DOSI
DEEP-OCEAN STEWARDSHIP INITIATIVE

POLICY BRIEF
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Sustaining Biodiversity Beyond National Jurisdictions: The Major Science Challenges

The remote location and limited access to deep-sea environments in Areas Beyond National Jurisdiction (ABNJ) leave many basic science questions on marine biodiversity unanswered. ABNJ encompasses >90% of the habitat on Earth known to support living organisms and 99% of ocean volume. However, to date, scientists have assessed only tiny fractions of the seafloor and the deep-water realm – the largest ecosystems on Earth. We do not know the number of species in the deep sea within even an order of magnitude. Estimates of small invertebrate species range from half to several million, and estimates of microbes may exceed 1 billion. The higher estimates suggest the deep sea may rival tropical rain forests and coral reefs in the biodiversity of its species pool. Based on our limited sampling, we do know that many deep-sea species grow slowly and some reach ages of 100s to 1000s of years. They mature slowly, produce fewer offspring, and are sparser in numbers than their shallow-water counterparts. These characteristics impart greater vulnerability to human perturbations such as fishing, climate change, mining and pollution, but because of their remoteness most deep-sea ecosystems remain among the most pristine habitats on Earth. Because they cover such a large portion of the planet, ABNJ contribute significantly to a wide range of ecosystem functions such as nutrient and carbon cycling, and habitat provision, and to ecosystem services such as fisheries. Today, with increasing interests in the effects of anthropogenic change and exploitation of potential resources in the deep sea, science advice is imperative. In particular, science can inform the development of societally-relevant policy that employs current instruments such as Area Based Management Tools and Environmental Impact Assessments of human activities, as well as other management tools such as temporal closures. The basic research questions that attract researchers to the deep sea can help plan for sustainable ocean use, in building cooperation, and in capacity development for Biodiversity Beyond National Jurisdiction.

Basic Science Questions

Because the deep ocean is poorly sampled, even some of the most basic questions on biodiversity remain unanswered. Among the most topical research topics include:

1. Who lives in or passes through different deep-sea environments? How quickly does species composition change over space and time? Does loss of species from one location mean global extinction or can the species re-establish from adjacent locations?
2. What are the ecological and functional connections among deep-sea habitats, and of deep-sea habitats and the upper ocean? Are there movements of genes, individual organisms, populations, species, nutrients and/or energy among spatially distinct entities (e.g. habitats, ecosystems)?
3. Can we predict where different species and ecosystems occur? Because the massive size of ABNJ precludes fully sampling them; can we develop surrogates that will assist with prediction?
4. How do living organisms in ABNJ impact Earth Systems such as nutrient and carbon cycling, other ecosystems, such as the upper ocean, as well as other life on Earth, including humans?
5. What is the response and recovery time of deep-sea populations from perturbations, whether from fishing gear, mining, climate change, or even natural events? And how do multiple impacts affect response and recovery?

The deep-sea scientific community is particularly interested in helping develop the most effective process that includes knowledge on these topics and supports effective ocean policy that will sustain biodiversity in ABNJ.

Linkages to Area-Based Management Tools

Scientific knowledge can inform the development of Area Based Management Tools and knowledge of baselines against which to monitor change. Knowing who lives in or moves through different environments can identify biodiversity hotspots, Vulnerable Marine Ecosystems and Ecologically and Biologically Significant Areas. Well-connected Marine Protected Areas and fisheries closures can support movement of wide-ranging species, supply of nutrients to areas of low productivity and sufficient recruitment to rebuild fish stocks. Predictive tools can support area-based management even in the case of incomplete knowledge as in the vast ABNJ. Understanding how biodiversity impacts Earth systems can help in ensuring sustainability of functions and services, and the key species that support them. Lastly, identifying vulnerability in deep-sea ecosystems and their ability to recover from perturbations can help prioritize which areas to protect against what activities.

