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Which are the main threats affecting the marine megafauna in the Bay of Biscay?

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ABSTRACT

The marine environment faces an increasing number of threats, mainly driven by anthropogenic activities, that are causing growing impacts on marine species and processes. In Europe, the EU Marine Strategy Framework Directive (MSFD) aims to achieve or maintain *Good Environmental Status* (GES) of the European waters by 2020. The Directive specifically refers to biodiversity with the first of the eleven qualitative descriptors (proposed to help describe what GES should look like) being *Biodiversity is maintained.* For this descriptor, the status of several functional groups, including marine megafauna species, need to be assessed using criteria such as population size and condition, and mortality due to bycatch in fishing gear, that compare current values against agreed thresholds. To contribute to this process, we performed an assessment of the threats affecting the marine megafauna community (*i.e.* seabirds and cetaceans) in the Bay of Biscay synthesizing the available evidences and identifying the main threats affecting the marine megafauna to help prioritise the required management and conservation actions. We analysed 4,023 admissions of seabirds recorded during 2004–2016 from four Wildlife Rehabilitation Centres to obtain an initial quantitative assessment of the pressures exerted on seabirds. The main marine threats identified in the Spanish North Atlantic sub-region were cachexia (52.3%), exposure to crude oil (10%) and interaction with fishing gears (5.3%). When considering all threats together, the common guillemot, the yellow-legged gull, the northern gannet, the great cormorant and the razorbill were the main affected species. In addition, we summarised the available information to perform an updated qualitative assessment of the severity of the threats faced by seabirds and cetaceans. The qualitative assessment showed that cetaceans are especially vulnerable to bycatch, vessel collision, and pollution-related threats, whilst seabirds are particularly sensitive to oil spills, bycatch and marine litter. This type of assessment studies can aid in the identification of priority areas and/or species where management measures should be applied to ensure that the ultimate goal of the MSFD, sustainable conservation of the marine environment, is reached.

1. Introduction

The marine environment faces an increasing number of threats that are causing growing impacts on marine species and processes; with over a third of the world's oceans estimated to suffer high or very high impacts (Halpern et al., 2008). These threats are mostly driven by anthropogenic activities, such as overexploitation of marine resources, pollution and habitat degradation and destruction (Dulvy et al., 2003; Halpern et al., 2007; IPBES, 2019). In addition, climate change-driven processes such as extreme weather events, increasing temperature and acidification are having serious effects on marine habitats (Descamps et al., 2015; Harley et al., 2006; Vaughan et al., 2001). These threats

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could have a cumulative effect and therefore the assessment of their spatio-temporal patterns could be of crucial importance (Halpern et al., 2015; Maxwell et al., 2013). In a recent assessment (IPBES, 2019), over 40% of marine ecosystems were highly impacted by climate-driven anthropogenic threats and 66% experienced cumulative impacts.

In Europe, the Marine Strategy Framework Directive (MSFD; 2008/56/EC) aims to provide the legal framework to achieve the sustainable use of marine goods and services of European waters by effectively managing human activities and pressures through an ecosystem-based approach. The MSFD requires Member States (MS) to follow a series of steps with the aim of achieving (or maintaining) *Good Environmental Status* (GES) of their waters by 2020 (see Santos & Pierce, 2015). One of the requirements of the Directive is that MS should define what GES means for their waters, in terms of the eleven qualitative descriptors provided. The Directive defines that GES will be reached when "*the overall state of the environment in marine waters provides ecologically diverse and dynamic oceans and seas which are healthy and productive*". MS are also required to set environmental targets and develop criteria (with associated thresholds) to reach GES, and to monitor the progress towards GES. The first descriptor of Biodiversity states that GES will be achieved when "*Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions"*. For this descriptor, the guidance provided by the European Commission (Cochrane et al., 2010) suggests a focus at the level of "functional group" (defined as "*an ecologically relevant set of species*") for assessment and reporting. Highly mobile groups of species such as cetaceans and seabirds are included as two of these functional groups. Cetaceans and seabirds ('marine megafauna' hereafter) have key roles in marine ecosystem functioning, with changes in their abundance and distribution impacting ecosystem structure, function and resilience (Baum and Worm, 2009; Estes et al., 2011).

The Bay of Biscay ('BoB' hereafter) hosts numerous seabird and cetaceans species of high conservation value. In the case of seabirds, many species breed in Northern Europe, but spend the non-breeding period in this area (Pettex et al., 2017). Among seabirds, there are species classified as "Critically Endangered" (Balearic shearwater *Puffinus mauretanicus*), "Endangered" (Atlantic puffin *Fratercula arctica*), "Vulnerable" (black-legged Kkittiwake *Rissa tridactyla*) and "Near threatened" (razorbill *Alca torda*) (IUCN, 2018). Of the common cetacean species, the fin whale *Balaenoptera physalus* is classified as "Near threatened" and both the sperm whale *Physeter macrocephalus* and the harbour porpoise *Phocoena phocoena* as "Vulnerable" in Europe (IUCN, 2018). At the Spanish level, ten cetacean and four seabird species are listed as "Threatened" in the Royal Decree for the Development of the List of Wild Species in Regime of Special Protection and the Spanish Catalogue of Endangered Species (RD139/2011).

There is an overall lack of knowledge on the severity of the impact of different threats (*e.g.* climate change, pollution, fishing, habitat-related changes) on seabirds and cetaceans in the BoB. This information is valuable in the context of the MSFD to develop criteria and their associated thresholds to determine if GES is reached. Within this context, we provided the first assessment of the impact of different threats on the marine megafauna community of the BoB based on two complementary approaches. Firstly, we evaluated the quantitative information gathered for seabirds at Wildlife Rehabilitation Centres (WRCs) to provide the basis for an initial assessment. Secondly, we carried out a literature review to (1) identify the main threats affecting both seabird and cetacean species occurring in the BoB and (2) evaluate their potential impact on both taxonomic groups. Both approaches were compared to provide a full assessment of their potential impact on the marine megafauna in the BoB.

2. Material and methods

2.1. Selection of species

The species considered were those listed as present in the North Atlantic sub-region of the Spanish initial evaluation document for the MSFD (MAGRAMA, 2012a, 2012b). The conservation status of the species listed was obtained at the global, European and national level. For global and European level, we used the International Union for the Conservation Nature criteria (IUCN; www.iucn.org) and checked whether the species was listed in the Annex I of the Birds Directive (BD; Council Directive 79/409/EEC) and/or in the Annex II of the Habitats Directive (HD; Council Directive 92/43/EEC). At the national level, we used for seabirds the Red Book of the Birds of Spain (Madroño et al., 2004) and for cetaceans the Red Book of Spanish vertebrates (Blanco and González, 1992) and the RD139/2011.

The marine megafauna list was composed by 35 seabird species belonging to nine families (Anatidae, Gaviidae, Procellariidae, Hydrobatidae, Sulidae, Phalacrocoracidae, Stercorariidae, Laridae and Alcidae) and 24 cetacean species belonging to five families (Balaenopteridae, Balaenidae, Delphinidae, Physeteridae and Ziphiidae) (see Table A1 and A.2, respectively). Based on the IUCN criteria, six seabird and five cetacean species at the global level and eight seabird and six cetacean species at the European level were identified as *threatened* (*i.e.* vulnerable, endangered or critically endangered). Furthermore, 33 seabird species were included in the Annex I of the BD and two cetacean species were included in the Annex II of the HD. At the national level, nine seabird and eleven cetacean species were listed as *threatened* by the RD139/2011.

2.2. Threats considered

An increasing number of threats could affect seabirds and cetaceans. We grouped the threats into different categories depending on their source: (a) *climate change*; (b) *pollution* which groups together all the threats associated with contamination (c) *fishing* that includes direct (*e.g.* bycatch) and indirect (*e.g.* prey depletion) interactions of megafauna with fishing activities; (d) *habitat-related changes* that includes threats related with habitat degradation, loss and destruction and (e) *others* that include a variety of marine threats such as vessel collision or disturbance due to tourism.

2.3. Impact assessment

2.3.1. Quantitative approach

Ethical statement: The rehabilitation programmes of the WRCs were conducted under the authorization of the appropriate departments of each regional government and were consistent with good veterinary practices.

Information of the admissions of marine megafauna species to WRCs were only available for seabirds in the southern BoB (Fig. 1). Information was gathered for a 13-year period (2004–2016) from the four existing WRCs in the southern BoB located in Gipuzkoa (Arrano Etxea WRC, 2004–2016), Bizkaia (Bizkaia WRC, 2004–2016), Cantabria (Cantabria WRC, 2010–2016) and Asturias (SERIDA, 2009–2016).

The WRCs' protocol (Fig. 2) involves recording the location, date of collection and admission, cause of admission, clinical evolution, date of release or death and, in the latter case, cause of death for each animal arriving at the WRCs. We coded the causes of admission into four different categories of threats, with a special focus on marine-related threats. *Cachexia* (*i.e.* extreme weight loss and muscle wasting) was included into climate change since this cause of admission has been related to extreme climatic events in the study area (Louzao et al., 2019). Similarly, *interaction with fishing gear* and *exposure to crude oil* were included into fishing and pollution, respectively. The remaining causes of admissions were included into the category *others*: *traumas*

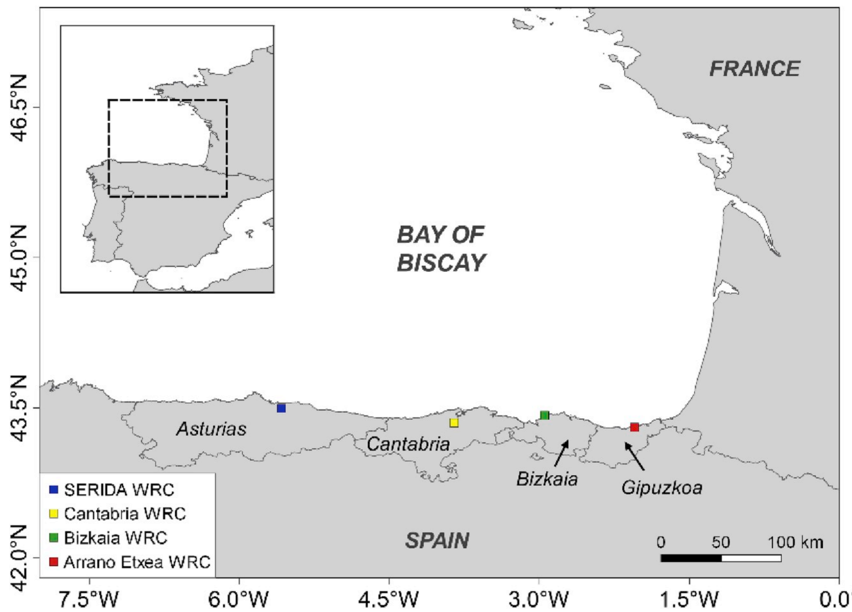

Fig. 1. Locations of the four Wildlife Rehabilitation Centres along the southern Bay of Biscay.

