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# Evaluation of data availability for the application of Key Biodiversity Area criteria for marine mammals

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## Abstract

The CBD set an ambitious target to protect at least 17% of terrestrial and inland water, and 10% of coastal and marine areas worldwide until 2020 and suggests that sites, identified as important biodiversity areas, should be prioritized. There is increasing demand from governments, NGOs and other stakeholders for a global, transparent and objective identification system, to allocate limited resources for the protection of biodiversity most efficiently. Since 2004 the IUCN has been working on a Key Biodiversity Area (KBA) standard, including a global consultation process. KBAs are meant to be applicable for all taxa and all ecosystems globally. I reviewed KBA criteria and examined data availability for marine mammals. 22.1% of all marine mammal species assessed by the IUCN are listed as threatened (Vulnerable, Endangered or Critically Endangered). Application of KBA criteria might be hindered by a lack of reliable data. 38.5% of all marine mammal species are listed as “data deficient”. In addition to this data paucity, marine mammals in comparison to terrestrial mammals, have very large ranges from 78,400 $km^2$ (*Phocoena sinus*) to 353,920,694 $km^2$ (*Balaenoptera acutorostrata*) and little site fidelity. Global abundance estimates vary between 97 (*Phocoena sinus*) and 12.5 million (*Lobodon carcinophaga*) with only 39% of all estimates being reliable. Species richness computations showed a concentration of species in the southern mid-latitudes, but populations densities are globally low and may make potential KBA sites unfeasible large. Overall data availability is very heterogeneous and the application of KBA criteria for marine mammals might be very different for many species, while for others it might work well.

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# 1. Introduction

## 1.1 Background

Industrialization and rapid population growth have been dramatically increasing the pressure on our environment during the last decades through unsustainable use of resources, rising emissions and pollution. Technological progress has intensified the use of the oceans and hardly are there any areas and ecosystems not affected by human use any longer. Over the last 50 years anthropogenic impact on ecosystems has been larger than ever before and species extinction rates have multiplied by 1000 against the background rates typical of Earth’s past (Pimm et al. 1995). One of the major problems arising from this, is a global biodiversity loss. Marine and terrestrial species suffered an average decline of about 30% in abundance between 1970 and 2000. Inland water species even declined by 50% (Secretariat of the Convention on Biological Diversity 2006). An intact biodiversity is an enjoyable condition for nature lovers and every species, be it a plant or an animal, has an intrinsic value. But biodiversity is also crucial for humanity. Stable ecosystems provide many essential goods like food and medicine, and diversity is known to increase the resilience of ecosystems. We do not yet fully understand (and maybe never will) all complex interdependencies in nature, possible chain reactions disrupting ecosystem functions cannot be ruled out. Roman et al. (2014) describe whales in a recent publication as “marine ecosystem engineers” that enhance primary productivity in feeding areas by recycling nutrients through a process called “whale pump” (i.e. feeding in depth and releasing faecal plumes near the surface). In the 20$^{th}$ century nearly 2.9 million large whales were killed by industrialized whaling. Fin whales (*Balaenoptera physalus*) and sperm whales (*Balaenoptera physalus*) alone account for 56.5% of all recorded killings. (Rocha 2015). A decline of possibly up to 90% in great whale numbers had likely altered the structure and function of the oceans (Roman et al. 2014). Conservation efforts are desperately needed worldwide, but where and how is arguable. Site and habitat conservation, rather than protection of single target species, are among the most effective strategies to protect biodiversity (Eken et al. 2004). But to reduce biodiversity loss globally in an efficient way, each nation’s limited resources must be concentrated on sites that contribute to the persistence of biodiversity most significantly. This is also recognized in the global policy process. It slowly started in 1992, when the Rio “Earth Summit”, a milestone in international environmental politics, was conducted. It was the first global environment conference after 20 years, and the second ever conducted, with 172 governments and 2400 NGO representatives attending (UN 1997). One of the results was the creation of the Convention on Biological Diversity (CBD) as a legally binding global treaty with the objective to conserve biodiversity (among others) (Secretariat of the Convention on Biological Diversity 2006). At their 6th conference in 2002 the CBD set the “2010 Biodiversity target” with the aim to “achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the greater benefit of all life on Earth” (Secretariat of the Convention on Biological Diversity 2006). This target was not satisfactorily met and thus at the CBDs 10th meeting in 2010 in Aichi, Japan, the “Strategic Plan for Biodiversity 2011-2020” including the ambitious “Aichi Biodiversity Targets” was set. In target 11 the CBD declares its aim to protect at least 17% of terrestrial and inland water, and 10% of coastal and marine areas worldwide until 2020 through “effective, ecologically representative and well-connected systems of protected areas and other area-based conservation measures”. Sites identified as important biodiversity areas are to be prioritized in particular (UNEP/CBD 2013). Obviously a globally agreed standard for this identification process is a prerequisite and the International Union for Conservation of Nature (IUCN) strives to deliver just that with their Key Biodiversity Area (KBA) concept, which was instigated in and is currently in its final developmental stages (IUCN 2014). This identification process is meant to work for all taxa worldwide and feedback on the criteria and thresholds is currently requested, especially in the marine realm (Eken et al. 2004; Langhammer et al. 2007; IUCN 2014). In this thesis I will examine the ongoing global processes for the identification of sites of ecological importance in the marine realm, focussing specifically on marine mammals. I will analyse and quantify to what extent single-taxa KBA criteria, as defined in the consulting paper (IUCN 2014), might be applicable for marine mammal species, a large and diverse group of animals with distinct features and requirements. Furthermore I will evaluate if the data available for marine mammals worldwide are sufficient to apply KBA criteria and thresholds and which uncertainties and obstacles might occur in this process.

## 1.2 Distinct marine mammal attributes with respect to KBA criteria application

Marine mammals form a diverse group of ca. 124 species that are usually subdivided into four large groups: cetaceans (whales, dolphins and porpoises), pinnipeds (seals, sea lions and walruses), sirenians (manatees and dugongs) and fissipeds (polar bear and otter) (Committee on Taxonomy 2014). The exact number of species varies dependent on the source of information. Some authors consider the polar bear not to be a marine mammal, others include freshwater species like the Ganges river dolphin (*Platanista gangetica*) or still list the Baji (*Lipotes vexillifer*), which is probably extinct for some years. Except from these more or less obvious reasons for differences in literature, there is a general problem with marine mammal's taxonomy (see chapter 3.2.1).

Marine mammals have all characteristics of mammals but are adapted to life in the marine realm. Among other modifications, their forelimbs and lower extremities transformed into flippers and flukes, their respiratory system developed to allow for long and deep dives and a thick layer of blubber evolved to protect them against cold temperatures (Whalefacts 2015). The extent of their adaption varies a lot. Whereas most marine mammals rely on the ocean for their existence, some do more so than others. All cetaceans, except a few freshwater species, live in the ocean through all their life and completely depend on it, whereas pinnipeds necessarily need land for breeding.

Our knowledge about marine mammals is surprisingly scarce, concerning how large marine mammals are. Some species have never been seen alive, even though they are scientifically recognized and known from a few strandings (e.g. the spade-toothed whale (*Mesoplodon traversii*)). Obviously marine mammals are more difficult to study and investigate, as most of them live permanently in the ocean, a three-dimensional space of more than 360 million $km^2$ surface area. They also have little site fidelity and are thus difficult to monitor. They can have very large distribution ranges, like the killer whale (*Orcinus orca*) which has one of the largest ranges exceeding 350,000,000 $km^2$ (in contrast: Whole Europe has an area of 10,180,000 $km^2$). In comparison to terrestrial mammals, many marine mammals occur in low densities and conduct very large migrations, thus contributing further to limiting our knowledge. In addition, many marine mammal species occupy areas of the open seas beyond national jurisdiction, where monitoring and especially managing is difficult.

## 1.3 Current marine mammal conservation issues and potential solutions

Nowadays threats directly related to anthropogenic activities often exceed natural threat levels and can have severe effects on populations or whole species. Marine mammals face different threats than terrestrial mammals, for which habitat conversion and habitat degradation are the largest hazard (Schipper et al. 2008). Table 1 lists the major threats for marine mammals today.

Table 1. Main threats for marine mammals (Data from Schipper et al. 2008).

| Threat | Example | Marine mammal species affected worldwide | Potential solutions in vulnerable areas |
|---|---|---|---|
| Accidental mortality | bycatch, entanglement and ship strikes | 78% | Mitigation measures: Modification of fishing gear or total ban of certain fishing gear (e.g. gillnets). Encouraging alternative fishing techniques. No take zones where appropriate.<br>Speed limits |
| Pollution | Oil spills, ballast and waste water discharges, terrestrial run-off.<br>Sound pollution | 60% | Stricter laws for water discharges. Global commitment to use less plastic and prevent harmful substances from being washed in the ocean.<br>Limiting of military sonar, banning of underwater explosive testing etc. |
| Commercial hunting | | 52% | Monitoring and enforcing the whaling moratorium. |
| New threats evolving with technological progress | Deep seabed mining<br>Climate change | ? | New technology needs new regulations. Climate change needs to be tackled with long term solutions to reduce $CO_2$ emissions worldwide. |

**Accidental mortality**

Today this is the dominant threat for marine mammals. Shipping in general increased a lot over the last decades, ca. 90% of the world trade is carried via ships today (Rochette et al. 2014). This massive increase in shipping has many negative impacts on the marine environment through pollution and a direct effect on marine mammals through collisions. A notable example for how large the effects of this accidental killings can be, is the North Atlantic right whale. It suffered a severe population decline through whaling and the major cause why this endangered species is not recovering are ship strikes. They alone are responsible for 35.5% of all recorded deaths between 1970 and 1999 (Knowlton & Kraus 2001).

To quantify the number of marine mammals killed through bycatch is difficult, but it is estimated to be in the hundreds of thousand per year, mainly but not exclusively through gillnets (Read et al. 2005).

**Pollution**

There are many kinds of pollution from a variety of different sources and with different consequences for marine life. These include chemical contaminants from oil spills, ballast and waste water discharges from ships, terrestrial run-off etc., but also sound pollution.

Chemical contaminants and marine debris are a well-known problem in the oceans and affect many taxa. Huge amounts of non-degradable plastic and so called “ghost nets” directly threaten animals which swallow plastic parts or get entangled in the nets. Sound pollution is a relatively new issue but of growing concern, because scientists found evidence of change in behaviour in whales, and mass strandings in response to high-intensity anthropogenic sound from sonar and airguns (e.g. Hildebrand 2005).

**Commercial hunting**

Commercial hunting used to be the major threat for marine mammals. Technological progress massively accelerated worldwide whaling to non-sustainable dimensions. Many whale species declined dramatically and worries they might be hunted to extinction led the International Whaling Commission (IWC) to declare a commercial whaling moratorium in 1985. Due to this protection some populations recovered or are still recovering, like the blue whale (*Balaenoptera musculus*), which was reduced to a few percent of its pre-exploitation stock size in the southern hemisphere. Its abundance is still comparably low but it is increasing at decent rates (IWC 2015). Other species do not seem to recover, like the North Pacific right whale (*Eubalaena japonica*) which was massively depleted (IWC 2015b) and is listed as endangered. There is only a fraction of its pre-whaling population left today, with no indication of a population growth whatsoever. The whaling moratorium is still in place but Norway and Iceland continue commercial whaling and caught almost 12,000, mainly minke whales since the ban. Japan continues whaling under special permits and caused the death of more than 16,000, mostly minke and bryde’s whales since the ban for “scientific reasons”. Aboriginal subsistence whaling since 1985 led to killing of almost 10,000 mostly minke and gray whales (IWC 2015). In addition to these numbers illegal and unreported hunting is probably happening worldwide and not quantifiable. Even though it is targeted only at certain species, direct harvesting still remains a major threat for marine mammals (Schipper et al. 2008).

**“Modern” threats**

With technological progress there are new threats evolving. Deep seabed mining is one example of a new imminent threat, with a wide variety of consequences from direct habitat destructions at site to the spread of sediment plumes sometimes containing heavy metals and acidic wastes (Rochette et al. 2014). Another rising challenge are cetacean-based tourist activities. If not managed correctly they can have a large impact on small populations (Reeves et al. 2003). A global threat which is difficult to quantify is climate change, which is arguably affecting ice-dependent species like the polar bear and maybe lots and lots of other species through rising water temperatures.

**Conservation strategies**

Conservation actions to combat these threats can be and have to be as manifold as the threats themselves. Which conservation measure is appropriate depends on the species, the habitat, the main threats, the cultural and socioeconomic factors and others. Accidental killings by ship strikes can be reduced by introducing speed limits in important areas (especially breeding areas) and known migration corridors. Noise pollution would be reduced in this important areas by a slower pace too, as would limiting of military sonar, banning of underwater explosive testing etc. Where bycatch is a dominant threat a modification of fishing gear or the total ban of certain fishing gear (e.g. gillnets) and the encouraging of alternative fishing techniques would help to lessen the danger (Reeves et al. 2003). Pollution is probably the most difficult to manage threat, as it would need global commitments and laws to reduce environmental pollution directly at sea, but also at coasts and even inland, because rivers transport huge amounts of sewage, agricultural run-offs into the ocean (e.g. Li & Daler 2004).

Independent from what measures are taken exactly, a strategically targeted site conservation program is preferable, even if it is based or targeting on a single species (Eken et al. 2004). Furthermore will a site based conservation protect other species in that area, so that large marine mammals can be used as “umbrella species”. As most marine mammals are permanently in the water, they are also very difficult to monitor and manage for more direct approaches. The only exception are deliberate killings for consumption, which can be managed through site based approaches (i.e. no-take zones) too, but also through site-independent measures like regulations (i.e. catch limits).

To assure (marine) protected areas are most efficiently located and delineated a transparent, objective and thorough system to identify important habitats is needed.

## 1.4 Existing processes to identify "important areas"

Several different identification systems and criteria exist today. These concepts focus on single taxa (e.g. Important Bird Areas), regional threats and significance (e.g. HELCOM 2015), specific habitats (e.g. Ramsar – The Convention on Wetlands), eminent threat (e.g. Alliance for Zero Extinction) or a composition of all taxa and a wide range of criteria (e.g. Key Biodiversity Areas) (Dunn et al. 2014).

Fundamentally there are two different kinds of concepts: A threshold approach with fixed thresholds for each criterion and a non-threshold or so called "expert based" approach. The former uses definite numbers (e.g. a site must contain 95% of the total population of a critically endangered species), whereas the latter asks for experts to assess the relative importance of a site for a given species (e.g. "Area containing habitat for the survival and recovery of endangered, threatened, declining species or area with significant assemblages of such species", EBSA). The greater flexibility of an expert-based approach can be especially useful when data are just not sufficient for certain species or areas to apply thresholds but local people are knowledgeable. Where quantitative data are reliable and sufficient to apply thresholds, an identification process using definite numbers is certainly more objective and transparent and therefore repeatable and consistent through time and space and among different users (Langhammer et al. 2007). A common feature of all priority site identification systems is the fact that they do not come with any legal obligation. They are purely scientific and can (and should) give advice to decision makers of all kind and therefore contribute to the establishment and management of present and future protected areas, but they do not come with any management commitments themselves (Dunn et al. 2014). A very diverse group of institutions will be interested in this process. NGOs of any kind and size, communities, governments, scientists but also investors and companies, international conventions, legal instruments and development banks. The various kind of applications would be similar diverse. Identified important biodiversity areas will help to prioritise sites for conservation, establish investment strategies, strengthen local communities or choose places for environmental research (IUCN 2014).

### 1.4.1 Important Bird and Biodiversity Areas (IBA)

The first international successful approach for a global standard for the identification of important sites was the Important Bird Areas approach (IBA), founded in 1980 by "Birdlife International" (Former "International Committee for Bird Protection" founded as early as 1922). Today this organisation is widely accepted and an official partner of the IUCN, in charge of their Red List of birds. IBAs are considered a great success: 2.77 million members and 10.8 million supporters contributed to identify more than 12,000 sites important for the persistence of bird diversity and including terrestrial, marine and freshwater regions, in more than 200 countries. IBAs thereby form the largest existing number of systematically identified, important biodiversity sites. In the development of the Key Biodiversity Area criteria, IBA criteria were of great influence and can be considered the base of IUCN's KBA approach (IUCN 2014). In 2013 IBAs were renamed to "Important Bird and Biodiversity Areas" to account for the importance of other taxa and biodiversity as a whole (BirdLife International 2014). Nevertheless, IBAs concentrate on areas important for the persistence of bird diversity predominantly. But they can still be a reliable first step in identifying important biodiversity areas (UNEP/CBD 2013).

