Aquatic Mammals 2020, *46*(2), 215-235, DOI 10.1578/AM.46.2.2020.215

Injuries, Malformations, and Epidermal Conditions in Cetaceans of the Strait of Gibraltar

Helena Herr,[1+] Patricia Burkhardt-Holm,[2+] Katharina Heyer,[3]
Ursula Siebert,[4] and Jörn Selling[3]

[1]*Center of Natural History – CeNak – University of Hamburg, Martin-Luther-King-Platz 3, 20146 Hamburg, Germany*
E-mail: helena.herr@uni-hamburg.de
[2]*University of Basel, Department of Environmental Sciences, Man-Society-Environment,*
Vesalgasse 1, 4051 Basel, Switzerland
[3]*firmm.org, Pedro Cortés 4, 11380 Tarifa, Spain*
[4]*Institute for Terrestrial and Aquatic Wildlife Research, University of Veterinary Medicine Hanover Foundation,*
Werftstraße 6, 25761 Buesum, Germany
+Equal author contribution

Abstract

The Strait of Gibraltar is a heavily used marine area, with intense fishing operations and one of the busiest shipping lanes worldwide. Concurrently, the Strait of Gibraltar is home to eight regularly occurring species of cetaceans. Thus, the potential for conflict between man and cetaceans is high. Injuries and external anomalies may serve as indicators for anthropogenic impacts and exposure to human activities. To explore potential impacts to cetacean populations inhabiting the Strait of Gibraltar, we analysed photographs taken opportunistically during whale-watching operations from 2001 to 2015. Externally visible conspicuous features and anomalies were detected in all of the eight regularly occurring cetacean species: short-beaked common dolphin (*Delphinus delphis*), striped dolphin (*Stenella coeruleoalba*), common bottlenose dolphin (*Tursiops truncatus*), long-finned pilot whale (*Globicephala melas*), killer whale (*Orcinus orca*), sperm whale (*Physeter macrocephalus*), fin whale (*Balaenoptera physalus*), and minke whale (*Balaenoptera acutorostrata*). Altogether, 502 anomalies were documented in 494 cases of affected cetaceans, including injuries, skin anomalies, emaciation, and neoplasia. Highest prevalence was noted for injuries (245 incidences) of which a minimum of 44 (17%) were consistent with anthropogenic injuries. Our results suggest that human activities in the Strait of Gibraltar, especially fishing activities, pose a threat, particularly to small and medium-sized cetaceans. We, therefore, recommend stricter management enforcement of existing guidelines and laws, as well as the implementation of an area-wide management plan.

Key Words: whales, dolphins, injury, disease, human impact, management

Introduction

The Strait of Gibraltar, the only passage between the Mediterranean Sea and the Atlantic Ocean, is a heavily used marine area (Halpern et al., 2008). The 14-km narrow strait separating Europe and Africa is one of the busiest shipping lanes worldwide (Halpern et al., 2008), with 60,000 vessels transiting the strait every year (Gibraltar Port Authority, 2019) and at least 60 ferries crossing the strait daily (Direct Ferries, 2019; FRS, 2019). Furthermore, commercial fishing is intense. By far, the most common are polyvalent vessels (73% in the western Mediterranean; Food and Agriculture Organization of the United Nations [FAO], 2018). Small pelagic fish, such as herring (*Clupea harengus*), sardine (*Sardina pilchardus*), and anchovy (*Engraulis encrasicolus*), represent nearly 50% of the catch, and a broad variety of miscellaneous fish contribute to the catch (García-Tiscar, 2009; FAO, 2018). Pelagic longlines target swordfish (*Xiphias gladius*), bluefin tuna (*Thunnus thynnus*), and albacore (*Thunnus alalonga*). Illegal fishing does occur, with cases of legally registered fishing vessels fishing illegally by using unregistered or illegal gear such as drift nets (Tydeman & Lutchman, 2012). Recreational fishing is widely practiced—particularly, big game fishing using big hooks and durable lines, which pose threats to cetaceans by means of hooking and entanglements, and cause wounds and deep cuts via fishing lines similar to longline fisheries (Gilman et al., 2006; Macías López et al., 2012). These activities are currently unmanaged in the waters of Gibraltar (Tydeman & Lutchman, 2012). Most fisheries have been shown to interact with marine mammals and may cause incidents (FAO, 2018). Longline fisheries are responsible for most of the incidental catches of vulnerable species, and those gears are likely responsible for numerous injuries (Macías López et al., 2012; Baez et al., 2013; De Vere et al., 2018; FAO, 2018). The Spanish driftnet fishery was banned in 1994 (Aguilar, 2000); however, driftnet fishing is still being carried out by non-EU Mediterranean fleets as well as illegally. Although illegal, driftnet fishing, targeting swordfish, is still performed in the Strait of Gibraltar and is responsible for the death of an estimated 1,500 to 2,000 common dolphins every year in the southern Alboran Sea (Tudela et al., 2005).

Adjacent to the Strait of Gibraltar, the Alboran Sea, as the westernmost part of the Mediterranean Sea, is known as an extremely productive ecosystem (Vergnaud Grazzini & Pierre, 1991). Upwelling of Mediterranean Sea bottom water at the west side of the Strait of Gibraltar leads to fertilisation of the area by nutrients, resulting in a high abundance of zooplankton, providing a food base for many species of predatory fish and cetaceans in the Alboran Sea (Wierucka et al., 2014). The high density of cetaceans in this intensely used marine area raises the potential for conflict between man and marine mammals (García-Tiscar, 2009).

The Strait of Gibraltar is home to eight regularly occurring species of cetaceans: short-beaked common dolphin (*Delphinus delphis*), striped dolphin (*Stenella coeruleoalba*), common bottlenose dolphin (*Tursiops truncatus*), long-finned pilot whale (*Globicephala melas*), killer whale (*Orcinus orca*), sperm whale (*Physeter macrocephalus*), fin whale (*Balaenoptera physalus*), and minke whale (*Balaenoptera acutorostrata*). Rarely, other species such as Risso's dolphin (*Grampus griseus*), humpback whale (*Megaptera novaeangliae*), and Cuvier's beaked whale (*Ziphius cavirostris*) occur. Interactions between human activities and cetaceans of the Strait of Gibraltar have only been investigated to a limited extent, focusing on specific activities (e.g., driftnet fishing: Tudela et al., 2005; ship strikes: Panigada et al., 2006) or single species (e.g., killer whales: Esteban et al., 2015; killer whales and bottlenose dolphins: García-Tiscar, 2009). While it is difficult to monitor interactions between cetaceans and humans on a wide scale, pathological investigations can provide insights into the impacts of human activities on cetaceans (Siebert et al., 2001; Domiciano et al., 2016; Jepson et al., 2016; Unger et al., 2017).

Although carcasses stranded along the coasts of the Strait of Gibraltar have been collected by a stranding network since 1991, the documentation of stranding events is on a low level, and no systematic pathological investigations have been performed (Rojo-Nieto et al., 2011; Masski & de Stephanis, 2015). Without pathological investigations, empirical evidence for cause-effect relationships is limited. In this case, observations of live cetaceans may provide indications of interactions with human activities or impacts of these activities. Photography has been demonstrated to be a useful tool for documenting health impairments and diseases in cetaceans (Thompson & Hammond, 1992; Bertulli et al., 2012; Luksenburg, 2014). Externally visible anomalies may be indicators for anthropogenic impacts and may serve to identify potential threats to cetacean populations (Van Bressem et al., 2003; Aznar et al., 2005; Brownell et al., 2007; Byard et al., 2012). Injuries and lesions may be indicative of direct interactions such as ship strikes or entanglement in fishing gear (Byard et al., 2012; Barcenas-de la Cruz et al., 2018). Skin diseases, external anomalies, and nutritional condition are regarded as indicators for health status, with pollution and other anthropogenic stressors believed to increase disease susceptibility in cetaceans (Aguilar & Borrell, 1994; Van Bressem et al., 2009; Schwacke et al., 2012). The number of reports on external anomalies such as skin diseases in cetacean species has been growing worldwide (Wilson et al., 2000; Brownell et al., 2007; Bearzi et al., 2009; Bertulli et al., 2012; Hart et al., 2012), especially from areas of intense human use or high pollution (Van Bressem et al., 2003; Bearzi et al., 2009). The western Mediterranean Sea and southwest Iberian Peninsula are global polychlorinated biphenyl (PCB) "hotspots" (Jepson et al., 2016), partly caused by the upwelling carrying and redistributing pollutants. PCB levels in cetaceans inhabiting this area well exceed the known marine mammal PCB toxicity thresholds and may be linked to population declines and reproductive toxicity (Jepson et al., 2016).

Geographic regions with a high degree of anthropogenic activity are of special importance for surveying impacts on cetaceans. Efforts can help to elucidate the potential, the extent, and the form of interaction between humans and marine mammals and may contribute to developing adequate conservation measures.

In the Strait of Gibraltar, whale-watching activities are regularly being carried out. During these operations, individual cetaceans and groups of cetaceans have been routinely photographed over the last 15 years. This collection of photographs provides a potentially valuable source of information to evaluate detectable health issues in the cetaceans observed. Our study aimed to provide a first qualitative assessment of the occurrence of injuries, malformations, epidermal conditions, and other visible health impairments in cetaceans of the Strait of Gibraltar.

Methods

Data Collection

Whale-watching operations were conducted in the Strait of Gibraltar by the foundation *firmm* (*foundation for information and research on marine mammals*) from 2001 to 2015 from late March to early November. In total, data were collected during 13,601 h at sea, covering a total track of 182,550 km. The number of trips per day depended on weather and tour demand, and it varied between none and five trips during high season (July-August/September). Each regular trip lasted 2 h, while specific killer whale trips of 3 h were offered in killer whale season (June through September). The trips started and ended in the harbours of Algeciras or Tarifa and ran southeastwards towards 35° 54.500 N, 5° 38.500 W, while the killer whale trips ran further west (start of search towards south and then east at 35° 55.540 N, 5° 43.404 W). Positions of sightings, including species identification, are shown in Figure 1. Animals were spotted visually from the crow's nest by dedicated observers (biologists) and were observed for a maximum of 15 min. Photographic data were collected opportunistically during the whale-watching operations on four different motorboats of different sizes (length: 9 to 16 m; width: 3 to 4.8 m) and power (250 to 1,000 CV). Animals were photographed at variable distances, with fin and sperm whales mostly in distances of 100 m or more while the distance to the smaller odontoceti was approximately 60 m (or less when animals approached the vessels). Conspicuous features or abnormal behaviour, which could indicate poor health, pain, or deformations not immediately visible, triggered taking photographs to enable later inspection. Photographs were also taken for aesthetic reasons, behavioural documentation, photo-identification, or memory.

