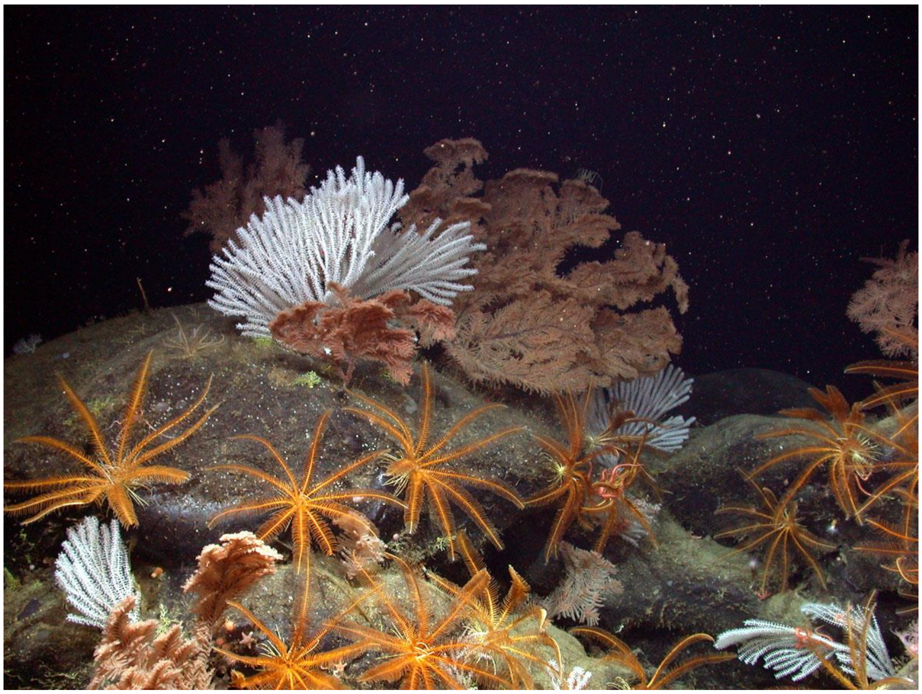
Marine Sanctuaries Conservation Series ONMS-14-08



A Review of Resource Management Strategies for Protection of Seamounts

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service
Office of National Marine Sanctuaries

March 2014

About the Marine Sanctuaries Conservation Series

The Office of National Marine Sanctuaries, part of the National Oceanic and Atmospheric Administration, serves as the trustee for a system of 14 marine protected areas encompassing more than 170,000 square miles of ocean and Great Lakes waters. The 13 national marine sanctuaries and one marine national monument within the National Marine Sanctuary System represent areas of America's ocean and Great Lakes environment that are of special national significance. Within their waters, giant humpback whales breed and calve their young, coral colonies flourish, and shipwrecks tell stories of our maritime history. Habitats include beautiful coral reefs, lush kelp forests, whale migrations corridors, spectacular deep-sea canyons, and underwater archaeological sites. These special places also provide homes to thousands of unique or endangered species and are important to America's cultural heritage. Sites range in size from one square mile to almost 140,000 square miles and serve as natural classrooms, cherished recreational spots, and are home to valuable commercial industries.

Because of considerable differences in settings, resources, and threats, each marine sanctuary has a tailored management plan. Conservation, education, research, monitoring and enforcement programs vary accordingly. The integration of these programs is fundamental to marine protected area management. The Marine Sanctuaries Conservation Series reflects and supports this integration by providing a forum for publication and discussion of the complex issues currently facing the sanctuary system. Topics of published reports vary substantially and may include descriptions of educational programs, discussions on resource management issues, and results of scientific research and monitoring projects. The series facilitates integration of natural sciences, socioeconomic and cultural sciences, education, and policy development to accomplish the diverse needs of NOAA's resource protection mandate. All publications are available on the Office of National Marine Sanctuaries Web site (http://www.sanctuaries.noaa.gov).

A Review of Resource Management Strategies for Protection of Seamounts

Oren T. Frey[1] and Andrew P. DeVogelaere[1]

[1] Monterey Bay National Marine Sanctuary, 99 Pacific Street #455, Monterey, CA 93940 USA

U.S. Department of Commerce
Penny Pritzker, Secretary

National Ocean and Atmospheric Administration
Kathryn Sullivan, Ph.D.
Acting Under Secretary of Commerce for Oceans and Atmosphere

National Ocean Service
Holly Bamford, Ph.D., Assistant Administrator

Office of National Marine Sanctuaries
Daniel J. Basta, Director

Silver Spring, Maryland
March 2014

Disclaimer

Report Availability

Electronic copies of this report may be downloaded from the Office of National Marine Sanctuaries web site at http://sanctuaries.noaa.gov.

Cover

Black coral, primnoid coral, and feather stars flourish 2,669 m (8,757 ft) deep on the pristine Davidson Seamount off the coast of California. Photo credit: MBARI/MBNMS.

Suggested Citation

Frey, Oren, and A.P. DeVogelaere. 2014. A Review of Resource Management Strategies for Protection of Seamounts. Marine Sanctuaries Conservation Series ONMS-14-08. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 52 pp.

Contact

Andrew P. DeVogelaere, andrew.devogelaere@noaa.gov, Mailing address: 99 Pacific Street #455, Monterey, CA 93940. Phone: 831.647.4228

Abstract

Seamounts are prominent undersea mountains characterized by complex topography that provide a variety of habitat for rich and diverse communities. Of the world's thousands of identified seamounts, most are difficult to access and few have been studied in any detail. Yet there is growing awareness that seamounts are special undersea features hosting unique and highly productive ecosystems, and they are of great interest to researchers in many fields. Over the past decade, there has been a strong push to protect seamount communities from threats ranging from deep-sea fishing to harvesting of non-living marine resources. A number of resource protection mechanisms exist for seamounts, ranging from national legislation to multi-lateral agreements to conserve seamounts on the high seas, using the authority of international instruments. Several prominent seamounts off the U.S. west coast have been protected, with Davidson Seamount in the Monterey Bay National Marine Sanctuary having the highest level of protection. While there are a number of other examples of seamount protection successes in both U.S. and foreign waters, as well as in waters beyond the jurisdiction of any nation, there is a wide range in both the scope of protective measures and in the designating governments' resource management capacities.

Key Words

Seamount, marine protected area, conservation, Monterey Bay National Marine Sanctuary, MBNMS, threats, deep-sea, resource protection

Table of Contents

List of Figures and Tables

Figure/Table Number and Title .... Page

What are Seamounts?

Seamounts are prominent undersea mountains that rise relatively steeply at least several hundred meters from the surrounding deep-sea floor. They are generally isolated and of volcanic and/or tectonic origin, and are typically cone-shaped features with a circular, elliptical or more elongated base (Santos et al. 2010; CBD 2008a; Davis et al. 2002). Although seamounts can be very large features in terms of their elevation and the footprint of their base, most definitions specify that seamounts do not emerge above the sea surface (Epp & Smoot 1989). Traditionally, geologists have included height as a defining factor of seamounts, and seamounts have been widely classified as geomorphological features with elevations exceeding 1,000 meters above the seabed (CBD 2008a; Baker et al. 2001). Pitcher et al. (2007) proposed an alternative definition that classifies seamounts as topographically distinct seafloor features that: a) are at least 100 meters high, b) do not break the sea surface, c) are not large banks and shoals, and d) are not situated on continental shelves. Satellite altimetry has been key in identifying large seamounts, which are considered those with heights exceeding 1,500 meters, regardless of depth (Santos et al. 2010). Smaller features, which are often older seamounts that have sunk under their own weight and the subsidence of the lithosphere, are referred to as knolls, mounds, or seamounds (Kitchingman and Lai 2004). These formations must be identified through remote sensing and local acoustic mapping, and have generally been less described and sampled.

Seamounts are often characterized by a complex topography that includes terraces, pinnacles, ridges, crevices and craters. Seamounts thus provide a variety of living conditions and substrates, creating suitable habitat for rich and diverse communities (van den Hove and Moreau 2007). As large features, seamounts also have a major effect on the physical structure of the water column (Rogers 2004). Oceanographic effects of seamounts include the formation of trapped waves, jets, eddies and closed circulations called Taylor Columns. These phenomena are usually associated with the upwelling of nutrient rich waters, which can lead to increased productivity in waters near the surface (Rogers 2004; Santos et al. 2010).

Distribution of Seamounts

Seamounts often, but not always, occur along mid-ocean ridges and the edges of tectonic plates, with more elongated seamounts occurring in areas of seafloor spreading (Davis et al. 2002). There is no agreed upon number of seamounts in the world, as multiple definitions have been used to distinguish between seamounts and seamounds. Additionally, many studies have relied on automatic (algorithmic) detection of potential seamounts by analysis of global gravity or bathymetric data obtained by satellite and direct ship tracks[1] (Allain et al. 2008). The use of

[1] In mapping seamounts and other sources of ocean-floor relief, ship track bathymetric data provide high resolution but only covers 10% of the world's oceans. Features are identified by comparing feature height to that of the neighboring seafloor, the slope of the flanks, and the area of the summit. Satellite altimetry offers an alternative method, which provides continuous coverage although at a lower resolution. Altimetry data products use gravity anomalies to predict bathymetry. Over the ocean, anomalies in free-air gravity are mainly caused by lateral density variations caused by undulations of the seafloor. The gravity field over a seamount is locally enhanced because basalt is much denser than seawater. Thus, local gravity maxima, together with gravity anomalies caused by deformations to the surrounding seafloor, can be used to identify seamount locations (Wessel et al. 2010).

predictive datasets introduces additional variability since the bathymetric maps used have varying levels of resolution (Kitchingman and Lai 2004). Moreover, due to limited ground truthing, existing seamount databases have largely remained unvalidated and require cross-checking to remove features that are not actually seamounts (Allain et al. 2008).

Using the traditional definition of seamounts as features with elevations greater than 1,000 meters, researchers have typically estimated that there are between 33,000 – 39,000 isolated large seamounts in the world (Yesson et al. 2011; Hillier and Watts 2007). A study by Kitchingman and Lai (2004) using a digital global elevation map distributed by the U.S. National Oceanographic and Atmospheric Agency (NOAA) found the number to be about 14,000. Including a wider range of seamount shapes or ridge peak and size could increase this number to 100,000 (CBD 2008a). While many seamounts are situated within states' exclusive economic zones (EEZs), an estimated 53% of the world's known seamounts are located in areas beyond the limits of national jurisdiction (CBD 2008c; Alder and Woods 2004). Although seamounts are found in every ocean basin and at most latitudes, over half of the world's known or inferred seamounts are located in the Pacific Ocean (CBD 2008c; Fig. 1). The U.N. Food and Agriculture Organization (FAO)'s division of the world's oceans into 19 marine statistical regions allows for useful summary information that describes the global distribution of seamounts by region. This regional summary is useful because it describes not only the quantity of seamount features, but also specifies the area they encompass and the extent to which they are included within marine protected areas (Table 1).

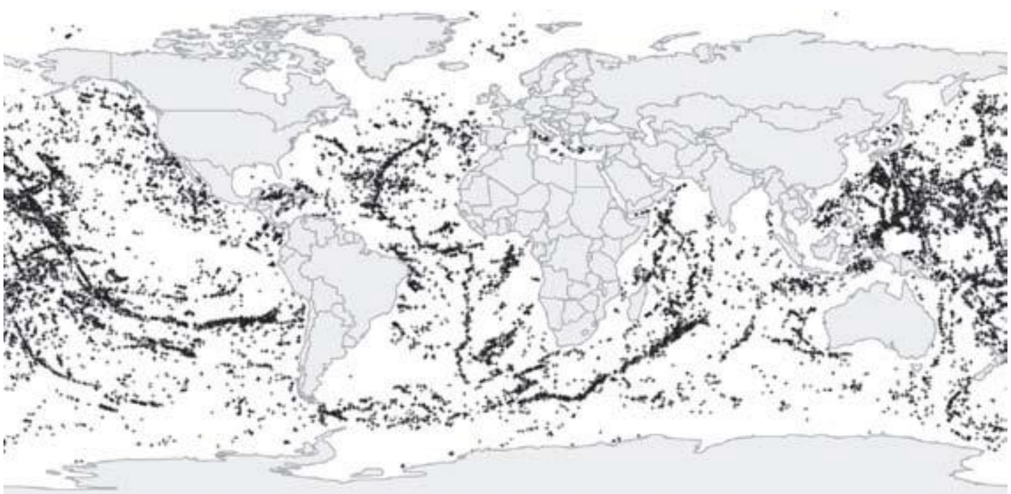


Figure 1. Estimated distribution of approximately 14,000 particularly well-defined (conical) large seamounts. Including a wider range of seamount shape or ridge peak and size could increase their number to 100,000. Figure from (CBD 2008c).

A very small proportion of the world's seamounts have been the subject of scientific study (Staudigel et al. 2010). Only about 350 seamounts have been sampled, and fewer than 200 have been studied in any detail (CBD 2008c). Just under 250 seamounts are listed on Seamounts Online (http://seamounts.sdsc.edu/), an online data portal that makes available data on species that have been observed or collected from seamounts (Fig. 2). Due to ease of access, most research has been conducted on seamounts in waters within national jurisdiction, and sampling has not been evenly distributed around the world (CBD 2008c).

Table 1. Number of seamounts by U.N. Food and Agriculture Organization (FAO) statistical regions based on 30 arc-sec bathymetry data, filtered to exclude overlapping features, as estimated by Yesson et al. (2011). Areas are in km^2. Productive seamounts are those with summit depths < 1,500 meters. "In MPA" refers to the number of seamounts with summits known to occur within marine protected areas listed on the World Database of Protected Areas, and "high seas" refers to seamounts in waters beyond the limits of national jurisdiction. Table from (Yesson et al. 2011).

Ocean	FAO region		Seamounts (1)				
	ID	Name	*n*	Area	Productive	in MPA	High seas
	37	Mediterranean & Black Sea	88	57,365	60	4	0
Arctic	18	Arctic	41	27,403	14	0	31
Atlantic	34	Eastern Central	764	600,603	150	1	614
	27	Northeast	567	393,012	244	0	299
	21	Northwest	102	79,233	23	0	91
	47	Southeast	819	699,888	241	0	668
	41	Southwest	634	490,682	107	3	432
	31	Western Central	1061	713,733	190	13	765
Atlantic total			3947	2,977,150	955	17	2869
Indian	57	Eastern	964	760,094	146	9	690
	51	Western	1614	1,216,271	372	0	1056
Indian total			2578	1,976,365	518	9	1746
Pacific	77	Eastern Central	3243	2,612,365	592	94	1434
	67	Northeast	382	267,226	72	0	280
	61	Northwest	1735	1,352,378	442	38	830
	87	Southeast	1599	1,169,534	402	18	1237
	81	Southwest	1384	1,140,405	336	31	969
	71	Western Central	3168	2,547,206	1304	57	611
Pacific total			11,511	9,089,114	3148	238	5361
Southern	48	Atlantic, Antarctic	813	611,463	222	0	475
	58	Indian, Antarctic	313	257,231	103	3	223
	88	Pacific, Antarctic	329	226,643	107	0	267
Southern total			1455	1,095,337	432	3	965
Global total			19,620	15,222,733	5127	271	10,972

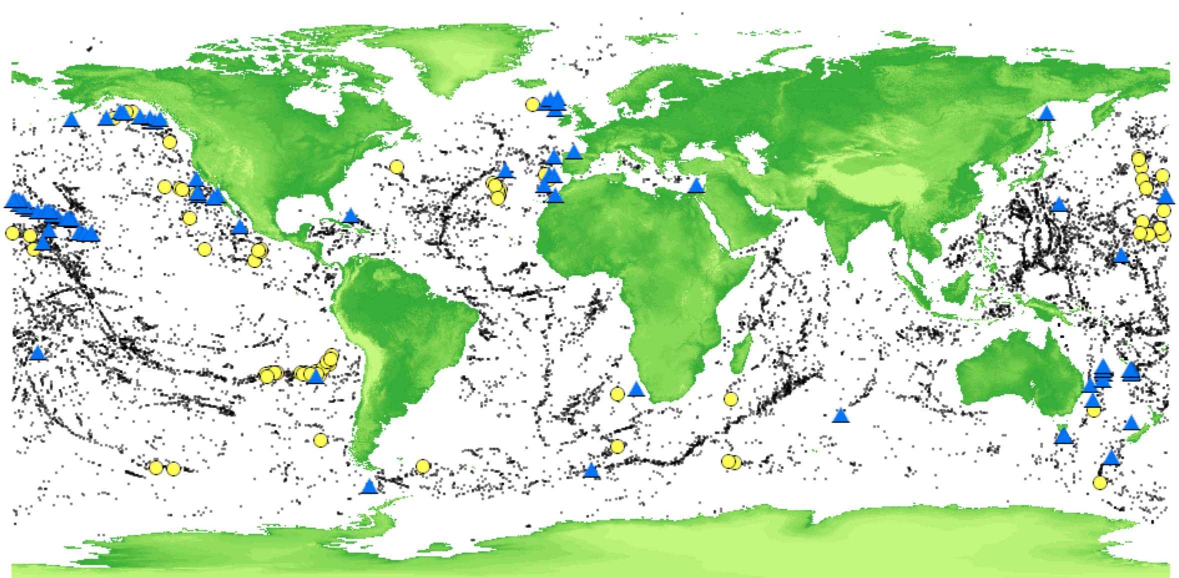


Figure 2. Locations of 171 seamounts for which *Seamounts Online* has invertebrate data. Circles indicate seamounts outside any country's exclusive economic zone (EEZ). Triangles indicate seamounts within EEZs. Small dots indicate the predicted locations of the > 14,000 unsampled seamounts identified by Kitchingman and Lai (2004). Figure from (Stocks 2004).

Why Are Seamounts Important?

Seamounts remain little-understood environments. The geology, oceanography, biodiversity, and ecology of seamounts, as well as the effects of human activities on seamount environments, have only recently begun to be studied (Gubbay 2003; DeVogelaere et al. 2005). However, it has become clear that seamounts are special undersea features hosting unique and highly productive ecosystems, and they are of great interest to researchers in many fields (e.g., Lundsten et al. 2009b, Lundsten et al. 2012, Staudigel et al. 2010, Pitcher et al. 2007).

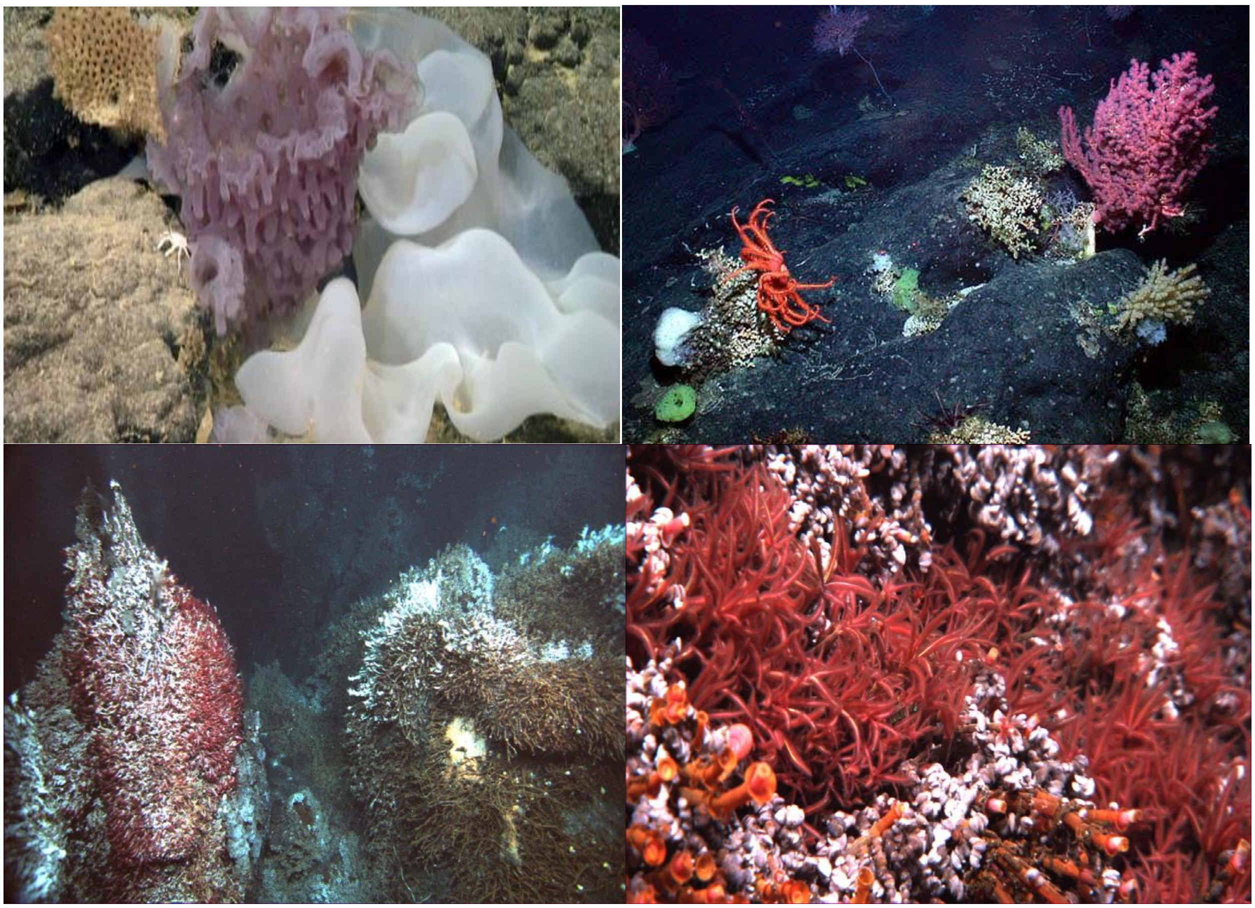


Figure 3. Examples of seamount organisms, including purple goiter sponge on Taney Seamount B (top left); gorgonian soft corals (*Paragorgia* sp. and *Metallogorgia* sp.), a brisingid sea star perched on a dead coral skeleton, and two species of sponge at the New England Seamount complex (top right); vent communities of palm worms, tubeworms, and limpets near the top of Hulk chimney, Main Endeavour Field, near Axial Seamount (bottom right and bottom left). Photo credits: MBARI; NOAA 2003; Bobbitt 2007.