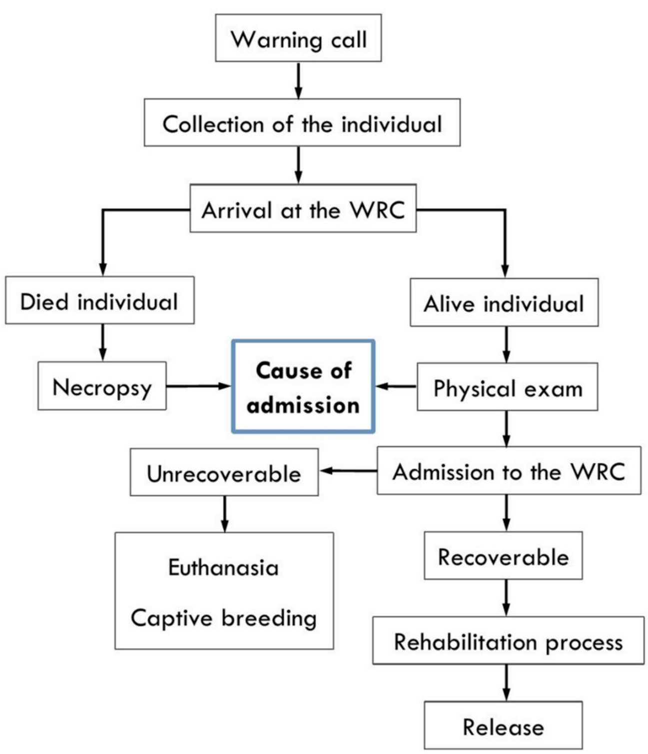

Fig. 2. The protocol implemented in the Wildlife Rehabilitaton Centres. The blue box shows the data used to perform the quantitative assessment. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

(subdivided into *car impact*, *gunshot*, *electrocution* and *undefined trauma*), *disease* (subdivided into *parasitic/infectious disease* and *others*), *orphaned*, *intraspecific interaction*, *without apparent lesions, other causes* (including *forfeited, poisoning* and *autolytic*) and *undetermined*.

We further analysed the causes of admissions by identifying the main affected seabird families/species and the temporal evolution of the number of individuals affected by each threat, both seasonally and inter-annually, testing whether there were statistically significant differences in seabird families/species and causes of admission using Chi-square tests. Furthermore, we explored the associated variability [*i.e.* coefficient of variation (CV)] of the percentage of admissions per year and species.

2.3.2. Qualitative approach

We carried out a literature review to (a) determine the main threats affecting directly or indirectly the cetacean and seabird species and (b) gather evidence (based on published data) on the likelihood of the impact of different threats. The scoring was based on a categorical codification of low, medium and high impact following the criteria used by the Working Group on Marine Mammal Ecology (WGMME) of the International Council for the Exploration of the Sea (ICES) (ICES, 2015). A *high* score was given when “there were evidences of negative population effects, mediated through effects on individual mortality, health and/or reproduction”; a *medium* score was given when “there were evidences or strong likelihood of impact at individual level on survival, health or reproduction, but population effects were not clear” and finally *low* score was given when there were “possible negative impacts on individuals, but weak evidence and/or infrequent occurrence”. Finally, the text “No evidence of threat to date in the area” was used for cases where there was no evidence of the impact of the threat in the BoB or it was not considered relevant for the species. The literature review was conducted on the ISI Web of Knowledge using the following key words: *cetacean*, *marine mammal*, *seabird*, *threat*, *pressure*, *East Atlantic* and *Bay of Biscay*. In addition, relevant reports and publications were accessed including the initial MSFD evaluations of Spain and France, the ICES reports of the Joint Working Group on Bird (JWGBIRD) and WGMME, the reports of the OSPAR ICG-COBAM expert group and the reports of the International Whaling Commission (IWC) Scientific Committee. Based on the review, we created a matrix of species and marine threats categories.

2.3.3. Quantitative versus qualitative assessments

The comparison of the quantitative and qualitative assessments was only possible for seabird species. We compared the number of admissions due to cachexia, exposure to crude oil and interaction with fishing gears in the quantitative assessment with the scoring obtained in the qualitative assessment of extreme weathers events, oil spills and by-catch, respectively. This comparative analysis was based on 26 seabird species included in both assessments. We transformed the number of admissions into impact scores for each species and threat by scoring as

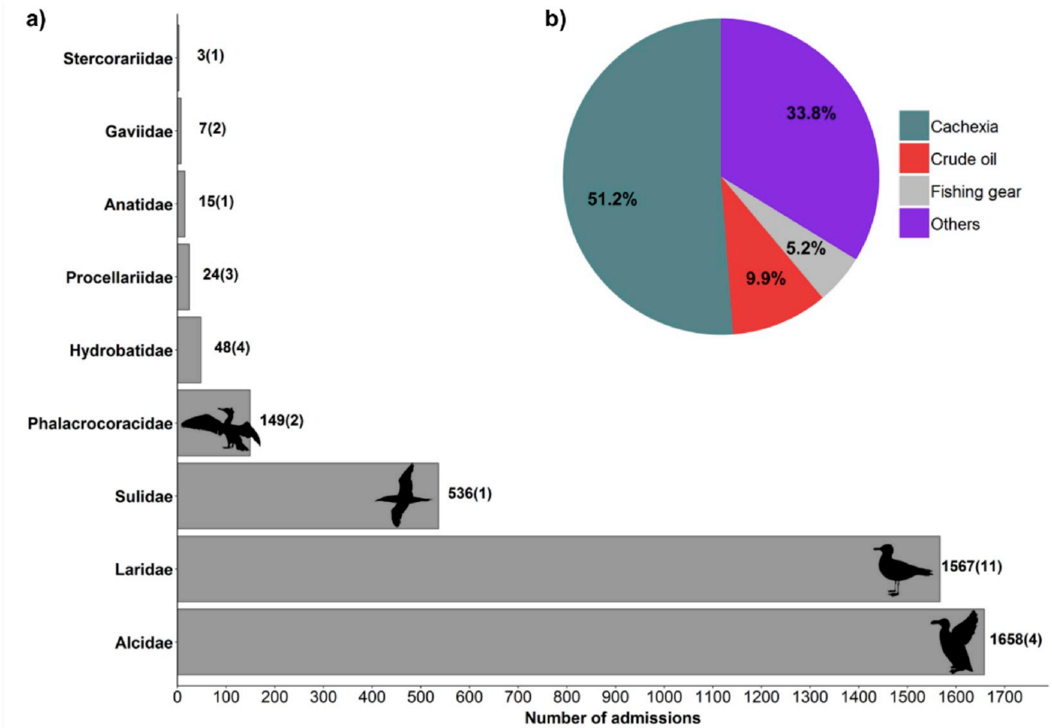

Fig. 3. a) Number of admissions at the Wildlife Rehabilitation Centres located in the southern Bay of Biscay (2004–2016) categorized by taxonomic family. The numbers to the right of the bars indicate the number of admissions and the number of species belonging to each family is given between brackets. b) Pie chart of the number of admissions by threats expressed as the percentage of the total number of admissions.

low when the percentage of the number of admissions for a given threat was < 33%. Similarly, scores of *medium* and *high* were assigned when the percentage of the number of admissions for a given threat ranged between 33% and 66% and > 66%, respectively. Then, we compared both sets of scores by threat.

3. Results

3.1. Quantitative impact assessment

3.1.1. Overall description

Data from a total of 4,023 admissions were available divided between WRCs as follows:: 1,616 (40.2%; 2014–2016 period) from the Gipuzkoa WRC, 1,854 (46.1%; 2014–2016 period) from the Bizkaia WRC, 227 (5.6%; 2010–2016 period) from the Cantabria WRC and 326 (8.1%; 2009–2016 period) from the Asturias WRC. The admissions included 29 species belonging to nine families (see Fig. 3a): Alcidae (41.2% of the total number of admissions), Laridae (38.9%), Sulidae (13.3%), Phalacrocoracidae (3.7%), Procellariidae (0.6%), Anatidae (0.4%), Gaviidae (0.2%) and Stercorariidae (0.07%). The common guillemot *Uria aalge* was the species most frequently admitted (36.3%, n = 1,459), followed by the yellow-legged gull *Larus michahellis* (26.8%, n = 1,078), the northern gannet *Morus bassanus* (13.3%, n = 536), the black-headed gull *Chroicocephalus ridibundus* (4.87%, n = 196), the great cormorant *Phalacrocorax carbo* and the razorbill (both 3%, n = 124).

The number of cases and the frequency distribution by cause of admission (summarised in 8 categories as previously explained) is shown in Table B1. The most frequent cause of admission was *cachexia* (51.2%, n = 2,061), followed by *exposure to crude oil* (9.9%, n = 397) and *interaction with fishing gears* (5.2%, n = 207). The category *others* included 33.8% of the admissions of which *undefined trauma* (12.9%, n = 511) and *orphaned* (5.7%, n = 224) were the main contributors (Fig. 3b).

3.1.2. Temporal variation of admissions

The most frequently recorded species (see details above) were registered every year, in contrast to those species which were less commonly recorded. Overall inter-annual variability (CV) of the most frequently recorded species ranged between 0.33 (great cormorants) and 0.66 (razorbills) (Table B2). By year, the Alcidae family was mainly recorded in 2004 and 2014, whilst the admissions of individuals of the families Laridae, Sulidae and Phalacrocoracidae remained almost constant during the study period (Fig. 4a). The highest number of admissions related to *cachexia* (the most prevalent cause of admission) were recorded in 2007, 2014 and 2016 ($\chi^2 = 1449.5$, df = 12, $p < 0.0001$; Fig. 4b). The most affected families were Alcidae (58.5%), Laridae (22.5%) and Sulidae (13.2%). Significant higher numbers of admissions due to *exposure to crude* oil took place in 2004 and 2007 ($\chi^2 = 1062$, df = 12, $p < 0.0001$; Fig. 4b). The most affected families were Alcidae (85.1%), Sulidae (8,4%) and Laridae (4.8%). For both threats, the most affected species was the common guillemot with 51.3% and 77.3% of the total admissions (considering all species together) corresponding to *cachexia* and *exposure to crude oil*, respectively. The number of admissions related to interaction with fishing gears remained almost stable over time (Fig. 4b). The most affected species were northern gannets (28.7%), yellow-legged gulls (8.6%), great cormorants (4.6%) and common guillemots (2.7%).

