Skin conditions, epizoa, ectoparasites and emaciation in cetaceans in the Strait of Gibraltar: An update for the period 2016–2020

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ABSTRACT

Cetacean populations in the Strait of Gibraltar are heavily impacted by human activities. Photographs are a valuable tool to monitor the external health of cetaceans. We visually screened 27,866 pictures taken during whale watching operations in the years 2016–2020 for abnormal conditions, such as emaciation, dermal diseases and epizoic infestations. Prevalence levels could not be calculated as data were obtained opportunistically. Dermal diseases were detected in 566 sightings and occurred in all species. Bottlenose dolphins were most strongly affected (n = 192). Hypopigmented skin lesions were most common in all species (n = 291). Tattoo skin disease-like lesions affected 16 animals (*T. truncatus*: n = 12; *G. melas*: n = 3; *D. delphis*: n = 1). Other observed conditions include expansive annular lesions in three juvenile pilot whales. Furthermore, we report the presence of open wounds in 28 animals (*G. melas*: n = 23; *T. truncatus*: n = 2; *P. macrocephalus*: n = 3). In three pilot whales, these wounds did not heal over a period of several years. Epizoic and ectoparasitic infestations include the observation of *Xenobalanus spp.* and *Pennella balaenopterae*. Multiple fin whales were sighted with very high numbers of *Pennella balaenopterae*, ranging up to 84 parasites per host. Emaciation was mainly detected in bottlenose dolphins (n = 36) and seemed to affect these animals more severely during specific years, potentially indicating fluctuations in prey availability.

KEYWORDS: CETACEANS; DERMAL DISEASES; EMACIATION; ECTOPARASITES; STRAIT OF GIBRALTAR

INTRODUCTION

The Strait of Gibraltar connects the Atlantic Ocean and Alboràn Sea. These waters are fertilised by nutrients provided by an upwelling of Mediterranean bottom water in the western part of the Strait (Wierucka *et al.*, 2014). This fertilisation leads to a high abundance of zooplankton, which provides a food base for predatory fish and seven regularly occurring cetacean species (Wierucka *et al.*, 2014), including common dolphins (*Delphinus delphis*), striped dolphins (*Stenella coeruleoalba*), common bottlenose dolphins (*Tursiops truncatus*), long-finned pilot whales (*Globicephala melas*), orcas (*Orcinus orca*), sperm whales (*Physeter macrocephalus*) and fin whales (*Balaenoptera physalus*). A variety of anthropogenic activities pose threats to these cetaceans.

The IUCN has classified these populations on a range from vulnerable to critically endangered (Azzolin *et al.*, 2020; Bearzi *et al.*, 2003; 2008; Carpinelli *et al.*, 2014; Castellote *et al.*, 2012; Esteban *et al.*, 2014; Verborgh *et al.*, 2016). The Strait is intensively fished (Burgos *et al.*, 2013; García-Tiscar, 2009) and the use of illegal driftnets has been reported (Tudela *et al.*, 2005; Tydeman and Lutchman, 2012). Fishing operations not only incur a severe threat of injuries and mortality (Gilman *et al.*, 2006; Ruiz Gondra *et al.*, 2017) but may also impact the nutritional state of apex predators. The Mediterranean Sea is among the marine areas with the highest proportion of

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unsustainably harvested fish stocks (FAO, 2020a). Extensive levels of harvest may lead to a competition between human catch and nutritional needs of cetaceans. As another aggravating factor, the local cetacean populations are exposed to very dense vessel traffic. The Strait is an international shipping lane with approximately 60,000 ships in transit every year.[1] Additionally, fast ferries are operated all year round, connecting the Spanish mainland with Morocco and the Spanish enclave Ceuta, with up to 156 ferries crossing the Strait during the main season.[2] Furthermore, these waters host a variety of offshore tourism activities, such as whale-watching tours and recreational fisheries. The dense vessel traffic leads to high levels of noise pollution and frequent disturbances that may affect the behaviour of cetaceans (Wright *et al*., 2007). Common dolphins are significantly less likely to continue foraging in the presence of whale-watching vessels which may have long-term impacts on their nutritional status (Stockin *et al*., 2008). Furthermore, frequent disturbances may lead to stress that compromises the immune system and increases susceptibility to disease (Wright *et al*., 2007). An impairment of immune function may be further aggravated by exposure to pollutants (Van Bressem *et al*., 2009a). The Mediterranean Sea is a global hotspot for PCB pollution (Marsili and Focardi, 1997; Marsili *et al*., 2018). The use of these chemicals was banned in 1987 (Marsili *et al*., 2018). After an initial peak in 1990, PCB blubber concentrations showed a steady decline until 2002 (Aguilar and Borrell, 2005; Jepson *et al*., 2016). Since 2003, PCB levels have stabilised at concentrations that still surpass toxicity thresholds (Bartalini *et al*., 2020; Jepson *et al*., 2016). As apex predators, odontocetes bioaccumulate these chemicals, which have adverse effects on their immune function (Van Bressem *et al*., 2009a; Marsili *et al*., 2018). The health condition of odontocetes can provide insights into ecosystem health as these animals act as pollution sentinels for persistent organic contaminants (Schwacke *et al*., 2013; Wells *et al*., 2004).

Photographic assessments are a useful tool to evaluate the external health of cetaceans and a valuable alternative to invasive research methods (Thompson and Hammond, 1992). Emaciation, massive epizoic infestations and high prevalence of cutaneous diseases are indicators of sub-optimal health (Aznar *et al*., 1994; Joblon *et al*., 2014; Van Bressem *et al*., 2009a). Reports of skin diseases in cetaceans have been increasing worldwide, especially in regions with intense human use (Mouton and Botha, 2012; Van Bressem *et al*., 2009a). *Xenobalanus globicipitis* and *Pennella balaenopterae* infestations are indicators of environmental changes that may affect the immune function of cetaceans (Aznar *et al*., 2005; 1994; Siciliano *et al*., 2020; Vecchione and Aznar, 2014). Changes in the prevalence of epizoic infestations have been observed during morbillivirus outbreaks in the Mediterranean Sea (Aznar *et al*., 2005; 1994). Previous studies that assessed body and skin disorders in the cetaceans in the Strait of Gibraltar between 2004–07 and 2001–15 reported skin diseases and malformations in multiple animals (Herr *et al*., 2020; Jiménez-Torres *et al*., 2013). The present study contributes to long-term surveillance of external conditions in cetaceans in the Strait of Gibraltar. Regular health assessments can provide insights into the impact of human activities on cetaceans and inform decision making on mitigation measures. Temporal changes in the occurrence of different skin lesions may indicate changes in the ecosystem and emergence of new pathogens. Furthermore, individual sperm whales, common dolphins, bottlenose dolphins, pilot whales and orcas are at least seasonally resident in the Strait of Gibraltar (De Stephanis *et al*., 2008; Esteban *et al*., 2016; Verborgh *et al*., 2009). Follow-up of individuals can provide information on survivorship and skin lesion progression over time.

MATERIALS AND METHODS

Data collection

The Foundation for Information and Research on Marine Mammals (firmm) operates two whale-watching boats from the end of March until early November every year; due to the coronavirus pandemic, the whale-watching season was shorter than normal in 2020. The number of trips per day depends on the weather and tour demand, and ranges from zero to eight. All regular trips last two hours. The seasonal occurrence of orcas is a tourist

[1] Gibraltar Port Authority: https://www.gibraltarport.com/port-information/about-the-pga (accessed 27 July 2023)

[2] Phone enquiry to Algeciras Port Authority (July 2023): https://www.apba.es/#

highlight in July and August when three-hour trips are also offered. During each trip, photographs are collected opportunistically by the crew. The pictures are used for behavioural documentation, photoidentification or as memories.

Injured or sick animals are photographed for subsequent inspection of the pictures. During the time frame of this study, a total of 27,866 pictures were taken (2016: n = 6,001; 2017: n = 3,814; 2018: n = 3,492; 2019: n = 9,882; 2020: n = 4,677) using Canon EOS 80D and EOS 670D cameras with 70–300mm lenses. The animals were photographed from varying distances. For sperm and fin whales, the distance was approximately 100m; for smaller odontocetes, about 60m; and less in cases where the animals approached the boat. The data also includes sighing of one minke whale (*Balaenoptera acutorostrata*) and one humpback whale (*Megaptera novaeangliae*), which are rare visitors to the Mediterranean Sea (Espada Ruíz *et al*., 2018; Fraija-Fernández *et al*., 2015; Frantzis *et al*., 2004).

Maturity categories

Individuals with foetal bands were classified as new-born (Kastelein *et al*., 1990); calves without foetal bands as juvenile; fully sized individuals as adult. Whenever group pictures were available, the maturity of individuals was determined by comparing the size of animals in the group. Other indicators included pigmentation patterns, such as the lighter colouration of pilot whale juveniles (Auger-Méthé and Whitehead, 2007) and behavioural aspects. Most sperm whales were observed solitarily and assumed to be adults, as females and calves are known to aggregate in larger nursing groups (Gannier *et al*., 2002).

