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Stomach contents of cetaceans stranded in the Canary Islands 1996–2006

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Stomach contents were analysed from 23 cetaceans, including individuals of 12 species from the families Delphinidae, Physeteridae, Kogiidae and Ziphiidae, stranded between 1996 and 2006 in the Canary Islands. Cephalopod mandibles (beaks) were found in 21 stomachs and fish remains (otoliths and jaw bones) appeared in 4 stomachs. Two stomachs contained only eye lenses. Cephalopods eaten by dolphins were mainly from the families Ommastrephidae, Sepiidae and Enoploteuthidae, whereas whales had mainly taken specimens of the oceanic squid families Histiotheutidae and Cranchiidae. Fish remains included a pelagic species (i.e. garfish, Belone belone*) in dolphin stomachs and bathypelagic (i.e. black scabbard fish,* Aphanopus carbo*, lantern fish,* Lampadena luminosa*) and demersal species* (Lophius *sp.*) *in a pygmy sperm whale* (Kogia breviceps) *stomach. Most of the prey species identified are not of commercial interest but one of the sperm whales* (Physeter macrocephalus) *contained a fishing hook among the stomach contents. Five (22%) of the cetaceans examined had also plastic debris in their stomachs, with big plastic items being taken by deep diving teuthophagous whales.*

Keywords: feeding, Canary Islands, cetaceans, cephalopods, plastic

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INTRODUCTION

The Canary Islands are situated within the biogeographical region of the Macaronesia which also includes the islands of Azores, Madeira, Savage Islands and Cape Verde (Carrillo, 2007). The Canary Islands are a major hotspot for marine mammals in European waters with 29 cetacean species recorded in the archipelago (Carrillo, 2007). The area's unique oceanographical characteristics are suitable for both tropical and temperate-water cetaceans, as warm oligotrophic waters of the open ocean coexist with nutrient-rich waters of the coastal upwelling regime brought by the Canary Current (Barton *et al.*, 1998). The narrow continental shelf leads to the presence of both oceanic and inshore cetacean species close to the coast (Martín *et al.*, 1992).

Most of the cetacean species recorded in the archipelago have a worldwide distribution or an extended presence in temperate and warm oceans. Sperm whales, *Physeter macrocephalus* (L., 1758), are widely distributed worldwide, with most of the sightings of the species taking place in deep waters and higher densities found in areas of high primary productivity (Whitehead, 2002). Sperm whales segregate by sex and females with calves in the northern hemisphere do not usually travel further north than 40–45°N, whereas juvenile and adult males migrate to higher latitudes in spring/summer returning to lower latitudes in winter (Best, 1979). Other species present in the Canary Islands and distributed worldwide in warm and temperate waters are the pygmy sperm whale *Kogia breviceps* (de Blainville, 1838), bottlenose dolphin, *Tursiops truncatus* (Montagu, 1821), Risso's dolphin, *Grampus griseus* (Cuvier, 1812), common dolphin, *Delphinus delphis* (L., 1758) and striped dolphin, *Stenella coeruleoalba* (Meyen, 1833) (Wells & Scott, 1999; Archer, 2002; Baird, 2002; McAlpine, 2002; Perrin, 2002b).

In addition, several cold-water cetacean species are at their southern distribution limit in Macaronesia whereas Macaronesia represents the northern distribution boundary for some warm-water species such as the Atlantic spotted dolphin, *Stenella frontalis* (Cuvier, 1829), rough-toothed dolphin, *Steno bredanensis* (Cuvier in Lesson, 1828), or Fraser's dolphin, *Lagenodelphis hosei* (Fraser, 1956) (Carrillo, 2007). The Atlantic spotted dolphin is endemic to the tropical and warm-temperate waters of the Atlantic (Perrin, 2002a) while Fraser's dolphin and rough-toothed dolphin occur in tropical and subtropical seas (Dolar, 2002; Jefferson, 2002). Other warm-water species common in the Canary Islands are Gervais' beaked whale, *Mesoplodon europaeus* (Gervais, 1838), which is restricted to the North Atlantic (Pitman, 2002) and the short-finned pilot whale, *Globicephala macrorhynchus* (Gray, 1846), which occurs both in tropical and subtropical oceans (Olson & Reilly, 2002).

Little is known about the diet of most of the Canary Islands' cetacean species. Previous reports have provided information on beaked whales (Ziphiidae) (Martín *et al.*, 1990; Hernández-García, 1995; Santos *et al.*, 2007b), short-finned pilot whale (Hernández-García & Martín, 1994) and pygmy sperm whale diets (Hernández-García & Martín, 1996).

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Stomach contents of sperm whales have been analysed from other Macaronesian islands such as Madeira and the Azores (Clarke, 1962; Clarke *et al.*, 1993).

The aim of this paper is to present new information on the feeding habits of cetaceans present in Canary Islands waters, an area where relatively little information is available on cetacean trophic ecology in spite of the high number of cetacean species present. We also compare our results with those of other European populations of the same species and examine possible threats to cetaceans in the archipelago relating to interactions with fisheries and consumption of plastic debris.

MATERIALS AND METHODS

Sample collection

Strandings were attended by Canarias Conservación, based in Tenerife and providing all year-round coverage for the occidental islands of the archipelago (e.g. Tenerife, La Gomera, La Palma and El Hierro) as a member of the local stranding network supported by the Natural Environment Department of the Canary Islands Government. Animals were measured and sexed, and cause of death was determined when possible. Detailed post-mortem examinations of the digestive tract were carried out in all animals and stomach contents were subsequently preserved in 70% ethanol. Stranding locations are shown in Figure 1.

Stomach contents of 23 cetaceans, including 12 species from 4 families, stranded between 1996 and 2006, were analysed (Table 1). The sample set comprised 5 sperm whales, 2 pygmy sperm whales, 1 Gervais' beaked whale, 1 Risso's dolphin, 2 short-finned pilot whales, 1 Fraser's dolphin, 3 Atlantic spotted dolphins, 3 striped dolphins, 1 bottlenose dolphin, 1 rough-toothed dolphin, 3 common dolphins and 1 Cuvier's beaked whale.

