



Review

Current global risks to marine mammals: Taking stock of the threats

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ABSTRACT

Marine mammals are impacted by many anthropogenic activities and mitigating these impacts requires knowledge about the geographic occurrence of threats. Here, we systematically reviewed, categorized and geo-referenced information from > 1780 publications about threats affecting 121 marine mammal species worldwide between 1991 and 2016. We created risk maps by assigning threat to countries where they had been reported, further refining spatial allocation to specific ocean basins and Longhurst biogeographical provinces and subsequent intersection with mapped species' distributions. We superimposed risk maps for different taxa and threats to visualize geographic patterns of risks and quantify risk severity with respect to number of species affected. Almost all marine mammal species have been reported to face at least one threat. Incidental catch affected the most species (112 species), followed by pollution (99 species), direct harvesting (89 species) and traffic-related impacts (86 species). Direct human activities, mainly fisheries, urban development, whaling/hunting and tourism were the major source of threats affecting most species (> 60 species). Risk areas were identified for 51% of marine mammal core habitat. Besides, the majority of local marine mammal communities are at high-risk in 47% of world coastal-waters. Hotspots were located mainly in temperate and polar coastal waters and in enclosed seas such as the Mediterranean or Baltic Sea. However, risk areas differed by threat types and taxa. Our maps show that human activities in coastal waters worldwide impose previously unrecognized levels of cumulative risk for most of marine mammal species, and provide a spatially explicit frame of reference for the assessment of mammals' species conservation status.

1. Introduction

For decades, it has been well known that many marine species are threatened directly or indirectly by human caused deterioration of their environment (International Union for Conservation of Nature and Natural Resources – IUCN, 2016). Marine mammals, a variable group encompassing 121 recognized mammal species, including cetaceans, pinnipeds, sea otters and sirenians (Committee on Taxonomy, 2016), are distributed throughout all the world's oceans (Berta and Sumich, 1999). Regardless of their size and status as “charismatic megafauna”, our current knowledge about species distributions and conservation status is still patchy, with 45 species (37% of species) being classified as “data deficient” by the International Union for the Conservation of Nature (International Union for Conservation of Nature and Natural Resources – IUCN, 2016). Moreover, because of their diversity and cosmopolitan presence in marine ecosystems, many marine mammal species are known to be impacted by various anthropogenic activities, including fisheries, hunting, transportation, oil and gas extraction (Whitehead et al., 2000; Gales et al., 2003; Reeves et al., 2003; Helm

et al., 2014). As a result, almost 33 species (i.e. half of all marine mammal species not classified as data deficient) are currently classified as globally endangered or threatened (International Union for Conservation of Nature and Natural Resources – IUCN, 2016).

Threat is a stressor, action or event that causes harmful effects, while risk is the possibility of experiencing harmful effects due to exposure to a threat factor (EPA, 1998). Threats impact the conservation status of taxa, putting species or populations at some level of risk of potential long-term or short-term extinction (Salafsky et al., 2008; International Union for Conservation of Nature and Natural Resources – IUCN, 2016). Threats can act at the level of individuals, or at population level. At either level, threats over marine mammals can have direct (mortalities and injuries) or indirect effects (physiological or behavioural changes resulting in reduced fitness or productivity). Generally, population-level effects – as well as synergistic effects of multiple stressors – are more difficult to quantify and measure (McHuron et al., 2017), however, even the magnitude of threats at the level of individuals can be difficult to assess for marine mammals. Threats acting at the level of individuals include, for instance, direct harvest (Clapham

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and Baker, 2009; Robards and Reeves, 2011), incidental entanglement in fishing gear (Read et al., 2006) and in marine debris (Baulch and Perry, 2014), as well as vessel collisions (Van Waerebeek et al., 2007) and infections (Van Bresseem et al., 2015). Whale watching is another important type of threat acting at both levels which has been shown to cause disturbance resulting in changes in behaviour, potentially linked to temporary, or permanent habitat exclusion (Avila et al., 2015). Acoustic pollution of the marine environment can affect marine mammals by masking echolocation signals and social vocalizations, or by causing damage of the hearing system (Weilgart, 2007; Gómez et al., 2016). Especially in coastal areas, species are also threatened by habitat loss – including the depletion of foraging grounds due industrial development and destructive fishing techniques (Marsh et al., 2002; Reeves et al., 2003). Pollutants, through bioaccumulation, can disrupt normal endocrine physiology in animals and contribute to the increase of infectious disease outbreaks (Desforgues et al., 2016) and oceanographic changes in marine environments related to climate change may either directly or indirectly impact many species through effects on prey or habitat availability (Simmonds and Isaac, 2007; Kaschner et al., 2011).

