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Migratory marine species: their status, threats and conservation management needs

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ABSTRACT

1. Migratory marine species (MMS) include many of the world's most charismatic organisms such as marine mammals, seabirds, turtles, sharks, and tuna. Many are now among the most threatened due to the diverse range of pressures they encounter during their extensive movements. This paper shows that 21% of MMS are classified as threatened (i.e. categorized as Critically Endangered, Endangered or Vulnerable). Sea turtles are the most threatened group (85%), followed by seabirds (27%), cartilaginous fish (26%), marine mammals (15%) and bony fish (11%). Taken together 48% of MMS are threatened, Near Threatened or Data Deficient.

2. As well as being threatened they share in common being wide-ranging animals, travelling through the waters of multiple nations as well as in Areas Beyond National Jurisdiction (ABNJ) during different times of the year. This makes their conservation a challenge, requiring coordinated action by many nations, international organizations, Multilateral Environmental Agreements (MEAs) and other stakeholders if their populations are to recover to healthy levels and be safeguarded into the future.

3. Even though they are wide-ranging, long-term studies reveal considerable site fidelity and well-defined habitats for many species and areas. These sites are prime candidates for enhanced management such as via Marine Protect Area (MPA) designations. However, existing management frameworks do not yet contribute sufficiently to MMS conservation, MPA networks need to be expanded to capture key areas, in many cases through the application of new dynamic management techniques such as time area closures.

4. Data on the distribution, abundance, behaviours and threats faced by many MMS are now available. These data should be used to inform the design of effective management regimes, such as MPAs, both within and beyond national jurisdictions. MEAs should ensure a full complement of MMS are included within species listings, and encourage further action to safeguard their populations.

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INTRODUCTION TO MIGRATORY MARINE SPECIES

Animal migration is the relatively long-distance movement of individuals on an annual or seasonal basis, triggered by local climate, food availability or for mating reasons. Migrations are known in many taxa: including *inter alia* birds, mammals, fish, insects and crustaceans. Migratory species are defined under the Convention on Migratory Species as 'the entire population or any geographically separate part of the population of any species or lower taxon of wild animals, a significant proportion of whose members cyclically and predictably cross one or more national jurisdictional boundaries'.[1]

Migratory marine species (MMS) include many of the world's most charismatic marine organisms such as seabirds, sharks, turtles, marine mammals, and tuna. MMS often have wide geographic distributions and perform cyclical movements, of significant but variable distances, between distinct geographical areas (e.g. movements between coastal areas and the open sea), for feeding (e.g. central place foraging in case of seabirds), reproduction (e.g. nesting sites, calving or spawning grounds) or other life-history stages and behaviours. All MMS share in common being highly mobile animals with large home ranges and the ability to travel several tens of kilometres each day. Tracking and photographic studies have revealed that some species such as the Arctic tern (*Sterna paradisaea*) and humpback whale (*Megaptera novaeangliae*) undertake the greatest migrations on earth (Rasmussen *et al.,* 2007; Egevang *et al.*, 2010). These movements take them through the waters and jurisdictions of multiple nations as well as into Areas Beyond National Jurisdiction (ABNJ). These species' international travel routes make their conservation a challenge, requiring coordinated actions by many nations, international organizations, Multilateral Environmental Agreements (MEAs) and industry regulators if their populations are to recover to healthy levels and be safeguarded into the future.

While each species fills its own ecological niche and may exhibit site fidelity in specific areas, they often overlap in distribution and habitat use. Multi-taxa aggregations, particularly species adapted to exploit highly clumped prey, can be found in areas of greatest food availability (Lascelles *et al.,* 2012). A large number of MMS are apex predators feeding at the top of the food chain while others exploit prey at different trophic levels. Many are considered 'marine focal species', having the potential to act as ecological indicators, flagship, or umbrella species (Zacharias and Roff, 2001). The presence, absence, or abundance of MMS can be used to estimate the occurrence of other less easily detectable species and their associated habitats (Caro and O'Doherty, 1999), as well as to understand the composition, state, or function of complex communities (Branton and Richardson, 2010). This makes them important indicators of marine ecosystems, their state reflecting oceanographic processes and anthropogenic pressures.

Removal of MMS from marine systems can have significant impacts on the ecosystem. For example the recent rapid declines of shark populations owing to overexploitation by fisheries have been shown to induce cascading ecosystem changes, such as mesopredator release (Ferretti *et al.,* 2010; Heithaus *et al.,* 2012). On the Scotian Shelf in Canada a vast general change in the ecosystem structure and species composition has been driven by the removal of fish and resulted in the emergence of a completely different set of dominant species, mainly invertebrates (Choi *et al.,* 2004). Heithaus *et al.* (2008) reviewed the ecosystem effects of the loss of marine top predators, many of them MMS, and found both direct mortality effects on the ecosystem (i.e. a possible population boom in the species they eat

[1]Art I, 1, a: CMS

and changes in population size of prey lower in the food chain), but equal, and in some places more significant, behavioural effects (i.e. changes in their prey's predator-avoiding behaviour once they are no longer at risk of being eaten).