Until recently Birdlife International's IBA programme concentrated mainly on terrestrial sites. Although there are no nesting colonies, roosting locations etc. found in the marine environment, there might be IBAs for seabirds on sea. This is why Birdlife International is working on expanding their program to the marine realm. In terrestrial environments the identification of IBAs is almost completed but for Seabirds it is just starting. Criteria are tested to see if they are applicable for marine seabirds as well. For further details see Birdlife international 2010.

### 1.4.2 Ecologically or Biologically Significant Areas (EBSA)

Another notable important-site identification process was finalized by the parties of the CBD in 2008. They launched a process to identify Ecologically or Biologically Significant Areas on a common scientific basis, first only considering areas beyond national jurisdiction, later broadened to all marine regions (Dunn et al. 2014). Unlike IBAs they are an official designation. The identification is based on the opinion of experts concerning global criteria. The EBSA process is the only internationally agreed on process having separated site-level criteria and network-level criteria. This reflects CBDs wish to actually put the site criteria into practice and establish new marine protected areas, even though the description of EBSAs does not come with any management commitment itself. In many cases a single management approach would probably not be successful anyway, because EBSAs can be very large (Dunn et al. 2014). The CBD acknowledged the fact that understanding of the EBSA process and its global relevance is poor in many countries. Capacity building and training was therefore included in workshops and even offered in separate workshops (e.g. in Senegal in 2012, after a call from African nations for greater involvement) (Dunn et al. 2008).

How exactly EBSAs will be utilized to guide decision makers is still unclear. International agreements and the legal process are not yet fully resolved (Dunn et al. 2014). Still EBSAs can already be used to inform existing approaches and institutions. For example did EBSAs identified in the Western South Pacific regional workshop influence the Cook Island's declaration of a marine reserve (Dunn et al. 2014). A number of EBSAs are already considered by COP in the Western South Pacific region and the wider Caribbean and Western Mid-Atlantic region. (For further details see http://www.cbd.int/ebsa/ebsas).

Building on the EBSA criteria the international partnership *Global Ocean Biodiversity Initiative (GOBI)* was founded. It is a collaboration of between the German Federal Agency for Nature Conservation (BfN), IUCN, UNEP World Conservation Monitoring Centre and many more with an explicit focus on conserving biodiversity in the deep seas and open oceans (GOBI 2015).

### 1.4.3 Alliance for Zero Extinction (AZE)

The AZE identifies sites that are the last refuge for species which are classified as Endangered or Critically Endangered in IUCN's Red List of Threatened Species. It thus focusses on species facing a serious risk of extinction and in need of the most urgent protection. The site can either be the species' last remaining habitat when its habitat is being destroyed or the species can have a natural very small global range. The AZE was formed in 2000 as a joint initiative of various national and international conservation organizations. It was launched in 2005 and today 588 sites for 920 species of various taxa (mammals, birds, amphibians, reptiles etc.) are recognized.

### 1.4.4 Important marine mammal areas (IMMA)

Emerged from a concern marine mammals were underrepresented in global conservation efforts, the International Committee on Marine Protected Areas (ICMMPA) was established in 2006. Their aim is to support marine mammal protection through site conservation approaches like marine protected areas. They strive to promote "best practice management" and strengthen the voice of marine mammal protection in planning initiatives, ocean conservation actions etc. Another intention is to provide a platform where people involved with marine mammals, managers, scientists and other stakeholders, can collaborate and share information and experiences. The first steps have been primarily networking and communicating by establishing regular MMPA conferences (ICMMPA 2015).

The ICMMPA is one of the founders of the IUCN Joint SSC/WCPA Task Force on Marine Mammal Protected Areas (MMPATF) which was created in 2013 and ought to direct more attention to the needs of marine mammals within the IUCN.

Currently ICMMPA establishes a standard to identify important marine mammal areas. Like other standards IMMAs are not marine protected areas with an imperative management plan themselves, but rather a scientific identification approach. Thus, they can give advice to governments, NGOs and other stakeholders which areas are of superior importance for marine mammals and promote their conservation.

### 1.4.5 Key Biodiversity Areas (KBA)

The number of different approaches to identify sites of significance for the persistence of biodiversity, rose concern that too many parallel processes, criteria and focal species might limit overall success. At the World Conservation Congress in 2004, IUCN members therefore asked the IUCN to work on a comprehensive approach and to "convene a worldwide consultative process to agree a methodology to enable countries to identify Key Biodiversity Areas" (IUCN 2014). This started the development of IUCN's KBA approach. In 2009 the *IUCN World Commission on Protected Areas* and the *IUCN Species Survival Commission* established the *Joint Task Force on Biodiversity and Protected Areas* to lead a global consultation process. Regional consultations and expert workshops followed.

The IUCN strives to combine and harmonize existing concepts with their KBA approach and thus to build an "overarching common framework" (IUCN 2014). As such it is meant to be more than a non-binding identification scheme but rather achieve official denomination by aligning criteria and thresholds with official processes like EBSAs or natural World Heritage sites (IUCN 2014). It builds on the long experience and expertise of successful concepts like the Important Bird Area concept and Alliance for Zero Extinction sites, among others. But the KBA standard extends these identification systems to other taxonomic groups without limitations. It is meant to be applicable for any taxa, anywhere in the world and in every environmental system (terrestrial, freshwater, marine) (IUCN 2014).

KBA-sites are identified using globally standardised criteria and thresholds applied by national and international constituencies (CBD 2013), based on species vulnerability and site irreplaceability (Margules & Pressey 2000). (For a full list of KBA criteria and thresholds see appendix A.) This means any data are gathered and analysed at the national level and after a review process then assessed against the global standard. This national and local involvement is meant to increase overall acceptance and thus conservation success.

The quantitative thresholds defined by the IUCN identify KBAs of global significance. KBA Partner organisations can also approve alternative thresholds that identify sites of regional importance and countries and institutions are explicitly encouraged to do so.

Any individual, organisation or government can approach the IUCN with a sincere interest to identify a KBA for a specific region. Proposed KBAs are then peer-reviewed to make sure criteria and thresholds are applied thoroughlyhttp://dict.leo.org/ende/index_de.html - /search=adv.&searchLoc=0&resultOrder=basic&multiwordShowSingle=on. If successful, a new KBA is listed on IUCN's website. A KBA committee monitors the nominating-process process and compliance of scientific standards and criteria. Sites that do not meet global thresholds for any of the criteria due to data deficiency, but are believed to do so once more data become available, can become candidate KBAs (IUCN 2014).

KBAs have clearly defined boundaries but no minimum or maximum size. They should nevertheless be large enough or be adequately interconnected to support viable populations of the target species (Eken et al. 2004). The spatial delineation should consider biological information and natural features like reef edges or depth contours (e.g. Ambal et al. 2012), but also the potential manageability of the site. It is an iterative process encompassing consultation of stakeholders and clarification of biological processes to achieve practical boundaries. No standardized global methods are provided yet and are therefore often subjective in cases where boundaries are not self-evident (i.e. islands or existing MPAs) (Edgar et al. 2008b). This is not fully unintended as it is acknowledged that delineation is very much context dependent and therefore requires a certain amount of flexibility.

Despite its capacious process, do KBAs not dictate any specific management plans, neither do they necessarily always indicate conservations priorities, because data on threats, costs and feasibility are not included (IUCN 2014). They form a scientific base for sites which could potentially be managed as protected areas to conserve biodiversity (CBD 2013) and should be used to identify gaps in already protected areas as well as promote the protection of important areas not yet under any kind of protection (IUCN 2014).

## 1.5 Application of currently existing processes to marine mammals

At the time of writing people in charge have been conducting a global consultation process, involving a wide range of stakeholders, to define a globally agreed standard on KBAs. A draft document containing revised criteria and adapted thresholds was already published in October 2014 to be reviewed by species experts (e.g. IUCN's SSC specialists groups).

There are already more than 13,000 KBA sites in more than 200 countries identified today. More than two thirds of those sites are located in developing countries (UNEP-WCMC 2014). In the marine realm first attempts were made, for example in the Galapagos Marine Reserve, where 41 threatened marine species, including 16 marine mammals live. A total of 38 KBAs were identified along the coastline, of which 27 are currently under some sort of protection (Edgar et al. 2008). Some problems arose in the identification process. The authors state that species not yet assessed on the Red List of Threatened Species had to be included, to cover all sites important for Galapagos Marine Reserve's biodiversity. Because marine species have little site fidelity except for breeding, they had to include site-associated fish, invertebrates and algae that are not yet assessed on the Red List but do comply with its criteria. They also did not use KBA criteria in a strict manner, because the whole coastline of the archipelago would have ended up as a KBA. To avoid this, they ignored sites holding Endangered or Vulnerable species in low numbers if those species were already covered in KBAs for other species. KBAs for these species were only identified if at least 1% of the global population was permanently or seasonally present at the site. This still resulted in nearly half of all identified KBAs triggered solely by the Galapagos sea lion (*Zalophus wollebaeki*). This possible over-representation of one species could not be avoided, because all alternatives were considered even worse. They conclude that for management strategies the assigning of different values to the KBAs would be helpful, meaning that not every KBA is equally important to protect (Edgar et al. 2008).

In the Philippines 128 terrestrial and freshwater KBAs and 123 marine KBAs were identified in 2006 and 2009. The terrestrial KBAs cover 20% of the country's land area but the marine KBAs only 1.93% of its EEZ. Altogether the KBAs contain 855 species of which 396 are globally threatened and 398 have a restricted range. More than half of the KBAs are unprotected. The government wants to use KBA identification to implement further biodiversity conservation projects. As a first step a set of criteria is being developed to assess and prioritize conservation measures and investments in KBAs. However, marine KBAs are not included in this process because the data are believed to be not sufficient. The marine KBAs are therefore seen as priorities for research and only areas that are "suspected to be important for conservation" (Ambal et al. 2012).

# 2. Methods

## 2.1 Assessment of data requirements for application of KBA criteria to marine mammals

I reviewed all single-taxa KBA criteria and thresholds in their most recent version (IUCN 2014, draft document) and registered the required information and data to test each criterion and thresholds for the identification of KBAs.

## 2.2 Assessment of data availability for application of KBA criteria to marine mammals

I assessed which of the required data to test single-taxa KBA criteria for a given site, are available and, where possible, to what extent and with which reliability. This is illuminated in more detail in each subsection below.

### 2.2.1 Taxonomy and population structure

Information about species taxonomy and population structure, including information about the existence of subspecies and regional populations, is crucial for all KBA criteria. Thus, as a first step, I evaluated the extent of ambiguities in marine mammal taxonomy, based on a comprehensive literature review about MM taxonomy, including comparison of the IUCN database (www.iucnredlist.org) with most recent taxon-specific expert assessments (Committee on Taxonomy 2014). I identified species with controversial taxonomy and registered differences in the recognition of subspecies. For further analyses I followed IUCN taxonomy because it is well evaluated and includes required conservation statuses for all species in their Red List of Threatened species.

For the purpose of this study, I assorted all marine mammal species into five taxonomic groups (Table 2).

Table 2. Taxonomic groups for further analyses.

| Group name | Definition | Number of species |
|---|---|---|
| Small Odontoceti | All “toothed whales” (Odontoceti) without the large beaked whales and sperm whales | 47 |
| Beaked and sperm whales | Beaked whales (Ziphiidae) and sperm whales | 24 |
| Mysticeti | All baleen whales | 15 |
| Pinnipeds | All Pinnipeds | 32 |
| Others | Manatees, dugong, otter and polar bear | 6 |

### 2.2.2 IUCN conservation status

Quantifying just how threatened a particular species is, is not easy, but nevertheless important. The IUCN Red List of Threatened Species is the global standard of species threat assessment and therefore used in the KBA standard as well (IUCN 2014). See IUCN 2012 for further details on the Red List criteria.

I looked up the most recent Red List classification for each species and calculated and plotted how marine mammals in total and the single taxonomic groups individually, are reflected in the Red List categories. I plotted the number of species listed as Data Deficient per global abundance category in a histogram to analyse, if data deficiency is related to low global population sizes.

To visualize where threatened species occur in comparably high concentrations globally, I created species richness maps for all species assessed as Vulnerable, Endangered or Critically Endangered. Species’ ranges were derived from AquaMaps (see 2.2.3) on a 0.5 x 0.5 degree grid with a prediction threshold of > 0.0 to assess the maximum range of species and > 0.6 to assess their core habitat.

### 2.2.3 Global distribution and habitat usage of marine mammals

I compiled species distribution ranges from the IUCN and from AquaMaps. With spatial data provided by the IUCN, and using the “Calculate Geometry” tool and “World Cylindrical Equal Area” projection in ArcMap (Esri 2011), I computed total range sizes for each species. IUCN distribution ranges are depicted as polygons of the shortest boundary between all known, inferred or projected sites of occurrence, excluding vagrancies (IUCN 2014). IUCN's binary (presence vs. absence) maps do not suggest a homogenous distribution within the range or that a given species occurs everywhere inside the range, but they do imply an equal probability of occurrence throughout the whole range (Kristin Kaschner, pers. comment).

An alternative source of information to estimate range sizes of marine mammal species are the outputs from the online species distribution tool AquaMaps (www.aquamaps.org). AquaMaps is an environmental niche model, which computes the relative occurrence of marine species by relating information about the environmental tolerance of a given species towards depth, salinity, temperature, primary productivity, and its association with sea ice or coastal areas to local environmental conditions (Kaschner et al. 2007). Unlike IUCN's distribution maps, which use a clear cut polygon of the species presence and absence, AquaMaps shows the relative probability of a species to occur in a given area by matching occurrence records and known habitat usage against local environmental conditions. This is mapped with a resolution of half-degree latitude / longitude, which corresponds to ca. 50 $km^2$ near the equator. The range maps are reproducible and transparent because they are computer generated (Kaschner et al. 2007). Validation has shown that a 0.6 threshold for many species may describe known core areas of species occurrence associated with high observed encounter rates (Kaschner et al, 2006 & 2011).

Because previous validation analyses have shown that AquaMaps predictions in some cases include not only realized but also the potential niche of a species, I calculated range sizes for different species using different probability thresholds as cut-off points. I then conducted a regression analysis to compare maximum range sizes from AquaMaps with IUCN's binary range maps to analyse which AquaMaps threshold would provide the closest fit to IUCN's range sizes.

To show of which size distribution ranges for marine mammals in general are, I plotted the frequency distribution of maximum range sizes through all marine mammal species in a histogram and mean range sizes per marine mammal family in a bar chart.

Global distribution ranges can play an important role in the vulnerability of a species and are therefore a criterion in the IUCN Red List assessment. I plotted mean range sizes for marine mammals in each conservation category to analyse if threatened species in general have smaller range sizes compared to not-threatened species. Range restrictedness is also important in the KBA standard. I computed which range sizes would trigger the definition of range restrictedness in the KBA draft document (IUCN 2014).

To analyse if distribution ranges and global population sizes are related, I plotted the distribution range of all species against their global abundance.

### 2.2.4 Global population estimates and abundance data of marine mammals

A major task was compiling and updating the available information about global abundances and associated uncertainties. Considerable effort was made to assure the most recent, global abundance estimates for all marine mammals species are used to test KBA criteria. In an extensive literature research the most current publications were reviewed and abundance estimates were collected in a database. Even though it cannot be guaranteed no more recent estimates were published after this literature research, or the most recent publication was always successfully found, the numbers used in this thesis can be considered up-to-date at the time of writing. To define minimum abundance categories, estimates were rounded down to the previous order of magnitude with one intermediate step (i.e. 500; 1,000; 5,000; 10,000 etc.).

A quality indicator was assigned to each abundance estimate, based on five criteria (table 3). Every estimate scores zero to four points per criterion. A multiplier for each criterion allows for weighting of the different criteria. The most important criteria was how much of the total distribution area of a species was actually surveyed or at least estimated, whereas the CV of the estimate is relatively negligible. If a survey covers the whole range of a species but the result has a high CV, this is still more reliable than a very precise survey, covering only 10% of the species' range. Table 3 lists the final ranking from 1 to 5 (1 being the best), depending on the number of points. This ranking allows for a quick and rough evaluation of the reliability of all global abundance estimates.

