Managing Noise through Marine Protected Areas around Global Hot Spots

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ABSTRACT

Anthropogenic noise sources may interact cumulatively or synergistically with other noise sources or with other threats facing cetaceans, though such impacts will be hard to determine, especially as noise could cause effects over thousands of kilometers. Marine Protected Areas (MPAs) are one of the most effective means to protect cetaceans and their habitat from such impacts. Models of cetacean distribution can identify cetacean "hot spots" globally, which can be used to determine the location of suitable MPAs, both in coastal areas and on the high seas. A case study of the Gully MPA off Nova Scotia is discussed and its policy toward seismic surveys. MPAs must be large enough to safeguard essential habitat and migration corridors and to accommodate highly mobile species. Management schemes should ideally encompass whole ocean basins, and a global network of marine reserves ensuring connectivity between them is needed. MPAs must be well-managed with strict, enforced regulations extending toward the entire ecosystem if they are to achieve their purpose. Alternatives to MPAs such as diverting shipping lanes and area/time closures for noise sources or other threats may be appropriate, though may not adequately safeguard the ecosystem.

KEYWORDS: Noise, management, ecosystem, regulations, sanctuaries, conservation, mitigation, MPAs, cetacean, global hot spots

INTRODUCTION

The threats confronting marine mammals, such as fisheries by-catch, habitat degradation, chemical pollution, whaling, vessel strikes, and global warming, do not often occur in isolation. These threats may interact cumulatively or synergistically. For instance, human impacts on marine ecosystems such as over-fishing, eutrophication, climate change and ultraviolet radiation interact to produce a magnified effect (Lotze and Worm, 2002; Worm *et al.*, 2002). Anthropogenic noise could similarly interact with marine mammal by-catch or ship collisions, preventing animals from sensing fishing gear or oncoming vessels, making them more vulnerable to injury or death, as some evidence seems to indicate (Todd *et al.* 1996; Andre *et al.*, 1997). This could theoretically either occur through masking or because noise has previously caused hearing impairment. Multiple sources of noise could also interact cumulatively or synergistically, such as when several seismic surveys are undertaken in adjacent or even the same areas.

Studies on fish have shown that '…failure to properly account for interactions occurring between stressors can lead to substantial underestimation of stressor effects, particularly as stressor intensity rises' (Power 1997). Thus, responsible management should take into account such cumulative and synergistic effects, yet these impacts are very difficult to determine and assess. This is especially the case for cetaceans, which spend most of their lives out of our sight underwater, and for noise, where impacts could occur over ranges of thousands of kilometers. Marine protected areas (MPAs) offer one of the most effective means to protect cetaceans and their habitat from the cumulative and synergistic effects of noise as well as from other anthropogenic stressors.[1] The UN Millennium Project aims to initially have 10% of the oceans set aside in marine reserves, with a long-term goal of 30% (Roberts *et al.*, 2006).

Not only are MPAs considered important for the conservation of cetaceans, but cetaceans can provide benefits for MPAs (Hooker and Gerber, 2004; Hoyt, 2005). Cetaceans can serve as indicator species and

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[1] The general term "marine protected area" is considered to include parks, reserves, preserves, sanctuaries, and refuges. I use it here as an area which has been legislated to protect and manage all or part of the enclosed ecosystem, not just a single species or group of species.

provide a monitoring system for problems such as chemical pollution, overfishing and changes in environmental conditions (Hoyt, 2005). The distribution and relative abundance of marine predators, such as cetaceans, can give a sense of prey distributions and ecosystem processes (Hooker and Gerber 2004). In the same way that dolphins guided tuna fishermen to tuna schools, cetaceans can guide us to concentrations of marine life. Cetaceans, along with other large and mobile animals like albatrosses, penguins, pinnipeds, and turtles, seek out places that are rich in prey (Roberts *et al.*, 2006).

DETERMINATION OF SITING FOR CETACEAN MPAs

As most cetacean distributions are poorly known, especially on the high seas, models to map global cetacean distributions have been developed (Redfern *et al.*, 2006). For instance, Kaschner *et al.* (In Press) used long-term averages of three habitat variables (depth, sea surface temperature and ice edge) to map the world-wide distributions of 115 marine mammal species. Species were assigned to habitat categories defined by these three variables based on published habitat preference data. This ecological niche model was called the RES (Relative Environmental Suitability) Model (Kaschner *et al.*, In Press).

Validation of the model using large-scale, long-term data sets from well-studied species showed that the distributions predicted by the model were very similar to the published ranges for most species (Redfern *et al.*, 2006; Kaschner *et al.*, In Press). Also, there was close correspondence between the model and the data sets in the species' variability of occurrence. This model is best used to answer broad questions about large-scale species distributions, however, as more detailed correlates between environmental features and species' occurrence (like warm core rings, etc.) are not incorporated. In its initial form, RES modeling also ignored factors such as intra- and inter-specific competition, seasonality, migration and changes in habitat preferences with different life cycle phases (Kaschner *et al.*, In Press), however, some of these are being incorporated at the moment and will further improve predictions. Its principal application is for species and areas of the world which are poorly studied. In these cases, RES modeling can help delineate MPAs or critical habitat on larger geographic scales by generating indices of biodiversity and species richness for various areas. For instance, a map of global marine mammal "hot spots," defined by areas that represent predicted highly suitable habitat (i.e. RES vales > 0.4) for a large number of species, could be produced using RES modeling (Fig. 1). Such modeling can be an important tool in mitigating anthropogenic impacts like noise, by noting which areas are likely to have sensitive species. Indeed, currently RES modeling and predictions are being incorporated into a risk mitigation tool to be used by the Royal Navy to plan future sonar exercises (Kaschner, pers. comm.). For seismic operations, such predictions may be used to anticipate which mitigation tools might be most effective, based on the species that are likely to be present.

