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Pelagic protected areas: the greatest parks challenge of the 21st century

ELLIOTT NORSE

"…the animals which live in the watery depths, above all in ocean waters…are protected against the destruction of their species at the hand of man. Their reproductive rate is so large and the means which they have to save themselves from his pursuits or traps are such that there is no evidence that he can destroy the entire species of any of these animals."
Jean-Baptiste Lamarck, Zoological Philosophy (1809)

Open oceans are being drained of their large wildlife, and traditional management tools have proven woefully ineffectual in slowing this loss. To save pelagic megafauna targeted by fisheries (e.g. sharks, billfishes, tunas) and killed incidental to fishing (e.g. sea turtles, albatrosses and dolphins), protected areas merit serious examination. Oceanic megafauna have been considered poor candidates for protection within marine protected areas (MPAs) because these animals are highly migratory and their movements were little-known by scientists until very recently. However, fishermen have learned to find them, and new tools allow scientists to understand their movements as well. Because pelagic megafauna concentrate in specific places at certain times that can be predicted or observed, place-based approaches can be used to conserve them. The highly migratory nature of pelagic megafauna does not preclude the use of protected areas which are, indeed, used to conserve highly migratory non-marine species. Some of the hotspots where pelagic megafauna congregate can shift, predictably or unpredictably, and this poses a novel challenge, one that can be met by establishing MPAs with dynamic boundaries. New tools and management strategies could protect these important, vulnerable animals even in the remote vastness of the High Seas.

ONCE THERE WERE NO PARKS because nobody saw the need for them and there were no means of creating them. But since growing human populations have demanded more and more of the earth's resources, protecting places has become essential to maintaining the crucial services that biological diversity provides. Rulers have created protected hunting preserves for centuries, and nations have been establishing national parks since Yellowstone in the 19th century. In the 20th century, our vision expanded with the creation of the first protected areas in nations' coastal waters. A legacy of such forward-thinking decision making is that many species and ecosystems that would otherwise have disappeared are still with us. Still, if people had acted earlier and had effectively protected more places, far fewer species – such as Bornean orangutans *Pongo pygmaeus* – would now be in danger of extinction. Furthermore, far fewer vital ecosystem services – such as protection of coastlines by mangroves and coral reefs from devastating tsunamis – would now be gone when we most need them. The best time to establish protected areas is when the greatest range of options is still available. And that requires the capacity to see the big picture, particularly the kind of vision called foresight.

A 21st-century vision for the oceans

Now, as humans have depleted resources on land and in coastal waters, resource extraction has expanded far beyond the sea-cloaked shoulders of continents – which marine scientists call continental shelves and slopes – into the vast ocean basins. Humans are now profoundly changing the world's remotest places, the last frontiers on earth. To reduce and stop the harm we are causing, we need a new strategy for quick and effective action. Having saved some crucial remnants of the earth's biodiversity by protecting areas on land and in coastal waters during the last two centuries, we need to take the obvious next step in the 21st century: protecting places in the open oceans.

The enigmatic, vast, last conservation frontier

The need for place-based conservation in the open oceans is not easy to comprehend for several reasons.

The first is that the open oceans are so poorly explored that they are still revealing their secrets. How can they need conservation when scientists are still making major discoveries? It is true that the sunlit blue epipelagic zone and the cold, black depths beneath them are still *terra incognita* and that scientists continue to uncover the mysteries of marine species and ecosystems. The aptly named 'megamouth' shark, *Megachasma pelagios*, measuring over five metres long and belonging to a new family, was discovered in 1976. From a few bones found on islands off New Zealand and Chile, scientists know that somewhere out there is a beaked whale species *Mesoplodon traversii* that has never been seen by humans. Only in the last few years have scientists taken the first photographs of giant squid *Architeuthis dux* in their deepsea habitat, and realised that there is another squid *Mesonychoteuthis hamiltoni*, even bigger than giant squid. It is not difficult to miss really large animals in the vastness of the open oceans.