Prey remains consisted principally of cephalopod mandibles (beaks) and eye lenses. Some fish otoliths, bones and eye lenses were also found. Beaks were retained in 70% ethanol while otoliths and bones of fish were kept dried. Crustacean, mollusc and parasite remains were identified to species level when possible (depending on their state of preservation) and were stored in 70% alcohol.

Sample analysis

Cephalopod beaks and fish otoliths and bones were identified using reference collections held at the University of Aberdeen and published guides (e.g. Clarke, 1986; Härkönen, 1986).

The numbers of cephalopods and fish present were estimated from the numbers of beaks, otoliths and jaw bones. Cephalopod length and weight were calculated from linear measurements on beaks based on a compilation of published regressions (e.g. Clarke, 1986; Santos *et al.*, 2002). Complete pairs of cephalopod beaks were rarely present and, in all cases, length and weight were estimated from the lower beak using standard measurements (rostral length for squid and hood length for octopus and sepiolids; Clarke, 1986). For stomachs in which one cephalopod species/size-class was represented by >30 beaks, a random sample of 30 to 100 beaks was measured. No published length–weight regressions were available for *Taningia danae* (Joubin, 1931), *Discoteuthis* spp. and beaks identified as *Cranchia/Lyocranchia* (family Cranchiidae). Each fish otolith/jaw bone was assumed to represent 0.5 fish. Total lengths of black scabbard fish, *Aphanopus carbo* (Lowe, 1839), garfish, *Belone belone* (L., 1761), and *Lophius* sp. were estimated from their lower jaws (dentaries) since no otoliths were available. Black scabbard fish and *Lophius* sp. weights were later derived applying a length–weight regression obtained from Fishbase (www.fishbase.org). Garfish weight was estimated from a published length–weight regression. No published length–weight relationships were available for the lantern fish, *Lampadena luminosa* (Garman, 1899).

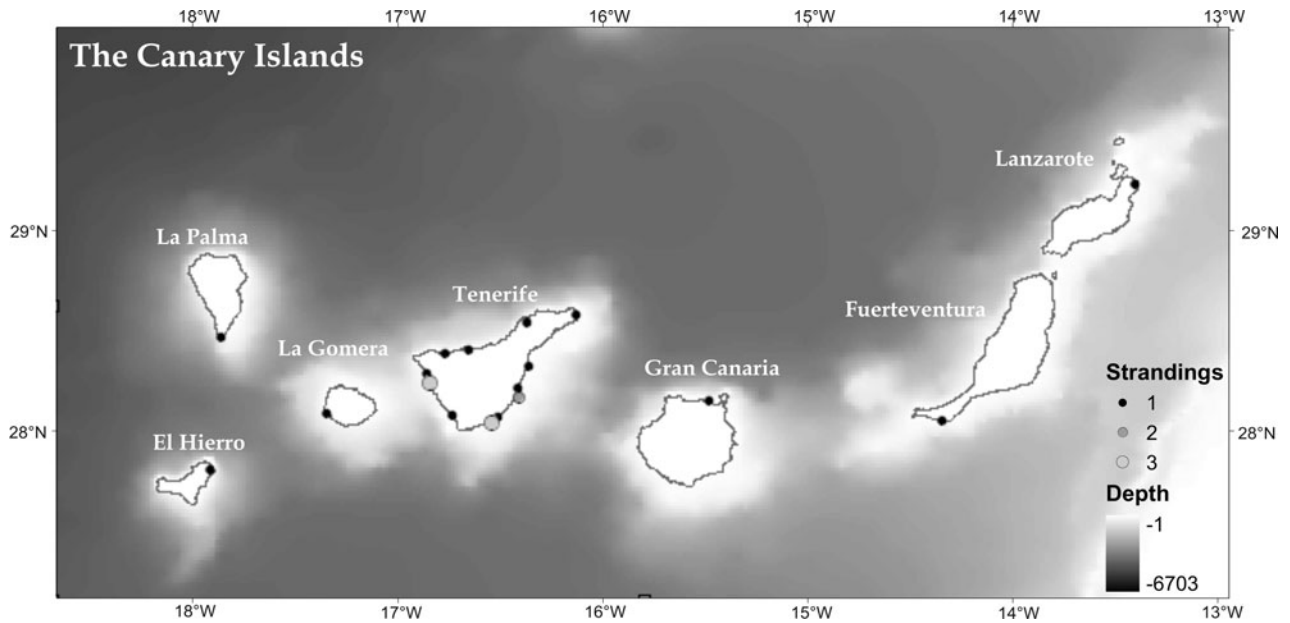

Fig. 1. Map of the study area, showing the locations of cetacean strandings in the present study.

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Table 1. Data on stranded cetaceans included in the analysis. Sperm whales (*Physeter macrocephalus*, Pma), pygmy sperm whales (*Kogia breviceps*, Kbr), Gervais' beaked whales (*Mesoplodon europaeus*, Meu), Risso's dolphins (*Grampus griseus*, Ggr), short-finned pilot whales (*Globicephala macrorhynchus*, Gma), Fraser's dolphins (*Lagenodelphis hosei*, Lho), Atlantic spotted dolphins (*Stenella frontalis*, Sfr), striped dolphins (*Stenella coeruleoalba*, Sco), bottlenose dolphins (*Tursiops truncatus*, Ttr), rough-toothed dolphin (*Steno bredanensis*, Sbr), common dolphins (*Delphinus delphis*, Dde) and Cuvier's beaked whales (*Ziphus cavirostis*, Zca).

