Caring for the Deep Sea

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Overview of Habitats

The deep sea is one of the most remote and expansive habitats on Earth, spanning depths of 200 m to beyond 10,000 m in the deepest trenches. The oceanic seafloor forms through a combination of seafloor spreading at mid-ocean ridges (MOR) and sedimentation of materials from the sea surface over millions of years, as ocean plates move from their origin at MOR to subduction zones. The generally uniform temperature and salinity, and absence of light, define an environment far less variable than in most shallow-water environments.¹

The area of sediment-covered seafloor comprises more habitat than all others on Earth combined. Near the continental shelf, sediments often contain terrigenous material transported by rivers and coastal currents, whereas sediments in the abyssal plains (sometimes more than one kilometer thick) are derived from the shells of open-water organisms. The composition of sediments defines the fauna living on and within them. Because of the absence of light, most deep-sea organisms depend on sinking food material produced in surface waters (phytodetritus), fecal pellets, fish or zooplankton carcasses, or material transported laterally (pieces of kelp and land-based organic material such as wood).

Exposed hard substratum occurs mainly in areas with relatively steep profiles, such as the walls of submarine canyons and the flanks of seamounts, as well as on newly produced seafloor near spreading centers. Strong currents typically characterize steep sloping environments, limiting accumulation of sediments, and exposing hard substratum.

Submarine canyons incise the continental slope and can range over 1,000 m in depth. Because of their topography, canyons can act as conduits of sediment,

¹ E. Ramirez-Llodra et al., “Deep, Diverse and Definitely Different: Unique Attributes of the World’s Largest Ecosystem,” Biogeosciences 7 (2010): 2851–2899.
phytodetritus, and other food falls, and influence the direction and velocity of ocean currents. Seamounts are underwater mountains, mostly volcanic in origin, that rise at least 1,000 m above the seafloor but do not break the sea surface. The exact number of seamounts is unknown, but they supply a large proportion of the hard substratum in the deep sea. Seamounts provide mosaics of different habitats of varying slope, depth, elevation, coarseness of substratum and hydrothermal activity, and their shape and elevation affect ocean circulation.

Areas at MOR are tectonically, and in some cases volcanically, very active. Slabs of basalt or chimney-like structures of sulphides comprise the newly created seafloor, where hydrothermal vents occur, expelling hot, chemically-altered seawater either through focused flows on chimneys or diffuse flows through cracks in the basalt. The hydrothermal fluid is enriched in toxic metals and hydrogen sulphide and devoid of oxygen, with temperatures that can reach 20–40°C in diffuse flows and > 400°C in the fluid emanating from black smokers.

Overview of Biological Communities

The soft-sediment communities that dominate the deep sea include species that remove particles from suspension and others that ingest sediment grains and associated food (Figure 1). Small worms, crustaceans, molluscs, and other invertebrates dominate these sediments; the limited and often poor quality of food limits the sizes and numbers of individuals that these environments can support. Fishes living near the seafloor feed on these organisms, but the cold temperatures and limited food result in reduced metabolic rates and organisms grow slowly, produce low numbers of offspring, and reproduce at a late age. Reduced numbers and size do not mean reduced diversity, however, and we now recognize the deep sea as among the most species-rich environments on Earth. These sedimentary organisms recycle carbon, nitrogen, and phosphate, the basic building blocks of life on Earth. Despite generally low process rates in the deep sea, these organisms play a vital role in the delivery of global ecosystem functions (that support life on Earth) and services (benefits derived by humans) because they cover such vast areas.

Species that occur on hard substratum need a firm surface on which to affix, typically suspension feeding and thus requiring currents that deliver a supply of food particles (Figure 1). The most common megafaunal invertebrate species include sponges, deep-water hard and soft corals, sea pens, anemones, bryozoans, and bivalves, whose sessile adult stages occupy canyon walls and
seamounts. These phyla can reach locally high abundances with favorable conditions such as adequate food supply. For example, increased local primary productivity can occur near the summit of seamounts. As a result, seamounts support large concentrations of reef-forming stony corals and gorgonian and soft corals, as well as dense aggregations of fish such as redfish, grenadiers, tuna, and sharks.

The communities at hydrothermal vents are highly specialized to the unique environmental conditions, with polychaetes, bivalves, gastropods, decapods, and fish dominating the biomass. Biodiversity in these habitats is lower than the surrounding deep sea, with mostly endemic species. Primary production by microbes that utilize the hydrothermal fluid drives these ecosystems and accumulates much higher biomass than in the surrounding deep sea. Most metazoan secondary producers harbor these microbes as obligate or facultative symbionts that supply them with a reliable source of carbon.
Knowledge Gaps

Less than 0.0001 percent of the area of the deep sea has been investigated, and not all habitats at the same rate. Hundreds of thousands (possibly millions) of species remain unknown and most will never be known. We lack fundamental knowledge on the structure and function of populations, communities, and ecosystems and the processes that regulate them. Certain benthic ecosystems are particularly data poor, such as in the abyssal plains and trenches. The remoteness and harshness (e.g., crushing pressures, no light) of the habitats make experimentation on rates of these processes challenging. One habitat that remains particularly elusive is the deep water-column, in the benthopelagic (1,000–4,000 m) and abyssopelagic (> 4,000 m) zones, where a virtually unknown fauna of deep-sea fishes, gelatinous zooplankton, and pelagic molluscs dominate.2