Whitehead *et al.* (In Prep.) developed a simpler method for determining which global areas represented areas of highest marine mammal diversity. Here, all species' normal ranges were digitized in 1º squares of latitude and longitude, based on information from field guides. Freshwater species, polar bears, sirenians, and otters were excluded. This method produced 10 broad areas of global high marine mammal diversity or "hot spots" (Fig. 2). In this method, diversity in coastal areas was probably overestimated, while diversity in the temperate Southern Hemisphere was probably underestimated (Whitehead *et al.*, In Prep.).

Such maps of global marine mammal "hot spots" can be compared to maps of "hot spots" of other species, such as billfish and tuna (Fig. 3). Billfish and tuna "hot spots" also correlate with predator diversity and formaniferan zooplankton diversity (Worm *et al.*, 2005). In this map, 50 hot spots of species richness, species density or both were found, representing 6.6% of global ocean area. Some of these same "hot spots" seemed to show up in predictions of cetacean distribution from RES models (Fig. 4).

MPAs ON THE HIGH SEAS

Clearly cetaceans are not just distributed around coastlines or within the EEZs of countries. About 80% of all cetacean species either spend most of their lives or have at least some essential habitat on the high seas (Hoyt 2005). Thus, MPAs or marine reserves must be located offshore as well, though MPAs have yet to be used on the high seas. Jurisdictional, management, compliance and enforcement issues become much more challenging in international waters.

Another frequent criticism of using MPAs on the high seas is that species there are too mobile to be able to be sufficiently safeguarded. However, species can be protected where and when they most need it, such as at breeding sites, nursery grounds or migration corridors, or when otherwise aggregated or vulnerable to anthropogenic effects (Roberts *et al.*, 2006). Such wide-ranging species may also require dynamic MPAs, where boundaries are delineated by the location of large-scale oceanographic features (Hyrenbach *et al.*, 2000). Environments which support highly mobile species or are especially vulnerable to damage should warrant larger MPAs (Roberts *et al.*, 2006).

MPAs AND OCEAN BASIN MANAGEMENT

To fully protect cetaceans and their habitats from wide-ranging anthropogenic noise and other impacts, a management scheme should encompass entire ocean basins. Anthropogenic noise is trans-boundary in nature. Seismic noise can flood through a region of almost 300,000 square kilometers, raising noise levels two orders of magnitude, continuously for days at a time (IWC, 2004). As such, a network of pelagic MPAs is required. In recognition of this, the Convention on Biological Diversity's 7th Conference of the Parties in 2004 committed to the establishment of a global network of marine protected areas by 2012 (Roberts *et al.*, 2006).

When MPAs are tied to static bathymetric features like submarine canyons (as the below Gully MPA case study represents) or seamounts, reefs, hydrothermal vents and shelf breaks, protection is more straightforward. However, many important pelagic habitats are not fixed in space or time. Such areas include: 1) persistent hydrographic features such as currents and frontal systems; and 2) ephemeral hydrographic features like upwellings and eddies (Hyrenbach *et al.*, 2000). Dynamic boundaries and greater buffer zones are needed to protect these large-scale features of the global oceans, which can be identified using satellite imagery and remote sensing. For precautionary management and to safeguard migratory pathways and movement corridors, many believe large MPAs should contain at least 50% of a population's natural marine habitat (e.g. Lauck *et al.*, 1998).

Roberts *et al.* (2006) have developed a global network of marine reserves on the high seas for Greenpeace (Fig. 5). This network was determined based on biological, physical and oceanographic data. Examples of biological data were: biodiversity distribution of cetaceans (Fig. 6), billfish and tuna species richness and density, at-sea movements of albatrosses, turtles, pinnipeds and penguins and finally, marine biomes. Oceanographic features used were: upwellings and downwellings and sea surface temperature gradients. Physical features included: bathymetry, bathymetric complexity, seamounts, bottom sediments and ocean trenches. All data were gridded into 5º latitude by 5º longitude cells, which were the size of the smallest marine reserves that Roberts *et al.* (2006) considered to be viable in the open ocean. These data enabled Roberts *et al.* (2006) to identify places that are biologically important and representative of biodiversity on the high seas. Interconnectivity between reserves, along with size, was deemed essential to ensure their long-term persistence. Thus, Roberts *et al.* (2006) aimed to protect 40% of the area of all habitats and biogeographic zones. Their proposed network consisted of 29 separate marine reserves comprising 40.8% of the area of the world's oceans.

EXISTING MPA CASE STUDY: THE GULLY

The Gully Marine Protected Area off Nova Scotia, Canada, was established in 2004 and covers 2,364 square kilometers. The Gully is a submarine canyon which is home to a diversity of mammal, fish and benthic organisms, including rare, vulnerable, and at-risk species, such as deep-sea corals and northern bottlenose whales (*Hyperoodon ampullatus*). The Gully contains a wide range of habitats and is highly productive. Regulations include general prohibitions against disturbance, damage, destruction or removal of any living organism or any part of its habitat. Regulations also recognize that human activities outside the MPA, including noise, can cause impacts within the MPA boundaries (DFO, 2006).