From a geological perspective, seamount abundance and distribution can be applied to inform research on the formation of the seafloor (Davis et al. 2007; Hillier and Watts 2007), and from an oceanographic point of view seamounts have considerable impact on the circulation of water masses and can affect large-scale events such as tsunami propagation (Mofjeld et al. 2001). The complex topography that often characterizes seamounts creates a variety of habitats that host rich and diverse ecological communities (Rogers 2004). Aggregations of open-ocean and deep-sea marine species, including fishes, sharks, sea turtles, marine mammals, and seabirds, are common around and above seamounts since food supplies and reproductive habitats tend to be more concentrated on seamounts than in the open ocean (Rogers 2004; Maxwell et al. 2012). When commercially valuable species are aggregated around seamounts, there can be strong incentives to develop fisheries for those species (Koslow 2001). Seamounts are also home to many deep-water coral reefs, which add further environmental complexity and can provide spectacular biogenic habitats (DeVogelaere et al. 2005).

Seamounts are thus widely recognized as biodiversity hotspots, and due to physical isolation taxa on some seamounts exhibit high levels of endemism (de Forges et al. 2000; Allain et al. 2008); though there is growing debate on endemism associated with seamounts (McClain et al. 2009). In addition to having the potential capacity to act as centers of endemism and speciation, some seamounts may act as "stepping stones" for the dispersal of coastal species (Brewin et al. 2007; Stocks 2009). Some species of fishes associated with seamounts are very slow growing and slow to mature, and exhibit extreme longevity (Koslow et al. 2000; Rogers 2004). The prevalence of large, slow-growing species such as cold-water corals, which are easily damaged by threats to seamounts, makes many seamount communities highly fragile. These dynamics, require careful management based on available scientific information and the precautionary principle in order to prevent overharvesting and habitat damage. Seamounts offer excellent case studies for understanding marine biodiversity patterns, and offer ecosystems for study that have not yet received scientific attention consistent with their biological and ecological value (Stocks 2009; CBD 2008c).

Threats to Seamounts

Seamounts worldwide face a number of threats. A variety of factors, such as seamount size and depth, accessibility, the types of resources present, and existing regulations and protections, cause the severity of these threats to vary highly from one seamount to another. However, most seamount communities are likely to be affected by some combination of these threats, which have been described in detail as they pertain to Davidson Seamount in the Monterey Bay National Marine Sanctuary (MBNMS 2012a).

Harvest of living marine resources

Seamounts are home to at least 70 species of commercially valuable fish and shellfish, and overexploitation of seamount fisheries (Fig. 4) is thought to pose the greatest risk to seamount habitats worldwide (Rogers 1994; Morato et al. 2010). Fishes targeted by deep-sea fisheries include orange roughy and oreos in the temperate South Pacific, toothfish in the Southern Ocean, pelagic armourhead in the North Pacific, several species of *Sebastes* along the continental slope of the North Pacific and North Atlantic, and alfonsino (*Beryx* spp.) in the tropics and subtropics (Koslow et al. 2001). Longline and trawl fisheries can operate at depths of more than 1,500 m, and can deplete stocks of long-lived, slow-growing, low-fecund species quickly, leading to commercial extinction if not well regulated (Koslow 2001; Gubbay 2003; CBD 2008b). The benthic environment can also be severely impacted by seamount trawl fisheries, which can remove deep-water reefs and associated fauna from heavily fished areas (Koslow 2001; Van den Hove and Moreau 2007). The Corner Rise Seamounts of the Northwest Atlantic are an example of the type of damage that seamount trawl fisheries can cause (Fig. 5). Recovery from these impacts may be very difficult, as a study by Williams et al. (2010) showed no change in the megabenthic assemblage consistent with recovery over a 5–10 year timeframe on seamounts where trawling had ceased.

Fisheries also exist in the waters above seamounts, and as fishing pressures increase in less regulated high seas areas, the loss of pelagic predators may cause impacts to deep-sea communities. Fishing pressure might be extended into deeper waters, and community composition could be altered if predation pressure were reduced due to fishing. Additionally, fragile, slow-growing precious corals (e.g. *Corallium* spp.) have been harvested in significant quantities in the North Pacific, often on seamounts (Andrews et al. 2002; Andrews et al. 2005). These corals continue to fetch very high prices on the market, and only some have been included in the Convention on International Trade in Endangered Species (CITES) Appendix III (UNEP-WCMC 2012).

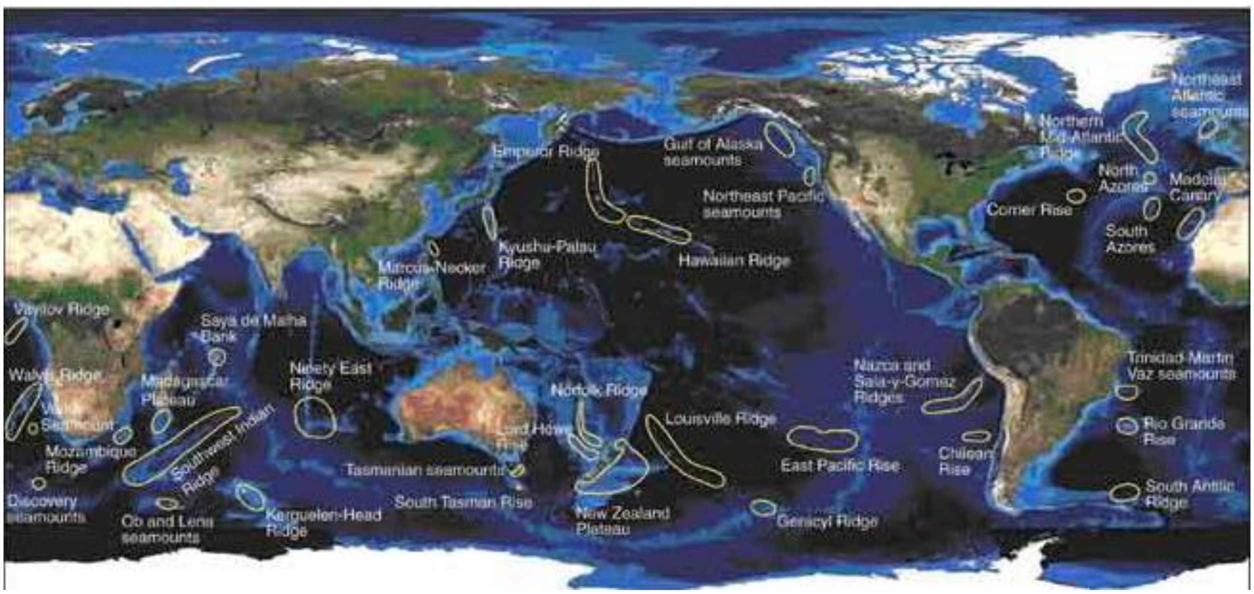


Figure 4. The distribution of major fisheries on seamounts and ridges, including those in the high seas and in national waters. Figure from (Rogers et al. 2008).

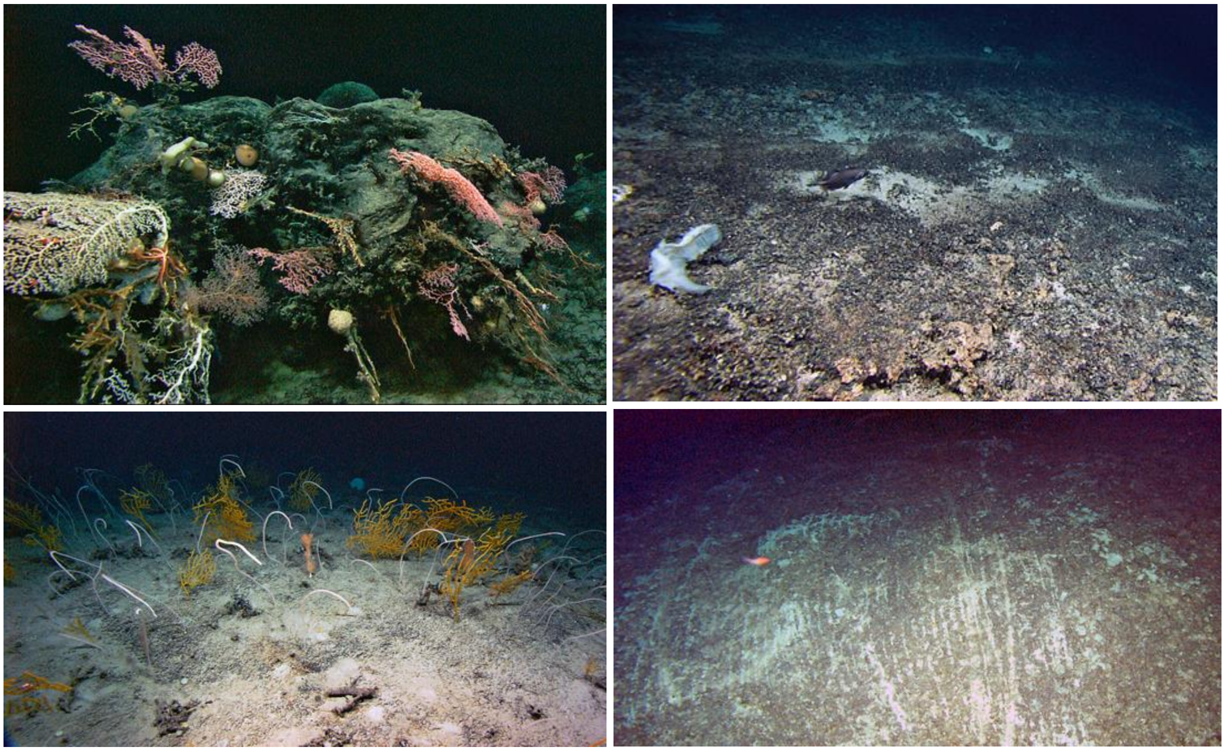


Figure 5. Destruction on the Corner Rise Seamounts of the Northwest Atlantic. Yakutat Seamount (1,430 m), with more than five species of coral and other species including brittle stars, starfish, crabs and mollusks (top left) and in 2005 with a dead coral bank showing extensive linear scars from trawling (top right); and Kükenthal Peak (725 m; Corner Seamount) with a community of whip corals, sea fans, and bamboo corals on a plateau that avoided trawling damage (bottom left) and with trawling scar marks that scientists say "effectively denuded" the seamount (bottom right). Figures adapted from (Kusek 2007; Waller et al. 2007).

Exploitation of non-living resources

An emerging threat to seamounts is the possibility that deep-sea mining companies may target seamount areas for new extractive activities. Some firms have investigated the potential to extract cobalt-rich ferromanganese oxide (Fe-Mn) crusts and polymetallic sulphides from seamounts (Stocks 2009). If such activities were to occur, the potential for impacts would include the loss of fossil records due to physical damage, the release of metals that affect benthic fauna, high levels of dissolved nutrients in the water column, damage to living resources using extracted resources as habitat or substrate, and the creation of sediment plumes and debris build-up at the base of the seamount (Sarma et al. 1998; CBD 2008b).

Offshore oil and gas exploration can also threaten seamount communities through the use of high-decibel seismic surveys, the release of "drilling muds" containing toxic contaminants (zinc, benzene, arsenic, radioactive materials) that are used to lubricate drill bits and maintain pressure, and the potential for spills and leaks (Patin and Cascio 1999).

Bioprospecting

The search for substances and genetic materials with potential industrial or commercial uses is termed bioprospecting, or sometimes bio-discovery (Van den Hove and Moreau 2007). Global sales of marine biotechnology products, including antivirals, antibiotics and anti-cancer compounds, were estimated at about US$2.4 billion for the year 2002 alone (Arico and Salpin 2006). The industry is poised for rapid growth, and unregulated harvesting is most likely on seamounts on the high seas, where a regulatory vacuum exists and overexploitation of commercially important species has already occurred. Although extensive harvesting may be restricted in some cases by difficult access and high costs, more likely scenarios involve the retrieval of small numbers of specimens for testing, screening, and further study (Van den Hove and Moreau 2007). The collection of sensitive species at any scale could damage fragile seamount ecosystems.

Unmanaged research collection

Studies have suggested that the number of undiscovered seamount species far exceeds the number of species already discovered, and research efforts will continue to intensify as resources allow (Arico and Salpin 2005). Research interest is particularly high for deep-sea corals such as gorgonians since they can live for centuries and have a worldwide distribution, thereby providing a source of isotopic and geochemical data that can help reconstruct historical changes in oceanographic conditions and ocean climate (Tsounis et al. 2010). Over time, unmanaged research activities can pose a variety of threats to seamount ecosystems including unsustainable collection rates, habitat destruction by vessels and equipment, alteration of local hydrological and environmental conditions, unintended introduction of pollutants, and light and noise impacts (Arico and Salpin 2005).

Sea temperature rise

Any changes in seawater temperatures as a result of anthropogenic global climate change may adversely affect the biological functioning of corals and other seamount organisms. Cold-water corals, such as *Lophelia pertusa*, have been shown to be extremely sensitive to the physical characteristics of overlying seawater (Rogers 2004). Changing sea temperatures will likely be the cause of associated changes in ocean currents – a phenomenon with potentially severe impacts on productivity patterns and the functioning of seamount ecosystems, which often benefit from upwellings of nutrient-rich waters and eddies of water around their summit (Santos et al. 2010). Warmer seawater could also reduce the ocean's overall primary productivity, thereby limiting the amount of organic matter that eventually falls to the seafloor and supplies deep-sea species with nutrients.

Ocean acidification

Currently, our oceans and marine organisms are experiencing the greatest increase in acidification of the past 300 million years, and mean ocean pH is predicted to be at its lowest level in 20 million years by 2050 (CBD 2008b; Turley et al. 2007). Although the full range of impacts that this drop in pH will have on deep-sea organisms remains unknown, the most profound effect involves acidic seawater de-saturating aragonite in water, limiting the ability of marine calcifying organisms that build their external skeletal material out of calcium carbonate (Hofmann et al. 2010). Since deeper waters at higher latitudes already experience a lowered carbonate saturation state, cold-water calcifying organisms like the corals and invertebrates found at many seamounts may be among the species most vulnerable to acidification.

Though ocean acidification poses the threat of extinction before the scientific community has begun to fully understand deep-sea ecosystems, the problem could be compounded should incentives increase for commercial interests to develop CO_2 sequestration schemes in the ocean (Santos et al. 2010). Ocean CO_2 sequestration could take the form of storing carbon in geological formations under the seabed, on the seafloor, and in the water column of the deep ocean. Seafloor storage would form deep-water lakes of liquefied CO_2, which is denser than surrounding seawater at depths over 3,000 meters (Hood et al. 2014). Though the time-delayed release of CO_2 from these lakes would slow the release of CO_2 into the atmosphere over the course of hundreds or thousands of years, the impact on deep-sea species and ecosystems that are unaccustomed to rapid environmental changes is largely unknown. Technological advances, market forces, and regulation of areas adjacent to seamounts will determine the extent to which CO_2 sequestration will exacerbate ocean acidification impacts on seamount communities.

Vessel Traffic

Although the risk of vessel groundings and sinkings are lower above seamounts than in coastal waters, spills can potentially occur from any transiting vessel carrying crude oil, bunker fuel, or other hazardous materials. Although petroleum products tend to float, heavier chemical compounds are more likely to sink and would introduce toxic substances to seamount environments. Another class of threat related to vessel traffic is the possibility for cargo from container ships to be lost at sea. Impacts of lost cargo can include the threat of benthic habitat crushing or smothering, the introduction of foreign habitat structure, entrapment of organisms, ingestion of foreign materials by marine life, and the introduction of chemical pollutants (Frey and DeVogelaere, *In review*.). Finally, shipwrecks and submerged vessels may contain fuel oil, hydraulic fluid, and other chemicals and fluids that may leach out into the marine environment, posing an environmental contamination threat to seamount communities.

Other Threats

Seamount environments are also threatened by additional human activities that impact all ocean areas. These include dumping of waste at sea, the accumulation of marine debris, military activities, the installation of underwater cables, and diminished water quality (NOAA 2008).

Prioritizing Seamounts for Protection

As some of the world's last wilderness areas, seamounts are considered vulnerable marine ecosystems (VMEs) by the FAO because they are often places that have both unique biodiversity and resources of commercial interest. When unregulated exploitation of those resources occurs, the results can be severe, both ecologically and economically. Due to their vulnerability to a wide range of threats, seamounts are of high interest for conservation. The lack of existing management in many areas where seamounts are found makes them ideal candidates for protection in the form of offshore and high-seas marine protected areas (MPAs; Alder and Woods 2004; Davies et al. 2007). However, seamounts are only beginning to attract the level of conservation attention that other classes of VMEs such as seagrasses and coral reefs have attracted (Fig. 6). Seamount MPAs can focus on both undisturbed and disturbed seamount communities. Although there is no single management model that can be applied to all seamounts, limiting certain activities on and around seamount areas, in the form of seamount MPAs may provide opportunities for research and monitoring (as sentinel sites), or as baselines for recovery (Morato et al. 2010). One of the main challenges to protecting more seamount areas is the large data gap that persists in seamount science; it can be difficult for management authorities to decide which seamounts should be prioritized for protection when seamount community structure and the effects human activities have on seamount ecology are only beginning to be understood (Morato et al. 2010).

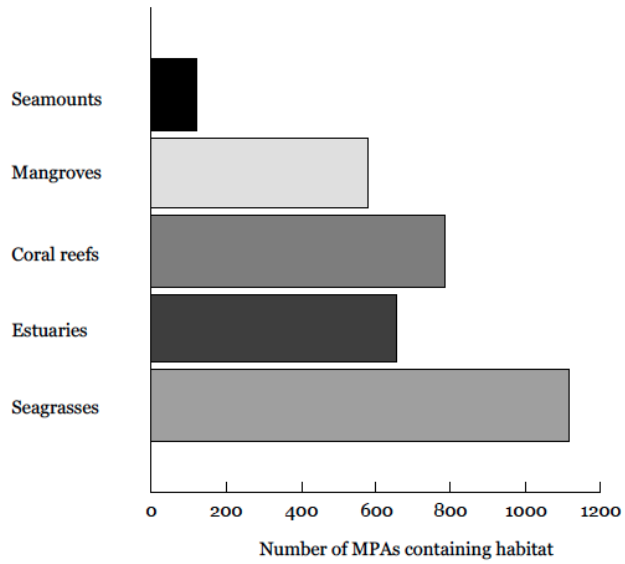


Figure 6. Number of MPAs worldwide containing different types of critical habitat. Figure from (Alder and Woods 2004).

Pitcher and colleagues (2010) have introduced a framework to standardize the parameters by which seamounts are characterized. The Seamount Ecosystem Evaluation Framework (SEEF) is a multidisciplinary tool developed to standardize the parameters by which seamounts are characterized. Part A of SEEF scores the extent of our knowledge about a range of attributes of individual seamounts, while Part B scores the relative severity of threats posed by human activities to the abundance and diversity of seamount resources. An initial SEEF has been produced for 15 seamounts in the Atlantic and Pacific Oceans, including Davidson Seamount in the MBNMS (Fig. 7). While the method used in developing the SEEF is useful, the authors suggest modifying the contents of the table given the availability of more recent information on resource management at Davidson Seamount and other sites.

Figure 7. Preliminary Seamount Ecosystem Evaluation Framework (SEEF) for 15 seamounts in the Atlantic and Pacific oceans. Figure from (Pitcher et al. 2010).