Code	Sex	Length	Date	Location	Island	Reconstructed weight of prey remains (g)
Pma-1	Female	970	25 October 2002	Fuencaliente	La Palma	77856.86
Pma-2*†	Male	953	11 October 2003	Valverde	El Hierro	93.43
Pma-3	Male	1090	6 February 2003	Jover	Tenerife	73422.63
Pma-4†	Female	1050	1 October 2004	Granadilla	Tenerife	357357.42
Pma-5†	Female	686	11 May 2005	Morrojable	Fuerteventura	1677377.34
Kbr-1	Unknown	245	1 May 2002	San Juan de la Rambla	Tenerife	–
Kbr-2**	Male	188	21 June 2006	Güimar	Tenerife	4429.51
Meu	Female	302	12 July 2004	Garachico	Tenerife	735.85
Ggr	Female	162	6 February 2005	Las Eras	Tenerife	182.53
Gma	Female	353	8 December 2001	Los Gigantes	Tenerife	1025.76
Lho	Female	200	17 April 2005	Haría	Lanzarote	543.90
Sfr-1	Male	182	21 July 2001	Montaña Pelada	Tenerife	40.46
Sfr-2	Male	184	4 January 2003	Playa de Antequera	Tenerife	–
Sfr-3	Male	140	27 March 2004	Los Gigantes	Tenerife	3.88
Sco-1	Female	160	7 March 2003	Granadilla	Tenerife	1206.34
Sco-2	Male	188	26 April 2004	Granadilla	Tenerife	29.64
Sco-3	Female	183	14 June 2005	El Poris	Tenerife	50.45
Ttr	Male	305	31 December 1996	Masca	Tenerife	408.87
Sbr	Female	240	20 May 2004	Arucas	Gran Canaria	7768.30
Dde-1	Male	200	9 April 1998	El Poris	Tenerife	0.89
Dde-2	Male	211	2 February 2004	Arona	Tenerife	42.77
Dde-3	Male	223	30 April 2006	Los Gigantes	Tenerife	358.07
Zca	Male	>490	4 June 2006	Valle Gran Rey	A Gomera	–

*, sexually mature; **, genital organs absent, advanced state of decomposition, partially eaten by sharks; †, cause of death was collision with ships.

It should be noted that the final reconstructed prey weight is an underestimation since broken or unidentified beaks, otoliths or lower jaws did not contribute to the total estimated prey weight. The same occurred when no length–weight relationships were available (see above).

For each individual cetacean analysed, relative importance for each prey type in its stomach contents was estimated using two standard indices: (a) proportion of the total number of prey; and (b) proportion of total prey weight.

RESULTS

The single specimen of Cuvier's beaked whale examined had only cephalopod eye lenses in its stomach and the stomach of one Atlantic spotted dolphin (Sfr-2) contained only fish eye lenses. These two animals were not included in further analyses.

Sperm whales

All five sperm whale stomachs contained cephalopod beaks and eye lenses. No fish remains where recorded and crustaceans (identified as *Lepas* sp.) were present in only one individual (Pma-3; Table 1). This whale also had a plastic bag in its stomach (size 31 × 20 cm) while a fishing hook of approximately 6 cm in length was present in the stomach of another whale (Pma-4). The number of cephalopod beaks in the stomachs ranged from 12 lower and 7 upper beaks (Pma-2) to 4856 lower and 5313 upper beaks (Pma-5). A minimum of 1 (Pma-2) and a maximum of 22 (Pma-5) cephalopod taxa were identified from the stomachs. Cephalopods from the genus *Histioteuthis* were the most numerous prey for four out of the five whales (Table 2).

Estimated sizes (dorsal mantle length (DML)) of *Histioteuthis* type A ranged from 85 mm to 229 mm with a mode at 125 mm, as compared to 44–110 mm (mode 85 mm) for *H. meleagroteuthis* (Chun, 1910), 252–369 mm (modes 295 and 315 mm) for *Galiteuthis armata* (Joubin, 1898), 119–361 mm (mode 250 mm) for *Teuthowenia megalops* (Proch, 1947) and 128–248 mm (mode 155 mm) for *Chiroteuthis veranyi* (Ferussac, 1835) (Figure 2). Seven beaks of the giant squid *Architeuthis* sp. were present with an estimated size-range of 738–1952 mm DML.

Reconstructed total biomass of prey represented by remains in sperm whale stomachs ranged from 93 g (Pma-2) to more than 1.5 tonnes (Pma-5).

Pygmy sperm whales and Gervais' beaked whale

Both pygmy sperm whale stomachs contained remains of crustacean exoskeletons, parasitic nematodes, cephalopod and fish. Sixteen cephalopod species and 4 different fish taxa were identified from the remains (Table 3). Four sheets of plastic (sizes ranging from 34 × 1 cm to 68 × 8 cm) and one plastic filament of approximately 10 cm in length were recovered also from one of the whale stomachs (Kbr-2).

The Gervais' beaked whale examined was the animal with the most plastic debris in its digestive tract: a complete plastic bag (size 44 × 24 cm) and pieces of another 2 (sizes 78 × 25 cm and 50 × 18 cm) were found together with 12 upper and 15 lower beaks from at least 3 different cephalopod species (Table 3). Three parasite nematodes were also found.

Estimated sizes (DML) of *Histioteuthis* type A found in the pygmy sperm whales ranged from 12 to 96 mm, as compared

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Table 2. Prey species and number of plastic items found in the stomachs of sperm whales, *Physeter macrocephalus* (Pma). For all prey species, number of beaks/other remains (N) and importance (%N, percentage by number; %W, percentage by weight) are indicated. For cephalopods number of beaks found are indicated (lower beaks, Lb, unless otherwise stated). The category *Histioteuthis* type A includes the species *Histioteuthis arcturi* Robson, 1948, *H. corona* Voss & Voss, 1962, *H. meleagroteuthis* Chun, 1910 and *H. bonellii* Clarke, 1980. The category *Chirotheuthis* type II includes beaks of the genus *Chiroteuthis* different from *Chiroteuthis veranyi* Ferussac, 1835 (Santos *et al.*, 2001).