Photoidentification

Photoidentification was limited due to the opportunistic nature of the data. We categorised the photographed animals as either photo-identifiable or not re-identifiable; only a limited number of individuals were deemed

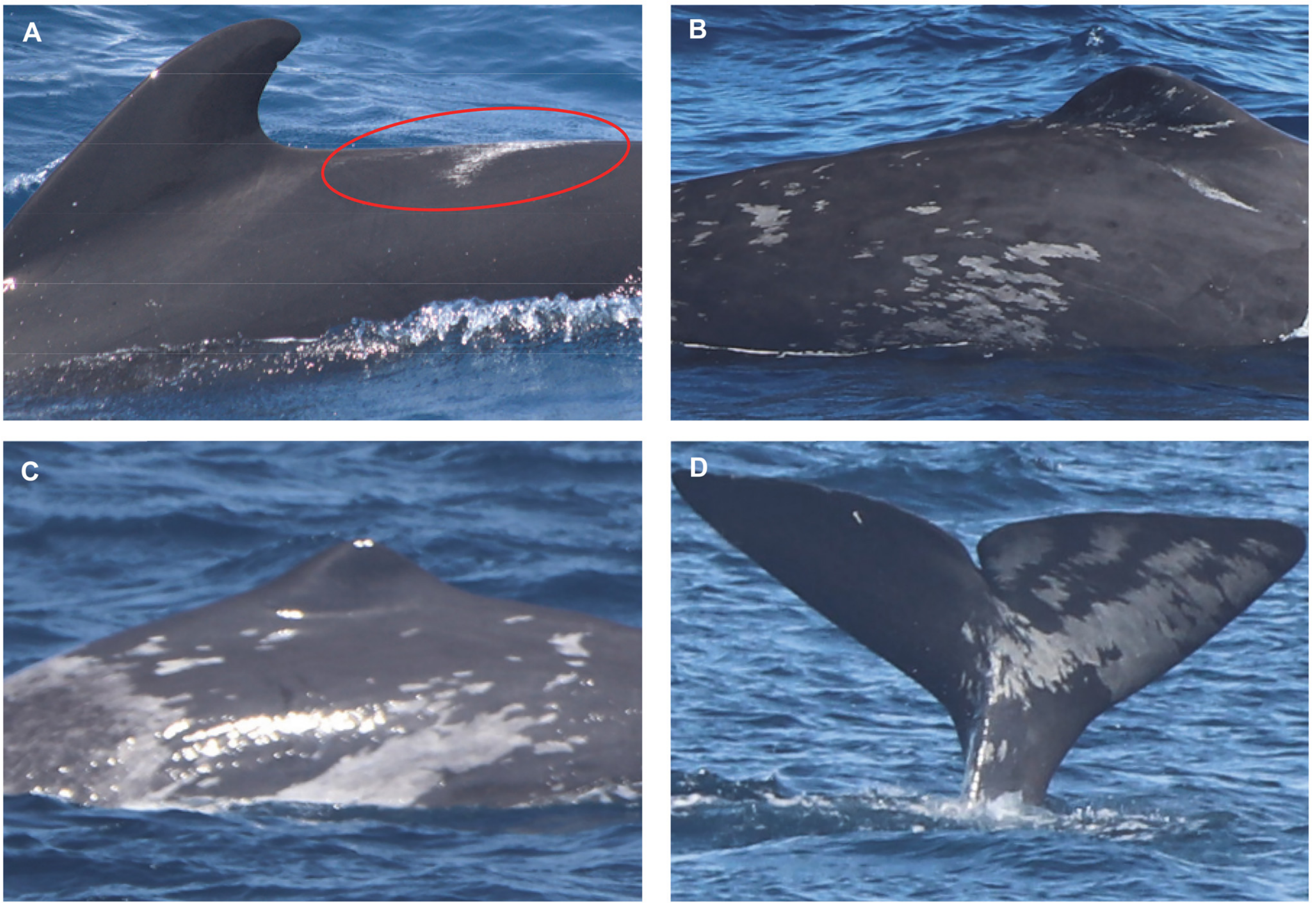

Fig. 1: Pigmentation: A) Adult pilot whale with a dense V-shaped saddle patch. B)–D) Adult sperm whales with potential cases of piebaldism.

to be re-identifiable. Therefore, no statements on the prevalence of abnormal conditions are given. Photoidentification was mainly based on dorsal fin markings (Bertulli *et al*., 2016); images were processed using the software Darwin 2.22. Scars or patterns of pigmentation were used as further distinctive features to discriminate individual animals (Bertulli *et al*., 2016). Such pigmentation patterns included white saddle patches (Auger-Méthé and Whitehead, 2007) observed in 12 pilot whales (Fig. 1A). For sperm whales, the photoidentification was mainly based on the observation of hypopigmented skin patches. These patches remained stable in ten individuals that were resighted in multiple years and were therefore assumed to be potentially caused by piebaldism (Figs 1B-D), an autosomal dominant inherited pigment anomaly (Oiso *et al.*, 2013). Parts of the skin are white and do lack pigmentation, while the eyes are normally coloured (Abreu *et al*., 2013). These unique pigmentation patterns are stable during the lifetime of an affected individual (Oiso *et al.*, 2013). Photoidentification was also conducted for individuals shown in the galleries of previous studies (Herr *et al*., 2020; Jiménez-Torres *et al*., 2013), but not all published photographs presented clearly distinctive features, which may explain low numbers of resighting.

Data analysis

Blurred or overexposed pictures were excluded from the analysis. The remaining photographs were screened visually for external disorders. In some cases, dermal lesions were detected, but the quality of the photo did not allow further evaluation. These animals have been listed as 'potentially affected by skin lesions'. Due to the opportunistic nature of the data collection, the prevalence of skin lesions or parasitic infestations was not evaluated statistically. We present the number of animals affected by skin lesions relative to the total number of available pictures per year and the number of animals affected by skin lesions per species relative to the number of pictures available per species. These numbers can only provide an indication. Based on the macroscopic appearance of observed anomalies and the literature, the external conditions were classified as follows.

Epizoa, ectoparasites and marks caused by parasitism

Ectoparasites and Epizoa were identified by their morphological appearance (Félix *et al.*, 2006; Fertl and Newman, 2018; Lehnert *et al.*, 2021; Maldini *et al.*, 2010; Scarff, 1986; Vecchione and Aznar, 2014). The severity of *Xenobalanus spp.* infestations was recorded as light (1–5 barnacles/fin), medium (6–10 barnacles/fin) or heavy (> 10 barnacles/fin) (Toth-Brown and Hohn, 2007). The number of cetaceans with a *Xenobalanus spp*. infestation were reported in two separate categories, depending on whether the animals were photo-identifiable or not re-identifiable (photographs only showing the fluke, dorsal fin or pectoral fins without any distinctive marking; therefore, double counts of individuals with *Xenobalanus spp.* cannot be avoided by any means). Round rather than oval shaped injuries or marks were classified as potential lamprey bites (Bertulli *et al*., 2012; Samarra *et al*., 2012). These marks were occasionally accompanied by skidding marks, which occur when a lamprey slides over the body of its host to reattach at a more favourable spot (Nichols and Tscherter, 2011).

Dermal anomalies – Tattoo skin disease-like dermatopathy (TSDL)

This category encompasses irregular grey or black lesions with a stippled appearance and resemble tattoo skin disease (Blacklaws *et al*., 2013; Geraci *et al*., 1979; Sanino *et al*., 2014; Van Bressem *et al*., 2015a). Lesions with similarity to regressing tattoos (Van Bressem *et al*., 2009b) were also included in this category. Tattoo skin lesions are caused by poxvirus infection (Bracht *et al*., 2006; Van Bressem *et al*., 2003a; 2003b; 2022).

Light grey skin lesions

Hypopigmented skin lesions, such as pale skin patches (Sanino *et al*., 2014), pale spots (Hart *et al*., 2012; Gonzalvo *et al*., 2015; Kautek *et al*., 2019; Sanino *et al*., 2014) and white-fringed spots (Bearzi *et al*., 2009; Gonzalvo *et al*., 2015; Wilson *et al*., 1997) are listed here.

Dark grey skin lesions

This category encompasses hyperpigmented lesions, such as dark-fringed spots (Geraci *et al*., 1979), dark spots (Sanino *et al*., 2014) and dark skin patches (Thompson and Hammond, 1992).

Cutaneous nodules

Small cutaneous elevations which are either pale or normally pigmented (Van Bressem *et al*., 2015b).

Expansive annular lesions

Ring-like lesions with a lighter grey outer ring and a paler inner core. The inner core may be obscured by an orange tinge (Van Bressem *et al*., 2015b).

Ulcerative dermatitis

This category describes wounds resembling a pale ulcerative dermatitis (Herr *et al*., 2020; Sanino *et al*., 2014; Van Bressem *et al*., 2015b).

Other

Dermal anomalies that could not be assigned to any of the categories above were classified as 'other'.

Wounds

Open wounds that did not appear to be caused by specific natural or anthropogenic agents, such as inter- or intraspecific aggression, fishery entanglements or boat propellors (Luksenburg, 2014; Moore and Barco, 2013).