Another framework for evaluating seamounts for protection has been developed in response to the Convention on Biological Diversity (CBD) goal of preserving 10% of all marine biomes by 2020 (Taranto et al. 2012). Achieving this goal requires the identification of ecologically or biologically significant marine areas (EBSA), including seamounts, in all biogeographic regions. There are seven selection criteria for nominating EBSA, including 1) uniqueness or rarity; 2) special importance for life-history stages of species; 3) importance for threatened, endangered or declining species and/or habitats; 4) vulnerability, fragility, sensitivity, or slow recovery; 5) biological productivity; 6) biological diversity; and 7) naturalness (Ardron et al. 2009). The ecosystem evaluation framework for seamounts developed by Taranto and colleagues (2012) combines the likelihood of a seamount constituting an EBSA and its level of human impact, with the result being the classification of individual seamounts into four major portfolio conservation categories. Application of the framework to eight case study seamounts classified half as deserving of protection (high EBSA likelihood and high threats exposure; Fig. 8). The sheer number of seamounts in the world, most of which have not been the subject of scientific study, makes comprehensive, global application of these tools a major undertaking.

Clark and colleagues (2011) attempted a global seamount classification by using “biologically meaningful” physical variables for which global-scale data are available. Four key environmental variables (potential species richness and abundance of a community, summit depth, oxygen levels, and seamount proximity to continents) were applied to the bathyal zone for seamounts in the Kitchingman and Lai (2004) dataset (Clark et al. 2011). The study identified 194 classes of seamounts with similar characteristics throughout the world’s oceans. These types of classification systems can be applied at any geographic scale, and action can most usefully be directed at regions, clusters of seamounts within reach of exploitative activities, and seamounts that have been studied in detail (Santos et al. 2010). Grouping seamounts by their general characteristics can thus assist resource managers in identifying which seamounts and seamount chains would offer the most “bang for the buck” if afforded protections.

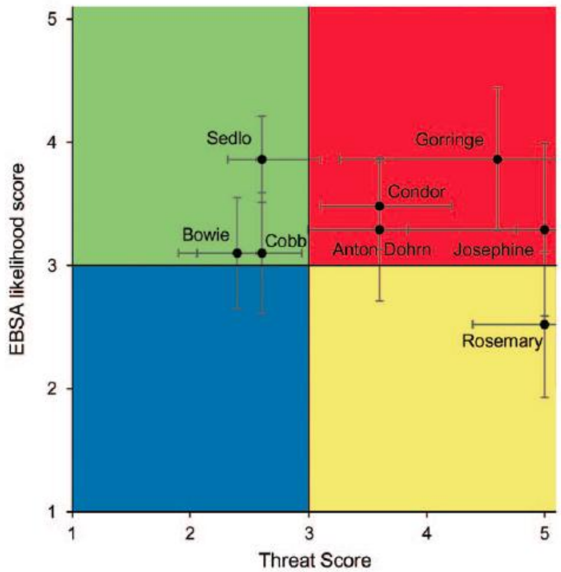


Figure 8. Seamount Ecologically or Biologically Significant Areas (EBSA) portfolio plot based on EBSA likelihood scores and threat scores for eight case studies. Four portfolio categories include Blue (low EBSA likelihood and low threats exposure), Yellow (low EBSA likelihood and high threats exposure), Green (high EBSA likelihood and low threats exposure), and Red (high EBSA likelihood and high threats exposure). Error bars represent the data uncertainty index proportional to data availability and quality. Figure from (Taranto et al. 2012).

Seamount Protection Mechanisms

Possible conservation measures for seamounts range from MPAs to activity-based restrictions, and also include regulation of activities beyond the immediate vicinity of seamounts (Probert et al. 2007). MPAs have been defined by the International Union for Conservation of Nature (IUCN) as: "Any area of inter-tidal or sub-tidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment" (CBD 2003). MPAs are managed to achieve different conservation objectives and have varying degrees of protection, ranging from fully protected reserve areas to areas that permit various user activities (CBD 2003).

A seamount's location plays an important part in its management effectiveness. Both territorial waters and EEZs comprise waters under national jurisdiction, and affording legal protection to seamounts in these settings is relatively straightforward since most countries already have a legal and administrative basis for designating and implementing MPA programs (Gubbay 2003). National policy instruments that may apply to seamounts include ocean and coastal planning efforts, fisheries management, minerals management, and legislation related to hazardous waste disposal, transportation and navigation, protected area designations or expansions, and biodiversity protection (Alder and Woods 2004). Once established, various tools can be used to manage seamount MPAs, including spatial zoning and closures, size considerations, mapping, enforcement, and policing (Santos et al. 2010). Although an estimated 155 countries have seamounts within their maritime jurisdictions, by 2004 only 22 had applied protected area legislation to all or a portion of them, and in some cases legislation did not result in meaningful protection (Alder and Woods 2004). Australia, New Zealand, Norway and the United States were among the first countries to protect seamounts in waters within national jurisdiction (Thiel and Koslow 2001).

In waters outside of EEZs, considered 'areas beyond national jurisdiction' (ABNJ) or the 'high seas,' there is often no specific legal mechanism for the designation of protected areas despite a mandate from the United Nations Convention of the Law of the Sea (UNCLOS) to protect and preserve the marine environment, to conserve natural resources, and to cooperate with other States in this regard (Gubbay 2003). Additionally, a 2007 UN General Assembly resolution on sustainable fisheries specifically mentions the needs to protect seamounts, calling upon states "to take action immediately, individually and through regional fisheries management organizations and arrangements, and consistent with the precautionary approach and ecosystem approaches, to sustainably manage fish stocks and protect vulnerable marine ecosystems, including seamounts, hydrothermal vents and cold water corals, from destructive fishing practices, recognizing the immense importance and value of deep-sea ecosystems and the biodiversity they contain" (UNGA 2007). The legal and geopolitical challenges associated with protecting seamounts and other habitats in ABNJ make high seas seamount MPAs a very recent phenomenon. Creating these areas requires a high degree of interdisciplinary cooperation between States working under the authority of a variety of binding and non-binding international legal instruments (Table 2). Several of these legal instruments and conventions may apply to some of the many activities related to regulating seamount exploitation (Table 3).

In settings where high seas MPAs are unlikely to be created, activity-based regulations offer an alternative means of providing protections for seamounts. Strategies are most likely to focus on fishing, as biologists and resource managers usually perceive deep-sea fisheries as the largest threat to seamounts. When their member countries have shared goals, the stronger regional fisheries management organizations (RFMOs) have the ability to regulate deep-sea fisheries in international waters, including gear restrictions and closed areas. Of the more than 30 RFMOs in existence, those that have been most engaged in regulating seamount fisheries – usually bottom trawling – are located in the North Atlantic, although there is also potential for RFMOs in other regions to take similar actions (Fig. 9; Probert et al. 2007). The management objectives of any institutional arrangement that is used should focus on a) managing seamounts on an ecosystem basis; b) taking a highly precautionary approach, given the limited knowledge of seamount ecosystems and their vulnerability to overexploitation; c) incorporating natural variability by taking an adaptive management approach; d) targeting recovery and restoration as well as prevention of degradation; and e) working within and across a wider management framework (Alder and Woods 2004; Santos et al. 2010).

Table 2. International instruments and their application in managing and protecting seamounts. UNCLOS, United Nations Convention on the Law of the Sea; IMO, International Maritime Organization; IUU, Illegal, Unreported and Unregulated (fishing). Table from (Alder and Woods 2004)

.

Instrument	Potential for Seamount Management and Protection
Binding	
UNCLOS-Mining Agreement	Under Article 162.2.x of UNCLOS the International Seabed Authority may disapprove an area for exploitation where substantial evidence exists that mining activities pose a serious risk to the marine environment. Article 145 provides for the protection and conservation of the natural resources of the Area and the prevention of damage to the flora and fauna in the marine environment.
UNCLOS – Pollution	Under Part XII of UNCLOS States are obliged to protect and preserve the marine environment, especially 'rare or fragile ecosystems as well as the habitat of depleted threatened or endangered species' and to take measures individually or collectively to not cause pollution within and beyond their jurisdictions.
UNCLOS - Fisheries	UNCLOS obliges States to cooperate and conserve the living resource of the high seas. The States that are party to the Convention can take whatever measures are necessary to 'maintain or restore populations of harvested species at levels which can produce the maximum sustainable yield' and measures such as marine protected areas are not prohibited.
Fish Stocks Agreement	This Agreement addresses the shortcomings of UNCLOS in dealing with straddling and highly migratory stocks and is very relevant to fish on seamounts. The Agreement requires States to adopt compatible management measures without specifying which measures prevail in the case of disagreements (de Fontaubert, 2001). The Precautionary Principle also features prominently in the agreement and obliges States to be more cautious when information is inferior and not to use a lack of information as justification to avoid taking appropriate conservation and management measures
Regional Fisheries Agreements/Conventions	Most agreements contain provisions to undertake a range of fisheries management options that could be used to protect and manage seamount resources including closing areas to fishing, restricting the use of specific gear (e.g. trawls) and the size of species caught. Agreements, which restrict the range of species they can manage may need to be amended to include seamount species.
Convention on Biological Diversity and Jakarta Mandate	Article 4 extends the Convention beyond national jurisdictions for processes and activities undertaken by member States while the Jakarta Mandate includes calls for the establishment of MPAs.
Convention on the International Trade of Endangered Species (CITES)	CITES could be used to the management and protection of selected seamount species. Currently there are no seamount species listed, however, there have been calls to add the Patagonian toothfish to the list (Willock, 2002).
London Convention and IMO Particularly Sensitive Sea Areas	Waste disposal at sea is managed through this convention. The activities of ships, including discharges in the vicinity of seamounts can also be managed using Particularly Sensitive Sea Areas (PSSAs).
World Heritage Area Convention	The Convention stipulates that World Heritage Areas must be contained within national boundaries and therefore of limited use in managing and protecting seamounts in international waters.
Regional Seas Programs	Some of the treaties that establish specific Regional Seas Programmes extend into the high seas. In additional some treaties have provisions and protocols to protect areas and wildlife.
Non Binding	
FAO Code of Conduct	The Code can be used to manage fisheries on seamounts.
Agenda 21 and World Summit on Sustainable Development (WSSD)	The international initiatives have called for the establishment of marine protected areas on the high seas. The WSSD called for a network of Marine and Coastal Protected Areas within and beyond national jurisdiction by 2012.
FAO International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing	Seamounts are considered major centres of IUU fishing and therefore addressing the issue of IUU will contribute to managing and protecting seamounts (Rigg, 2004).

Table 3. Activities related to seamount exploitation and protection, as well as relevant authorities. CBD, Convention on Biological Diversity; COP, Conference of the Parties; MOP, Meeting of the Parties; UNCLOS, United Nations Convention on the Law of the Sea; RFMO, Regional Fishery Management Organization; UNFSA, United Nations Fish Stocks Agreement; FAO, Food and Agriculture Organization of the United Nations; IPOA, International Plan of Action; IUU, Illegal, Unreported and Unregulated (fishing); ICCAT, International Convention for the Conservation of Atlantic Tunas; CMS, Convention on Migratory Species; UNFCCC, United Nations Framework Convention on Climate Change; IMO, International Maritime Organization; MEPC, Maritime Environment Protection Committee; MSC, Maritime Safety Committee. Table adapted from (Santos et al. 2010).

Activities	*Legal basis*	*Relevant authority*
Designation of MPAs (within EEZs)	National legislation	National ministries/agencies
Designation of MPAs (High Seas)	CBD Regional Seas Conventions UNCLOS	CBD COP Regional Seas Conventions MOPs International Sea Bed Authority
Fishing (within EEZs)	National or regional legislation	National ministries/agencies
Fishing (High Seas)	RFMOs National legislation UNCLOS, UNFSA and other associated agreements	RFMOs National ministries/agencies Informal consultations of the Parties to the UNFSA
Fishing (general)	FAO Code of Conduct for Responsible Fisheries, FAO Compliance Agreement IPOA-IUU IPOA-Sharks	FAO FAO FAO
Tuna and billfish fisheries	ICCAT (Atlantic region only)	ICCAT (Atlantic region only)
Bycatch of migratory species	CMS	CMS COP
Mineral, petroleum, gas and oil extraction	UNCLOS	National ministries/agencies for the legal continental shelf, International Sea Bed Authority for areas beyond
Bioprospecting	UNCLOS CBD	National ministries/agencies for the legal continental shelf, International Sea Bed Authority for areas beyond CBD COP
Pollution	Regional Seas Conventions	Regional Seas Conventions Secretariats and MOPs
Climate change	UNFCCC	UNFCCC COP
Shipping	UNCLOS & IMO instruments	IMO's MEPC, MSC and Assembly

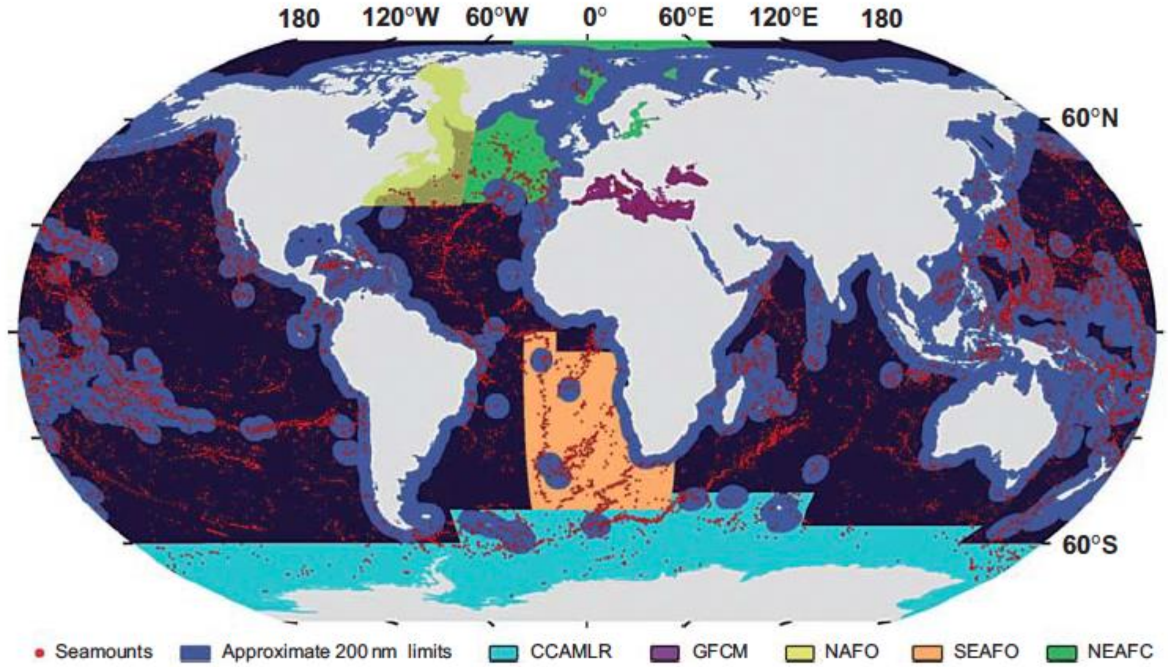


Figure 9. Regional Fishery Management Organizations (RFMOs) that have competence to regulate deep-sea fisheries. Dark blue, areas that lack coverage by an RFMO with the competence to manage deep-water fisheries on the high seas. Colored areas (in light blue, purple, green yellow, and orange), where RFMOs have a mandate to regulate deep-water fisheries. CCAMLR, Convention for the Conservation of Antarctic Marine Living Resources; GFCM, General Fisheries Commission for the Mediterranean; NAFO, North West Atlantic Fisheries Organization; SEAFO, South East Atlantic Fisheries Organization; NEAFC, North East Atlantic Fisheries Commission. Figure from (Probert et al. 2007).

Review of Protections for Seamounts

Here we describe some of the better-known seamounts and seamount chains, focusing on particularly notable characteristics and the status of implementing protective conservation measures, if any. This section is broken into sections of increasing geographic scale, starting with seamounts offshore of the U.S. West Coast, and then expanding to seamounts in or relatively near other parts of the U.S. EEZ. The protections afforded to seamounts located within the U.S. EEZ are then summarized (Table 4). Finally, we conclude by highlighting several examples of successful seamount protection that have been undertaken globally.

Offshore U.S. West Coast

Several seamounts are found off the U.S. West Coast, including several complexes off of central California, defined as extending from Point Conception in the south to San Francisco Bay in the north (Fig. 10). Of the seamount complexes listed here that are located within the U.S. EEZ, most have been designated as habitat areas of particular concern (HAPC) by the Pacific Fishery Management Council (PFMC; PFMC 2005). HAPCs are a subset of essential fish habitat (EFH) designations. Five types of HAPC have been defined by NOAA Fisheries for the Pacific groundfish fishery on the west coast: estuaries, canopy kelp, seagrass, rocky reefs, and "areas of interest," which may encompass a variety of submarine features, such as banks, seamounts, and canyons (PFMC 2005). As prominent features in the underwater landscape, these seamounts are considered important to Pacific groundfish management, of which the rockfish complex is part of, since currents generated by seamounts retain rockfish larvae and zooplankton, a principal food source for rockfish (PFMC 2005).

HAPCs are defined as areas that are rare, particularly susceptible to human-induced degradation, especially ecologically important, or located in an environmentally stressed area (NMFS 2011). Although designation as HAPC does not automatically afford any additional regulatory protection under the Magnuson-Stevens Act, federal actions with potential adverse impacts to HAPC are more carefully scrutinized during the consultation process and are subject to more stringent EFH conservation recommendations (NMFS 2011). Thus, designation of HAPC helps to prioritize and focus conservation efforts. In order to protect or minimize impacts from fishing on EFH or HAPCs of Pacific coast groundfish, EFH Conservation Areas have been designated along the west coast of the U.S., including over select seamounts. The extent to which activities are prohibited or restricted by an EFH Conservation Area varies from no use of bottom trawl gear, no use of bottom trawl gear other than demersal seine, no use of any bottom contact gear, to no use of bottom contact gear or other gear deployed deeper than 500 fathoms (Fig. 10).

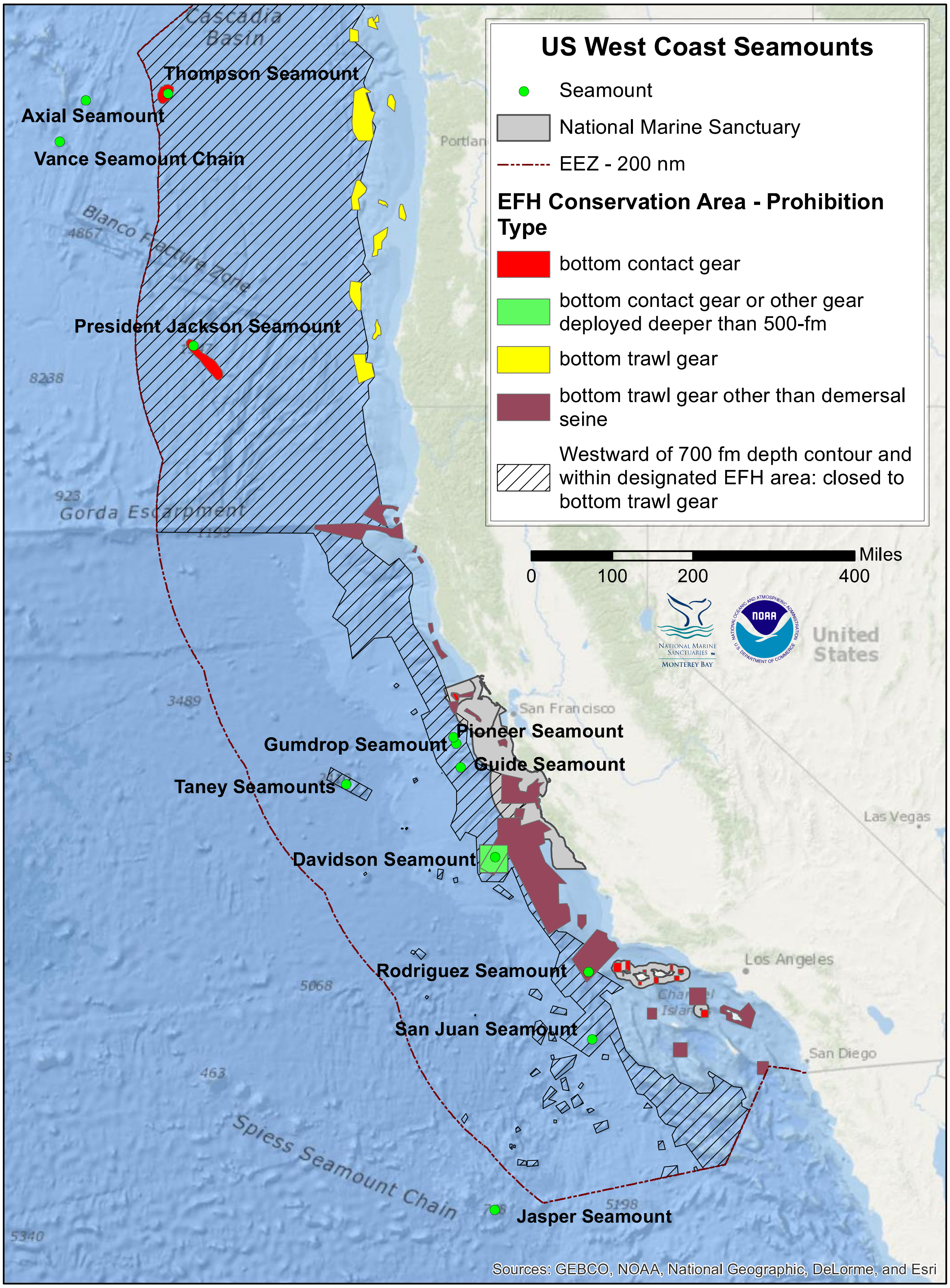


Figure 10. Location and protection status (if any) of seamount complexes off the U.S. west coast. The Davidson Seamount Management Zone is part of the Monterey Bay National Marine Sanctuary, and shares the same boundaries as the EFH designation shown for Davidson Seamount. Map credit: Chad King, MBNMS.