Fujifilm FinePix 4700 ZOOM (2001 to 2005) and Canon EOS 300D (2005 to 2015) cameras with 70-200 mm lenses were utilised. Photo-identification of individuals was not an objective during the whale-watching operations. However, especially due to conspicuous features, several animals could be identified as individuals and were encountered and photographed on multiple occasions. This allowed for tracking of individual life histories.

Animals were described as calves when fetal bands were still visible or the individuals were clearly smaller than the conspecifics.

Dorsal fin images and additional photographs that encompassed large portions of the body during surfacing or of the entire animal while breaching were taken opportunistically. In addition, deceased animals encountered floating in the water as well as carcasses found on beaches were opportunistically photographed. Two Cuvier's beaked whales, one humpback whale, two bottlenose dolphins, three striped dolphins, and three unidentified dolphins were found along the Spanish coast of Algeciras and Tarifa from 2001 to 2015.

Data Analysis

All photographs were scanned visually. First, pictures of insufficient quality (i.e., blurred, overexposed, or too dark) were excluded, and then all of the remaining pictures were inspected for visible conspicuous features in cetaceans. In total, 35,205 photographs were taken, and 788 images showing externally visible conspicuous features were extracted. Based on the observed structures rather than presumed aetiology, the following categories were established for classification of four different types of conspicuous features:

1. Emaciation – Characterised by postcranial depression and/or clearly defined rib impressions under the skin (Domiciano et al., 2016)

2. Deformation – Bent down dorsal fins, humps, and lordosis

3. Injury – Blunt and sharp trauma, cuts, and lesions

4. Skin Anomaly – Epizoa, neoplasia, piebaldism, and skin diseases

Prevalence and severity were not evaluated statistically due to the opportunistic nature of the study and a bias towards animals with conspicuous features being photographed; therefore, our study did not allow for control of the proportion of animals with conspicuous features and was qualitative rather than quantitative in its approach. Assessments were conducted visually based on photographs; biopsies were not available. Appearance of skin anomalies was described, compared to published aetiology for diagnosis, and judged based on expert opinion by a pathologist with more than 20 years of experience in wildlife health assessment. Apart from existing expertise in the field (e.g., Siebert et al., 2001, 2006) and standard handbooks of marine mammal medicine (e.g., Dierauf & Gulland, 2001), we consulted published works on skin anomalies (e.g., Abreu et al., 2013; Bertulli et al., 2012), epizoic infestations (e.g., Aznar et al., 2005; Loizaga de Castro, 2014), lesions and deformities (e.g., Brownell et al., 2007; Bearzi et al., 2009; Byard et al., 2012; Hart et al., 2012), nutritional conditions (e.g., Gómez-Campos et al., 2011; Domiciano et al., 2016), and disease (e.g., Bermudez et al., 2009; Van Bressem et al., 2009).

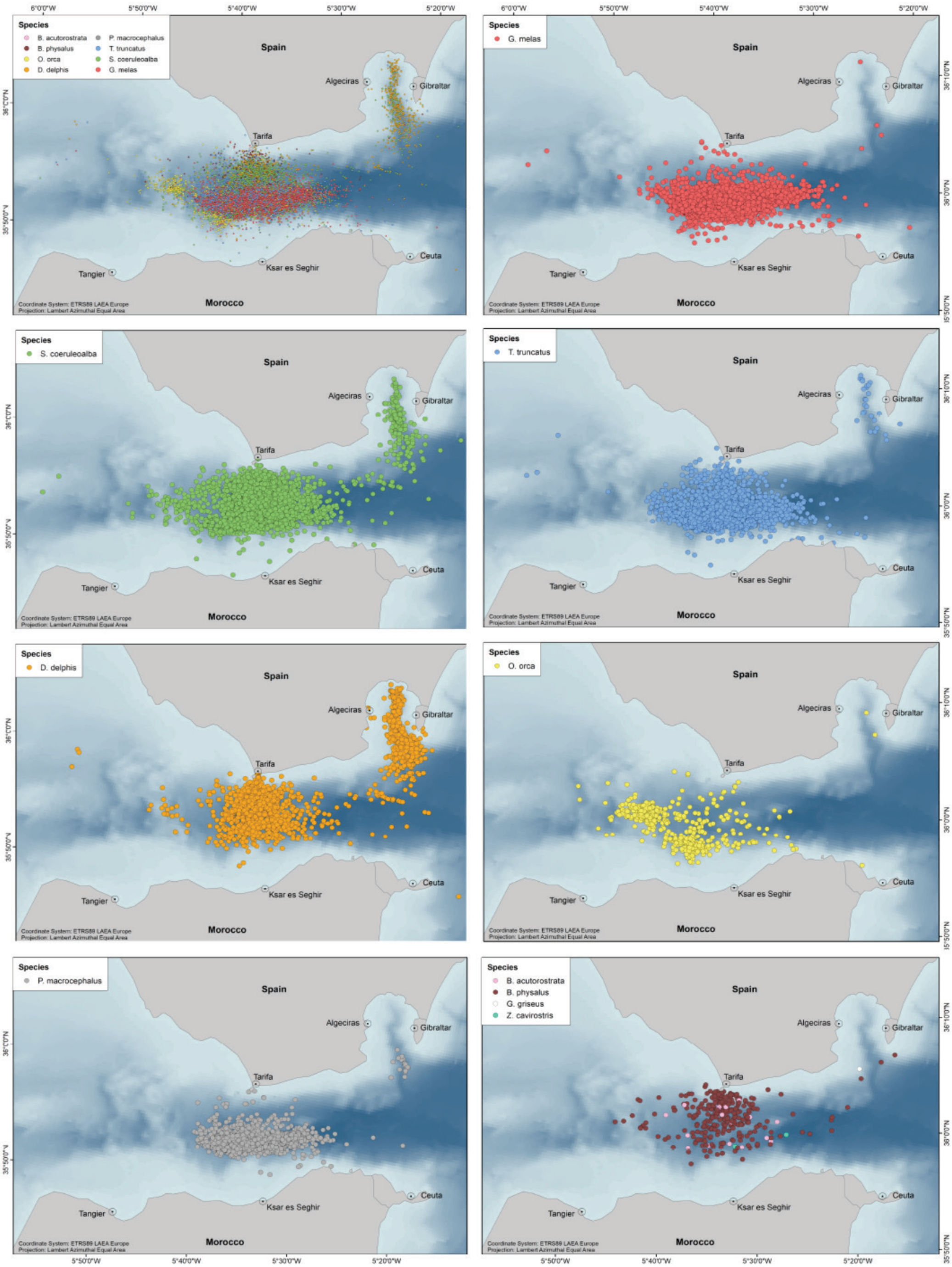

Figure 1. Positions of cetacean sightings recorded during whale-watching operations in the Strait of Gibraltar by the organisation *firmm* between 1999 and 2015. **Note:** Distribution of sightings reflects the area of operation and effort of whale-watching tours and does not represent a quantitative estimation of cetacean distribution in the Strait of Gibraltar.

The visual appearance of the ribs was used as an indication for emaciation in this study (Joblon et al., 2014). Injuries were described based on pathological expertise from 20 years of necropsy experience, possibly including the description of the injury-causing agent (e.g., medium-sharp force agent, blunt trauma, etc.). Specific types of injuries may be attributed to certain human activities. We used criteria detailed by Luksenburg (2014) to assess if observed injuries could be attributed to specific human impacts—for example, linear severed dorsal fins and cleanly severed body parts are most likely the result of amputation by a clean linear surface such as knife cuts, propeller hits, or fishing gear. Indentations or lacerations in the epidermis, especially around the head, dorsal fin, flippers, and fluke, likely result from entanglement in fishing gear (lines and/or nets; Luksenburg, 2014). For an estimate of the share of anthropogenic injuries, we assigned the categories "Unlikely," "Probable," and "Suspected" to injuries as established by Moore et al. (2013).

The quality of the photographs and purely visual inspection did not always allow for a definite determination of anomalies. Therefore, we describe the anomalies, their potential origin, or diagnosis as far as the pictures allow, and we point out uncertainties or multiple possible interpretations.

Results and Discussion

In total, 788 photographs were evaluated for visible anomalies. Of these cases, 494 animals showing at least one anomaly were detected (Table 1). Some animals presented several different anomalies at the same time. Altogether, 502 anomalies were documented. Injuries were the most frequently documented feature (245 cases), followed by skin diseases (102 cases) and epibionts (97 cases). Thirty-four cetaceans had indications of emaciation, 12 presented piebaldism, seven cases of neoplasia were documented, and five cases of deformations were reported. All eight regularly occurring cetacean species of the Strait of Gibraltar were affected by one or more anomalies. Three carcasses of small dolphins could not be identified at species level due to advanced decomposition.

Emaciation

We observed emaciation in 33 bottlenose dolphins (Figure 2A & B) and in one killer whale (Figure 2C). Emaciation describes unnatural thinness of individuals and is characterised by muscular and adipose tissue atrophy, with consequent postcranial depression and clearly defined rib impressions under the skin (Domiciano et al., 2016). Emaciation is usually caused by severe malnourishment or starvation. As such, it may occur as a result of food deprivation, infection

Table 1. Number of observed animals per species in each subcategory of observed anomalies. In some cases, individuals showed more than one feature; thus, the total number of animals with conspicuous features was only 494. Ddel = *Delphinus delphis*, Scoe = *Stenella coeruleoalba*, Unid = unidentified cetacean, Ttru = *Tursiops truncatus*, Gmel = *Globicephala melas*, Oorc = *Orcinus orca*, Pmac = *Physeter macrocephalus*, Bacu = *Balaenoptera acutorostrata*, and Bphy = *Balaenoptera physalus*.