The highest percentage of admissions was recorded in winter (31.4%, n = 1,264), followed by spring (23.2%, n = 935), summer (23.2%, n = 935) and fall (22.1%, n = 889). Seasonal admissions of the main families are shown in Fig. 5a. The family Alcidae showed more significant admissions in winter and spring ($\chi^2 = 1095.5$, df = 3, $p < 0.0001$), whereas the family Laridae was the main familiy admitted in summer and fall ($\chi^2 = 399.89$, df = 3, $p < 0.0001$). The families Sulidae and Phalacrocoracidae were significantly most frequently admitted in fall than the rest of the year ($\chi^2 = 133.1$, df = 3, $p < 0.0001$; $\chi^2 = 45.497$, df = 3, $p < 0.0001$, respectively). The most frequent causes of admission varied among seasons (Fig. 5b). We detected significant differences in the number of admissions between

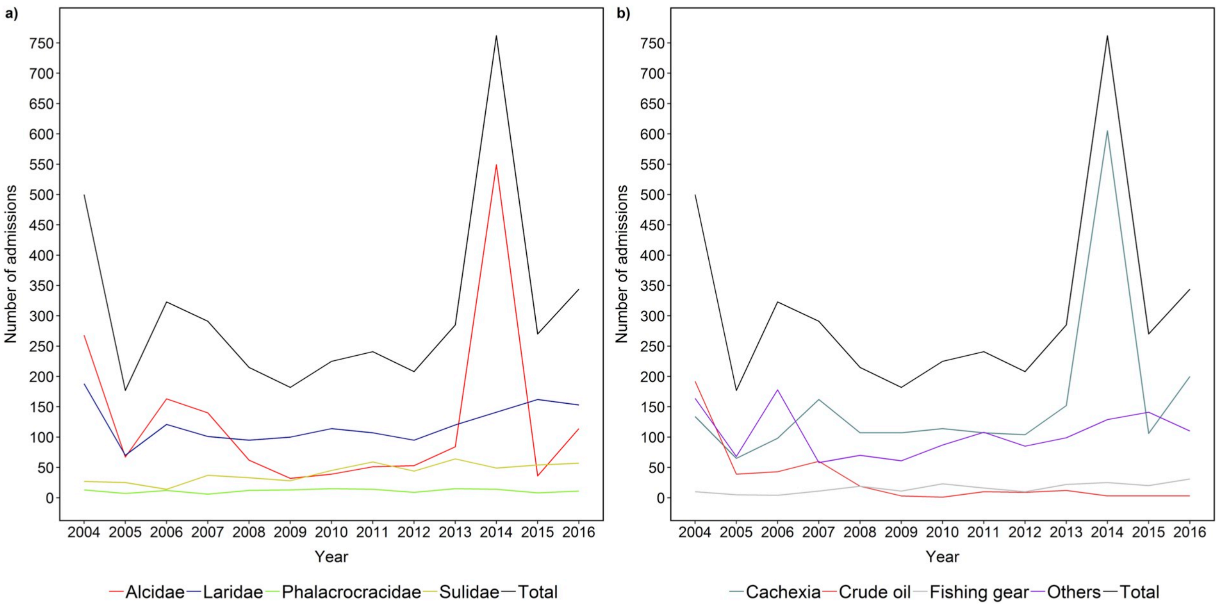

Fig. 4. Annual admissions of a) the four most frequently admitted seabird families and b) the main marine threats and others recorded at the Wildlife Rehabilitation Centres in the southern Bay of Biscay (2004–2016).

seasons for all threats, with the exception of the *interaction with fishing gears* ($\chi^2 = 8.16$, df = 3, p = 0.06). In the case of *cachexia* and *exposure to crude oil* ($\chi^2 = 384.04$, df = 3, $p < 0.0001$; $\chi^2 = 240.99$, df = 3, $p < 0.0001$, respectively), the highest number of admissions were recorded in winter and during both winter and spring, respectively. Admissions due to *undefined traumas* and *orphaned* ($\chi^2 = 121.38$, df = 3, $p < 0.0001$; $\chi^2 = 388.75$, df = 3, $p < 0.0001$, respectively) were more numerous in summer and fall.

3.2. Qualitative impact assessment

3.2.1. Cetaceans

Threats related to climate change were scored as *low* for most of the selected species (31.8%). However, the increase in water temperature was scored as a *medium* for 31.8% of the species (Table 1). In relation to pollution, 27.1% of the species scored *high* or *medium* due to the potential effect of persistent organic pollutants (*e.g.* PCBs), considered to be especially dangerous for the long-finned pilot whale *Globicephala melas*, the killer whale *Orcinus orca*, the bottlenose dolphin *Tursiops truncatus* and the harbour porpoise. Almost 23% of the species scored *medium* for the impact of marine litter (*e.g.* plastics), whilst ghost fishing scored *medium* for 13.6% of the species. Sixty-eight percent of the species scored *medium* (40.9%) or *high* (27.2%) for acoustic pollution (*e.g.* seismic surveys or mining). Finally, all the species scored *low* for oil spills. In relation to fishing, bycatch was identified as particularly dangerous for 54.5% of the species (13.6% *medium* and 40.9% *high*) while overfishing scored *low* for all the species. Habitat related threats scored *low* for all species, except the harbour porpoise. This species

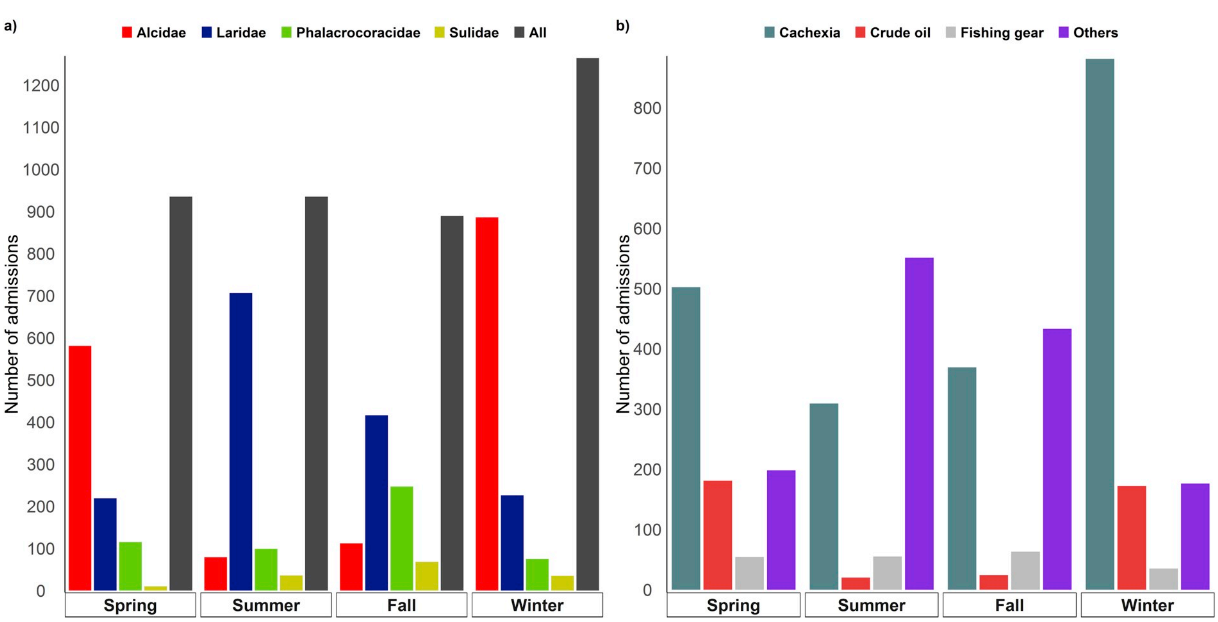

Fig. 5. Seasonal admissions of a) the four most frequently admitted seabird families and all the admissions and b) the main threats and other causes of admission at Wildlife Rehabilitation Centres of the southern Bay of Biscay (2004–2016).

Table 1
Threat matrix for cetaceans in the Bay of Biscay. This matrix is an updated version derived from the one developped by the Working Group on Marine Mammal Ecology (WGMME; ICES, 2015) and it is based on the literature reviewed in this work. (*) indicates that the evaluation was obtained from the WGMME report; (†) indicates that the threat is referenced for the same species but in another area. Numbers in superscript indicate the reference used to evaluate the effect (references are included in Appendix C). Colours highlight the effect of the threats as L: low (green), M: medium (yellow) and H: high (red).

		Minke whale	Sei whale	Blue whale	Fin whale	Humpback whale	Common dolphin	Long-finned pilot whale	Short-finned pilot whale	Risso's dolphin	Killer whale	False killer whale	Striped dolphin
Climate change	Elevated temperatures	M[2]	L[1]	L[1]	L[1]	L[1]	M[3,5]	L[2]	L[1]	L[1]	L[2]	L[1]	L[1,2]
	Ocean acidification	L[4]	L[4]	L[4]	L[4]	L[4]	L	L	L	L	L	L	L
	Sea level rise	L	L	L	L	L	L	L	L	L	L	L	L
	Extreme weather events	L	L	L	L	L	L	L	L[5]	L	L	L	L
	Shifts in ocean current patterns	L	L	L	L	L	L	L	L	L	L	L	L
Pollution	Chemical contamination (e.g. PCB, DDT)	L[5]	L[†,8]	L	L*[5]	L	M*[12]	H*[5]	L[5]	L*	H*[15]	L	M*
	Marine litter (e.g. plastics, microplastics)	M*[5]	L	L[†,24]	L*[5]	L[5]	M[5]	L*[5]	L[5]	L*[5]	L*[5]	L[5]	L*
	Ghost fishing	M[5,7]	L	L	L*[5]	L[†,25,26]	L*	L*	L	L*	L*	L	L*
	Eutrophication	L	L	L	L	L	L	L	L	L	L	L	L
	Acoustic pollution (e.g. sonar, seismic surveys)	M*[5,6]	L[†,8]	L	M*	M[6]	H[5,6]	L*	L	M*	L[5]	L	M*
	Light pollution	No evidence of threat											
	Oil spills	L[5,14]	L	L	L[5]	L	L[5,17]	L[5,14]	L	L[14]	L[14]	L	L
Fishing	Overfishing	L[6]	L	L	L[6]	L[6]	L[11]	L[6]	L	L*	L*[5]	L	L*[11]
	Bycatch	M[23]	L	L	L*	M[5]	H*[5,7,9,10]	H[†,5,22,23]	H[5]	H[5,23]	L*	L	M*[†,5,22,23]
Haitat-related changes	Habitat los	L	L	L	L*	L	L*	L*	L	L*	L*	L	L*
	Habitat degradation	L	L	L	L*	L	L*	L*	L	L*	L*	L	L*
	Invasive species	L	L	L	L	L	L	L	L	L	L	L	L
	Coastal urbanization	L	L	L	L	L	L	L	L	L	L	L	L
Others	Introduction of pathogens (ballast waters)	L[5]	L[5]	L	L	L	L*[5]	L*	L	L*	L*	L	L*
	Vessel collision	M*[5,6]	H[†,8]	L	H[5]	H[5,6]	M[5]	H[5]	H[5]	L*	L*	L	L*
	Tourism (e.g. whale/birdwatching)	L*	L	L	L*	L	L*	L*[5]	L[5]	L*	L*	L	L*

