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Retrospective study of foreign body-associated pathology in stranded cetaceans, Canary Islands (2000–2015)☆

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ABSTRACT

Marine pollution, overrepresented by plastic, is a growing concern worldwide. However, there is little knowledge on occurrence and detrimental impacts of marine debris in cetaceans. To partially fill in this gap of knowledge, we aimed to investigate the occurrence and pathologies associated with foreign bodies (FBs) in a large cohort of cetaceans (n = 465) stranded in the Canary Islands. The Canary Islands shelter the greatest cetacean biodiversity in Europe, with up to 30 different species, of which nine are regularly present year around. We found at least one ingested FB in 36 out of 465 (7.74%) studied cetaceans, involving 15 different species, including eight out of the nine (80%) cetacean species present year-round in the Canary Islands. Risso's dolphin was the species most affected, followed by sperm whale, beaked whale and mysticetes. Plastic FB were the most common item found (80.56%). FB was directly associated with death in 13/36 (36.11%) animals. Poor body condition and deep diving behavior were found to be risk factors for FB ingestion, whereas the adult age was a protective factor. To the authors knowledge this is the first study that use statistical analysis to investigate risk and protective factors for FB ingestion. This study also provides insights of the potential impact caused by ingested FBs on the animal's health and mortality. This knowledge is critical to better understand and assess the impact of FB in cetaceans setting the scientific basis for prospective impact monitoring and future conservation policies.

1. Introduction

The current period has been coined the ‘Plastic Age’ (Yarsley and Couzens, 1945) from a merging anthropological and ecological standpoint, as plastic has become the most prevalent and widespread element of marine litter (Cozar et al., 2014). Three hundred million tons of plastic are produced each year (Plastics Europe, 2015), from which up to 12.7 million tons are dumped into the ocean annually (Jambeck et al., 2015). It has been estimated that 250,000 tons of plastic are floating in the oceans (Eriksen et al., 2014), representing more than 50% of marine litter (Laist, 1987; Derraik, 2002; Moore, 2008; Simmonds, 2012; Di Beneditto and Ramos, 2014). The accumulation of marine debris is a growing global concern and an important threat to marine biodiversity (European Parliament and Council, 2008). At least 693 species have been described interacting with marine debris and 92% of encounters involved plastics (Gall and Thompson, 2015). Thousands of marine debris interactions, primarily involving entanglement and ingestion, have been reported in many cetacean species worldwide to date (Derraik, 2002; Gregory, 2009; Baulch and Perry, 2014; Lusher et al., 2018). Both above-mentioned interactions have proven devastating for individual cases and alarming for certain cetacean populations (Baulch and Perry, 2014; Fossi et al., 2016; Lusher et al., 2018).

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Since the first report in 1970 (Laist, 1987), at least 462 cetaceans from 48 species ingested marine debris, being plastic the most commonly observed item (46%) (Baulch and Perry, 2014). The number of cases of foreign body (FB) ingestion in cetaceans increases each year all over the world (Baulch and Perry, 2014; Lusher et al., 2015, 2018; Unger et al., 2016, 2017). Unknown cetacean population mortality rates and partial necropsy examinations of stranded animals may result in an underestimation of interactions between cetaceans and marine litter (Williams et al., 2011). The scientific committee of the International Whaling Commission (IWC) encourages intensifying the studies on interaction between marine debris and cetaceans (IWC, 2016). Recognized immediate and chronic foreign body (FB) associated clinicopathological consequences include: starvation, malnutrition, loss of body condition (Laist, 1997), limited predator-avoidance capabilities (Secchi and Zarzur, 1999), reduced growth rates, reduced longevity, and reduced reproductive capacity (Laist, 1987; McCauley and Bjorndal, 1999; Gregory, 2009), as well as general debilitation mainly secondary to bleeding ulcers, obstructions, impaction and/or perforation of the digestive tract (Walker and Coe, 1990). Nevertheless, mortality rates and sublethal consequences in cetaceans remain poorly understood (Simmonds, 2012), especially in mysticetes (Fossi et al., 2016). Some reports have indicated no apparent pathology or health impact in individuals that ingested FBs (Denuncio et al., 2011; Mazzariol et al., 2011; Unger et al., 2016); however, their long-term deleterious effects have been less studied (Jacobsen et al., 2010; Simmonds, 2012).

Several hypotheses have been formulated to explain FB ingestion: 'mistaken identity' with a prey (Carpenter and Smith, 1972), close proximity to the debris with a prey target or not echolocating at the ultimate approach to the prey (Ross, 1984; Mead, 1989), juvenile inexperience (Di Beneditto and Ramos, 2014), prey capture mechanism in beaked whales (MacLeod, 2007), playful and curious behavior (Laist, 1987), disease factors, and the stranding events (Walker and Coe, 1990).

The Canary Islands are located within the Macaronesia and shelter the greatest cetacean biodiversity in European waters, with up to 30 cetacean species recorded (Banco de Datos de Biodiversidad de Canarias). Four of these species are classified as endangered by the International Union for Conservation of Nature (IUCN): North Atlantic right whale (*Eubalaena glacialis*), blue whale (*Balaenoptera musculus*), sei whale (*Balaenoptera borealis*), and fin whale (*Balaenoptera physalus*). Nine cetacean species are regularly present year-round: common bottlenose dolphin (*Tursiops truncatus*), short-finned pilot whale (*Globicephala macrorhynchus*), striped dolphin (*Stenella coeruleoalba*), Risso's dolphin (*Grampus griseus*), sperm whale (*Physeter macrocephalus*), pygmy sperm whale (*Kogia breviceps*), Cuvier's beaked whale (*Ziphius cavirostris*), Blainville's beaked whale (*Mesoplodon densirostris*) and Gervais' beaked whale (*Mesoplodon europaeus*) (Martín et al., 2009). Recent reports revealed that the 'Canary Current' brings marine debris from the open Atlantic Ocean to the Canary Islands (Baztan et al., 2014). The concentration of plastic debris in the shallow waters of this archipelago is approximately 200–500 g.km^{-2} (Cozar et al., 2014).