Table 3. Criteria for the allocation of points to assess the quality of global abundance estimates.

| Criterion | 4 | 3 | 2 | 1 | 0 | Points |
|---|---|---|---|---|---|---|
| CV or 95% conf. interval of estimate | ≤ 0.5 | ≤ 1.0 | - | large min/max range | no uncertainty or range provided | **x 0.5** |
| Proportion of species range covered by reliable surveys | ≥ 70% | ≥ 40% | ≥ 20% | < 20% | None or unknown | **x 2** |
| Proportion of species range covered by reliable estimates | ≥ 80% | ≥ 50% | ≥ 30% | < 30% | None or unknown | **x 2** |
| Year of estimate | Since 2000 | 1990-1999 | 1979 - 1989 | older than 1979 | unknown | **x 1** |
| Confidence in survey | Rigorous survey with definite survey area, time period and information about uncertainties. | Survey without definite survey area, but information about uncertainties | Survey without definite survey area, but giving a range (i.e. min/max estimates) | very general estimate, no defnite time period or area, no uncertainties (mostly secondary references) | No clearly documented survey method. Maybe inferred from other species | **x 1** |

Table 4. Allocation of points to the final global abundance estimate reliability rank.

| Points | 26 - 22 | 17 - 21 | 12 - 16 | 6 - 11 | < 6 |
|---|---|---|---|---|---|
| Rank | **1** | **2** | **3** | **4** | **5** |

I plotted the number of species in each abundance category to analyse which global abundance categories are most frequent, thus how abundant the majority of marine mammal species are and how the different taxonomic groups differ in this context. I then plotted the individual global abundance estimate for each species and color-coded the reliability of the estimate and each species' IUCN conversation category to see how they correspond with each other.

### 2.2.5 Data availability for proposed surrogates of global population estimates in the KBA criteria

Application of the thresholds in criteria A1 and B1 requires a reliable estimate of the global population of a species. If this information is not available, the KBA standard allows for the following surrogates to be used to calculate the proportion of the global population at a given site.

1) number of individuals,
2) area of occupancy,
3) extent of suitable habitat,
4) extent of occurrence,
5) number and area of sites, or
6) unique genetic diversity.

They are to be used in this particular order to assure the best available data are used (IUCN 2014). Two range definitions are used in this context: The *extent of occurrence* (EOO) and the *area of occupancy* (AOO). The EOO is defined as the "area contained within the shortest continuous imaginary boundary" including all known, inferred and projected occurrences without vagrancies of one species (IUCN 2012). The AOO is an area within the EOO, excluding all unsuitable and known unoccupied habitats. It is acknowledged that estimates might be inconsistent and it might be necessary to standardize them, but there still seem to be some obstacles in this process (IUCN 2012). Figure 1 shows two examples how distribution information of a species (A) can be delineated as an EOO (B) and how the AOO is achieved by totalling all occupied grid squares (C) (IUCN 2012).

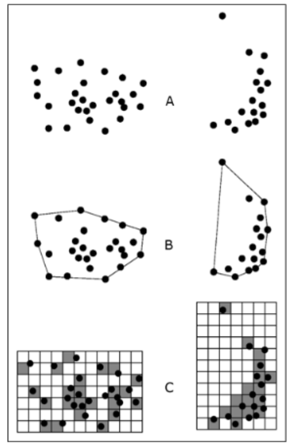



Figure 1. The spatial distribution of a species (A), the associated extent of occurrence (B) and the calculating method (sum of occupied squares) for the area of occupancy (C) (IUCN 2012).

The range sizes of IUCN's binary maps equal very roughly the EOO for each species (pers. comment Michael Hoffmann, IUCN, 06/03/2015). The prerequisite for the proper calculation of an AOO within an EOO is a representative survey coverage. The best source for marine mammal occurrence records is OBIS-SEAMAP (http://seamap.env.duke.edu), an online spatial database where observations of marine mammals, sea turtles and seabirds can be registered and compiled. Visual records data from airplanes and vessels were extracted for a 10-year period from 01/01/2005 to 31/12/2014. I investigated to what extent AOOs could be obtained using OBIS-SEAMAP data and analysed the taxonomic coverage of currently available occurrence records. I then selected species with a high number of sightings (i.e. *Tursiops truncates*, *Phocoena phocoena*, *Megaptera novaeangliae*) to visually compare the spatial distribution of records with the overall known occurrence and see if OBIS data can be used to calculate AOOs.

The surrogate "extent of suitable habitat" is defined as the "area of potentially suitable vegetation types within the altitudinal preferences and geographic distribution of the species" (IUCN 2014). It is assumed to be equal to the core range predicted through AquaMaps. The surrogate "unique genetic diversity" is not further considered here, because it is hardly applicable for marine mammals due to data deficiency.

I reviewed an exceptional case of extinction risk and urgent conservation need in the context of these surrogates. In a brief case study the recent case of the vaquita (*Phocoena sinus*), currently one of the most threatened mammals worldwide, was examined and its "vaquita refuge" was tested, as an exemplary site, against the surrogates. The size of the refuge had to be estimated using a scaled picture, because no information could be retrieved. Only approximately half of the population are considered to live inside the refuge (CIRVA 2014). The size of the AOO was retrieved from the Red List of Threatened Species. Further background information on this case is given in appendix B.

### 2.2.6 Global marine mammal species richness patterns

I used Aquamaps' predicted species distributions to produce patterns of species richness for each taxonomic group, using thresholds 0.0 (maximum range) and 0.6 (core habitat).

## 2.3 Population density and area computations

I calculated homogenous population densities for all marine mammal species by dividing the number of species by its distribution area. I used IUCN's binary distribution ranges, AquaMaps' largest distribution ranges (probability of occurrence > 0.0) and core area ranges (probability of occurrence >0.6) and then plotted all three sets of densities per species, to analyse how similar they are.

With AquaMaps' maximum ranges, I computed how large corresponding areas would have to be to meet thresholds in criterion A1b and A1c in the KBA standard.

# 3. Results

## 3.1 Data requirements for application of KBA criteria to marine mammals

Table 5 summarizes the data requirements of each single-taxa criterion.

Table 5. Summary of data requirements for the application of KBA criteria to marine mammals.

| Data requirements / Criteria and Sub-Criteria | Taxonomy & population structure | Distribution (Range sizes, occurrence) | Global population size | IUCN conservation status | Behavioural information (breeding, aggregations etc.) | Number of "functional reproductive units" | Other |
|---|---|---|---|---|---|---|---|
| A1: Threatened taxa | ✓ | ✓ | ✓ | ✓ | | ✓ | |
| B1:Geographically restricted species | ✓ | ✓ | ✓ | ✓ | | ✓ | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| D1:Demographic aggregations | ✓ | ✓ | ✓ | | ✓ | | |
| D2: Ecological refugia | Not applicable in the marine realm | | | | | | |
| D3: Source populations | ✓ | ✓ | ✓ | | ✓ | | Adult population, reliable quantitative data on breeding grounds |
| E: Biodiversity through quantitative analysis | ✓ | ✓ | ✓ | | | | Area necessary to ensure the global persistence of the species with probability of 90% in 100 years (measured by quantitative viability analysis or inferred by expert knowledge) |

## 3.2 Data availability for application of KBA criteria to marine mammals

Some considerable effort was invested in many parts of the world to gather data about marine mammal population sizes, abundances and other information. The following subsections show the results of my analysis of data availability.

### 3.2.1 Taxonomy and population structure

The evaluation of marine mammal taxonomy revealed some general ambiguities for some species, as well as differences between the two comprehensive databases (IUCN and Committee on Taxonomy). In total 13 species (10.5%) are listed somehow different in both databases. A few of these dissimilarities concern the recognition of a true species: The new species *Sousa sahulensis* (Australian humpback dolphin) is already recognized by the Committee on Taxonomy, but not listed at the IUCN yet. *Mesplodon hotaula* is considered a synonym for *Mesoplodon ginkgodens* by the IUCN, but a true species at the Committee on Taxonomy.

The other differences concern the recognition of subspecies. Whereas the Committee on Taxonomy lists 30 species with subspecies, the IUCN lists only 26 species. The number of subspecies varies widely as well (Table 6).

Table 6. Differences in the assessment of subspecies between the IUCN Red List of Threatened Species and the Committee on Taxonomy.

| Species | IUCN | Committee on Taxonomy |
|---|---|---|
| *Arctocephalus australis* | 2 subspecies:<br>*A.a. australis*,<br>*A.a. gracilis*. | *A.a. australis* and *gracilis* synonymized.<br>2 subspecies:<br>*A.a. australis*,<br>unnamed subspecies in Peruvian waters |
| *Arctocephalus philippii* | No subspecies. *Arctocephalus townsendi* is considered a true species. | 2 subspecies:<br>*A.p. philippii* (Juan Fernandez fur seal),<br>*A.p. townsendi* (Guadalupe fur seal). |
| *Balaenoptera edeni* | *Balaenoptera brydei* is considered a synonym for *Balaenoptera edeni* | *Balaenoptera brydei* is considered a subspecies of *Balaenoptera edeni*. |
| *Balaenoptera musculus* | 4 subspecies:<br>*B.m. musculus*,<br>*B.m. indica*,<br>*B.m. brevicauda*,<br>*B.m. intermedia* (assessed as CR) | Additional yet unnamed subspecies in Chilean waters |
| *Balaenoptera physalus* | 2 subspecies:<br>*B.p. physalus*,<br>*B.p. quoyi*. | Additional subspecies *B.p. patachonica* |
| *Megaptera novaeangliae* | No subspecies, but separately assessed subpopulations.<br>Worldwide Red List status: LC.<br>Arabian Sea subpopulation: EN.<br>Oceania subpopulation: EN. | 3 subspecies:<br>*M.n. kuzira* (North Pacific),<br>*M.n. novaeangliae* (North Atlantic),<br>*M.n. australis* (Southern Hemisphere). |
| *Orcinus orca* | No subspecies | 2 unnamed subspecies: Resident and Transient form |
| *Phoca vitulina* | 5 subspecies:<br>*P.v. mellonae*,<br>*P.v. concolor*,<br>*P.v. vitulina*,<br>*P.v. stejnegeri*,<br>*P.v. richardii.* | *P.v. stejnegeri* and *P.v. concolor* no longer considered subspecies. |

Aside from these differences there are fundamental problems with marine mammal taxonomy. Particularly noteworthy is the uncertainty is the taxonomy of Bryde's whales. The IUCN calls it the "Bryde's Whale complex", because it is not resolved at all how many true and/or subspecies there are. In 2003 one subpopulation of *Balaenoptera borealis* was recognized as a true species, now named *Balaenoptera omurai*.

### 3.2.2 IUCN conservation status

Figure 2 depicts how marine mammals are listed in the IUCN Red List of Threatened species. 22.1% of all marine mammal species assessed by the IUCN are listed as threatened (Vulnerable, Endangered or Critically Endangered). 11.5% are under severe threat (Critically Endangered and Endangered). These numbers are alarming, and they even ignore the fact that a large portion (38.5%) of species is listed as "data deficient", which means there is inadequate information to assess their risk of extinction properly.

All six species of the taxonomic group named "others" are listed as threatened, as are 33% of Mysticeti, and 25% of all Pinnipeds. Only 4% of beaked and sperm whales are listed as threatened, but this is simply due to the fact that 88% of them are listed as Data Deficient, as are 40 % in the group of small Odontoceti and 33% of all Mysticeti.

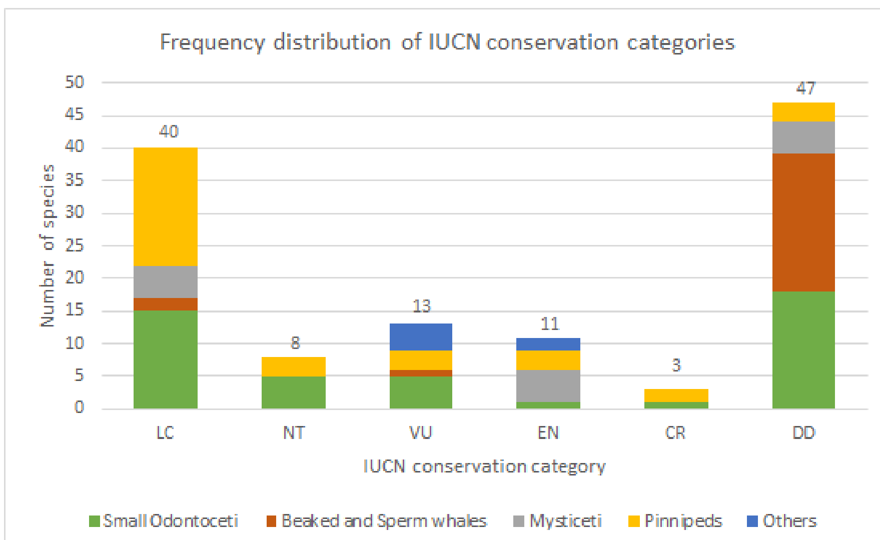



Figure 2. Classification of all marine mammals separated into five taxonomic groups in the IUCN Red List of Threatened Species. Status on January 2015.

Not all Data Deficient species have low global abundances (figure 3). 19% have a global abundance of at least 100,000 animals. A large proportion (45%) though, does have a very low global abundance of less than 5,000 animals.

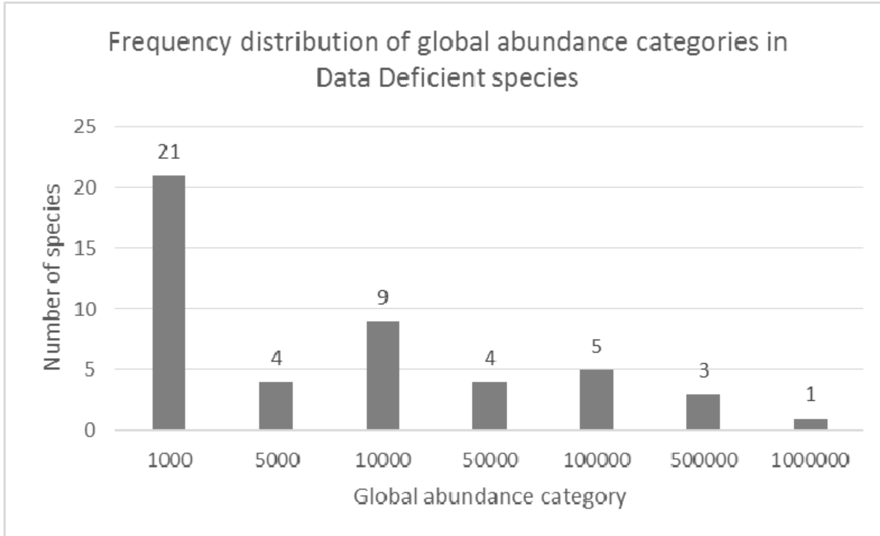



Figure 3. Categorized global abundances of species listed as Data Deficient. (n = 47, mean = 70,872).

The species richness maps (figure 4 and 5) show a concentration of threatened species around New Zealand and the coast of South Australia, but otherwise mostly in the northern hemisphere. A minimum of five (ca. 23% of all threatened species assessed by AquaMaps) threatened species concentrate in the northern North Atlantic, and in the North Pacific, in the Bering Sea, Sea of Okhotsk, around Japan and at the West coast of North America. The core habitats of threatened species are even further north with particular high concentrations of species in the Bering Sea and Gulf of Alaska.

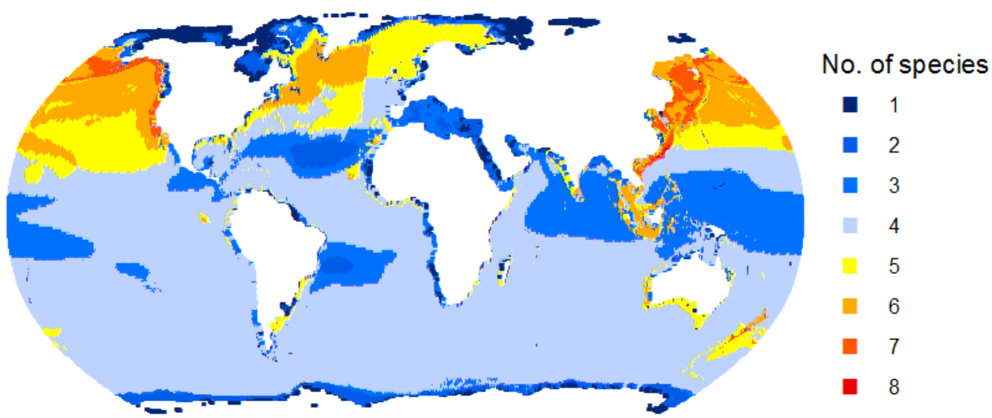



Figure 4. Global distribution pattern of threatened species (AquaMaps prediction with probability > 0.0).