Similarly, it was not until 1977 that scientists first discovered deepsea hydrothermal vent ecosystems that have since been found around the world. No less remarkable was the discovery in the 1980s and 1990s of extensive *Lophelia pertusa* coral reefs in the deepsea off Norway and Ireland. Scientists are still far from finding many of the world's seamounts, active and extinct undersea volcanoes that can rise thousands of metres from the deep seafloor. Indeed, only a few hundred of the many thousands of seamounts have been studied by biologists, but these few studies, combined with general understanding of ocean currents, tell us that seamounts are the deep ocean equivalents of islands. They are markedly different from benthic habitats that surround them, and the species that inhabit them are often endemic (species found nowhere else) to individual seamounts, seamount clusters or chains. Their value in biological diversity is consequently immense.

Although systematic scientific exploration of the open oceans began in the 1800s, we are still learning that they are more complex and dynamic than anyone realised. The fact that scientists haven't fully explored oceanic ecosystems does not mean it would be wise to wait before we start protecting them. On land, we will probably never see scientists announce the discovery of

Indo-Pacific blue marlin Makaira mazara, *Hawaii, USA. Many large animals (megafauna) living in the upper layers of the open ocean are exquisitely adapted for moving long distances between scarce but rich concentrations of food animals, or between places where they feed and breed. Some migrate thousands of kilometres. Can protected areas be used to conserve them?* Photo: Masa Ushioda/coolwaterphoto.com.

bigfoot, chupacabras and mokele-mbembe, but a few large species continue to be found in the last-remaining unexplored ecosystem remnants. They include the recently discovered saola or Vu Quang ox *Pseudoryx nghetinhensis* in Vietnam and the Chacoan peccary *Catagonus wagneri* in Paraguay. Nobody would argue that the existence of as-yet undescribed species or unexplored ecosystems on land is a valid reason for waiting to protect imperiled places. To avoid losing biodiversity and the services it provides, the opposite argument makes much more sense, both on land and the sea.

A second reason why place-based conservation in the open ocean strikes some people as peculiar is that the oceans' immensity leads some to assume that they are an invulnerable cornucopia. After all, the Pacific Ocean alone would be larger than all of the continents even if there were two Australias. Moreover, fishes have long been regarded as being so fecund that many societies made them symbols of fertility, and scientists have opined that this makes them extinction-proof. Even Rachel Carson the marine biologist whose paeans to the sea brought her public acclaim in the 1950s, before she catalysed the revolution in environmental thinking with her 1962 book *Silent Spring*, largely overlooked human impact on the sea. Because relatively few people venture even tens of metres below the oceans' surface and fewer still read the rapidly growing scientific literature on marine conservation, many assume that oceans are inexhaustible. Indeed, it was only in the 1990s (Norse 1993; Marine Conservation Biology Institute 1998) that hundreds of scientists began calling attention to their severely declining health. Decision makers have scarcely begun to heed these calls for action.

The oceans' immensity no longer protects them. Seafarers and scientists now see the sea's face pockmarked with floating trash. There are measurable amounts of synthetic toxic chemicals in even the remotest places in the oceans. Shipping, oil exploration and sonar now generate such a cacophony, in what Jacques-Yves Cousteau once (1956) called *The Silent World*, that intense sounds have apparently killed whales in the Bahamas and the Canary Islands. We increasingly

Leatherback sea turtle Dermochelys coriacea *hooked on longline off North Carolina, USA. Leatherbacks migrate long distances between places where they feed and beaches where they nest. These movements make them highly vulnerable to being caught and drowned by pelagic longlines set for tunas and swordfish. Scientists now project that leatherbacks will be extinct in the Pacific Ocean within the next few decades.* Photo: © Herb Segars/gotosnapshot.com

see changes that portend devastating impacts in the near future from global warming. But by far the biggest human impact in the open oceans to this point is commercial fishing. Landmark scientific studies by Pauly *et al*. 1998, Watling and Norse 1998, Hutchings 2000, Jackson *et al*. 2001, Watson and Pauly 2001, Myers and Worm 2003, Lewison *et al*. 2004b and Devine *et al*. 2006, show that both the magnitude of impacts from fishing and the vulnerability of marine species and ecosystems are far greater than had been thought. The cornucopian view of the oceans is wrong.

A third reason why the concept of protecting places in the open oceans might seem strange is sensory. People's senses do not equip them to perceive the oceans' heterogeneity. We think of the land as a patchwork of places, but perceive the fluid medium above the seafloor as so interconnected and featureless that anything happening anywhere affects everywhere. Yet scientists know that the inscrutably wavy surface of the oceans conceals remarkable biological and geological heterogeneity. New scientific tools, including images showing phytoplankton abundance patterns in surface waters taken by orbiting satellites show that oceans have distinct places and, in marked contrast to places on land, some of these places move.