Overview of Human Pressures

Climate change is expected to have significant impact in the deep sea. The composition and abundance of the dominant primary producers, secondary consumers, and associated trophic links in surface waters will change throughout the world’s ocean, and, most importantly for the deep sea, in the large gyres overlying the abyssal plains. These changes, in turn, will affect the export of surface production to the deep sea, where it constitutes the main source of energy. The total available energy to the deep sea is expected to decrease, and changes in food quality may lead to taxonomic shifts in the dominant players, and possible associated changes in ecosystem function. The warmer, more acidic waters associated with global change are already moving into the deep ocean. For organisms with shells or calcium carbonate skeletons, such as deep-water corals, significant impacts are expected, with cascading effects on other fauna that feed on these organisms or depend on them for habitat. In some parts of the ocean, reduced abundances and reduced biological diversity already occur in oxygen depleted areas known as oxygen minimum zones. Climate change and nutrient loading are increasing the spatial extent and frequency of such zones.3

2 R. Danovaro, P.V.R. Snelgrove, and P. Tyler, “Challenging the Paradigms of Deep-sea Ecology,” Trends in Ecology and Evolution 29, no. 8 (2014): 465–475.
3 E. Ramirez-Llodra et al., “Man and the Last Great Wilderness: Human Impact on the Deep Sea,” PLoS One 6, no. 8 (2011): e22588, doi.org/10.1371/journal.pone.0022588.
The collapse of many coastal fisheries has pushed fishing pressure into deeper waters over the last 50 years. Arguably, no deep-sea fishery is sustainable because recovery of populations is very slow. Some deep-sea fisheries target specialized habitats, such as seamounts and canyons, focusing pressure and causing serial depletion. Because many of these fisheries occur in international waters, known as areas beyond national jurisdiction (ABNJ), they are poorly managed and monitored, if at all, leaving behind depleted habitats often badly damaged by bottom-contact fishing gear.

Oil and gas activities occur on all continental margins, except Antarctica, and continue to expand. The effects of these activities can be localized to a few hundreds of meters during equipment installation and up to kilometers during discharge of drilling muds and other water-based toxic or smothering discharges. Unpredictable effects can occur over tens of kilometers and throughout the water column during accidental oil blowouts, as with the Deep Water Horizon in the Gulf of Mexico in 2010. The impacts can range from the destruction of long-lived, slow growing, vulnerable marine ecosystems, to changes in ecosystem functions. The effects may persist over years to decades or longer, depending on the magnitude and frequency of the activities or accidents.

Deep-sea mining has been gaining momentum both within exclusive economic zones (EEZs) and in the Area where the International Seabed Authority (ISA) has already granted contracts for mining exploitation in the Clarion-Clipperton Zone in the Pacific Ocean, the Mid-Atlantic Ridge, and the Southwest Indian Ridge. The targeted resources are manganese nodules in the abyssal plains, massive seafloor sulphide deposits on hydrothermal vents, and cobalt crusts on seamounts for valuable metals such as nickel, copper, cobalt, gold, and silver. Mining activities destroy bottom habitat during the physical removal of nodules, sulphides, and crusts, and generate smothering plumes during physical removal and disposal of discharges from the support ship. Recovery of the sediment ecosystems in the abyssal plains is expected to take decades to centuries, and millennia for individual nodules. Ecosystems at hydrothermal vents are not uniformly resilient to disturbance and recovery may take from a few years to decades or centuries. Mining of cobalt crusts will affect vulnerable marine ecosystems that abound on seamounts that can be several centuries old, and require several decades to centuries to recover.

Needs and Solutions

Many of the pressures in the deep sea require global solutions, such as the reduction in carbon dioxide emissions, and a deep-sea specific strategy to
mitigate their impacts is not feasible. However, some pressures can be alleviated by sustainable practices. While it is almost impossible to predict with any accuracy the overall impact of anthropogenic activities on deep-sea habitats, the precautionary principle can guide our efforts as we continue to collect more information.

The deep sea exemplifies the ‘tragedy of the commons’; the lack of clear ‘ownership’ of resources creates a challenge for effective management, particularly in ABNJ. Increasing recognition of the problem has led to some international efforts to reduce pressures in particularly sensitive areas, such as those with abundant deep-water corals; however, these efforts are complicated by challenges of appropriate legal tools, adequate enforcement, and international compliance.

Clearer and stricter guidelines can be used to control the activities of extractive industries, such as oil and gas and deep-sea mining. While oil and gas activities generally fall within national jurisdictions, international agreements are needed for the regulation of mining in the Area. The mandate and responsibility for safeguarding ecosystems from serious harm in the Area falls within the ISA. Given the increasing momentum, and the already awarded contracts, the ISA needs to accelerate the development of regional strategic management plans and regulations that protect the marine environment from serious harm.

One spatial tool that we have available is an effective network of marine protected areas (MPAs). Many states are designing such networks to protect representative ecosystems and enhance the overall resilience of the deep sea to disturbance. In British Columbia, Canada, an offshore MPA is being considered that will include all known hydrothermal vents and many seamounts in the EEZ. In the United States, national marine monuments were established to protect submarine canyons and seamounts off New England. International efforts by scientists, contractors, and the ISA are attempting to design networks of areas protected from the influence of any mining activities, following the same elements as those for MPAs.

**Conclusion**

The vastness of the deep sea can lull us into thinking that it is inexhaustible. However, evidence of human impacts is now seen in every deep-sea environment that has been explored, even in the deepest trenches, spanning from contaminants to trawl scars to garbage. Because the deep sea is one of the most pristine remaining habitats on Earth, we must develop effective strategies to
preserve its rich biodiversity and ecosystem functions and services. We have
the opportunity to collect baseline information prior to development, so that
we know what ‘normal’, ‘unimpacted’, or ‘healthy’ actually mean. However, just
as rapid advancements in science technology offer hope, parallel advances in
fishing and oil/mineral development are accelerating pressures and increas-
ing the urgency to address the problem. “Caring for the deep sea” will require
regional and international cooperation, compromise and creativity. We cannot
afford to wait; we must act now to protect this unique and irreplaceable part
of the ocean commons.