		Bottlenose dolphin	White-beaked dolphin	Harbour porpoise	Pigmy sperm whale	Sperm whale	North Atlantic bottlenose whale	Blainville's beaked whale	True's beaked whale	Sowerby's Beaked whale	Cuviers's beaked whale
Climate change	Elevated temperatures	L[1]	M[1,2]	M[1]	L[1]	L[1,5]	M[1,2]	L[1]	M[1]	M[1]	L[1]
	Ocean acidification	L	L	L	L	L	L	L	L	L	L
	Sea level rise	L	L	L[6]	L	L	L	L	L	L	L
	Extreme weather events	L	L	L	L	L[5]	L[5]	L	L	L	L
	Shifts in ocean current patterns	L	L	L	L	L	L	L	L	L	L
Pollution	Chemical contamination (e.g. PCB, DDT)	H*[12]	L[5]	H*[12]	L	L*[5]	L*	L[5]	L	L*	L[5]
	Marine litter (e.g. plastics)	L*	L[5]	L*[5]	L[5]	M*[5]	M*	L[5]	L[5]	L[†,27]	M*[16]
	Ghost fishing	L*	L	L*	L	L*[5]	M*	L	L	L	M*
	Eutrophication	L	L	L	L	L	L	L	L	L	L
	Acoustic pollution (e.g. sonar, seismic surveys)	H[†,6]	M[5,6]	H[†,5,6]	L	M*	M*	H[†,5,13]	H[†,13]	M*[†,13]	H*[5,13]
	Light pollution	No evidence of threat									
	Oil spills	L[14]	L	L[14]	L	L	L	L	L	L	L
Fishing	Overfishing	L[11,19]	L[6]	L[11]	L	L[6]	L*	L	L	L*	L*
	Bycatch	H*[5,6,15,21,23]	H[5]	H*[5,6,11,15,20]	H[5]	L*[23]	L*	L	L	L*	H[5]
Haitat-related changes	Habitat loss	L*	L	L*	L	L*	L*	L	L	L*	L*
	Habitat degradation	L*	L	L*	L	L*	L*	L	L	L*	L*
	Invasive species	L	L	L	L	L	L	L	L	L	L
	Coastal urbanization	L	L	M[6]	L	L	L	L	L	L	L
Others	Introduction of pathogens (ballast waters)	L*	L	L*	L	L	L*	L	L	L*	L*
	Vessel collision	L	L	H[5]	H[5]	H*	M[†,28]	L	L	L*	H[5]
	Tourism (e.g. whale/birdwatching)	M*	L	L*	L	L*	L*	L	L	L*	L*

scored *medium* for impact of coastal urbanization. Regarding other threats, introduction of pathogens scored *low* for all the species, while the impact of vessel collision was *high* and *medium* for the 40.9% and 13.6% of the species, respectively. Finally, tourism scored *medium* for the bottlenose dolphin and *low* for the remaining species.

3.2.2. Seabirds

Concerning climate change, 2.7% of the species scored *high* impact due to the increase of water temperature and 11.1% scored *medium* due to the occurrence of extreme weather events (both especially important for the European storm-petrel *Hydrobates pelagicus*). The remaining

Table 2
Threat matrix based on the literature reviewed in this work for seabirds in the Bay of Biscay. (†) indicates that the threat is referenced for the same species but in another area. Numbers in superscript indicate the reference used to evaluate the effect (references are included in Appendix C). Colours highlight the effect of the threats as L: low (green), M: medium (yellow) and H: high (red).

		Black scoter	Red-breasted merganser	Red-throated loon	Black-throated loon	Common loon	Cory's shearwater	Manx shearwater	Great shearwater	Sooty shearwater	Balearic shearwater	Northern fulmar	European-storm petrel
Climate change	Elevated temperatures	L	L	L	L	L	L	L	L	L[†,46,47]	L[29,31]	L	H[30]
	Ocean acidification	L	L	L	L	L	L	L	L	L	L	L	L
	Sea level rise	L	L	L	L	L	L	L	L	L	L	L	L
	Extreme weather events	L	L	L	L	L	L	L	L	L	L	L[68]	H[32]
	Shifts in ocean current patterns	L	L	L	L	L	L	L	L	L	L	L	L
Pollution	Chemical contamination (e.g. PCB, DDT)	L[†,54]	L	L	L	L	L[†,50,56,79]	L[†,79]	M[†,78]	L[†,80]	M[35]	L	L
	Marine litter (e.g. plastics)	L	L	L[†,86]	L[†,88]	L	M[†,95]	M[†,90]	L[77]	L[†,89]	L[77]	L[77,81,82,83]	L[†,91]
	Ghost fishing	L	L	L[†,87]	L[†,87]	L[†,87]	L	L	L	L	L	L	L
	Eutrophication	L	L	L	L	L	L	L	L	L	L	L	L
	Acoustic pollution (e.g. sonar, seismic surveys)	No evidence of threat											
	Light pollution	L	L	L	L	L	M[†,58,72,73]	L[†,72]	M	M[†,76]	L[†,75]	L	L[†,72,74,75]
	Oil spills	M[36,104]	M[36]	M[36]	M[36]	M[36,104,106]	L[36]	L[36]	L[36,104]	L[36]	L[36]	L[106]	H[43,104]
Fishing	Overfishing	L	L	L	L	L	L	L	L	L	L	L	L
	Bycatch	L[†,98]	L[†,85]	L[†,85]	L	L[†,86]	L[†,100,101]	M[23]	M[†,65]	H[†,63,65]	M[23]	M[23,65]	L
Haitat-related changes	Habitat loss	L	L	L	L	L	L	L	L	L	M[103]	L	M[102]
	Habitat degradation	L	L	L	L	L	L	L	L	L	M[103]	L	L
	Invasive species	L	L	L	L	L	H[†,99]	L	L	L	L	L	L
	Coastal urbanization	L	L	L	L	L	L	L	L	M[†,76]	L	L	L
Others	Introduction of pathogens (ballast waters)	L	L	L	L	L	L	L	L	L	L	L	L
	Vessel collision	L	L	L	L	L	L	L	L	L	L	L	L
	Tourism (e.g. whale/birdwatching)	L	L	L	L	L	L	L	L	L	L	L	L

		Leach's storm-petrel	Band-rumped storm-petrel	Northern gannet	Great cormorant	European shag	Pomarine jaeger	Arctic jaeger	Great skua	Mediterranean gull	Little gull	Sabine's gull	Black-headed gull
Climate change	Elevated temperatures	L	L	L	L	L	L	L	L	L	L	L	L
	Ocean acidification	L	L	L	L	L	L	L	L	L	L	L	L
	Sea level rise	L	L	L	L	L	L	L	L	L	L	L	L
	Extreme weather events	L	L	M[68]	L[68]	L[68]	L	L	L	L	L	L	L[68]
	Shifts in ocean current patterns	L	L	L	L	L	L	L	L	L	L	L	L
Pollution	Chemical contamination (e.g. PCB, DDT)	L	L	L[39]	L[†,51]	L	L	L	L[†, 79]	L	L	L	L[†,52]
	Marine litter (e.g. plastics)	L[†,92]	L	H[77]	M[77]	L[77]	L[†, 93]	L	L[†, 84,95]	L[77]	L	L[†,93]	M[77]
	Ghost fishing	L	L	M[59]	M[†,65]	L	L	L	L	L	L	L	L
	Eutrophication	L	L	L	L	L	L	L	L	L	L	L	L
	Acoustic pollution (e.g. sonar, seismic surveys)	No evidence of threat to date in the area											
	Light pollution	L[†,70]	L	L	L	L	L	L	L	L	L	L	L
	Oil spills	L	L	H[36,40]	L[36]	H[36,40,42,44]	L	L	L[104]	M[36]	M[36]	M[36]	M[36,104]
Fishing	Overfishing	L	L	L[†,48]	L	L	L[†,48]	L[†,48]	L[†,48]	L	L	L	L
	Bycatch	L	L	M[23]	L[†,85]	H[109]	L	L	L	L	L	L	L[†,85,88]
Haitat-related changes	Habitat loss	L	L	L	L	L	L	L	L	L	L	L	L
	Habitat degradation	L	L	L	L	L	L	L	L	L	L	L	L
	Invasive species	L	L	L	L	H[109]	L	L	L	L	L	L	L
	Coastal urbanization	L	L	L	L	L	L	L	L	L	L	L	L
Others	Introduction of pathogens (ballast waters)	L	L	L	L	L	L	L	L	L	L	L	L
	Vessel collision	L	L	L	L	L	L	L	L	L	L	L	L
	Tourism (e.g. whale/birdwatching)	L	L	L	L	M[107]	L	L	L	L	L	L	L

(continued on next page)

Table 2 (*continued*)