Cephalopod prey		Pma-1 (970 cm)			Pma-2 (953 cm)			Pma-3 (1090 cm)			Pma-4 (1050 cm)			Pma-5 (686 cm)		
Family	**Species**	**N**	**%N**	**%W**	**N**	**%N**	**%W**	**N**	**%N**	**%W**	**N**	**%N**	**%W**	**N**	**%N**	**%W**
Ommastrephidae	*Todarodes sagitattus*	1	0.41	0.75	–	–	–	–	–	–	–	–	–	75	1.54	9.99
Gonatidae	*Gonatus* sp.	–	–	–	–	–	–	–	–	–	7	0.60	0.56	9	0.19	0.05
Architeuthidae	*Architeuthis* sp.	–	–	–	–	–	–	3	2.08	2.75	1	0.09	2.96	3	0.06	1.41
Vampiroteuthidae	*Vampiroteuthis infernalis*	–	–	–	–	–	–	–	–	–	1	0.09	0.08	–	–	–
Ancistrocheridae	*Ancistrocheirus lesveuri*	–	–	–	–	–	–	–	–	–	4	0.34	0.69	6	0.12	0.19
Cranchiidae	*Teutowenia* sp.	5	2.02	1.26	–	–	–	–	–	–	44	3.77	1.39	76	1.57	0.53
	Megalocranchia sp.	–	–	–	–	–	–	6	4.17	1.89	7	0.60	–	131	2.7	1.07
	Megalocranchia sp.?	5	2.02	1.44	–	–	–	2	1.39	2.04	–	–	–	–	–	–
	Galiteuthis armata	30	12.15	8.63	–	–	–	2	1.39	0.68	202	17.31	13.13	480	9.89	5.67
	Taonius pavo	–	–	–	1	8.30	100	–	–	–	14	1.20	0.50	70	1.44	0.37
	Unidentified	–	–	–	–	–	–	–	–	–	25	2.14	2.39	–	–	–
Mastigoteuthidae	*Mastigoteuthis* sp.	–	–	–	–	–	–	–	–	–	7	0.60	0.84	12	0.25	0.14
Histioteuthidae	*Histioteuthis bonellii*	17	6.88	11.04	–	–	–	–	–	–	7	0.60	0.84	12	0.25	0.14
	Histioteuthis meleagroteuthis	11	4.45	2.57	–	–	–	–	–	–	13	1.11	0.33	103	2.12	0.82
	Histioteuthis type A	148	59.92	67.01	–	–	–	106	73.61	60.74	511	43.79	63.16	3202	65.94	68.06
	Histioteuthis reversa	2	0.81	0.23	–	–	–	–	–	–	12	1.03	0.25	24	0.49	0.15
Pholidoteuthidae	*Pholidoteuthis bochmai*	–	–	–	–	–	–	–	–	–	8	0.69	3.9	47	0.97	2.54
Chiroteuthidae	*Chiroteuthis veranyi*	5	2.02	0.87	–	–	–	1	0.69	0.20	32	2.74	1.54	53	1.09	0.34
	Chiroteuthis type II	–	–	–	–	–	–	–	–	–	7	0.60	0.26	36	0.74	0.32
Onychoteuthidae	*Moroteuthis* sp.	3	1.22	2.43	–	–	–	–	–	–	18	1.54	4.47	4	0.08	0.15
Cycloteuthidae	*Cycloteuthis sirventi*	–	–	–	–	–	–	–	–	–	–	–	–	28	0.58	0.56
	Discoteuthis sp.	–	–	–	–	–	–	–	–	–	20	1.71	–	18	0.37	–
Lepidoteuthidae	*Lepidoteuthis grimaldii*	3	1.22	3.77	–	–	–	2	1.39	12.08	1	0.09	2.17	17	0.35	4.10
Octopoteuthidae	*Octopoteuthis* sp.	–	–	–	–	–	–	–	–	–	15	1.28	1.33	72	1.48	1.07
	Taningia danae	–	–	–	–	–	–	–	–	–	–	–	–	7	0.14	–
Alloposidae	*Haliphron atlanticus*	–	–	–	–	–	–	1	0.69	3.22	2	0.17	0.04	4	0.08	0.02
Unidentified		–	–	–	–	–	–	1	0.69	–	46	3.94	–	–	–	–
Broken		17	6.88	–	11	91.70	–	4	2.78	–	170	14.48	–	329	6.78	–
Upper beaks, Ub		470	–	–	7	–	–	70	–	–	1565	–	–	5313	–	–
	Unidentified octopus Ub	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total Lb		244	100	100	12	100	100	144	100	100	1167	100	100	4856	100	100
Plastic items					1											

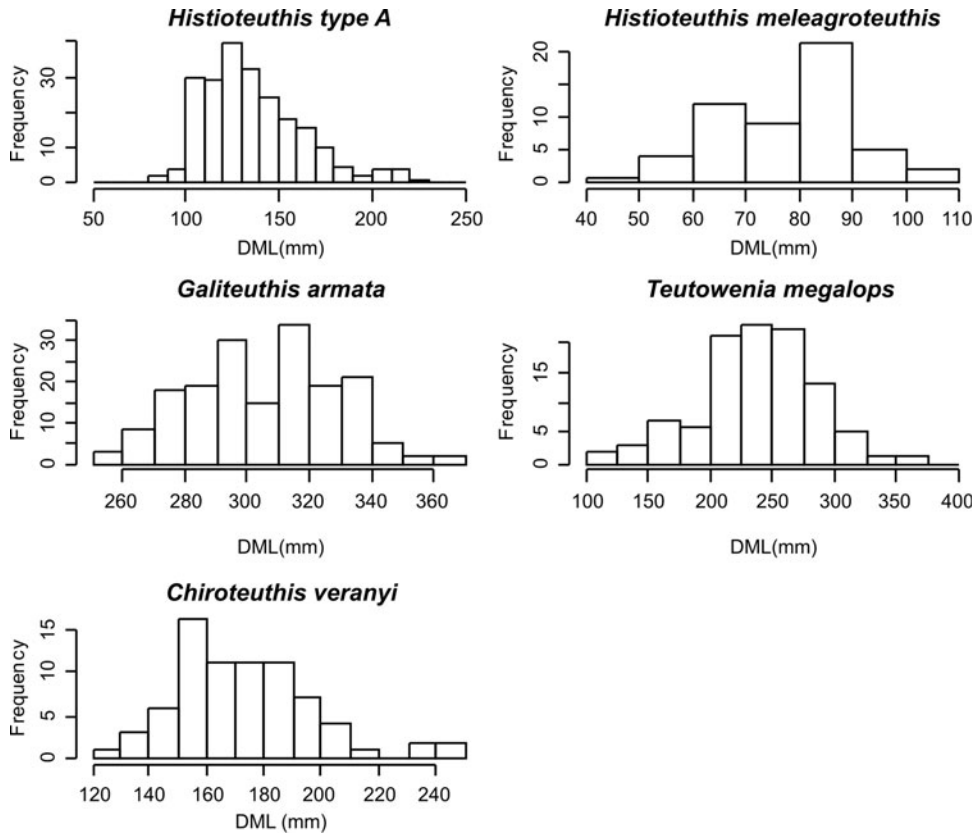

Fig. 2. Frequency distribution of estimated prey size (DML, dorsal mantle length) of the main prey taken by sperm whales in the Canary Islands.

to 32–65 mm for *H. meleagroteuthis*, 77–286 mm for *Taonius pavo* and 45–112 mm for *Chiroteuthis veranyi*. A beak of the giant squid *Architeuthis* sp. (131 mm estimated DML) was also found together with a specimen of black scabbard fish (*Aphanopus carbo*) (490 mm estimated total length). In the case of the Gervais' beaked whale, estimated sizes of *H. meleagroteuthis* type A (DML) were 8 and 111 mm, while the size of *C. veranyi* was estimated at 120 mm and sizes of *T. pavo* ranged from 71 to 231 mm.