		Number of animals with conspicuous features									
Categories	Subcategories	Ddel	Scoe	Unid	Ttru	Gmel	Oorc	Pmac	Bacu	Bphy	Total
Emaciation					33		1				34
Deformations	Bent down dorsal fins		2				1				3
	Humps & lordosis				2						2
Injuries		7	3	3	36	111	31	46		8	245
Skin anomalies	Epizoa	2			22	45	7	3	1	17	97
	Neoplasia				5		2				7
	Piebaldism	2						10			12
	Skin diseases	1	4		39	27	16	12		3	102
	Total	12	9	3	137	183	58	71	1	28	502

Figure 2. Cetaceans with signs of emaciation: (A) Female bottlenose dolphin with calf (both emaciated, with ribs visible), (B) two adult bottlenose dolphins with calf (the one to the right is emaciated, with ribs visible), and (C) killer whale (ribs visible).

by pathogens, diseases, or injuries (Fenton et al., 2017). Moreover, it can be age dependant (Gómez-Campos et al., 2011). In the field, emaciation can be difficult to detect, particularly when animals are moving and arching their bodies (Joblon et al., 2014). Visibility of the rib impressions is indicative of advanced emaciation in comparison to less easily detectable signs (Joblon et al., 2014). Therefore, the animals reported as emaciated in this study represent a minimum number. There is potential for emaciation in additional animals that went undetected.

Deformations

Physical deformities found in this study were classified as conformational and spinal deformities (Bearzi et al., 2009). Severely bent dorsal fins were observed in two striped dolphins and in one male killer whale (Figure 3A & B). While 5 to 6% of wild male killer whales exhibit bent dorsal fins, this deformity was rarely observed in other cetaceans such as striped dolphins (Alves et al., 2018). Bent fins have been suggested to be caused by a variety of factors, comprising both anthropogenic as well as natural causes (Alves et al., 2018). They may result from poor health or stress, or from entanglement with fishing gear (Visser, 1998; Baird & Gorgone, 2005).

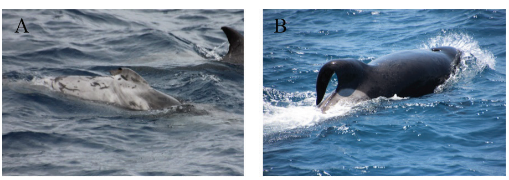

Figure 3. Bent dorsal fins: (A) Striped dolphin with dorsal fin bent down to the left, and (B) male killer whale with bent dorsal fin (and additional skin disease; see Figure 35B).

One bottlenose dolphin (Figure 4A) was observed with a lump at the genital area, similar to a swelling described in a dusky dolphin (*Lagenorhynchus obscurus*) off the Argentine coast with cestode cysts of *Phyllobotrium delphini* in the blubber (Loizaga de Castro, 2014). Since the skin of the animal in our study did not look necrotised (as described for the large abdominal swelling caused by *P. delphini*), the cause of the lump remains unclear. A bottlenose dolphin (Figure 4B & C) showed humps at both sides of the base of the dorsal fin and presented lordosis, an anterior concavity in the curvature of the lumbar and cervical vertebral column as viewed laterally (Wise et al., 1997). This is a first report for lordosis in this region. However, identification, particularly of mild lordosis, may be difficult to ascertain in the field (Weir & Wang, 2016). In the observed case, lordosis may have been caused by a physical trauma or may be a congenital condition. The sharp-angled shape of the spine and the incision at the caudal base of the dorsal fin suggest trauma.

Figure 4. (A) Bottlenose dolphin with swelling at the genital area, and (B & C) bottlenose dolphin with humps at both sides of the base of the dorsal fin and lordosis.

Injuries

Injuries were the most common conspicuous features observed with 245 documented cases. Injuries observed included blunt and sharp force traumata, including cuts, lesions, lacerations, and dismemberments of fin or fluke parts, as well as visible signs (scars) of healed traumata.

Scars (Figures 5 through 8) could be attributed to natural causes in some cases—for example, skidding marks of lampreys (Figure 5B). These scars from former sea lamprey attachments were generally found on the dorsal part of the body in accordance with previous findings (Silva et al., 2014). This is likely due to the relatively thin epidermis and reduced water flow on this part of the body in comparison to flippers and flukes, and the continual expansion of the ventral pouch during feeding in baleen whales. The sliding marks sometimes found associated with bite marks are thought to result from fish skidding over the skin to reattach at a more favourable location as observed in a fin whale (Figure 5B). Other scars

Figure 5. Fin whales with scars: (A) Scar perpendicular to body axis; (B) skidding marks of sea lampreys; and (C) incisive scar behind eye, above flipper.

Figure 6. Sperm whales with scars: (A) Scars of unknown origin; (B) scars possibly inflicted by squid; and (C) scars on fluke—may be a rake mark.

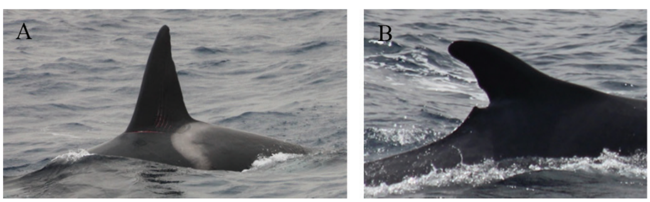

Figure 7. Various scars: (A) Rake marks on a male killer whale, and (B) cut-out part of the dorsal fin of a fin whale.

Figure 8. Scars: (A) Male killer whale with marks on back, (B) pilot whale with a linear scar or abrasion along the back, and (C) bottlenose dolphin with linear scar or abrasion at cranial base of dorsal fin.

likely of natural origin included marks found on sperm whales probably inflicted by squid beaks (Figure 6B) and rake marks in sperm (Figure 6C) and killer (Figure 7A & B) whales. The origin of several scars remained unclear and could have been of natural as well as of anthropogenic origin (Figures 5A & C, 6A, 7B, & 8A-C); however, interaction with fishing gear may be suspected in some cases of very linear scars or cut-like abrasions (e.g., Figure 8B & C; Luksenburg, 2014).

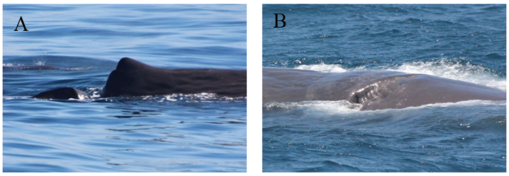

Figure 9. Injuries from trauma probably caused by ship collisions: (A) Sperm whale with deep trauma at caudal base of dorsal fin, and (B) cranial trauma on sperm whale.

A variety of severe trauma and injuries were observed in this study (Figures 9 through 21). Based on photographs, the cause of trauma could not be identified with certainty in all cases. However, the typicality of certain reoccurring traumata suggests specific agents. The two photographs in Figure 9 show deep traumata at the dorsal side of the body in sperm whales consistent with ship collisions. The presence of such parallel and roughly equidistant incising injuries (Figure 9B) is typically associated with propeller-induced trauma (Moore et al., 2013). Fishing lines are suspected to have caused deep lacerations and incisions (Figures 10 to 16), especially for those at the base of the dorsal fin (e.g., Figure 11A-C), or to even be the cause of parts of

Figure 10. Pilot whales with injuries likely of anthropogenic origin: (A & B) Cuts on the dorsal part, possibly from collision or fishing lines; and (C) fresh laceration, possibly from big game gaff or fish hook.

Figure 11. Three pilot whales with injuries probably from lines of big game fishing activity: (A) Deep linear laceration of the skin at the trailing edge, likely caused by medium-sharp force agent; (B) similar injury with barnacles attached to tip of dorsal fin; and (C) partly severed dorsal fin, potentially from previous cut from fishing line or collision trauma.

Figure 12. Deep cuts of probable anthropogenic origin: (A) Pilot whale with deep cut in dorsal fin from collision trauma or fishing line incision in September 2001, with healed incision showing reepithelialisation; (B) same individual in September 2013; and (C) deep linear laceration into cranial base of dorsal fin, potentially caused by fishing line.

Figure 13. Injuries potentially inflicted by fishing lines: (A) Pilot whale with partially severed dorsal fin, healed and reepithelialised; (B) cut in the caudal base of dorsal fin of a bottlenose dolphin; and (C) healing laceration (sharp trauma).

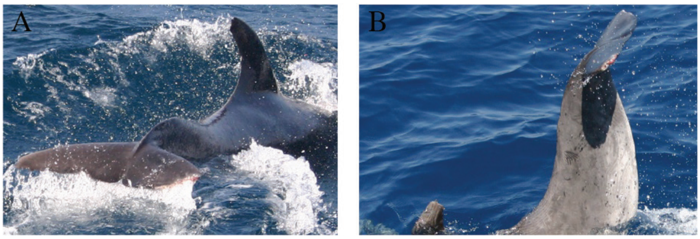

Figure 14. Severed portions of the body: (A) Bottlenose dolphin in April 2007 with severed portion of the right side of fluke; and (B) same animal in September 2008 with additional severed portion, this time to the left side of the fluke. The dolphin either suffered twice from a similar injury-causing agent, or a degenerative process of unknown etiology is abrading the fluke.

Figure 15. Dolphins with various injuries potentially of anthropogenic origin: (A) Bottlenose dolphin with open wound at tip of lower jaw, (B) partially severed dorsal fin of striped dolphin, and (C) fully severed dorsal fin of a common dolphin.