		Common gull	Lesser black-backed gull	Yellow-legged gull	Great black-backed gull	Kittiwake	Sandwich tern	Common tern	Arctic tern	Little tern	Common guillemot	Razorbill	Atlantic puffin
Climate change	Elevated temperaturas	L	L	L	L	L	L	L	L	L	L[†,71]	L	L
	Ocean acidification	L	L	L	L	L	L	L	L	L	L	L	L
	Sea level rise	L	L	L	L	L	L	L	L	L	L	L	L
	Extreme weather events	L	L[68]	L	L[68]	M[68]	L	L	L	L	H[67,68]	M[68]	M[68,68]
	Shifts in ocean current patterns	L	L	L	L	L	L	L	L	L	L[†,66]	L	L
Pollution	Chemical contamination (e.g. PCB, DDT)	L	L	M[34]	L	L	L	M[†,53,57,79]	L	L	L[†,54]	M[33]	L[†, 79]
	Marine litter (e.g. plastics)	L	L[†,85,97]	M[†,95,97]	L	M[77]	L[77]	L[77]	L	L[†,96]	H[77]	H[77]	H[77]
	Ghost fishing	L	L	L	L	L	L	L	L	L	L[†,87]	L	L
	Eutrophication	L	L	L	L	L	L	L	L	L	L	L	L
	Acoustic pollution (e.g. sonar, seismic surveys)	No evidence of threat to date in the area											
	Light pollution	L	L	L	L	L	L	L	L	L	L	L	M[†,110]
	Oil spills	M[36]	M[36]	M[36,41,45]	M[36]	M[36,104]	L[36]	M[36]	M[36]	M[36]	H[36,38,40,104]	H[36,37,38]	H[36,38,40]
Fishing	Overfishing	L	L	L	L	L[†,45,69]	L	L	L	L	L	L	L[†,55]
	Bycatch	L	L[†,94]	L	L	L[†,85]	L[†,94]	L	L	L[†,96]	H[†,60,61,62]	M[†,65]	M[23]
Haitat-related changes	Habitat loss	L	L	L	L	L	L	L	L	L	L	L	L
	Habitat degradation	L	L	L	L	L	L	L	L	L	L	L	L
	Invasive species	L	L	L	L	L	L	L	L	L	L	L	L
	Coastal urbanization	L	L	L	L	L	L	L	L	L	L	L	L
Others	Introduction of pathogens (ballast waters)	L	L	L	L	L	L	L	L	L	L	L	L
	Vessel collision	L	L	L	L	L	L	L	L	L	L	L	L
	Tourism (e.g. whale/birdwatching)	L	L[106]	L	L	M[†,108]	L[106]	L[106]	L	L	M[†,108]	L	L

threats related to climate change scored *low* for all the species. In relation to pollution, persistent organic pollutants scored *medium* for 13.8% of the species and *low* for the remaining species. Impact of marine litter scored *medium* for 16.6% of the species, *high* for 11.1% and *low* for the remaining 71.3% of the species. Impact of ghost fishing scored *medium* for the northern gannet and the great cormorant and *low* for the remaining species. All the species showed a *low* impact due to eutrophication. Light pollution scored *medium* for 11.1% of the species, being especially relevant for the family Procellariidae, and impact of oil spills scored *medium* and *high* for 47.2% and 16.6% of the species, respectively. Regarding the interaction with fishing, overfishing scored *low* for all the species, whilst 13.8% and 19.4% of the species scored *high* or *medium* due to bycatch. For threats associated with habitat change, 5.5% of the species scored *medium* due to habitat loss and *high* due to invasive species. However, 5.4% of the species showed a *medium* or *high* score due to habitat loss or habitat degradation, respectively. Impact of tourism scored *medium* or *high* for only 8.3% and 2.7% of the species, respectively (Table 2).

3.3. Quantitative versus qualitative assessments

The comparison of the assessments (Fig. 6) between the admissions caused by cachexia and the occurrence of extreme weather events showed that the quantitative assessment rated a higher number of species as experiencing *medium* or *high* impact. In the case of the admissions related to the exposure to crude oil (caused mainly by oil spills), the qualitative approach classified the effect of this threat as *low*, *medium* and *high* depending of the species. However, the quantitative approach scored this threat as *low* for all the species. Concerning the interaction with fishing gear the quantitative approach scored *low* for most of the species, while a small percentage of species scored *medium*. Regarding the bycactch in the qualitative approach, the majority of species scored *low,* while the remaining species scored *medium* or *high*.

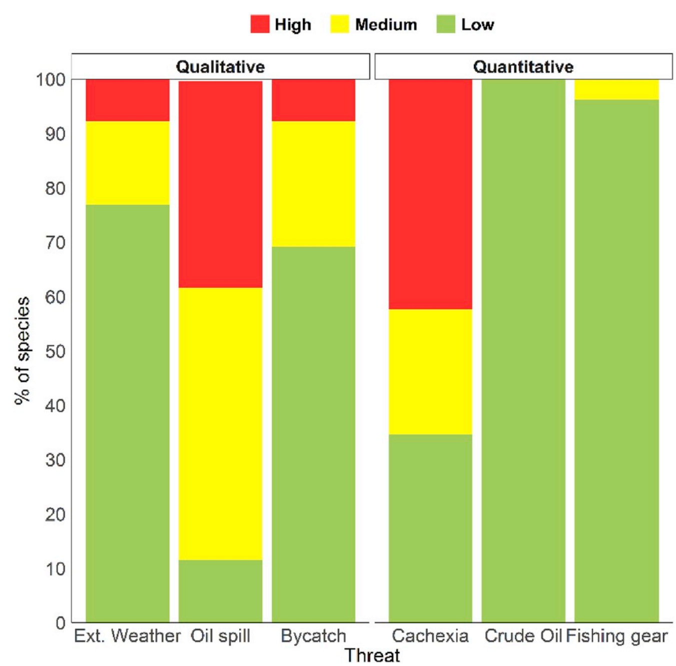

Fig. 6. Comparison between the impacts of the threats scored in the qualitative and quantitative assessments (left and right panels, respectively).

4. Discussion

The lack of knowledge on the impact that different threats could have on seabird and cetacean individuals and populations hampers the development of suitable mitigation measures despite the efforts of several expert groups in summarising the existing evidence and categorising these threats. The present study advances our knowledge on the main threats faced by the marine megafauna community in the BoB by providing new (quantitative) evidence of their impact on seabird species (based on WRCs records) and updating the information (qualitative) in relation to the severity of these threats on cetacean species.

4.1. Evaluating threat impacts based on monitoring schemes

The causes of admission to WRCs can be used to evaluate the impact of multiple threats on seabird populations (Sleeman and Clark, 2003). However, long-term studies of seabird admissions to WRCs covering more than a decade are scarce (Haman et al., 2013; Montesdeoca et al., 2017). We compiled data spanning 13 years (from 2004 to 2016) that corresponds to the longest time series analysed in the study area.

Potential biases in the WRCs data are related to possible differences in the probability (1) of arrival to the coast, (2) of being encountered and (3) of being delivered to WRCs (Louzao et al., 2019). However, we considered that these datasets can provide useful information on the prevalence of certain threats, as it is the case of cetacean strandings.

When considering all threats together, the common guillemot, the yellow-legged gull, the northern gannet, the black-headed gull, the great cormorant and the razorbill were the most affected species, since they are the most abundant species in the North Atlantic subregion (MAGRAMA, 2012a,b). Although cachexia was the main cause of admission for all the above-mentioned species, exposure to crude oil for common guillemots and razorbills, and the interaction with fishing gear for northern gannets were the second main causes of admission. However, the second main cause of admission for the yellow-legged gull was orphaned, for the black-headed gull undefined trauma and for the great cormorant gunshot. In the case of the yellow-legged gull, the location of the breeding grounds and their low dispersion rate along the northern Iberian coast favoured the collection of orphaned individuals (Arizaga et al., 2014, 2010). Regarding the great cormorants, the admission of individuals with gunshots may be due to the well-known existing conflict of the species with river fishermen (Carss and Marzano, 2005), as great cormorants are perceived as competitors.

Admitted cachectic individuals, mainly common guillemots, suffered extreme weakness and starvation in the winters of 2006/2007 and 2013/2014 (present study; Louzao et al., 2019), coinciding with a succession of extreme and persistent weather events in the study area (Morley et al., 2016). Extreme wind conditions, as prolonged stormy weather, can reduce the flight capacity and, consequently, increase the foraging costs for seabirds (Finney et al., 1999; Fort et al., 2009). In the case of exposure to crude oil, the highest number of admissions was reached during late winter - early spring of 2004 and 2007. Crude oil can suffocate seabirds by ingestion and cause the loss of water-proofing, thermal insulation and buoyancy by preventing them from diving or flying and eventually leading to starvation (Troisi et al., 2016). Finally, although the interaction with fishing gears (*e.g.* bycatch) is considered the most important threat to seabirds (Croxall et al., 2012), this threat represented only 5.3% of the total admissions to WRCs. This could be explained by the low probability of arrival of bycaught seabird carcasses to the coast. However, the higher bycatch incidence among those species known to interact with fisheries (*e.g.* northern gannet, yellow-legged gull and great cormorant) (ICES, 2017; Votier et al., 2013) is well reflected.

4.2. Overall threats to marine megafauna

4.2.1. Climate change

It is expected that climate change will impact directly on the populations of cetaceans and seabirds by modifying the physical and chemical characteristics of their environment and indirectly by affecting the distribution, availability and accessibility to their prey (Hemery et al., 2007; Simmonds, 2016). Among the different processes characterising climate change, ocean warming is believed to be forcing range shifts due to the changes in the location of thermal niches (Edwards and Richardson, 2004; Gregory et al., 2009), altering food web dynamics (Hays et al., 2005) and producing a northerly shift of marine megafauna species (Hemery et al., 2007; Macleod, 2009). While ocean acidification could produce trophic cascades (Lassalle et al., 2012; Sydeman et al., 2012) due to changes in primary production (Duarte et al., 2013), the sea level rise could reduce breeding grounds (Croxall et al., 2012). Extreme weather events have increased in frequency and severity (Cai et al., 2014; Ummenhofer and Meehl, 2017) causing seabird mortality events due to starvation, exhaustion and drowning (*i.e.* cachexia) (Morley et al., 2016), lower breeding success (Zuberogoitia et al., 2016) and more cetacean stranding due to the increased incidence of rough conditions (Simmonds, 2017). This is well reflected on the quantitative assessment, where cachexia was the main cause of seabirds' admissions to WRCs, specially for the common guillemot and the razorbill.

4.2.2. Pollution

There are still high concentrations of organic pollutants in the marine environment that can affect cetacean and seabird reproduction, immunosuppression and increase susceptibility to disease (*i.e.* polychlorinated biphenyl, PCBs) (Jepson et al., 2016; Romero-Romero et al., 2017). Increasing levels of chemical pollutants such as nitrogen or phosphorus derived from plant fertilizers can cause harmful and increasingly frequent phytoplankton blooms and eutrophication (Anderson et al., 2012; McCauley et al., 2015). Marine litter has become a concern with increased evidence of the impact of plastics, microplastics and abandoned fishing gears on marine ecosystems (Gall and Thompson, 2015; OSPAR, 2000). Few studies have examined to what extent seabirds and cetaceans are affected by plastic and microplastics in the BoB. Hernandez-Gonzalez et al. (2017) found microplastics in 100% of the stomachs of common dolphin analysed, while Franco et al. (2019) found microplastics in 12%, 18%, 27% and 33% of the stomachs of common guillemots, northern gannets, Atlantic puffins and black-headed gulls, respectively. Discarded nets and lines (ghost fishing), which can continue to fish, it is becoming a growing problem as new gear materials (particularly synthetic fibers) do not decay and continue to catch non-target species (Macfadyen et al., 2009). Cetaceans are more affected(Stelfox et al., 2016), but seabirds are also impacted when scavenging in the lost gears (Žydelis et al., 2013), as is the case of the northern gannets, for which Rodríguez et al. (2013) reported a 0.36% entanglement incidence over the Cantabrian and Galician coasts. Noise pollution is produced by vessel traffic, sonars and seismic exploitation among others (Evans, 2006) mainly affecting cetaceans by altering their acoustic communication, distributions patterns, provoking stress responses and impacting foraging behaviours by masking the sound produced by prey movement (Blair et al., 2016; Gomez et al., 2016). Light pollution, mostly affecting seabird species, can originate from both terrestrial (*e.g.* coastal anthropogenic transformation) or marine (*e.g.* vessels and offshore oil and gas platforms) sources, inducing attraction and disorientation (Rodríguez et al., 2019, 2017, 2015b) provoking strikes (Merkel and Johansen, 2011; Rodríguez et al., 2015a). Cory's and Balearic shearwaters, Atlantic puffin and storm-petrels have been reported as the main affected species (Fontaine et al., 2011; Rodríguez et al., 2017, 2015a; Rodríguez and Rodríguez, 2009; Wilhelm et al., 2013).