This study aims to investigate the pathologic findings associated with foreign bodies (FB associated pathology) and to study retrospectively the interaction between cetaceans and marine debris in the Canary Islands based on *postmortem* examinations.

2. Materials and methods

Four hundred and seventy-five cetaceans, stranded dead or alive along the coasts of the Canary Islands between January 2000 and December 2015, were necropsied following standardized protocols (Kuiken and García Hartmann, 1991). Stranding epidemiology (location and date), life history data (species, age category, gender, gonad maturation, were systematically recorded following standardized protocols (Geraci and Lounsbury, 2005). During the necropsy, the body condition and the decomposition code of the carcass were evaluated. The digestive tract (i.e.: mouth, pharynx, esophagus, gastric chambers, intestines, and anus) was carefully dissected and examined. Gastric contents were routinely photographed, visually analyzed, described, and collected. Representative tissue samples were collected, fixed in 10% neutral buffered formalin, embedded in paraffin, processed and stained with hematoxylin and eosin as routine for histopathologic analysis.

Age categories were established based on total body length (Perrin et al., 2009) and histologic gonadal examinations (Geraci and Lounsbury, 2005) in: neonate or newborn (i.e.: animals with vibrissal hairs or vibrissal crypts, unhealed navel, fetal folds over the body, and soft and folded dorsal fin and tail flukes), calf (i.e.: animal with presence of milk in its stomach, or about the size of a nursing calf), juvenile, (i.e.: sexually immature animal with a body length smaller than the adult but larger than a calf), subadult, (i.e.: body length of an adult but immature gonads), and adult (i.e.: mature gonads).

The conservation condition of the animal was determined following Kuiken and García Hartmann, 1991 classification, with a small modification for code 1: we defined code 1 as an animal that has recently died or euthanized. The other codes remained the same: fresh (code 2), slight skin dryness, corneal opacity, onset of rigor mortis and/or presence of cadaveric lividity that disappears by digital pressure; moderate (code 3), also with delimited small red imbibition spots; advanced (code 4), skin slippage and blistering, sinked eyeball, tympanization due to gas formation, thickening of the tongue, protrusion of genitals and large imbibition spots; and very advanced autolysis (code 5), skin losing, ocular protrusion, tympanization with protrusion and/or evisceration of abdominal organs, liquefaction, mummification or adipocera.

Body condition was estimated based on the external physical conformation: the degree of concavity or convexity ventrolateral to the dorsal fin, the degree of depression posterior to the blowhole, the visibility of the ribs and transverse apophysis, as well as the presence or absence of nucal and epicardial fat (Joblon et al., 2014). Four categories were established: very poor, animals with extremely concave dorsal profile, visible costal reliefs, body fat low or absent, and fatty serous atrophy; poor, animals with concave dorsal profile, low body fat and the ribs can be noted by palpation; fair, animal with dorsal profile straight or slightly convex and moderate body fat; and good, animals with a dorsal convex profile and abundant body fat.

Pathological categories (Arbelo et al., 2013) were stablished for each case according with anatomopathological findings in: anthropogenic pathologies [i.e.: FB associated pathology (when the lesions due to FB presence are directly related to the death of the animal), ship collisions, interaction with fishing activities, military maneuvers using sonar, and atypical mass stranding], natural or "not directly anthropogenic pathologies" [i.e.: pathology associated with significant loss of body condition, with good body condition, neonatal-perinatal pathology, intra/interspecific traumatic interactions, and typical mass stranding] and not determined.

For statistical purposes, species with very low stranding events were removed ($n = 10$) (Table 1). In addition, age categories were regrouped in the following categories: neonate/calves, juvenile/subadults and adults. Body condition categories were regrouped in two categories: poor/very poor and good/fair. Finally, the strandings were also studied by location. For this purpose, we grouped Fuerteventura and Lanzarote coasts (eastern islands), as well as El Hierro, La Palma and La Gomera coasts (western islands), and left alone Tenerife and Gran Canaria coast.

We defined deep diving species as those known to dive deeper than 500m for foraging (*Kogia* spp, *Physeter macrocephalus*, *Ziphius cavirostris*, *Mesoplodon* spp, *Globicephala macrorhynchus* and *Grampus griseus*) (Gannier, 1998; Astruc and Beaubrun, 2005; Aguilar de Soto, 2006; Tyack, 2006; Watwood et al., 2006; West et al., 2009).

2.1. Statistical analysis

In order to identify the factors associated with the presence of FB and FB associated pathology, categorical variables (i.e.: age, sex, sex mature, species, coast, FB presence, FB associated pathology, body condition) were expressed as frequencies and percentages, and compared as appropriate, using the Chi-square ($\chi2$) test or the exact Fisher test (Table 2).