Environmental Impact Assessments

The assessment of impacts of different activities on ecosystems cannot be done in the absence of basic science knowledge. Only by knowing who lives in a given environment can we know how species abundance, biomass, or composition can change. We can infer how different activities may disrupt the connections among habitats and ecosystems and reduce resilience. By understanding the roles these ecosystems play in the delivery of ecosystem functions and services, we can better evaluate their impact on Earth systems and develop effective strategies to sustain their integrity. Given the complexity of ecosystems and their functions, predictive tools can be used to develop indicators that provide simple metrics of ecological status, thus streamlining environmental assessments. Lastly, we can develop assessment tools

Fig 1 Snails and shrimp on a 30m high venting chimney in the Marianas. Photo courtesy of NOAA/SOI.

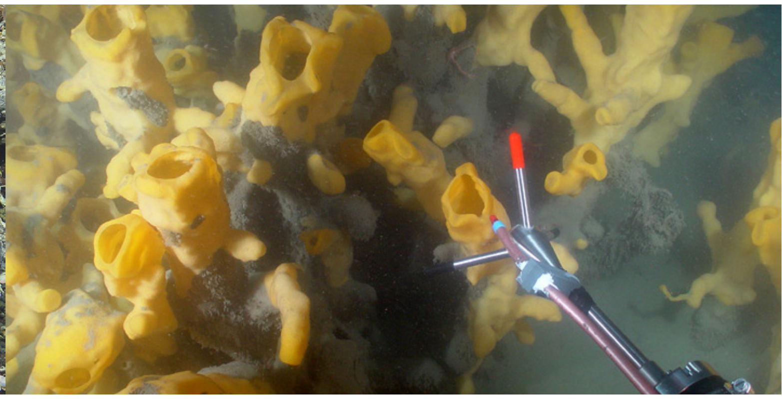


Fig 2 Measuring water and nutrient exchange around glass sponge reefs in British Columbia. Photo courtesy of VJT.

that are appropriate for known vulnerabilities of different ecosystems and species.

Can Science Answer These Questions?

The vast size and heterogeneity of the deep sea means that monitoring over time is a considerable and costly challenge. For the most part, deep-sea biodiversity assessments have largely depended on dedicated oceanographic cruises and traditional sampling methods such as nets, water samplers, and bottom grabs. However, a variety of remotely operated vehicles and towed camera systems have returned large amounts of image data in the past 30 years adding a new visual dimension to our exploration and analysis of these ecosystems. Acoustic tools are particularly useful for broad water column assays for mesopelagic organisms. With many countries now looking to ABNJ for research and exploration, our most successful tools include international collaboration on large projects and integration of datasets.

Rapidly Developing Tools

In recent decades, rapid development in sensor technology has improved our capacity for sustained monitoring of the geochemical environment in which organisms live. Sensors for measuring temperature, salinity, and ocean current matured decades ago but, more recently, stable and accurate sensors for nutrients, oxygen and carbon dioxide provide a far more comprehensive assessment of deep-sea environments. Autonomous underwater vehicles (AUVs) have reduced reliance on submersibles for in situ observation. Ocean gliders and passive floats such as ARGO can sample the ocean over distances of 1000s of km and time periods of many months, with increasing complex sensor suites and enhanced depth capacity. Parallel advances in genetic tools can distinguish similar species (genetic barcoding), provide information on linkages among populations of a given species (connectivity), and identify adaptations to specific environments. Environmental DNA (eDNA) shows promise in documenting the presence of a known species in a particular location. Although in situ applications of these approaches remain largely in development, they offer impressive potential for sustained monitoring. Cabled observatories provide power to sensors and communicate data continuously or near continuously in time, whereas non-cabled moorings can relay data collected at depth through satellite communication from surface buoys.

Digital imaging has advanced our assessment of biodiversity for some groups such as water column microbes, different groups of larger plankton, large fishes and invertebrates, as well as many types of organisms living on hard bottom or the sediment surface on the seafloor; organisms living in sediments remain a challenge. Major advances in computational capacity support far more sophisticated models and predictions than were possible even a decade ago, using a greater number and variety of variables and much larger data volumes. Many of these new technologies are expensive but as their use increases, more are produced thereby reducing the cost.