The Gully MPA has three management zones with differing levels of protection (Fig. 7). Zone 1, containing the deepest parts of the canyon, is deemed the most vulnerable partially because it is thought to represent the core habitat of the year-round resident northern bottlenose whale. The ecosystem in waters deeper than 600 m is fully protected. Zone 2 supports diverse benthic communities, and thus regulations strictly protect the canyon head and sides (300-600 m), feeder canyons and the continental slope. Net fisheries and mobile fishing gear are prohibited. Zone 3, which includes the shallow sand banks on either side of the canyon, is considered to be the least sensitive zone. Commercial activities proposed in this zone are assessed on a case by case basis. Fishing is not permitted in Zone 1, but hook and line fisheries for halibut, tuna, shark and swordfish are allowed in Zones 2 and 3 (DFO, 2006).

Seismic Noise Considerations

In 1998, the offshore oil and gas regulator, the Canada-Nova Scotia Offshore Petroleum Board (CNSOPB), adopted a policy which prohibited exploration activities in the Gully. Exploration licenses were issued for surrounding waters while the Gully was being assessed as a candidate MPA (Fig. 8). Expanded environmental assessments were recommended for seismic exploration within a 10 km buffer around the Gully (Davis *et al.*, 1998). Acoustic monitoring was undertaken in 2003 coincident with two seismic programs conducted near the Gully. Sound level measurements taken at that time demonstrated the importance of field validation to verify model predictions. For one seismic program southwest of the Gully, extrapolated measurements showed that levels were 14 dB higher in the Gully than originally predicted in the environmental assessment (McQuinn and Carrier 2005).

Now that the Gully is a designated MPA, adjacent seismic surveys must comply with enhanced mitigation measures, operational codes of conduct and effects monitoring programs. The Department of Fisheries and Oceans and the CNSOPB are currently developing protocols and guidelines for the conduct of seismic surveys around the MPA (Macnab, In Press). An intergovernmental and multi-stakeholder collaborative planning process will serve as input into an integrated ocean management plan for the area surrounding the Gully (Rutherford *et al.*, 2005). In 2006, the northern bottlenose whale was officially listed as endangered, meaning it had legal protection under the Species at Risk Act (SARA). As such, the recovery planning process could require additional mitigation measures, such as time and area exclusions, acoustic monitoring, etc. (Macnab, In Press). Because the Gully is a fixed bathymetric feature and because the bottlenose whale population is resident there year-round, its designation as MPA, if properly managed, has a good chance of benefiting this species.

MEANINGFUL REGULATION OF MPAs

For MPAs to serve their function in protecting cetaceans and their habitat, regulations must be suitably strict and meaningful. Too often has the public been disappointed to find that marine reserves or sanctuaries have been so “in name only.” Ideally, in the case of anthropogenic noise, ambient levels should not be exceeded within MPA boundaries (where ambient levels are mostly the result of natural noise). In the Stellwagen Bank National Marine Sanctuary, noise pollution has recently been recognized as a potential factor limiting the growth of whale populations (Scheifele and Darre, 2005). Also, fisheries must be carefully managed to preserve the ecosystem, as well as to protect the prey source for cetaceans. Safeguarding fish brood stocks, increasing fish production and preserving fish habitat will all indirectly contribute to cetacean conservation (Reeves, 2000). In the absence of such protection, however, it is unlikely that MPAs will be able to achieve the necessary conservation goals for cetaceans. Thus, it is important that no-take zones be an integral part of MPA management. Fisheries restrictions will not only directly benefit fish and invertebrate populations, but protect cetaceans against by-catch and disturbance from fishing vessels (Reeves, 2000), some of which will be acoustic in nature (e.g. bottom dragging, engine and gear noise, etc.).

An important consideration in the successful establishment of MPAs is that designation must be viewed as a beginning rather than as an end in the conservation process (Reeves, 2000). After site designation, there must be long-term funding and oversight, well-considered management plans, monitoring, and good enforcement.

ALTERNATIVES TO MPAs

While MPAs, if managed appropriately, are clearly among the most effective means to preserve cetacean habitat, there may be other, simpler means to protect cetaceans in the interim. Diverting shipping lanes or using time and area exclusions to regulate anthropogenic threats such as noise sources may be powerful tools in themselves and perhaps less cumbersome. Especially if immediate protection is necessary and desirable, such measures may be able to be put into practice sooner than waiting for designation of a MPA. In November 2004, for example, Spanish authorities announced a moratorium on the military use of sonar in the waters around the islands of Lanzarote and Fuerteventura out to a distance of 50 km, in response to the many beaked whale strandings that have been linked to military maneuvers involving sonar.[2] This is the first time that a government has acted to prohibit all active naval sonar from waters that contain particularly sensitive species (Dolman, In Press). Similarly, as a result of a series of unusual strandings of adult humpback whales, *Megaptera novaeangliae*, near Abrolhos Bank, Brazil, that were coincident with seismic surveys in 2002 (Engel *et al.*, 2004), seismic surveys have been excluded between July and November, during the breeding season of humpback whales (Dolman, In Press).