The species considered as MMS for this paper were defined as those vertebrates that move between the waters of at least two jurisdictions during the course of their annual cycles. Assessment of which species met this definition were determined by Whale and Dolphin Conservation- for marine mammals, BirdLife International- for seabirds, Maguire *et al.* (2006) - for fish listed as highly migratory, straddling, transboundary or high seas stocks, and IUCN (2013) - for marine turtles; see Table 1 for a further breakdown of migratory traits. Assessment of some species groups, particularly fish, was problematic owing to our limited knowledge of their migratory behaviour and ecology and in some cases generalizations of species traits within Family were therefore needed. Based on this definition 829 MMS from five classes, 22 orders and 68 families were included within this analysis.[2]

This paper follows a pressure-state-response type model and summarizes (1) the conservation status of MMS, (2) the key threats they face, (3) how well existing management regimes cater for their conservation, and (4) makes recommendations for future management improvements.

IUCN RED LIST STATUS

Previous analyses have shown that many marine species groups are now among the most threatened. Schipper *et al.* (2008) reviewed 120 marine mammal species and found 36% to be globally threatened (i.e. categorized as Critically Endangered, Endangered or Vulnerable). Croxall *et al.* (2012) assessed 346 seabird species and found more than half were in decline, they are more threatened than any other groups of birds with 28% globally threatened, 5% in the highest category of Critically Endangered, and a further 10% Near Threatened. IUCN (2013) assessed six of the seven marine turtle species as globally threatened, with the other Data Deficient. Some turtle populations have declined by as much as 80% in the past 20 years (Lewison and Crowder, 2007). Dulvy *et al.* (2014) assessed 465 species of shark and found 16% to be threatened. Camhi *et al.* (2009) named 64 shark species, one-third of all oceanic shark species, as being at risk of extinction due to fishing and shark finning. Some populations of sharks have declined by as much as 99% in the past 35 years (Myers *et al.,* 2007).

The IUCN Red List criteria show that 21% of MMS are classified as threatened, with sea turtles the most threatened group (85%), followed by seabirds (27%), cartilaginous fish (26%), marine mammals (15%), and bony fish (11%). A further 11% of MMS are classified as Near Threatened. A number of species, particularly marine mammals (42%) and cartilaginous fish (33%), are classified as Data Deficient hampering threat assessments. Taken together 48% of MMS are threatened, Near Threatened or Data Deficient, (see Figure 1 for further information). Only 15% of MMS included within this study are currently listed on CMS Appendices; 80% of those included within Annex I and 34% of those on Annex II are threatened.

THREATS AND PRESSURES

MMS share common threats and pressures, their susceptibility to them driven by a combination of key behaviours and movements throughout the year. Several of the threats faced by MMS are site specific while others are more widely distributed and have cumulative effects. Therefore some threats need to be tackled and managed at ocean basin scales (e.g. bycatch managed through fleet-wide mitigation regulation), whereas area-based conservation approaches (e.g. MPAs, seasonal fisheries closures, restrictions on shipping activities) can be applied to overcome others (e.g. overfishing, oil spills, ship strikes, anthropogenic noise). Understanding and modelling the cumulative effects of multiple pressures impacting a given population is a major

[2]The listings include Actinopterygii (bony fishes - primarily salmon, tuna, billfish), Chondrichthyes (cartilaginous fishes - primarily sharks and rays), Aves (seabirds), Mammalia (marine mammals) and Reptilia (sea turtles).

Table 1. Typology of MMS: species are divided into suggested groupings according to aspects of their ecology and capacity for long distance movement. Groupings are based on generalizations of species traits within Family. Assessment of some species groups, particularly fish, was problematic owing to our limited knowledge of their migratory behaviours and ecology

Species grouping	Description	Bony Fish	Cartilaginous Fish	Birds	Marine mammals	Turtles	Total
Very highly migratory species	Species that travel very large distances on a regular basis, e.g. circumnavigating the globe	52	0	32	11	0	**95**
Highly migratory species	Species that travel medium distances on a regular basis, e.g. cross ocean basins	75	66	131	28	7	**307**
Migratory species	Species that travel shorter distances on a regular basis, e.g. crossing between two or more countries	106	102	156	63	0	**427**
Total	**No. species**	**233**	**168**	**319**	**102**	**7**	**829**

