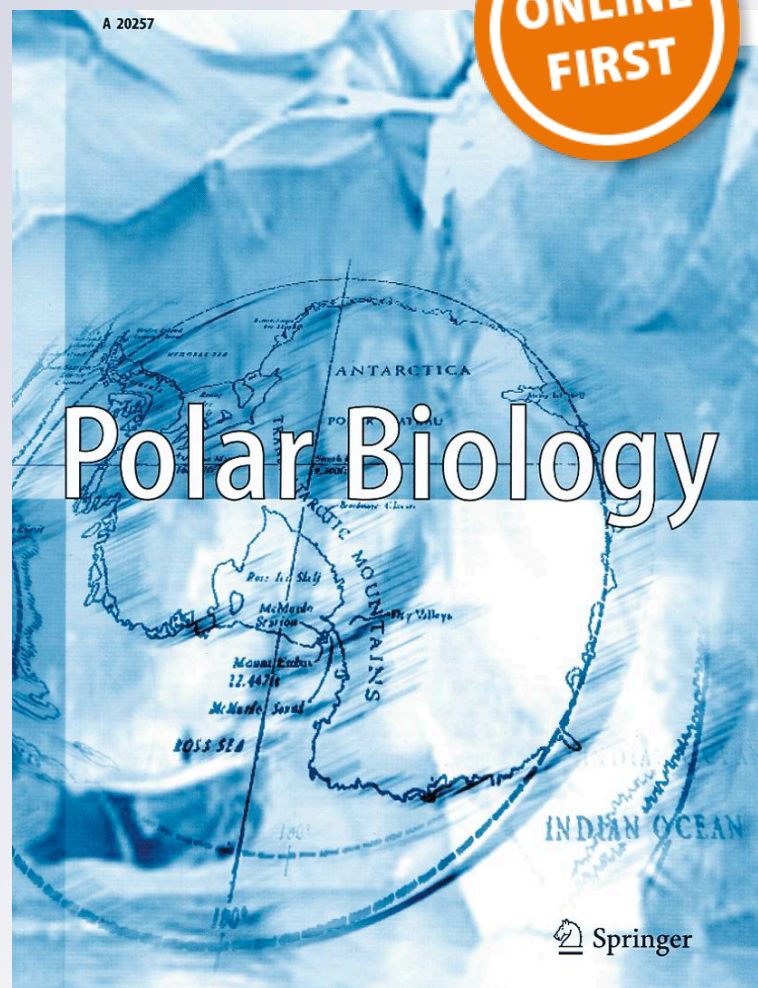
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Stomach contents of long-finned pilot whales (*Globicephala melas*) from southern Chile

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Abstract The widely distributed long-finned pilot whale (*Globicephala melas*) has been reported off the Chilean coast, from Iquique (20°12'S) south to Navarino Island (55°15'S; 67°30'W), but little is known about its biology or ecology in the region. Here, we report on the prey of this species, identified by stomach content analyses from animals stranded on Holget Islets, Beagle Channel, southern Chile in August 2006. The stomachs of seven individuals (six females and one male) contained cephalopod remains. The prey composition found in these southern Chilean pilot whales was similar to that described in other parts of the world and the Southern Ocean. This is the first report on the feeding habits of this species from Chile.

Keywords *Globicephala melas* · Beagle Channel · Mass stranding · Stomach content · Cephalopods · Southern Ocean

Introduction

Marine mammal feeding is often poorly understood due to environmental and behavioral challenges: observations are difficult (feeding usually takes place below the surface), researcher presence can disturb animals' foraging behavior, and feeding events may occur quickly (Heithaus and Dill 2002). Some aspects of feeding, such as diet, are possible to study by the analysis of digestive tracks of stranded individuals and analyses of prey hard structures that resist the digestion process, such as bones and cephalopod beaks (Perrin and Geraci 2002). Mass stranding events offer the rare opportunity of collecting data from many individuals, which gives a better representation of the feeding habits of those species.

The long-finned pilot whale (*Globicephala melas*, Traill 1809) is a widely distributed cetacean. In the Northern Hemisphere (*G. m. melas* subspecies), it is found only in the Atlantic Ocean north of 20°N; however, they are more extended in the Southern Hemisphere (*G. m. edwardii* subspecies), where they range in the southern South Pacific, South Atlantic, and mostly across the Southern Ocean (Olson and Reilly 2002). Off South America, this species has been recorded along the coast of Chile from Iquique (20°12'S) south to Navarino Island (55°15'S; 67°30'W) in the Cape Horn area, and also near the offshore island of San Ambrosio (26°20'37"S; 79°53'28"W) (Aguayo-Lobo et al. 1998). In the southwestern South Atlantic, this species has been recorded from southern Brazil, Uruguay, along the coast of Argentina (Bastida and Rodríguez 2003; Crespo et al. 2008), and around the Falkland (Malvinas) Islands (Otley et al. 2008; www.falklandsconservation.com/wildlife/FISStateOfTheEnvRpt08.pdf). It has also been reported around the South Shetland Islands, in the Antarctic Peninsula area (Aguayo-Lobo et al. 1998).