Figure 16. Fishing gear still attached to animals: (A) Remnants of drift net entangled around caudal peduncle of a pilot whale, and (B) fishing line remains at cranial base of dorsal fin of a female killer whale.

the body being severed such as fins (Figures 12A-C & 15B & C) and flukes (Figure 14A & B) (Baird & Gorgone, 2005; Luksenburg, 2014). Several other cases of injuries are suspected to stem from fishing activities such as big game fishing (from big hooks) or long-lining, causing punctures and ripped wounds (Figure 10C) (Macías López et al., 2012); injuries to the rostrum of dolphins (Figure 15A) that could have been inflicted during interaction with fishing nets (Moore et al. 2013); and dorsal edge marks observed in dolphins (Figure 13B) that may have been caused by intragroup activities, particularly occurring in adult males, but could also have resulted from interactions with fishing gear (Baird & Gorgone, 2005; Bamford & Robinson, 2016). Occasionally, fishing gear was still attached to the animal (Figure 16A & B) confirming the cause of the injury. Remnants of a drift net were observed on a pilot whale, with yellow buoys entangled around the caudal peduncle (Figure 16A). These buoys are typically used in driftnet fishing. Derelict remains of damaged nets are regularly observed in the area. Drift nets pose an especially high risk for cetaceans and have been banned in the Strait of Gibraltar by the European Union (EU) since 2002.

Direct interaction between fishermen and cetaceans is a known occurrence in the Strait of Gibraltar. Depredation by killer whales associated with bluefin tuna fisheries in the Strait of Gibraltar is well known (Esteban et al., 2015), and associated bycatch in the large pelagic longline fishery has been reported for several species (Macía Lopez et al., 2012). Interaction with fisheries has been recognised as a very frequent cause of anthropogenic trauma in stranded cetaceans in other regions—for example, in the Canary Islands or along the California coast (Carrillo & Ritter, 2010; Masski & de Stephanis, 2015; Barcenas-de la Cruz et al., 2018; Díaz-Delgado et al., 2018).

In a few cases, tags were identified as potential causes for injury (Figures 17 & 18). Cetaceans in this area are intensely studied for a variety of research questions, and animals were targeted in the recent past for tagging or biopsy sampling (106 long-finned pilot whales, five Risso's dolphins, and 22 bottlenose dolphins; de Stephanis et al., 2008; Giménez et al., 2018). The population sizes of the cetacean species in the Strait of Gibraltar is moderate. For example, the pilot whale population was assessed to range between 147 to 265 individuals (Verborgh et al., 2009), though it is likely that signs of fresh or healed injuries in animals sampled by invasive techniques were recorded in our observations. In one pilot whale (Figure 18A), ulceration occurred around a LIMPET tag still attached to the animal. These tags are usually placed on the animal remotely, using a crossbow or an airgun, with retention petals penetrating into the blubber

Figure 17. Excisions in three pilot whales: (A) Excised integument on right side of body, (B) excised integument at base of dorsal fin, and (C) excision at the dorsal fin. B and C show typical locations for transmitter placements.

Figure 18. Injuries from tagging devices: (A) Pilot whale with ulcerated and necrotising injury around a transmitter attached to its fin, (B) pilot whale with ulcerated and necrotising injury of unknown origin, and (C) same animal with necrotising skin at the base of the fin.

Figure 19. Excisions or ulcerations: (A) Bottlenose dolphin with lesion beside cranial base of dorsal fin, (B) pilot whale with excised or ulcerating integument at left anterior side of dorsal fin, and (C) sperm whale with healing excision or ulceration lesion in front of dorsal fin.

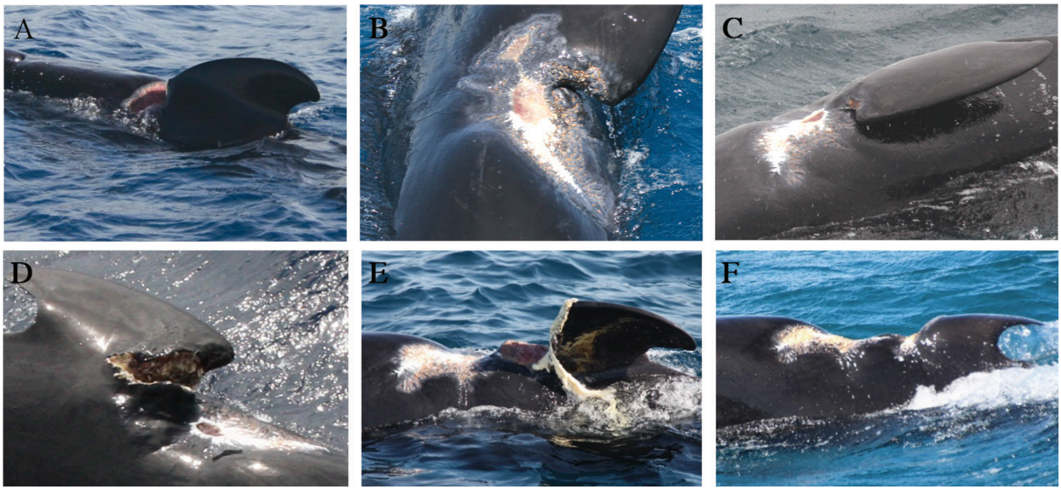

Figure 20. Fate of an injured pilot whale: (A) Deep laceration at cranial base of dorsal fin in July 2008, either inflicted by a propeller or big game fishing activities; (B) the same individual with wound tissue subject to a degenerative process in May 2009, which may be due to secondary infection with pathogenic agents; (C) the same individual in September 2010; the injury seemed to have healed and stabilised; (D) the dorsal fin starts breaking away in July 2011; (E) in August 2011, ulcerated tissue was observed to be necrotising; and (F) this photo shows an apparently stabilised injury on March 2013 but with vesicular tissue of yellowish colour. This was the last sighting of the animal.

and keeping the tag in place (Andrews et al., 2019). While these kinds of tags usually have a minimal impact on the sampled animal, they can at times elicit foreign body reactions for which ulceration and necrosis can occur (Dierauf & Gulland, 2001). In another pilot whale, based on the typical wound pattern, a similar tag fixed at the base of the dorsal fin was suspected to have caused an ulcerating wound on the left side of the fin (Figure 18B) with necrotising tissue at the base of the fin on the right-hand side (Figure 18C). However, according to local research institutions, it was asserted that this animal, identified as Gm_Gib_067 in cetidmed.com (a Mediterranean Sea photo-identification catalogue), had never been tagged by the local research group (Philippe Verborgh, pers. comm., 13 June 2016). Therefore, the origin of the wound, and the ulceration and necrosis in this individual remain dubious. In another pilot whale, barnacle-infested scars present a pattern reminiscent of previous tag placement (Figure 27A; section on epibionts), with a circular scar and three lumps where the petals may have penetrated the skin. Other circular wounds in the integument close to the base of the fin (where tags typically are placed) may represent healing tissue from previous tag attachments and associated ulceration. This has to remain speculative based on the available photographs (Figures 17A-C & 19A-C).

In some cases, a follow-up of injured animals was possible when they were individually identifiable, allowing observation of healing processes

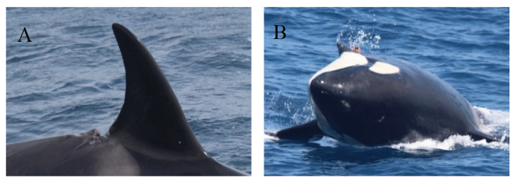

Figure 21. Fate of a female killer whale with injuries likely from fisheries interaction: (A) In August 2015, with a cut at the caudal base of dorsal fin; and (B) with a severed right flipper.

and health consequences for the individual. This was the case in a pilot whale photographed in 2001 and again in 2013 (Figure 12A & B) with a deep vertical incision in the fin, probably caused by either a propeller or a fishing line (Luksenburg, 2014). The two observations, 12 years apart, provide evidence for the survival of the animal.

A different progression of an injury was witnessed in an individually identified pilot whale regularly observed by the whale-watching organisation. It showed a deep laceration at the cranial base of the dorsal fin in July 2008, possibly caused either by a ship's propeller or a big game fishing line (Figure 20A). In 2009, the pilot whale showed inflammation, with possibly suppurative necrotising tissue in connection with reactive and repair processes, at the base of the dorsal fin (Figure 20B). In September 2010, the injury seemed to have healed and stabilised (Figure 20C). The dorsal fin started to break away

Figure 22. Carcasses: (A) Bottlenose dolphin stranded at the beach "El Balneario" (Tarifa, Spain) in May 2011 with remnants of rope entangled around caudal peduncle; (B) striped dolphin with hole similar to those caused by a fisherman's gaff used to pull fish on board (stranded November 2014); and (C) common dolphin, dead, deep laceration anterior to dorsal fin from possible propeller strike. It could not be determined from the picture if the injury was the cause of death or inflicted *postmortem*.

Figure 23. Carcasses: (A) Unidentified dolphin (probably *S. coeruleoalba* or *D. delphis*), with half of fluke severed and remnant of rope entangled around caudal peduncle; (B) unidentified dolphin (probably *S. coeruleoalba* or *D. delphis*), with both paddles of fluke severed; and (C) mutilated young male common dolphin recovered floating dead at the surface in July 2015.

Figure 24. Carcasses: (A) Unidentified dolphin (probably *S. coeruleoalba* or *D. delphis*) with (B) a stone tied to the fluke (same individual, before and after recovery).

in July 2011 (Figure 20D); and in August 2011, ulcerated tissue was observed to be necrotising (Figure 20E). In March 2013, the injury apparently had stabilised, and secondary healing of the injury was documented with granulation tissue formation and loss of skin pigmentation (Figure 20F). This case clearly demonstrates the longevity and severe consequences of anthropogenic injuries, with secondary infections imposing additional risks and health implications.

In a third case, a female killer whale was spotted with a deep laceration at the base of her dorsal fin and a severed right flipper (Figure 21A & B). We suspect ropes of drift nets may have caused these injuries because the marks surrounding the incision at the dorsal fin are consistent with rope marks associated with that fishery. Moreover, killer whale pods are known to regularly interact with fishermen in the Strait of Gibraltar (Esteban et al., 2015).