To mitigate negative impacts on species, identification of areas for marine mammal conservation is needed (Corrigan et al., 2014). Visualizations of geographic patterns of known or potential impacts on ecosystems and species in the form of maps, so-called “risk maps”, allow the identification of risk hotspots and are often used for prioritization of conservation measures or actions (e.g. Halpern et al., 2008, 2015; Schipper et al., 2008; Trebilco et al., 2011; Coll et al., 2012). To date, some efforts have been made to assess threats for all or some marine mammals at global scales. These efforts have either assessed worldwide anthropogenic impacts focusing on specific taxa, such as pinnipeds and mysticetes (Kovacs et al., 2012; Thomas et al., 2015) or only migratory species (Lascelles et al., 2014) and do not provide spatial detail. Similarly, Schipper et al. (2008), Pompa et al. (2011), Davidson et al. (2012), González-Suárez et al. (2013) and Albouy et al. (2017) have included all marine mammals in their analyses, but in a generic way and therefore do not allow the analysis of threats specific to species, to location or to time of year. Although some studies have attempted to summarize and visualize threat levels of a specific type of threat in geographic space (e.g. by-catch: Lewison et al., 2014), an overview of our current knowledge about the presence and location of different threats that different marine mammal species are exposed to worldwide is currently lacking. Hence, to establish appropriate conservation actions and mitigate any impacts for marine mammals, one first needs to know where threats have been documented and which species are known to be affected.

Here, we constructed a geo-spatial database of published information of threats affecting 121 marine mammal species, from which we subsequently produced a series of risk maps visualizing global patterns. Risk maps as GIS files and the database used for their construction are made freely available for non-commercial use to support global and local research and conservation actions. Our threat classification expands upon the existing IUCN Threats Classification (Salafsky et al., 2008; International Union for Conservation of Nature and Natural Resources – IUCN, 2016) by including new terms that are specific to marine mammals. Threat allocation in space was based on intersections of several geo-spatial layers including political, oceanographic and species-specific information. Superimposing the resulting risk maps for specific threat types across species groups and vice versa provides a quantitative visualization of our current knowledge about different threats affecting marine mammals, and offers a frame-of-reference for the assessment of conservation status of marine mammal species and a starting point for the quantification of the cumulative effects of human activities on marine mammal populations and habitats.

2. Methods

2.1. Database of marine mammal threats

We defined a threat to a marine mammal as an event that induces, to the individual, disturbance, behavioural and distribution changes, disease, health problems, physical restraint, injury or death; or, at the population level, decrease breeding success, gene flow or population size. To document which threats affect which marine mammal species where and when, we compiled a database from the scientific literature. This involved three steps: 1) the definition of threat types, 2) the compilation of information about species-specific threats documented in the scientific literature, and 3) the standardized spatial allocation of threats using available geo-political, oceanographic and ecological map layers.

2.2. Threat classification scheme

To define threat types, we modified and expanded the existing Threats Classification Scheme of the International Union for the Conservation of Nature (International Union for Conservation of Nature and Natural Resources – IUCN, 2016), including new terms that are relevant for marine mammals. Our approach classifies different types of threat by identifying the threat category (proximate origin, which is the agent inflicting the actual harm itself) and the threat source (defined as the ultimate origin of the threat). An attribute was added to allow for further distinction within the fairly generic threat categories used originally by the IUCN (e.g. within “traffic”: boat noise vs collision with boats). Within this classification scheme the same threat category can therefore be linked to different ultimate threat sources (e.g. noise pollution due to military activities or from energy production). Similarly, threat attributes can be associated with more than one threat category (e.g. incidental catch in ghost nets, which is both incidental catch and pollution; some liquid waste, such as ballast water, is part of pollution and traffic; noise produced from boat engines is part of pollution and traffic).

We identified seven threat categories, 28 threat attributes and 13 threat sources affecting currently the marine mammals (Fig. 1). The seven threat categories were based on the agent inflicting the actual harm and were: incidental catch, direct harvesting, pollution, traffic, pathogens, resource depletion and ocean-physics alteration. Each of the threat categories was subdivided into a threat attribute with additional information such as type of pollution or reason for harvesting and others. We distinguished two general types of threat sources, those related to direct human activities and those that are not. Threat sources, following the IUCN threat classification scheme were: aquaculture and agriculture; fisheries, hunting and whaling; energy production from oil, gas and mining; energy production from nuclear power; energy production from renewable resources; residential and industrial development; tourism and recreation; scientific research; military activities; climate change and geological events; and unknown or unreported (see Appendix A for definitions). Only climate change and geological events were defined as threat sources not directly related to human activities. Finally, the detailed combinations of threat category, threat attribute and threat source create 110 threat sorts (e.g. pollution-liquid wastes-URBA or pollution-liquid wastes-MILI; see threat database in Appendix B for details). This newly developed classification scheme allows for a maximum in flexibility and accuracy when encoding information from the literature, while at the same time ensuring that encoded data can be mapped back easily to the IUCN Threat Classification Scheme.

2.3. Literature sources, search criteria and data encoded

To compile documented threats to marine mammals we used sources provided in the IUCN Red List (International Union for Conservation of Nature and Natural Resources – IUCN, 2016) and the

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