Emaciation

Visible rip impressions are a sign of advanced starvation and were used as the main indicator of malnutrition (Domiciano *et al*., 2016; Joblon *et al*., 2014).

Humps

Humps may be caused by tumours, abscesses or cestodes and were defined as clearly circumscribed or irregular in shape (De Castro *et al*., 2014; Geraci *et al*., 1987; Geraci and St. Aubin, 1987; Kautek *et al*., 2019).

Bent dorsal fins

The intensity of bending was defined based on the breakdown point between the fin tip and sagittal plane and on an estimated angle (Alves *et al*., 2018).

RESULTS AND DISCUSSION

Photoidentification

Except for common dolphins, multiple individuals of all resident species were resighted over several years (*G. melas*: n = 56; *T. truncatus*: n = 47; *O. orca*: n = 12; *P. macrocephalus*: n = 10).

Prior to our work, two studies documented the occurrence of dermal diseases in the local cetacean populations (Herr *et al*., 2020; Jiménez-Torres *et al*., 2013). We resighted two bottlenose dolphins that were

Fig. 2: Recent photograph of a previously reported adult bottlenose dolphin: Adult bottlenose dolphin sighted with one *Xenobalanus spp.* attached to the dorsal fin.

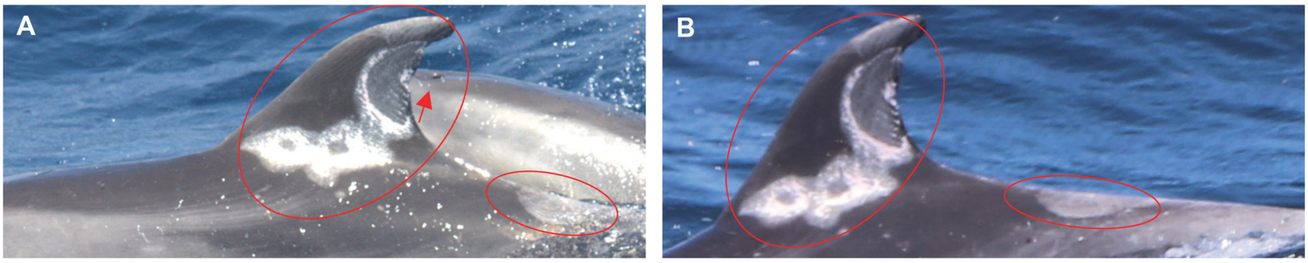

Fig. 3: Recent photographs of a previously reported adult bottlenose dolphin: A) Adult bottlenose dolphin sighted in 2016 with patchy depigmentation of the fin and the back (red circles). The animal has one *Xenobalanus spp.* attached to the dorsal fin (red arrow). B) The same individual in 2020. The lesions have not changed over the past five years.

Fig. 4: Diatoms, sea lamprey marks and cyamids: A) Juvenile striped dolphin with orange patches. B) Adult pilot whale with a sea lamprey attached to the fluke and a potential lamprey bite and a skidding mark (red circle) laterally. C) Adult pilot whale with a severe, degenerating wound in the centre of the dorsal fin. The wound is colonised by cyamids.

described in these studies. We observed one adult bottlenose dolphin with one *Xenobalanus spp.* attached to the dorsal fin (Fig. 2). The animal had been previously documented with ulcerative dermatitis (Herr *et al*., 2020: Fig. 32B). Another adult bottlenose dolphin was sighted every year with a patchy depigmentation of the fin and back (Fig. 3). These lesions remained stable and have not changed over the course of the last five years. Both studies presented these lesions previously (Herr *et al*., 2020: Fig. 27C; Jiménez-Torres *et al*., 2013: Fig. 4F).

Epizoa and ectoparasites

23 cetaceans (*D. delphis*: n = 1, *G. melas*: n = 2, *O. orca*: n = 1; *P. macrocephalus*: n = 8; *S. coeruleoalba*: n = 6, *T. truncatus*: n = 5) were sighted with orange patches (Fig. 4A). Orange patches (OP) only occurred locally (thoracically: n = 3; ventrally of the dorsal fin: n = 5; dorsally: n = 6; cranially: n = 3; snout: n = 2; ventrally of the eye: n = 1; caudally of the blowhole: n = 1; caudal peduncle: n = 1; peduncle: n = 1). No animal was sighted being covered in an orange hue as has been described in bottlenose dolphins from the British Isles (Wilson *et al*., 1997) and California (Maldini *et al*., 2010). OP are likely caused by diatoms and these lesions have limited pathological significance (Van Bressem *et al*., 2015b), but diatoms can occasionally penetrate the skin and become saprophytic (Geraci and St Aubin, 1987).

20 animals exhibited potential sea lamprey marks and one adult pilot whale was sighted with a sea lamprey attached to the fluke (Fig. 4B). The animal was observed fluke-slapping, seemingly trying to get rid of the sea lamprey. Cyamids colonised a severe wound affecting the central part of the dorsal fin of a pilot whale (Fig. 4C). The suspected aetiology of the wound is discussed in Hanninger *et al.* (in press).

We also observed a humpback whale (Fig. 5A) with *Coronula spp.* and *Conchoderma spp.* attached to the jaw and the presence of multiple former attachment sites, as it has been described in other ocean provinces (Félix *et al*., 2006; Fertl and Newman, 2018; Scarff, 1986).

Xenobalanus spp. infestation (Fig. 5B/C) only affected delphinids and was detected in 229 pictures of animals (*D. delphis*: n = 9; *S. coeruleoalba*: n = 18; *T. truncatus*: n = 29*; G. melas*: n = 141; *O. orca*: n = 32) classified as not re-identifiable (severity: light: n = 141; medium: n = 9; heavy: n = 8; severity undeterminable: n = 71). Regarding potentially re-identifiable individuals, 236 animals (*D. delphis*: n = 9; *S. coeruleoalba*: n = 12; *T. truncatus*: n = 90; *G. melas*: n = 91; *O. orca*: n = 34) were sighted with *Xenobalanus spp.* attached to their extremities (severity:

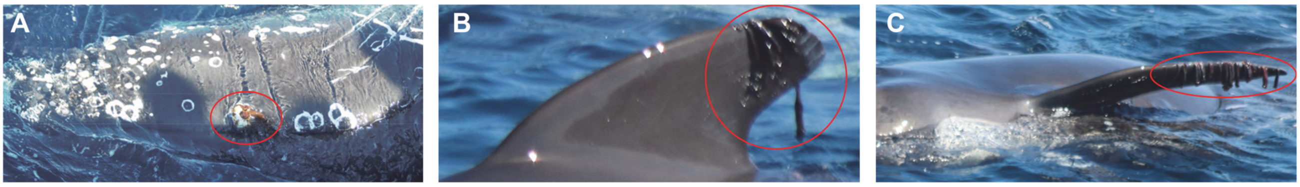

Fig. 5: Barnacle colonisations: A) Humpback whale with barnacles attached and multiple former attachment sites. B) Juvenile pilot whale with heavy *Xenobalanus spp.* colonisation of the dorsal fin, as well as tooth rake marks. C) Adult pilot whale with a heavy *Xenobalanus spp.* colonisation of the pectoral fin.

Fig. 6: *Pennella balaenopterae* infestations and other observations: A)–C) Fin whales with a *Pennella balaenopterae* infestation. D) Fin whale with dark-fringed lesions and a high number of *Pennella balaenopterae* attached. E) Sperm whale with small crater-like scars.

light: n = 184; medium: n = 9; heavy: n = 8; severity undeterminable: n = 35). The severity of these infestations was classified as light in most cases. Heavy colonisation was detected in all years, except 2017.

Several individuals infested with *Xenobalanus spp*. showed additional abnormal features, such as orange skin patches (*T. truncatus*: n = 1; *S. coeruleoalba*: n = 1), dermal diseases (*D. delphis*: n = 2; *G. melas*: n = 41; *O. orca*: n = 7; *T. truncatus*: n = 24; *S. coeruleoalba*: n = 4), injuries (*G. melas*: n = 4; *T. truncatus*: n = 1), emaciation (*T. truncatus*: n = 5), wounds (*G. melas*: n = 1) or combinations of these anomalies (*G. melas*: n = 4; *T. truncatus*: n = 4; *O. orca*: n = 1). 17 further animals were classified as 'potentially affected by skin lesions' (*D. delphis*: n = 2; *G. melas*: n = 7; *O. orca*: n = 1; *S. coeruleoalba*: n = 1; *T. truncatus*: n = 6). These numbers only refer to animals that were classified as photo-identifiable and need to be interpreted cautiously. In delphinids, 385 animals showed dermal diseases without a visible *Xenobalanus spp.* colonisation.