President Jackson Seamounts

The President Jackson Seamounts are a series of eight linearly arranged seamounts, located just west of the northern Gorda Ridge, off the coast of southern Oregon and within the U.S. EEZ. The PFMC has designated the President Jackson Seamounts as a HAPC Area of Interest. Additionally, the President Jackson Seamounts EFH Conservation Area has been created, with an area of 986.753 km^2 (MCI and WF 2012) that is closed to all bottom contact gear.

Thompson Seamount

Thompson Seamount is located off the coast of Washington, near the limit of the U.S. EEZ. The PFMC has designated Thompson Seamount as a HAPC Area of Interest. Additionally, the Thompson Seamount EFH Conservation Area has been created, with an area of 428.122 km^2 (MCI and WF 2012) that is closed to all bottom contact gear.

Axial Seamount and Cobb-Eickelberg Seamount Chain

The seamounts of the Cobb-Eickelberg Seamount Chain have been primarily created by the Cobb hotspot, which currently underlies Axial Seamount, the southern-most volcano of the seamount chain. Other seamounts in the southeastern part of the chain include Brown Bear Seamount, connected to the larger Axial Seamount by a small ridge, Cobb Seamount, and Eickelberg Seamount. The chain extends to the northwest as far as 1,800 km, to Marchand and Chirikof Seamounts in the Gulf of Alaska to the south of Kodiak Island (Chadwick et al. 2005). With the exception of its far northwestern extent, most of the seamounts in the chain fall outside the U.S. and Canadian EEZs and are thus not eligible for any kind of protection under national legislation.

Vance Seamounts

The Vance Seamounts are a chain of seamounts just south of Axial Seamount that erupted at another point in time along the Juan de Fuca Ridge and have since moved westward of the ridge (MBARI 2012f). These seamounts, with deep summits that barely crest 2000 m, are located outside the U.S. EEZ and are not protected by any national or international mechanisms.

Gumdrop, Pioneer, and Guide Seamounts

Gumdrop, Pioneer, and Guide Seamounts are located about 120 km offshore, north of Monterey Bay and just outside the western boundary of the Monterey Bay National Marine Sanctuary. The volume of each of these seamount complexes is estimated to be at least 100 km^3 (MBARI 2012a). These seamounts have been classified as HAPC Areas of Interest and are protected from bottom trawl gear as they lie within the EFH Conservation Area westward of the 700 fathom depth contour.

Taney Seamounts

The Taney Seamounts are further offshore, and consist of five aligned volcanoes ranging in volume from 11 to 187 km^3, with an average volume of 86 ± 64 km^3 (MBARI 2012b). The Taney Seamounts are not protected from exploitation. They have been designated by the PFMC as HAPC Areas of Interest and have been designated as an EFH Conservation Area in which bottom trawl gear is prohibited.

Davidson Seamount

Davidson Seamount stands approximately 130 km to the southwest of Monterey, and with an estimated volume of 320 km^3 is almost as large as Guide, Pioneer, and Gumdrop Seamounts combined (MBARI 2012c). At 26 miles long and 8 miles wide, it is one of the largest known seamounts in U.S. waters (MBNMS 2012b). Although its summit is 1,250 m below the sea surface (DeVogelaere et al. 2005), Davidson is also one of the better-studied seamounts in the world (MBNMS 2012b). Since 2006, Davidson Seamount has been classified as a HAPC Area of Interest and has received an elevated level of protection with an EFH Conservation Area where all fishing below 3,000 feet prohibited.

Because Davidson Seamount has special national significance relative to ocean conservation, ecological, scientific, educational, aesthetic, and historical qualities, in 2009 the waters surrounding it were added to the MBNMS as the Davidson Seamount Management Zone (DSMZ; MBNMS 2009). The DSMZ is a protected area bounded by a square approximately 30 nautical miles (nm) per side, centered on the crest of the Davidson Seamount. The zone's surface area is approximately 585 square nm, and the submerged lands there under are included within the DSMZ (NMSP 2008). Federal regulations governing the DSMZ include (NMSP 2008) the prohibition of:

- Moving, removing, taking, collecting, catching, harvesting, disturbing, breaking, cutting, or otherwise injuring, or attempting to move, remove, take, collect, catch, harvest, disturb, break, cut, or otherwise injure, any Sanctuary resource located more that 3,000 feet below the sea surface within the Davidson Seamount Management Zone. This prohibition does not apply to fishing below 3000 feet within the Davidson Seamount Management Zone, which is prohibited pursuant to 50 CFR part 660 (Fisheries off West Coast States).

- Possessing any Sanctuary resource the source of which is more than 3,000 feet below the sea surface within the Davidson Seamount Management Zone. This prohibition does not apply to possession of fish resulting from fishing below 3000 feet within the Davidson Seamount Management Zone, which is prohibited pursuant to 50 CFR part 660 (Fisheries off West Coast States).

Rodriguez Seamount

Rodriguez Seamount, also referred to as Rodriguez Guyot, is 250 km south of Davidson Seamount and is located about halfway up the continental rise, about 60 km offshore of Point Conception (MBARI 2012d; Lundsten et al. 2009b). It rises about 1,675 m from the surrounding seafloor to reach a minimum water depth of 650 m, and has a calculated volume of at least 205 km^3 (MBARI 2012d). A remotely operated vehicle dive at Rodriguez Seamount detected evidence of previous bottom trawling activity (Lundsten et al. 2009a). Currently, an EFH Conservation Area protects Rodriguez Seamount from bottom trawl gear other than demersal seine gear.

San Juan Seamount

San Juan Seamount is located south of Rodriguez Seamount in southern California. Although the summit of San Juan Seamount is presently 560 m below sea level, there is evidence that it was a volcanic island between 10-14 MYBP (Paduan et al. 2009; MBARI 2012e). The seamount has been designated by the PFMC as a HAPC Area of Interest, and it is within an EFH Conservation Area that prohibits the use of bottom trawl gear.

Jasper Seamount

Jasper Seamount is located about 500 km west-southwest of San Diego. It is a component of the Fieberling-Guadalupe seamount trail, with a height of 3,500 m and a summit depth of 700 m (Genin et al. 1986). Jasper Seamount does not lie within the U.S. or Mexican EEZs and is not currently protected by any national or international mechanisms.

Other Seamounts in or near U.S. Waters

New England Seamounts

The New England Seamount Chain consists of over 30 major volcanic peaks and extends over 1,200 km in length, from Georges Bank to the eastern end of the Bermuda Rise, making it the longest seamount chain the North Atlantic (NOAA 2003). Bear Seamount, rising from the continental slope at depths of 2,000-3,000 m to a generally flat summit at 1,100 m depth, is the oldest and most inshore of the chain, while Nashville Seamount is the youngest and furthest from shore (Fig. 11). The summits of all the New England Seamounts are over 1,000 m depth. The chain includes Allegheny Seamount, Asterias Seamount, Balanus Seamount, Bear Seamount, Buell Seamount, Gerda Seamount, Gilliss Seamount, Gosnold Seamount, Gregg Seamount, Hodgson Seamount, Kelvin Seamount, Kiwi Seamount, Manning Seamount, Michael Seamount, Mytilus Seamount, Nashville Seamount, Panulirus Seamount, Picket Seamount, Physalia Seamount, Rehoboth Seamount, Retriever Seamount, San Pablo Seamount, Sheldrake Seamount, and Vogel Seamount.

Of these only Bear, Physalia, Retriever, and Mytilus are within the U.S. EEZ and within the area of national jurisdiction (Fig 12). Exploratory commercial fishing has occurred on some of the more inshore seamounts in the chain (NOAA 2003). At this time, there are no EFH or other federal protections for any of the New England Seamounts. However, the New England Fishery Management Council is currently developing EFH Omnibus Amendment 2, and the process has recommended Bear, Physalia, Retriever, and Mytilus Seamounts as discrete coral zones (NEFMC 2012). EFH protections seem likely to be designated on these seamounts when Omnibus Amendment 2 is adopted. Additionally, a large square area outside the U.S. EEZ (bound by 35°N, 39°N, 57°W, and 64°W) is currently closed to bottom fishing by the Northwest Atlantic Fisheries Organization as a seamount protection zone (NAFO 2012). This protection is temporary and currently extends until December 31, 2014 (NAFO 2012).

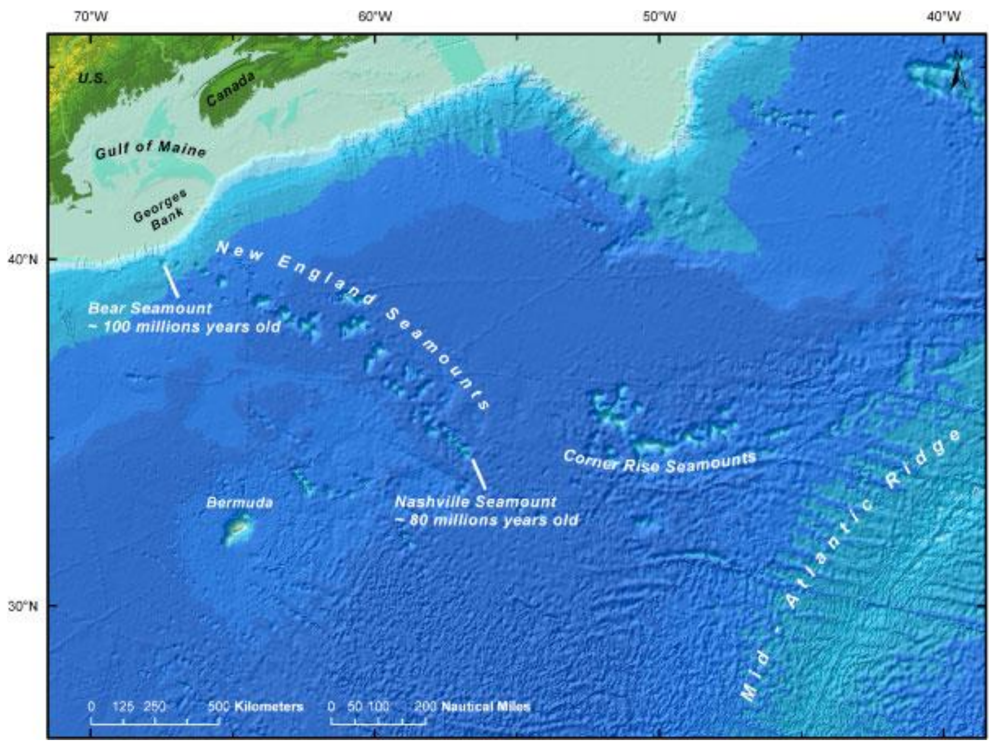


Figure 11. The New England Seamount Chain and the Corner Rise Seamounts. Map from: http://www.gulfofmaine-census.org/.

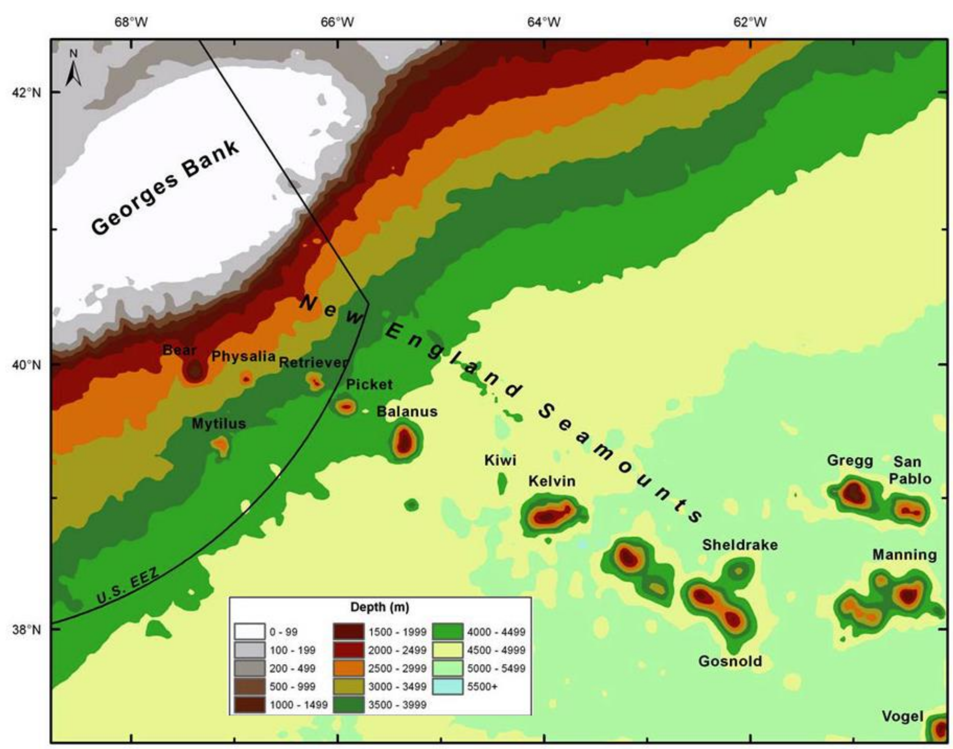


Figure 12. The western New England Seamounts. Bear Seamount, Physalia Seamount, Retriever Seamount, and Mytilus Seamount fall within the U.S. EEZ. Map from: http://www.gulfofmaine-census.org/.

Corner Rise Seamounts

The Corner Rise Seamounts are found significantly further offshore than the New England Seamounts, well beyond the U.S. EEZ (Fig. 11). They are a large chain with more than 50 major peaks and complex coral ecosystems (Shank 2010). Approximately 20,000 tons of fish (including 175 species, but predominantly Alfonsino) were removed from the Corner Rise Seamounts by Soviet fishing vessels from 1976–1996 (Shank 2010). An August 2005 research expedition aboard NOAA ship *Ronald H. Brown* documented the first visual verification of trawling damage to this remote area. The summits of Yakutat and Kükenthal Seamounts were effectively denuded of large sessile fauna and no longer support habitat forming corals in any significant numbers (Fig. 5; Kusek 2008; Waller et al. 2007). Other observations included wide scars, broken crusts, displaced boulders and upturned corals presumably from trawl doors or ground gear, and narrow scars and cuts through sponges either from trawl weights or long-line components (Waller et al. 2007). Currently, the Corner Rise chain is closed to bottom fishing by the NAFO as a seamount protection zone bound by 35°N, 36°N, 48°W, and 52°W (NAFO 2012). This protection is temporary and extends until December 31, 2014 (NAFO 2012).

Alaska Seamount Habitat Protection Area

The Alaska Seamount Habitat Protection Area (ASHPA) consists of 15 individual Habitat Areas of Particular Concern within the Bering Sea and Aleutian Islands (BSAI) and Gulf of Alaska (GOA) Management Areas (Fig. 13; NMFS 2006). The ASHPA restricts fishing with bottom contact gear in these distinct seamount areas, with a protected area totaling approximately 5,300 nm^2 (NMFS 2012). Bottom contact gear is defined as nonpelagic trawl, dredge, dinglebar, pot, or hook-and-line gear. Protected seamounts include Dickens Seamount, Denson Seamount, Brown Seamount, Welker Seamount, Dall Seamount, Quinn Seamount, Giacomini Seamount, Kodiak Seamount, Odessey Seamount, Patton Seamount, Chirikof & Marchand Seamounts, Sirius Seamount, Derickson Seamount, Unimak Seamount, and Bowers Seamount (NMFS 2006).

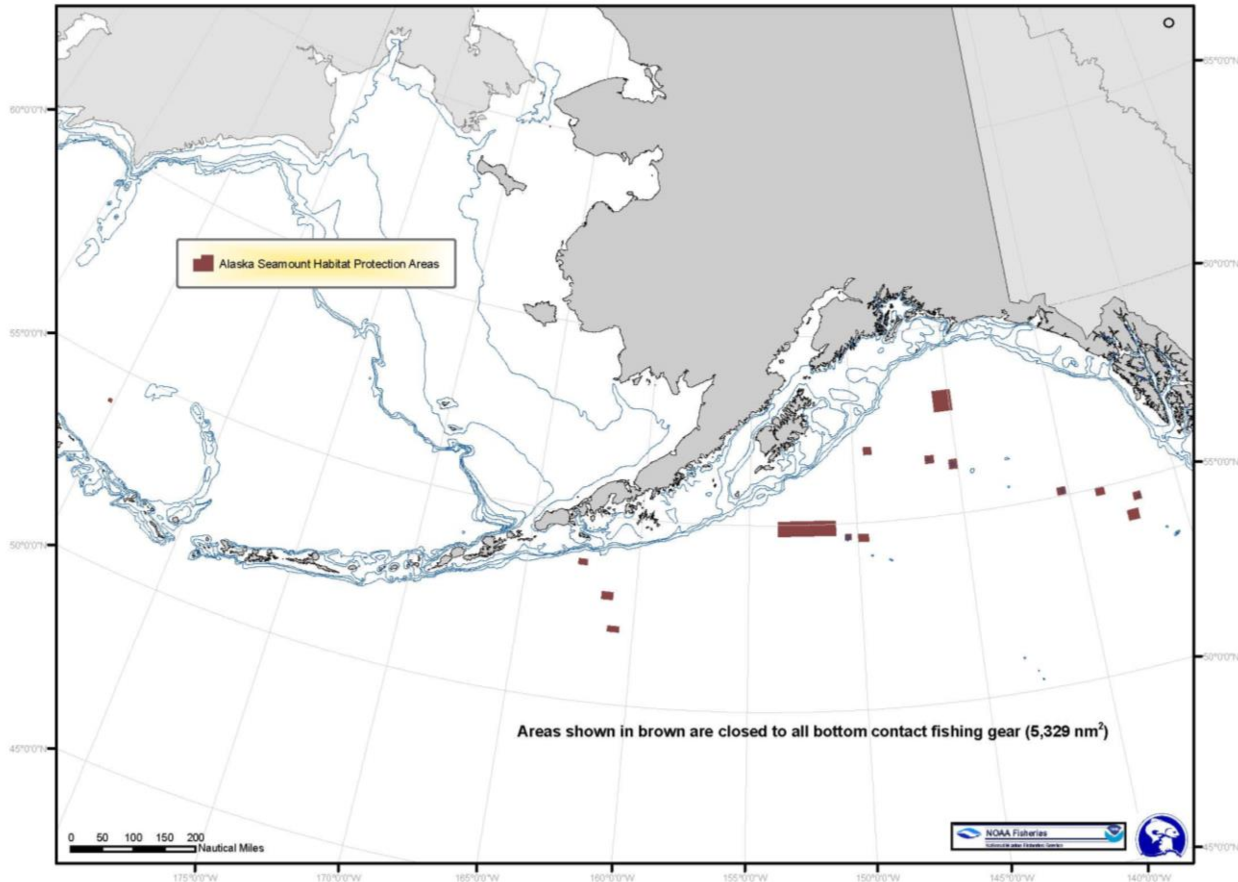


Figure 13. The Alaska Seamount Habitat Protection Area restricts fishing with bottom contact gear in 15 distinct seamount areas within the Bering Sea and Aleutian Islands (BSAI) and Gulf of Alaska (GOA) Management Areas. Figure from http://www.fakr.noaa.gov/habitat/efh/ashpa.pdf.

Lō`ihi Seamount

The newest creation of the Hawaii hotspot, Lō`ihi Seamount is an active underwater volcano in the Hawaiian-Emperor seamount chain, located 34 km southeast of the island of Hawaii, with its summit approximately 1000 m below the ocean surface (Malahoff 2000). Although marine life around Lō`ihi is not believed to be as diverse as at less active seamounts, Lō`ihi's sustained hydrothermal vents support unique biological communities such as jelly-like microbial mats and other extremophiles (Malahoff 2000). While Lō`ihi serves as a research hub given its proximity to Hawaii, it is not currently afforded any protections.