In this article, I explain why we need a far more expansive conservation vision for the open oceans, one commensurate with the growing understanding of our present and future impacts. An obvious starting place would be protecting seamounts, which are clearly definable biological hotspots rising above the seafloor. But we need to go further and identify the most important hotspots in the water column (the pelagic realm), and then to act decisively to protect them.

Although establishing a comprehensive and effective system of protected places in the open oceans will undoubtedly be a long, ongoing process – as protecting places on land and in coastal waters is – the confluence of rapidly growing need and opportunity suggest that we cannot afford to wait.

Conservation in the biggest ecosystem on earth

The marine environment covers more than twice the area of terrestrial and freshwater ecosystems combined, and constitutes perhaps 99% of the volume of the biosphere that is permanently inhabited by animals and plants (Norse 1994). The vast majority of attention to the sea concerns estuaries, enclosed seas, continental shelves and/or areas within nations' Exclusive Economic Zones (EEZs), where productivity of living things is highest, human impacts are greatest and research from shore-based facilities is easiest. However, these areas make up only a minority of the marine realm. Some 64% of it is high seas, beyond individual nations' jurisdictions.

Oceans are home to myriad species, perhaps millions of them, from seabirds flying above the waves and insects skating on the tropical sea surface to fishes and invertebrates dwelling in hadal 11-kilometre depths in the deepest ocean trenches. They range from microscopic bacterioplankton to gigantic blue whales *Balenoptera musculus*. More than 98% of marine animal species are benthic, living in, on or immediately above the seafloor (Thurman and Burton 2001). Nonetheless, the water column well above the seafloor is home to thousands of species. The large animals in these upper layers – the oceanic pelagic megafauna – are not only ones people care about, but ones which form the basis for some of the most important fisheries, and which are the top predators in these ecosystems.

In comparison with the sediment-and plankton-rich brown waters of estuaries and green waters usually overlying continental shelves, the blue surface waters and black depths of the open oceans are a much thinner broth. The upper epipelagic layer of the open oceans is low in nutrients and hence less productive of organic material per unit area. Phytoplankton there are eaten by zooplankton whose faeces sink below the epipelagic zone to the seabed, averaging nearly 4,000 metres below. This 'rain of poops' and other organic material, including dead whales and sunken wood, provides all of the food in the deepsea except for the food produced at hydrothermal vents and cold seeps.

Since hungry mouths intercept food particles as they sink, food becomes scarcer with increasing depth. Immediately below the epipelagic zone is the mesopelagic zone, where fishes, squids and crustaceans hide from predators in darkness during the day, but ascend into the relatively food-rich epipelagic zone under cover of night. Deeper still are bathypelagic and abyssopelagic zones. Perhaps the most abundant fishes in the world are bathypelagic bristlemouths in the genus *Cyclothone*. After eliminating all the sea's other, more desirable fishes, we could eat *Cyclothone* if only they weren't highly dispersed (making the energy cost of catching them prohibitive), less than five cm long, and possessing oily, soft and fast-rotting flesh. Fortunately, this makes them and other, less-abundant deepsea pelagic fishes that share these attributes safe from fishing pressure for the foreseeable future.

So the pelagic waters of the open oceans are averagely low in food resources and in large animals, but there are important exceptions. One is waters overlying some seamounts. In other places, upwelling of deeper, nutrient-rich waters into the well-lighted epipelagic zone provides a basis for much higher than average phytoplankton production. Another exception is convergence zones, where water masses of differing density meet and floating objects aggregate (Hyrenbach *et al.* 2000). Such areas of higher productivity are fairly localised, making these oasis-like hotspots in the desert-like open oceans particularly important to conserve. Moreover, some areas of the open oceans have much higher megafaunal species diversity than others (Worm *et al.* 2005).