Pennella balaenopterae

These copepods were attached to the bodies of 53 fin whales (Fig. 6A–D), 14 sperm whales and one humpback whale with numbers of parasites per host varying from one to approximately 84. The highest counts of parasites occurred in a fin whale that was classified as 'potentially affected by skin lesions' and in another one affected by dark-fringed lesions (Fig. 6D). In the latter case, the total number of all parasites on visible body parts was approximately 84. *Pennella balaenopterae* infestation was observed to co-occur with dermal diseases in eight sperm and 18 fin whales. One of these individuals also had an injury. Six further animals were classified as 'potentially affected by skin lesions'. The animals exhibited skin lesions, but the quality of the photos was not sufficient to enable further evaluation.

11 sperm and four fin whales were sighted with small crater-like scars (Fig. 6E). *P. balaenopterae* are deeply embedded in the skin of whales and not easily removeable. The scars may be the remains of *P. balaenopterae* embedding into the skin, after the death of the copepod.

A high prevalence of *Xenobalanus globicipitis* and *Pennella balaenopterae* infestations are an indicator of cetacean health and have been linked to environmental changes that affect immune function (Aznar *et al*., 2005; 1994; Siciliano *et al*., 2020; Vecchione and Aznar, 2014). Infectious diseases, emaciation and wounds may facilitate colonisation.

Skin conditions

We detected dermal lesions on 566 animals (Table 1). Our statements on the aetiology of these lesions remain speculative. Several diseased animals (including animals classified as 'potentially affected by skin lesions') showed

Table 1
Overview of the number of cetaceans with skin lesions.

Description	2016	2017	2018	2019	2020
Tattoo skin disease-like lesions	4	3	3	6	–
Light grey lesions	30	26	63	140	32
Dark grey lesions	10	8	11	58	2
Combination of light and dark grey lesions	3	8	7	36	3
Cutaneous nodules	4	6	8	6	2
Expansive annular lesions	–	–	1	2	–
Ulcerative dermatitis	1	1	2	9	–
Others	–	–	1	5	1
'Potentially affected by skin lesions'	3	4	17	34	6
Total	55	56	113	296	46

additional conspicuous features: such as *Xenobalanus spp.* (n = 95) or *Pennella balaenopterae* infestations (n = 31); orange patches (n = 7); emaciation (n = 15); humps (n = 3); ulcerations (n = 6); injuries (n = 8); or a combination of these additional conspicuous features (n = 12). These changes may indicate cumulative effects of impaired immune function.

Tattoo skin disease-like dermatopathy (TSDL)

16 animals (*T. truncatus*: n = 12; *G. melas*: n = 3; *D. delphis*: n = 1) exhibited tattoo skin disease-like lesions (Figs 7 and 8). In six animals, TSDL co-occurred with other skin alterations, such as light grey (n = 4) or dark grey skin lesions (n = 2). Tattoo skin disease-like lesions may be under-reported as the photo quality was not always sufficient to detect the characteristic stippled pattern. 13 of these cases were classified as TSDL at confidence levels ranging from 75–100% (M.-F. Van Bressem, pers. comm.).

The remaining three cases were grouped in this category with a higher degree of uncertainty. Two animals potentially presented the remains of tattoo skin disease-like lesions (Fig. 7E; Van Bressem *et al.*, 2009b). The third – rather uncertain case – occurred in a neonate pilot whale (Fig. 7F). The lesion morphologically resembled a tattoo-like lesion (Blacklaws *et al.*, 2013), but tattoos are rarely observed in neonates, as new-born calves are protected by maternal immunity (Van Bressem *et al.*, 2003b; 2008b; 2009b).

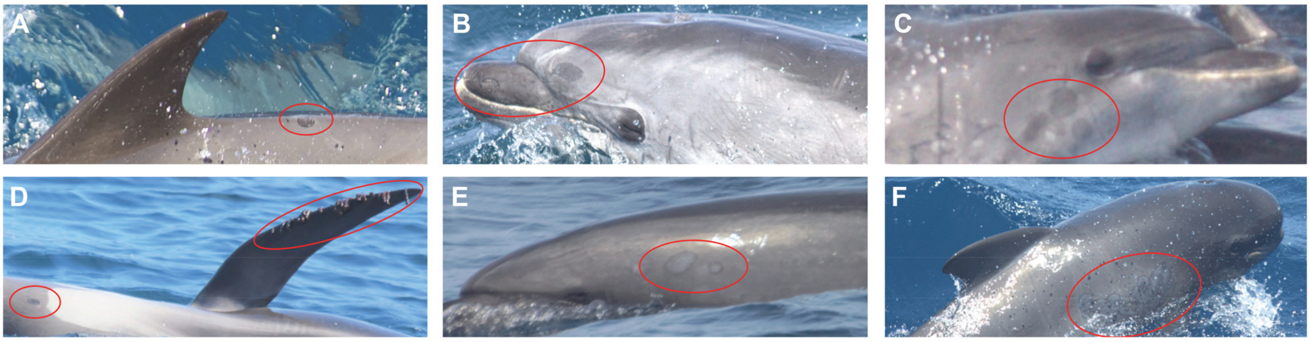

Fig. 7: Tattoo skin disease-like dermatopathy: A) Adult common dolphin with a tattoo skin disease-like lesion (TSDL) at the dorsum. B) & C) Adult bottlenose dolphins with TSDL cranially. D) Adult pilot whale with a TSDL at the lower jaw (small red circle) and a heavy *Xenobalanus spp.* colonisation of the pectoral fin (large red circle). E) Potential remains of tattoo skin disease-like lesions on an adult bottlenose dolphin. F) Pilot whale neonate with a potential TSDL laterally.

Fig. 8: Skin lesion progression over time in an adult bottlenose dolphin: A) Emaciated bottlenose dolphin sighted in 2016 with light grey circular and pale-fringed skin patches. B) & C) The animal was resighted in 2019 with tattoo skin disease-like lesions on top of the depigmented tissue and potential TSDL cranially.

Light grey skin lesions

This category includes hypopigmented skin lesions, such as pale and white skin patches, pale spots and pale-fringed spots (Bearzi *et al*., 2009; Gonzalvo *et al*., 2015; Hart *et al*., 2012; Sanino *et al*., 2014; Wilson *et al*., 1997). Pale skin patches might arise during the healing of a prior trauma (Hart *et al*., 2012) or might be a healing stage of pale dermatitis (Van Bressem *et al*., 2015b). Herpes viral infections and attachment of ectoparasites are also potential explanations (Hart *et al*., 2012). 14 sperm whales were sighted with extensive pale skin patches. These lesions were attributed to shedding and not listed as disorder (Brownell Jr. *et al*., 2007; Fortune *et al*., 2017). Extensive skin lesions were detected in two bottlenose dolphins. One individual was sighted with depigmentation of a large area of body (Fig. 9A/B). In 2019, this individual was resighted with additional dark and white skin patches (Fig. 9C). Another emaciated individual presented large skin lesions that appeared to be a combination of dark and pale skin patches (Fig. 10A). Pale skin patches (PSP) were occasionally associated with superficial rake marks, which might have facilitated colonisation by pathogens (Fig. 10B). PSP at body orifices (Fig. 10C) may potentially be caused by a fungal infection (Mazzariol *et al*., 2015; Van Bressem *et al*., 2008a). We observed white skin patches and cream-coloured lesions (Fig. 11), which might be an acute stage of pale dermatitis (Van Bressem *et al*., 2015b). We also observed cryptogenic grey lesions (Fig. 12) which were slightly raised in relief and resembled the lesions reported in neonatal Risso's dolphin calves from Chile (Van Bressem *et al*., 2008b). Light grey skin patches with a circinate shape were detected in 24 bottlenose dolphins (Fig. 13) and co-occurred with target-like lesions in three bottlenose dolphins (Fig. 14). The macroscopic aspect of these three animals morphologically resembled a case of a panniculitis caused by *Mycobacterium chelonae* in a captive bottlenose dolphin (Wünschmann *et al*., 2008). Herpes viral infections may have caused spotted (Fig. 15) and pale-fringed lesions (Fig. 16), but the aetiology of these lesions is mostly unknown (Hart *et al*., 2012; Van Bressem *et al*.,

Fig. 9: Skin lesion progression over time in an adult bottlenose dolphin: A) & B) Adult bottlenose dolphin sighted in 2016. A large area of the body is depigmented. C) In 2019, the animal was sighted with additional dark and white lesions.

Fig. 10: Pale skin patches: A) Emaciated adult bottlenose dolphin with a combination of dark and pale skin patches. The lesions have a velvety aspect. B) Adult pilot whale with fresh tooth rake marks laterally. The bite mark is surrounded by pale skin patches. C) New-born pilot whale with a raised pale skin patch surrounding the blowhole.