Reconstructed prey biomass was 4429 g for the second pygmy sperm whale and 736 g for the Gervais' beaked whale (Table 1).

Risso's dolphin and short-finned pilot whale

A total of 55 lower and 30 upper beaks belonging to 4 cephalopod taxa (*Histioteuthis* type A, *Mastigoteuthis* sp., Sepiolidae and *Enoploteuthis* sp.) were recovered from the Risso's dolphin analysed (Table 3). The total prey reconstructed weight was 183 g (Table 1).

Only two lower beaks were found in the short-finned pilot whale stomach (Table 3). Reconstructed weight of the 2 prey taxa identified (*Todarodes sagittatus* of 309 mm DML and *Megalocranchia* sp. of 506 mm DML) was estimated to be more than 1 kg (Table 1).

Fraser's dolphin

The stomach of the single Fraser's dolphin examined contained 22 lower and 25 upper beaks from at least 6 cephalopod species (Table 4). One parasite isopod and one parasitic nematode were also found. In addition, 2 small pieces of plastic (sizes 11 × 2 cm and 10 × 3 cm) and a plastic filament of approximately 10 cm in length were present. Total reconstructed prey weight was 544 g (Table 1) with *Histioteuthis* type A (DML 16–50 mm) contributing with 64% by number and 67% by weight of the total prey biomass.

Atlantic spotted dolphins

Two Atlantic spotted dolphin stomachs were analysed and the lower beaks present were identified as belonging to the taxa *Histiotheuthis* type A and *Enoploteuthis* sp. (Table 4). Total reconstructed prey weight was 40 g for the first dolphin and less than 4 g for the second dolphin (Table 1). Remains of crustaceans (infraclass Cirripedia) were also found in one stomach.

Striped dolphins

The stomach of one dolphin contained 14 upper and 23 lower beaks from 5 cephalopod species. The most important prey species was *Chiroteuthis veranyi* which made up to 43% by number and 34% by weight of the total prey (Table 4). Cephalopod lenses and three parasite nematodes were also present. The other two stomachs examined contained lower beaks of *C. veranyi*, *Mastigoteuthis* sp. and *Octopoteuthis* sp. (Table 4). A plastic filament of around 10 cm in length was also present in one of the stomachs.

Estimated sizes of the squid *Histioteuthis* type A ranged from 23 to 62 mm DML whereas *C. veranyi* ranged from 82 to 145 mm DML. Reconstructed total weights of prey taken

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Table 3. Prey species and number of plastic items found in the stomachs of pygmy sperm whales, *Kogia breviceps* (Kbr), Gervais' beaked whales, *Mesoplodon europaeus* (Meu), Risso's dolphins, *Grampus griseus* (Ggr) and short-finned pilot whales, *Globicephala macrorhynchus* (Gma). For all prey species, number of beaks/other remains (N) and importance (%N, percentage by number; %W, percentage by weight) are indicated. For cephalopods number of beaks found are indicated (lower beaks, Lb, unless otherwise stated). For fish the type of remains are indicated. The category *Histioteuthis* type A includes the species *Histioteuthis arcturi*, *H. corona*, *H. meleagroteuthis* and *H. bonellii*. The category *Chirotheuthis* type II includes beaks of the genus *Chiroteuthis* different fromm *Chiroteuthis veranyi* (Santos *et al.*, 2001).