Hancock Seamounts

The Hancock Seamounts are within the U.S. EEZ at the far northwestern end of the Northwestern Hawaiian Islands, and are principally comprised of two guyots (WPRFMC 2010). The Hancock Seamounts are the only known habitat for armorhead (*Pseudopentaceros wheeleri*) within the U.S. EEZ. While there has never been a U.S. fishery targeting this fish, continued exploitation outside the U.S. EEZ by foreign fleets has kept the stock in an overfished condition (NMFS 2010). From 1986-2010, the Western Pacific Regional Fishery Management Council (WPRFMC) and NMFS instituted a series of 6-year domestic fishing moratoria at the Hancock Seamounts (NMFS 2010). In 2010, as the most recent moratorium was expiring, NMFS created the Hancock Seamounts Ecosystem Management Area (Fig. 14), which prohibits fishing for and possession of bottomfish and seamount groundfish at the seamounts until the armorhead stock is rebuilt (NMFS 2010). A minimum rebuilding time of 35 years for the U.S. portion of the armorhead stock was established (WPRFMC 2010), meaning that these seamount communities are protected from bottomfishing pressure in the near to medium term.

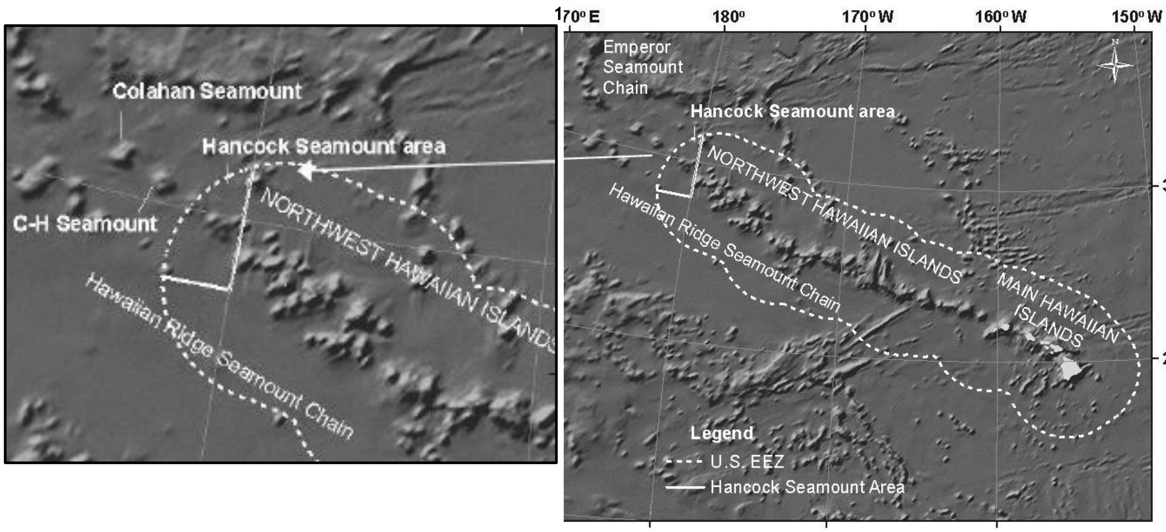


Figure 14. The Hancock Seamounts are depicted in relation to the U.S. EEZ (dashed line) and Northwestern and Main Hawaiian Islands (right). The Hancock Seamounts Ecosystem Management Area (solid line) is currently defined as waters within the EEZ that are west of 180° W and north of 28° N. The Hancock Seamounts are near the southern portion of the Emperor Seamount Chain and Colahan and C-H Seamounts (inset at left). Figure adapted from: (WPRFMC 2010).

Table 4. Comparison of protections for seamounts located within U.S. EEZ.

Seamount Complex	Designated Habitat Area of Particular Concern	Designated Essential Fish Habitat	Other MPA	Closed to all bottom contact gear	Seamount Specific Management Plan	Key References
Gumdrop	Yes	Yes	No	No	No	MBARI 2012a; Davis et al. 2002
Pioneer	Yes	Yes	No	No	No	MBARI 2012a; Kogan et al. 2006; Davis et al. 2007; Lundsten et al. 2009b
Guide	Yes	Yes	No	No	No	MBARI 2012a; Davis et al. 2002
Taney	Yes	Yes	No	No	No	MBARI 2012b; Clague et al. 2000
Davidson	Yes	Yes	Yes	Yes	Yes	DeVogelaere et al. 2005; McClain et al. 2009; Lundsten et al. 2009a; Lundsten et al. 2009b
Rodriguez	No	Yes	No	No	No	Davis et al. 2002; MBARI 2012d; Lundsten et al. 2009a; Lundsten et al. 2009b; Paduan et al. 2009
San Juan	Yes	Yes	No	No	No	Paduan et al. 2009; MBARI 2012e
President Jackson	Yes	Yes	No	Yes	No	Clague et al. 2000; MBARI 2012g
Thompson	Yes	Yes	No	Yes	No	Hourigan 2009
Bear	No	No	No	No	No	NEFMC 2012; Moore et al. 2003; Moore et al. 2004
Physalia	No	No	No	No	No	NOAA 2003
Retriever	No	No	No	No	No	NEFMC 2012
Mytilus	No	No	No	No	No	
Alaska Seamounts HPA	Yes	Yes	No	Yes	No	NMFS 2006
Lō`ihi	No	No	No	No	No	
Hancock Seamounts EMA	No	No	No	No	No	NMFS 2010; WPRFMC 2010

Examples of Other Seamount Conservation Measures

Bowie Seamount, Canada

The Bowie Seamount complex encompasses the Bowie, Hodgkins, and Davidson[2] Seamounts and the surrounding abyssal plain and is located 180-230 km west of Haida Gwaii (Queen Charlotte Islands), British Columbia, within the Canadian EEZ (FOC 2012; Canessa et al. 2003). Bowie is the shallowest seamount in Canada, rising from a depth of 3,000 m to within 24 m of the surface (FOC 2012). The area, called Sgaan Kinghlas by the native Haida people, provides a habitat that is rare in the northeast Pacific and is an area of high biological productivity (FOC 2012). Though the area has not been extensively studied, researchers have documented the presence of more than 158 plant and animal taxa, including 50+ taxa of macroinvertebrates, 53+ taxa of fishes, and 16+ taxa of birds (Canessa et al. 2003). There have also been observations of a number of species listed under Canada's Species at Risk Act (SARA), including the Ancient Murrelet, Steller Sea Lion, Orca, and Boccacio rockfish (FOC 2012).

In December 1998, the Bowie Seamount Pilot Marine Protected Area was created, and the Bowie complex was designated as Canada's seventh MPA on April 17, 2008 (Fig. 15). The conservation objective of the Bowie Seamount MPA is to conserve and protect the unique biodiversity and biological productivity of the area's marine ecosystem, which includes the Bowie, Hodgkins and Davidson seamounts and the surrounding waters, seabed and subsoil (FOC 2012). As the Bowie Seamount complex has longstanding cultural significance, management and planning of the MPA has been a close collaboration between Fisheries and Oceans Canada and the Council of the Haida Nations (FOC 2012).

[2] The Davidson Seamount referenced here is not the same Davidson Seamount as the one in the MBNMS discussed above.

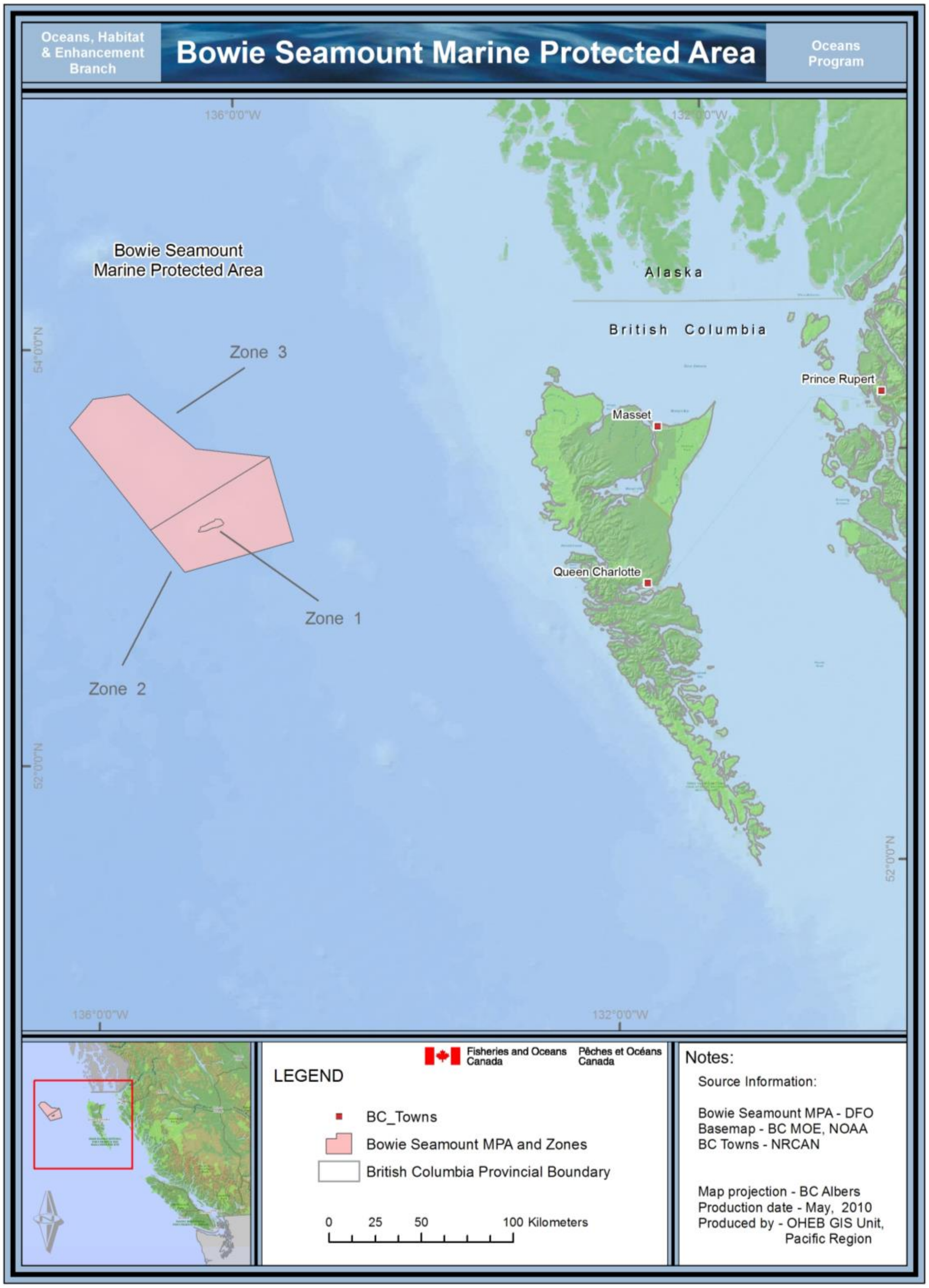


Figure 15. Bowie Seamount Marine Protected Area, offshore Haida Gwaii (Queen Charlotte Islands), British Columbia, Canada. Map credit: Fisheries and Oceans Canada.

Regulations for the MPA include prohibitions against disturbing, damaging or destroying, or removing, any living marine organism, any part of an organism's habitat, and any part of the seabed. Additionally, activities that are likely to harm marine organisms or their habitats are prohibited, including depositing, discharging or dumping any substance. However, commercial and recreational fishing that are carried out in accordance with Canada's Fisheries Act are allowed (Oceans Act 2008, SOR 2008-124).

Australian Commonwealth Marine Reserves

Australia has a massive EEZ, amounting to the third largest marine estate of any nation in the world (DSEWPC 2012a). In 1998, the Commonwealth of Australia, State, and Territorial governments committed to the establishment of a National Representative System of Marine Protected Areas (NRSMPA) by 2012. By late 2012, over 40 new Commonwealth marine reserves[3] have been announced, adding to the smaller existing network that had been in gradual development since 1982. Australia's national MPA system will result in 3.1 million km^2 of ocean being managed primarily for biodiversity conservation (DSEWPC 2012a). Regional ten-year management plans are currently under development for the new marine reserves, and while some regions are on a faster track, in most cases transitional management is in place until July 2014.

In the past, protection of seamount habitats in Australia was focused on the Tasmanian Seamounts Marine Reserve, off the southeast coast of Tasmania. This reserve, created in 1999, was revoked in July 2007 due to incorporation into the much larger Huon Commonwealth Marine Reserve (CMR; Fig. 16). Huon CMR protects primarily deeper waters of 3,000 m and more, which are home to a large complex of seamounts, many of which are believed to serve as "species dispersal stepping stones" between seamounts of the Tasman Sea and of the Indian Ocean (DSEWPC 2012b). Of the more than 70 seamounts in the reserve, many of which rise into the top 1,000 m of the water column, some have been extensively trawled, some are recovering from trawling, and others have never been trawled (Fig. 17). The Huon CMR protects a total area 9,991 km^2, of which 9,602 km^2 is a zoned for multiple use and a smaller segment of 389 km^2 is zoned as a benthic sanctuary, with stricter protections (Table 5; DSEWPC 2012b).

Several other CMRs in the Australian NRSMPA also protect seamount habitats and communities, including Flinders CMR (27,043 km^2), Freycinet CMR (57,942 km^2), South Tasman Rise CMR (27,704 km^2), Central Eastern CMR (70,054 km^2), Gifford CMR (5,829 km^2), New Lord Howe CMR (110,139 km^2), Norfolk CMR (188,443 km^2), and the New Coral Sea CMR (989,842 km^2). It should be noted that zoning varies greatly within and between these reserves, and that current interim management measures are subject to change in the near-term. Conservation value assessments completed over the past decade for many of the recently pronounced CMRs – such as Norfolk CMR, containing the Norfolk Seamounts – consolidate valuable information on the physical and biological environments of protected seamount communities and discuss how current and potential uses can be accommodated and balanced (Williams et al. 2006).

[3] Marine reserves are a subset of marine protected areas (MPAs) that typically provide an elevated level of protection and feature no-extraction or no-take policies.

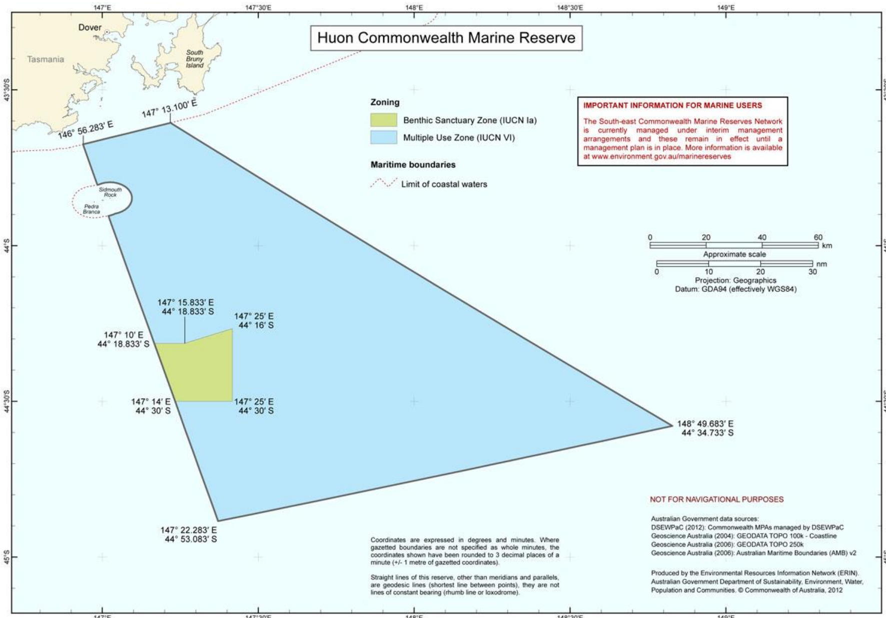


Figure 16. Huon Commonwealth Marine Reserve, Australia, including both the multiple use zone and the benthic sanctuary zone. Map credit: (DSEWPC 2012b).

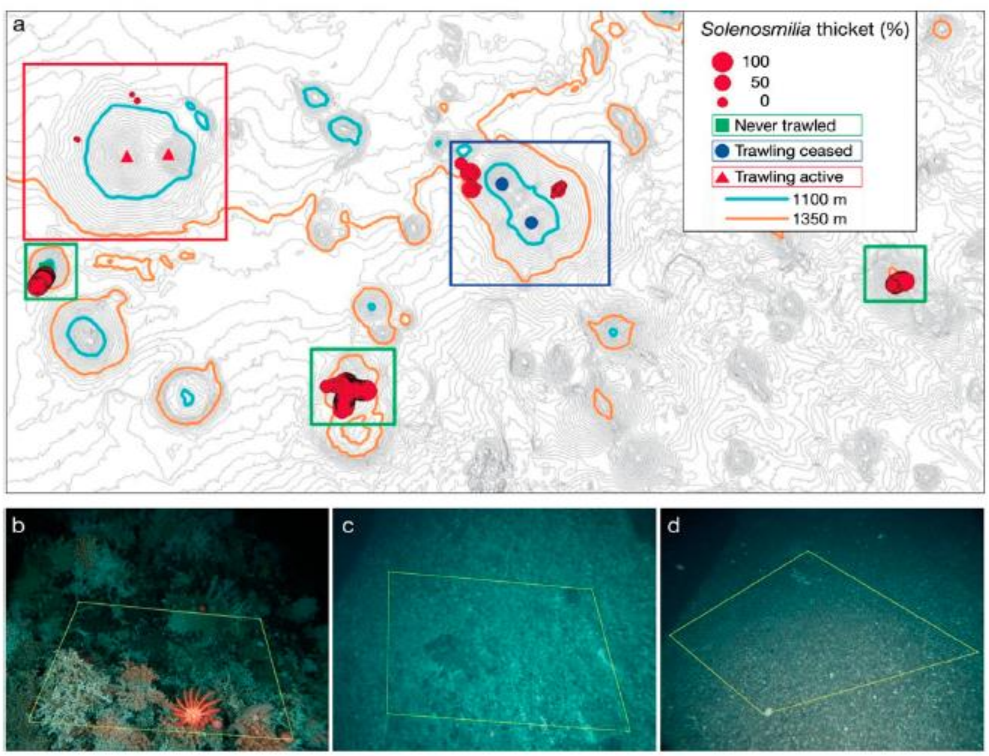


Figure 17. (a) Graduated bubbles showing the percent cover of *Solenosmilia* thicket (3-dimensional framework built by live *S. variabilis* and its dead skeletons) on seamounts south of Tasmania with differing fishing histories (indicated by symbol and frame colour), and representative images of Tasmanian seamounts (b) that were never trawled, (c) where trawling ceased 5 to 10 yr ago and (d) where trawling is active. Figure from (Althaus et al. 2009).

Table 5. Allowed and prohibited activities in zones of the Huon Commonwealth Marine Reserve, Australia. Table from (DSEWPC 2012b).

Legend

✓ - Allowed in zone

✗ - Not allowed in zone

R - Registration under an approval from the Director of National Parks is required before any commercial fishing vessel is allowed in the zones. Conditions apply to the approval. Contact the Department of the Environment, Water, Heritage and the Arts for more information.

I - 'Individual approval' from the Director of National Parks is required. Each application will be assessed on a case by case basis. Contact the Department of the Environment, Water, Heritage and the Arts for more information.

Activity	Multiple use zone	Benthic sanctuary zone
Recreational activities		
Recreational fishing*	✓	✓ [1]
Scuba diving & snorkeling	✓	✓
Scientific research		
Research and monitoring	I	I
Commercial activities		
Shipping	✓	✓
Commercial tourism, including dive/snorkel tours, nature watching	I	I
Charter fishing	I	I [1]
Mining - Seismic survey #	✓	✗
Mining - Transit #	✓	✓
Mining - All other #	I	✗
Transiting in a commercial fishing vessel	R	R
Commercial fishing (except fishing activities listed below	R	✗
Pelagic fishing[1]	R	R
Demersal trawl	✗	✗
Danish seine	✗	✗
Gillnetting (below 183m)	✗	✗
Scallop dredging	✗	✗

<u>New Zealand</u>

New Zealand has taken a number of far-reaching measures to protect the seamounts found in its EEZ, which is one of the largest in the world. Two legal mechanisms have facilitated New Zealand's conservation accomplishments. The 1996 Fisheries Act focuses on enabling sustainable use of fishery resources but also allows for the creation of benthic protection areas (BPAs) to limit fishing pressure, while the Biodiversity Strategy of 2000 calls for protection of 10 percent of New Zealand's marine environment by 2010 and the establishment of an MPA Policy (Spear and Cannon 2012).