Several animals that were found dead exhibited severe injuries, but it was not possible to determine whether they were inflicted *ante*- or *postmortem* (Figures 22, 23 & 24). A laceration in the dorsal part and the caudal peduncle of a common dolphin (Figure 22C) was likely caused by a ship propeller. However, since no necropsy was performed, it could not be determined if the injury had been inflicted *ante*- or *postmortem*. This specific kind of injury has been described before in other studies (Byard et al., 2012). Remnants of fishing gear (Figures 22A & 23A) strongly suggest bycatch. Some injuries, like severed flukes (Figure 23A, B & C) or stones tied to flukes (Figure 24A & B) suggest intended sinking or removal from the net of bycaught carcasses by fishermen (Collins et al., 2002; Moore et al., 2013) and provide further indication for an unknown number of bycatch cases in the Strait of Gibraltar.

Altogether, 44 injuries were consistent with anthropogenic impacts, 36 observed injuries were classified as "Probable" for anthropogenic origin, and eight injuries were classified as "Suspected."

Skin Anomalies

Epizoa—Various epibionts were documented in our study, including copepods (Figures 25A-C & 26A & B) and barnacles. Barnacles were the most common epizoa in our observations (Figures 26C, 27A-C & 28A-C). Epizoic crustaceans like barnacles are suitable indicators of health in cetacean populations (Aznar et al., 2005; Vecchione

Figure 25. Copepods (*Pennella balaenopterae*) on whales: (A) Fin whale, (B) minke whale, and (C) sperm whale.

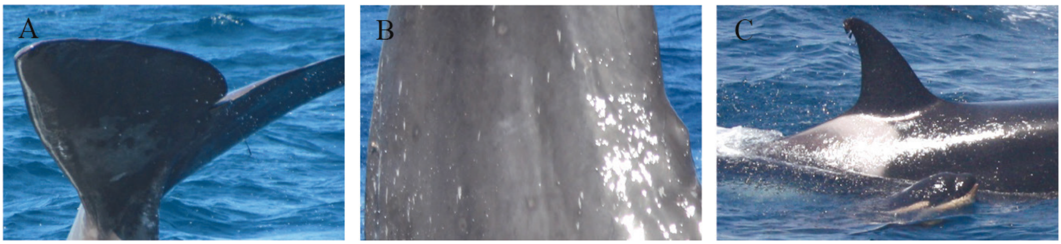

Figure 26. Crustacean epibionts: (A) Copepod attached to ventral side of a sperm whale's fluke with patchy depigmentation, (B) neoplasia or epibiont at ventral side of caudal area of sperm whale also with dark-fringed spots, and (C) barnacles (*Xenobalanus globicipitis*) attached to tip of dorsal fin of female killer whale.

Figure 27. Barnacles as epibionts: (A) Pilot whale with barnacles at scar of formerly attached transmitter on dorsal fin, (B) pilot whale calf with dense colony of barnacles on dorsal fin and flipper, and (C) bottlenose dolphin with barnacles at dorsal fin and patchy depigmentation of fin and back (probably infection with fungus and/or virus since the appearance of the lesion changed since it was first spotted on 2 October 2005).

Figure 28. Barnacles as epibionts on dolphins: (A) Fluke of a bottlenose dolphin with barnacles and depigmentation, (B) fluke of a bottlenose dolphin, and (C) common dolphin with barnacles.

& Aznar, 2008). An increase of prevalence of infestation with *Xenobalanus* and *Pennella* was noted during the first documented morbillivirus epizootic in the Mediterranean in 1990 (Mazzariol et al., 2015), possibly with a high susceptibility related to the immunosuppressive effects of the viral infection (Aznar et al., 2005). Immune suppression was also reported to be associated with PCB exposure in bottlenose dolphins (Schwacke et al., 2012). The western Mediterranean Sea and southwest Iberian Peninsula are recognised as global PCB hotspots for marine mammals (Jepson et al., 2016). Fin whales are known to be affected by morbillivirus and concurrent epizoic infestations in the Strait of Gibraltar (Mazzariol et al., 2015). *Pennella* sp. are little-known copepods that are frequent parasites of large whales. During whale-watching operations, *Pennella* sp. are regularly observed on fin whales migrating through the Strait of Gibraltar (no photograph). *Xenobalanus globicipitis* is a non-pathogenic epizootic crustacean that fixes onto the trailing edges of dolphins' fins and is not known to pose a threat under normal conditions because of its non-invasive nature. One bottlenose dolphin was observed in the Bay of Algeciras (no photograph available) with a widespread colony of *Xenobalanus* on flippers, fluke, and fin. The animal was swimming very slowly, supported by two dolphins.

Neoplasia—Neoplasia were observed in bottlenose dolphins and killer whales in seven cases altogether. They were typically observed on the jaws, and occasionally the surrounding epidermis was affected (Figures 29, 30 & 31A). Viral

Figure 29. Neoplasia in bottlenose dolphins spreading to the epidermis of upper and lower jaw: (A, B & C) Oral papillomatous neoplasia, hyperplasia, or granulomatous inflammation or a combination of these; deformation of the lower jaw—either congenital or due to condition.

Figure 30. Bottlenose dolphin with papillomatous oral neoplasia: (A) Affecting the epidermis of upper and lower jaw, and (B & C) cauliflower-like proliferation protruding at the right side of upper jaw.

Figure 31. Neoplasia in bottlenose dolphins: (A) Deformation with depigmented epidermis and possibly emerging neoplasia, and (B & C) neoplasia of young bottlenose dolphin right next to blow hole.

or chemical clues are known to cause carcinogenesis in marine mammals (Newman & Smith, 2006). Possible agents inducing the disease are *Alpha papilloma* virus (which can cause neoplasia if coexistent with herpesvirus; Rehtanz et al., 2010) and *Lacazia loboi* (lobomycosis; Bermudez et al., 2009; Ueda et al., 2013). The neoplasia observed in this study in a young bottlenose dolphin (Figure 31B & C) may have been caused by previous trauma (rake marks and skin lesion below blowhole are visible), while excrescence of the air sac is a more plausible cause. In two killer whales, anomalies were observed which could be neoplasia but could also be caused by inflammations or cysts induced by epidermal parasites such as helminthes (Bertulli et al., 2012; Van Bressem et al., 2015) (Figure 32A).

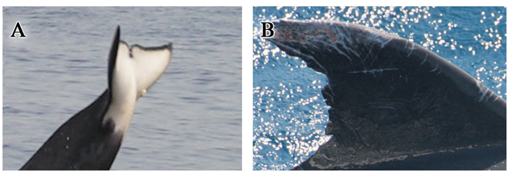

Figure 32. Skin anomalies: (A) Killer whale with anomaly at the ventral side of the fluke, and (B) dermatitis with an abraded and ulcerated fin tip of a bottlenose dolphin.

Bottlenose dolphins (Figures 29 & 30) were observed with oral neoplasia. Oral squamous-cell carcinoma was postulated as the end stage of an infection with papillomavirus in a dolphin, although papillomavirus was not demonstrated in the neoplasms (Newman & Smith, 2006). Another cause for the oral neoplasia may be lobomycosis lesions (Baruzzi et al., 1989). Lobomycosis is an invasive chronic granulomatous skin disease with lesions in dolphins and humans (Mazzariol et al., 2015). To the authors' knowledge, no cetaceans other than dolphins have ever been reported with this disease. Granulomatous masses in the oral cavity have been described by Ueda et al. (2013) in a bottlenose dolphin in captivity. The lower prevalence of lacaziosis-like disease (LLD) in dolphins found in the Atlantic Ocean in comparison to the higher prevalence in the Indian River Lagoon in Florida suggests that environmental conditions within the estuary may favour viability of *Lacazia loboi* and/or that immune compromise in resident estuarine dolphins is a precursor to the disease (Murdoch et al., 2010).

Piebaldism—Piebaldism is a (partial) lack of pigmentation but with normal colouration of the eyes (Abreu et al., 2013). It is a congenital condition not associated with disease or healing processes like other pigmentation losses. It was observed in 12 cases in this study (Figures 33A-C & 35A).

Figure 33. Piebaldism: (A) On dorsal fin and back of a sperm whale; it is unknown if this is a congenital condition; (B) on a dorsal fin of a common dolphin; and (C) common dolphin with widespread piebaldism on dorsal fin, lateral and ventral sides of body.

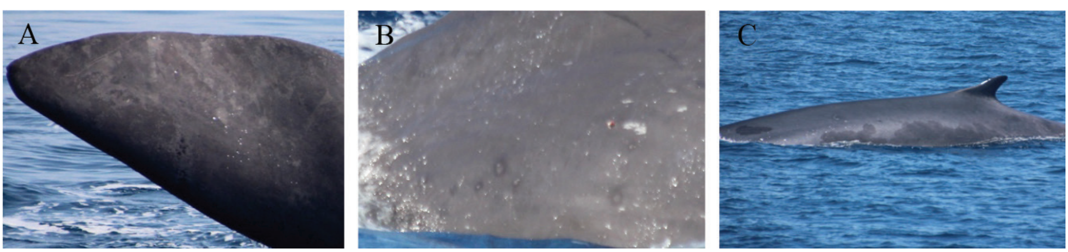

Figure 34. Dark patches and dark-fringed patches: (A) Black and depressed spots on dorsal side of the right paddle of the fluke of a sperm whale with unknown ethiology, (B) sperm whale with dark-fringed spots and a small red protuberance (quality of photo does not allow us to identify whether it is an epibiont or neoplasia), and (C) fin whale with large dark patches mainly on lateral aspect of body with unknown etiology.

Figure 35. Orange and pale patches: (A) Orange skin (likely diatoms) on a sperm whale, plus piebaldism and scars; (B) pale spots on skin of a female killer whale; and (C) black and dark-fringed spots on male killer whale (the same as in Figure 3C; probably different stages of the same disease).

Figure 36. Tattoo-like lesions: (A) Tattoos on subadult pilot whales; (B) large tattoo on young pilot whale; and (C) pale and slightly raised patch of velvety consistence on pilot whale calf, which might be a super-infected tattoo.