In order to identify factors that maintain independent association with the outcome, a multivariate logistic regression analysis was performed. The variables that showed significant association with the corresponding outcome in univariate analysis were entered into the multivariate analysis. Selection of variables based on complete enumeration algorithm and Bayes information criterion (BIC) was then performed. The models were summarized as coefficients (SE), p-values (likelihood ratio test) and odds ratios which were estimated by confidence intervals at 95%. Statistical significance was set at $p < 0.05$. Data were analyzed using the R package, version 3.3.1 (R Development Core Team, 2016).

3. Results

This sixteen-year retrospective study revealed that FBs were found in 36 cetaceans (7.74% of stranded and necropsied cetaceans in the archipelago); being plastic the most prevalent item found (80.56%). Fifteen cetacean species were affected by marine debris ingestion. We described ulcerative gastritis with digested blood (14/36; 38.89%), impacted stomach (9/36; 25%) and gastro-intestinal perforations (3/36; 8.33%), as the main lesions contributing to the death of 13 animals. High statistical significance differences for FB presence were detected between species, age, body conditions and diving behavior. Poor body condition and deep diving were found to be risk factors for FB ingestion; meanwhile the adult age was a protective variable.

3.1. Foreign bodies found in stranded cetaceans

In the present study, 36/465 (7.74%) cetaceans presented FB ingestion. Plastic debris, mainly plastic bags, but also plastic caps, nylon wires, and cylindrical plastic items were found within the gastric contents in 29/36 (80.56%) animals. This represented 29/465 (6.24%) of total necropsied animals considered in the study. Ropes and threads (7/36; 19.44%), metal filaments (3/36; 8.33%), electric wire (1/36; 2.78%), fragments of cloth (1/36; 2.78%) and glass fragments (1/36; 2.78%) were also observed. Nine animals had more than one item in the digestive tract. (Table 1. Fig. 1).

3.2. Foreign body-associated lesions

FBs were found in the oral cavity (tongue, maxilla, jaw), esophagus, first gastric compartment and intestine. Two entangled whales were included in the FB cases, since the ropes and net were also affecting the digestive tract: a fin whale with a thick and long rope around the tongue that reached the stomach and a common minke whale with a 5.5 m long net entangled in the first third of the jaw and right pectoral fin as well as the dorsal fin.

Ulcerative gastritis with presence of luminal blood (14/36; 38.89%) and impacted stomach (9/36; 25.00%) were observed in animals with FB ingestion. Also, gastro-intestinal perforations (3/36; 8.33%), ulcerative glossitis (2/36; 5.56%), stomatitis (2/36; 5.56%), healed ulcers (2/36; 5.56%) and petechiae (1/36; 2.78%) were observed. Pathological findings related to FB were absent in ten necropsied animals with presence of FBs (Table 1. Fig. 1).

3.3. Pathological categories

Pathological categories identified in the set of animals with FBs included: FB associated pathology (13/36; 35.14%); pathology associated with a significant loss of body condition (12/36; 33.33%); ship collision (5/36; 13.89%); intra- or interspecific traumatic interaction (2/38; 5.26%); pathology associated with a good body condition (3/36; 8.33%) and fishing interaction (1/36; 2.78%). The cause of death could not be determined in one animal that had FBs due to its advanced decomposition code.

The cause of death of 13 out of 36 cetaceans with FBs (35.14%) was related to gastrointestinal impaction (11/36; 30.56%) or gastro-intestinal perforations (2/36; 5.56%) (Table 1; Fig. 1). These cases represented 2.8% of total necropsied animals (13/465).

3.4. Statistical study of factors

3.4.1. Temporality of stranding events

The yearly average occurrence of FB ingestion in this study was 2.25 animals, 36 cases over 16 years. A higher number of animals ($n = 6$) was detected in 2014. Despite this focally increased number of FB ingestion in 2014, the statistical analysis discarded any trend, either in FB ingestion (Fig. 2) or FB associated pathology.

3.4.2. Location of stranded cetaceans

Statistically, stranding location is not a relevant epidemiologic factor regarding FB presence (p-value = 0.253) (Table 2). In decreasing order, animals with FBs stranded mostly in Tenerife (14/36; 38.89%), Gran Canaria (11/36; 30.56%), Fuerteventura and Lanzarote (11/36; 30.56%). Stranding location of FB associated pathology cases presented the same trend: Tenerife (5/13; 38.46%), Gran Canaria (4/13; 30.77%), Fuerteventura and Lanzarote (4/13; 30.77%). These results showed no significant difference for FB associated pathology and stranding location (p-value = 0.718). Western islands did not present FB or FB associated pathology cases. (Table 2).

3.4.3. Species

A total of 15 species presented FBs (Tables 1 and 2). Eight out of nine cetacean species regularly present year around in the Canary Islands presented FBs: Risso's dolphin (4/12; 33.33%), Blainville's beaked whale (2/6; 33.33%), sperm whale (6/28; 21.43%), Cuvier's beaked whale (5/33; 15.15%), Gervais' beaked whale (1/11; 9.09%), pygmy sperm whale (1/28; 3.57%), striped dolphin (3/92; 3.26%) and common bottlenose dolphin (1/40; 2.5%). In this study 34/448 (7.59%) odontocetes and 2/17 (11.76%) mysticetes were affected by FB ingestion.

Statistically significant differences were found between species with FBs presence (p-value< 0.001) (Table 2). Species with the highest prevalence of FB ingestion were Risso's dolphin (4/12; 33.33%), sperm whale (6/28; 21.43%) and Mesoplodon sp. (4/19; 21.05%). No statistically significance differences were found between species presenting with FB associated pathology (p-value = 0.105) (Table 2).