Many oceanic hotspots, including seamounts, mid-ocean ridges and banks, are raised topographic features with their own distinctive and imperiled communities of life (see Earle, this issue). However, the pelagic realm is home to remarkable megafauna, including sharks, tunas, billfishes, sea turtles, seabirds and cetaceans. Some, including whale sharks *Rhyncodon typus*, manta rays *Manta birostris*, leatherback turtles *Dermochelys coriacea* and blue whales feed mainly on zooplankton, but most megafauna are predators of fishes and squids. New tagging technologies have made it increasingly clear that many oceanic megafauna migrate vast distances through desert-like low-nutrient waters to certain places where food can be far more concentrated. Food-rich places may be more or less permanently located above certain seamounts or occur where water masses converge, or, they may be ephemeral, appearing for weeks or months, and then disappearing. In either case, the story seems to be the same: blooming plankton populations provide food for large schools of small pelagic fishes and squids that, in turn, attract pelagic megafauna that congregate at these features to feed and (in some cases) breed (Block *et al.* 2005). Thus, while big oceanic wildlife are thinly spread on average, abundance at these pelagic hotspots can be very high.

Fishermen know this, and focus their efforts on finding the places where their target species concentrate. Indeed, commercial and even recreational fishermen can now subscribe to services that send them frequent faxes or e-mails showing the best places to fish, based on interpretations of satellite oceanography (for example, www.roffs.com/commercial/about.htm). Large marine animals now face human predators with up-to-date information and safer, faster industrial fishing vessels that use global position systems and fish-finders to determine where to place their drift gillnets, 100-kilometre longlines or huge purse seines. Refuges are no longer available even in the vast open oceans, so oceanic fishing is now like shooting fish in a barrel.

Not surprisingly, populations of many target species have been severely reduced. Species that are caught by accident are at even greater risk. Baum and Myers (2004) recently reported that oceanic whitetip sharks *Carcharhinus longimanus* – perhaps the most abundant large animals on earth – experienced population reductions of 99.7% in the Gulf of Mexico after tuna longlining began there in the 1950s.

Conservation efforts in open oceans thus far have mainly been focused on: 1) ending the killing of great whales including sperm whales *Physeter macrocephalus*, right whales *Eubalaena* spp. and rorquals such as blue and humpback *Megaptera novaeangliae* whales; 2) regulating the catch of wildlife species that are targeted, including neon flying squids *Ommastrephes bartrami*,

Dolphins attacking baitball. Long-beaked common dolphins Delphinus capensis *trap great masses of South American sardines* Sardinops sagax *against the sea surface off South Africa, where they are eaten by the dolphins and other large predators, including sharks, fur seals and seabirds. Protecting dense concentrations of small pelagic fishes at oceanographic discontinuities and along their migratory pathways can be used to conserve pelagic megafauna in coastal waters and on the high seas.* Photo: © Doug Perrine/SeaPics.com

Pacific salmon *Oncorhynchus* spp., bigeye *Thunnus obesus* and other tunas, and swordfish *Xiphias gladius*; and 3) reducing bycatch of sharks, sea turtles, dolphins, porpoises, petrels and albatrosses caught incidental to oceanic longlining, driftnetting, purse seining and pair trawling.

Global bodies such as the International Whaling Commission (IWC) and regional fishery management organisations (RFMOs) such as the International Commission for the Conservation of Atlantic Tunas (ICCAT) have hardly proven to be conservation success stories. After achieving mixed success for several decades, IWC-pushed by Japan, Iceland and Norway – is now moving toward renewal of commercial whaling. ICCAT has presided over the steep decline of northern bluefin tunas *Thunnus thynnus* and swordfish. Species-specific high seas conservation has been conspicuously ineffectual, even compared with conservation within nations' EEZs. Many pelagic megafauna are in steep decline: Thresher sharks *Alopias* spp. in the Northwest Atlantic declined 80% between 1986 and 2003 (Baum *et al*. 2003); white marlin *Tetrapterus albidus* are being considered for listing under the US Endangered Species Act; nesting Pacific leatherback sea turtles have declined over 95% in the last two decades (Lewison *et al*. 2004a) and have a 50% chance of extinction within 10–30 years; a number of large tubenose seabirds, including southern giant petrels *Macronectes giganteus* and wandering albatross *Diomedea exulans* are in severe decline. The rapid disappearance of pelagic megafauna leads one to wonder whether there might be a better way to conserve them on the high seas.