Figure 37. Tattoos and pigmentation anomalies: (A) Pale patch (discolouration/depigmentation) of pilot whale calf with spotted fringes; (B) pale, spotted pilot whale calf; and (C) tattoo-like lesions/dark-fringed annular spots with dark centre on another pilot whale calf.

Figure 38. Tattoo-like lesions in bottlenose dolphins: (A) Very large tattoo-like lesions on bottlenose dolphin, potentially an advanced stage of tattoo lesions with secondary infection by fungus or virus; (B) bottlenose dolphin with large, depigmented patch on dorsal area behind the head, and pale spots and pale raised patch below dorsal fin; and (C) large tattoo-like lesions on a bottlenose dolphin.

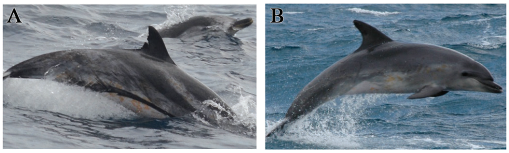

Figure 39. Diatom colonisation: (A) Orange patches of diatoms colonising the skin of a striped dolphin, and (B) orange patches of diatoms colonising the skin of a bottlenose dolphin.

Skin Diseases—The following forms of potentially disease-related altered pigmentation were observed: dark spots/patches (Figures 34A), dark-fringed spots (Figures 34B, 35C & 37C), black spots (Figures 34C & 35C), orange patches (Figure 35A), pale spots/patches (Figures 35B, 37A & B & 38B), tattoo lesions (Figures 36A-C, 37C & 38A & C), abraded fin tips (Figure 32B), and colonisation with diatoms (Figure 39A & B).

Pigmentation anomalies in cetaceans do not necessarily indicate disease. There is a natural variation in pigmentation—for example, in sperm whales for which light patches belong to individual pigmentation patterns (Alessi et al., 2014). Furthermore, a natural shedding of the skin can cause pigmentation patterns (Brownell et al., 2007). Often, pigmentation patterns (mostly pigmentation loss) occur only after a skin disease, indicating healing (Van Bressem et al., 2003). Viruses have been postulated as agents (Wilson et al., 2000; Van Bressem et al., 2004; Domiciano et al., 2016); for example, morbillivirus is known to change the colouration of blubber, sometimes with subcutaneous oedema (Echeverri-Zuluaga et al., 2015). Pale patches on bottlenose dolphins have been associated with herpesvirus (Hart et al., 2012); and dark-fringed spots (e.g., sperm whale in Figure 34B and killer whale in Figure 35C), especially, can point to poxvirus. Based on the photographs, this conclusion cannot be drawn with any certainty. Tattoo lesions are manifestations of the healing process after a poxvirus infection; they can be infected by opportunistic bacteria and/or fungus (Van Bressem et al., 2003). Studies of the development of dark and pale lesions suggest that they are linked, with dark lesions being precursors to pale lesions (Wilson et al., 2000). Based on photographs, the origin of skin anomalies in this study had to remain speculative in most cases and was mostly restricted to a description of the observed pattern. Although no prevalence was analysed in this study, pilot whale calves seemed to be the main group affected (Figures 36 & 37). With regard to tattoo-like lesions, adult bottlenose dolphins were most often observed in this study (Figure 38). A bottlenose dolphin was also observed with dermatitis (Figure 32B) as well as an abraded and ulcerated fin tip for which rake marks might have served as an entrance for opportunistic pathogenic agents. We found orange patches on sperm whales (Figure 35A), bottlenose dolphins, and striped dolphins (Figure 39A & B) which are likely epidermal diatoms that pose no threat to the animal (Van Bressem et al., 2015).

Cutaneous anomalies, such as skin diseases caused by viral, bacterial, or fungal pathogenic agents, may reflect immunosuppression due to altered environmental conditions and disturbance through anthropogenic impacts (Van Bressem et al., 2009; Hart et al., 2012). Also, persistent pollutants can affect the health of cetaceans (Siebert et al., 1999, 2006; Weijs & Zaccaroni, 2016). The concentrations of organochlorine contaminants in the blubber of bottlenose dolphins in the Western Mediterranean and Northeast Atlantic seas are among the highest recorded globally (Aguilar & Borrell, 1994; Jepson et al., 2016). This, together with the known effects of these contaminants, suggests that pollutants may contribute to the incidence of some of the skin diseases we reported.

Conclusion

This study provides the first photographic review to evaluate cetacean health implications in the Strait of Gibraltar. It demonstrates the variety of anthropogenic injuries of cetaceans in this highly used marine area. The Strait of Gibraltar's cetaceans face multiple human impacts, the cumulative effects of which are unknown. Many injuries documented in this study are consistent with impacts from human activities, particularly from fishing lines used in recreational fisheries and nets from commercial and illegal fisheries. Additionally, traumata indicative of vessel collisions were documented. Other stressors, such as prey depletion, noise, and contamination, are likely to have indirect effects, potentially causing immunological impairments leading to enhanced susceptibility with regard to skin disease, a variety of which is reported in this study. Dedicated research on the health status of the cetaceans in this area is needed in combination with effort-related surveys to provide quantitative estimates of the effects of human impacts on the cetacean populations.

The number of leisure boats and fishing operations in the Strait of Gibraltar is steadily increasing, with only limited management and regulations in place. Big game fishing has been subject to a tuna fish quota and has been limited to a certain period of time in summer for several years now. Illegal fishing is regularly being witnessed, however, sometimes with remarkably high effort during the summer months. In addition, whale-watching regulations that have set safety distances to cetacean pods since 2007 (per the Spanish Royal Decree 1727/2007), which recreational fishing vessels also have to adhere to, apply only to Spanish waters (northern half of the Strait of Gibraltar). There are no such regulations in force for Moroccan waters. Moreover, these regulations are regularly disregarded by recreational fishing boats, which approach cetaceans in the hope that their presence indicates high concentrations of fish (authors' pers. obs.).

Based on the observations from this study, there is a need for the improvement of management and regulations for human activities in the Strait of Gibraltar. Especially harmful fishing practices (use of drift nets and long-lining recreational big game fishing) need to be monitored and regulated. We suggest imperative monitoring of human impacts on the cetacean populations of the Strait of Gibraltar. Stricter enforcement and control of existing laws, such as the Spanish Royal decree 1727/2007, for whale watching, catch quota for recreational fishing, and the ban of drift nets are needed to effectively protect the local cetacean populations. To ensure area-wide protection regardless of national borders, the implementation of a management plan for the whole Strait of Gibraltar to mitigate anthropogenic impacts is highly recommended.

Acknowledgments

This study was conducted with the support of the foundation *firmm*, which offers educational whale watching and a platform for observation, with continuous and ongoing data collection since 1999. Special thanks to the skippers, sailors, guides, and volunteers who helped to make this work possible through their effort.

Literature Cited

Abreu, M. S. L., Machado, R., Barbieri, F., Freitas, N. S., & Oliveira, L. R. (2013). Anomalous colour in neotropical mammals: A review with new records for *Didelphis* sp. (Didelphidae, Didelphimorphia) and *Arctocephalus australis* (Otariidae, Carnivora). *Brazilian Journal of Biology*, *73*(1), 185-194. https://doi.org/10.1590/S1519-69842013000100020

Aguilar, A. (2000). Population biology, conservation threats and status of Mediterranean striped dolphins (*Stenella coeruleoalba*). *Journal of Cetacean Research and Management*, *2*(1), 17-26.

Aguilar, A., & Borrell, A. (1994). Abnormally high polychlorinated biphenyl levels in striped dolphins (*Stenella coeruleoalba*) affected by the 1990-1992 Mediterranean epizootic. *Science of the Total Environment*, *154*, 237-247. https://doi.org/10.1016/0048-9697(94)90091-4

Alessi, J., Aïssi, M., & Fiori, C. (2014). Photo-identification of sperm whales in the north-western Mediterranean Sea: An assessment of natural markings. *Aquatic Conservation*, *24*(Supp. 1), 11-22. https://doi.org/10.1002/aqc.2427

Alves, F., Towers, J. R., Baird, R. W., Bearzi, G., Bonizzoni, S., Ferreira, R., Halicka, Z., Alessandrini, A., Kopelman, A. H., Yzoard, C., Rasmussen, M. H., Bertulli, C. G., Jourdain, E., Gullan, A., Rocha, D., Hupman, K., Mrusczok, M-T., Samarra, F. I. P., Magalhães, S., Weir, C. R., . . . Dinis, A. (2018). The incidence of bent dorsal fins in free-ranging cetaceans. *Journal of Anatomy*, *232*, 263-269. https://doi.org/10.1111/joa.12729

Andrews, R. D., Baird, R. W., Calambokidis, J., Goertz, C. E. C., Gulland, F. M. D., Heide-Jørgensen, M-P., Hooker, S. K., Johnson, M., Mate, B., Mitani, Y., Nowacek, D. P., Owen, K., Quakenbush, L. T., Raverty, S., Robbins, J., Schorri, G. S., Shpak, O. V., Townsend, F. I., Jr., Unart, M., Wells, R. S., & Zerbini, A. N. (2019). Best practice guidelines for cetacean tagging. *Journal of Cetacean Research and Management*, *20*, 27-66.