3.4.4. Diving behavior

Statistically significant differences were found between deep diving and shallow diving species and FB presence (p-value = 0.004) (Table 2), deep divers (21/36; 58.3%) presented the

Table 1
Cetaceans stranded with foreign body (FB) on the Canary Islands (January 2000 to December 2015). For each animal (36) we describe the species; stranding date (day/month/year) and location (F: Fuerteventura; GC: Gran Canaria; L: Lanzarote; T: Tenerife); gender (F: female; M: male); age; body condition (1: very poor; 2: poor; 3: fair; 4: good); decomposition code (1: very fresh, 2: fresh; 3: moderate autolysis; 4: advanced autolysis); FB observed; stomach contents; pathological findings and pathological categories (FBAP: foreign body associated pathologies; SC: Ship collision; FI: Fishing interaction; I: Intra/interspecific interaction; NPGBC: Natural pathology associated with good body condition; NPALBC: Natural pathology associated with significant loss of body condition; N.D.: Not determined). Species with very low stranding events within the study period were removed from the study for statistical purposes: rough-toothed dolphins (*Steno bredanensis*; n = 3) Fraser's dolphin (*Lagenodelphis hosei*; n = 3), false killer whale (*Pseudorca crassidens*; n = 2); Orca (*Orcinus orca*; n = 1) and harbour porpoise (*Phocoena phocoena*; n = 1). Of these animals, only one Fraser's dolphin presented with FB.

Case	Species	Stranding date	Stranding location	Gender	Age	Body condition	Decomposition code	FB	Stomach contents	Pathological findings	Pathological category
1	*Balaenoptera physalus*	15/04/2000	F	F	Adult	1	2	Rope	N.D.	Glossitis and impacted stomach	FBAP
2	*Physeter macrocephalus*	12/06/2000	T	M	Calf	4	4	Plastic bags	Squid beaks	No	SC
3	*Ziphius cavirostris*	16/07/2000	T	F	Juvenile	2	3	Plastic bags	Squid beaks	Impacted stomach. Digested blood in stomach	FBAP
4	*Stenella frontalis*	10/03/2001	T	M	Juvenile	2	3	Plastic bags	N.D.	Impacted stomach. Digested blood in stomach	FBAP
5	*Kogia breviceps*	15/01/2002	GC	M	Juvenile	4	4	Plastic debris	Squid beaks and digested fishes	No	FI
6	*S. frontalis*	25/01/2002	GC	M	Adult	N.D.	4	Plastic bags	N.D.	Impacted stomach. Digested blood in stomach	FBAP
7	*P. macrocephalus*	06/02/2003	T	M	Adult	1	3	Plastic wire	Squid beaks and lens	Ulcerative stomatitis with associated necrosis and fibrosis	FBAP
8	*Mesoplodon densirostris*	18/04/2004	T	M	Adult	2	1	Plastic debris and stone	Fishes	No	NPALBC
9	*S. coeruleoalba*	26/04/2004	T	M	Subadult	2	2	Plastic bag	N.D.	Impacted stomach	FBAP
10	*Steno bredanensis*	06/08/2004	GC	M	Juvenile	1	2	Plastic debris	Squid beaks and not digested food	Congestion and ulcerative gastritis	NPALBC
11	*P.macrocephalus*	11/05/2005	F	F	Subadult	4	4	Plastic debris	Squid beaks and lens	Perforation and ulcerative gastritis.	SC
12	*S. frontalis*	10/12/2005	GC	M	Adult	2	2	Hook and glass fragment	Absence	No	NPALBC
13	*M. europaeus*	06/04/2006	GC	F	Juvenile	3	2	Thread and metal filament	Squid beaks	Perforation and ulcerative gastritis.	FBAP
14	*Z. cavirostris*	06/07/2006	T	ND	Juvenile	3	3	Plastic debris and plastic wire	Squid beaks	Impacted stomach. Digested blood in stomach	FBAP
15	*S. frontalis*	01/01/2007	L	F	Subadult	3	1	Plastic bags	Absence	Impacted stomach. Digested blood in stomach. Ulcerative gastritis.	FBAP
16	*M. bidens*	16/04/2007	L	M	Adult	1	2	Plastic plug	Absence	Healed ulcers	SC
17	*Delphinus delphis*	28/04/2007	T	M	Adult	2	3	Plastic debris and ropes	Fishes	No	NPALBC
18	*Grampus griseus*	20/04/2008	T	M	Juvenile	2	2	Ropes, plastic debris and metal filaments	N.D.	Ulcerative gastritis	NPALBC
19	*St. frontalis*	26/04/2008	F	F	Calf	2	3	Plastic debris	Squid beaks and lens	No	NPALBC
20	*G. griseus*	07/11/2008	F	F	Calf	1	2	Thread	Squid beaks	Healed ulcers	I
21	*S. bredanensis*	18/11/2008	GC	M	Adult	1	2	Plastic bag	Squid beaks	Digested blood and ulcerative gastritis	NPALBC
22	*S. coeruleoalba*	22/01/2009	F	F	Adult	2	2	Metal filament	N.D.	Congestion and ulcerative gastritis	NPALBC
23	*B. acutorostrata*	09/04/2009	GC	F	Calf	1	2	Netting remains	Digested food	Ulcerative glossitis and stomatitis	FBAP
24	*P. macrocephalus*	27/06/2009	T	F	Adult	3	3	Rope	Absence	Digested blood, ulcerative gastritis and congestion.	SC
25	*P. macrocephalus*	16/03/2010	T	F	Calf	3	3	Plastic bags and stones	Squid beaks and digested food	Petechiae	I
26	*G. griseus*	22/04/2010	T	M	Juvenile	2	1	Plastic bag and sand	Squid beaks (3)	Ulcerative gastritis	NPALBC
27	*Z. cavirostris*	13/06/2011	T	M	Subadult	3	4	Plastic debris	N.D.	No	SC
28	*P. macrocephalus*	07.09.2011	T	F	Adult	3	4	Electric wire, nylon wire	Squid beaks	No	N.D.
29	*G. griseus*	03/11/2012	F	M	Subadult	2	3	Plastic bags and rope	N.D.	Impacted stomach. Digested blood in stomach. Ulcerative gastritis. Forestomach mucosa hyperplasia.	FBAP