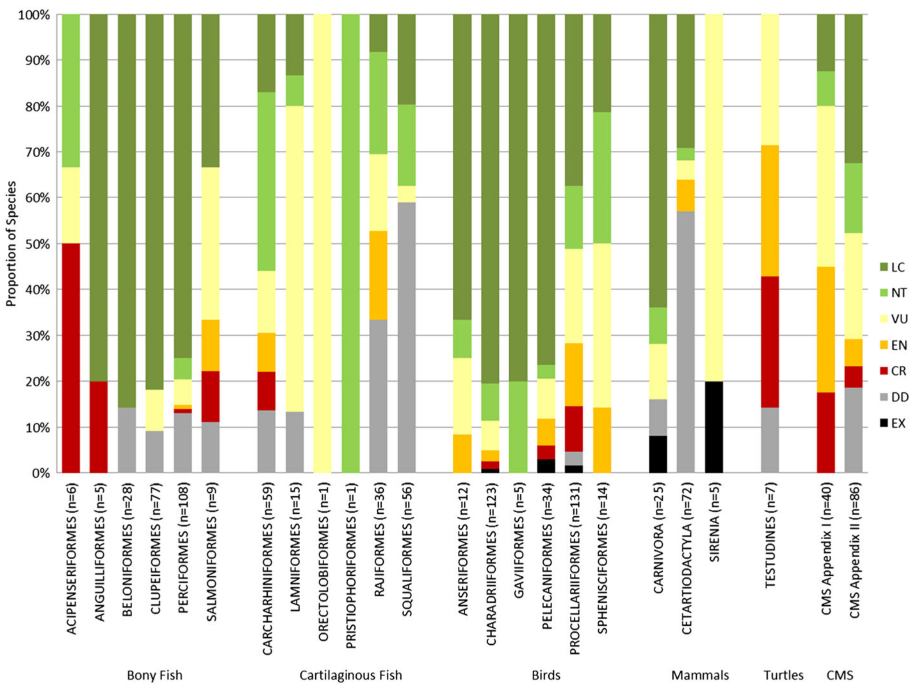

Figure 1. Number of species in each IUCN Red List category and threat level for MMS in selected orders of MMS. Categories: EX, Extinct; DD, Data Deficient; CR, Critically Endangered; EN, Endangered; VU, Vulnerable; NT, Near Threatened; LC, Least Concern. N.B. Anguilliformes includes 12 species which could be classified as MMS, though IUCN Red List information was only available at the time of analysis for five of these. Source: IUCN 2013. The IUCN Red List of Threatened Species. Version 2013.2. <http://www.iucnredlist.org>. (Downloaded 20 Feb 2014).

research and management issue that is crucial for properly assessing the conservation status and needs of that population. Marine planners need to ensure management (i.e. regulations and zoning) is tailored to address the particular threats evident to those species in that place. Understanding exactly what problem needs to be solved is the key to effective management, through individual MPAs as well as through the overall network of sites and other conservation measures.

IUCN threat information for the MMS included within this study highlights 10 primary drivers that were common across species groups (Table 2). Brief summaries of the evidence of impacts resulting from three of these drivers (fishing and harvesting of aquatic resources; pollution; and climate change and severe weather) are provided. Invasives are recognized as a major threat, though they are not summarized here, as this threat is most applicable to birds when in terrestrial environments.

Fishing and harvesting of aquatic resources

Fishing and harvesting of aquatic resources is the biggest threat to MMS, driven by both intentional

Table 2. Top 10 threats to MMS as coded to level 1 threats under the IUCN Red List threats classification. Numbers reflect the number of times that a threat is assigned, though note each species may have multiple threats within a level 1 threat type, hence the totals are greater than the number of species included within the analysis. See IUCN (2014a) for definitions of threats

Threat type	Bony fish	Cartilaginous fish	Birds	Marine mammals	Turtles	Total
Fishing and harvesting of aquatic resources	179	342	160	191	12	**884**
Invasive and other problematic species, genes and diseases	13		221	29	1	**264**
Pollution	62	11	69	116	5	**263**
Climate change and severe weather	31		154	65	5	**255**
Residential and commercial development	23	10	38	18	7	**96**
Human intrusions and disturbance	1	3	48	16	3	**71**
Natural system modifications	31	1	15	14		**61**
Energy production and mining	1		34	7	1	**43**
Transportation and service corridors	7	2	12	21		**42**
Agriculture and aquaculture	10		14	3	2	**29**
Total	**358**	**369**	**765**	**480**	**36**	**2008**

and unintentional take, as well as persecution and control. Incidental capture of non-target species in fishing gear associated with long-line, trawl and gillnet fisheries, or 'bycatch', is a common consequence of marine fisheries worldwide (Zydelis *et al.,* 2009; Lewison *et al.,* 2014). For MMS high mortality rates causing population level impacts have been reported for seabirds (Anderson *et al.,* 2011; Zydelis *et al.,* 2013), sea turtles (Lewison *et al.,* 2004; Moore *et al.,* 2009; Wallace *et al.,* 2010a; Fossette *et al.,* 2014), marine mammals (Read *et al.,* 2006; Moore *et al.,* 2009; Reeves *et al.*, 2013) and sharks (Camhi *et al.,* 2009; Petersen *et al.,* 2009). Pelagic longline fisheries have been estimated to catch more than 200 000 loggerhead (*Caretta caretta*) and 50 000 leatherback (*Dermochelys coriacea)* turtles each year (Lewison *et al.,* 2004). The global fisheries bycatch of marine mammals is estimated at around half a million individuals a year (Read *et al.,* 2006*)*. Longline fisheries are estimated to catch 300 000 seabirds a year (Anderson *et al.,* 2011) and gillnet fisheries a further 400 000 seabirds a year (Zydelis *et al.,* 2013). The South African pelagic longline fishery alone is estimated to catch 70 000 sharks each year (Petersen *et al.,* 2009).

Overfishing (both forage species and predatory species that help aggregate food sources) has been cited as a reason for decline for a number of MMS. Five of eight tuna species are now globally threatened or Near Threatened, blue (*Makaira nigricans*) and white (*Kajikia albidus*) marlins are deemed Vulnerable, and striped marlin (*Kajikia audax*) has been classified as Near Threatened (Collette *et al.,* 2011). Up to 90% of many large, open-water fish have been depleted by industrial-scale fishing over the last half-century (Freitas *et al.*, 2008). The removal of these species can have negative impacts on other MMS, such as cetaceans and seabirds, who rely on them to aggregate prey.