Cephalopod prey		**Kbr-1 (245 cm)**			**Kbr-2 (188 cm)**			**Meu (302 cm)**			**Ggr (162 cm)**			**Gma (353 cm)**		
Family	**Species**	**N**	**%N**	**%W**	**N**	**%N**	**%W**	**N**	**%N**	**%W**	**N**	**%N**	**%W**	**N**	**%N**	**%W**
Ommastrephidae	*Todarodes sagitattus*	–	–	–	9	6.21	25.44	–	–	–	–	–	–	1	50	70.10
Sepiolidae	*Stoloteuthis* sp.	–	–	–	3	2.07	0.24	–	–	–	–	–	–	–	–	–
	Unidentified	–	–	–	–	–	–	–	–	–	19	34.55	29.38	–	–	–
Enoploteuthidae	*Enoploteuthis* sp.	–	–	–	–	–	–	–	–	–	28	50.91	10.01	–	–	–
Architeuthidae	*Architeuthis* sp.	–	–	–	1	0.69	0.46	–	–	–	–	–	–	–	–	–
Vampiroteuthidae	*Vampiroteuthis infernalis*	–	–	–	1	0.69	0.39	–	–	–	–	–	–	–	–	–
Cranchiidae	*Megalocranchia* sp.	–	–	–	2	1.37	5.76	–	–	–	–	–	–	1	50	29.90
	Taonius pavo	–	–	–	20	13.79	10.87	11	73.33	57.41	1	1.82	34.82	–	–	–
	Cranchia/Lyocranchia	–	–	–	12	8.28	–	–	–	–	–	–	–	–	–	–
Mastigoteuthidae	*Mastigoteuthis* sp.	–	–	–	9	6.21	6.62	–	–	–	–	–	–	–	–	–
Histioteuthidae	*Histioteuthis meleagroteuthis*	–	–	–	4	2.76	4.57	–	–	–	–	–	–	–	–	–
	Histioteuthis type A	–	–	–	9	6.21	10.03	2	13.33	36.66	1	1.82	16.05	–	–	–
	Histioteuthis type A?	–	–	–	5	3.45	2.59	–	–	–	–	–	–	–	–	–
	Histioteuthis reversa	–	–	–	8	5.52	4.58	–	–	–	–	–	–	–	–	–
Pholidoteuthidae	*Pholidoteuthis bochmai*	–	–	–	3	2.07	8.41	–	–	–	–	–	–	–	–	–
Chiroteuthidae	*Chiroteuthis veranyi*	–	–	–	14	9.66	4.43	1	6.67	5.93	–	–	–	–	–	–
	Chiroteuthis type II	–	–	–	2	1.37	1.44	–	–	–	–	–	–	–	–	–
Onychoteuthidae	*Moroteuthis* sp.	–	–	–	4	2.76	6.25	–	–	–	–	–	–	–	–	–
Braquioteuthidae	*Braquioteuthis* sp.?	–	–	–	1	0.69	0.12	–	–	–	–	–	–	–	–	–
Octopoteuthidae	*Octopoteuthis* sp.	–	–	–	1	0.69	3.34	–	–	–	–	–	–	–	–	–
Unidentified		–	–	–	27	18.62	–	1	6.67	–	–	–	–	–	–	–
Broken		–	–	–	4	2.76	–	–	–	–	2	3.64	–	–	–	–
Upper beaks, Ub		3	75	–	115	–	–	12	–	–	30	–	–	0	–	–
Total Lb		0			139			15			55			2		
Fish prey																
Family	Species															
Trichiuridae	*Aphanopus carbo*	–	–	–	2 dentaries	0.69	3.62	–	–	–	–	–	–	–	–	–
Myctophidae	*Lampadena luminosa*	–	–	–	2 otoliths	0.69	–	–	–	–	–	–	–	–	–	–
Lophiidae	*Lophius* sp.	–	–	–	2 dentaries	0.69	0.82	–	–	–	–	–	–	–	–	–
Gadidae	Unidentified	–	–	–	2 dentaries	0.69	–	–	–	–	–	–	–	–	–	–
Unidentidied otolith		1	25	–	–	–	–	–	–	–	–	–	–	–	–	–
Broken/eroded otoliths		–	–	–	9	1.37	–	–	–	–	–	–	–	–	–	–
														–	–	–
Total prey		4	100	–	145	100	100	15	100	100	15	100	100	2	100	100
Plastic items		0			3			11			0			0		

Table 4. Prey species and number of plastic items found in the stomachs of Fraser's dolphins, *Lagenodelphis hosei* (Lho), Atlantic spotted dolphins, *Stenella frontalis* (Sfr) and striped dolphins, *Stenella coeruleoalba* (Sco). For all prey species, number of beaks/other remains (N) and importance (%N, percentage by number; %W, percentage by weight) are indicated. For cephalopods number of beaks found are indicated (lower beaks, Lb, unless otherwise stated). The category *Histioteuthis* type A includes the species *Histioteuthis arcturi*, *H. corona*, *H. meleagroteuthis* and *H. bonellii*.

Cephalopod prey		Lho (200 cm)			Sfr-1 (182 cm)			Sfr-3 (140 cm)			Sco-1 (160 cm)			Sco-2 (188 cm)			Sco-3 (183 cm)		
Family	Species	N	%N	%W	N	%N	%W	N	%N	%W	N	%N	%W	N	%N	%W	N	%N	%W
Ommastrephidae	*Todarodes sagitattus*	2	8.00	17.99	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Enoploteuthidae	*Enoploteuthis* sp.	2	8.00	0.42	1	25.00	1.51	6	100	100	–	–	–	–	–	–	–	–	–
	Enoploteuthis sp.?	–	–	–	2	50.00	1.24	–	–	–	–	–	–	–	–	–	–	–	–
Cranchidae	*Megalocranchia* sp.	–	–	–	–	–	–	–	–	–	5	21.74	29.79	–	–	–	–	–	–
	Taonius pavo	2	8.00	9.68	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mastigoteuthidae	*Mastigoteuthis* sp.	1	4.00	3.61	–	–	–	–	–	–	1	4.35	4.00	–	–	–	1	50.00	27.57
Histioteuthidae	*Histioteuthis* type A	16	64.00	67.16	1	25.00	97.24	–	–	–	3	13.04	13.75	–	–	–	–	–	–
Chiroteuthidae	*Chiroteuthis veranyi*	–	–	–	–	–	–	–	–	–	10	43.48	34.03	1	100	100	–	–	–
Braquioteuthidae	*Braquioteuthis* sp.	1	4.00	1.14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Octopoteuthidae	*Octopoteuthis* sp.	–	–	–	–	–	–	–	–	–	1	4.35	18.43	–	–	–	1	50.00	72.43
Unidentified		1	4.00	–	–	–	–	–	–	–	3	13.04	–	–	–	–	–	–	–
Upper beaks		22	–	–	0	–	–	0	–	–	14	–	–	0	–	–	2	–	–
Total Lb		25	100	100	4	100	100	6	100	100	23	100	100	1	100	100	2	100	100
Plastic items		3			0			0			0			0			1		

by the three striped dolphins were 1206 g, 30 g and 50 g, respectively (Table 1).

Bottlenose dolphin and rough-toothed dolphin

The stomach of the bottlenose dolphin contained remains of three cuttlefish *Sepia* sp., two dentaries from a garfish (*Belone belone*) and a third unidentified fish dentary (Table 5). One specimen of the mollusc *Dentalium* sp. and several fish vertebrae were also found.

The rough-toothed dolphin stomach contained 15 upper and 23 lower beaks identified as *Illex* sp. and *Sepia* sp. and eight garfish dentaries (4 fish) (Table 5). One parasitic nematode and several cephalopod lenses were also present.

The estimated size of the garfish was 37 cm for the specimen in the stomach of the bottlenose dolphin and between 45 and 60 cm for that in the rough-toothed dolphin. The size-range (DML) of *Sepia* sp. was 73–137 mm for the bottlenose dolphin and 71–193 mm for the rough-toothed dolphin. The bottlenose dolphin had taken 409 g of prey while the rough-toothed dolphin had taken 7768 g (Table 1).

Common dolphins

Few prey remains were found in the common dolphin stomach contents. The remains consisted of cephalopod beaks of *Enoplotheuthis* sp. and Ommastrephidae (Table 5). The estimated reconstructed weights of prey were <1 g, 43 g and 358 g for each dolphin (Table 1).