A novel solution: protecting places in the open oceans

Traditional responses to the disappearance of pelagic megafauna include reducing fishing pressure or modifying gear. Unfortunately, the open oceans are the least-protected places on earth, and few measures have proven effective there because international regulatory institutions are particularly weak. Modifying fishing gear – for example, through use of streamer lines (Morgan and Chuenpagdee 2003) and circle hooks (Epperley and Boggs 2004) – can bring about significant reductions in bycatch mortality, but these measures are far from universal at present. The disappearance of pelagic megafauna calls for a new tool: protecting places in the pelagic realm through temporary closures and permanent marine protected areas (MPAs), including no-take marine reserves (Norse *et al*. 2005).

Marine protected areas are usually seen as tools best used for conserving species that move relatively little after early life history stages. Because many epipelagic megafauna are highly migratory, moving hundreds or thousands of kilometres between places where they apparently feed or breed, some scientists think that protected areas cannot be effective conservation tools. They reason that these species would spend too much time being vulnerable to fishing outside the MPAs unless they encompass populations' entire ranges, which, in many cases, means an entire ocean basin. Clearly, humankind is not yet ready to make such extensive commitments to save pelagic megafauna except in very specific cases such as the IWC's Indian Ocean Whale Sanctuary. However, there are ways that far smaller protected areas could be strategically placed to conserve highly migratory large epipelagic animals.

This strategy depends on the fact that key activities occur in more or less predictable (or detectable) places that comprise a small fraction of the total open ocean habitat. In terrestrial, riverine and coastal ecosystems there are ample precedents for conserving places crucial for highly migratory species including breeding aggregations, calving grounds, stopover feeding grounds and even migratory corridors. This is true even for heavily exploited species. Canada and the USA, for example, have used breeding habitat protection in the Prairie Pothole provinces and States to ensure continued large populations of ducks that are hunted by the millions. There is no inherent reason why we could not protect the places where pelagic wildlife are most concentrated and, hence, most vulnerable.

To do that, we need to understand that the sea is not the same as the land in all ways. In some cases – for example, above shallow seamounts – oceanic hotspots stay put. But other hotspots can move at least tens of kilometres in a day, which makes conservation on the high seas an unprecedented challenge. Protecting these crucial ecosystem features requires that we envision a new kind of protected area, one that moves as hotspots move. Using tools such as satellite pop-up tags, we can compare species' distributions with satellite oceanography data to discern patterns. Because such data are expensive to collect, establishing key correlations between species' distributions and oceanographic features will allow oceanographic data to be used as proxies for concentrations of species of particular concern, which is likely to be far less expensive.

Nesting canvasback duck Aythya valisineria. *Many species of ducks are highly migratory, but are effectively conserved by protecting the places where they nest, even though they may be hunted away from their breeding grounds. Protecting key feeding and breeding grounds can be used to conserve other highly migratory species, such as pelagic megafauna on the high seas.* Photo: Ducks Unlimited BC Canada.

If megafauna and commercial fishermen can locate moving hotspots in a dynamic ocean, so can those working to conserve oceanic wildlife.

Using static or dynamic protected areas to conserve epipelagic megafauna on the high seas will require more than a sound conceptual framework; it will also require political regimes capable of ensuring that neither legal nor illegal fishing undermines places meant to protect oceanic hotspots. At present, such regimes do not exist. Moreover, strong rules are not enough; effective enforcement is crucial on the high seas, far from shore-based and even ship-based observers. We will need to integrate new enforcement technologies, including vessel monitoring systems, event data recorders, radar satellite observation (which can pierce clouds and darkness) and satellites that use visual wavelengths whose high resolution images are capable of identifying individual fishing boats with the accuracy required in courts of law.

In a world where many nations are failing to protect marine animals within their EEZs, protecting pelagic megafauna might seem hopelessly farfetched. But new technologies have yielded crucial information about the movements of these species. More visionary thinking about MPAs that are either fixed or move as their habitats move, as well as about new integrated systems of enforcement tools, make this a real possibility. Compared with the increasing acceptance of protected areas on land and in nearshore waters, the idea of protecting oceanic megafauna on the high seas is surely the toughest conservation sell on earth. Whether or not humankind will do this is not a question of science or technology, but of political will.

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***Elliott A. Norse**, Ph.D., a marine and forest conservation biologist, is President of Marine Conservation Biology Institute in Bellevue, Washington, USA and a Pew Fellow in Marine Conservation. E-mail: elliott@mcbi.org.*