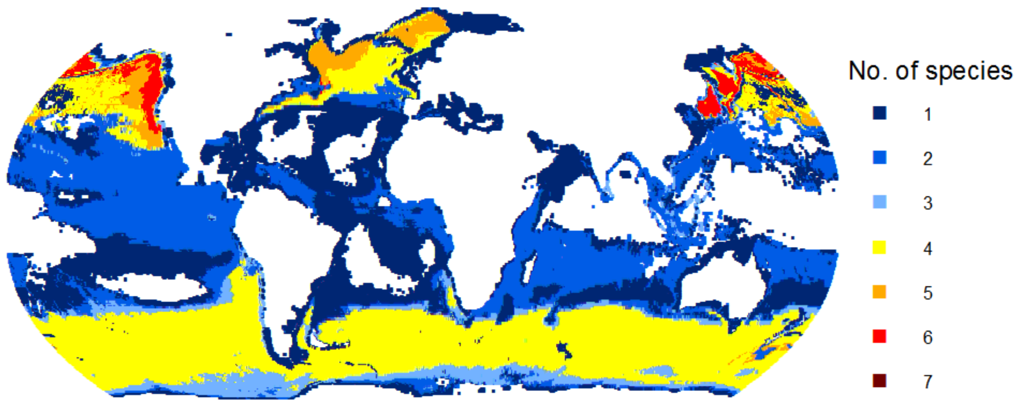



Figure 5. Global core habitat distribution pattern of threatened species (AquaMaps prediction with probability > 0.6).

### 3.2.3 Global distribution and habitat usage of marine mammals

The reciprocal validation and quantitative comparison between IUCN's binary range maps and the ranges as they would be defined through AquaMaps' prediction revealed a close fit ($R^2 = 0.9359$) for Aquamaps' largest distribution ranges (probability for a species to occur within is greater zero) (figure 6). The ranges for species to occur with a probability of greater 0.2 still have a close fit ($R^2 = 0.8967$) to IUCN's ranges as well, but the correlation gets worse almost linearly. It is justifiable to assume using Aquamaps' largest distribution ranges will produce very similar results than using IUCN's ranges, and they provide the additional opportunity to look at core habitats (probability of occurrence >0.6).

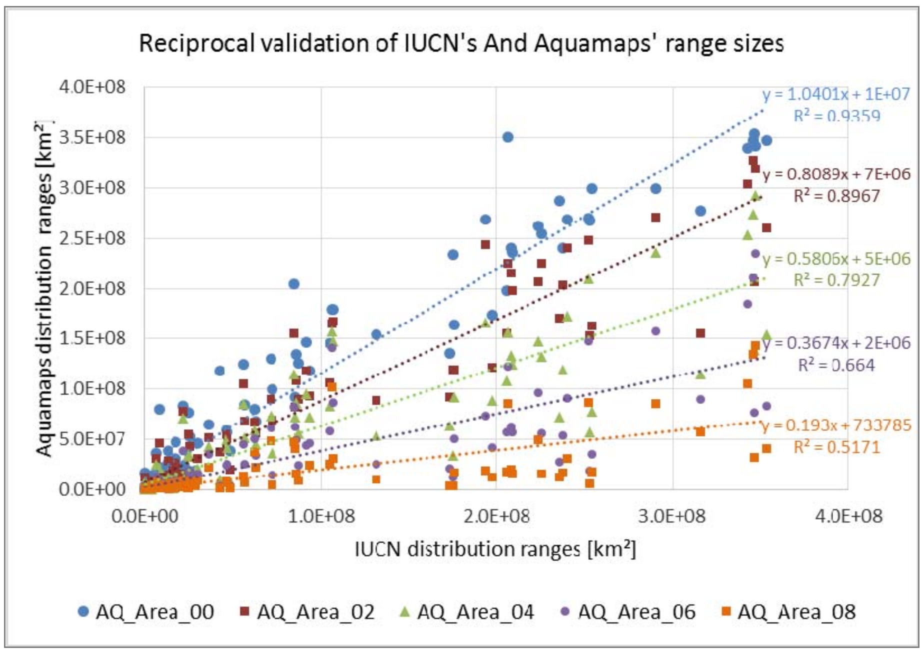



Figure 6. Reciprocal validation of IUCN's range sizes and Aquamaps' range sizes with occurrence-probability of >0, >0.2, >0.4, >0.6 and >0.8.

The vaquita (*Phocoena sinus*) has the smallest range of all marine mammals with an estimated 78,400 km². The IUCN range size is even much smaller, only 16,520 km². The AquaMaps range size is probably positively biased and shows the vaquita's historical range which has been decreasing for years (Kristin Kaschner, pers. comment 22/02/2015). The common minke whale (*Balaenoptera acutorostrata*) has the largest distribution (353,920,694 km²), followed by the fin whale (*Balaenoptera physalus*) (350,566,485 km²) and killer whale (*Orcinus orca*) (347,482,971 km²). 31% of all 116 marine mammals covered in AquaMaps have a range size of more than 100,000 km², 18.1% of more than 200,000 km² and 4.3% of more than 300,000 km².

Figure 7 depicts how maximum range sizes (Aquamaps occurrence probability >0.0) of marine mammals are distributed through all species. The mean range size of all marine mammals projected by Aquamaps, is 85,288,600 km².

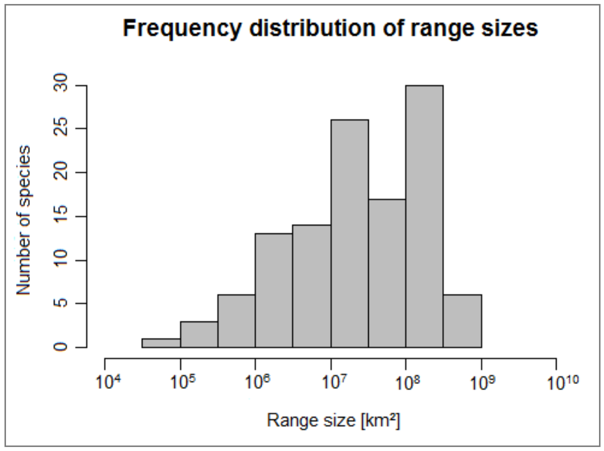



Figure 7. Frequency of distribution ranges for marine mammals with Aquamaps probability >0.0 (n = 116; min ≈ 78,400 km²; mean ≈ 85,288,600 km²; median ≈ 20,910,000 km²)

Figure 8 depicts the mean range sizes of marine mammal families. *Physeteridae* have the largest range size, but this family only contains one species, the sperm whale (*Physeter macrocephalus*). The second largest mean range size has the family *Balaenopteridae* containing 8 species, amongst others the minke whale (*Balaenoptera acutorostrata*) fin whale and humpback whale (*Megaptera novaeangliae*).

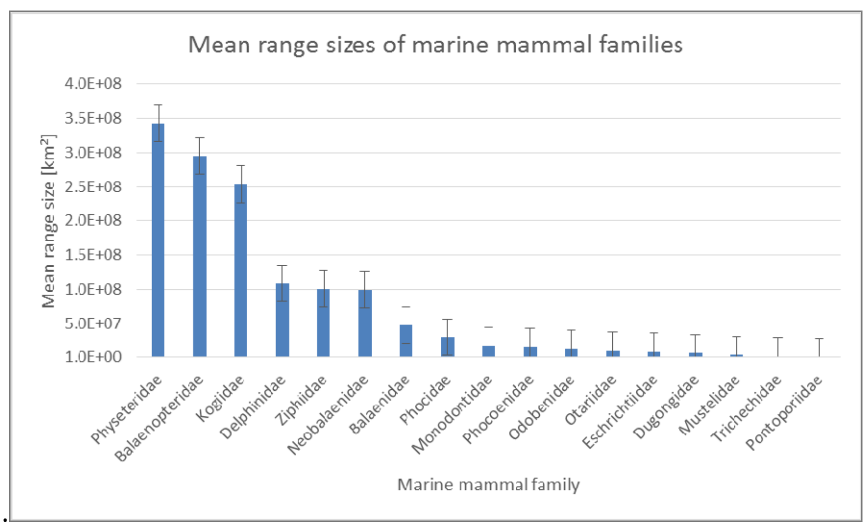


Figure 8. Mean range sizes of all marine mammal families, sorted by size.

Figure 9 depicts how range sizes are reflected in the IUCN Red List categories. Species listed as Critically Endangered have very small distribution ranges. The fact Endangered species have a relatively large average range size, is mainly due to the blue whale (Balaenoptera musculus), fin whale (Balaenoptera physalus) and sei whale (Balaenoptera borealis), which are listed as Endangered but have very large range sizes.

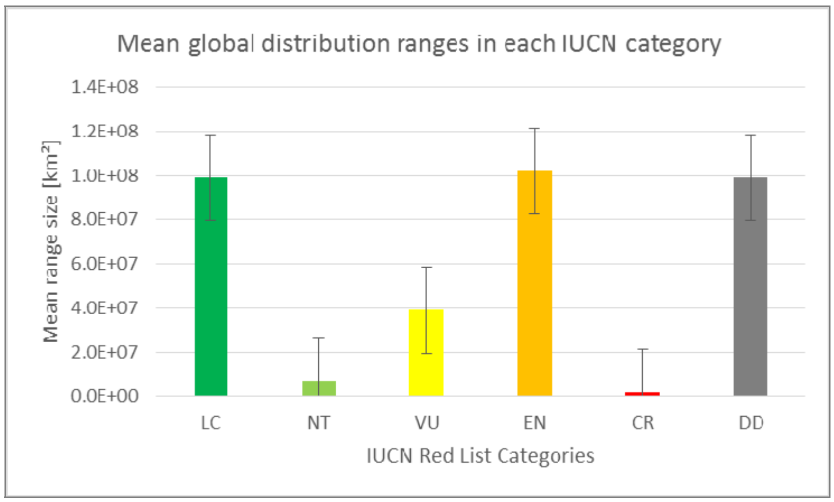



Figure 9. Mean range sizes of all marine mammals within one IUCN conservation category.

Figures 10 to 14 depict the distribution range of all marine mammal species against their global population, grouped in the five taxonomic groups. Mysticetes have the largest average range size because many of the very widely distributed species (blue whale, right whale, minke whales) are part of this group. The group of beaked and sperm whales has large distributions as well, but any result for this group is largely biased by the lack of reliable data. Range sizes in the taxonomic group “others” are only available for the dugong, sea otter and West Indian manatee and they all have relatively small range sizes. Whereas almost all mysticetes and many small odontocetes have range sizes exceeding 100 million km², only two pinniped species distribute that far. Regardless of their smaller ranges are pinniped species more abundant than most mysticetes and small odontocetes.

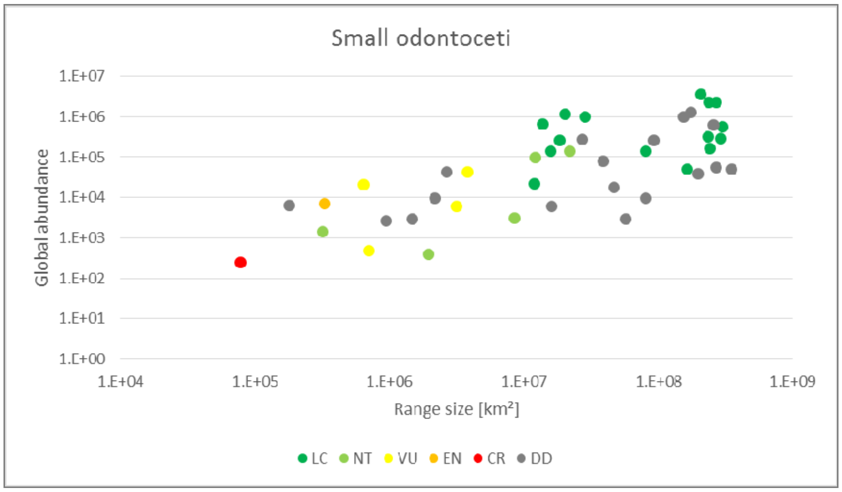



Figure 10. Distribution range against global population size for all small odontocetes (mean = 89,482,700 km²).

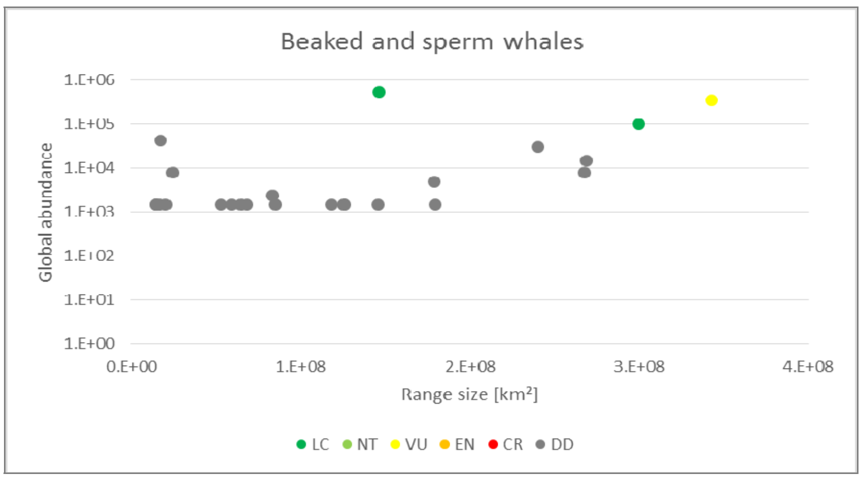



Figure 11. Distribution range against global population size for all beaked and sperm whales (mean = 122,985,000 km²).

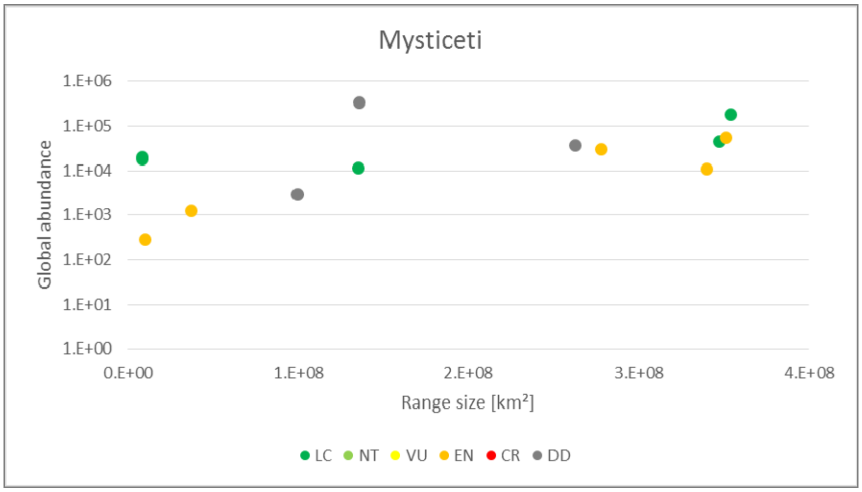



Figure 12. Distribution range against global population size for all mysticetes (mean = 181,752,700 km²).

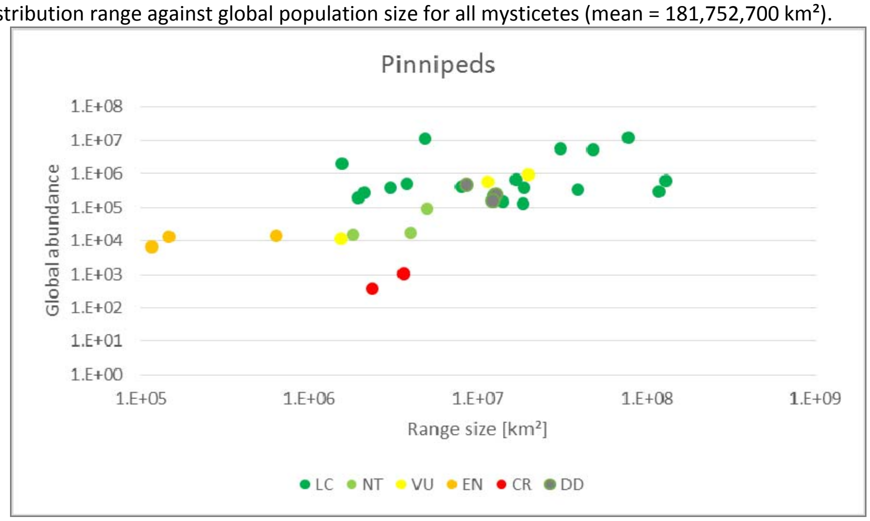



Figure 13. Distribution range against global population size for all pinnipeds (mean = 19,702,700 km²).