Aznar, F. J., Perdiguero, D., Pérez del Olmo, A., Repullés, A., Agustí, C., & Raga, J. A. (2005). Changes in epizoic crustacean infestations during cetacean die-offs: The mass mortality of Mediterranean striped dolphins *Stenella coeruleoalba* revisited. *Diseases of Aquatic Organisms*, *67*, 239-247. https://doi.org/10.3354/dao067239

Baez, J. C., Macías, D., Camiñas, J. A., Ortiz de Urbina, J. M., García-Barcelona, S., Bellido, J. J., & Real, R. (2013). By-catch frequency and size differentiation in loggerhead turtles as a function of surface longline gear type in the western Mediterranean Sea. *Journal of the Marine Biological Association of the United Kingdom*, *93*(5), 1423-1427. https://doi.org/10.1017/S0025315412001841

Baird, R. W., & Gorgone, A. M. (2005). False killer whale dorsal fin disfigurements as a possible indicator of long-line fishery interactions in Hawaiian waters. *Pacific Science*, *59*, 593-601. https://doi.org/10.1353/psc.2005.0042

Bamford, C. C. G., & Robinson, K. P. (2015). An analysis of dorsal edge markings in short-beaked common dolphins (*Delphinus delphis* L.) from the Bay of Gibraltar and the Moray Firth. *Journal of the Marine Biological Association of the United Kingdom*, *96*(4), 999-1004. https://doi.org/10.1017/S0025315415001150

Barcenas-de la Cruz, D., DeRango, E., Johnson, S. P., & Simeone, C. A. (2018). Evidence of anthropogenic trauma in marine mammals stranded along the central California coast, 2003-2015. *Marine Mammal Science*, *34*(2), 330-346. https://doi.org/10.1111/mms.12457

Baruzzi, R. G., Rodrigues, D. A., Michalany, N. S., & Salomão, R. (1989). Squamous-cell carcinoma and lobomycosis (Jorge Lobo's Disease). *International Journal of Dermatology*, *28*(3), 183-185. https://doi.org/10.1111/j.1365-4362.1989.tb02459.x

Bearzi, M., Rapoport, S., Chau, J., & Saylan, C. (2009). Skin lesions and physical deformities of coastal and offshore common bottlenose dolphins (*Tursiops truncatus*) in Santa Monica Bay and adjacent areas, California. *Ambio*, *38*(2), 66-71. https://doi.org/10.1579/0044-7447-38.2.66

Bermudez, L., Van Bressem, M-F., Reyes-Jaimes, O., Sayegh, A. J., & Paniz-Mondolfi, A. E. (2009). Lobomycosis in man and lobomycosis like disease in bottlenose dolphin, Venezuela. *Emerging Infectious Diseases*, *15*(8), 1301-1303. https://doi.org/10.3201/eid1508.090347

Bertulli, C. G., Cecchetti, A., Van Bressem, M-F., & Van Waerebeek, K. (2012). Skin disorders in common minke whales and white-beaked dolphins off Iceland: A photographic assessment. *Journal of Marine Animals and Their Ecology*, *5*(2), 29-40.

Brownell, R. L., Jr., Carlson, C. A., Galletti Vernazzani, B., & Cabrera, E. (2007). *Skin lesions on blue whales off southern Chile: Possible conservation implications?* (Paper 130). U.S. Department of Commerce. http://digitalcommons.unl.edu/usdeptcommercepub/130

Byard, R. W., Winskog, C., Machado, A., & Boardman, W. (2012). The assessment of lethal propeller strike injuries in sea mammals. *Journal of Forensic and Legal Medicine*, *19*, 158-161. https://doi.org/10.1016/j.jflm.2011.12.017

Carrillo, M., & Ritter, F. (2010). Increasing numbers of ship strikes in the Canary Islands: Proposals for immediate action to reduce risk of vessel-whale collisions. *Journal of Cetacean Research and Management*, *11*(2), 131-138.

Collins, T., Minton, G., Baldwin, R., Van Waerebeek, K., Hywel-Davies, A., & Cockcroft, V. (2002). *A preliminary assessment of the frequency, distribution and causes of mortality of beach cast cetaceans in the Sultanate of Oman, January 1999 to February 2002* (IWC Scientific Committee Document SC/54/O4). International Whaling Commission.

de Stephanis, R., Cornulier, T., Verborgh, P., Salazar Sierra, J., Pérez Gimeno, N., & Guinet, C. (2008). Summer spatial distribution of cetaceans in the Strait of Gibraltar in relation to the oceanographic context. *Marine Ecology Progress Series*, *353*, 275-288. https://doi.org/10.3354/meps07164

de Stephanis, R., García-Tiscar, S., Verborgh, P., Esteban-Pavo, R., Pérez, S., Minvielle-Sebastia, L., & Guinet, C. (2008). Diet of the social groups of long-finned pilot whales (*Globicephala melas*) in the Strait of Gibraltar. *Marine Biology*, *154*(4), 603-612. https://doi.org/10.1007/s00227-008-0953-8

Díaz-Delgado, J., Fernandez, A., Sierra, E., Sacchini, S., Andrada, M., Vela, A. I., Quesada-Canales, O., Paz, Y., Zucca, D., Groch, K., & Arbelo, M. (2018). Pathologic findings and causes of death of stranded cetaceans in the Canary Islands (2006-2012). *PLOS ONE*, *13*(10), e0204444. https://doi.org/10.1371/journal.pone.0204444

Dierauf, L. A., & Gulland, F. M. D. (2001). *Handbook of marine mammal medicine: Health, disease, and rehabilitation*. CRC Press. https://doi.org/10.1201/9781420041637

Direct Ferries (2019). Homepage. https://www.directferries.de/tarifa_tanger faehre.htm

Domiciano, I. G., Domit, C., Broadhurst, M. K., Koch, M. S., & Bracarense, A. P. F. R. L. (2016). Assessing disease and mortality among small cetaceans stranded at a World Heritage Site in southern Brazil. *PLOS ONE*, *11*(2), e0149295. https://doi.org/10.1371/journal.pone.0149295

Echeverri-Zuluaga, M., Duque-García, Y. H., & Ruiz-Saenz, J. (2015). Morbillivirus de los delfines: Patógeno re-emergente en la población de cetáceos [Dolphin morbillivirus: Re-emerging pathogen in the cetacean population]. *Universitas Scientiarum*, *20*(1), 29-41. https://doi.org/10.11144/Javeriana.SC20-1.mdpr

Esteban, R., Verborgh, P., Gauffier, P., Giménez, J., Guinet, C., & de Stephanis, R. (2015). Dynamics of killer whale, blue fin tuna and human fisheries in the Strait of Gibraltar. *Biological Conservation*, *194*, 31-38. https://doi.org/10.1016/j.biocon.2015.11.031

Fenton, H., Daoust, P. Y., Forzán, M. J., Vanderstichel, R. V., Ford, J. K. B., Spaven, L., Lair, S., & Raverty, S. (2017). Causes of mortality of harbor porpoises *Phocoena phocoena* along the Atlantic and Pacific coasts of Canada. *Diseases of Aquatic Organisms*, *122*, 171-183. https://doi.org/10.3354/dao03080

Food and Agriculture Organization of the United Nations (FAO). (2018). *The state of Mediterranean and Black Sea fisheries*. General Fisheries Commission for the Mediterranean. 172 pp.

FRS. (2019). Home page. https://www.frs.es/en/plan-your-trip/our-routes

García-Tiscar, S. (2009). *Interacciones entre delfines mulares (*Tursiops truncatus*), orcas (*Orcinus orca*), y pesquerias en el mar de Alboran y Estrecho de Gibraltar* [Interactions between bottlenose dolphins (*Tursiops truncatus*), killer whales (*Orcinus orca*), and fisheries in the Alboran Sea and Strait of Gibraltar] (Dissertation thesis). Universidad Autonoma de Madrid, Madrid, Spain. 301 pp.

Gibraltar Port Authority. (2019). Homepage. https://www.gibraltarport.com/port-information

Gilman, E., Brothers, N., McPherson, G., & Dalzell, P. (2006). A review of cetacean interactions with long-line gear. *Journal of Cetacean Research and Management*, *8*(2), 215-223.

Giménez, J., Cañadas, A., Ramírez, F., Afán, I., García-Tiscar, S., Fernández-Maldonado, C., Castillo, J. J. C., & de Stephanis, R. (2018). Living apart together: Niche partitioning among Alboran Sea cetaceans. *Ecological Indicators*, *95*, 32-40. https://doi.org/10.1016/j.ecolind.2018.07.020

Gómez-Campos, E., Borrell, A., & Aguilar, A. (2011). Assessment of nutritional condition indices across reproductive states in the striped dolphin (*Stenella coeruleoalba*). *Journal of Experimental Marine Biology and Ecology*, *405*(1), 18-24. https://doi.org/10.1016/j.jembe.2011.05.013

Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V., Micheli, F., D'Agrosa, C., Bruno, J. F., Casey, K. S., Ebert, C., Fox, H. E., Fujita, R., Heinemann, D., Lenihan, H. S., Madin, E. M. P., Perry, M. T., Selig, E. R., Spalding, M., Steneck, R., & Watson, R. (2008). A global map of human impact on marine ecosystems. *Science*, *319*(5865), 948-952. https://doi.org/10.1126/science.1149345

Hart, L., Rotstein, D. S., Wells, R. S., Allen, J., Barleycorn, A., Balmer, B. C., Lane, S. M., Speakman, T., Zolman, E. S., Stolen, M., McFee, W., Goldstein, T., Rowles, T. K., & Schwacke, L. H. (2012). Skin lesions on common bottlenose dolphins (*Tursiops truncatus*) from three sites in the Northwest Atlantic, USA. *PLOS ONE*, *7*, e33081. https://doi.org/10.1371/journal.pone.0033081

Jepson, P. D., Deaville, R., Barber, J. L., Aguilar, A., Borrell, A., Murphy, S., Barry, J., Brownlow, A., Barnett, J., Berrow, S., Cunningham, A. A., Davison, N. J., ten Doeschate, M., Esteban, R., Ferreira, M., Foote, A. D., Genov, T., Giménez, J., Loveridge, J., Llavona, A., . . . Law, R. J. (2016). PCB pollution continues to impact populations of orcas and other dolphins in European waters. *Scientific Reports*, *6*, 18573. https://doi.org/10.1038/srep18573

Joblon, M. J., Pokras, M. A., Morse, B., Harry, C. T., Rose, K. S., Sharp, S. M., Niemeyer, M. E., Patchett, K. M., Sharp, W. B., & Moore, M. J. (2014). Body condition scoring system for delphinids based on short-beaked common dolphins (*Delphinus delphis*). *Journal of Marine Animals and Their Ecology*, *7*(2), 5-13.

Loizaga de Castro, R. (2014). First record of cestocysts of *Phyllobotrium delphini* (Phyllobotriidae) from dusky dolphins (*Lagenorhynchus obscurus*) of Argentine coast. *Hydrobiologia*, *24*(3), 307-310.