While this example would probably fall into the category of MPA rather than a time and area exclusion, another area that addresses noise-producing activities in its regulations is the Marine Mammal Protection Zone in the Great Australian Bight Marine Park (GABMP) in southern Australia. It prohibits oil and gas exploration, and seasonally, also excludes vessel traffic. This is to provide protection from disturbance to several marine mammal species, especially the calving grounds of the southern right whale, *Eubaleana australis* (Australia, 2005).

ENFORCEMENT AND COMPLIANCE

MPAs will serve little purpose if not properly enforced. Enforcement becomes especially challenging on the high seas, though vessels can be detected, located, and monitored remotely using acoustic and satellite technologies. Vessels equipped with transponders or black boxes can be tracked, and if their movements or activities were in violation of MPA regulations, can be fined. Jurisdictional issues complicate enforcement and thus, these will need to be resolved before MPAs can be appropriately managed.

CONCLUSIONS

Well-managed MPAs provide one of the most effective ways to protect cetaceans and their habitat from the cumulative and synergistic impacts of anthropogenic noise and other stressors. However, protection in MPAs must extend to the entire ecosystem, including fish and invertebrate stocks, to truly serve their purpose. MPAs must be large enough to safeguard essential habitat and migration corridors and to accommodate highly mobile species. Management schemes should ideally encompass whole ocean basins. Global networks of MPAs must be well-designed to ensure ecological connectivity between individual MPAs. The tools are becoming increasingly available to identify “hot spots” for cetaceans as well as other species, and to map the oceanic features necessary to establish a global network of MPAs. Zoning, including buffer zones, can be useful in designing MPAs to protect against stressors such as noise. Alternatives to MPAs such as diverting shipping lanes and area/time closures for noise sources and other threats can provide protection for cetaceans while avoiding the more cumbersome process of establishing MPAs. However, these are probably best used as interim measures, as they may not carry the same legislative weight as MPAs and their protection may not be far-ranging enough to safeguard the ecosystem.

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[2] Resolución 79/2004, 102 Boletín Oficial del Estado 16643-45; Statement of Bono Martinez, Senior Defense Minister of Spain (statement made to the Spanish Parliament on 3 Nov. 2004).

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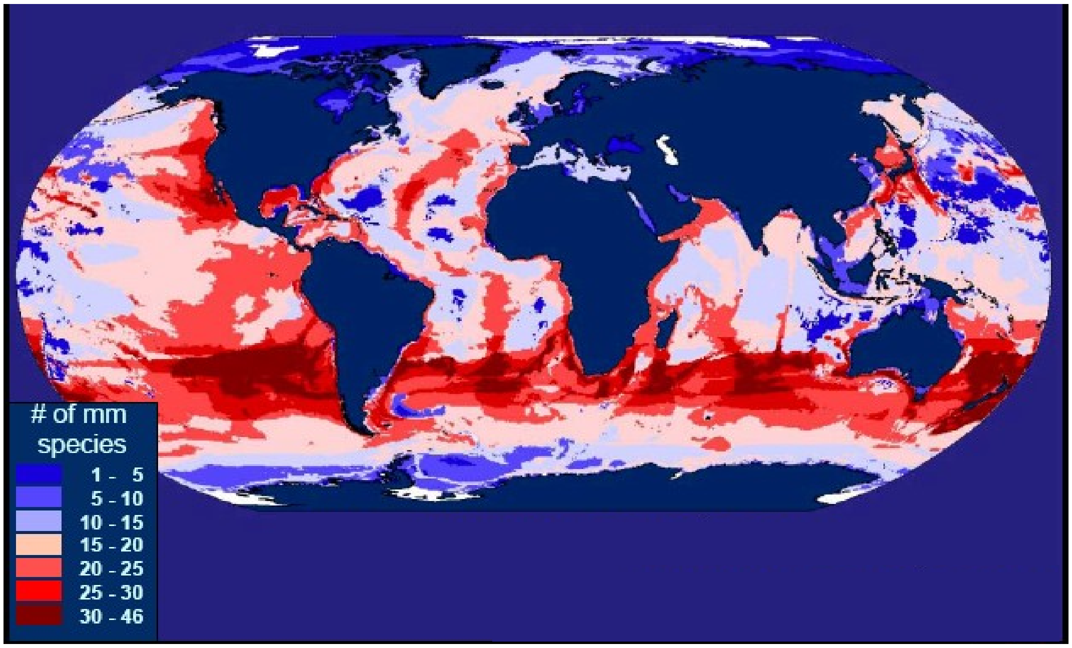

Fig. 1. Assumed presence for all marine mammal species (n=115) using RES (Relative Environmental Suitability) modeling. RES threshold (similar to probability of occurrence) > 0.4, which corresponds to when sighting rates significantly increase in test data sets used in validation of the model (Kaschner and Worm, In Prep.). Courtesy of K. Kaschner.