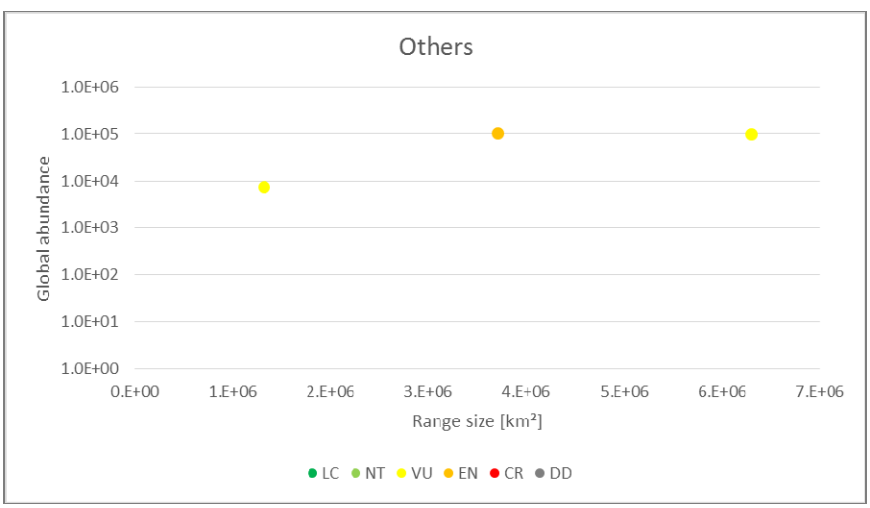



Figure 14. Distribution range against global population size for all species in the taxonomic group “others” (mean = 3,776,100 km²).

The definition of range restrictedness in the KBA draft document considers species within the lowest quartile of range sizes in a globally analysed Class or Order "range restricted" (IUCN 2014). A class can be a very large group, in our case it would be the class of Mammalia, which includes all terrestrial and marine mammals. Compiling distribution ranges for every single mammal is not feasible. The 25th percentile for all marine mammals for which AquaMaps ranges exist, is ca. 4,890,000 km².

Marine mammals are separated into three Orders: *Carnivora* (36 species of marine mammals, more than 280 species in total), *Cetacea* (90 species) and *Sirenia* (4 species) (Committee on Taxonomy 2014). The mean range size for the lowest quartile of all *Carnivora* is unknown and it is questionable if it would make sense to mix a group of terrestrial and marine mammals in this context. For the 39 marine mammals considered alone, 33 range sizes are available in AquaMaps and the 25th percentile would be ca. 2,335,000 km². For cetaceans the 25th percentile is ca. 14,150,000 km² and for the 4 sirenians only 2 are available in AquaMaps with the lower one being 6,301,000 km²
If no sufficient data are available, range restrictedness is defined by a "global extent of occurrence less than 10,000 km²" (IUCN 2014). As shown above, not a single marine mammal has a range size of less than 10,000 km².

### 3.2.4 Global population estimates and abundance data of marine mammals

The global abundance estimates, compiled during the literature review, varied between 97 estimated vaquitas (*Phocoena sinus*) left and 12.5 million Crabeater seals (*Lobodon carcinophaga*).

Pinnipeds have by far the largest average global population size, with more than 70% of all species having a global population exceeding 100,000 individuals (figure 15). While this is also true for 42.5% of all small odontocetes, 30% of them have low global population sizes of less than 10,000 animals, thus forming a very heterogeneous group. 75% of all beaked and sperm whales have global population sizes of less than 10,000 animals, but figure 17 shows how uncertain abundance estimates for these species are. Mysticetes do not have very large population sizes, 86% have a global population size of less than 100,000.

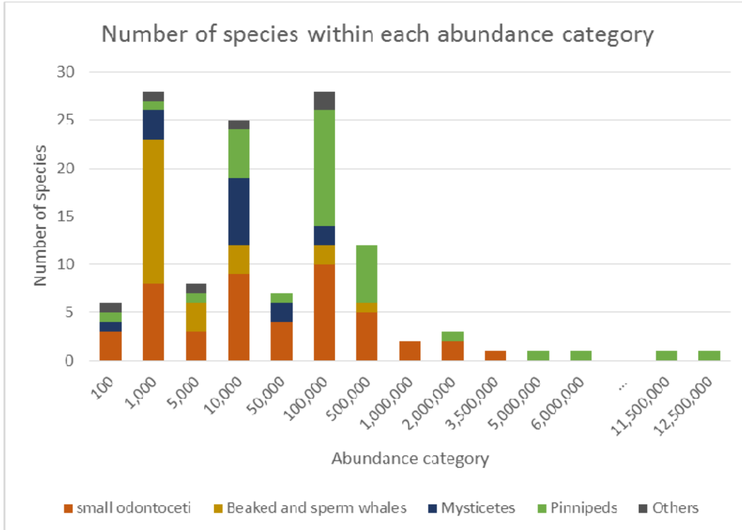



Figure 15. Number of species per global abundance category. Stacked bars show allocation of taxonomic groups.

Table 7 lists the results of the quality ranking of global population abundance estimates. Very reliable estimates are available for 21 species and relatively certain estimates for another 27 species (in total ca. 39%). For the 39 species with rank 3 the global abundance estimates can be considered an approximate estimation, whereas abundance estimates for species in category 4 and even more 5 (almost 30%) should be regarded highly uncertain and biased and can, if anything, only be regarded as a rough estimate of the magnitude of population size.

Table 7. Quality of global abundance estimates from 1 (very reliable estimate) to 5 (very unreliable estimate)

| Rank | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| No. of species | 21 | 27 | 39 | 13 | 24 |

Figure 16 to 20 depict the global abundances of all marine mammals individually and the corresponding quality rank for each abundance estimate. Beaked and sperm whales have the worst coverage of reliable global abundance estimates, 75% are ranked 4 and 5 and only 8% are of rank 1 or 2. Small odontocetes' global abundance estimates are very heterogeneous. 28% of the species' abundance estimates are reliable (1 and 2), but 21% are not (4 and 5). Estimates for the global abundance of pinniped species are reliable, 75% are ranked 1 and 2 and only 12% ranked 4 and 5.

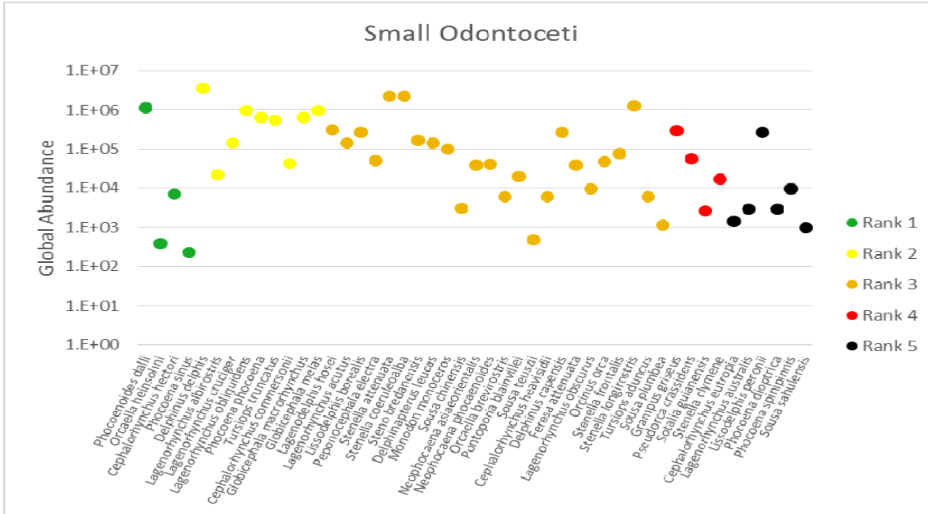



Figure 16. Global abundance of small odontocetes, sorted by abundance estimate quality rank.

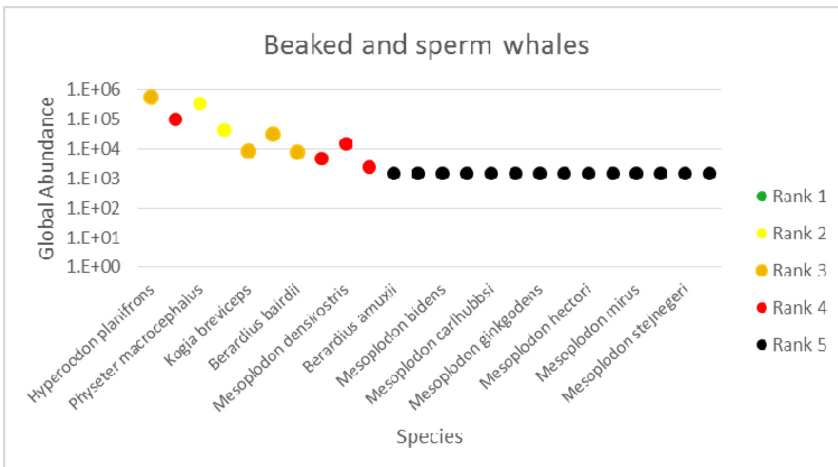



Figure 17. Global abundance of beaked and sperm whales, sorted by abundance estimate quality rank.

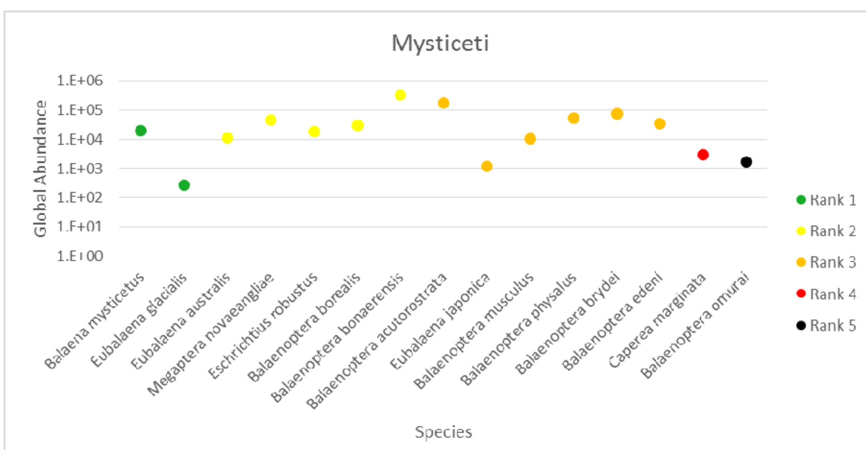



Figure 18. Global abundance of mystecetes, sorted by abundance estimate quality rank.

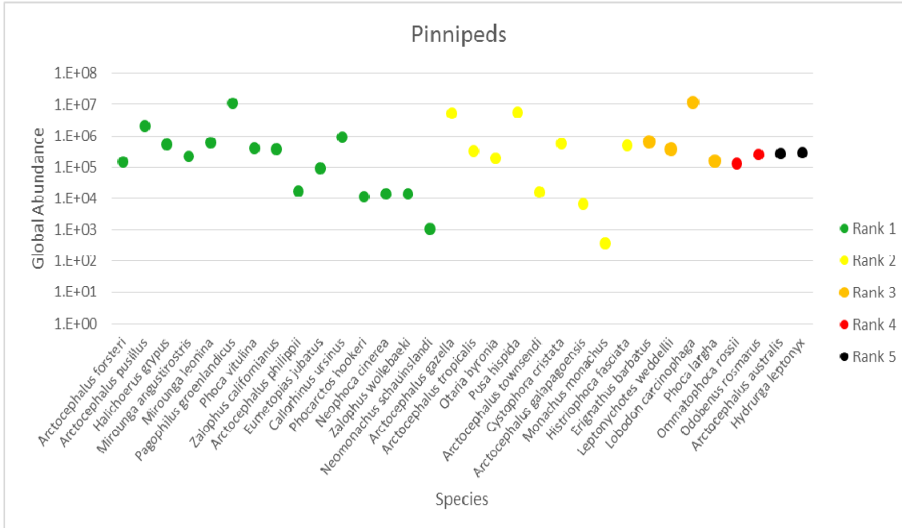



Figure 19. Global abundance of pinnipeds, sorted by abundance estimate quality rank.

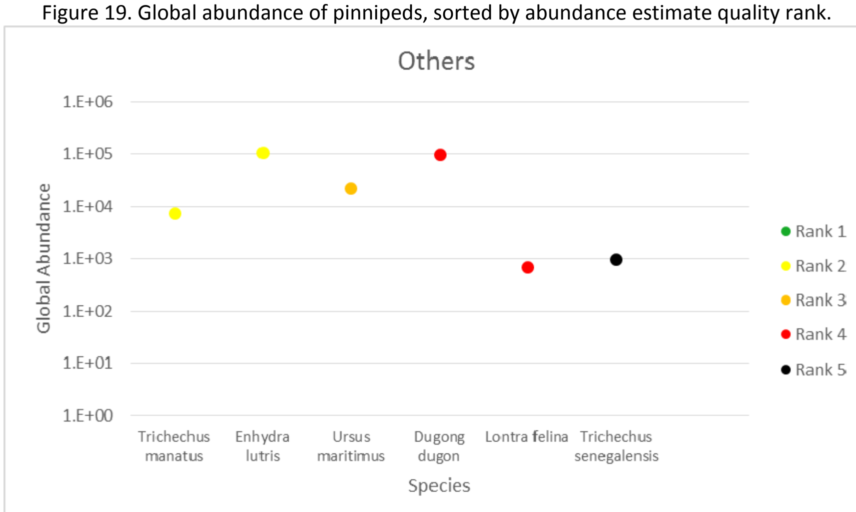



Figure 20. Global abundance of „others“, sorted by abundance estimate quality rank.

Figure 21 to 25 depict each species' global abundance and its IUCN conservation status. Species assessed as Least Concern in general have larger global population sizes. Critically Endangered and Endangered species on the other hand, on average have lower abundance estimates. One exception are sea otters (*Enhydra lutris*) which have an estimated global population size exceeding 100,000 animals but are still listed as Endangered, because the species suffered a severe population decline and has relatively low genetic diversity, what makes it vulnerable.

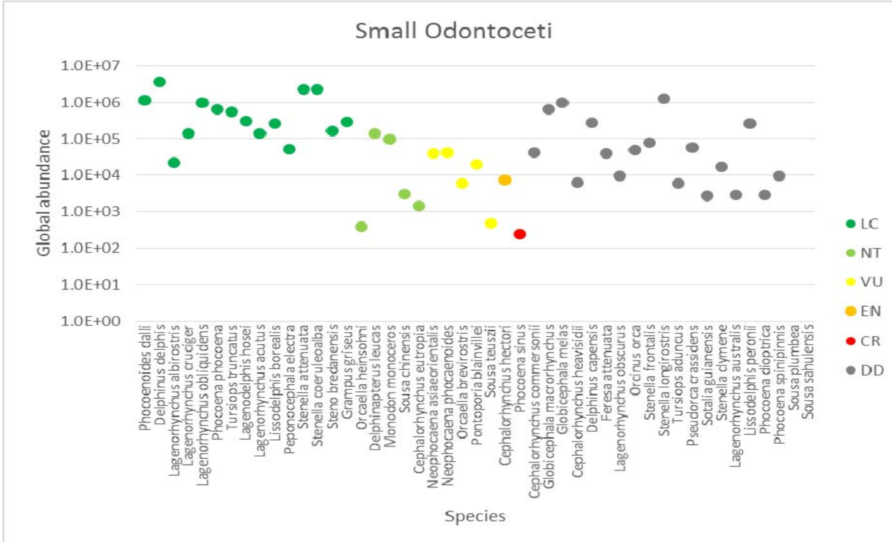



Figure 21. Global abundance of small odontocetes, sorted by IUCN conservation status.