Cury *et al.* (2011) assessed prey abundance and breeding success for 14 bird species within the Atlantic, Pacific, and Southern Oceans and found that when less than one-third of the maximum prey biomass was available seabird productivity was negatively affected. Other examples where overfishing has been cited as a reason for MMS decline include short-beaked common dolphins (*Delphinus delphis*) in Greece (Bearzi *et al.*, 2006), marbled murrelet (*Brachyramphus marmoratus*) in California (Becker and Beissinger, 2006) and a range of top predators in the North Sea (Camphuysen, 2005).

Pollution

Pollution, in a range of forms, caused by agriculture, domestic, forestry, industry, military and urban development is another primary threat to MMS. Oil pollution at sea can have population level impacts on MMS, particularly where spills occur in sensitive areas. Single spills have been recorded as killing up to a quarter of a million birds (García *et al.*, 2003). Cetaceans are at greatest risk when surfacing to breathe (Geraci and St. Aubin, 1990), with recent estimates suggesting more than 1150 cetacean deaths may be linked to the Deepwater Horizon oil spill (NOAA, 2014). Since its advent, plastic in the form of solid waste materials has become ubiquitous in all oceans of the world and entanglement and ingestion of this material by MMS is now a widespread problem. More than 260 species (including turtles, fish, seabirds and mammals) have been reported to ingest or become entangled in plastic debris, resulting in impaired movement and feeding, reduced reproductive output, lacerations, ulcers, and death (Laist, 1997; Derraik, 2002; Wabnitz and Nichols, 2010). More recently, the ingestion of toxic substances leached from plastic fragments, known as microplastics, have been shown to impact MMS (Fossi *et al.,* 2012). Chemicals such as persistent organic pollutants (POP) have also been identified as a threat to a number of marine mammals. These compounds rarely kill individuals directly but impair their immune and reproductive systems, leading to reduced survival and fecundity (Jepson *et al.*, 1999; Hall *et al.*, 2006). Examples of species that have declined as a result of POP include killer whales (*Orcinus orca*) in the Southern Ocean (Noel *et al.*, 2009), beluga whales (*Delphinapterus leucas*) in Alaska (URS Corp, 2010) and seals in the Baltic (Nyman *et al.*, 2003). Underwater noise pollution causes behavioural, acoustic and physiological responses in cetaceans that can lead to impacts on populations (Nowacek *et al.*, 2007). Collisions caused by light pollution from offshore platforms, while difficult to quantify, occur episodically in low-visibility conditions, with up to tens of thousands of seabirds observed in single collision events (Montevecchi, 2006). Light pollution is also an issue for turtles at nesting beaches both during egg laying and nestling emergence (Kamrowski *et al.*, 2012).

Climate change

Climate change and severe weather driven by habitat shifts and alterations, storms and flooding, and temperature extremes also scored highly as a threat to MMS. Climate change is likely to affect MMS in several negative ways by reduced productivity or direct mortality. There is potential for other species to benefit positively from climate change through the availability of new feeding or breeding areas. Species' sensitivity and adaptive capacity depends on a suite of taxon-specific biological and ecological traits; as well as the degree to which they are exposed to changes in climate (Burek *et al.,* 2008; Foden *et al.,* 2013). Known negative impacts include loss of habitat (Moore and Huntington, 2008; Witt *et al.,* 2010), decreased marine productivity (Steinacher *et al.*, 2010), shifts in location of prey items (Forcada and Trathan, 2009; Sydeman *et al.,* 2012; Evans and Bjorge, 2013), and shifts in range and migration routes due to changes in ocean currents and sea surface temperature (MacLeod, 2009; Hazen *et al.,* 2012; Heide-Jorgensen *et al.,* 2012).

As the world strives to reduce carbon dioxide and other emissions via the development of new technologies, such as marine renewable devices, these in turn pose new threats to MMS. Offshore wind farms, wave and tidal energy capture have all been shown to negatively impact MMS either through direct mortality due to collisions (Hüppop *et al.*, 2006; Everaert and Stienen, 2007; Grecian *et al.*, 2010), habitat loss, or increased energy expenditure due to displacement (Desholm and Kahlert, 2005; Fox *et al.*, 2006; Witt *et al.*, 2012). In some cases marine renewables structures can provide new habitats around which marine communities can develop. With commercial fishing unlikely to be permitted within the vicinity of marine renewable devices these areas may therefore become de facto 'no-take zones' in which fish, and consequently piscivorous MMS, thrive (Inger *et al.*, 2009).

EXISTING MANAGEMENT FRAMEWORKS

MMS occur within territorial waters (i.e. to 12 nautical miles), Exclusive Economic Zones (EEZ – to 200 nm) and in ABNJ meaning they are subjected to varied, and changing legislation and management frameworks during different parts of their annual cycles. States have sovereignty and sovereign rights over the animals that are present in areas under their jurisdiction (i.e. their territorial waters and EEZ) at any point in time[3] though they may be subject to international legal obligations with respect to conservation and sustainable use.