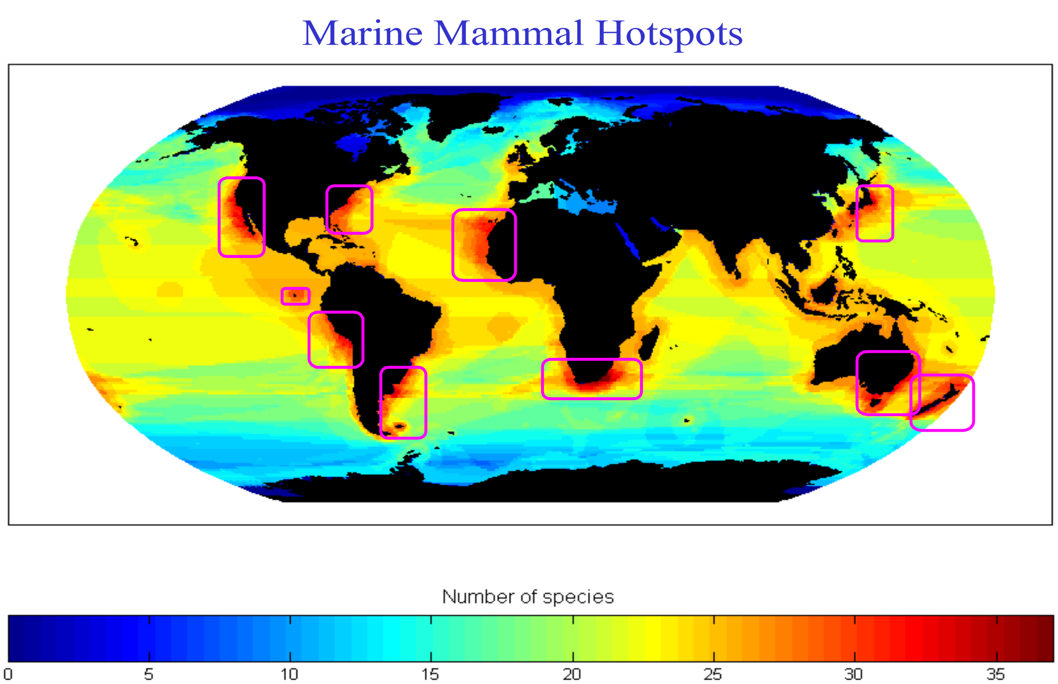

Fig. 2. Top ten marine mammal hot spots based on species diversity. Species' normal ranges, determined by field guides, were digitized in 1° squares of latitude and longitude. Diversity in coastal areas was probably overestimated, while diversity in the temperate Southern Hemisphere was probably underestimated (Whitehead *et al.*, In Prep.). Courtesy of H. Whitehead.

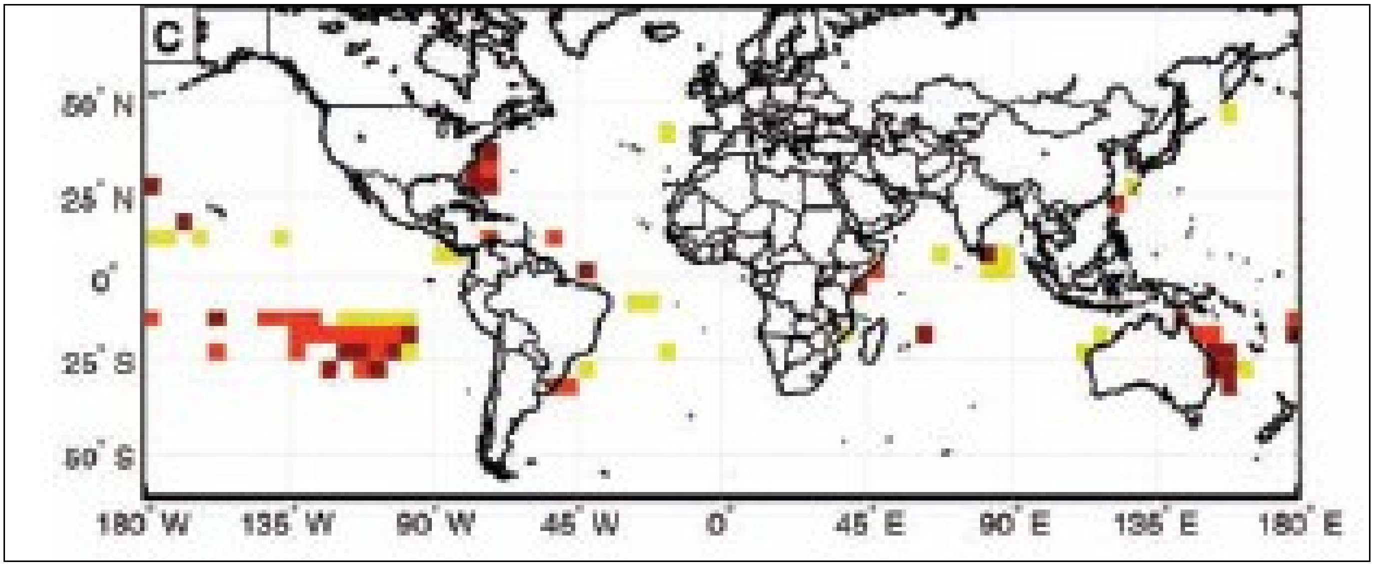

Fig. 3. Top 50 global hot spots of billfish and tuna, which also correlate with predator and formaniferan zooplankton diversity. These represent 6.6% of global ocean area. Yellow squares--species richness; Orange--species density; Maroon-- both richness and density. From Worm *et al.* (2005). Reprinted with permission from Science.