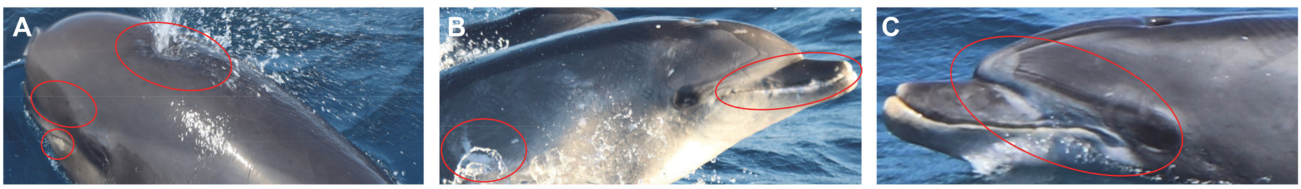

Fig. 11: White skin patches and cream-coloured lesions: A) Pilot whale calf with a raised cream-coloured patch at the lower lip (small red circle) and pale skin patches surrounding the blow hole (large red circle). There are also dark spots and one pale spot (medium-sized red circle) on the body. B) Adult bottlenose dolphin with white skin patches at the jaw and on the body. The skin patches seem to have a raised and velvety aspect. C) Adult bottlenose dolphin with a white skin patch cranially. The lesion has a velvety appearance.

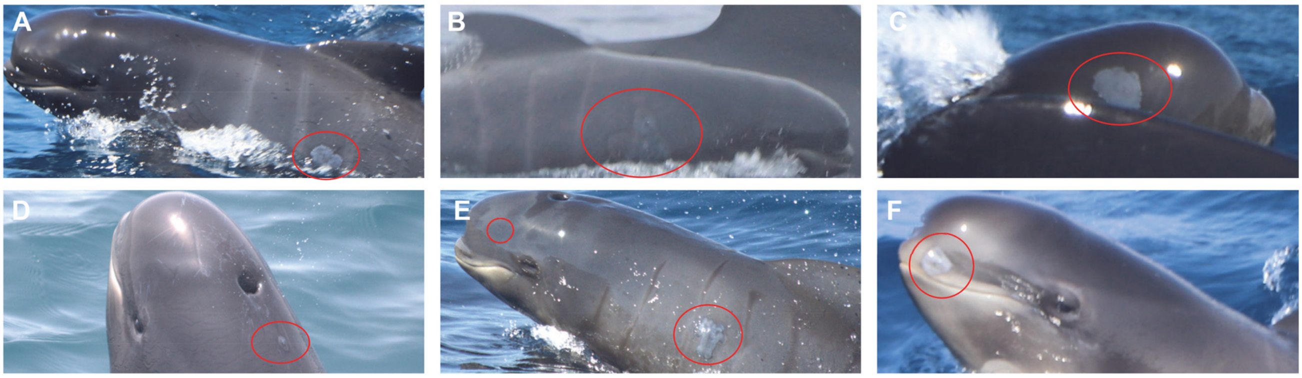

Fig. 12: Crypotgenic grey lesions: A)–C) Newborn pilot whales with grey rounded lesions. The lesions appear to be slighly raised in relief. D) Juvenile pilot whale with a raised grey patch caudal to the blowhole. E) New-born pilot whale with a raised patch of velvety consistency laterally (large red circle) and a pale-fringed spot cranially (small red circle). F) Neonatal pilot whale with a raised patch with velvety consistency at the upper jaw.

Fig. 13: Light grey circinate lesions: A) & B) Adult bottlenose dolphins with light grey circinate lesions (red circles). C) Adult bottlenose dolphin with pale spots and pale circinate lesions (red arrows); there is also a dark skin patch (large red circle) laterally and a black spot with a white, raised fringe (small red circle) at the peduncle.

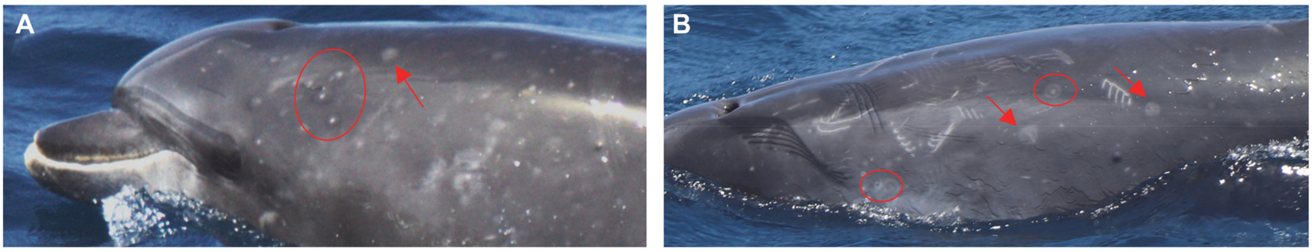

Fig. 14: Target-like lesions: A) Adult bottlenose dolphin with pale spots, a pale circinate lesion (arrow) and target-like lesions (red circle). The target-like lesions seem to be slightly raised, with central ulceration. B) Adult bottlenose dolphin with a dark spot, a white-fringed spot, pale spots, pale circinate lesions (arrows) and two target-like lesions (red circles).

Fig. 15: Pale spots: A) Adult pilot whale with pale spots on the lateral surface of the dorsal fin. B) Adult pilot whale with pale spots cranial. C) Adult sperm whale with potential piebaldism and pale spots.

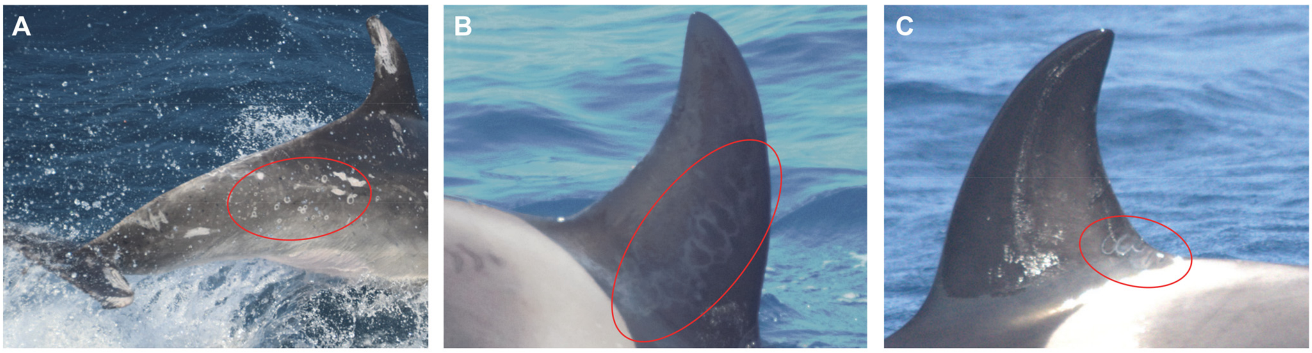

Fig. 16: Pale- or white-fringed spots: A) Adult bottlenose dolphin with white skin patches and white fringed spots. B) & C) Adult orcas with white-fringed spots on the dorsal fin.

1994). Some light grey lesions exhibited a velvety aspect (Figs 10A, 11B/C, 12E/F; Hart *et al*., 2012; Herr *et al*., 2020; Riggin and Maldini, 2010; Van Bressem *et al*., 2003a; 2015b) that potentially indicates a superinfection (Van Bressem *et al*., 2003a; 2015b).

Dark grey skin lesions

This category includes hyperpigmented skin lesions, such as dark-fringed lesions (Fig. 17; Geraci *et al*., 1979), dark spots (Sanino *et al*., 2014) and dark skin patches (Thompson and Hammond, 1992). A new-born pilot whale was sighted with multiple dark-fringed annular lesions (Fig. 17C) similar to a previously reported case in this region (Herr *et al*., 2020: Fig. 37C). The evolution of dark fringed spots suggest they may be precursors of tattoo skin disease-like lesions (Geraci *et al*., 1979), but dark-fringed skin lesion samples obtained from bottlenose dolphins in the Northwest Atlantic tested negative for pox viruses (Hart *et al*., 2012). Herpes viral infections have been postulated as a causative agent of dark spotted lesions (Fig. 18), but the aetiology of these lesions is generally unknown (Hart *et al*., 2012; Van Bressem *et al*., 1994). We also observed dark skin patches (Fig. 19) resembling cases previously described in bottlenose dolphins from Scotland (Thompson and Hammond, 1992). The aetiology of these lesions is unknown.

In our study, 57 animals exhibited a combination of light grey and dark skin lesions (Figs 9C, 10A, 11A, 13C, 14B, 18B, 19A).

Fig. 17: Dark-fringed lesions: A) Adult bottlenose dolphin with an abraded and ulcerated fin tip (large red circle). Laterally there is a dark-fringed lesion (red circle). B) Adult bottlenose dolphin with a dark-fringed spot cranially. C) New-born pilot whale with dark-fringed annular lesions.

Fig. 18: Dark spots: A) Adult striped dolphin with dark spots. B) Pilot whale calf with tooth rake marks at the leading edge of the dorsal fin. The surrounding tissue has a pale, patchy pigmentation (medium-sized red circle). There are two *Xenobalanus spp.* attached to the dorsal fin (red arrow). At the body, there are pale spots (small red circle), dark spots and one dark-fringed spot (large red circle). C) Adult sperm whale with a dark-spotted fluke.

Fig. 19: Dark skin patches: A) Adult fin whale with dark patches, pale spots, a *Pennella balaenopterae* (small red circle) and a skidding mark (large red circle). B) New born pilot whale with a hyperpigmentation of the head and/or a hypopigmentation of other body areas as well as dark and dark-fringed spots. C) Adult sperm whale with dark patches at the peduncle.