Table 1 (*continued*)

Case	Species	Stranding date	Stranding location	Gender	Age	Body condition	Decomposition code	FB	Stomach contents	Pathological findings	Pathological category
30	*Z. cavirostris*	09/02/2013	L	M	Juvenile	3	3	Plastic debris	Squid beaks and lens	Intestinal perforation and ulcerative gastritis.	FBAP
31	*M. densirostris*	12/02/2014	L	F	Adult	4	3	Rope and plastic debris	Squid, squid beaks and fishes	Ulcerative gastritis and petechiae	NPAGBC
32	*K. breviceps*	20/03/2014	GC	F	Calf	3	2	Plastic debris	N.D.	Impacted stomach. Digested blood in stomach. Congestion and ulcerative gastritis	FBAP
33	*S. coeruleoalba*	23/03/2014	GC	F	Subadult	3	1	Plastic debris	N.D.	Ulcerative gastritis	NPAGBC
34	*S. bredanensis*	01/05/2014	GC	M	Calf	2	1	Plastic debris, sand	Sea sponges	No	NPALBC
35	*Z. cavirostris*	06/06/2014	L	F	Adult	3	3	Plastic debris	Squid beaks and crustaceans	Congestion and digested blood	NPAGBC
36	*Tursiops truncatus*	23/07/2014	GC	F	Adult	2	2	Clothes (bra)	Fishes	No	NPALBC

Table 2
Characteristics of the cetaceans according to presence/absence of FB and FB associated pathology. Categorical variables are expressed as frequencies and percentages - in brackets- and were compared, as appropriate, using the Chi-square ($\chi 2$) test or the exact Fisher test.

	Overall	*FB presence*				*FB Associated Pathology*			
	N = 465	No N = 429	Yes N = 36	p-value	Test	No N = 452	Yes N = 13	p-value	Test
Age				0.053	Chi^2			0.024	Fisher
Neonate/Calve	126 (27.1)	114 (26.6)	12 (33.3)			121 (26.8)	5 (38.5)		
Juvenile/Subadult	135 (29.0)	120 (28.0)	15 (41.7)			128 (28.3)	7 (53.8)		
Adult	204 (43.9)	195 (45.5)	9 (25.0)			203 (44.9)	1 (7.7)		
Sex				0.913	Chi^2			0.871	Chi^2
Female	216 (47.7)	199 (47.6)	17 (48.6)			210 (47.6)	6 (50.0)		
Male	237 (52.3)	219 (52.4)	18 (51.4)			231 (52.4)	6 (50.0)		
Sex mature				0.067	Chi^2			0.043	Chi^2
Immature	228 (49.2)	205 (48.0)	23 (63.9)			218 (48.4)	10 (76.9)		
Mature	235 (50.8)	222 (52.0)	13 (36.1)			232 (51.6)	3 (23.1)		
Species				<.001	Fisher			0.105	Fisher
Misticets	17 (3.7)	15 (3.5)	2 (5.6)			15 (3.3)	2 (15.4)		
Kogia spp.	34 (7.3)	32 (7.5)	2 (5.6)			33 (7.3)	1 (7.7)		
Mesoplodon spp.	19 (4.1)	15 (3.5)	4 (11.1)			18 (4.0)	1 (7.7)		
Delphinus delphis	45 (9.7)	44 (10.3)	1 (2.8)			45 (10.0)	0		
Globicephala macrorhynchus	41 (8.8)	41 (9.6)	0			41 (9.1)	0		
Grampus griseus	12 (2.6)	8 (1.9)	4 (11.1)			11 (2.4)	1 (7.7)		
Physeter macrocephalus	28 (6.0)	22 (5.1)	6 (16.7)			27 (6.0)	1 (7.7)		
Stenella coeruleoalba	92 (19.8)	89 (20.7)	3 (8.3)			91 (20.1)	1 (7.7)		
S. frontalis	83 (17.8)	78 (18.2)	5 (13.9)			80 (17.7)	3 (23.1)		
Steno bredanensis	21 (4.5)	18 (4.2)	3 (8.3)			21 (4.6)	0		
Tursiops truncatus	40 (8.6)	39 (9.1)	1 (2.8)			40 (8.8)	0		
Ziphius cavirostris	33 (7.1)	28 (6.5)	5 (13.9)			30 (6.6)	3 (23.1)		
Coast				0.253	Fisher			0.718	Fisher
Hierro/Palma/Gomera	22 (4.7)	22 (5.1)	0			22 (4.9)	0		
Tenerife	130 (28.0)	116 (27.0)	14 (38.9)			125 (27.7)	5 (38.5)		
Gran Canaria	137 (29.5)	126 (29.4)	11 (30.6)			133 (29.4)	4 (30.8)		
Fuerteventura/Lanzarote	176 (37.8)	165 (38.5)	11 (30.6)			172 (38.1)	4 (30.8)		
Body condition				0.002	Chi^2			0.065	Fisher
Poor/Very poor	140 (33.6)	120 (31.4)	20 (57.1)			133 (32.8)	7 (58.3)		
Good/Fair	277 (66.4)	262 (68.6)	15 (42.9)			272 (67.2)	5 (41.7)		
Diving behavior				0.004	Chi^2			0.172	Fisher
Shallow diver	298 (64.1)	283 (66.0)	15 (41.7)			292 (64.6)	6 (46.2)		
Deep diver	167 (35.9)	146 (34.0)	21 (58.3)			160 (35.4)	7 (53.8)		