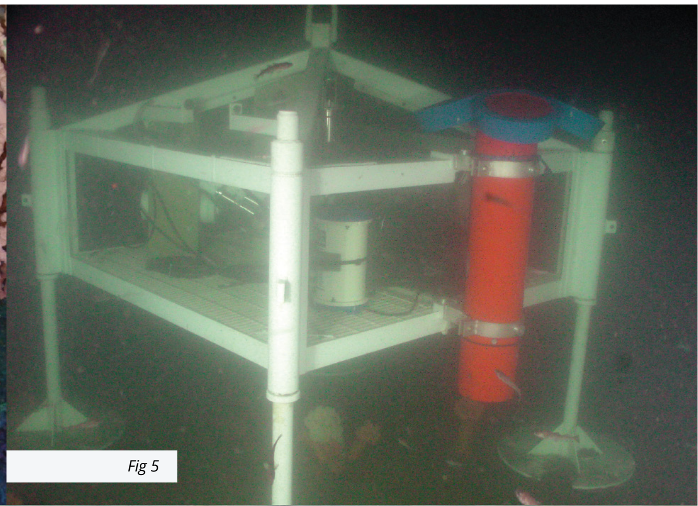
Major Challenges and Benefits

Sustaining biodiversity in ABNJ will require resolution of several key challenges. The high level of unknown biodiversity in many deep-sea environments will require baseline assessment in high priority areas. The large size and remoteness of ABNJ will require careful prioritization and cooperation to maximize return on effort. The high cost and technological challenge will help promote international cooperation and technology transfer in the form of training and enhanced access to novel tools. Data sharing can also enhance capacity development.

Fig 3 The Remotely Operate Vehicle for Ocean Sciences (ROPOS) is deployed from a surface ship on a fibre optic tether that allows scientists to watch real time video feed on board the ship and even from land via satellite relay. Manipulator arms are used to collect samples and facilitate measurements. Photo courtesy of PVRS.

The Payoff

Effective ocean policy that promotes sustainable ocean use will help support healthy oceans as well as healthy and fair economies. This holistic approach can help society take advantage of sustainable "blue economy" opportunities for ecosystem-based approaches in resource extraction, whether from living resources such as fisheries or marine genetic resources, or from non-living resources such as minerals.



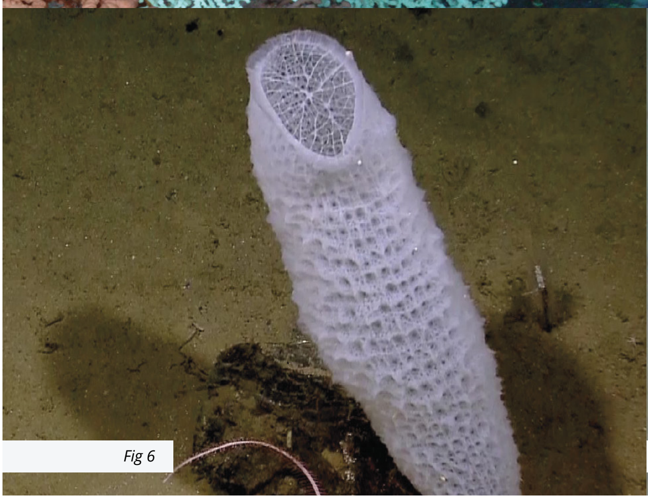


Fig 4 Deep-water bubble-gum coral can grow to > 3 m tall and can live for > 1000 years. They require strong currents to get enough food delivered to them. Photo courtesy of AM.

Fig 5 Long-term observatories such as VENUS provide evidence for natural and human-caused ocean change. Photo courtesy of Ocean Networks Canada.

Fig 6 The Venus flower basket sponge is a marvel of architecture to sieve bacteria from the water. Photo courtesy of NOAA

Fig 7 The muddy seafloor hosts some of the highest biodiversity on the planet. Currents are slow allowing the footprints of animals that live or move through here to persist. Photo courtesy of AM.

ABOUT DOSI

The Deep-Ocean Stewardship Initiative seeks to integrate science, technology, policy, law and economics to advise on ecosystem-based management of resource use in the deep ocean and strategies to maintain the integrity of deep-ocean ecosystems within and beyond national jurisdiction.

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