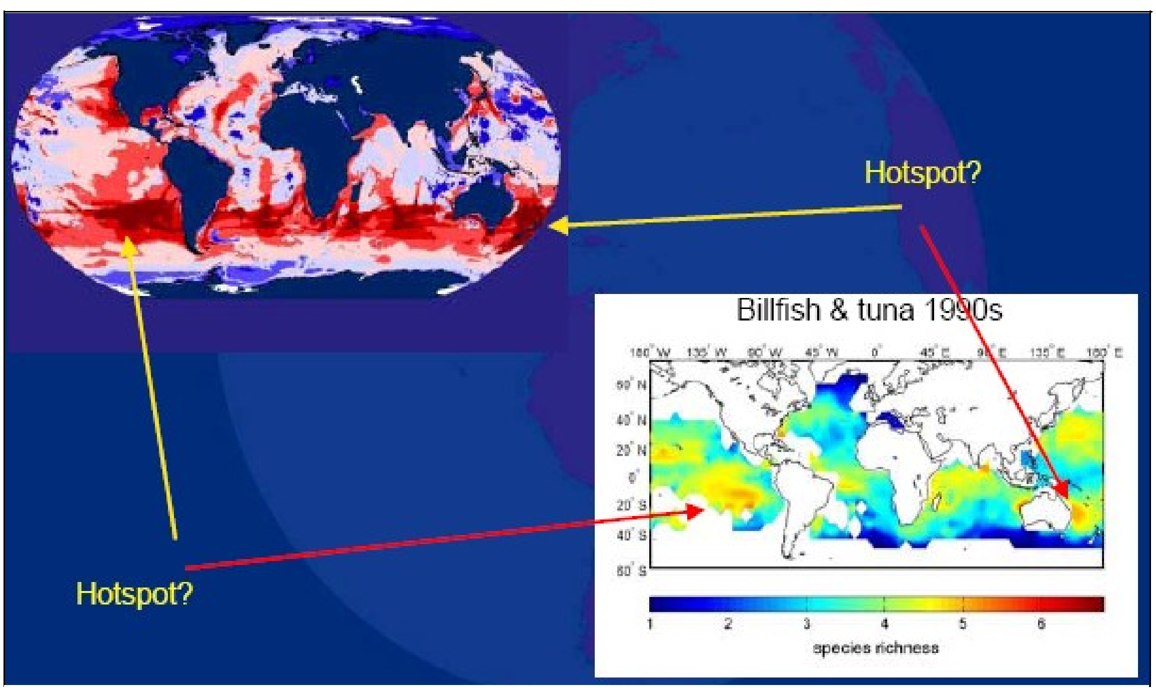

Fig. 4. Comparison of Fig. 1 (marine mammal hot spots) and Fig. 3. (billfish and tuna hot spots) From Worm *et al.* (2005). Reprinted with permission from Science. Courtesy of K. Kaschner.