Luksenburg, J. A. (2014). Prevalence of external injuries in small cetaceans in Aruban waters, southern Caribbean. *PLOS ONE*, *9*(2), e88988. https://doi.org/10.1371/journal.pone.0088988

Macías López, D., García Barcelona, S., Báez, J. C., De La Serna, J. M., & Ortiz de Urbana, J. M. (2012). Marine mammal bycatch in Spanish Mediterranean large pelagic longline fisheries, with a focus on Risso's dolphin (*Grampus griseus*). *Aquatic Living Resources*, *25*, 321-331. https://doi.org/10.1051/alr/2012038

Masski, H., & de Stephanis, R. (2015). Cetaceans of the Moroccan coast: Information from a reconstructed strandings database. *Journal of the Marine Biological Association of the United Kingdom*, *98*(Special Issue 5), 1029-1037. https://doi.org/10.1017/S0025315415001563

Mazzariol, S., Cozzi, B., & Centelleghe, C. (2015). *Handbook for cetaceans' strandings*. The coffee house art&adv.

Moore, M. J., van der Hop, J., Barco, S. G., Costidis, A. M., Gulland, F. M. D., Jepson, P. D., Moore, K. T., Raverty, S., & McLellan, W. A. (2013). Criteria and case definitions for serious injury and death of pinnipeds and cetaceans caused by anthropogenic trauma. *Diseases of Aquatic Organisms*, *103*, 229-264. https://doi.org/10.3354/dao02566

Murdoch, M. E., Mazzoil, M., McCulloch, S., Bechdel, S., O'Corry-Crowe, G., Bossart, G. D., & Reif, J. S. (2010). Lacaziosis in bottlenose dolphins *Tursiops truncatus* along the coastal Atlantic Ocean, Florida, USA. *Diseases of Aquatic Organisms*, *92*, 69-73. https://doi.org/10.3354/dao02282

Newman, S. J., & Smith, S. A. (2006). Marine mammal neoplasia: A review. *Veterinary Pathology*, *43*(6), 865-880. https://doi.org/10.1354/vp.43-6-865

Panigada, S., Pesante, G., Zanardelli, M., Capoulade, F., Gannier, A., & Weinrich, M. (2006). Mediterranean fin whales at risk from fatal shipstrikes. *Marine Pollution Bulletin*, *52*(1), 287-298. https://doi.org/10.1016/j.marpolbul.2006.03.014

Rehtanz, M., Ghim, S., McFee, W., Doescher, B., Lacave, G., Fair, P. A., Reif, J. S., Bossart, G. D., & Jenson, A. B. (2010). Papilloma virus antibody prevalence in free ranging and captive bottlenose dolphins (*Tursiops truncatus*). *Journal of Wildlife Diseases*, *46*(1), 136-145. https://doi.org/10.7589/0090-3558-46.1.136

Rojo-Nieto, E., Álvarez-Díaz, P. D., Morote, E., Burgos-Martín, M., Montoto-Martínez, T., Sáez-Jiménez, J., & Toledano, F. (2011). Strandings of cetaceans and sea turtles in the Alboran Sea and Strait of Gibraltar: A long-time glimpse of the north coast (Spain) and the south coast (Morocco). *Animal Biodiversity and Conservation*, *34*(1), 151-163.

Schwacke, L. H., Zolman, E. S., Balmer, B. C., De Guise, S., George, R. C., Hoguet, J., Hohn, A. A., Kucklick, J. R., Lamb, S., Levin, M., Litz, J. A., McFee, W. E., Place, N. J., Townsend, F. I., Wells, R. S., & Rowles, T. K. (2012). Anaemia, hypothyroidism and immune suppression associated with polychlorinated biphenyl exposure in bottlenose dolphins (*Tursiops truncatus*). *Proceedings of the Royal Society B: Biological Sciences*, *279*, 48-57. https://doi.org/10.1098/rspb.2011.0665

Siebert, U., Wünschmann, A., Weiss, R., Frank, H., Benke, H., & Frese, K. (2001). Post-mortem findings in harbour porpoises (*Phocoena phocoena*) from the German North and Baltic Seas. *Journal of Comparative Pathology*, *124*, 102-114. https://doi.org/10.1053/jcpa.2000.0436

Siebert, U., Joiris, C., Holsbeek, L., Benke, H., Failing, K., Frese, K., & Petzinger, E. (1999). Potential relation between mercury concentrations and necropsy findings in cetaceans from German waters of the North and Baltic Seas. *Marine Pollution Bulletin*, *38*, 285-295. https://doi.org/10.1016/S0025-326X(98)00147-7

Siebert, U., Tolley, K., Víkingsson, G. A., Ólafsdottir, D., Lehnert, K., Weiss, R., & Baumgärtner, W. (2006). Pathological findings in harbour porpoises (*Phocoena phocoena*) from Norwegian and Icelandic waters. *Journal of Comparative Pathology*, *134*, 134-142. https://doi.org/10.1016/j.jcpa.2005.09.002

Silva, S., Araujo, M. J., Bao, M., Mucientes, G., & Cobo, F. (2014). The haematophagous feeding stage of anadromous populations of sea lamprey *Petromyzon marinus*: Low host selectivity and wide range of habitats. *Hydrobiologia*, *734*, 187-199. https://doi.org/10.1007/s10750-014-1879-4

Thompson, P. M., & Hammond, P. S. (1992). The use of photography to monitor dermal disease in wild bottlenose dolphins (*Tursiops truncatus*). *Ambio*, *21*(2), 135-137.

Tudela, S., Kai, A., Maynou, F., El Andalossi, M., & Guglielmi, P. (2005). Driftnet fishing and biodiversity conservation: The case study of the large-scale Moroccan driftnet fleet operating in the Alboran Sea (SW Mediterranean). *Biological Conservation*, *121*, 65-78. https://doi.org/10.1016/j.biocon.2004.04.010

Tydeman, C., & Lutchman, I. (2012). *The management of marine living resources in the waters around Gibraltar* (Report to H. M. Government of Gibraltar). https://www.gibraltar.gov.gi/new/sites/default/files/1/15/Management_of_marine_living_resources_in_the_waters_around_Gibraltar.pdf

Ueda, K., Sano, A., Yamate, J., Itano Nakagawa, E., Kuwamura, M., Izawa, T., Tanaka, M., Hasegawa, Y., Chibana, H., Izumisawa, Y., Miyahara, H., & Uchida, S. (2013). Two cases of lacaziosis in bottlenose dolphins (*Tursiops truncatus*) in Japan. *Case Reports in Veterinary Medicine*, *2013*, 318548. https://doi.org/10.1155/2013/318548

Unger, B., Herr, H., Benke, H., Böhmert, M., Burkhardt-Holm, P., Dähne, M., Hillmann, M., Wolff-Schmidt, K., Wohlsein, P., & Siebert, U. (2017). Marine debris in harbour porpoises and seals from German waters. *Marine Environmental Research*, *130*, 77-84. https://doi.org/10.1016/j.marenvres.2017.07.009

Van Bressem, M-F., Raga, J. A., Di Guardo, G., Jepson, P. D., Duignan, P. J., Siebert, U., & Van Waerebeek, K. (2009). Emerging infectious diseases in cetaceans worldwide and the possible role of environmental stressors. *Diseases of Aquatic Organisms*, *86*(2), 143-157. https://doi.org/10.3354/dao02101

Van Bressem, M-F., Van Waerebeek, K., Raga, J. A., Gaspar, R., Di Beneditto, A. P., Ramos, R., & Siebert, U. (2003). *Tattoo disease of odontocetes as a potential indicator of a degrading or stressful environment: A preliminary report* (Paper SC/55/E1). Presented to the Scientific Committee of the International Whaling Commission.

Van Bressem, M-F., Flach, L., Reyes, J. C., Echegaray, M., Santos, M., Viddi, F., Félix, F., Lodi, L., & Van Waerebeek, K. (2015). Epidemiological characteristics of skin disorders in cetaceans from South American waters. *Latin American Journal of Aquatic Mammals*, *10*(1), 20-32. https://doi.org/10.5597/lajam190

Vecchione, A., & Aznar, F. J. (2008). The mesoparasitic copepod *Pennella balaenopterae* and its significance as a visible indicator of health status in dolphins (Delphinidae): A review. *Journal of Marine Animals and Their Ecology*, *7*(1), 4-11.

Vergnaud Grazzini, C., & Pierre, C. (1991). High fertility in the Alboran Sea since the last glacial maximum. *Paleoceanography and Paleoclimatology*, *6*(4), 519-536. https://doi.org/10.1029/91PA00501

Weijs, L., & Zaccaroni, A. (2016). Toxicology of marine mammals: New developments and opportunities. *Toxicology*, *70*, 1-8. https://doi.org/10.1007/s00244-015-0233-9

Weir, C. R., & Wang, J. Y. (2016). Vertebral column anomalies in Indo-Pacific and Atlantic humpback dolphins *Sousa* spp. *Diseases of Aquatic Organisms*, *120*, 179-187. https://doi.org/10.3354/dao03026

Wierucka, K., Verborgh, P., Meade, R., Colmant, L., Gauffier, P., Esteban, R., de Stephanis, R., & Cañadas, A. (2014). Effects of a morbillivirus epizootic on long-finned pilot whales *Globicephala melas* in Spanish Mediterranean waters. *Marine Ecology Progress Series*, *502*, 1-10. https://doi.org/10.3354/meps10769

Wilson, B., Grellier, K., Hammond, P. S., Brown, G., & Thompson, P. M. (2000). Changing occurrence of epidermal lesions in wild bottlenose dolphins. *Marine Ecology Progress Series*, *205*, 283-290. https://doi.org/10.3354/meps205283

Wise, L. D., Beck, S. L., Beltrame, D., & Beyer, B. K. (1997). Terminology of developmental abnormalities in common laboratory mammals (Version 1). *Teratology*, *55*, 249-292. https://doi.org/10.1002/(SICI)1096-9926(199704)55:4<249::AID-TERA5>3.0.CO;2-W