[3]United Nations Convention on the Law of the Sea 1982, Part V, Article 56 1a.

In EEZs MPAs may be designated under national legislation in conformity with the United Nations Law of the Sea, and currently global coverage stands at 2.8% (IUCN and UNEP-WCMC, 2013), still far below the Convention on Biological Diversity (CBD) target of 10% protection by 2020. Despite some recent rapid progress such protection is practically non-existent in most ABNJ (0.14% global coverage; IUCN and UNEP-WCMC, 2013), where the lack of legal frameworks for making and enforcing MPA designations (Ardron *et al*., 2008) hampers conservation efforts for MMS and limits the effectiveness of MPA networks for their conservation. Other conservation management measures besides MPAs can be governed and implemented by authorities such as fisheries bodies (e.g. Regional Fisheries Management Organizations (RFMOs)), the International Maritime Organization, or the International Seabed Authority, and to some extent Multilateral Environmental Agreements (MEAs) including Regional Seas Conventions. MMS therefore come under the successive sovereignty of each of the states situated along their migration route and under the rules and regulations of international authorities working in ABNJ. Conservation measures only taken by some of these states or authorities may therefore be of little overall benefit to MMS unless others follow suit; a lack of compliance or management by one state undermines the conservation work of another. International cooperation among all states and authorities along the same migration route is therefore essential if successful conservation outcomes are to be achieved (CMS, 2013).

Multilateral Environmental Agreements (MEAs) with a specific MMS conservation remit

At global and regional levels many MEAs include species lists for which conservation actions are prioritized. Many additional MMS, not currently included, may qualify for listing under these MEAs and should be formally considered for such action to complement measures implemented by other management bodies such as RFMOs. Many MEAs also include MPA targets that will together form networks of connected, representative and well-managed sites. In many cases MEAs promote other management measures for the conservation of marine species, however, they often fail to outline what these are, who will implement them, and how information can best be shared and communicated between agreements and industry.

The Convention on Migratory Species (CMS) is the prime international legal instrument to address migratory species conservation, covering both endangered migratory species (Appendix I) and migratory species whose conservation status requires international cooperation to maintain or improve (Appendix II). Resolutions promulgated under the convention encourage CMS Parties – including their flag vessels in ABNJ – to minimize threats to migratory marine species with respect to by catch, ocean noise, and adverse impacts on cetaceans. These resolutions, complemented by others addressing marine debris, ecological networks and connectivity, climate change, and the CMS Global Programme of Work for Cetaceans, form a suite of measures that CMS Parties may implement individually or collectively. The convention has provided the basis to conclude several additional global or regional legally binding agreements relevant to MMS (e.g. African-Eurasian Waterbirds Agreement (AEWA); Agreement for Conservation of Albatross and Petrels (ACAP); Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic Area; Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas; Wadden Sea Agreement) as well as a number of less formal Memorandums of Understanding (MoU) (e.g. Dugong, Mediterranean Monk Seal, Pacific Islands Cetaceans, Migratory Sharks, West African Aquatic Mammals, Marine Turtles of Atlantic Coast of Africa, Indian Ocean and Southeast Asia Marine Turtles). For endangered MMS Contracting Parties to CMS and its Agreements and MoU signatories strive towards strictly protecting these animals, conserving or restoring the places where they live, mitigating obstacles to migration and controlling other factors that might endanger the species.

UNCLOS lists many MMS (e.g. tuna and tuna-like species, marlin, sailfish, swordfish, ocean going sharks, dolphins and other cetaceans) as Highly Migratory Species (Article 64 and Annex 1), as a straddling stock or as a transboundary stock (Maguire *et al.*, 2006). Straddling stocks range both within an EEZ as well as in ABNJ, while transboundary stocks range in the EEZs of at least two countries. Based on these classifications a stock can be both transboundary and straddling.

Management effectiveness of existing approaches

Seabirds are addressed by a number of MEAs and international processes. Those most actively undertaking work include ACAP (29 species), EU Bird's Directive (all seabirds in EU), OSPAR Convention (nine species), AEWA (78 species), Barcelona Convention (14 species), CMS (20 seabird species on Annex I; 50 on Annex II), Bern Convention (more than 30 species), HELCOM (11 species), Bucharest Convention (three species), Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) (seven species), Conservation of Arctic Flora and Fauna (CAFF) (three species), North American Agreement on Environmental Cooperation (one species), and CITES (six species). Other MEAs that have this remit but are not yet active include the Nairobi Convention (47 species), Jeddah Convention (lists not yet provided by contracting parties), Abidjan Convention (considering adding a species list), and Cartagena Convention (five species).

More than 50 shark species are included as Highly Migratory Species under Annex I of UNCLOS but only a handful currently enjoy species-specific protection under the world's RFMOs, and many of these have yet to be implemented domestically (Dulvy *et al.,* 2014). The CMS Migratory Sharks MoU so far only covers seven sharks, yet there may be more than 150 chondrichthyans that regularly migrate across national boundaries (Dulvy *et al.,* 2014). Despite two decades of effort, just 17 sharks and rays are listed by the Convention on International Trade in Endangered Species (CITES), with five of these listed in 2013 (Mundy-Taylor and Crook, 2013; Vincent *et al*., 2013).