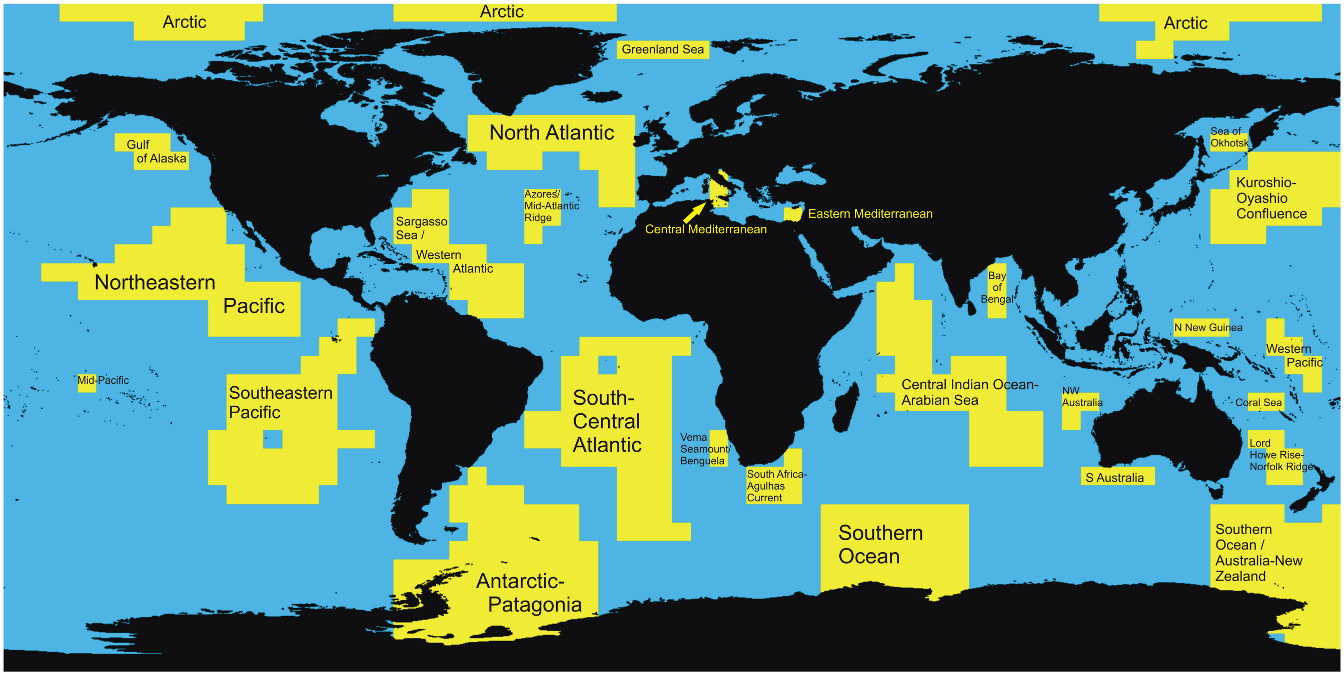

Fig. 5. Proposed global network of marine reserves (in yellow) in the high seas. 1) Greenland Sea; 2) North Atlantic; 3) Azores/Mid-Atlantic Ridge; 4) Eastern Mediterranean; 5) Central Mediterranean; 6) Sargasso Sea/Western Atlantic; 7) South-Central Atlantic; 8) Antarctic-Patagonia; 9) Vema Seamount-Benguela; 10) South Africa-Agulhas Current; 11) Southern Ocean; 12) Southern Ocean-Australia/New Zealand; 13) Central Indian Ocean-Arabian Sea; 14) Bay of Bengal; 15) Northwestern Australia; 16) South Australia; 17) Lord Howe Rise and Norfolk Ridge; 18) Coral Sea; 19) Northern New Guinea; 20) Western Pacific; 21) Kuroshi-Oyashio Confluence; 22) Sea of Okhotsk; 23) Gulf of Alaska; 24) Northeastern Pacific; 25) Southeastern Pacific; R) Representative areas. This network represents 40% of the area of the world's oceans. From Roberts *et al.* 2006. Reprinted with permission from Greenpeace and C. Roberts. Available at: http://oceans.greenpeace.org/highseas-report.

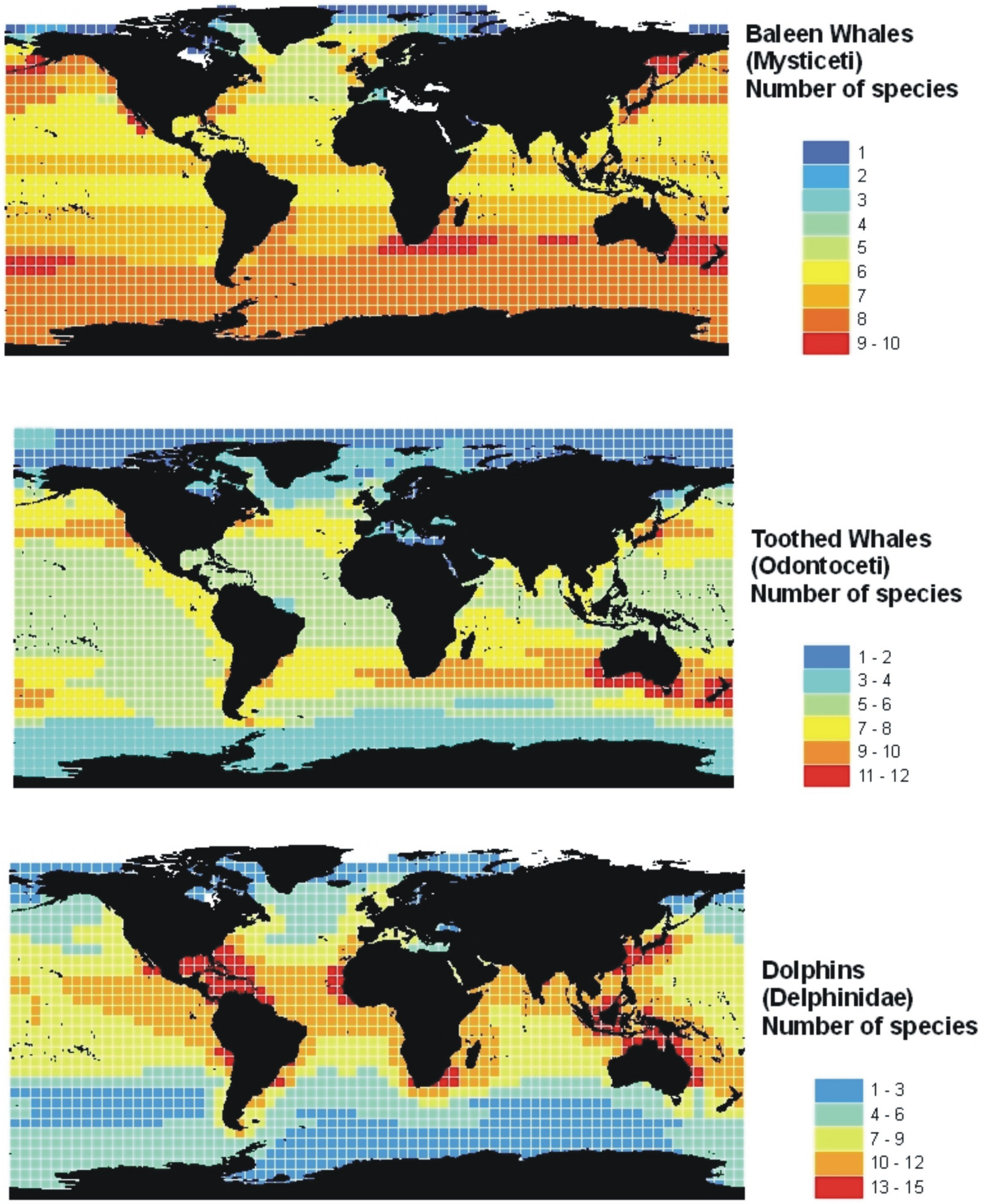

Fig. 6. Maps of distributions of 73 cetacean species using http://en.wikipedia.org/wiki/cetaceans and a 5º by 5º grid. Maps represent numbers of species of: Mysticetes (top); Odontocetes, excluding Delphinidae (middle); and Delphinidae (bottom). From Roberts *et al.* (2006). Reprinted with permission from Greenpeace and C. Roberts. Available at: http://oceans.greenpeace.org/highseas-report