highest prevalence while shallow divers the lowest (15/36; 41.7%). Regarding with the total deep-diving necropsied cetaceans, 21/167 (12.57%) of them presented FB.

Deep diving behavior was found to be a risk factor for the presence of FB (OR = 3.330; 95%CI = 1.470; 7.546) (Table 3). In contrast, the relationship between diving behavior and animals with FB associated pathology was not as clear (p-value = 0.172): deep diver (7/13; 53.8%) and shallow diver (6/13; 46.2%) (Table 2).

3.4.5. Sex and gonads maturation

No significant difference (p-value = 0.913) regarding sex and FB presence [females (17/36; 48.6%); males (18/36; 51.4%)] nor sex and FB associated pathology (p-value = 0.871) [(females (6/13; 46.15%); males (6/13; 46.15%)] were found (Table 2). The sex could not be determined in one animal with FB ingestion due to evisceration with loss of reproductive tissues produced by shark bites.

Quasi statistically significant differences (p-value = 0.067) for

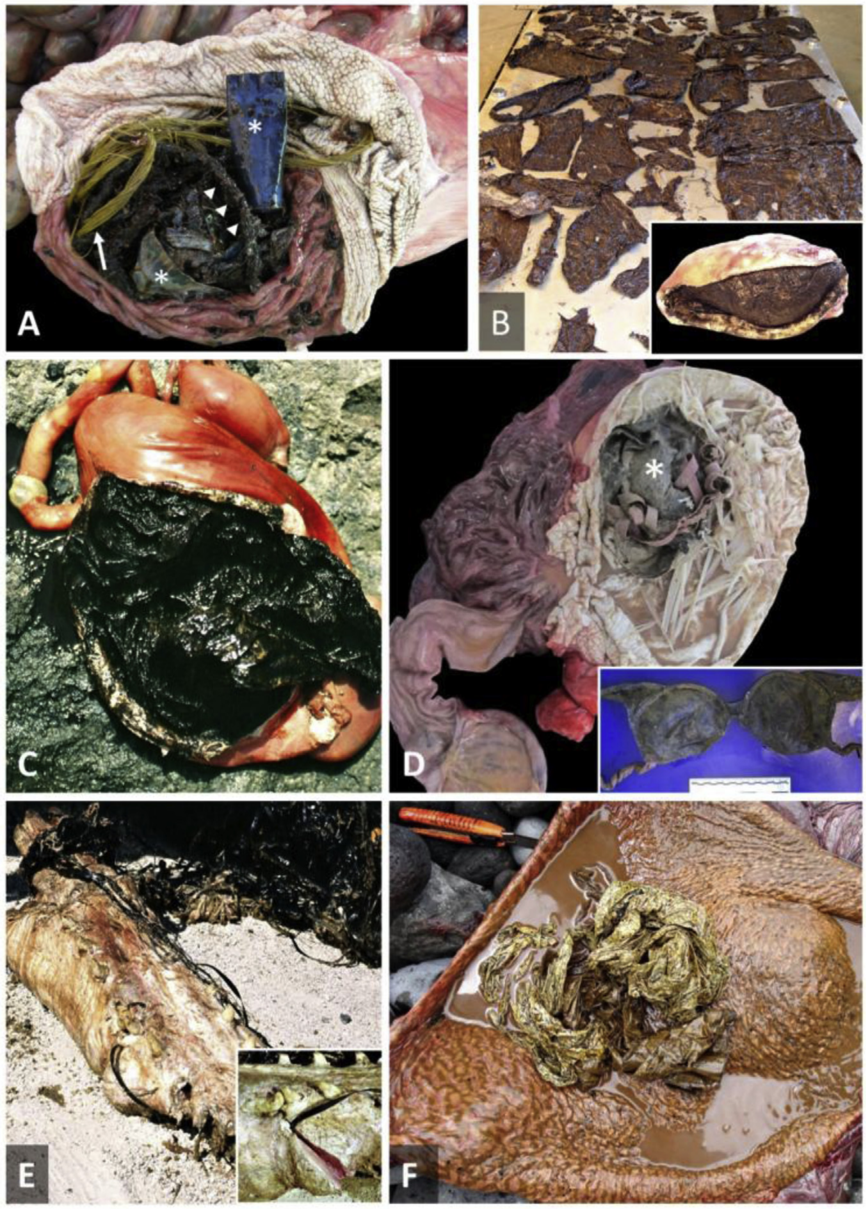

Fig. 1. A, Obstruction of the forestomach caused by plastic debris (asterisk), metal filament (arrow) and ropes (arrowheads), *Grampus griseus*, case 20; B, Approximately 20 digested plastic bags found in the forestomach, stomach impaction (inset), *Stenella frontalis*, case 15; C, Impaction of the forestomach caused by plastic debris, *S. frontalis*, case 4; D, Foreign body (a bra) with digested fishes in the forestomach, exposed mainstomach and piloric stomach, full bra found in the forestomach (inset), *Tursiops truncatus*, case 36; E, Plastic packing tape in oral cavity wrapped with pieces of ropes and nets and large quantity of marine organisms (algae, crustaceans, molluscs), penetrating lesion into oral mucosa caused by the foreign body (inset), *Physeter macrocephalus*, case 7; Plastic debris in the main stomach, congestion and digested blood, *Ziphius cavirostris*, case 14.

presence of FBs were found between sexually immature (23/36; 63.89%) and mature (13/36; 36.11%) animals (Table 2). This difference was statistically significant for FB associated pathology (p-value = 0.043), where the majority of the animals dead due to FB ingestion were immature (10/13; 76.92%). Mature animals affected by FB ingestion represented only 3/13 (23.08%) of the FB associated pathology cases (Table 2).

3.4.6. Age