The International Convention on the Regulation of Whaling deals with management and conservation of large whales (all baleen whales, and the sperm whale) and permits the designation of sanctuaries.[4] In designating a sanctuary under the auspices of the Convention, the only regulatory measures that can be taken involve prohibiting the harvest of all large whale species at any time from a specified geographic area, irrespective of their conservation status. Other threats, such as habitat loss and pollution, are not covered (Gerber *et al.*, 2005; Zacharias *et al.*, 2006). Despite these challenges, some sanctuaries have obtained government and charity funding to research and develop conservation initiatives for migratory marine mammals.

How well MMS are covered by existing MEAs and MPAs has been reviewed on several occasions (de Klemm, 1994; Hooker and Gerber, 2004; Hoyt, 2011; Davies *et al.,* 2012). These studies conclude that MPAs are effective tools for MMS conservation, but that current MPA networks do not capture enough of the key areas used by MMS. For example the Natura 2000 Network in European Union (EU) waters has established a network of more than 100 Special Areas of Conservation used by bottlenose dolphins and/or harbour porpoises. However, these areas have been criticized for their small sizes and being limited to only two cetacean species (Hoyt, 2011). The ICES working group on marine mammal ecology examined 344 existing or declared MPAs designed for, or of interest to, marine mammals (ICES, 2011). It was concluded that in a majority of cases the scientific basis for establishing these MPAs, their generally small size in relation to home ranges of species and current lack of appropriate management plans represented strong limitations to their effectiveness.

In general, existing MPAs have been designated primarily for reasons other than MMS conservation, however, it is still possible to determine how often MMS use MPAs, though few studies have assessed this, and those that have produce mixed results. In the northern Atlantic a network of high seas MPAs has been declared under OSPAR to promote the conservation of marine biodiversity from the sea bed

[4]Article V International Convention on the Regulation of Whaling 1946

to the water column, including several taxa of MMS (O'Leary *et al.,* 2012), but the extent to which management actions are implemented is unclear. The California marine sanctuaries have been shown to provide reasonable protection for seabirds as a group (Nur *et al.*, 2011) but offer little protection to Hawaiian albatrosses foraging in the area (Hyrenbach *et al*., 2006). Studies of Namibian MPAs, designed using seabird tracking data and designated specifically for seabird conservation, have shown that African penguins (*Spheniscus demersus*) have responded positively to MPA designation (Ludynia *et al.,* 2012). Studies of humpback whale using Glacier Bay in the North Pacific and Stellwagen Bank National Marine Sanctuary in the North Atlantic have shown there are years when no or few whales have been present in these MPAs owing to changes in prey distribution (Hoyt, 2011). The Pelagos Sanctuary for Mediterranean Marine Mammals was established in 1999 to protect cetaceans in the waters of France, Italy and Monaco (Notarbartolo di Sciara *et al.*, 2008), but there are concerns about its effectiveness (Notarbartolo di Sciara, 2011). For other MMS, modelling studies have demonstrated that no-take reserves can effectively protect fish that migrate in and out of the reserve, but whether the reserve is beneficial or not depends on the life stages protected by the reserve, the migratory behaviour of the fish, and the level of fishing effort and size-selectivity of the fishery outside the reserve (Guénette *et al.,* 2000; Apostolaki *et al.,* 2002; West *et al.,* 2009). In Mexico significant and rapid increases in the abundance of striped marlin was noted during two separate multi-year closures of the EEZ to longline fishing (Jensen *et al.,* 2010). Tracking studies of larger sharks have revealed that individuals often move considerable distances over short periods and may not reuse the same areas until weeks, months or even years later (Holland *et al.,* 1999; Heithaus *et al.,* 2002). However, at Glover's Reef Marine Reserve, off the coast of Belize, Caribbean reef shark (*Carcharhinus perezi*) were shown to spend two-thirds of their time inside the Reserve (Chapman *et al.*, 2005). Research at the Great Barrier Reef Marine Park showed that the time reef sharks spent in the MPA varied seasonally (Knip *et al.,* 2012).

ADDITIONAL MANAGEMENT RECOMMENDATIONS

Data on distribution, abundance, behaviours and threats should inform the design of effective management regimes for MMS. Management decisions should be guided by (1) the location of key areas, (2) when these areas are used by MMS, (3) what variables are explaining presence of MMS in a given area, (4) what threats may be impacting the MMS and associated habitats and processes, (5) what management actions are needed to address these threats, and (6) how any management intervention can best be monitored to assess effectiveness.

Data on MMS should become an integral part of management and decision-making in the marine environment particularly through fisheries, shipping, and offshore energy (renewable and extractive) regulations. MEAs should acknowledge the potential of MMS as indicators, and use data on their abundance, distribution, biology and ecology to guide the location of MPAs and other forms of Marine Spatial Planning. Comprehensive management approaches accounting for both cumulative human impacts and trade-offs among multiple stressors must be applied in planning the use of marine resources.