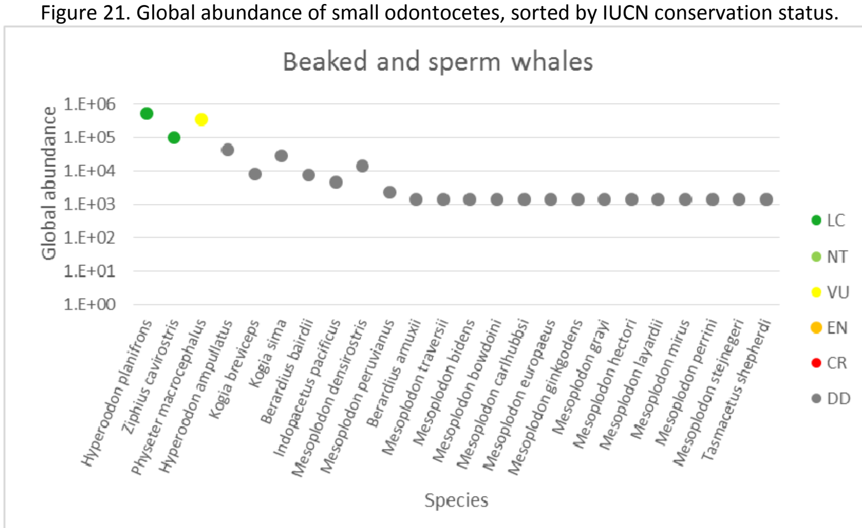



Figure 22. Global abundance of beaked and sperm whales, sorted by IUCN conservation status.

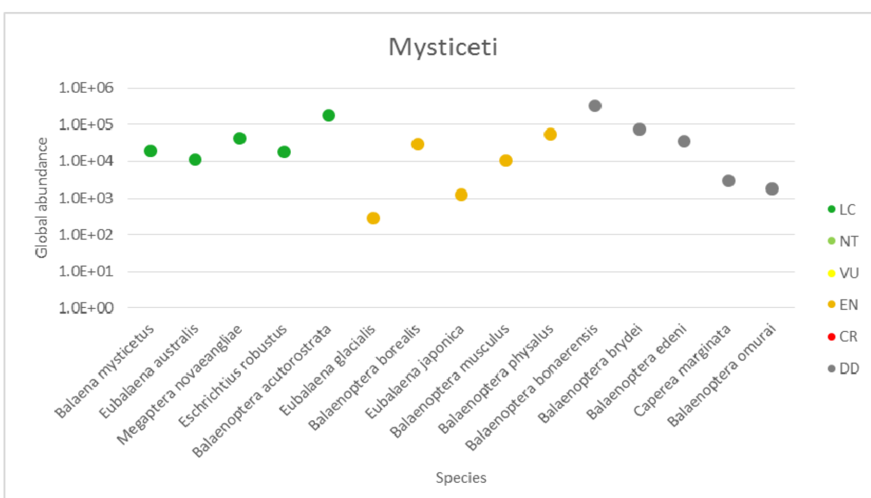



Figure 23. Global abundance of mystecetes, sorted by IUCN conservation status.

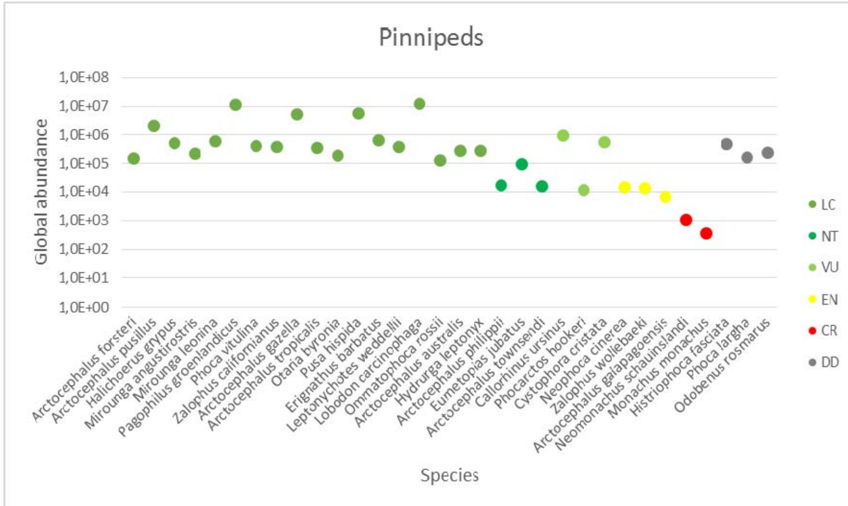



Figure 24. Global abundance of pinnipeds, sorted by IUCN conservation status.

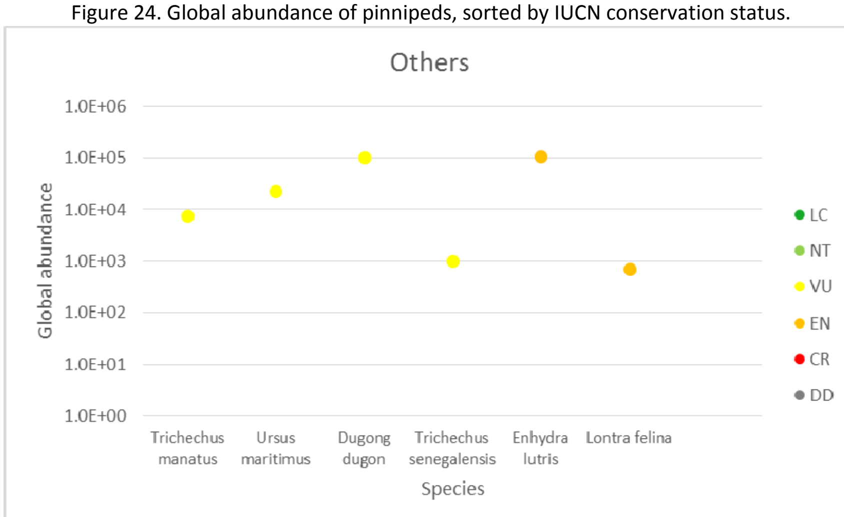



Figure 25. Global abundance of “others”, sorted by IUCN conservation status

### 3.2.5 Data availability for proposed surrogates of global population estimates in the KBA criteria

My analysis of OBIS-SEAMAP data showed 45% of all marine mammal species were on average observed less than once a year. 60% of all species were not observed on average at least 10 times per year. Data paucity was most prevalent in taxonomic group of beaked and sperm whales with 46% of the species observed a maximum of three times in the ten year period. In the same time 28% of all pinnipeds and all small odontocetes were observed a maximum of six times. Visual comparison between the spatial distribution of records and overall known occurrence for the five species with the highest number of sightings, indicated a very heterogeneous sampling effort, thus making the data unsuitable for the calculation of AOOs.

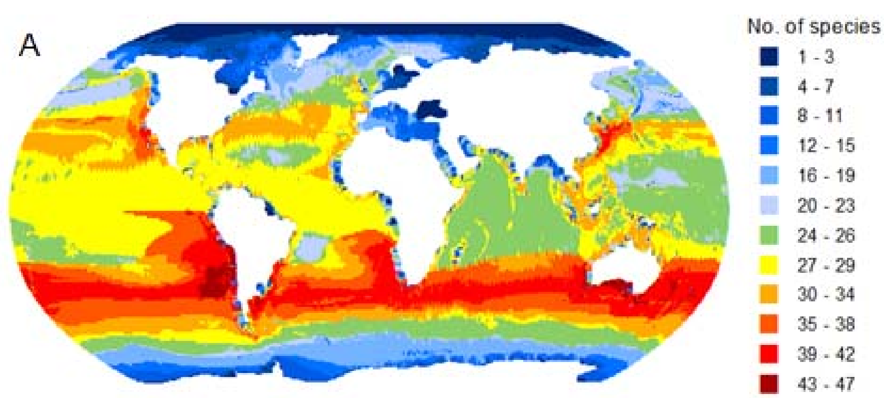
The case study ought to demonstrate how surrogates can be applied if global population estimates are missing. Background information on the vaquita and its urgent situation are provided in appendix B. Table 8 lists the value of each surrogate for the "vaquita refuge" as an exemplary site of interest and the corresponding global value. The site's proportion of the global value is the information which would be considered to recognize the site as a KBA or not. It is getting smaller with each step, because the size of the area from one surrogate to the next increases. The vaquita refuge holds approximately half of the global population. Unlike the global population, the number of individuals would also include juveniles. As no information whatsoever about the age structure of the vaquita population are available, both are considered equal here. The refuge would trigger many thresholds and qualifiy as a KBA, no matter if and which surrogate is used (Table 8).

Table 8. Surrogates for a missing estimate of global population size to test KBA criteria.

| Surrogate | Site (vaquita refuge) | Global | Proportion [%] | Criteria met | Would qualify as KBA? |
|---|---|---|---|---|---|
| **Global population** | **48** | **97** | **50** | A1b, A1d, B1, D1, D2, D3 | ✓ |
| Number of individuals | 48 | 97 | 50 | A1b, A1d, B1, D1, D2, D3 | ✓ |
| Area of occupancy [km²] | 1,500 km² | 2,000 | 75 | A1b, A1d, B1, D1, D2, D3 | ✓ |
| Extent of suitable habitat | 1,500 km² | 24,600 | 6 | A1b, A1d, B1, D1, D3 | ✓ |
| Extent of occurrence [km²] | 1,500 km² | 78,400 | 1.9 | A1b, A1d, B1, D1, D3 | ✓ |
| Number and area of sites, or | Vaquitas are restricted to one site only. | | | | |

### 3.2.6 Global marine mammal species richness patterns

Figures 26 to 30 depict predictions of species richness patterns for each taxonomic group derived from AquaMaps with threshold 0.0 (A) for the maximum range and 0.6 (B) for the core habitat. Species richness of the taxonomic group “others” is not depicted here, because data for the few species are too scarce. Overall species richness seems to be highest in the mid-latitudes, between 15°S and 45°S with around a third of all species occurring there. Core habitats concentrate in this belt of high species richness as well and especially around New Zealand, South Africa and also in the western Caribbean waters around Galapagos. Small odontocetes concentrate on coastal waters with up to 40% of the species especially around the coasts of eastern and western South America, West Africa, Australia, Indonesia and China. Species richness is also comparably high in the whole Atlantic. Small odontocetes’ core habitats concentrate especially in the Caribbean, around Galapagos, on the African coast and at Indonesian waters. The species richness patterns for beaked and sperm whales are very imprecise, thus look like large uniform surfaces of the same species richness in the maps. They concentrate globally around 30°S and core areas of highest species richness are offshore at this latitude, around New Zealand and Galapagos. Species richness for the mysticetes looks very much alike, with high concentration of species between 35°S and 50°S and at the West coast of South America. Pinniped species are relatively evenly distributed worldwide with only a few species near the equator and hightest concentration at the coast of the Gulf of Alaska.



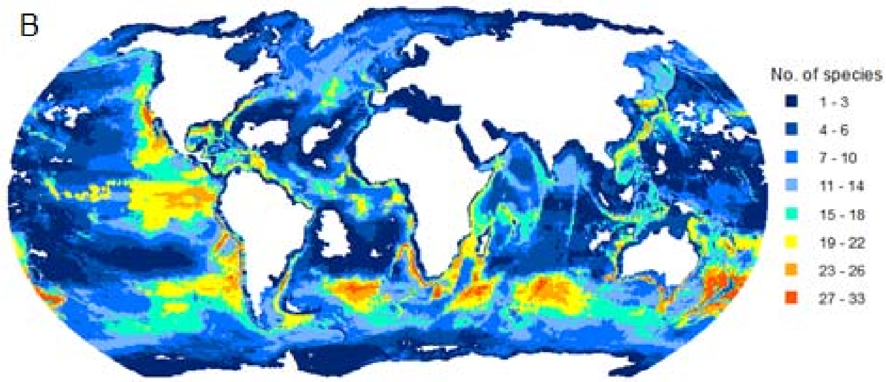



Figure 26. AquaMaps prediction of marine mammal species richness patterns. **All marine mammals**, threshold 0.0 (A) and 0.6 (B).

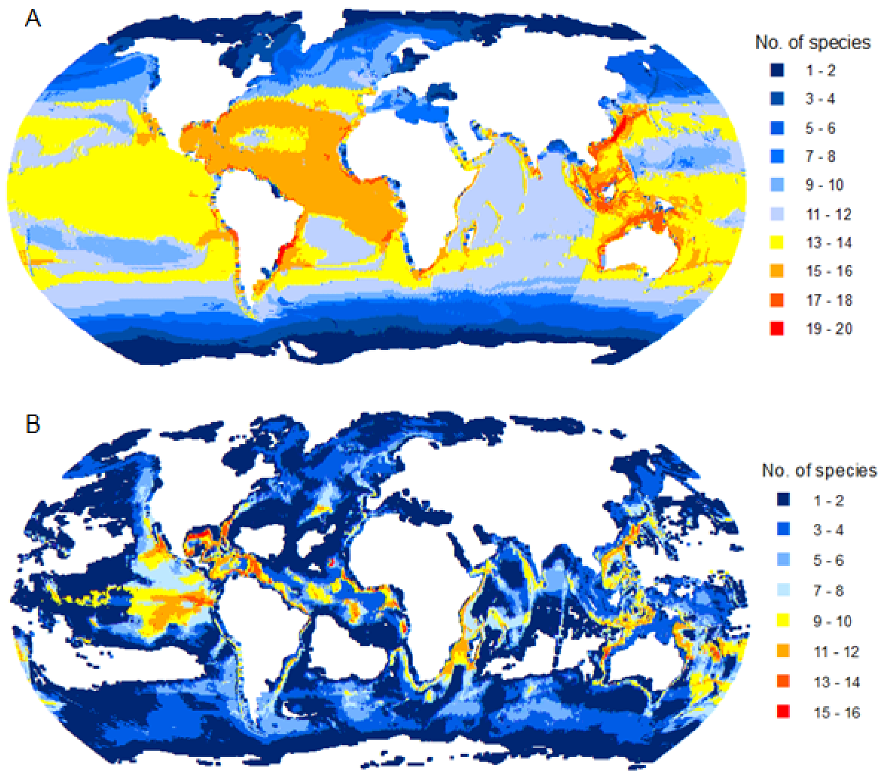



Figure 27. AquaMaps prediction of marine mammal species richness patterns. **Small odontocetes**, threshold 0.0 (A) and 0.6 (B).

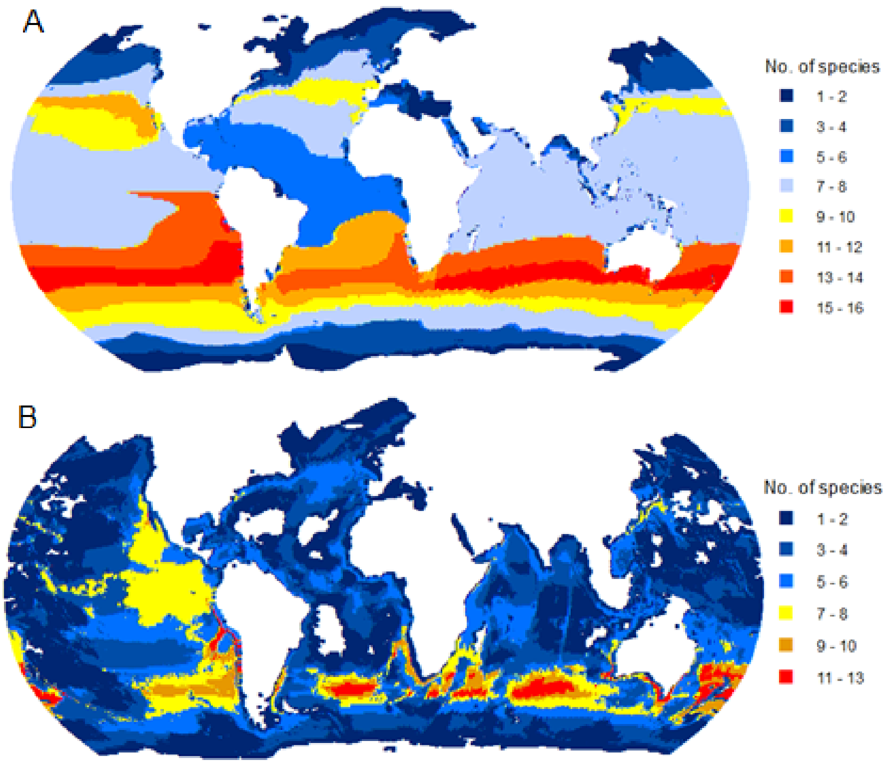



Figure 28. AquaMaps prediction of marine mammal species richness patterns. **Beaked and sperm whales**, threshold 0.0 (A) and 0.6 (B).