Finally, the BoB is an area at high-risk of oil spills, in fact, more than 70% of the total oil consumed in the EU is transported through the English Channel (Lavín et al., 2006) with two big oil spills taking place in the BoB in recent years, the “Erika” in 1999, and the “Prestige” in 2002 (Lorance et al., 2009). Seabird populations are particularly vulnerable to oil spill events due to their distribution and foraging behaviour, as is the case of auks, which perform migrations during winter into areas where they are highly vulnerable to these events (Le Rest et al., 2016), such as the BoB. As the results of the quantitative assessment showed, the exposure to crude oil represents an importante threat to the seabirds inhabiting the BoB.

4.2.3. Fishing

Overfishing, the main cause of declining fish stocks, reduces the resources available for higher-trophic level species (Blyth et al., 2004) and has been linked to declines in predator populations (Lassalle et al., 2012; McCauley et al., 2015). Bycatch can also directly affect seabird and cetacean species causing mortality (Peltier et al., 2016). Gillnets and trawls are the gears where most cetacean bycatch is reported to take place, whilst long-lines represent a bigger threat for seabirds (Bellido et al., 2011). In the BoB, the common dolphin is the most reported bycatch cetacean species (Peltier et al., 2014; Spitz et al., 2013) although many of the other commonly present species are also affected (Goetz et al., 2015). In the case of seabirds, there is no robust data to assess bycatch levels in the area due to low observation effort (ICES, 2017).

4.2.4. Habitat-related changes

There are many habitat-related changes taking place in the marine environment, such as habitat loss or degradation (Airoldi et al., 2008). Structurally complex habitats are becoming rarer across temperate marine environments such as the BoB (Lotze et al., 2006) due to habitat degradation (*e.g.* developing of the coastline, dredging, vessel traffic, seismic surveys or military sonar; Butterworth, 2017) which leads to a biodiversity loss by deacreasing abundances and species richness (Airoldi et al., 2008). Likewise, although there are still unknown consequences of biodiversity loss (Worm et al., 2006), it may lead to a decrease in the foraging success of seabirds and cetaceans by modifying their intra and interspecific interactions difficulting their foraging success (*e.g.* cetaceans are important for foraging seabirds since they use the presence of hunting individuals to detect prey patches; Henkel, 2009; Veit and Harrison, 2017).

Habitat-related changes may also be associated with the rapid growth of the world population. In many areas, as well as in the BoB, overpopulation has resulted in the development and urbanization of beaches and shores for recreational uses. This has produced an impact upon several cetacean species such as bottlenose and common dolphins and harbour porpoises (Gibson, 2005) as well as coastal seabird species such as yellow-legged and Mediterranean gulls, great cormorant or European shag (Croxall et al., 2012).

4.2.5. Others

Other threats posing a risk to marine megafauna in the BoB are related with the rising demand for tourist activities at sea (*e.g.* whale- and bird-watching) that can disturb and change the behaviour of cetacean and seabird species with associated temporal or permanent habitat exclusion (Avila et al., 2018). Furthermore, the requirements caused by the growing human population have increased shipping, boosting the likelihood of collisions (particularly affecting baleen whales and large odontocetes such as sperm and fin whales; ICES, 2015). Shipping is also the cause of a growing threat, the introduction of non-native species through their transport in the ballast waters which can in turn transmit new pathogens to the indigenous species of the BoB (Butrón et al., 2011).

5. Conclusions

The marine megafauna of the BoB faces several threats with species scoring differently under different threats depending on their biology and habitat use. The information collected and summarised in the present work can help identify conservation priorities (combination of threats and species requiring the most urgent management measures), work needed in the context of MSFD and other relevant legislation. Our complementary assessment is of special relevance for threatened species inhabiting the BoB for which there are many conservation actions underway or proposed, both in Europe and in the BoB, such as the identification of Important Bird Areas (IBAs; BirdLife International) and Special Protection Areas (SPAs; EU Natura, 2000 network), particularly in offshore regions. However, additional management measures are needed and these should include a decrease in the use of artificial lighting, the management of coastal and inland development surrounding important seabird breeding areas, development of rapid and trans-boundary response plans to oil spills, establishment of observer programmes on gillnet fisheries and improvement of the current observer programs in other fisheries to assess bycatch, assessment of resources overexploitation and establishment of long-term research programs to assess population trends regarding climate change and severe weather events (ICES, 2016; IUCN, 2018; Rodríguez et al., 2019). The creation of a coordinated networks between the administration and WRCs to forecast the massive arrival of individuals to the coasts should also be considered.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.csr.2019.07.009.

References

Airoldi, L., Balata, D., Beck, M.W., 2008. The Gray Zone: relationships between habitat loss and marine diversity and their applications in conservation. J. Exp. Mar. Biol. Ecol. 366, 8–15. https://doi.org/10.1016/j.jembe.2008.07.034.

Anderson, D.M., Cembella, A.D., Hallegraeff, G.M., 2012. Progress in understanding harmful algal blooms: paradigm shifts and new technologies for research, monitoring, and management. Ann. Rev. Mar. Sci. 4, 143–176. https://doi.org/10.1146/annurev-marine-120308-081121.

Arizaga, J., Aldalur, A., Herrero, A., Cuadrado, J.F., Díez, E., Crespo, A., 2014. Foraging distances of a resident yellow-legged gull (*Larus michahellis*) population in relation to refuse management on a local scale. Eur. J. Wildl. Res. 60, 171–175. https://doi.org/10.1007/s10344-013-0761-4.

Arizaga, J., Herrero, A., Galarza, A., Hidalgo, J., Aldalur, A., Cuadrado, J.F., Ocio, G., 2010. First-year movements of yellow-legged gull (*Larus michahellis Lusitanius*) from the southeastern Bay of Biscay. Waterbirds 33, 444–450. https://doi.org/10.1675/063.033.0403.

Avila, I.C., Kaschner, K., Dormann, C.F., 2018. Current global risks to marine mammals: taking stock of the threats. Biol. Conserv. 221, 44–58. https://doi.org/10.1016/j.biocon.2018.02.021.

Baum, J.K., Worm, B., 2009. Cascading top-down effects of changing oceanic predator abundances. J. Anim. Ecol. https://doi.org/10.1111/j.1365-2656.2009.01531.x.

Bellido, J.M., Santos, M.B., Pennino, M.G., Valeiras, X., Pierce, G.J., 2011. Fishery discards and bycatch: solutions for an ecosystem approach to fisheries management? Hydrobiologia. https://doi.org/10.1007/s10750-011-0721-5.

Blair, H.B., Merchant, N.D., Friedlaender, A.S., Wiley, D.N., Parks, S.E., 2016. Evidence for ship noise impacts on humpback whale foraging behaviour. Biol. Lett. 12, 20160005. https://doi.org/10.1098/rsbl.2016.0005.

Blanco, J.C., González, J.L., 1992. Libro Rojo de los Vertebrados de España. Madrid, Spain.

Blyth, R.E., Kaiser, M.J., Edwards-Jones, G., Hart, P.J.B., 2004. Implications of a zoned fishery management system for marine benthic communities. J. Appl. Ecol. 41, 951–961. https://doi.org/10.1111/j.0021-8901.2004.00945.x.

Butterworth, A., 2017. Marine mammal welfare: behaviour judge ambiguous cues more optimistically. In: Human Induced Change in the Marine Environment. Springer Nature, Cham, Switzerland. https://doi.org/10.1007/978-3-319-46994-2.

Butrón, A., Orive, E., Madariaga, I., 2011. Potential risk of harmful algae transport by ballast waters: The case of Bilbao Harbour. Mar. Pollut. Bull. 62, 747–757. https://doi.org/10.1016/j.marpolbul.2011.01.008.

Cai, W., Borlace, S., Lengaigne, M., Van Rensch, P., Collins, M., Vecchi, G., Timmermann, A., Santoso, A., Mcphaden, M.J., Wu, L., England, M.H., Wang, G., Guilyardi, E., Jin, F.F., 2014. Increasing frequency of extreme El Niño events due to greenhouse warming. Nat. Clim. Chang. 4, 111–116. https://doi.org/10.1038/nclimate2100.

Carss, D.N., Marzano, M., 2005. Reducing the conflict between cormorantsand fisheries