In November 2000, 18 seamount closures were established, preventing all dredging and bottom trawling around 25 underwater topographical features (including 19 seamounts) and their associated benthic ecosystems in an area that now amounts to 115,200 km^2 (MPI 2012; Helson et al. 2009). Together with the creation of a small network of no-take marine reserves, the seamount closures resulted in a protection level of about 2% of New Zealand's EEZ in the mid 2000s (MPI 2012). In 2007, the area under protection was dramatically increased when the Government of New Zealand accepted an industry proposal to close 17 additional areas as BPAs (Fig. 18). Deepwater Group Ltd., a collective representing approximately 95% of the ITQs in New Zealand's mid- and deep-water fisheries, was instrumental in pushing forward this pro-active proposal (Helson et al. 2009). The BPAs, which went into effect in November 2007 and cover an additional 1,250,000 km^2 of habitat, prohibit dredging entirely and restrict trawling to waters at least 100 m above the seafloor (MPI 2012). This closed area is approximately four times the landmass of New Zealand and at the time was the largest marine protection initiative ever undertaken in a nation's EEZ (MPI 2012). The seamount closures remain, with a slightly higher level of protection as trawling is not allowed in those areas at any depth. Additionally, the plan included a provision for the fishing industry to pay for a share – 33%, or up to NZ$330,000 per year – of deepwater benthic research (MPI 2012).

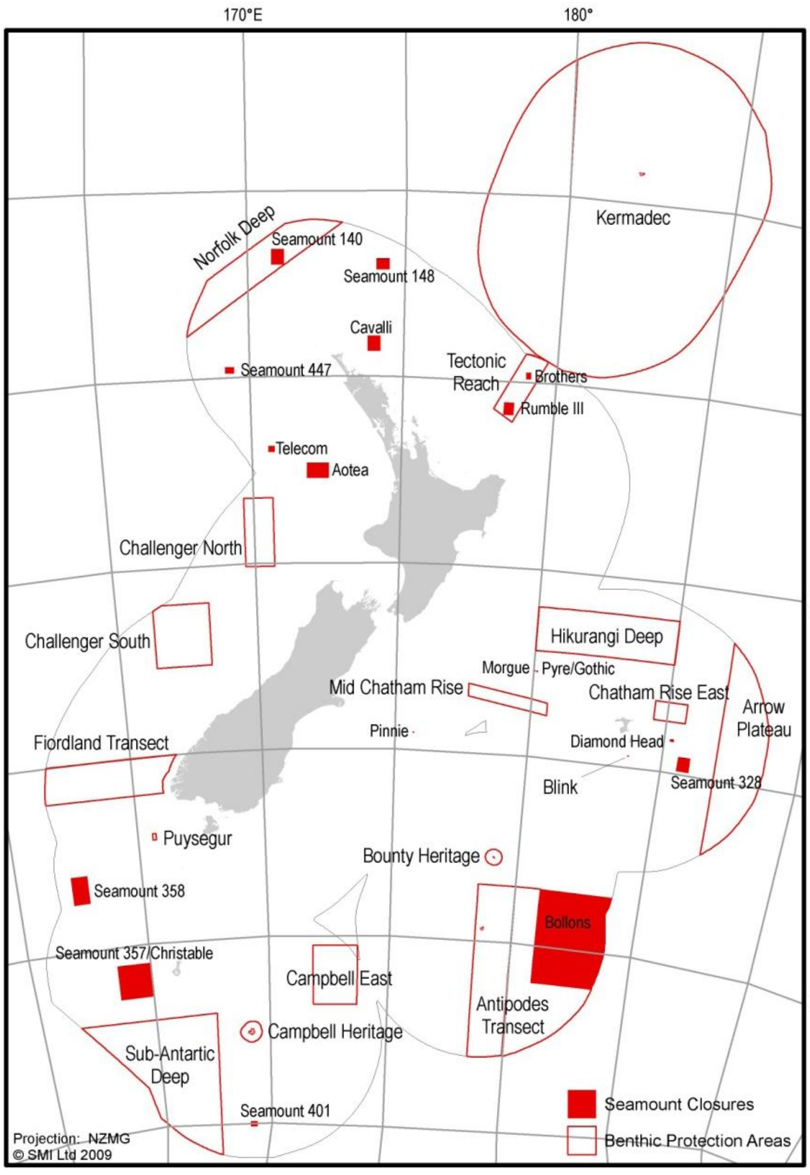


Figure 18. Location of benthic protection areas (BPAs) and seamount closures in New Zealand's EEZ. Map credit: (Spear and Cannon 2012).

New Zealand has stricter forms of marine protection than the seamount closures and BPAs provide, such as 'no-take' marine reserves. Mining, other human disturbances, and, in BPAs, fishing 100 m or more above the seafloor are all activities that are not restricted in these areas. However, 52% of New Zealand's seamount over 1,000 m in height are now protected in BPAs and seamount closures, as are 88% of active hydrothermal vents (MPI 2012). Presently, approximately 34% of New Zealand's marine environment has management restrictions in place, of which seamount closures and BPAs account for 97% of the protected area (MFE 2012).

Northeast Atlantic

Nowhere in the world has more progress been made in the development of high seas seamount-focused MPAs than in the heavily impacted Northeast Atlantic (O'Leary et al. 2012). The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR), was created in 1992 to take the place of the Oslo and Paris Conventions for the prevention of environmental pollution by dumping and landbased sources, respectively (the first created in 1972 and the latter in 1974; UNEP 2010). OSPAR, whose 16 contracting parties include all coastal states of the Northeast Atlantic, the European Community and three land-locked states connected via river catchments, has since been amended to cover non-polluting human activities that can adversely affect the biological diversity of its maritime area, which includes all waters of the Atlantic and Arctic Oceans north of 36ºN and east of 42ºW except the Mediterranean and Baltic Seas (UNEP 2010). OSPAR takes an ecosystem approach and has a mandate to conserve and restore marine ecosystems through regional action. The OSPAR area contains many seamounts, including some at depths that have been accessible to deepwater bottom trawling (Fig. 19; WWF Germany 2012). Many of the region's seamounts are little-explored and believed to be near-pristine and likely to contain unique species (MCI and WF 2012).

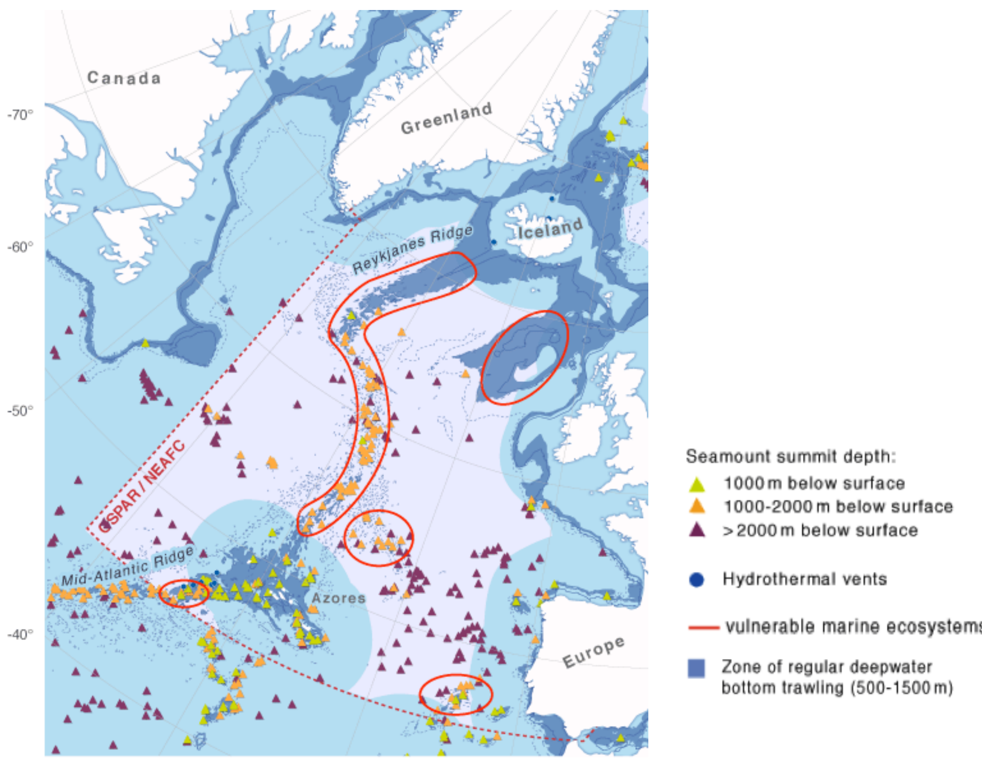


Figure 19. Seamounts and hydrothermal vents in the OSPAR Convention Area / Northeast Atlantic Fisheries Convention (NEAFC) Regulatory Area. Figure from (WWF Germany 2012).

As might be expected, seamount MPAs were first pursued within the national waters of each OSPAR Contracting Party, and several were implemented prior to the proposal of seamount

MPAs in ABNJ (O'Leary et al. 2012). These include the Formigas Islets & Dollabarat Bank Nature Reserve (Azores/Portugal), D. João de Castro Seamount (Azores/Portugal), Sedlo Seamount (Azores/Portugal), and El Cachucho (Spain; Santos et al. 2010). Additionally, in 2006 the Spanish fisheries administration prohibited the use of gears equipped with rockhoppers to restrict the access of trawlers to hard bottom areas in Spanish waters containing biogenic habitats (such as Galicia Bank and Le Danois Bank seamounts). The Le Danois Bank was also declared an MPA in 2008, and all bottom contact gear was prohibited (Santos et al. 2010). Additionally, in 2004 the region's RFMO, the North-East Atlantic Fisheries Commission (NEAFC), which has the competence to regulate fisheries through various mechanisms, adopted extensive spatial conservation measures to protect areas identified as VMEs from bottom trawling (Fig. 20; O'Leary et al. 2012). These temporary closures, which include seamounts on the Mid-Atlantic Ridge, in the ocean basins to the east and west, and on Reykjanes Ridge have since been extended, and others have been introduced (Santos et al. 2010).

OSPAR Recommendation 2003/3, adopted at the 2003 Ministerial Meeting of the OSPAR Commission, paved the way for the development of a network of high seas MPAs, with WWF, the Netherlands, Portugal, and France being some of the key early actors (UNEP 2010; O'Leary et al. 2012). As the scientific case for protection was made and site selection began, the signing of memoranda of understanding with other key authorities, including the IMO, the International Seabed Authority, and the NEAFC were key as work progressed. Although an early proposal for a Charlie-Gibbs Fracture Zone MPA (including Faraday and Hecate Seamounts), advanced the fastest, in September 2010 OSPAR designated the world's first high seas MPAs, totaling six protected areas in areas beyond national jurisdiction, with a total area of 286,200 km^2 (O'Leary et al. 2012). These included Altair Seamount MPA (4,408.71 km^2), Antialtair Seamount MPA (2,207.68 km^2), Milne Seamount MPA (20,913 km^2), Josephine Seamount MPA (19,370 km^2), Mid-Atlantic Ridge North of the Azores MPA (93,568 km^2), and Charlie-Gibbs South MPA (145,249 km^2). Many of these areas overlap with existing NEAFC closures (Fig. 20). Josephine Seamount was the first seamount to be discovered as a direct result of oceanic exploration, and in February 2012 became the first case added to the international repository of marine Ecologically or Biologically Significant Areas (EBSAs; OSPAR Commission 2012).

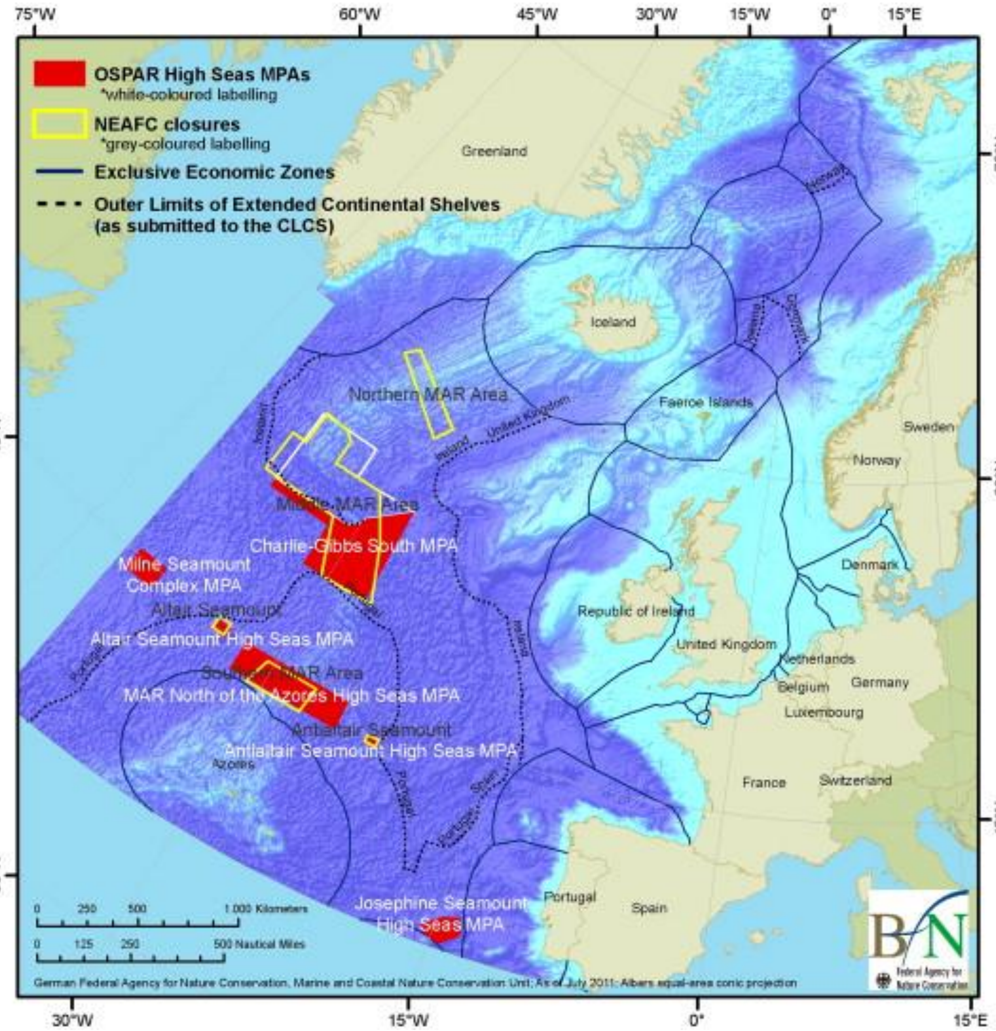


Figure 20. The current network of OSPAR MPAs and fishery closures implemented by the North East Atlantic Fisheries Commission (NEAFC). The Charlie-Gibbs Fracture Zone MPA was originally proposed in 2010 as a single MPA, including both the Charlie-Gibbs South MPA (in red, fully in ABNJ) and the area outlined in white (within the area claimed as Iceland's extended continental shelf). In June 2012, after two years of international negotiations, the Charlie-Gibbs North MPA (white outline, not labeled) was added as the 7th high seas MPA in the region. Figure from (O'Leary et al. 2012).

These designations were complicated by the 2009 submissions of several OSPAR Contracting Parties to the UN Commission on the Limits of the Continental Shelf to extend their continental shelves beyond their EEZs (UNEP 2010). Portugal's new claims to an enlarged area of seabed meant that the following Seamount MPAs had water columns in ABNJ and seabeds belonging to Portugal: new Altair, Antialtair, Josephine, and the Mid-Atlantic Ridge North of the Azores. Fortunately, Portugal was highly supportive of these protected areas, and designations were made by both Portugal for the seabed and by OSPAR for overlying waters (O'Leary et al. 2012). In the case of the Charlie-Gibbs Fracture Zone MPA, originally adopted "in principle" in 2008 as an area totaling 323,900 km², Iceland claimed seabed rights for more than half of the proposed area. This political delay caused the MPA to be split into two, with only the southern portion that fell fully in ABNJ being designated in 2010. By mid-2012, negotiations with Iceland had progressed, allowing for the designation of the Charlie-Gibbs North MPA, adding the remaining 178,651 km² of fracture zone habitat and bringing the network's total size to almost 465,000 km²

(WWF Germany 2012). It has been estimated that the north and south Charlie-Gibbs MPAs together encompass predicted 115 seamounts and 447 predicted knolls (Yesson et al. 2011). Owen (2010) explores the possible frictions associated with managing a "hybrid" MPA with integrated dual legislation and management of composite MPAs on the extended continental shelf of a coastal State. Also, in cooperation with OSPAR and other partners, in June 2012 WWF Germany launched a media outreach website titled "Charlie-Gibbs Marine Protected Area – Preserving Diversity in the High Seas" (WWF Germany 2012). The site consolidates resources on all of the OSPAR high seas seamount MPAs.

The designations of the OSPAR high seas MPAs represent a first step. OSPAR is now continuing discussions with other international authorities and bodies to develop management plans. Although NEAFC bottom trawl closures are in place over much of the newly designated areas, they are not permanent in nature. OSPAR background documents for each of the OSPAR high seas MPAs, which served as nominations for protection proforma, list a number of human activities that "will or might need regulation via management plans." These include: deep sea and high seas fishing using fixed and mobile gears (both at the seabed and in the water column), vessel traffic, seabed mining or other resource exploitation, bioprospecting, cable laying, underwater noise, and military sonar (OSPAR Commission 2010). The background documents for each seamount complex also list habitats and species that are either threatened, declining, or of special concern (OSPAR Commission 2010).

Costa Rica

The Las Gemelas Seamounts are located in the Eastern Tropical Pacific (ETP) about 55 km southwest of Coco Island, Costa Rica, and are believed to act as stepping-stones for long distance migratory species while also forming a marine corridor of key breeding and feeding waters for tuna and sharks (Alvarado et al. 2012; Fundácion MarViva 2011). A 2009 scientific expedition led by National Geographic found large numbers of encrusting and structure-forming invertebrates at Las Gemelas, including glass sponges, octocorals, black corals, stony corals, and calcified hydroids (Starr and Green 2010). Additionally, each dive at Las Gemelas Seamounts revealed different intact habitats, suggesting high habitat diversity and number of species (Starr and Green 2010). Several previously undescribed fish species were found, and there are likely additional fish and invertebrate species that are new to science (Fundácion MarViva 2011; Starr and Green 2010). This expedition was important in highlighting the seamount's ecological significance at a regional and global level.

On March 2, 2011, the Government of Costa Rica announced the creation of the Seamounts Marine Management Area (SMMA; 9,640 km^2), which includes the Las Gemelas Seamounts and surrounds the existing 1,989 km^2 Coco Island Marine Reserve (Fig. 21; MINAET 2011; Alvarado et al. 2012). The SMMA triples Costa Rica's MPA coverage, represents 1.6% of Costa Rica's jurisdictional waters, and together with the marine reserve it buffers is second in size only to Galapagos National Park in terms of marine protected areas in the ETP (Miliani 2012; Fundácion MarViva 2011). Management measures for the SMMA will not be as strict as for the Coco Island Marine Reserve, which is a fully protected non-fishing zone and a UNESCO World Heritage Site. The SMMA is closed to trawl nets, purse seine nets, oil exploration, and oil exploitation, but will allow regulated tourism, sport fishing, some commercial fishing, and scientific research (MINAET 2011; Miliani 2012).

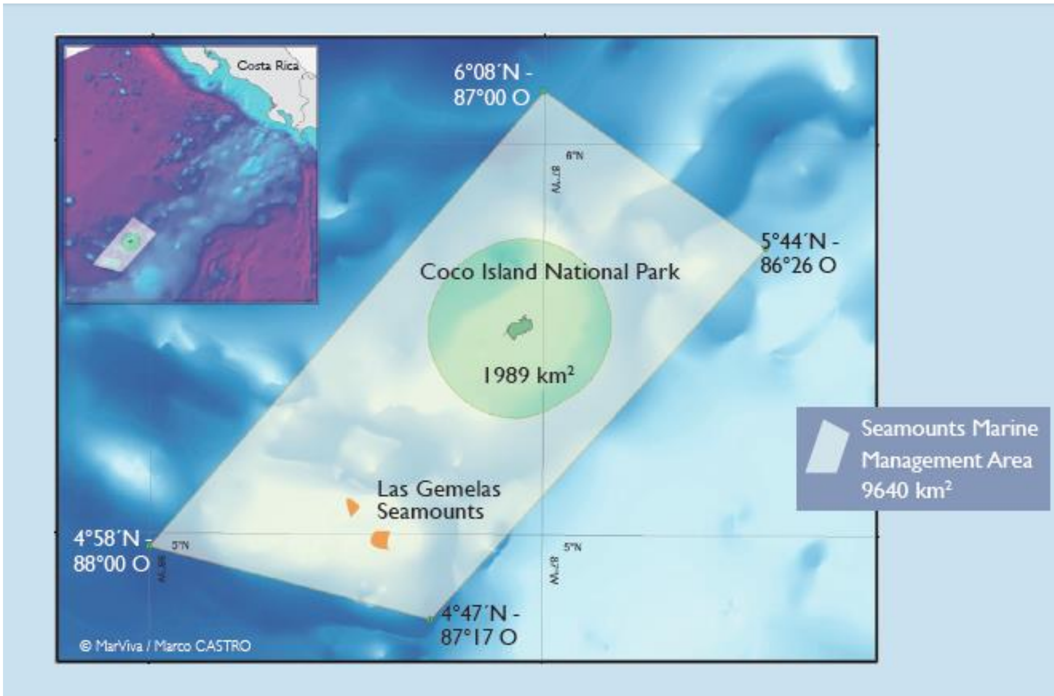


Figure 21. Seamounts Marine Management Area, surrounding Cocos Island, Costa Rica. Map credit: MarViva.