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The long-finned pilot whale frequently suffers mass strandings (Olson and Reilly 2002; Perrin and Geraci 2002). A significant number of the strandings result in high mortality of the whales involved. During these events, important biological and ecological aspects of the species may be gathered, including diet. Stomach content analyses after necropsy have revealed that cephalopods are the main prey item for the long-finned pilot whale in different parts of its worldwide distribution, such as Argentina (Clarke and Goodall 1994), Brazil (Santos and Haimovici 2001), Falkland (Malvinas) Islands (H. Otley pers. comm.), Australia (Gales et al. 1992), New Zealand (Beatson et al. 2007a, b; Beatson and O'Shea 2009), along the USA, Atlantic coast (Gannon et al. 1997) and the coast of Normandy, English Channel (De Pierrepont et al. 2005).

In Chile, little is known about the biology and ecology of this species due to the limited number of records of both sightings and strandings. Some single strandings have been reported (Venegas and Sielfeld 1978), but only three mass strandings had been recorded. The first occurred in March 1979, on Windhond Bay (55°15'S; 67°30'W), Navarino Island (Venegas and Sielfeld 1980) involving 125 individuals. The second occurred at Poseidón Bay (52°17'S; 69°13'W), in the Strait of Magellan, in August 1982 including 61 pilot whales (C. Venegas pers. comm.). The third, of 13 individuals, was on Holger islets (54°56'S; 67°15'W), Beagle Channel, in August 2006 (Olavarria unpublished data). Only in the latter case were stomach content samples collected. Their analyses are reported here. Our aim was to get new insights into the prey species composition of long-finned pilot whales from southern Chile, to complement the sparse information in the Southern Ocean.

Materials and methods

The stranding and sample collection

On August 8, 2006, a group of 13 long-finned pilot whale stranded along the coasts of the Holget islets, Beagle Channel, in southern Tierra del Fuego. The stranding was found by the crew of a Chilean Navy helicopter patrolling the area. Due to the remoteness of the area, 5 days passed before it was possible for one of us (CO) to visit the area. Of the 13 whales, one had floated into the Beagle Channel, where fishermen found and flensed it. Additionally, a single pilot whale was found in the easternmost part of the Beagle Channel, on the coast of Estancia Moat the same month. This pilot whale is believed to be from the same stranding. Only skeletal remains were collected (RNP Goodall pers. comm.).

In the field, the sex and several morphological measurements were recorded, and samples were obtained. Sex identification was confirmed later by DNA analysis from skin samples (Gilson et al. (1998); Olavarria unpublished data). Necropsies performed on seven of the 13 individuals allowed for collection of the stomach content from six females and one male. The examination of intestines revealed prey remains in only one individual (in the rectum). Weather and time constraints prevented the examination of other individuals.

All prey remains from stomach and intestine contents were stored in 95 % ethanol until laboratory analyses. Samples were washed with water and retained using a 1-mm sieve (Beatson et al. 2007a). Cephalopod beaks and a few eye lenses were found after washing; however, only individual beaks were used in further analyses given the lack of references for identifying species using eye lenses. Beaks were cleaned using a soft brush and separated into upper or lower beak categories. The species identification was performed by comparison with key references (Clarke 1986; Kubodera et al. 1998; Lu and Ickeringill 2002; Xavier and Cherel 2009). Rostral and hood length (RL and HL, respectively) were measured according to Xavier & Cherel (2009) protocol, using a ruler under a microscope (uncertainty of the rule was ± 0.5 mm). The mantle length (ML) and total weight (TW) were estimated using the regression equations in Xavier and Cherel (2009).

Results

A total of 148 mandibles were taken from the stomachs and intestines of the 7 pilot whales and 86 % of those were identified. The remaining 14 % could not be identified due to being partially broken, poor development of structures and/or the lack of representation in the taxonomic keys of Southern Ocean cephalopod species.

The majority of squid beaks were found in the stomachs of only two whales (ID numbers 801 and 805) (Table 1). Three cephalopod species were identified: *Chiroteuthis veranyi*, *Martialia hyadesi* and *Moroteuthis ingens*. A few beaks from the genus *Moroteuthis* formed a fourth group, which was not possible to identify to species level. *Martialia hyadesi* and *Moroteuthis ingens* were the most abundant prey species. For the last two species, the RL and HL values (and the estimated ML and TW) show that a range of prey sizes were consumed by these long-finned pilot whales (Tables 2, 3).

Discussion

The diet of long-finned pilot whales stranded in southern Chile seems to be comprised exclusively by cephalopods.