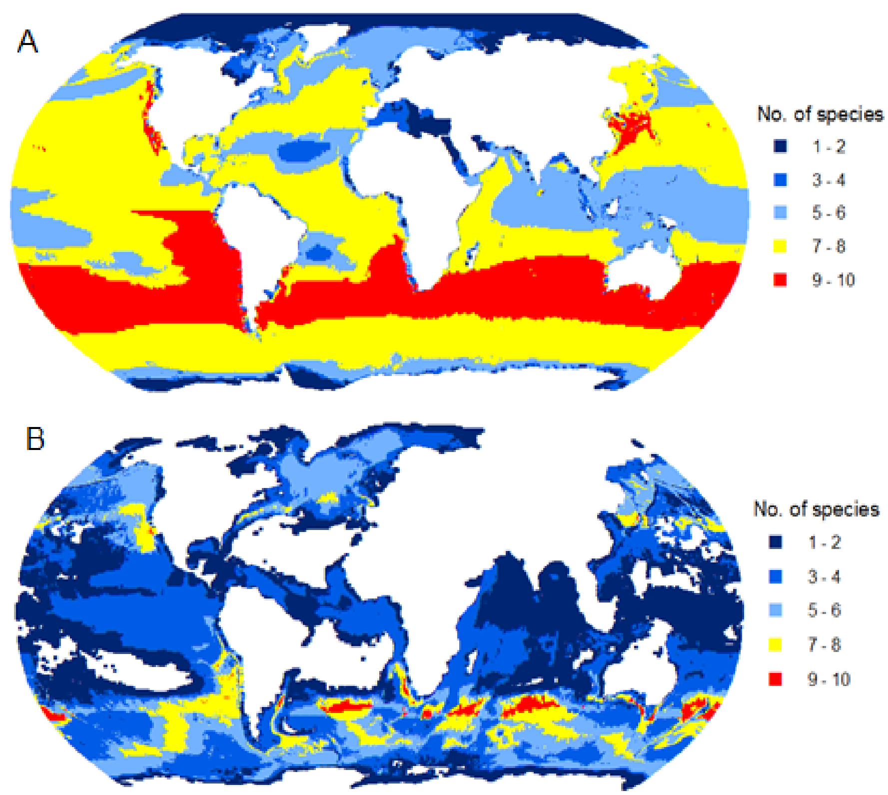



Figure 29. AquaMaps prediction of marine mammal species richness patterns. **Mysticetes**, threshold 0.0 (A) and 0.6 (B).

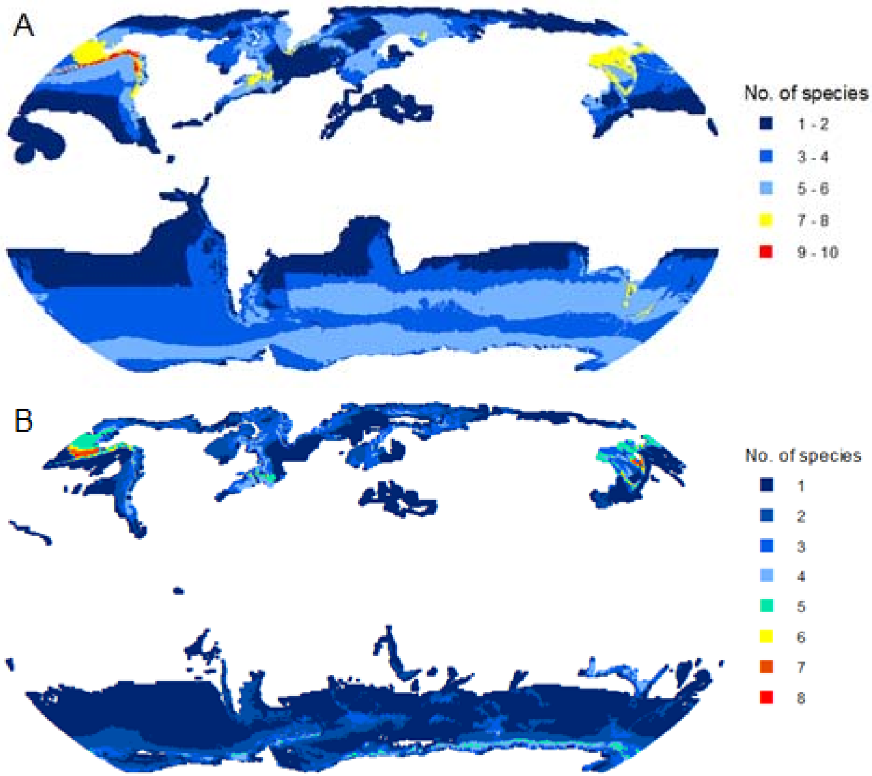


Figure 30. AquaMaps prediction of marine mammal species richness patterns. **Pinnipeds**, threshold 0.0 (A) and 0.6 (B)

### 3.3 Population density and corresponding extent of required areas for KBA thresholds

The population densities of IUCN's binary distribution ranges and Aquamaps' largest distribution ranges were very similar (figure 31). Thus, for the further analysis, AquaMaps is used solely. The mean density for species maximum range is 0.05 animals / km² and for their core area 0.116 animals / km².

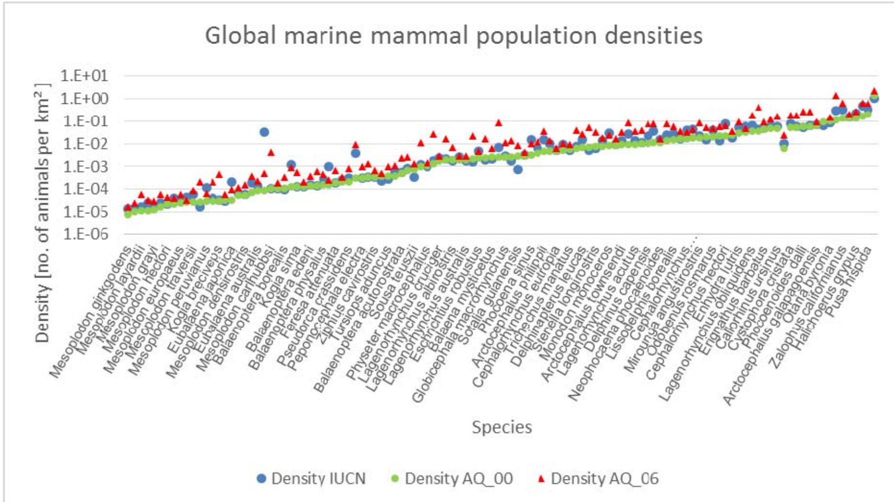



Figure 31. Marine mammals population densities for IUCN's distribution range and Aquamaps' distribution range (threshold >0.0 and >0.6) (ordered by size) (Mean AQ 0.0 = 0.05 animals / km². Mean AQ 0.6 = 0.116 animals / km². Mean IUCN density = 0.049 animals / km²).

A site holding threatened species can qualify under criterion A1 (threatened taxa) as a KBA. For Vulnerable species the given site has to hold at least 1% of its global population and for Endangered or Critically Endangered species, at least 0.5% of its global population. Table 9 shows how large the corresponding areas for all threatened marine mammals would have to be.

Table 9. Required size for a site to hold the percentage of the global population of a threatened marine mammal as demanded in criterion A1 in the KBA standard.

| Species | IUCN status | Threshold | Global abundance | Population Density [animals / km²] | Corresponding area [km²] |
|---|---|---|---|---|---|
| *Phocoena sinus* | CR | 0.5% | 245 | 0.00313 | 392 |
| *Arctocephalus galapagoensis* | EN | 0.5% | 7000 | 0.06095 | 574 |
| *Zalophus wollebaeki* | EN | 0.5% | 14000 | 0.09594 | 730 |
| *Cephalorhynchus hectori* | EN | 0.5% | 7300 | 0.02227 | 1,639 |
| *Neophoca cinerea* | EN | 0.5% | 14780 | 0.02332 | 3,169 |
| *Pontoporia blainvillei* | VU | 1% | 21000 | 0.03288 | 6,386 |
| *Sousa teuszii* | VU | 1% | 500 | 0.00072 | 6,959 |
| *Monachus monachus* | CR | 0.5% | 380 | 0.00016 | 11,678 |
| *Trichechus manatus* | VU | 1% | 7600 | 0.00575 | 13,207 |
| *Phocarctos hookeri* | VU | 1% | 11855 | 0.00776 | 15,274 |
| *Neomonachus schauinslandi* | CR | 0.5% | 1100 | 0.00030 | 18,091 |
| *Enhydra lutris* | EN | 0.5% | 106822 | 0.02883 | 18,529 |
| *Orcaella brevirostris* | VU | 1% | 6200 | 0.00198 | 31,313 |
| *Neophocaena phocaenoides* | VU | 1% | 43000 | 0.01130 | 38,044 |
| *Eubalaena glacialis* | EN | 0.5% | 291 | 0.00003 | 49,953 |
| *Dugong dugon* | VU | 1% | 100000 | 0.01587 | 63,016 |
| *Cystophora cristata* | VU | 1% | 592100 | 0.05240 | 113,002 |
| *Eubalaena japonica* | EN | 0.5% | 1250 | 0.00003 | 183,647 |
| *Callorhinus ursinus* | VU | 1% | 958000 | 0.04885 | 196,092 |
| *Balaenoptera borealis* | EN | 0.5% | 30295 | 0.00011 | 1,385,702 |
| *Balaenoptera musculus* | EN | 0.5% | 11000 | 0.00003 | 1,697,990 |
| *Balaenoptera physalus* | EN | 0.5% | 56276 | 0.00016 | 1,752,832 |
| *Physeter macrocephalus* | VU | 1% | 360000 | 0.00105 | 3,423,774 |

# 4. Discussion

In many parts of the world environmental awareness is rising and people are slowly beginning to understand the harmful effects humanity has on its environment. Many national parks, nature reserves etc. exist today but not every protected area is a large gain for the protection of global biodiversity. Protected areas all are not always located in areas where the most protection is needed. Political and economic reasons for a particular siting are manifold and decision-makers will often feel immense pressure to not intervene with existing uses like commercial fishery when delineating protected areas. This can lead to gaps and redundancies in protected area planning and limit their success in conserving biodiversity (Margules & Pressey 2000). A recent notable example how stakeholder input can bias marine protected area (MPA) planning, is the Australian South-East Marine Region. The Australian Government announced eager plans to establish one of the largest MPA networks worldwide. In the public consultation process the fishing lobby put pressure on decision-makers that MPAs would raise social and economic costs, if they were to interfere with the fishing industry too much. They were successful, as a quote from the Minister for the Environment and Heritage shows: “We have made more than 20 adjustments to boundaries and zoning that will reduce the impact on commercial fishing by more than 90 per cent […] The new MPA network will not prevent prospective oil and gas areas from being explored and developed” (Edgar et al. 2008b). Most of the no-take zones are almost exclusively located in deep sea areas (> 1500 m depth). Relatively low impact fishery (i.e. longlining) and aquaculture are still permitted almost everywhere. Scallop dredging is considered the biggest threat in the area but not affected at all by the new regulations. Even known areas of significance like the Bonney Upwelling, containing regular congregations of Endangered Blue whales (*Balaenoptera musculus*), were not included. Clearly the process was biased. Even though a large MPA network was established, its conservation benefits are highly questionable (Edgar et al. 2008b).

Many stakeholders and governments worldwide have a sincere interest in their own country’s biodiversity, because it is fundamental to our well-being. Because environmental protection does not bring any short-term profits, it is still neglected too often. The existence of a transparent and objective standard, could have two positive effects. Governments can allocate their very limited resources to areas where success is most likely, thus increasing efficiency in conservation planning. Secondly will NGOs, scientists and other governments be informed where areas important for the persistence of global biodiversity are, and this will hopefully create some kind of constructive pressure. Furthermore it will provide a better opportunity to monitor global conservation efforts. However, establishing an identification system that includes all taxa and all ecosystems worldwide is challenging. The taxonomic group of marine mammals reveals these obstacles quite well. Even though they are very large animals, they are underrepresented in many conservation approaches, probably mainly due to a lack of knowledge and the management difficulties in areas beyond national jurisdiction. This thesis can hopefully contribute to evaluate how far-reaching this data paucity is and if this might lead to poor representation in the KBA process as well.

## 4.1 Taxonomy

Our lack of knowledge about marine mammals is reflected in its taxonomy. Even seemingly well-known, charismatic species like the killer whale (*Orcinus orca*), are not fully elucidated yet. It is possible the species consist of different subspecies or even different true species we are unifying under *Orcinus orca*. Furthermore did new genetic analyses lead to changes in marine mammal's taxonomy during the last decades. While some are still debated about, others are broadly accepted, like the split of the dwarf minke whale (Balaenoptera *acutorostrata*) and the Antarctic minke whale (*Balaenoptera bonaerensis*) into two separate species. Since 2000 the International Whaling Commission (IWC) Scientific Committee has officially recognized all northern hemisphere minke whales and all southern hemisphere dwarf minke whales as *B. acutorostrata*, and all Antarctic minke whales as *B. bonarensis* (IWC 2001). This not only changed species numbers, but also puts all abundance estimates and sighting records prior the late 1990s into perspective, as they all refer to a single species and cannot be assigned to one particular species now. There are other species like the Omura's whale (*Balaenoptera omurai*) which was only described recently (2003) and for which basically no information regarding abundance, habitat preferences, diet etc. are available (Wada, Oishi & Yamada 2003). Even more recent, in July 2014, the Australian humpback dolphin (*Sousa sahulensis*) was described and is not even listed at the IUCN yet (Jefferson 2014). Some cases remain unresolved and cause a lot of controversy. This is especially true for the recognition of subspecies, even for the blue

whale (*Balaenoptera musculus*), the largest animal living on our planet. An even more extreme example would be the group of Bryde's whales (*Balaenoptera brydei* and *Balaenoptera edeni*), where it is not known until today how many true species and how many subspecies exist. It might all be one species *B. edeni* with some subspecies, or it might as well be more than two true species.
The confusion in marine mammal taxonomy is not only an indication for the difficulties in studying these animals, but also causes problems because it is fundamental for the assessment of species' conservation status and any conservation and management approach.

## 4.2 Threats for marine mammals

Overall threat levels are higher among marine mammals than terrestrial mammals (Schipper et al. 2008). 22.1% of all marine mammal species assessed by the IUCN are threatened (Vulnerable, Endangered or Critically Endangered) according to the Red List categories. A large portion (38.5%) of species is listed as "Data Deficient" and as 45% of those do have very low global abundances of less than 5,000 animals, some would certainly qualify as threatened as well, once sufficient data would become available. Around 36% of all marine mammals might be threatened opposed to 25% of all terrestrial mammals. Data deficiency is worse for marine mammals as well, with only 14.7% of all terrestrial mammals categorized as data deficient (Schipper et al. 2008). Data deficiency is a serious problem for any conservation management whatsoever, but especially for any identification or conservation approach including criteria and thresholds. It should therefore be a priority for research.

The three marine mammal species seriously facing extinction and thus classified as Critically Endangered, are the Mediterranean monk seal (*Monachus monachus*), the Hawaiian monk seal (*Neomonachus schauinslandi*) and the Vaquita (*Phocoena sinus*). But there are other subspecies individually assessed as Critically Endangered, even though their parent species is not (as much) threatened. The North Island population of the Endangered Hector's dolphin, which was recently recognized a true subspecies (*Cephalorhynchus hectori maui*), is considered Critically Endangered. Even small subpopulations that are no true subspecies are sometimes separately assessed. The

Irrawaddy dolphin (*Orcaella brevirostris*) is listed as Vulnerable, but its Mahakam River subpopulation is considered as Critically Endangered. This examples reveal a great challenge for any identification scheme as they show how a matter of scale can have a large effect on the result. A site holding a population of Irrawaddy dolphins would maybe not trigger a threatened taxa criterion but in the case of the Mahakam River, the single subpopulation of Irrawaddy dolphins alone would probably qualify this site as a KBA and EBSA because of the imminent threat of its extinction. The question is whether or not it makes sense to go deeper than the species and maybe subspecies level. But even then, the differentiation between a subpopulation and an actual subspecies is not trivial. The Northern Island Hector's dolphin was just recently (2002) recognized as a subspecies. Who knows how many more subpopulations will be identified as true subspecies in the future? Aside from the technical question on which scale an important site identification should operate, it is also a question of data availability. The problems with marine mammal taxonomy were already mentioned, assessing every single subpopulation individually would be a major task if not utopian.