Several international NGOs were instrumental in the designation of the SMMA, including Fundácion MarViva, Conservation International, and the Nature Conservancy. Although Costa Rica was not able to provide any funding, it created the SMMA with the understanding that these groups were committed to providing funding and coordinating monitoring and enforcement in the face of the government's limited resources (Téllez 2011). As the SMMA's designation prohibits foreign fishing vessels within its bounds but allows for local fishing effort, involved NGOs are planning to actively engage local fishermen in monitoring any illegal activities (Téllez 2011).

British Indian Ocean Territory (BIOT)

The entirety of the Chagos Archipelago, extending to the boundaries of the BIOT EEZ, was designated by the British government as a no-take marine protected area (MPA) on April 1, 2010 (Sheppard et al. 2012a). The new Chagos MPA covers 639,661 km^2, and its creation effectively doubled the global cover of no-take MPAs (Sheppard et al. 2012b). The MPA creation built on existing protections in a much smaller spatial area, as an Environmental Preservation and Protection Zone had already been declared to regulate activities in some of the most important habitats (NSMC 2012). Yesson et al. (2011) determined that 86 seamounts (>1000m elevation) and 243 knolls (200–999m elevation) are predicted to occur within the Chagos MPA (Fig. 22). Globally, this designation increased the world's protection of seamounts by 17% and knolls by 40%, based on the estimate by Yesson et al. (2011) that only 506 seamounts and 606 knolls lay in protected areas as of 2009 (Sheppard et al. 2012a).

While attention has focused on the Chagos MPA's protection of shallow-water ecosystems, the reserve contains more than 10% of all Indian Ocean seamounts and is thus significant for its protection of deep-water ecosystems as well (Sheppard et al. 2012a). Almost no biological data exists on the benthic communities of the Chagos-Laccadives Ridge, and that which has been collected from deeper habitats of the MPA is mainly from exploratory or commercial fishing (Sheppard et al. 2012a). Although many other Indian Ocean ridges and seamounts have been fished or are subject to continuing or expanding fisheries, it is believed that there has never been deep-water fishing or trawling on seamounts in the Chagos MPA and that associated communities of invertebrates and fish are still largely intact (Sheppard et al. 2012a). The Chagos MPA's lack of disturbance due to its remote location and low levels of human activities make it particularly important on a regional level.

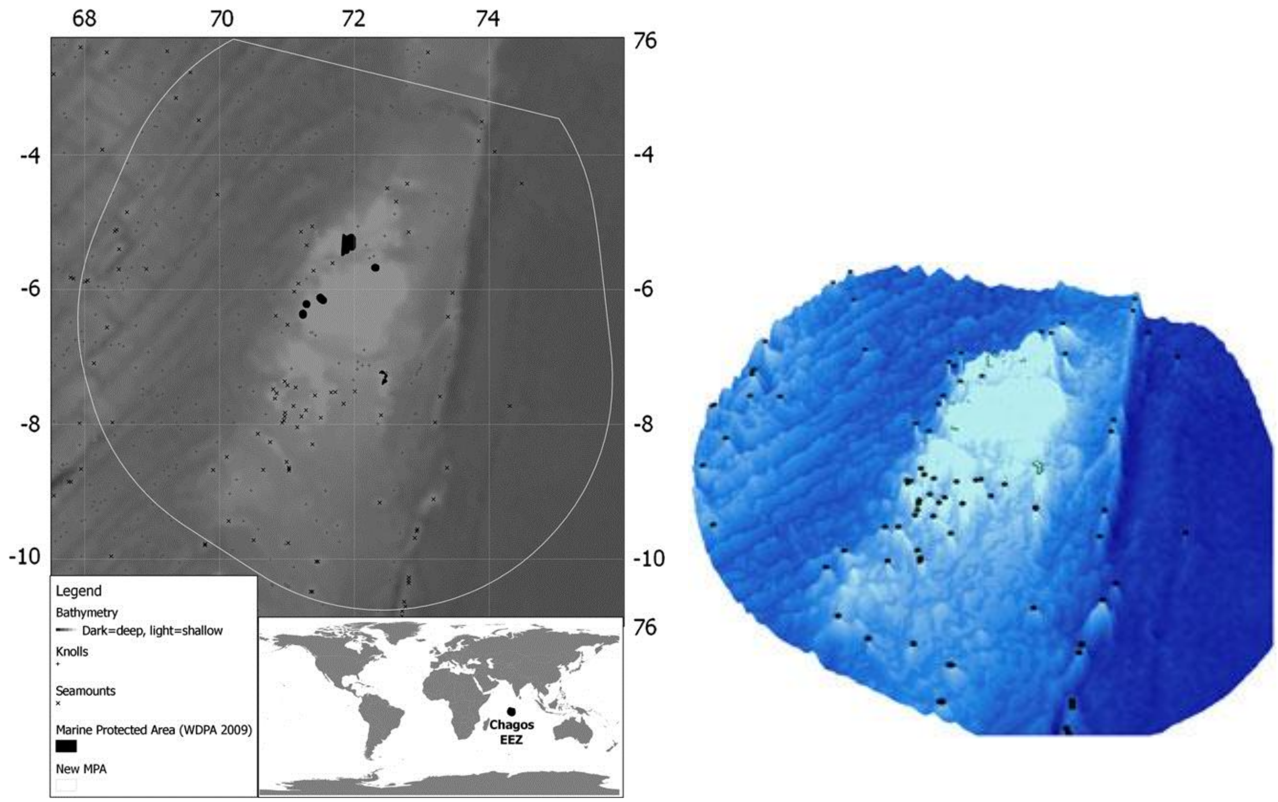


Figure 22. The marine protected area around Chagos, British Indian Ocean Territory (left). This new MPA covers 86 seamounts and 243 knolls. Seamounts of the Chagos MPA are shown with bathymetry data from shuttle radar topography mission 30 arc-second grid (upper right; http://www2.jpl.nasa.gov/srtm/). Figures from: (Yesson et al. 2011) and (Sheppard et al. 2012).

The BIOT Administration is currently working on the development of a management plan for the Chagos MPA, and there is not currently a plan in place (Dunne 2012). An independent team of scientists and conservationists has prepared a list of science needs for consideration in a management plan, and funding of seamount exploration through the U.K. Natural Environment Research Council is discussed (Sheppard et al. 2012b). A number of concerns have been raised surrounding the adequacy of available resources to patrol and enforce the Chagos MPA (NSMC 2012; Dunne 2012; Sheppard et al. 2012b). There is only one patrol vessel for the BIOT, which takes up to two days to transit from one side of the MPA to the other and which is capable of being outrun by large modern fishing vessels (Dunne 2012; NSMC 2012). Revenue from the sale of fishing licenses that previously offset the costs of operating the patrol vessel will now have to come from other sources as all fishing licenses expired in 2010 with the creation of the MPA (Dunne 2012). A charitable donation of £3.5 million over a five-year period to fund MPA enforcement from the Swiss-based Bertarelli Foundation offers a short-term solution, but increasing funding levels will be key to the MPA's success (NSMC 2012). One option is collecting contributions from international scientific bodies for the maintenance of the MPA in exchange for research access (NSMC 2012).

Conclusions

Seamounts are found in all of the world's oceans, yet due to their location in deep-sea environments they are often not readily accessible to scientific investigation. Thus, we have only begun to understand the biological communities that seamount complexes support. Where ecological research has occurred, such as at Davidson Seamount in the Monterey Bay National Marine Sanctuary, seamount habitats have been found to host spectacular species assemblages. Although seamounts and the waters surrounding them are widely recognized as biodiversity hotspots, these environments are also threatened by a variety of human activities. Threats to seamounts range from deep-sea fishing and mining to bioprospecting and ocean acidification.

Only in recent years have there have been efforts by marine resource managers to focus on seamounts when considering habitats for protection. While national legislation offers the easiest means of protecting seamount resources, the majority of seamounts are located in waters beyond the limits of any nation's jurisdiction. NOAA Fisheries has prioritized a number of prominent seamounts off the U.S. west coast for protection as Habitat Areas of Particular Concern, and many of these have been protected from fishing pressure by being included within Essential Fish Habitat Conservation Areas. Of these, only Davidson Seamount has a seamount-specific management plan that restricts activities other than fishing. Elsewhere in U.S. waters, seamount complexes have been designated as special management areas or are just beginning to be considered for protection. A number of international successes, most notably the extensive system of benthic protection areas and seamount closures in New Zealand, offer examples for other nations to place the protection of deep-sea seamount resources as a conservation priority. Even more encouraging is the recent use of international instruments and authorities to create an emerging network of high seas MPAs to protect seamount ecosystems, as has occurred in the Northeast Atlantic.

Only a small fraction of the world's fragile seamount communities are managed by Federal or state governments at this time. Increased deep-sea research will facilitate better understanding of little-studied seamount habitats, and educating the public about species found at seamounts and the threats they face will help to build further support for expanding the number of protections afforded to seamounts. Comprehensive management plans should be developed by the respective management agencies for seamount areas that have been protected, to ensure that conservation goals are clear and that there are adequate enforcement mechanisms in place. Finally, given seamounts are of global interest, international cooperation is needed to better understand seamount protection options, to consider conservation strategies in international waters, and to enforce regulations in remote and resource-limited regions.

Literature Cited

Alder, J. and L. Woods. 2004. Managing and protecting seamounts ecosystems. In: Morato, T. and D. Pauly (eds), Seamounts: Biodiversity and Fisheries. Fisheries Centre Research Reports 12(5):67–73.

Allain, V., J.-A. Kerandel, S. Andréfouët, F. Magron, M. Clark, D.S. Kirby, and F.E. Muller-Karger. 2008. Enhanced Seamount Location Database for the Western and Central Pacific Ocean: Screening and Cross-checking of 20 Existing Datasets. Deep-Sea Research I 55:1035-1047.

Alvarado, J.J., J. Cortés, M.F. Esquivel, and E. Salas. 2012. Costa Rica's Marine Protected Areas: status and perspectives. Revista de Biología Tropical 60(1):129-142.

Andrews, A., E. Cordes, M. Mahoney, K. Munk, K. Coale, G. Cailliet, and J. Heifetz. 2002. Age, growth, and radiometric age validation of a deep-sea, habitat-forming gorgonian (*Primnoa resedaeformis*) from the Gulf of Alaska. Hydrobiologia 471:101-110.

Andrews, A.H., G.M. Cailliet, L.A. Kerr, K.H. Coale, C. Lundstrom, and A.P. DeVogelaere. 2005. Investigations of age and growth for three deep-sea corals from the Davidson Seamount off central California. In: Freiwald, A. and J.M. Roberts (eds.), Cold-water Corals and Ecosystems. Springer-Verlag, Berlin Heidelberg, pp. 1021-1038.

Ardron, J., D. Dunn, C. Corrigan, K. Gjerde, P. Halpin, J. Rice, E. Vanden Berghe, and M. Vierros. 2009. Defining ecologically or biologically significant areas in the open oceans and deep seas: Analysis, tools, resources and illustrations. A background document for the CBD expert workshop on scientific and technical guidance on the use of biogeographic classification systems and identification of marine areas beyond national jurisdiction in need of protection, Ottawa, Canada, 29 September – 2 October 2009.

Arico, S. and C. Salpin. 2005. Bioprospecting of Genetic Resources in the Deep Seabed: Scientific, Legal and Policy Aspects. United Nations University Institute of Advanced Studies. Accessed Septebmer 20, 2012 at http://www.ias.unu.edu/binaries2/DeepSeabed.pdf

Arico, S. and C. Salpin. 2006. Gambling in the deep sea. European Molecular Biology Organization. EMBO Reports 7(1):17-21.

Althaus, F., A. Williams, T.A. Schlacher, R.J. Kloser, M.A. Green, B.A. Barker, N.J. Bax, P. Brodie, and M.A. Schlacher-Hoenlinger. 2009. Impacts of bottom trawling on deep-coral ecosystems of seamounts are long-lasting. Marine Ecology Progress Series 397:279–294.

Baker, C.M., B.J. Bett, D.S. Billett, and A.D. Rogers, A.D. 2001. An environmental perspective. In WWF, IUCN, and WCPA (eds.) The status of natural resources on the high seas. WWF/IUCN, Gland, Switzerland: 3-68.

Bobbitt, A. 2007. NeMO 2007 Cruise Report: Axial Volcano, Endeavour Segment, and Cobb Segment, Juan de Fuca Ridge. Pacific Marine Environmental Laboratory, NOAA. 169p.

Brewin, P.E., K.I. Stocks, and G. Menezes. 2007. A history of seamount research. In: Pitcher, T.J., T. Morato, P.J.B. Hart, M.R. Clark, N. Haggan, and R.S. Santos (eds.). 2007. Seamounts: Ecology, Conservation and Management. Fish and Aquatic Resources Series, Blackwell, Oxford, UK, pp. 41-61.

Canessa, R.R., K.W. Conley, and B.D. Smiley. 2003. Bowie Seamount Pilot Marine Protected Area: An Ecosystem Overview Report. Canadian Technical Report of Fisheries and Aquatic Sciences 2461. Science Branch, Fisheries and Oceans Canada. 98p.

Chadwick, J., M. Perfit, I. Ridley, I. Jonasson, G. Kamenov, W. Chadwick, R. Embley, P. le Roux, and M. Smith. 2005. Magmatic effects of the Cobb hot spot on the Juan de Fuca Ridge. Journal of Geophysical Research 110, B03101, doi:10.1029/2003JB002767.

Clague, D.A., J.R. Reynolds, and A.S. Davis. 2000. Near-ridge seamount chains in the northeastern Pacific Ocean. Journal of Geophysical Research 105(B7):16,541-61.

Clark, M. R., D. Tittensor, A. D. Rogers, P. Brewin, T. Schlacher, A. Rowden, K. Stocks, and M. Consalvey. 2006. Seamounts, Deep-Sea Corals and Fisheries: Vulnerability of Deep-Sea Corals to Fishing on Seamounts Beyond Areas of National Jurisdiction. UNEP-WCMC, Cambridge, UK.

Clark, M. R., L. Watling, A. A. Rowden, J. M. Guinotte, and C. R. Smith. 2011. A global seamount classification to aid the scientific design of marine protected area networks. Ocean and Coastal Management 54(1):19-36.

Convention on Biological Diversity (CBD). 2003. Marine and coastal biodiversity: Review, further elaboration, and refinement of the programme of work. The value and effects of marine and coastal protected areas on marine and coastal biological diversity: a review of available information. Note by the Executive Secretary to the 8th Meeting. United Nations Environment Programme, Convention on Biological Diversity, Subsidiary Body on Scientific, Technical and Technological Advice. Accessed January 23, 2013 at: http://www.cbd.int/doc/meetings/sbstta/sbstta-08/information/sbstta-08-inf-12-en.pdf

Convention on Biological Diversity (CBD). 2008(a). Options for Preventing and Mitigating the Impact of Some Activities on Selected Seabed Habitats. Background document to the note by the Executive Secretary on options for preventing and mitigating the impact of some activities to selected seabed habitats, and ecological criteria and biogeographic classification systems of marine areas in need of protection. United Nations Environment Programme, Convention on Biological Diversity, Subsidiary Body on Scientific, Technical and Technological Advice. Accessed September 18, 2012 at: http://www.cbd.int/doc/meetings/sbstta/sbstta-13/information/sbstta-13-inf-13-en.doc

Convention on Biological Diversity (CBD). 2008(b). Marine and Coastal Biological Diversity:

Options for Preventing and Mitigating the Impact of Some Activities on Selected Seabed Habitats. Background Document Presented at the 13th Meeting. United Nations Environment Programme, Convention on Biological Diversity, Subsidiary Body on Scientific, Technical and Technological Advice. Accessed September 15, 2012 at: http://www.cbd.int/doc/meetings/sbstta/sbstta-13/official/sbstta-13-04-en.pdf

Convention on Biological Diversity (CBD). 2008(c). Synthesis and Review of the Best Available Scientific Studies on Priority Areas for Biodiversity Conservation in Marine Areas beyond the Limits of National Jurisdiction. Montreal, Technical Series No. 37, 63 p. Accessed September 12, 2012 at http://www.cbd.int/doc/publications/cbd-ts-37-en.pdf

Davies, A.J., J.M. Roberts, and J. Hall-Spencer. 2007. Preserving deep-sea natural heritage: emerging issues in offshore conservation and management. Biological Conservation 138(3–4):299–312.

Davis, A.S, D.A. Clague, W. A. Bohrson, G. B. Dalrymple, and H. G. Greene. 2002. Seamounts at the continental margin of California: A different kind of oceanic intraplate volcanism. Geological Society of America Bulletin 114(3):316-333.

Davis, A.S., D.A. Clague, and J.B. Paduan. 2007. Diverse origins of xenoliths from seamounts at the continental margin, offshore central California. Journal of Petrology 48(5):829-852.

de Forges, B.R., J.A. Koslow, and G.C.B. Poore. 2000. Diversity and endemism of the benthic seamount fauna in the southwest Pacific. Nature 405: 944-947.

Department of Sustainability, Environment, Water, Population, and Communities (DSEWPC). 2012a. Commonwealth Marine Reserves. Australian Government. Accessed November 28, 2012 at http://www.environment.gov.au/marinereserves/index.html

Department of Sustainability, Environment, Water, Population, and Communities (DSEWPC). 2012b. Huon Commonwealth Marine Reserve. Australian Government. Accessed November 28, 2012 at http://www.environment.gov.au/marinereserves/south-east/huon/index.html.

DeVogelaere, A.P., E.J. Burton, T. Trejo, C.E. King, D.A. Clague, M.N. Tamburri, G.M. Cailliet, R.E. Kochevar, and W.J. Douros. 2005. Deep-sea corals and resource protection at the Davidson Seamount, California, U.S.A. In Freiwald, A. and J.M. Roberts (eds). 2005. Cold-water Corals and Ecosystems. Springer-Verlag Berlin Heidelberg, pp. 1189-1198.

Dunne, R. 2012. The Chagos Archipelago: EPPZ & MPA Patrol Vessel. Accessed November 29, 2012 at https://sites.google.com/site/thechagosarchipelagofacts/eppz-mpa/patrol-vessel

Epp, D. and N.C. Smoot. 1989. Distribution of seamounts in the North Atlantic. Nature 337: 254-257.

Fisheries and Oceans Canada (FOC). 2012. Bowie Seamount Marine Protected Area. Accessed

November 28, 2012 at http://www.pac.dfo-mpo.gc.ca/oceans/protection/mpa-zpm/bowie/index-eng.htm.

Frey, O. and A.P. DeVogelaere. *In review*. Container Loss: The Containerized Shipping Industry and the Phenomenon of Containers Lost at Sea. Marine Sanctuaries Conservation Series. Office of National Marine Sanctuaries, Silver Spring, MD.

Fundación MarViva. 2011. Costa Rica Seamounts Marine Management Area. Pamphlet. 4 p. Accessed November 21, 2012 at http://www.marviva.net/index.php/es/nuestro-trabajo/publicaciones/doc_download/44-costa-rica-seamounts-marine-management-area

Genin, A., P.K. Dayton, P.F. Lonsdale, and F.N. Spiess. 1986. Corals on seamount peaks provide evidence of current acceleration over deep-sea topography. Nature 322: 59-61.

Gubbay, S. 2003. Seamounts of the North-East Atlantic. Oceanic Seamounts: an Integrated Study (OASIS). Frankfurt, Germany: WWF. 40 p.

Hein, J. 2004. Geologists and Biologists Endeavor to Understand Seamount Environments Off California**.** U.S Geological Survey Sound Waves 57:4-6.

Helson, J., S. Leslie, G. Clement, R. Wells, and R. Wood. 2010. Private rights, public benefits: Industry-driven seabed protection. Marine Policy 34:557-566.

Hillier, J.K. and A.B. Watts. 2007. Global Distribution of Seamounts from Ship-track Bathymetry Data. Geophysical Research Letters 34: L13304, doi:10.1029/2007GL029874.

Hofmann, G.E., J.P. Barry, P.J. Edmunds, R.D. Gates, D.A. Hutchins, T. Klinger, and M.A. Sewell. 2010. The effect of ocean acidification on calcifying organisms in marine ecosystems: An organism to ecosystem perspective. Annual Review of Ecology, Evolution, and Systematics 41:127–147.

Hood, M., P. Brewer, P. Haugan, and H.O. Poertner (eds). 2014. What is ocean carbon sequestration? Ocean Acidification Network. Accessed March 18, 2014 at http://www.ocean-acidification.net/FAQocs.html.

Hourigan, T.F. 2009. Managing fishery impacts on deep-water coral ecosystems of the USA: emerging best practices. Marine Ecology Progress Series 397:333-340.