Fig. 20: Cutaneous nodules: A) Adult sperm whale with a normally pigmented nodule on the fluke. B) Adult sperm whale with potential piebaldism and a normally pigmented cutaneous nodule laterally. The individual also presented two fresh, parallel, linear lacerations at the lateral body surface and two similar parallel faded scars. C) Adult bottlenose dolphin with a pale cutaneous nodule at the upper jaw (large red circle) and a dark-fringed spot at the melon (small red circle).

Fig. 21: Expansive annular lesions: A) New-born pilot whale with expansive annular lesions (EAL). B) Pilot whale calf with EAL. The lesions have a pale outer ring and the centre appears slightly orange. C) New-born pilot whale sighted on 24.05.2019 with cryptogenic grey lesions and brownish annular lesions. The lesions have a pale fringe. D) On 29.06.2019, these annular lesions were no longer visible, the light grey lesions remained visible.

Cutaneous nodules

These nodules may be either pale or normally pigmented (Fig. 20). In one bottlenose dolphin, a nodule was observed on the beak (Fig. 20C), potentially indicating an early-stage papilloma virus infection, as it has been previously described in the region (Herr *et al*., 2020). Cutaneous nodules co-occurred with additional dermal lesions in nine animals (Fig. 20C; dark grey lesions: n = 5; light grey lesions: n = 4). The aetiology of cutaneous nodules is mostly unknown, but aetiological agents include fungi (*Fusarium spp.*, *Paracoccidioides brasiliensis* and *Trichophyton spp.*) and the bacteria *Streptococcus iniae* (Bonar and Wagner, 2003; Tanaka *et al*., 2012; Van Bressem *et al*., 2008a; 2013; 2014).

Expansive annular lesions

Expansive annular lesions were only observed in two years and only affected juvenile pilot whales (Fig. 21). One juvenile was observed multiple times and exhibited a combination of annular and cryptogenic grey lesions (Fig. 21C/D). Over time, the annular lesions appeared to be regressing.

Ulcerative dermatitis

13 bottlenose dolphins were sighted with ulcerative dermatitis on the leading edge of the dorsal fin (Fig. 22). Abraded fin tips were only observed on bottlenose dolphins. The abraded fin tips seemed to consist of a dense pattern of tooth rake marks, which may serve as entry point for pathogens. Seven individuals exhibited additional dermal lesions, such as light (Fig. 22C; n = 4) or dark grey lesions (n = 2) or both types of lesions (n = 1).

Other observations

Seven animals presented dermal lesions that could not be assigned to any of the previous categories. Thus, we observed a red protuberance (Fig. 23A), volcano-like lesions (Fig. 23B/C; n = 4), brownish spots and normally pigmented depressed dots.

Fig. 22: Ulcerative dermatitis: A) Adult bottlenose dolphin with a mild *Xenobalanus spp.* colonisation of the dorsal fin and healed pale dermatitis on the leading edge of the dorsal fin. B) Adult bottlenose dolphin with jagged notches in the trailing edge of the dorsal fin, an abraded fin tip and healed pale dermatitis. C) Adult bottlenose dolphin with an abraded and ulcerated fin and a light grey skin patch at the lateral surface of the dorsal fin.

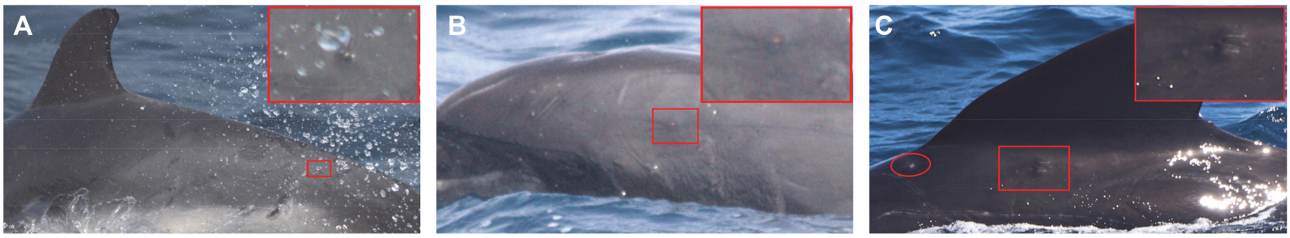

Fig. 23: Other observed dermal anomalies: A) Adult striped dolphin with a small, red protuberance on the peduncle. B) Adult bottlenose dolphin with a volcano-like lesion laterally. C) Adult pilot whale with an open wound dorsally (red circle), an irregular-shaped hump and a volcano-like lesion (red square).

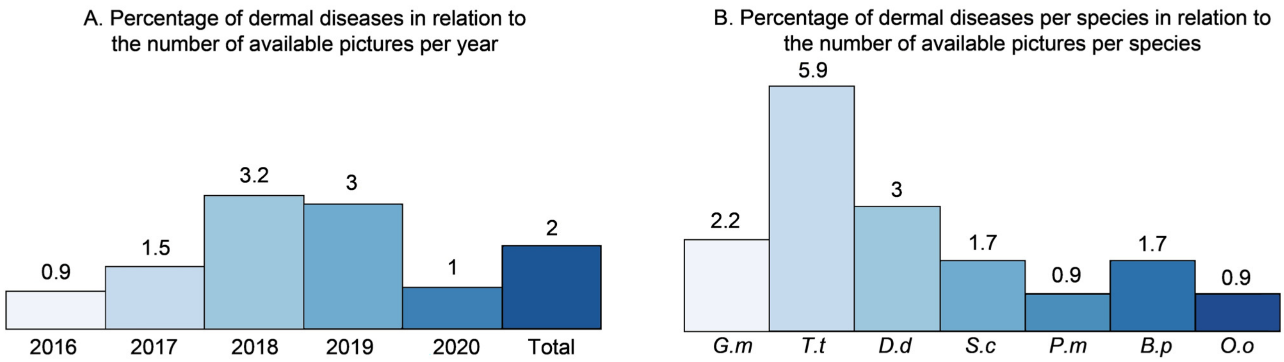

Fig. 24: A) The number of animals affected by dermal diseases relative to the total number of available pictures per year (rounded values). B) The number of affected animals per species relative to the number of pictures available per species (rounded values). *G.m.* = *Globicephala melas*; *T.t.* = *Tursiops truncates*; *D.d.* = *Delphinus delphis*; S.c. = *Stenella coeruleoalba*; *P.m.* = *Physeter macrocephalus*; *B.p.* = *Balaenoptera physalus*; *O.o.* = *Orcinus orca.*

Over the investigated period, comparatively high numbers of dermal diseases were detected in 2018 and 2019 (Fig. 24A) with annular lesions being only seen during these two years. Compared with the other years, 2018 and 2019 had lower average sea surface temperatures in multiple months[3]. The probability of skin lesions may decrease as the water temperature increases (Croft *et al*., 2020; Hart *et al*., 2012). Sea surface temperature was correlated with lesion prevalence in captive bottlenose dolphins (Croft *et al*., 2020) and in free-ranging bottlenose dolphins from the Northwest Atlantic (Hart *et al*., 2012). However, it was argued that high temperatures may only resolve tattoo skin lesions macroscopically or induce subclinical disease in captive dolphins (Van Bressem *et al*., 2022). More studies are needed to evaluate the relation between sea surface temperature and skin lesion

[3] Sea surface temperatures in Tarifa: *https://seatemperature.info/february/tarifa-water-temperature.html* (accessed 27 July 2023).

prevalence. With respect to the number of affected animals per species (Fig. 24B), the total number of pictures taken does approximately reflect sighting probabilities, except for fin and sperm whales and orcas. Individual fin and sperm whales were often photographed multiple times and the seasonal occurrence of orcas is a tourist highlight, with plenty of pictures being taken. Thus, these ratios cannot provide any indication of disease prevalence. Regarding the other species, our data indicates that bottlenose dolphins are most strongly affected by dermal diseases. The IUCN had classified this population as vulnerable based on mortalities due to fishing gear, overfishing and habitat degradation (Bearzi *et al*., 2008). The group sizes are continuously decreasing from year to year (Selling, 2019). Our qualitative study can only provide an indication of the prevalence of dermal diseases. Between the years 2004–07, tattoo skin lesions were reported in 4.5% of the individuals and it was concluded that the holo-endemic epidemiological pattern is typical of poxvirus disease in healthy odontocete populations (Jiménez-Torres *et al*., 2013). The health conditions of this population may have deteriorated in recent years; thus, we reiterate the need for updated data on disease prevalence.