Like various other approaches for the identification of important sites, the KBA approach explicitly includes threatened species to increase the focus on species which are already under pressure of any kind. One obstacle in this sub-criterion's threshold is the term "functional reproductive unit". It is defined as the "minimum number and/or a combination of individuals necessary to trigger a successful reproductive event at a site" (IUCN 2014) and is meant to ensure a population is still viable and can be sustained through reproduction. Whereas this functional reproductive unit is maybe obvious for larger terrestrial mammals which can be easily monitored, sexed and where basic mating strategies and habits are known, this is difficult for marine mammals. Virtually no abundance estimates include information about the sex of the animals or the age structure of a group. The overall sex-ratio in marine mammals seems to be close to 1:1 (e.g. Currey and Rowe 2008, Hamner et al. 2012, Australian Marina Mammal Centre 2014), but the age of sexual maturity and the age structure of a population are hard to assess. Furthermore is mating behaviour not well known for most marine mammal species. One exception are pinniped species which are easier to study than any other marine mammal species because they mate on land and are annual seasonal breeders. The vast majority of pinnipeds are polygynous but harem sizes can differ a lot (Atkinson 1997). Male elephant seals

(*Mirounga leonia*) of a high dominance rank can mate with more than 100 females in one single season, whereas in contrast more than two third of all males do not copulate at all. The observed mean harem size was 66 for single-male harems (Modig 1996). But what does this tell us about the number of species necessary to form one functional reproductive unit? The whole concept of functional reproductive units seems difficult to apply and vague, especially for marine mammals.

### 4.3 Marine mammal range sizes and distribution patterns

Range restricted species are particularly vulnerable and therefore covered in the KBA criteria. Originally species were considered range restricted in the KBA standard, if they have a global range of less than 50,000 km² (Langhammer et al. 2007). In the recent publication, species within the lowest quartile of species' range sizes in a globally analysed Class/Order are considered range-restricted or, if this data is not available, species having a global extent of occurrence less than 10,000 $km^2$. But this definition is not a precondition for the application of the restricted range threshold, because this would ignore all widely distributed species with a few areas of high concentration ("clumped populations") (IUCN 2014). Even though the definition of range restrictedness is not a precondition for a species to trigger the criteria, it is very questionable for marine mammals. The 25th percentile for all marine mammals for which AquaMaps ranges exist, is approximately 4,890,000 km². This is very far away from the surrogate 10,000 km², not a single marine mammal species would qualify under that. It is also far away from the threshold of 50,000 km², used in previous publications. The actual threshold (site holding ≥ 20% of global population), which is not linked to the definition whatsoever, would also be difficult to apply for marine mammals.  As shown in 3.3, the size of the potential site would get unfeasible large. Another KBA criteria related to range restrictedness deals with "centres of endemism", which are areas that hold a high percentage of endemic taxa compared to total diversity of species in the same Class or Order and are less than 50,000 $km^2$ in size (IUCN 2014). To trigger the associated threshold, a site has to regularly hold ≥ 33% of species within a vertebrate class with global ranges restricted to this site (IUCN 2014). The Class "*Mammalia"* is a huge class containing more than 5,000 species. Thus this criterion is not applicable for marine mammals.

## 4.4 Global species richness patterns

My distribution maps show a clear concentration of marine mammal species in the southern mid-latitudes (3.2.6). Schipper et al. (2008) used binary IUCN range maps and concluded a concentration of marine mammal species at the equator, especially in coastal areas and an overall low species richness in the southern hemisphere. Considering the results of my own analysis I doubt that this is correct. Maybe the large proportion of wide ranging species built a "background layer" of high species richness. Any coastal, range restricted species on this background would then give the impression of a particular high species richness at coasts at the equator. However, range maps have to be treated with caution either way. They oversimplify the spatial variability of species distribution, creating the impression of homogenous distribution throughout a species' range. A high species richness might also be a sign for marginal habitat where many species' ranges overlap, and should therefore not always be considered an indicator for important habitats (Williams et al. 2014).

## 4.5 Global population estimates

Kaschner et al. (2012) estimated the global coverage of visual cetacean line-transect surveys, the most widespread method to estimate cetacean abundance on a large scale. The enormous area that has to be covered and the low density and detectability makes reliable surveys difficult and requires extensive survey effort. Only ca. 25% of the world's oceans were covered by these surveys in a 30-year period until 2005 and more than half of these areas was only surveyed once or twice, not allowing for any kind of trend analysis. Waters under US and northern European jurisdiction were surveyed intensely, whereas survey effort in the South Atlantic, large parts of the Pacific and of the Indian Ocean was very low. This sampling bias is also reflected in the OBIS-SEAMAP database. Sightings are heavily concentrated in the northern hemisphere, especially in the continental shelf and slope waters (Kaschner et al. 2007).

Reliable global abundance data are required to identify KBAs. My test of surrogates showed how different the computed proportions are, varying between 75% (AOO) to 1.9% (EOO). Even if they worked in the case of the vaquita, they are not comparable at all and would maybe not trigger criteria for species which are more widely distributed and numerous. More data and effort is necessary to validate the use of surrogates in the KBA standard. The wish to make KBAs work for all taxa everywhere around the globe should nevertheless not spoil and weaken its ambition by allowing too much creativity when applying criteria.

## 4.6 Conclusion

Even though the KBA standard is elaborated and might bring great benefit to the conservation of global biodiversity, there are some obstacles which have to be addressed. Criteria and thresholds certainly have to be further tested for applicability in the marine realm and for cases of data deficiency. As this data paucity is true for a large portion of the pelagic realm, this is a serious obstacle to all processes trying to identify important marine areas. Although it is stressed explicitly (e.g. Eken et al. 2004) that KBA identification does not require complete data sets, a minimum of reliable data have to be available. The major problem is the emerging misbalance: Fisheries, deep-sea mining and other industries exploiting the oceans, are not hampered by a lack of knowledge (Weaver & Johnson 2012). Therefore it is of particular importance to think about the handling of missing data in every important area identification process. This is especially true and obvious for a hard-to-assess taxonomic group like marine mammals, but also for many other taxa. For some marine mammal species it is questionable if any kind of thresholds will be applicable in the near future. Even on a small-scale regional level the data might be too scarce.

Furthermore, as with any other identification scheme, describing an area is not enough to protect it. Processes have to be streamlined and tested for success and cooperative behaviour of stakeholders has to be stimulated. Otherwise progress might be very slow or not existent, like in the case of the Sargasso Sea EBSA, where regional fisheries did not know how to react and nothing moved for almost two years (Rochette et al. 2014). In many cases enforcement will be or is the biggest problem. A marine protected area without enforcement is not bringing much benefit to nature conservation. Enforcement is especially difficult in areas where fishing has been or is the main source of income and deeply anchored in the culture and minds of local people (see appendix A).

That said, KBAs could form an excellent starting point for the creation of a worldwide network of protected areas and thus contribute to the global protection of biodiversity.

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## Appendix A. KBA criteria and thresholds.

Table 10. Key Biodiversity Area criteria and thresholds as of October 2014 (IUCN 2014).

| Criteria and Sub-Criteria | Thresholds |
|---|---|
| **A: Threatened biodiversity** | |
| A1: Threatened taxa | (a) Site regularly holds ≥95% of the global population of a globally Critically Endangered (CR) or an Endangered (EN) taxon; OR<br>(b) Site regularly holds ≥0.5% of the global population AND ≥5 functional reproductive units of a globally Critically Endangered (CR) or Endangered (EN) taxon; OR<br>(c) Site regularly holds ≥1% of the global population AND ≥10 functional reproductive units of a globally Vulnerable (VU) taxon; OR<br>(d) Site regularly holds ≥0.1% of the global population AND ≥5 functional reproductive units of a globally Critically Endangered (CR) or Endangered (EN) taxon qualifying under Criterion A of The IUCN Red List of Threatened Species; OR<br>(e) Site regularly holds ≥0.2% of the global population AND ≥10 functional reproductive units of a globally Vulnerable (VU) taxon qualifying under Criterion A of The IUCN Red List of Threatened Species. |
| A2: Threatened ecosystem types | (a) Site holds ≥5% of the global extent of a globally CR or EN ecosystem type; OR<br>(b) Site holds ≥10% of the global extent of a globally VU ecosystem type. |
| **B: Geographically restricted biodiversity** | |
| B1: Geographically restricted species | Site regularly holds ≥20% of the global population and ≥10 functional reproductive units of a species. |
| B2: Centres of endemism | Site regularly holds ≥33% of the complement of species within a vertebrate Class or non-vertebrate Order whose restricted ranges collectively define a centre of endemism. |
| B3: Biome restricted assemblages | Site regularly holds [≥X%] (not defined yet) of the set of species restricted to a particular [biome] |
| B4: Geographically restricted ecosystem types | Site holds ≥20% of the global extent of an ecosystem type. |
| **C: Ecological Integrity** | |
| Outstanding ecological integrity | Site is one of ≤2 sites per region of outstanding ecological integrity characterized by wholly intact species assemblages, comprising the composition and abundance of native species and their interactions. |
| **D: Biological processes** | |
| D1: Demographic aggregations | Site regularly or predictably holds an aggregation representing ≥1% of the global population of a species during one or more key stages of its life |

| | |
|---|---|
| | cycle |
| D2: Ecological refugia | Site supports ≥20% of the global population of one or more species during periods of environmental stress, within a moving window of 100 years. |
| D3: Source populations | Site maintains ≥20% of the global adult population of a species through production of propagules, larvae, or juveniles. |
| **E: Biodiversity through quantitative analysis** | |
| Sites of very high irreplaceability for the global persistence of biodiversity as identified through a comprehensively quantitative analysis of irreplaceability<br>This criterion is applied to species (or other relevant biodiversity elements) that can be used to trigger one or more of the other criteria (A-D). | Site has a level of irreplaceability of 0.90 or higher (on a 0-1 scale), measured by quantitative spatial analysis, and is characterized by the regular presence of ≥ 10 functional reproductive units of a species, or ≥ 5 units in case of geographically restricted EN or CR species.<br><br>The irreplaceability analysis should be based on the contribution of individual sites to minimum representation targets defined to achieve species persistence. |

A site is considered to be a Key Biodiversity Area if it meets one criterion, but each site should nevertheless be tested against all criteria.

## Appendix B. Imminent risk of extinction for the vaquita.

The vaquita (*Phocoena sinus*) is a small porpoise, restricted to the northern Gulf of California, Mexico. With an estimated maximum of 78,400 km² (AquaMaps prediction) it has the smallest distribution range of all marine mammals. This distribution is probably even positively biased and outdated. After the baiji (*Lipotes vexillifer*) is considered to be extinct, the vaquita is now the most critically endangered marine small cetacean and one of the most threatened mammals worldwide (Rojas-Bracho et al. 2006). Because of its extremely threatened status and the interesting process that is undergoing to save it, it shall be illuminated a little more in detail here. The vaquita is listed as Critically Endangered (CR) in the Red List of Threatened Species since 1996. Its total abundance was estimated to be only 245 individuals in 2008 (Gerrodette et al. 2011). The most recent estimate looks even worse, only 97 animals were thought to be left in mid-2014. The main cause of population decline is undisputable bycatch with gillnets, where vaquitas get entangled and drown (CIRVA 2014). D'Agrosa, Lennert-Cody & Vidal (2000) estimated 84 mortalities per year in 1993/94 at only one of three main fishing ports. Using data from fisherman interviews, this number would be lowered to 39 but would still be fatally high either way. The rising decline in the last years is mainly due to a large increase in illegal fishery for totoaba (*Totoaba macdonaldi*) due to increased demand from China, where its swim bladder is considered an expensive delicacy and medical treatment. This does not only affect the critically endangered totoaba population but also the vaquita through bycatch (CIRVA 2014).

**Conservation actions**

The Mexican government invested more than 30 million US$ in conservation measures. In 2005 the "Vaquita refuge" was established and all commercial fishing activities, including the use of gillnets, within were banned. Unfortunately this refuge only contains about half of the population (Fig.20). Another problem was the lack of enforcement. The new refuge reduced the use of gillnets, but violations are still frequent and artisanal fishing, which is an important income for local communities, continues on a large scale (CIRVA 2014). Rodríguez-Quiroz (2010) discovered that approximately 62% of the total catch in the Upper Gulf of California was caught in marine protected areas and 100% of the vaquita refuge was used for artisanal fishing. Outside of the refuge industrial fishing including gillnets is still frequent. The government has been paying compensation to fishers who are willing to stop fishing or switch to vaquita-safe methods in the area. So called fishing permit buyouts reduced fishing pressure a little (Barlow et al. 2010). The government and NGOs also invested in gear-conversion towards vaquita-safe fishery gear. A newly invented net allows fishermen to continue catching shrimp without any bycatch of vaquitas. The success of this is so far disappointing, because fishermen are having problems obtaining trawling permits and by the ironical fact that gillnets block the small trawls (CIRVA 2014).

The situation is critical despite all efforts, and the vaquita's imminent risk of extinction rises global concern. Many NGOs (i.e. IWC, WWF, IUCN) are urging the government to take action (e.g. http://www.whale.org/world-unites-vaquita/). The Mexican government is under international pressure, even more after the insufficient measures from China caused the extinction of the baiji. A gillnet exclusion zone covering the whole species range (figure 20) and a large increase in enforcement capacity to fully stop any further bycatch of vaquita was suggested. This immediate ban and a decent enforcement might be the only chance to save the the vaquita. In December 2014 the Mexican Government published a plan that gives reason to hope. A complete ban of gillnets for two years in the proposed exclusion zone, further compensation for affected fishermen, and the creation of community enforcement groups to assist authorities, are the most promising elements of this plan (IUCN 2015). The crucial point is now, how fast authorities put this plan into practice and if this is fast enough to save the vaquita.

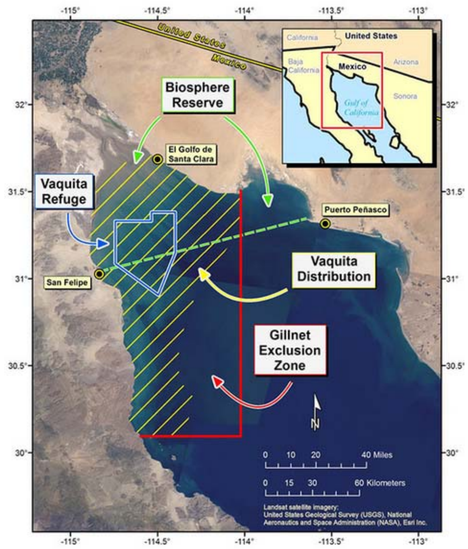


Figure 32. Vaquita distribution, refuge and proposed gillnet-exclusion-zone (CIRVA 2014).

The vaquita's case is a good example, where site-based conservation could be very successful. The species is not directly hunted and its habitat is intact, it is only collateral damage that could be prevented if the fishery is managed accordingly. This is also a good example how a site-based conservation approach can protect more than one species, in this case two critically endangered species, the vaquita and the totoaba. If the vaquita's range would have been identified as an important area, the vaquita refuge maybe would have been larger or would have been established earlier.

## Declaration of originality

I hereby declare that this thesis was entirely my own work and that any additional sources of information have been duly cited.

I certify that, to the best of my knowledge, my thesis does not infringe upon anyone's copyright nor violate any proprietary rights and that any ideas, techniques, quotations, or any other material from the work of other people included in my thesis, published or otherwise, are fully acknowledged in accordance with the standard referencing practices. Furthermore, to the extent that I have included copyrighted material, I certify that I have obtained a written permission from the copyright owner(s) to include such material(s) in my thesis and have included copies of such copyright clearances to my appendix. I declare that this thesis has not been submitted for a higher degree to any other University or Institution.

Freiburg, 19.03.2015, Heiko Schmidt