Kitchingman A. and S. Lai. 2004. Inferences of potential seamount locations from mid-resolution bathymetric data. In: Morato T. and D. Pauly (eds) Seamounts: biodiversity and fisheries. Fish Cen Res Rep Univ Vancouver 12(5):7–12.

Kogan, I., C.K. Paull, L.A. Kuhnz, E.J. Burton, S.V. Thun, H.G. Greene, J.P. Barry. 2006. ATOC/Pioneer Seamount cable after 8 years on the seafloor: Observations, environmental impact. Continental Shelf Research 26:771-787.

Kontner, J.G., H. Staudigel, and J. Gee. 2010. Spotlight: Jasper Seamount. Oceanography 23(1):40-41.

Koslow, J.A., G.W. Boehlert, J.D.M. Gordon, R.L. Haedrich, P. Lorance, and N. Parin. 2000. Continental slope and deep-sea fisheries: Implications for a fragile ecosystem. ICES Journal of Marine Sciences 57:548-557.

Koslow, J.A. 2001. Fish Stocks and Benthos of Seamounts. In: Thiel, H. and J.A. Koslow (eds) Managing Risks to Biodiversity and the Environment on the High Sea, Including Tools Such as Marine Protected Areas: Scientific Requirements and Legal Aspects. Bonn, Germany: German Federal Agency for Nature Conservation. 214 p.

Koslow, J.A., G.W. Boehlert, J.S.M. Gordon, R.L. Haedrich, P. Lorance and N. Parin. 2001. The impact of fishing on continental slope and deep-sea ecosystems. ICES J. Mar. Sci. 57:548-557.

Kusek, K.M. 2008. Coral catastrophe on the Corner Rise Seamounts: Fishing trawlers likely caused extensive damage to deep-sea coral communities. Oceanus 46(2). Accessed October 4, 2012 at http://www.whoi.edu/oceanus/viewArticle.do?id=33769

Lundsten, L., C. R. McClain, J. P. Barry, G. M. Cailliet, D. A. Clague, and A. P. DeVogelaere. 2009a. Ichthyofauna on three seamounts off southern and central California, USA. Marine Ecology Progress Series 389:223-232.

Lundsten, L., J. P. Barry, G. M. Cailliet, D. A. Clague, A. P. DeVogelaere, and J. B. Geller. 2009b. Benthic invertebrate communities on three seamounts off southern and central California, USA. Marine Ecology Progress Series 374:23-32.

Lundsten, L., S.B. Johnson, G.M. Cailliet, A.P. DeVogelaere, and D.A. Clague. 2012. Morphological, molecular, and in situ behavioral observations of the rare deep-sea anglerfish *Chaunacops coloratus* (Garman, 1899), order Lophiiformes, in the eastern North Pacific. Deep-Sea Research I 68:46-53.

Malahoff, A. 2000. Loihi Submarine Volcano: A unique, natural extremophile laboratory. Office of Oceanic and Atmospheric Research, NOAA. Accessed November 8, 2012 at http://www.oar.noaa.gov/spotlite/archive/spot_loihi.html

Marine Conservation Institute (MCI) and Waitt Foundation (WF). 2012. MPAtlas. http://www.mpatlas.org

Maxwell, S.M., J.J. Frank, G.A. Breed, P.W. Robinson, S.E. Simmons, D.E. Crocker, J.P. Gallo-Reynoso, and D.P. Costa. 2012. Benthic foraging on seamounts: a specialized foraging behavior in a deep-diving pinniped. Marine Mammal Science 28(3):E333–344.

McClain, C.R., L. Lundsten, M. Ream, J. Barry, and A. DeVogelaere. 2009. Endemicity, biogeography, composition, and community structure on a northeast Pacific seamount. PLoS

ONE 4(1):e4141. doi:10.1371/journal.pone.0004141

Miliani, K. 2012. Costa Rica: Área Marina de Manejo Montes Submarinos. The Nature Conservancy. Accessed February 1, 2013 at http://espanol.tnc.org/dondetrabajamos/costarica/lugares/isladelcoco.html

Ministerio de Ambiente, Energía y Telecomunicaciones de Costa Rica (MINAET). 2011. Decreto Ejecutivo Nº 36452-MINAET del 03/03/2011: Creación del Área Marina de Manejo Montes Submarinos. La Gaceta 121. Accessed February 1, 2013 at http://documentos.cgr.go.cr/content/dav/jaguar/USI/normativa/2011/DECRETOS/DE-36452.doc

Ministry for the Environment (MFE). 2012. Marine Management Tools. Government of New Zealand. Accessed November 28, 2012 at http://www.mfe.govt.nz/environmental-reporting/oceans/protected-areas/management-tools.html

Ministry for Primary Industries (MPI). 2012. Benthic Protection Areas. Government of New Zealand. Accessed November 28, 2012 at http://www.fish.govt.nz/en-nz/Environmental/Seabed+Protection+and+Research/Benthic+Protection+Areas.htm

Mofjeld, H.O., V.V. Titov, F.I. González, and J.C. Newman. 2001. Tsunami scattering provinces in the Pacific Ocean. Geophysical Research Letters 28(2):335–337.

Monterey Bay Aquarium Research Institute (MBARI). 2012a. Mapping Program: Gumdrop, Pioneer, and Guide Seamounts. Accessed October 24, 2012 at http://www.mbari.org/data/mapping/seamounts/guide2gumdrop.htm.

Monterey Bay Aquarium Research Institute (MBARI). 2012b. Mapping Program: Taney Seamounts. Accessed October 24, 2012 at http://www.mbari.org/data/mapping/seamounts/taney.htm

Monterey Bay Aquarium Research Institute (MBARI). 2012c. Mapping Program: Davidson Seamount. Accessed October 24, 2012 at http://www.mbari.org/data/mapping/seamounts/davidson.htm

Monterey Bay Aquarium Research Institute (MBARI). 2012d. Mapping Program: Rodriguez Seamount. Accessed October 24, 2012 at http://www.mbari.org/data/mapping/SBBasin/rodriguez.htm

Monterey Bay Aquarium Research Institute (MBARI). 2012e. Continental Margin Seamounts. Accessed October 26, 2012 at http://www.mbari.org/volcanism/Seamounts/Seam-ContlMarg.htm

Monterey Bay Aquarium Research Institute (MBARI). 2012f. Mapping Program: Vance Seamounts. Accessed November 12, 2012 at http://www.mbari.org/data/mapping/seamounts/vance.htm

Monterey Bay Aquarium Research Institute (MBARI). 2012g. Mapping Program: President Jackson Seamounts. Accessed January 25, 2013 at http://www.mbari.org/data/mapping/seamounts/presjackson.htm

Monterey Bay National Marine Sanctuary (MBNMS). 2009. Monterey Bay National Marine Sanctuary Davidson Seamount Management Plan. Living Document, version 5.0. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, National Marine Sanctuary Program.

Monterey Bay National Marine Sanctuary (MBNMS). 2012a. Davidson Seamount Management Zone Threats Assessment. Technical Report 2012-1, 39p.

Monterey Bay National Marine Sanctuary (MBNMS). 2012b. Davidson Seamount. Accessed October 31, 2012 at http://montereybay.noaa.gov/research/dsmz/welcome.html

Moore, J.A., M. Vecchione, B.B. Collette, R. Gibbons, K.E. Hartel, J.K. Galbraith, M. Turnipseed, M. Southworth, and E. Watkins. 2003. Biodiversity of Bear Seamount, New England Seamount Chain: Results of exploratory trawling. Journal of Northwest Atlantic Fishery Science 31:363-372.

Moore, J.A., M. Vecchione, B.B. Collette, R. Gibbons, K.E. Hartel. 2004. Selected fauna of Bear Seamount (New England Seamount chain), and the presence of "natural invader" species. Archive of Fishery and Marine Research 51(1-3): 241-250

Morato, T., T.J. Pitcher, M.R. Clark, G. Menezes, F. Tempera, F. Porteiro, E. Giacomello, and R.S. Santos. 2010. Can We Protect Seamounts for Research? A Call for Conservation. Oceanography 23(1):190-199.

National Marine Fisheries Service (NMFS). 2006. Final Rule: Fisheries of the Exclusive Economic Zone off Alaska. Federal Register 71 (124), 36694-36714. Codified at 50 CFR Part 679.

National Marine Fisheries Service (NMFS). 2010. Final Rule: Fisheries in the Western Pacific; Hawaii Bottomfish and Seamount Groundfish; Measures To Rebuild Overfished Armorhead at Hancock Seamounts. Federal Register 75 (217), 69015-69016. Codified at 50 CFR Part 665.

National Marine Fisheries Service (NMFS). 2011. Habitat Areas of Particular Concern. Accessed October 17, 2012 at http://swr.nmfs.noaa.gov/hcd/hcd_webcontent/socal/hapc.htm.

National Marine Fisheries Service (NMFS). 2012. Habitat Areas of Particular Concern in the Alaska Region. Accessed November 12, 2012 at http://alaskafisheries.noaa.gov/habitat/efh/hapc/hapc_ak.pdf

National Marine Sanctuary Program (NMSP). 2008. Final Rule: GFNMS; MBNMS; and CBNMS Regulations. Federal Register 73 (225), 70488-70540. Codified at 15 CFR Part 22.

National Oceanic and Atmospheric Administration (NOAA). 2003. Ocean Explorer: Mountains in the Sea, July 11 – July 19, 2003. Accessed November 12, 2012 at http://oceanexplorer.noaa.gov/explorations/03mountains/

National Oceanic and Atmospheric Administration (NOAA). 2008. Monterey Bay National Marine Sanctuary Final Management Plan. Prepared as part of the Joint Management Plan Review. Volume III, October 2008, US Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, National Marine Sanctuary Program, 478 p.

New England Fishery Management Council (NEFMC). 2012. Omnibus Essential Fish Habitat Amendment 2: Deep-sea coral management alternatives. Draft, June 2012. Accessed February 1, 2013 at http://www.nefmc.org/habitat/planamen/efh_amend_2/June_2012_Coral_Alternatives.pdf

North Sea Marine Cluster (NSMC). 2012. Managing Marine Protected Areas: a case study examining the Chagos Archipelago. Marine Protected Area Network Report. 24p.

Northwest Atlantic Fisheries Organization (NAFO). 2012. NAFO Conservation and Enforcement Measures. NAFO FC Doc. 12/1 Serial No. N6001. Accessed November 8, 2012 at http://archive.nafo.int/open/fc/2012/fcdoc12-01.pdf

O'Leary, B.C, R.L. Brown, D.E. Johnson, H. von Nordheim, J. Ardron, T. Packeiser, and C.M Roberts. 2012. The first network of marine protected areas (MPAs) in the high seas: The process, the challenges and where next. Marine Policy 36(3):598-605.

OSPAR Commission. 2010. Background document on Milne Seamount. Publication number 524/2010. 17p.

OSPAR Commission. 2012. Atlantic seamount becomes the first case added to international repository of Ecologically or Biologically Significant Marine Areas. OSPAR news, February 17, 2012. Accessed November 28, 2012 at http://www.ospar.org/content/news_detail.asp?menu=00600725000000_000019_000000

Owen, D. 2010. Interactions between management of a water column marine protected area in the high seas of the OSPAR maritime area and the exercise of sovereign rights regarding subjacent outer continental shelf. Report to WWF Germany. 55p.

Pacific Fishery Management Council (PFMC). 2005. Amendment 18 (Bycatch Mitigation Program) and Amendment 19 (Essential Fish Habitat) to the Pacific Coast Groundfish Fishery Management Plan for the California, Oregon, and Washington Groundfish Fishery. 98p.

Paduan, J.B., D.A. Clague, and A.S. Davis. 2009. Evidence that three seamounts off southern California were ancient islands. Marine Geology 265(3-4):146-156.

Patin, S. and E. Cascio (translator). 1999. Environmental Impact of the Offshore Oil and Gas Industry. EcoMonitor Publishing, East North Port, New York. 425 p.

Pitcher, T.J., T. Morato, P.J.B. Hart, M.R. Clark, N. Haggan, and R.S. Santos (eds.). 2007. Seamounts: Ecology, Conservation and Management. Fish and Aquatic Resources Series, Blackwell, Oxford, UK.

Pitcher, T.J., T. Morato, K. I. Stocks, and M. R. Clark. 2010. Seamount Ecosystem Evaluation Framework (SEEF): A tool for global seamount research and data synthesis. Oceanography 23:123–125.

Probert, P. K., S. Christiansen, K. M. Gjerde, S. Gubbay, and R. S. Santos. 2007. Management and conservation of seamounts (Chapter 20): 442-475. In: T. J. Pitcher, T. Morato, P. J. B. Hart, M. R. Clark, N. Haggan, and R.S. Santos (Eds.). Seamounts: Ecology, Fisheries and Conservation. Blackwell Publishing, Oxford, UK. XXIV + 527p.

Rogers, A.D. 1994. The Biology of Seamounts. Advances in Marine Biology 30:305-350.

Rogers, A.D. 2004. The Biology, Ecology and Vulnerability of Seamount Communities. International Union for Conservation of Nature & Natural Resources. Accessed July 7, 2011 at http://cmsdata.iucn.org/downloads/alexrogers_cbdcop7_seamounts_complete1_1.pdf

Rogers, A.D, M.R. Clark, J.M. Hall-Spencer and K.M. Gjerde. 2008. The Science behind the Guidelines: A Scientific Guide to the FAO Draft International Guidelines (December 2007) For the Management of Deep-Sea Fisheries in the High Seas and Examples of How the Guidelines May Be Practically Implemented. Gland, Switzerland: IUCN Global Marine Programme. 48 p.

Sanctuary Integrated Monitoring Network (SIMoN). 2012. Monitoring Project: Pioneer Seamount Ocean Acoustic Observatory. Accessed October 24, 2012 at http://sanctuarysimon.org/projects/project_info.php?projectID=100159

Santos, R.S., F. Tempera, and T. Morato. 2010. Background Document for Seamounts. OSPAR Commission Biodiversity Series. 30 p.

Sarma, K., M.V. Ramana, V. Subrahmanyam, and K.S. Krishna. 1998. Seamounts an additional tool to confirm the nature of the crust and to locate possible mineral resources for dredging. Mar. Georesources and Geotechnology 16(1):41-51.

Shank, T.M. 2010. New England and Corner Rise Seamounts. Oceanography 23(1):104-105.

Sheppard, C.R.C., M. Ateweberhan, B.W. Bowen, P. Carr, C.A. Chen, C. Clubbe, M.T. Craig, R. Ebinghaus, J. Eble, N. Fitzsimmons, M.R. Gaither, C-H. Gan, M. Gollock, N. Guzman, N.A.J. Graham, A. Harris, R. Jones, S.Keshavmurthy, H. Koldewey, C.G. Lundini, J.A. Mortimer, D. Obura, M. Pfeiffer, A.R.G. Price, S. Purkis, P. Raines, J.W. Readman, B. Riegl, A. Rogers, M. Schleyer, M.R.D Seaward, A.L.S. Sheppard, J. Tamelander, J.R. Turner, S.

Visram, C. Vogler, S. Vogt, H. Wolschke, J.M-C. Yang, S-Y. Yang and C. Yesson. 2012a. Reefs and islands of the Chagos Archipelago, Indian Ocean: why it is the world's largest no-take marine protected area. Aquatic Conservation: Marine and Freshwater Ecosystems 22:232–261.

Sheppard, C., P. Carr, N. Graham, A. Harris, C. Head, H. Koldewey, J. Meeuwig, J. Mortimer, S. Purkis, A. Price, C. Roberts, M.H. Schleyer, A. Sheppard, J. Tamelander, and J. Turner. 2012b. Conservation and Management in British Indian Ocean Territory (Chagos Archipelago). Unpublished report. 28p.

Spear, B. and J. Cannon. 2012. Benthic Protection Areas: Best Practices and Recommendations. Sustainable Fisheries Partnership. 36p. Accessed November 28, 2012 at http://cmsdevelopment.sustainablefish.org.s3.amazonaws.com/2012/04/20/SFP_Benthic_Protection_Areas_Report_2012_April-97c98c67.pdf

Starr, R.M and K. Green. 2010. Fishes of Las Gemelas Seamounts and Isla del Coco: Preliminary Findings of September 2009 Submersible Surveys. California Sea Grant Extension Publications, California Sea Grant College Program, UC San Diego. 14 p.

Staudigel, H., A.A.P. Koppers, J.W. Lavelle, T.J. Pitcher, and T.M. Shank (eds). 2010. Special Issue on Mountains in the Sea. Oceanography 23(1).

Stocks, K. 2009. SeamountsOnline: An Online Information System for Seamount Biology. Version 2009-1. World Wide Web electronic publication. Accessed September 14, 2012 at http://seamounts.sdsc.edu

Taranto, G.H., K.Ø. Kvile, T.J. Pitcher, and T. Morato. 2012. An Ecosystem Evaluation Framework for Global Seamount Conservation and Management. PLoS ONE 7(8):e42950. doi:10.1371/journal.pone.0042950.

Téllez, R. 2011. NGOs to pick up tab for protecting prized Isla del Coco marine park. Tico Times, May 20, 2011. Available at http://www.ticotimes.net/layout/set/print/Current-Edition/Top-Story/News/NGOs-to-pick-up-tab-for-protecting-prized-Isla-del-Coco-marine-park_Friday-May-20-2011.

Thiel, H. and J.A. Koslow (eds.). 2001. Managing risks to biodiversity and the environment on the high sea, including tools such as marine protected areas: Scientific requirements and legal aspects. Proceedings of the Expert Workshop held at the International Academy for Nature Conservation, Isle of Vilm, Germany, 27 February - 4 March 2001. German Federal Agency for Nature Conservation, Bonn, 214p.

Tsounis, G., S. Rossi, R. Grigg, G. Santangelo, L. Bramanti, and J. Gili. 2010. The exploitation and conservation of precious corals. Oceanography and Marine Biology: An Annual Review 48:161-212.

Turley, C.M., J.M. Roberts, and J.M. Guinotte. 2007. Corals in deep-water: will the unseen hand of ocean acidification destroy cold-water ecosystems? Coral Reefs 26:445-448.

UN Environment Programme (UNEP). 2010. High Seas MPAs: Regional Approaches and Experiences. Side event at the 12th Global Meeting of the Regional Seas Conventions and Action Plans, Bergen, Norway, 20th – 22nd September 2010. UNEP (DEPI)/RS.12 /INF.6.RS. 38p.

UNEP-WCMC. 2012. UNEP-WCMC Species Database: CITES-Listed Species On the World Wide Web. Accessed September 14, 2012 at http://www.unep-wcmc-apps.org/isdb/CITES/Taxonomy/tax-genus-result.cfm/isdb/CITES/Taxonomy/tax-genus-result.cfm?displaylanguage=eng&Genus=1154&source=animals&Country=

UN General Assembly (UNGA). 2007. Resolution 61/105 [Sustainable Fisheries]. A/RES/61/105. March 6, 2007.

Van den Hove, S. and V. Moreau. 2007. Deep-sea biodiversity and ecosystems: A scoping report on their socio-economy, management, and governance. UNEP World Conservation Monitoring Centre. 88 p.

Waller, R., L. Watling, P. Auster and T. Shank. 2007. Anthropogenic impacts on the Corner Rise seamounts, north-west Atlantic Ocean. J. Mar. Biol. Ass. U.K. (87):1075–1076.

Wessel, P., D.T. Sandwell, and S-S. Kim. 2010. The Global Seamount Census. In: Staudigel, H., A.A.P. Koppers, J.W. Lavelle, T.J. Pitcher, and T.M. Shank (eds). 2010. Special Issue on Mountains in the Sea. Oceanography 23(1).

Western Pacific Regional Fishery Management Council (WPRFMC). 2010. Amendment 2 to the Fishery Ecosystem Plan for the Hawaii Archipelago: Management measures for the Hancock Seamounts to address the overfished condition of armorhead (*Pseudopentaceros wheeleri*), including an environmental assessment. 41 p.

Williams, A., F. Althaus, and D. Furlani. 2006. Assessment of the conservation values of the Norfolk Seamounts area: A component of the Commonwealth Marine Conservation Assessment Program 2002-2004. Report to the Department of Environment and Heritage, Australia. 173p.

Williams, A., T. A. Schlacher, A. A. Rowden, F. Althaus, M. R. Clark, D. A. Bowden, R. Stewart, N. J. Bax, M. Consalvey, and R. J. Kloser. 2010. Seamount megabenthic assemblages fail to recover from trawling impacts. Marine Ecology 31 (Suppl. 1):183–199.

WWF Germany. 2012. Charlie-Gibbs Marine Protected Area: Protecting diversity in the high seas. Accessed November 28, 2012 at http://www.charlie-gibbs.org/

Yesson, C., M.R. Clark, M.L. Taylor, and A.D. Rogers. 2011. The global distribution of seamounts based on 30 arc seconds bathymetry data. Deep-Sea Research I 58:442-453.