Wounds

28 animals (*G. melas*: n = 23; *T. truncatus*: n = 2; *P. macrocephalus*: n = 3) were sighted with open wounds that did not appear to be caused by specific, natural or anthropogenic agents (Figs 23C and 25–27). These wounds

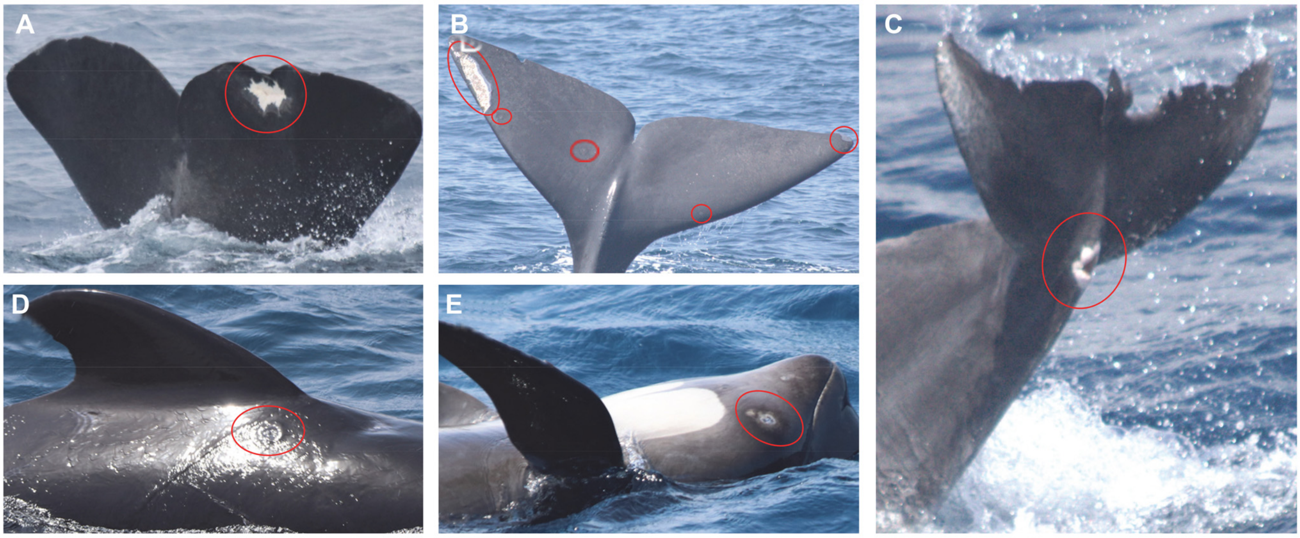

Fig. 25: Wounds: A) Adult sperm whale with a healed wound at the trailing edge of the fluke. B) Sperm whale with an open wound at the leading edge of the fluke (large red circle). There are pale spots on the dorsal surface of the fluke and the tip of the fluke is depigmented (small red circles). C) Adult bottlenose dolphin with an open wound ventrally to the fluke. D) Adult pilot whale with a circular wound laterally. E) Adult pilot whale with a wound at the lower jaw.

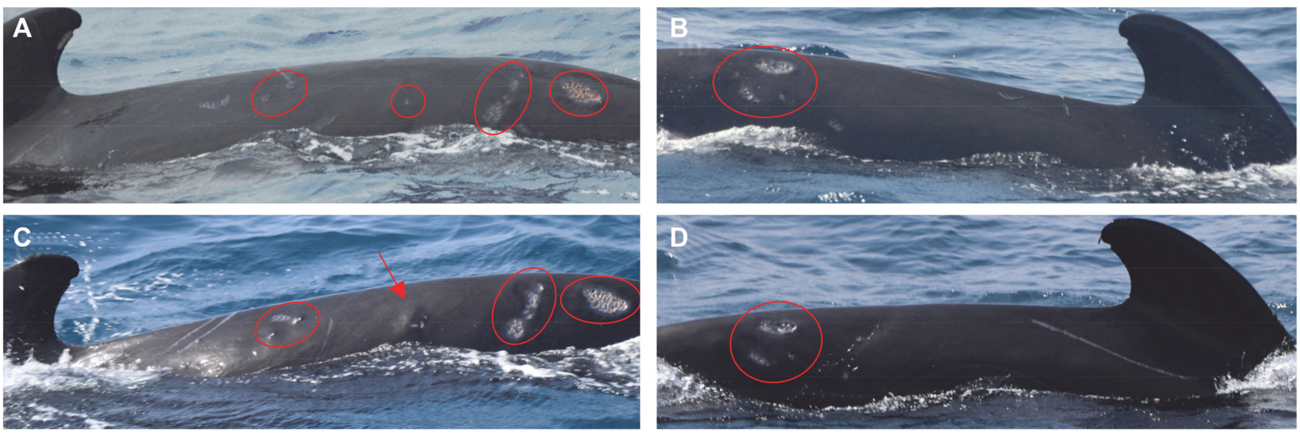

Fig. 26: Wound progression over time in an adult pilot whale: A) & B) In 2016, the animal was sighted with open wounds at both sides of the body. C) & D) The animal in 2019. Some of the wounds had enlarged slightly and the animal acquired a hump on the peduncle (red arrow). One *Xenobalanus spp.* was attached to the dorsal fin.

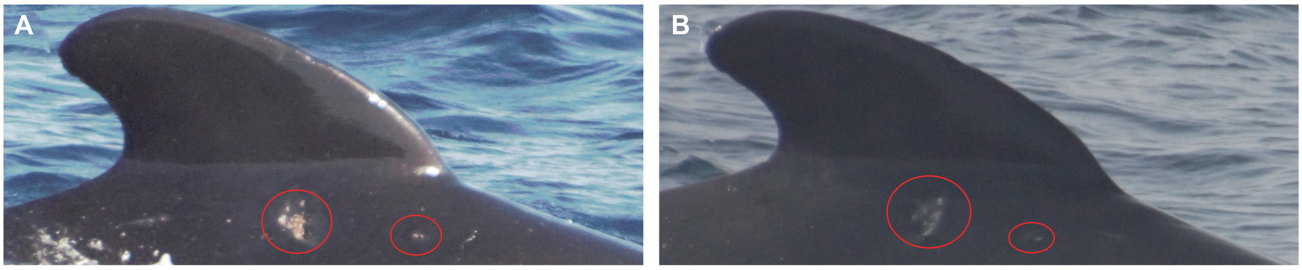

Fig. 27: Wound progression over time in an adult pilot whale: A) Adult pilot whale sighted with two ulcerations laterally in 2016. B) The animal was resighted in 2018. The ulcerations had not healed. This animal had not been resighted since 31.07.2018.

Fig. 28: Emaciated animals: A) Emaciated adult striped dolphin with two dark spots below the dorsal fin. B) Emaciated adult bottlenose dolphin with dark lesions thoracically. C) Emaciated adult bottlenose dolphin with *Xenobalanus spp.* attached to all extremities.

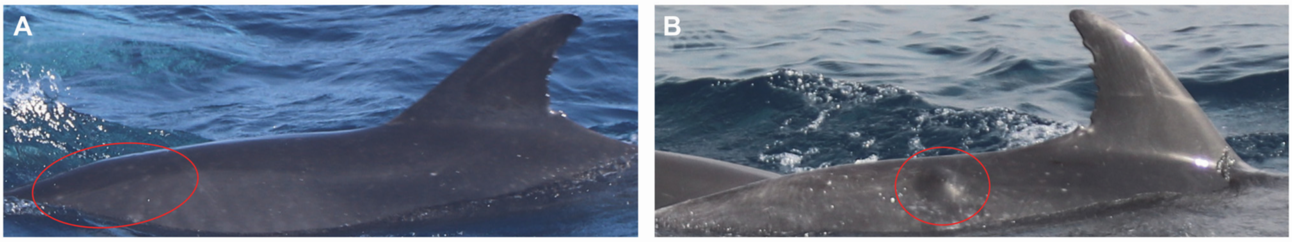

Fig. 29: Anomalies detected in one adult bottlenose dolphin. A) & B) Emaciated adult bottlenose dolphin sighted with pale spots and a hump on the peduncle.

may potentially be caused by an internal aetiology or infections (Patel *et al*., 2006). Follow-up of the affected animals was only possible for three pilot whales, whose wounds had not healed after periods of two to five years (Figs 26 and 27). This observation may potentially indicate weakened immune function that impairs healing.

Emaciation

Malnutrition was detected in 36 adult bottlenose dolphins and one adult striped dolphin (Figs 8A, 10A, 28, 29). Protruding ribs were used as the main indicator: this feature is a sign of advanced starvation (Joblon *et al*., 2014; Domiciano *et al*., 2016). Several emaciated animals showed additional conspicuous features, such as *Xenobalanus spp.* colonisation (n = 5), dermal diseases (n = 12) or both (n = 3). One individual was sighted with a hump and pale spots (Fig. 29). Three further animals were classified as 'potentially affected by skin lesions'. These pathological changes may represent cumulative effects of poor nutrition. In our data, thinness seemed to affect bottlenose dolphins most severely in 2018 and 2019. Emaciation may not necessarily indicate prey depletion but can also occur as a result of morbillivirus infections or severe injuries (Beineke *et al*., 2005; Flach *et al*., 2019; Pettis *et al*., 2017). Moreover, emaciation can also be a symptom of old age (Gómez-Campos *et al*., 2011). A study covering the years 2004–07 did not detect any signs of emaciation in the local bottlenose dolphin population (Jiménez-Torres *et al*., 2013). Herr and colleagues reported nine cases of emaciation in 2001–07 and 24 cases in 2008–15 (Herr *et al*., 2020). These observations might indicate fluctuations in prey availability as reported for bottlenose dolphins observed around La Gomera (Kautek *et al*., 2019). According to a stomach content analysis of bottlenose dolphins in Cádiz, European hake is one of the most consumed prey species (Giménez *et al*., 2017). European hake is also among the most important commercial fish species in the

Mediterranean Sea and these fish stocks face high fishing pressure (FAO, 2020a; 2020b). Animals in the Strait of Gibraltar are also exposed to dense vessel traffic and frequent disturbances, which may impact their foraging behaviour (Stockin *et al*., 2008).