on a pan-european scale: REDCAFE - summary and national overviews. In: NERC/ Centre for Ecology & Hydrology. CEH Projec.
Cochrane, S.K.J., Connor, W., Nilsson, P., Mitchell, I., Reker, J., Franco, J., Valavanis, V., Moncheva, S., Ekebom, J., Nygaard, K., Serrão Santos, R., Naberhaus, I., Packeiser, T., Bund, W. van de, Cardoso, A.C., 2010. Marine Strategy Framework Guidance on the Interpretation and Application of Descriptor 1: Biological Diversity. Luxembourg.
Croxall, J., Butchart, S., Lascelles, B., Stattersfield, A., Sullivan, B., Symes, A., Taylor, P., 2012. Seabird conservation status, threats and priority actions: a global assessment. Bird. Conserv. Int. 22, 1–34. https://doi.org/10.1017/S0959270912000020.
Descamps, S., Tarroux, A., Varpe, Ø., Yoccoz, N.G., Tveraa, T., Lorentsen, S.H., 2015. Demographic effects of extreme weather events: snow storms, breeding success, and population growth rate in a long-lived Antarctic seabird. Ecol. Evol. 5, 314–325. https://doi.org/10.1002/ece3.1357.
Duarte, C.M., Hendriks, I.E., Moore, T.S., Olsen, Y.S., Steckbauer, A., Ramajo, L., Carstensen, J., Trotter, J.A., McCulloch, M., 2013. Is ocean acidification an open-ocean syndrome? Understanding anthropogenic impacts on seawater pH. Estuar. Coasts 36, 221–236. https://doi.org/10.1007/s12237-013-9594-3.
Dulvy, N.K., Sadovy, Y., Reynolds, J.D., 2003. Extinction vulnerability in marine populations. Fish Fish. 4, 25–64. https://doi.org/10.1046/j.1467-2979.2003.00105.x.
Edwards, M., Richardson, A.J., 2004. Impact of climate change on marine pelagic phenology and trophic mismatch. Nature 430, 881–884. https://doi.org/10.1038/nature02808.
Estes, J.A., Terborgh, J., Brashares, J.S., Power, M.E., Berger, J., Bond, W.J., Carpenter, S.R., Essington, T.E., Holt, R.D., Jackson, J.B.C., Marquis, R.J., Oksanen, L., Oksanen, T., Paine, R.T., Pikitch, E.K., Ripple, W.J., Sandin, S.A., Scheffer, M., Schoener, T.W., Shurin, J.B., Sinclair, A.R.E., Soulé, M.E., Virtanen, R., Wardle, D.A., 2011. Trophic downgrading of planet earth. Science 333, 301–306. https://doi.org/10.1126/science.1205106.
Evans, P.G.H., 2006. Conservation of cetaceans. In: Sixth European Seminar on Marine Mammals: Biology and Conservation, Valencia (Spain).
Finney, S., Wanless, S., Harris, M.P., 1999. The effect of weather conditions on the feeding behaviour of a diving bird, the common guillemot *Uria aalge*. J. Avian Biol. 30, 23–30. https://doi.org/10.2307/3677239.
Fontaine, R., Gimenez, O., Bried, J., 2011. The impact of introduced predators, light-induced mortality of fledglings and poaching on the dynamics of the Cory's shearwater (*Calonectris diomedea*) population from the Azores, northeastern subtropical Atlantic. Biol. Conserv. 144, 1998–2011. https://doi.org/10.1016/j.biocon.2011.04.022.
Fort, J., Porter, W.P., Gremillet, D., 2009. Thermodynamic modelling predicts energetic bottleneck for seabirds wintering in the northwest Atlantic. J. Exp. Biol. 212, 2483–2490. https://doi.org/10.1242/jeb.032300.
Franco, J., Fort, J., García-Barón, I., Loubat, P., Louzao, M., del Puerto, O., Zorita, I., 2019. Incidence of plastic ingestion in seabirds from the Bay of Biscay (southwestern Europe). Mar. Pollut. Bull. 146, 387–392. https://doi.org/10.1016/j.marpolbul.2019.06.077.
Gall, S.C., Thompson, R.C., 2015. The impact of debris on marine life. Mar. Pollut. Bull. 92, 170–179. https://doi.org/10.1016/j.marpolbul.2014.12.041.
Gibson, L., 2005. A critical evaluation of the Bay of Biscay as a candidate for a Marine Protected Area. MSc thesis. University of Wales, Bangor.
Goetz, S., Read, F.L., Ferreira, M., Portela, J.M., Santos, M.B., Vingada, J., Siebert, U., Marçalo, A., Santos, J., Araújo, H., Monteiro, S., Caldas, M., Riera, M., Pierce, G.J., 2015. Cetacean occurrence, habitat preferences and potential for cetacean-fishery interactions in Iberian Atlantic waters: results from cooperative research involving local stakeholders. Aquat. Conserv. Mar. Freshw. Ecosyst. 25, 138–154. https://doi.org/10.1002/aqc.2481.
Gomez, C., Lawson, J.W., Wright, A.J., Buren, A.D., Tollit, D., Lesage, V., 2016. A systematic review on the behavioural responses of wild marine mammals to noise: the disparity between science and policy. Can. J. Zool. 94, 801–819. https://doi.org/10.1139/cjz-2016-0098.
Gregory, B., Christophe, L., Martin, E., 2009. Rapid biogeographical plankton shifts in the north atlantic ocean. Glob. Chang. Biol. 15, 1790–1803. https://doi.org/10.1111/j.1365-2486.2009.01848.x.
Halpern, B.S., Frazier, M., Potapenko, J., Casey, K.S., Koenig, K., Longo, C., Lowndes, J.S., Rockwood, R.C., Selig, E.R., Selkoe, K.A., Walbridge, S., 2015. Spatial and temporal changes in cumulative human impacts on the world's ocean. Nat. Commun. 6, 7615. https://doi.org/10.1038/ncomms8615.
Halpern, B.S., Selkoe, K.A., Micheli, F., Kappel, C.V., 2007. Evaluating and ranking the vulnerability of global marine ecosystems to anthropogenic threats. Conserv. Biol. 21, 1301–1315. https://doi.org/10.1111/j.1523-1739.2007.00752.x.
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, 948–952. https://doi.org/10.1126/science.1149345.
Haman, K.H., Norton, T.M., Ronconi, R.A., Nemeth, N.M., Thomas, A.C., Courchesne, S.J., Segars, A., Keel, M.K., 2013. Great shearwater (*Puffinus gravis*) mortality events along the eastern coast of the United States. J. Wildl. Dis. 49, 235–245. https://doi.org/10.7589/2012-04-119.
Harley, C.D.G., Randall Hughes, A., Hultgren, K.M., Miner, B.G., Sorte, C.J.B., Thornber, C.S., Rodriguez, L.F., Tomanek, L., Williams, S.L., 2006. The impacts of climate change in coastal marine systems: climate change in coastal marine systems. Ecol. Lett. 9, 228–241. https://doi.org/10.1111/j.1461-0248.2005.00871.x.
Hays, G.C., Richardson, A.J., Robinson, C., 2005. Climate change and marine plankton. Trends Ecol. Evol. 20, 337–344. https://doi.org/10.1016/j.tree.2005.03.004.
Hemery, G., D'Amico, F., Castege, I., Dupont, B., D'Elbee, J., Lalanne, Y., Mouches, C., 2007. Detecting the impact of oceano-climatic changes on marine ecosystems using a multivariate index: the case of the Bay of Biscay (North Atlantic - European Ocean). Glob. Chang. Biol. 14, 1–12. https://doi.org/10.1111/j.1365-2486.2007.01471.x.
Henkel, L.A., 2009. Co-occurrence and aggregation of marine birds and mammals in Monterey Bay, California, USA. Mar. Ecol. Prog. Ser. 387, 295–303. https://doi.org/10.3354/meps08082.
Hernandez-Gonzalez, A., Saavedra, C., Gago, J., Covelo, P., Santos, M.B., Hernandez-Gonzalez, A., Saavedra, C., Gago, J., Covelo, P., Santos, M.B., 2017. Analysis and quantification of microplastics in the stomachs of common dolphin (*Delphinus delphis*) stranded on the Galician coasts (NW Spain). In: Baztan, J., Jorgensen, B., Pahl, S., Thompson, R.C., Vanderlinden, J.P. (Eds.), Fate and Impact of Microplastics in Marine Ecosystems. Elsevier, pp. 123–124. https://doi.org/10.1016/B978-0-12-812271-6.00121-6.
ICES, 2017. Report of the working group on bycatch of protected species (WGBYC), ICES CM 2017. Woods hole. Massachusetts, USA. https://ICES_CM2011/ACOM:16.
ICES, 2016. Working Group on Bycatch of Protected Species (WGBYC), Ices Cm 2016/ Acom:27. ICES HQ, Copenhagen, Denmark. https://ICES_CM_2012/ACOM:28.
ICES, 2015. Report of the Working Group on Marine Mammal Ecology. WGMME), London, UK.
IPBES, 2019. Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science- Policy Platform on Biodiversity and Ecosystem Services. IPBES Secretariat, Bonn, Germany.
IUCN, 2018. The IUCN Red List of Threatened Species. Version 2018-2. Downloaded on 14 December 2018. http://www.iucnredlist.org.
Jepson, P.D., Deaville, R., Barber, J.L., Aguilar, À., 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, Á., Martin, V., Maxwell, D.L., Papachlimitzou, A., Penrose, R., Perkins, M.W., Smith, B., De Stephanis, R., Tregenza, N., Verborgh, P., Fernandez, A., Law, R.J., 2016. PCB pollution continues to impact populations of orcas and other dolphins in European waters. Sci. Rep. 6. https://doi.org/10.1038/srep18573.
Lassalle, G., Gascuel, D., Le Loch, F., Lobry, J., Pierce, G.J., Ridoux, V., Santos, M.B., Spitz, J., Niquil, N., 2012. An ecosystem approach for the assessment of fisheries impacts on marine top predators: the Bay of Biscay case study. ICES J. Mar. Sci. 69, 925–938. https://doi.org/10.1093/icesjms/fss049.
Lavín, A., Valdés, L., Sánchez, F., Abaunza, P., Forest, A., Boucher, J., Lazure, P., Jegou, A.-M., 2006. The Bay of Biscay: the encountering of the ocean and the shelf. In: The Sea Volume 14B: the Global Coastal Ocean. Interdisciplinary Regional Studies and Syntheses. Harvard University Press, pp. 933–1001.
Le Rest, K., Certain, G., Debétencourt, B., Bretagnolle, V., 2016. Spatio-temporal modelling of auk abundance after the Erika oil spill and implications for conservation. J. Appl. Ecol. 53, 1862–1870. https://doi.org/10.1111/1365-2664.12686.
Lorance, P., Bertrand, J. a., Brind'Amour, A., Rochet, M.-J., Trenkel, V.M., 2009. Assessment of impacts from human activities on ecosystem components in the Bay of Biscay in the early 1990s. Aquat. Living Resour. 22, 409–431. https://doi.org/10.1051/alr/2009049.
Lotze, H.K., Lenihan, H.S., Bourque, B.J., Bradbury, R.H., Cooke, G., Kay, M.C., Kidwell, S.M., Kirby, M.X., Peterson, C.H., Jackson, J.B.C., 2006. Depletion, degredation, and recovery potential of estuaries and coastal seas. Science 312, 1806–1809. https://doi.org/10.1126/science.1128035.
Louzao, M., Gallagher, R., García-Barón, I., Chust, G., Intxausti, I., Albisu, J., Brereton, T., Fontán, A., 2019. Threshold responses in bird mortality driven by extreme wind events. Ecol. Indicat. 99, 183–192. https://doi.org/10.1016/j.ecolind.2018.12.030.
Macleod, C.D., 2009. Global climate change, range changes and potential implications for the conservation of marine cetaceans: a review and synthesis. Endanger. Species Res. 7, 125–136. https://doi.org/10.3354/esr00197.
Madroño, A., González, C., Atienza, J.C., 2004. Libro Rojo de las Aves de España. Dirección General para la Biodiversidad-SEO/BirdLife, Madrid, Spain.
MAGRAMA, 2012a. Estrategias Marinas. Mamíferos Marinos, Evaluación Inicial Y Buen Estado Ambiental. pp. 445.
MAGRAMA, 2012b. Estrategias Marinas. Grupo Aves. Evaluación Inicial Y Buen Estado Ambiental. Ministerio de Agricultura, Alimentación y Medio Ambiente, pp. 296.
Maxwell, S.M., Hazen, E.L., Bograd, S.J., Halpern, B.S., Breed, G.A., Nickel, B., Teutschel, N.M., Crowder, L.B., Benson, S., Dutton, P.H., Bailey, H., Kappes, M.A., Kuhn, C.E., Weise, M.J., Mate, B., Shaffer, S.A., Hassrick, J.L., Henry, R.W., Irvine, L., McDonald, B.I., Robinson, P.W., Block, B.A., Costa, D.P., 2013. Cumulative human impacts on marine predators. Nat. Commun. 4, 1–9. https://doi.org/10.1038/ncomms3688.
Macfadyen, G., Huntington, T., Cappell, R., 2009. Abandoned, Lost or Otherwise Discarded Fishing Gear. FAO Fisheries and Aquaculture Technical Paper 523.
McCauley, D.J., Pinsky, M.L., Palumbi, S.R., Estes, J.A., Joyce, F.H., Warner, R.R., 2015. Marine defaunation: animal loss in the global ocean. Science 347 1255641–1255641. https://doi.org/10.1126/science.1255641.
Merkel, F.R., Johansen, K.L., 2011. Light-induced bird strikes on vessels in Southwest Greenland. Mar. Pollut. Bull. 62, 2330–2336. https://doi.org/10.1016/j.marpolbul.2011.08.040.
Montesdeoca, N., Calabuig, P., Corbera, J.A., Orós, J., Underhill, L., Parsons, N., 2017. A long-term retrospective study on rehabilitation of seabirds in Gran Canaria Island, Spain (2003-2013). PLoS One 12, e0177366. https://doi.org/10.1371/journal.pone.0177366.
Morley, T.I., Fayet, A.L., Jessop, H., Veron, P., Veron, M., Clark, J., Wood, M.J., 2016. The seabird wreck in the Bay of Biscay and Southwest Approaches in 2014 : a review of reported mortality. Seabird 29, 22–38.
OSPAR, 2000. Quality Status Report 2000: Region IV–Bay of Biscay and Iberian Coast. OSPAR Commission, London.
Peltier, H., Authier, M., Deaville, R., Dabin, W., Jepson, P.D., van Canneyt, O., Daniel, P., Ridoux, V., 2016. Small cetacean bycatch as estimated from stranding schemes: the common dolphin case in the northeast Atlantic. Environ. Sci. Policy 63, 7–18. https://