Quasi statistically significant differences (p-value = 0.053) for presence of FBs were found between age categories. Highest prevalence was detected in juveniles/subadults (15/36; 41.7%) followed by calves (12/36; 33,33%), being adults the lowest (9/36; 25.0%) (Table 2). There was an absence of FB in neonates.

The difference between age categories for FB associated pathology was statistically significant (p-value = 0.024) (Table 2). The highest prevalence in FB associated pathology was in juveniles/subadults (7/13; 53.85%). Only one adult died by FB associated pathology (1/13; 7.69%). The adult age showed independent association with the presence of FB and was found to be a protective factor (OR = 0.233; 95%CI = 0.084; 0.641) (Table 3).

3.4.7. Body condition

The results show a high statistical significance difference between the presence of FB and body condition (p-value = 0.002) (Table 2), being poor condition (13/36; 36.11%) the highest prevalence and good the lowest (4/36; 11.11%). Poor body condition was found to be a risk factor for the presence of FB (OR = 4.080; 95%

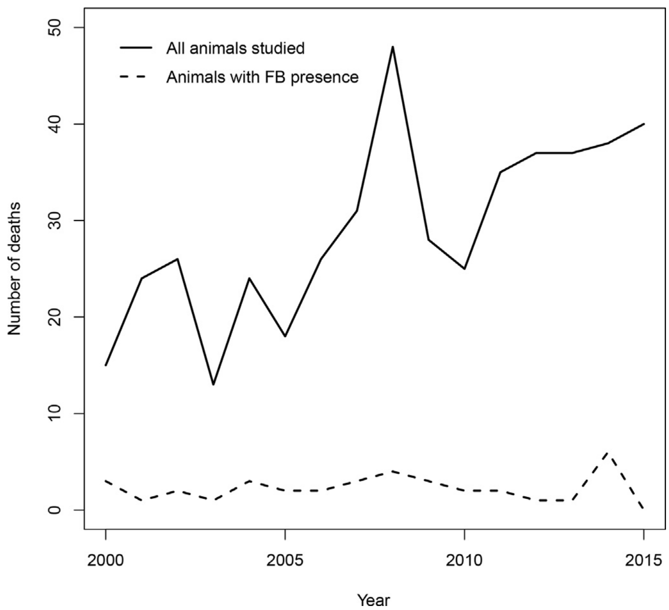

Fig. 2. Total studied cetaceans and foreign body cases per year of studied period (2000–2015).

Table 3
Multivariate logistic regression for the presence of foreign body. Odds ratio (OR), confidence interval (CI).

	Coefficient (SE)	P	OR (95% CI)
(Intercept)	−3.211 (0.416)	<0.001	0.040 (0.018; 0.091)
Adult age	−1.459 (0.517)	0.005	0.233 (0.084; 0.641)
Poor body condition	1.406 (0.419)	<0.001	4.080 (1.794; 9.278)
Deep diving behavior	1.203 (0.417)	0.004	3.330 (1.470; 7.546)

CI = 1.794; 9.278) (Table 3). In contrast, the relationship between body condition and animals with FB associated pathology was not as clear (p-value = 0.065) (Table 2): poor/very poor (7/13; 53.85%) and good/fair (5/13; 38.46%). In one case body condition could not be determined due to its advanced decomposition state.

4. Discussion

Plastic has been described as the most ubiquitous and prevalent debris in the ocean (Cozar et al., 2014). In this study, the FB most frequently found in stranded cetaceans was plastic (80.56%) as in the literature (e.g. Baulch and Perry, 2014). Other marine debris found in stranded cetaceans are nets, threats or ropes used by fishing activities (e.g. Jacobsen et al., 2010). Domestic and agricultural items have also been reported (e.g. De Stephanis et al., 2013; Unger et al., 2017).