Bottlenose dolphins are known for their acrobatic jumps, which provide a good view of their chest. It is likely that emaciation was harder to detect in other delphinids. Drone images could provide valuable insights into the nutritional status of pilot whales and orcas (Currie *et al*., 2021; Durban *et al*., 2021; Noren *et al*., 2019). Such an approach is highly recommended, especially for the critically small orca population. In the Strait of Gibraltar, orca feed on Atlantic bluefin tuna and are known to interact with human fisheries. The eastern Atlantic bluefin tuna stock is considered to be in a phase of rebuilding (Block *et al*., 2019; ICCAT, 2021), but conflicts between fishermen and orcas have been reported (De Stephanis *et al*., 2002).

Table 2
Additional observations in animals with humps.

Additional observations	Number of individuals
Skin lesions	3
Skin lesions and emaciation	1
Skin lesions and open wound and injury	1
Skin lesions and open wound	1
Skin lesions and *Xenobalanus spp.*	1
Open wound and *Xenobalanus spp.*	1
Tooth rake marks	1

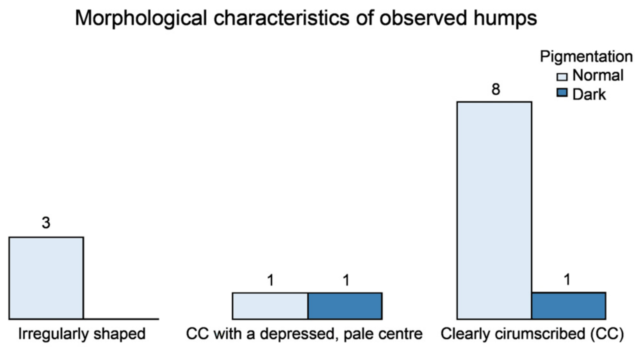

Fig. 30: Morphological characteristics of observed humps. CC = clearly circumscribed.

Humps

Humps were detected in multiple species (*D. delphis*: n = 1; *T. truncatus*: n = 3; *G. melas*: n = 7; *P. macrocephalus*: n = 1; *B. physalus*: n = 2) and during all years. The humps observed were described according to their morphology (Fig. 30) as either normally (Figs 23C, 26C, 29B, 31A–E) or dark pigmented (Fig. 31F) and as clearly circumscribed (Figs 26C, 29B, 31A–D) or irregularly shaped (Fig. 23C). In two cases, the humps appeared to have a depressed central pit (Fig. 31E/F). Most affected animals were sighted with only one hump. One adult sperm whale exhibited multiple swollen dark pigmented lesions (Fig. 31F). The aetiology of the humps is unknown, but the morphological variation observed indicates a variety of pathological agents. Cestode cysts were described in the case of one dusky dolphin (De Castro *et al*., 2014). Wound infections may be another explanation, as one pilot whale was sighted with fresh rake marks in direct proximity of swelling (Fig. 31B). Furthermore, it is striking that humps co-occurred with open wounds in three pilot whale adults (Figs 23C and 26). Further research is necessary to evaluate if these observations are coincidental or whether there may be a link between these health impairments.

Deformities

Bent dorsal fins were observed in nine male orcas and one adult fin whale (Fig. 32). Most bending deformities were classified as slightly bent. In two orcas, the fins were considered to be moderately bent. Physical injuries,

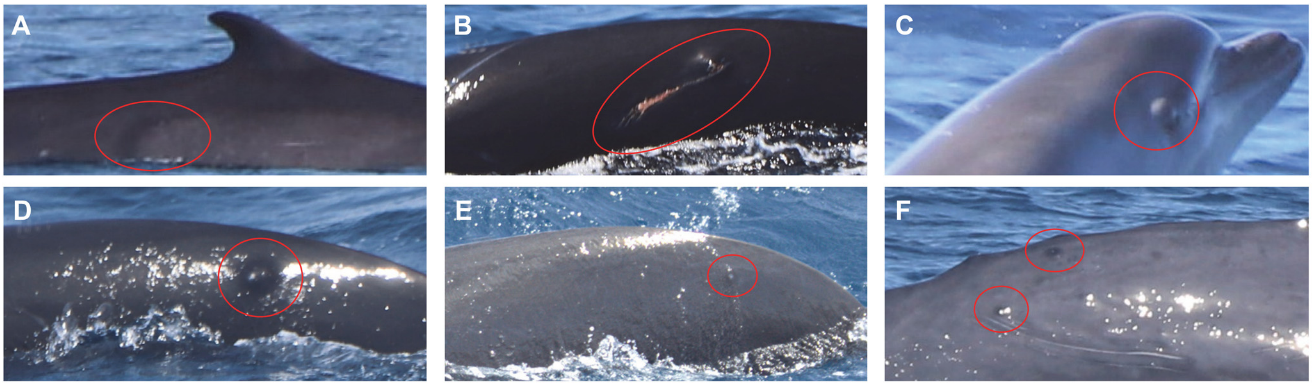

Fig. 31: Examples of humps: A) Fin whale with a normally pigmented, clearly circumscribed hump laterally. B) Adult pilot whale with a fresh wound (possibly a rake mark) on the peduncle. The surrounding tissue is swollen. C) Adult bottlenose dolphin with a normally pigmented, clearly circumscribed hump above the eye. D) Adult pilot whale with a normally pigmented, clearly circumscribed hump on the peduncle. E) Pilot whale calf with a hump on the peduncle. The swelling has a pale depressed centre. F) Adult sperm whale with two dark circular swellings at the peduncle. One swelling seems to have a pale depressed centre. The animal was resighted in the same year with further dark humps dorsally.

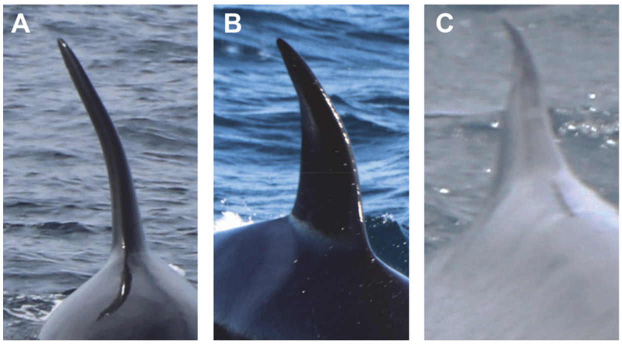

Fig. 32: Bent dorsal fins: A) & B) Adult male orcas with moderately bent dorsal fins (more than one third of the dorsal fin affected). C) Fin whale with a slightly bent dorsal fin. The last third of the dorsal fin is bent and the estimated angle is less than 30 degrees.

such as boat collisions and fishery entanglements, might be an anthropogenic cause of bent dorsal fins (Alves *et al*., 2018). Stress, age and illness are possible natural factors that might impact nutrient intake and affect the thickness of the blubber (Alves *et al*., 2018; Kastelein *et al*., 2016). Furthermore, the prevalence of bending deformities is high among male orcas. Male orcas have an especially long dorsal fin, ranging from 1 to 1.8m in height (Alves *et al*., 2018). Indeed, the cases observed in this study mainly involved male orcas. Associated injuries, indicating a traumatic origin, were not detected.

CONCLUSIONS

This study provides an update on the external health conditions of cetaceans in the Strait of Gibraltar. Our work documents a broad range of dermal diseases that may be caused by a variety of pathogens. Many types of dermal lesions have previously been documented in this region. Newly observed skin lesions, such as target-like lesions and expansive annular lesions, are a cause for concern and could indicate a deteriorating marine environment and the presence of new pathogens. Together with the observed ectoparasitism, increased disease susceptibility is possible among these populations. This indication is further strengthened by the observation of potentially superinfected skin conditions, ulcerating and chronic wounds and cases of multimorbidity. The health conditions of bottlenose dolphins seem to provide a particular cause for concern as this species was most strongly affected by dermal diseases (n = 192) and emaciation (n = 36). Annual variance in the prevalence of dermal diseases and emaciation could potentially be explained by environmental factors, such as sea temperature fluctuations and fluctuations in prey availability. Quantitative estimates of skin alterations, research on their aetiology and their relationship to environmental factors are needed. We recommend a monitoring of the chemical pollution, not only of legacy pollutants, such as PCBs, but also emerging contaminants, such as flame retardants and PFAS (per- and poly-fluoroalkyl substances).

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AUTHORS' DECLARATION

This work was conducted in conformity with Spanish legal requirements.

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