doi.org/10.1016/j.envsci.2016.05.004.
Peltier, H., Jepson, P.D., Dabin, W., Deaville, R., Daniel, P., Van Canneyt, O., Ridoux, V., 2014. The contribution of stranding data to monitoring and conservation strategies for cetaceans: developing spatially explicit mortality indicators for common dolphins (*Delphinus delphis*) in the eastern North-Atlantic. Ecol. Indicat. 39, 203–214. https://doi.org/10.1016/j.ecolind.2013.12.019.
Pettex, E., Laran, S., Authier, M., Blanck, A., Dorémus, G., Falchetto, H., Lambert, C., Monestiez, P., Stéfan, E., Van Canneyt, O., Ridoux, V., 2017. Using large scale surveys to investigate seasonal variations in seabird distribution and abundance. Part II: the Bay of Biscay and the English Channel. Deep Sea Res. 141, 86–101. https://doi.org/10.1016/j.dsr2.2016.11.008.
Rodríguez, A., Arcos, J.M., Bretagnolle, V., Dias, M.P., Holmes, N.D., Louzao, M., Provencher, J., Raine, A.F., Ramírez, F., Rodríguez, B., Ronconi, R.A., Taylor, R.S., Bonnaud, E., Borrelle, S.B., Cortés, V., Descamps, S., Friesen, V.L., Genovart, M., Hedd, A., Hodum, P., Humphries, G.R.W., Le Corre, M., Lebarbenchon, C., Martin, R., Melvin, E.F., Montevecchi, W.A., Pinet, P., Pollet, I.L., Ramos, R., Russell, J.C., Ryan, P.G., Sanz-Aguilar, A., Spatz, D.R., Travers, M., Votier, S.C., Wanless, R.M., Woehler, E., Chiaradia, A., 2019. Future directions in conservation research on petrels and shearwaters. Front. Mar. Sci. 6, 1–27. https://doi.org/10.3389/fmars.2019.00094.
Rodríguez, A., García, D., Rodríguez, B., Cardona, E., Parpal, L., Pons, P., 2015a. Artificial lights and seabirds: is light pollution a threat for the threatened Balearic petrels? J. Ornithol. 156, 893–902. https://doi.org/10.1007/s10336-015-1232-3.
Rodríguez, A., Holmes, N.D., Ryan, P.G., Wilson, K.J., Faulquier, L., Murillo, Y., Raine, A.F., Penniman, J.F., Neves, V., Rodríguez, B., Negro, J.J., Chiaradia, A., Dann, P., Anderson, T., Metzger, B., Shirai, M., Deppe, L., Wheeler, J., Hodum, P., Gouveia, C., Carmo, V., Carreira, G.P., Delgado-Alburqueque, L., Guerra-Correa, C., Couzi, F.X., Travers, M., Corre, M. Le, 2017. Seabird mortality induced by land-based artificial lights. Conserv. Biol. https://doi.org/10.1111/cobi.12900.
Rodríguez, A., Rodríguez, B., 2009. Attraction of petrels to artificial lights in the Canary Islands: effects of the moon phase and age class. Ibis 151, 299–310. https://doi.org/10.1111/j.1474-919X.2009.00925.x.
Rodríguez, A., Rodríguez, B., Negro, J.J., 2015b. GPS tracking for mapping seabird mortality induced by light pollution. Sci. Rep. 5, 1–11. https://doi.org/10.1038/srep10670.
Rodríguez, B., Bécares, J., Rodríguez, A., Arcos, J.M., 2013. Incidence of entanglements with marine debris by northern gannets (*Morus bassanus*) in the non-breeding grounds. Mar. Pollut. Bull. 75, 259–263. https://doi.org/10.1016/j.marpolbul.2013.07.003.
Romero-Romero, S., Herrero, L., Fernández, M., Gómara, B., Acuña, J.L., 2017. Biomagnification of persistent organic pollutants in a deep-sea, temperate food web. Sci. Total Environ. 605– 606, 589–597. https://doi.org/10.1016/j.scitotenv.2017.06.148.
Santos, M.B., Pierce, G.J., 2015. Marine mammals and good environmental status: science, policy and society; challenges and opportunities. Hydrobiologia 750, 13–41. https://doi.org/10.1007/s10750-014-2164-2.
Simmonds, M.P., 2017. Evaluating the welfare implications of climate change for cetaceans. In: Marine Mammal Welfare: Human Induced Change in the Marine Environment and its Impacts on Marine Mammal Welfare. Springer, Cham, pp. 125–135. https://doi.org/10.1007/978-3-319-46994-2_8.
Simmonds, M.P., 2016. Cetaceans and global warming. In: Laffoley, D., Baxter, J. (Eds.), Explaining Ocean Warming: Causes, Scale, Effects and Consequences. Full Report. IUCN, Gland, Switzerland, pp. 303–320.
Sleeman, J.M., Clark, E.E., 2003. Clinical Wildlife Medicine : A New Paradigm for a New Century. J 17, 33–37. https://doi.org/10.1647/1082-6742(2003)017[0033:CWMANP]2.0.CO;2.
Spitz, J., Chouvelon, T., Cardinaud, M., Kostecki, C., Lorance, P., 2013. Prey preferences of adult sea bass Dicentrarchus labrax in the northeastern Atlantic: implication for bycatch of common dolphin *Delphinus delphis*. ICES J. Mar. Sci. 70, 452–461.
Stelfox, M., Hudgins, J., Sweet, M., 2016. A review of ghost gear entanglement amongst marine mammals, reptiles and elasmobranchs. Mar. Pollut. Bull. 111, 6–17. https://doi.org/10.1016/j.marpolbul.2016.06.034.
Sydeman, W.J., Thompson, S.A., Kitaysky, A., 2012. Seabirds and climate change: roadmap for the future. Mar. Ecol. Prog. Ser. https://doi.org/10.3354/meps09806.
Troisi, G., Barton, S., Bexton, S., 2016. Impacts of oil spills on seabirds: unsustainable impacts of non-renewable energy. Int. J. Hydrogen Energy 41, 16549–16555. https://doi.org/10.1016/j.ijhydene.2016.04.011.
Ummenhofer, C.C., Meehl, G.A., 2017. Extreme weather and climate events with ecological relevance: a review. Philos. Trans. R. Soc. Biol. Sci. 1723, 20160135. https://doi.org/10.1098/rstb.2016.0135.
Vaughan, D.G., Marshall, J., Connolley, W.M., King, J.C., Mulvaney, R., 2001. Devil in the detail. Science 293, 1777–1779. https://doi.org/10.1126/science.1065116.
Veit, R.R., Harrison, N.M., 2017. Positive interactions among foraging seabirds, marine mammals and fishes and implications for their conservation. Front. Ecol. Evol. 5, 121. https://doi.org/10.3389/fevo.2017.00121.
Votier, S.C., Bicknell, A., Cox, S.L., Scales, K.L., Patrick, S.C., 2013. A bird's eye view of discard reforms: bird-borne cameras reveal seabird/fishery interactions. PLoS One 8, e57376. https://doi.org/10.1371/journal.pone.0057376.
Wilhelm, S.I., Schau, J.J., Schau, E., Dooley, S.M., Wiseman, D.L., Hogan, H.A., 2013. Atlantic puffins are attracted to coastal communities in eastern newfoundland. Northeast. ON Nat. 20, 624–630. https://doi.org/10.1656/045.020.0409.
Worm, B., Barbier, E.B., Beaumont, N., Duffy, J.E., Folke, C., Halpern, B.S., Jackson, J.B.C., Lotze, H.K., Micheli, F., Palumbi, S.R., Sala, E., Selkoe, K.A., Stachowicz, J.J., Watson, R., 2006. Impacts of biodiversity loss on ocean ecosystem services. Science 314, 787–790. https://doi.org/10.1126/science.1132294.
Zuberogoitia, I., Zabala, J., Etxezarreta, J., Crespo, A., Burgos, G., Arizaga, J., 2016. Assessing the impact of extreme adverse weather on the biological traits of a European storm petrel colony. Popul. Ecol. 58, 303–313. https://doi.org/10.1007/s10144-016-0538-1.
Žydelis, R., Small, C., French, G., 2013. The incidental catch of seabirds in gillnet fisheries: a global review. Biol. Conserv. 162, 76–88. https://doi.org/10.1016/j.biocon.2013.04.002.