DISCUSSION

The high marine mammal biodiversity of the Canary Islands is reflected in the sample set which included both coastal and oceanic dolphins and several species of toothed whales. Results from this study show the importance of cephalopods in the diet of several different species of cetaceans in the research area. Even those cetacean species generally described as mainly piscivorous (e.g. common dolphin, see Silva, 2001; Santos *et al.*, 2004; Pusineri *et al.*, 2007) contained more cephalopod than fish remains in the present dataset.

Traditionally teuthophagous species such as the sperm whale, pygmy sperm whale, long finned pilot whale, Risso's dolphin and to a lesser extent Gervais' beaked whale (e.g. Clarke *et al.*, 1993; González *et al.*, 1994; Santos *et al.*, 1999, 2006a, 2006b, 2007b) also had a diet dominated by cephalopods in the present sample but with some differences from what other authors have found in the north-eastern Atlantic. In the case of the sperm whale, which is the species with the highest sample size in the present study, prey diversity was much higher in the Canary Islands than reported in other studies. A total of 23 different prey taxa was found in 5 whales in the Canary Islands compared to 15 prey taxa found in 17 sperm whales stranded in the Azores (Clarke *et al.*, 1993), 10 prey taxa recorded in 17 sperm whales stranded in Scotland, Denmark and Belgium (Santos *et al.*, 1999) and 11 prey taxa present in 5 sperm whales stranded in Scotland, The Netherlands and Ireland (Santos *et al.*, 2002).

Most recent studies on sperm whale diet in the north-eastern Atlantic are based in the examination of stomach contents from stranded whales, mainly around the North Sea waters (Lick *et al.*, 1995; Clarke, 1997; Santos *et al.*, 1999,

Table 5. Prey species and number of plastic items found in the stomachs of bottlenose dolphins, *Tursiops truncatus* (Ttr), rough-toothed dolphins, *Steno bredanensis* (Sbr) and common dolphins, *Delphinus delphis* (Dde). For all prey species, number of beaks/other remains (N) and importance (%N, percentage by number; %W, percentage by weight) are indicated. For cephalopods number of beaks found are indicated (lower beaks, Lb, unless otherwise stated). For fish the type of remains are indicated.

Cephalopod prey		Ttr (305 cm)			Sbr (240 cm)			Dde-1 (200 cm)			Dde-2 (211 cm)			Dde-3 (223 cm)		
Family	Species	N	%N	%W	N	%N	%W	N	%N	%W	N	%N	%W	N	%N	%W
Ommastrephidae	*Illex* sp.	–	–	–	7	25.93	23.92	–	–	–	–	–	–	–	–	–
	Unidentified	–	–	–	–	–	–	–	–	–	1	100	100	2	100	100
Sepiidae	*Sepia* sp.	3	60.00	88.14	16	59.26	67.16	–	–	–	–	–	–	–	–	–
Enoploteuthidae	*Enoploteuthis* sp.	–	–	–	–	–	–	1	100	100	–	–	–	–	–	–
Upper beaks		3	–	–	15	–	–	–	–	–	1	–	–	1	–	–
Total Lb		3			23			1			1			2		
Fish prey																
Family	Species															
Belonidae	*Belone belone*	2 dentaries	20.00	10.89	8 dentaries	14.81	8.93	–	–	–	–	–	–	–	–	–
Unidentified		1 dentary	20.00	–	–	–	-	–	–	–	–	–	–	–	–	–
Total prey		5	100	100	27	100	100	1	100	100	1	100	100	2	100	100
Plastic items		0						0			0			0		

2002) where the most important food resource was identified as squid from the genus *Gonatus*, probably *Gonatus fabricii*. *Gonatus fabricii* is the most abundant squid from Arctic and sub-Arctic areas with a distribution that extends south to about 60°N (Kristensen, 1983). González *et al.* (1994) identified *Histioteuthis* spp. as the most important prey category for one sperm whale stranded in Galicia (north-western Spain) and Santos *et al.* (2006a) obtained similar results for a sperm whale calf stranded in Ireland. In the present study the main prey category both by number and weight was also the oceanic family Histiotheuthidae (they made up more than 50% by weight in all but one of the sperm whales analysed in this paper). As found by Santos *et al.* (2006a), *Histioteuthis* type A was the most important type within the Histioteuthidae.

In common with previous studies, our results also show no evidence of inshore feeding, since no coastal species were present among the prey remains and no fresh remains were found (i.e. no cephalopod flesh was recovered, which would indicate that the whales had not been feeding immediately prior to stranding). Cephalopod mandibles can remain in the stomach for several days (Clarke & MacLeod, 1974). This accumulation could result in the overestimation of cephalopod importance compared to other types of prey, for example fish, the remains of which would be eliminated more quickly from the stomachs. In fact, it is highly likely that the estimated 1.5 tons of food represented by remains recovered from one of the sperm whales in the present study represented several days' feeding.

Santos *et al.* (2006b) identified 15 different cephalopod families from 14 pygmy sperm whales stranded in Galicia (north-western Spain), Scotland and France and the family Histioteuthidae was the most important. Previous studies in the Azores and Canary Islands archipelagos also recorded histioteuthids as the main prey of pygmy sperm whales (Martins *et al.*, 1985; Hernández-García, 1995). Although in the present study only two specimens were examined, our results are in agreement with previous work since the families Histioteuthidae, Chirotheutidae and Ommastrephidae were the most numerous prey. In addition, a beak from the giant squid *Architeuthis* sp., a species generally believed to contribute only to the diet of sperm whales (Clarke, 1996), was found in one of the pygmy sperm whales. The squid size was estimated as 131 mm DML, which is considerably smaller than the estimated sizes of the *Architeuthis* found in the sperm whale stomachs (738–1952 mm DML) described here.

A total of 13 cephalopod and 4 fish families were identified from the remains found in two pygmy sperm whale stomachs, again highlighting the high prey diversity found in our sample. In addition to cephalopods, two bathypelagic fish species (black scabbard fish, *Aphanopus carbo*, and lantern fish, *Lampadena luminosa*) and some demersal fish were also found in one of the pygmy sperm whales. Remains of bathypelagic fish species such as Sloane's viperfish *Chauliodus sloani* (Bloch & Schneider, 1801) were identified from a pygmy sperm whale stranded in Galicia (north-western Spain) by Santos *et al.* (2006b).