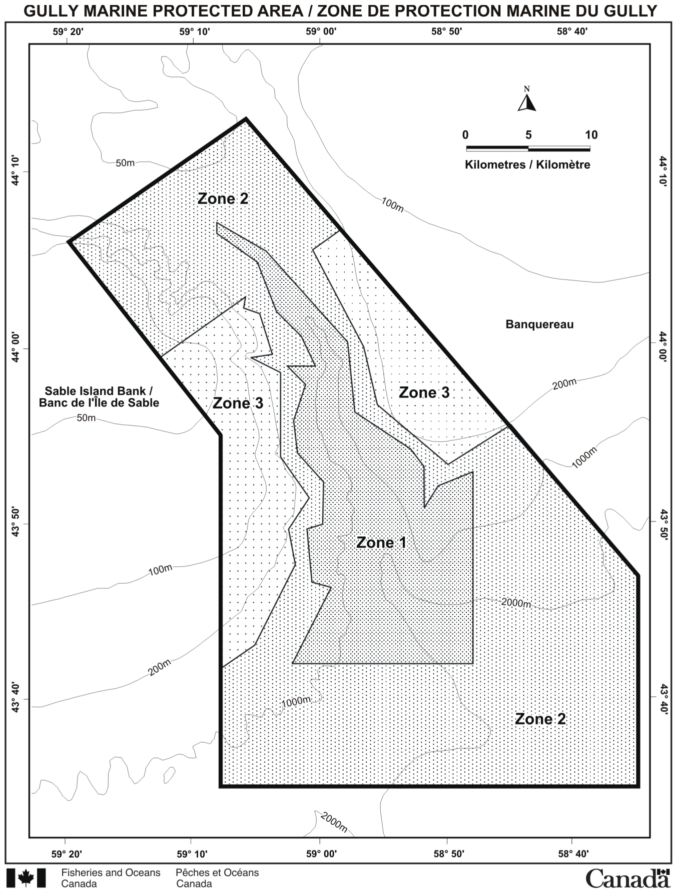

Fig. 7. The Gully Marine Protected Area off Nova Scotia, Canada, showing Management Zones 1, 2 and 3.

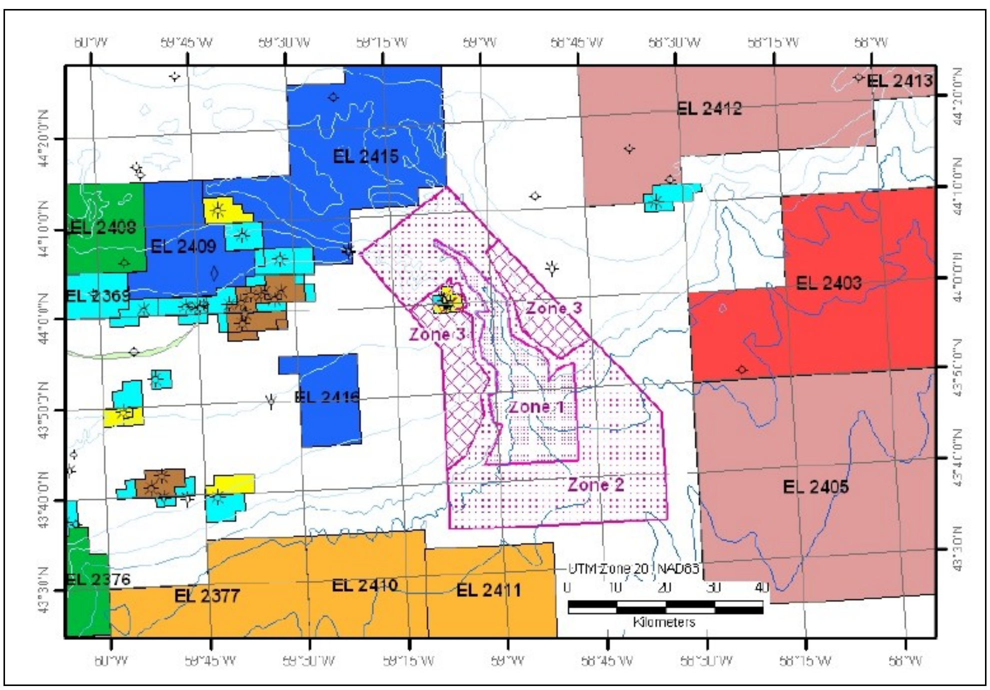

Fig. 8. Petroleum exploration licenses (coloured blocks) surrounding the Gully Marine Protected Area (middle) off Nova Scotia, Canada (not current).