Table 1 Prey composition and frequency in stomach contents of *G. melas* on the Holger Islets, Beagle Channel, southern Chile

Individual pilot whale	801	803	804	805	805 Rectum ^a	806	807	809
Sex	F	F	F	F	F	F	F	M
Length of whale (cm)	444	439	259	423	423	465	410	515
Chiroteuthidae								
<i>Chiroteuthis veranyi</i>					2			
Ommastrephidae								
<i>Martialia hyadesi</i>	17	2	1	20	1	1		
Onychoteuthidae								
<i>Moroteuthis ingens</i>	20	1		19	3	15	1	4
<i>Morotheuthis</i> sp.				7	1			
Unidentified	2	2	3	4	1		1	
Total upper cephalopod beaks	22	3	2	18	3	4	0	0
Total lower cephalopod beaks	17	2	2	32	5	12	2	4

^a The only individual with prey remains in the intestine

Table 2 Cephalopod beak measurements from *G. melas* stranded on the Holger Islets, Beagle Channel, southern Chile

Cephalopod species	Upper beak				Lower beak			
	N	Mean (mm)	Range (mm)	SD	N	Mean (mm)	Range (mm)	SD
<i>Moroteuthis ingens</i>								
RL	25	5.76	9.50–2.50	1.60	32	8.73	11.50–1.00	1.96
HL	25	16.20	26.00–7.00	4.68	32	6.57	9.00–1.80	1.28
<i>Martialia hyadesi</i>								
RL	7	5.03	8.00–2.00	2.36	28	6.97	9.50–3.00	1.58
HL	7	14.00	20.50–5.50	6.22	28	6.23	8.00–3.00	1.23

Table 3 Mean mantle length (ML) and total weight (TW) estimated from lower beak rostral length (LRL; following regression equations in Xavier and Chereil 2009) for cephalopod species from *G. melas* stranded on Holger Islets, Beagle Channel, southern Chile

Species	N	LRL (mm)		ML (mm)		TW (gr)	
		Mean	SD	Mean	SD	Mean	SD
<i>M. ingens</i>	32	8.73	1.96	311.71	47.80	850.94	267.36
<i>M. hyadesi</i>	28	6.97	1.58	307.45	46.57	578.89	236.21
<i>C. veranyi</i>	1	4.5		121.47		45.61	

This is consistent with studies undertaken in other parts of the Southern Ocean, where this group is the main prey for the species (Gales et al. 1992; Clarke and Goodall 1994; H Otley pers. comm.; Beatson et al. 2007a, b; Beatson and O'Shea 2009). Some of the studies have shown a proportion of fish in their diet (Gales et al. 1992; H. Otley pers. comm.; R. N. P. Goodall, pers. comm.), which were not found here. This could be the result of a difference in diet preference or of sampling.

The three species identified here as prey of long-finned pilot whales have been found distributed in Chilean waters (Vega 2009). *Moroteuthis ingens* is found south of 39°S, but more commonly south of 42°S off Chile (Vega 2009).

In other locations, this species has been reported in sub-antarctic waters north of the Antarctic Convergence (Roper et al. 1985). *M. ingens* has been also found south of the subtropical convergence off Patagonia and New Zealand; however, it probably has a circumantarctic distribution (Kubodera et al. 1998). The full bathymetric range of distribution of this epipelagic oceanic species is unknown (Vega 2009), although it has been recorded at 400 m (Roper 1981). *Martialia hyadesi* is found south of 40°S in the southwestern South Atlantic, South Pacific and Southern Ocean (Roper et al. 1985; Nesis 1987; Wormuth 1998; Vega 2009). Its bathymetric distribution in the southwestern South Atlantic indicates that mainly lives in waters

deeper than 250 m (González et al. 1997). *Chiroteuthis veranyi* has been reported for Peru and northern and central Chile south to 40°–45°S (Nesis 1972, 1987; Rocha 1992; Alexeyev 1994). It has been suggested that near the Cape Horn, this species could have an Atlantic origin. The bathymetric distribution of adults shows that they live in the mesopelagic and bathypelagic zone to depths of up to 2,000 m (Nesis 1972, 1987).

Two out of the three species of cephalopods found in our study had been reported as prey of the long-finned pilot whale before, *M. ingens* from Falkland (Malvinas) Islands (H. Otley pers. comm.) and *C. veranyi* in New Zealand (Beatson et al. 2007b) and off Brazil (Santos and Haimovici 2001). They also have been reported as prey of other marine predators. *M. ingens* is common in the diet of the king penguin (*Aptenodytes patagonicus*), wandering albatross (*Diomedea exulans*), royal albatross (*Diomedea epomophora*) and southern opah (*Lampris immaculatus*) (Clarke and Goodall 1994; Cherel et al. 1996; Cherel and Klages 1998; Cherel and Weimerskirch 1999; Jackson et al. 2000; Xavier and Cherel 2009). *C. veranyi* is present in the diet of a wide range of predators, such as albatrosses, petrels, fish, dolphins, toothed whales and seals (Xavier and Cherel 2009). This species is not usually an important prey item, except in the case of the Patagonian toothfish at the Kerguelen Islands (Cherel et al. 2004). *Martialia hyadesi* has been commonly found in the diet of albatrosses, petrels, penguins, fish, toothed whales and sharks, but has not previously been reported as prey of long-finned pilot whales (Cherel and Klages 1998; Croxall et al. 1999; Waugh et al. 1999; Xavier et al. 2003; Xavier and Cherel 2009).

Cephalopods are important prey items of several species of marine mammals, and the analysis of their stomach contents helps to better understand the trophic interactions in the marine environment. The data presented here contribute to the understanding of a particularly poorly understood region.

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