FB ingestion caused fatal lesions in 13/36 (36.11%) animals. Similar lesions associated with ingested marine debris leading to eventual death have been previously described in the literature (e.g. Abollo et al., 1998; Stamper et al., 2006; Arbelo et al., 2013). In addition, ten animals with presence of FB had neither grossly nor microscopically evident lesions associated with FB ingestion. In a similar way Unger et al., 2016 described the presence of FB with absence of event lesions in a mass stranding of sperm whales along the North Sea coast in 2016. Mortality rates and sublethal harmful effects due to FB ingestion remain poorly understood (Williams et al., 2011; Simmonds, 2012), so further research is needed. It is important to consider that 50% of species reported in this archipelago were affected by FB ingestion. A fin whale and six sperm whales, cataloged as endangered and vulnerable species at IUCN red list, were affected by marine debris pollution. Scarce reports have described FB in cetaceans of the Canary Islands before (Fernández et al., 2009; Arbelo et al., 2013), increasing from 8 to 15 affected species in this study. The impact of marine debris in cetaceans is of major conservation concern and should be further analyzed and compared with other geographical areas (Besseling et al., 2015; Unger et al., 2016). In this study, both odontocetes and mysticetes were affected by FB ingestion. High discrimination capacity has been assumed in odontocetes, which exhibit an active feeding linked to a highly developed echolocation system used for predation and orientation (Walker and Coe, 1990). By contrast, mysticetes present passive feeding behavior, filter the water to catch preys. Thus, baleen whales have been used as a 'monitoring species' because of their exposure to marine debris and microplastics directly from the water column as well as via prey species (Fossi et al., 2012, 2014, 2016). According to the similar percentages of affected animals found between both groups, we propose that odontocetes species be considered as sentinels of ocean macrolitter pollution.

Our results suggest that deep diving species ingest more FB than shallow diving species, as previously reported (Lusher et al., 2018). Species with some degree of association with the sea bottom are suggested to be bioindicators of marine debris pollution in previous studies (Di Beneditto and Ramos, 2014). However, this is the first study that has statistically analyzed the relationship between diving behavior and FB ingestion. The depth where the FB ingestion occurs is still unknown. No statistical significance was found between diving behavior and FB associated pathology. This could be explained by the small number of FB associated pathology cases.

This is the first study that has statistically analyzed the relationship between age categories and FB ingestion. Our results suggested that the adult age is a protection factor. Juvenile and subadult animals were the most affected ages by FB ingestion, followed by calves, while there was an absence of FB in neonates. Some authors have pointed out a 'mistaken identity' with a prey (Carpenter and Smith, 1972) or the foraging inexperience of immature animals (Di Beneditto and Ramos, 2014) as a possible cause of FB ingestion. In cetaceans, it is well known that juveniles are more curious about marine debris and interact more often with it (Laist, 1987). In other species of marine mammals, the presence of FB were most commonly found in juveniles (Unger et al., 2017). Neonates with FB have not been reported. Their feeding and social maternal dependence may explain this lack of interaction.

This study is also the first one in studying statistically the relationship between body condition and FB presence in cetaceans. Previously, starvation, malnutrition (Laist, 1997) or limited predator-avoidance capabilities (Secchi and Zarzur, 1999) were described as consequence of FB ingestion. Other authors proposed loss body condition as a risk factor for FB ingestion (Baird and Hooker, 2000; de Meirelles and do Rego Barros, 2007; Unger et al., 2017) associated or not with pre-existing disease factors, such as parasitism (Walker and Coe, 1990). Our study showed high statistical significance between body condition and presence of FB. Poor body condition was found to be a risk factor for FB ingestion but not for FB associated pathology. Acute lethal lesions, such as perforation or impaction, caused the death of the animals without loss of body condition in 5 cases (5/13; 38.46%). Loss of body condition can also occur as a consequence of FB ingestion in chronic cases. Though, in other cases the presence of FB was not associated with lesions or a deficient body condition, as previously reported (Unger et al., 2016). The long-term deleterious effects of FB ingestion have been less studied (Jacobsen et al., 2010; Simmonds, 2012) and need further research.

Additional investigations should take special emphasis on microplastics, plastic fragments smaller than 5 mm. Their toxicological potential is due to persisted organic pollutants (POP's) added during plastics' manufacture and other contaminants (e.g. polyethylene, polypropylene and phthalates) adsorbed from the surrounding seawater. Those pollutants are considered human and wildlife health risks that can potentially affect the physiology of organisms (Teuten et al., 2007; Latini, 2005) and be bioaccumulated on the food-chain (Carpenter and Smith, 1972; Teuten et al., 2009; Cole et al., 2011). Microplastics have been found in at least 180 marine species, including a True's beaked whale (*Mesoplodon mirus*) and a humpback whale (*Megaptera novaeanglia*) (Besseling et al., 2015; Lusher et al., 2015). Also, the presence of leached plastic additives has indicated chronic exposure in Mediterranean fin whales (Fossi et al., 2012).

5. Conclusions

The results from this study provided insights of the potential impact cause by ingested FBs on the animal's health and mortality. Marine debris were found affecting many different species of both shallow and deep diving behavior, the latter group being the most affected. Most FBs were of plastic nature. Ingested FB were associated with cause of death in more than one third of the cases, due to lethal lesions such as impactions and gastrointestinal perforations. To the authors knowledge this is the first study that used statistical analysis to investigate risk and protective factors for FB ingestion: poor body condition and deep diving behavior were found to be risk factors for FB ingestion, meanwhile the adult age was a protective factor. The results from this study contributes to increase the knowledge of FB impact in cetacean's health. This is critical to set the scientific basis for prospective impact monitoring and future conservation policies.

Declaration of interests

None.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.envpol.2018.09.012.

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