For effective conservation, populations of MMS should be managed as single units, irrespective of jurisdictional boundaries. An essential aspect of ecological management is the conservation of suitable habitats along the full length of migration routes. Management and protection of many MMS may be most efficiently and effectively achieved by coordinated efforts across national boundaries, adopting ecosystem-wide management measures combining both area-based and ocean basin scale regulation, aimed at targeting and tackling multiple threats. Without planning and implementation made at the international level it will be impossible to achieve effectively managed and monitored networks of sites that fulfil the goals of connectivity, representativity and resilience, as specified by CBD's Aichi Target 11. Managing MMS at the international level will require shifts towards more flexible management and monitoring regimes, using our understanding and modelling of ecosystem dynamics to adapt to the changing nature of the ocean. See Table 3 for details of key habitats, threats and management needs for MMS.

Fisheries management

Management of fisheries ultimately affects the susceptibility of species to threats such as targeted take, accidental bycatch and overfishing of the prey base. Bycatch is a significant problem leading to the decline of ecologically, economically and culturally important species. Action must be taken at an international level (within RFMOs and other fisheries management bodies) to reduce MMS bycatch in fisheries and ensure that ecosystem approaches underpin implementation of fisheries management. Alterations to fishing methods, recognition of targeted species, increased observers, increased data collection and the application of time–area closures are all necessary measures to reduce bycatch. The consumption needs of MMS should be built into fish stock assessments and setting of catch limits to ensure enough food is available to sustain MMS populations (Cairns, 1992).

Where and when to protect or manage

In general, to best protect a specific population, the optimal protected area would encompass that population's year-round distribution. However, in the case of MMS this may encompass entire ocean basins, making it politically and practically unrealistic. The question therefore becomes whether limited spatial protection in specific parts of a species' range, such as breeding or feeding grounds, is worthwhile? Identifying the benefit of partial-range protection requires ongoing monitoring, both before and after MPA designation, with appropriate baselines set against which to assess management effectiveness. Unfortunately, assessing benefits of MPA designations for species and ecosystems is often hampered by a lack of both long-term monitoring programmes and measurable goals and objectives.

Table 3. Main habitat types for MMS, the threats, responsibility, and management needed within them. Species values reflect the percentage of each species assigned to each habitat type, non-marine habitats are not shown but are included within percentage calculations. NJ: within national jurisdiction; ABNJ: Areas Beyond National Jurisdiction. See IUCN (2014b) for definitions of habitats

Habitat type	Major threats	Species groups effected	NJ vs ABNJ	Static vs Dynamic	Major management actions
Marine intertidal (area of shore between the extremes of high and low tides)	fishing and harvesting of aquatic resources; pollution; climate change and severe weather; residental and commercial development; human intrusions and disturbance; energy production and mining	Turtles (24%), Marine mammals (12%), Birds (7%), Bony fish (5%), Cartilaginous fish (4%),	NJ	Static	Spatial management; temporal management
Marine neritic (below extreme low tide nearshore to edge of continental or oceanic island shelf)	fishing and harvesting of aquatic resources; pollution; climate change and severe weather; residential and commercial development; human intrusions and disturbance; energy production and mining; transportation and service corridors	Birds (68%), Bony fish (55%), Cartilaginous fish (50%), Turtles (40%), Marine mammals (28%)	NJ	Mostly Static	Spatial management; temporal management; dynamic management; general regulations
Marine oceanic (deeper than and beyond the continental or island shelf)	fishing and harvesting of aquatic resources; pollution; climate change and severe weather; energy production and mining; transportation and service corridors	Marine mammals (41%), Cartilaginous fish (30%), Bony fish (18%), Turtles (16%), Birds (13%)	NJ and ABNJ	Static and Dynamic	Spatial management; temporal management; dynamic management; general regulations
Marine deep benthic (deep ocean floor zone)	fishing and harvesting of aquatic resources; pollution; energy production and mining	Cartilaginous fish (9%),	NJ and ABNJ	Static	Spatial management

Scientific consensus exists on the use of migratory species data to support MPA design. MPAs, even on quite small scales, can make an effective contribution towards the conservation of MMS and as such are considered a key tool in their conservation. However, in order to achieve adequate species conservation, MPAs must be used in conjunction with additional and species-specific management measures beyond their boundaries, as part of an ecosystem-based approach within zoned management planning (Halpern *et al.,* 2010; Guidetti *et al.,* 2013). Where required, effective no-take marine reserves need to be large (Claudet *et al.*, 2008) and encompass not only diverse habitats (e.g. ocean reefs, seagrass flats, lagoons) but also the areas that connect them. Perhaps the most important feature of MPA establishment is that designated areas are truly important to species and ecosystems, rather than simply being designated on a mainly political and economic basis to reach MEA targets (Devillers *et al.,* 2014).

CBD Aichi Target 11 states that networks of MPAs should be developed 'especially in areas of particular importance for biodiversity and ecosystem services'. This suggests that some measure of what is important is required, and indeed the CBD has tried to guide this via the establishment of criteria and a process to identify the most Ecologically or Biologically Significant Marine Areas (EBSAs) in need of protection (Dunn *et al.*, 2014). A range of criteria and approaches exist for prioritizing sites for protection and management (Roberts *et al.*, 2003; Gilman *et al.*, 2011). Some of the most commonly used in a MMS policy context include Key Biodiversity Areas (Bass *et al.*, 2011), Important Bird Areas (BirdLife International, 2010; Delord *et al.*, 2014), Vulnerable Marine Ecosystems (Ardron *et al.*, 2013), Regional Management Units for marine turtles (Wallace *et al.*, 2010b), Seasonal and Dynamic Management Areas for cetaceans (Asaro, 2012) and Important Marine Mammal Areas as proposed by the IUCN Task Force on Marine Mammal Protected Areas. Ultimately these aim to provide an ecological, biogeographic or oceanographic rationale for site selection and boundaries. Until now there has been limited engagement and collaboration between these approaches, making it difficult to achieve consistency, allow comparison at a range of scales, and ensure they inform EBSA and other management processes in the most useful way.