There is little information available on the diet of Gervais' beaked whales. MacLeod (2005) argues that both cephalopod and fish are an important part of the diet for the genus *Mesoplodon*. One specimen of Gervais' beaked whale stranded in the Canary Islands was analysed by Santos *et al.* (2007b) and indeed contained remains of both cephalopods (family

Cranchiidae) and fish (viperfish, *Chauliodus* sp.). Martín *et al.* (1990) reported jaw bones of *Chauliodus sloani* and cephalopod beaks in the stomach of a whale stranded in the same area. In our sample, the single stomach analysed did not contain fish remains but the squid identified were oceanic species of the families Cranchiidae and Histioteuthidae already recorded in the diet of the species. Feeding on this prey is consistent with the habitat of these deep-diving whales (MacLeod, 2005).

Risso's dolphin has been described as a teuthophagous predator with both oceanic and neritic cephalopod species contributing to its diet (Clarke, 1996) as expected from its habitat range. In the present sample a single stomach was analysed but it contained both coastal (e.g. Enoploteuthidae and Sepiidae) and oceanic (*Taonius pavo* and *Histioteuthis* type A) species. Oceanic cephalopods were the main prey in terms of weight while coastal cephalopods were more numerous. Only oceanic cephalopods (the ommastrephid *Todarodes sagittatus* and the cranchiid *Megalocranchia* sp.) were found in the single specimen of short-finned pilot whale examined. The species has been recorded as feeding on both neritic and oceanic cephalopods with ommastrephids being the main prey in most areas (Clarke, 1996).

Of the remaining cetacean species analysed, common dolphin diet has been described as mainly piscivorous and opportunistic, with cephalopods and fish species being important contributors to the diet in the north-eastern Atlantic (Silva, 2001; Santos *et al.*, 2004; Pusineri *et al.*, 2007). In our sample, the 3 stomachs analysed did not contain any fish remains and both coastal (enoploteuthids) and offshore (ommastrephids) cephalopods were found. Cephalopods and fish (both neritic and oceanic species) have been recorded in the diet of striped dolphins (López, 2003; Ringelstein *et al.*, 2006; Spitz *et al.*, 2006; Santos *et al.*, 2008). Clarke (1996) indicated that *Stenella coeruleoalba* favours ommastrephids, loligids, enoploteuthids and lycoteuthids although none of these taxa are represented in our results. Only oceanic species of cephalopods (*Megalocranchia* sp., *Mastigoteuthis* sp., *Histioteuthis* type A, *Chiroteuthis veranyi* and *Octopoteuthis* sp.) were recorded in the three striped dolphin stomach contents analysed here.

Bottlenose dolphins are thought to be opportunistic predators, with a wide variety of locally abundant prey being found in their stomachs (Barros & Odell, 1990). Our sample consisted of one stomach in which both cuttlefish (*Sepia* sp.) and garfish remains were found. Both prey species have a coastal distribution which would indicate inshore feeding although in other parts of the north-eastern Atlantic the bottlenose dolphin is thought to also feed in offshore waters (Santos *et al.*, 2007a).

Little is known of the diets of rough-toothed dolphin, Fraser's dolphin and Atlantic spotted dolphin. Aguiar dos Santos & Haimovici (2001) identified the squid *Loligo plei* (Lesueur, 1821) as the most important prey for 6 Atlantic spotted dolphins and one rough-toothed dolphin from Brazil, where *L. plei* can be locally abundant in the outer shelf and inner slope. On the other hand, Fraser's dolphins are known to feed on mesopelagic prey including cephalopods and fish (Aguiar dos Santos & Haimovici, 2001; Dolar *et al.*, 2003). In our study both coastal (*Sepia* sp. and *Belone belone*) and oceanic (*Illex* sp.) species were present in the diet of the rough-toothed dolphin. Inshore (*Enoploteuthis* sp.) and offshore (*Histioteuthis* type A) cephalopods were found also in the Atlantic spotted dolphin stomach. Again, oceanic (*Todarodes sagittatus, Taonious pavo, Mastigoteuthis* sp., *Histioteuthis* type A and *Braquioteuthis* sp.) and coastal (*Enoploteuthis* sp.) prey were identified as part of the Fraser's dolphin diet.

The present sample size is small but provides an insight into the diet of many species of cetaceans which inhabit the waters of the Canary Islands Archipelago. Our results highlight the importance of cephalopods in the diet of all the species studied, although it should be noted that hard remains such as cephalopod beaks could be accumulated in the stomachs over longer periods than less robust prey tissues such as crustacean exoskeletons and fish bones. Taking all this into account, it is worth highlighting the high prey diversity found in the stomachs of most species (particularly the sperm and pygmy sperm whales) when compared with data from stomach contents of stranded individuals from other areas.

The main prey categories taken by sperm, pygmy sperm and Gervais' beaked whales in the present study belonged to two oceanic cephalopod families, Histioteuthidae and Cranchiidae. Different sizes of squid were taken by the different predators which would help reduce interspecific competition.

Most of the dolphin species analysed (even those whose distribution is mainly oceanic), had both inshore and offshore prey species in their stomachs which may point to regular feeding trips towards inshore waters. The narrow width of the continental shelf in the Canary Islands may make possible the exploitation of both niches. Most of the prey species eaten by the cetaceans are of little or no commercial value, although the presence of a hook in a sperm whale stomach suggests that this species sometimes interacts with human fishing activities. Sperm whales have been found to interact with the longline fisheries in other regions by removing catches from fishing gear (Sigler *et al.*, 2008).

Finally, we would like to highlight the high prevalence of plastic debris among the stomach contents analysed. Although food remains were found in all the cases that plastics were present, it has been suggested previously that the presence of artificial materials in high concentrations could prevent the evacuation of the stomach (Santos *et al.*, 2001) and could cause the death of the animal (Gomerčić *et al.*, 2006). All the cetacean species included in the present study are recorded in Annexe IV of the Habitats Directive from the EU (Directive 92/43/CEE) as species of community interest in need of strict protection.

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