Concentrations of globally threatened, range- or biome-restricted species are clear conservation targets. Most MMS also have certain critical periods or areas in their life cycles in which they congregate for a number of reasons (e.g. staging, foraging, breeding, migration bottlenecks). These areas often play an irreplaceable role in maintaining species populations, but also make species particularly vulnerable to threats during these times. Such areas lend themselves well to traditional MPA-type designations by being able to safeguard large proportions of populations (and sometimes species diversity) within relatively discrete areas that can be easily managed through restrictions on harmful activities (Hooker and Gerber, 2004; Hooker *et al.,* 2011). Trade-offs and different analyses may be required to determine how best to capture both high individual species density and species richness, as these aspects are not always found in the same place (Kaschner *et al.,* 2011).

Significant advances have also been made in the compilation and analysis of MMS data to support the justification and monitoring of MPAs. These include combining data into habitat models, for example comparing distribution predictions from at-sea surveys and individual tracking data (Louzao *et al.*, 2009; Mannocci *et al.*, 2014), and abundance estimates derived from spatial models and design-based line transect methods (de Segura *et al.*, 2007). Spatiotemporal models of the spawning migration of Icelandic capelin (*Mallotus villosus*) have been developed using sea surface temperature and currents as explanatory variables (Barbaro *et al.,* 2008). Coupling data on species distribution, abundance and movement from at-sea surveys and satellite tracking devices with remotely sensed oceanographic environmental data are now becoming common place (Shillinger *et al.,* 2008; Block *et al.,* 2011; Louzao *et al.*, 2011; Oppel *et al.*, 2012; Mannocci *et al.*, 2013). These types of modelling approaches are critical in predicting distributions in unsurveyed areas, capturing the dynamic changes occurring within the marine environment in MPA design, as well as aiding conservation planning under future climate scenarios.

The temporal and spatial movements of MMS can often be targeted at dynamic aspects of the marine environments and associated oceanographic variables such as frontal regions and areas of upwelling (Hyrenbach *et al.,* 2000). These sites are of critical importance to species during particular life-history stages but are limited in their use to a few days, weeks or months each year. To include these areas within management frameworks will either require managing over a large area that captures all interannual variability (recognizing that at any given time some parts of this larger area will be less important) or developing predictive models that show how these features move around, with management tracking these features. Currently, most management frameworks make it difficult to rapidly adjust management needs and regimes during the year, resulting in less effective management of these mobile features. Dynamic ocean management (DOM) responds frequently to spatial and temporal changes in the marine environment and is emerging as a means of marine resource management that can reduce conflicts arising as a result of competing objectives (Hobday *et al.,* 2014). DOM requires scientific, technological, management, legal, and policy capacity across a range of elements. To date, this approach has been applied in a limited number of situations around the world for MMS conservation, but has been used effectively to manage human activities affecting MMS, such as direct exploitation of tuna (Hobday and Hartmann, 2006; Hobday *et al.,* 2011), turtle bycatch (Howell *et al.,* 2008) and ship strikes (Van Parijs *et al.,* 2009; Asaro, 2012). The widespread integration of DOM into management frameworks and the identification of appropriate species for this technique are urgently needed.

The concept of sister sanctuaries (Reeves, 2009) has been a starting point for establishing some degree of cohesion between widely separated sites along the migration routes of some MMS. In 2011 a three-way partnership between the Agoa Sanctuary (around Martinique and Guadeloupe), the Stellwagen Bank National Marine Sanctuary (USA) and the Marine Mammal Sanctuary (Dominican Republic), was established to link the breeding and feeding grounds for humpback whale in the North Atlantic (Hoyt, 2011). Similar agreements have been proposed for humpback whale sites in the North Pacific (Reeves, 2009). In 2009, the US and Kiribati agreed on a sister sanctuary relationship between two large MPAs important for MMS, the Phoenix Islands Protected Area and the Papahanaumokuakea Marine National Monument. The East Pacific Conservation Marine Corridor (formerly the Eastern Tropical Pacific Seascape) is an attempt to link existing MPAs and coastal parks of Colombia, Panama, Costa Rica and Ecuador to protect MMS. In the western south Pacific, a number of countries (e.g. American Samoa, Cook Islands, Fiji, French Polynesia, New Caledonia, Niue, Palau, Papua New Guinea, Samoa, Tokelau, Tonga, Vanuatu) have established sanctuaries used by MMS, which comprise a loose network through Pacific agreements (Hoyt, 2011). Enhancing the overall value of such networks relies on improved capacity building, harmonization of best practices, as well as data and knowledge sharing among scientists and managers working in the same region.

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