MBON

MARINE BIODIVERSITY OBSERVATION NETWORK

AN OBSERVING SYSTEM FOR LIFE IN THE SEA

By Francisco P. Chavez, Robert J. Miller, Frank E. Muller-Karger, Katrin Iken, Gabrielle Canonico, Katharine Egan, James Price, and Woody Turner

INTRODUCTION

Life in the sea provides immense benefits to humans, from the food we eat to the air we breathe to the climate we live in. And because of human activities, the once seemingly vast and inexhaustible seas are changing—increasingly threatened by global-scale impacts, such as warming and acidification, as well as those that are more localized, like overfishing and pollution. Meanwhile, many of the species that live in the sea remain unknown. Even for the known species, our understanding of their roles in the ecosystem is still limited. Now more than ever, increased observation of life in the sea is required to find and describe unknown species, observe shifts in species abundance and distribution, identify adaptability and resilience to climate change, and understand vital roles that species play in our marine systems. New and emerging technologies promise to enable observation over the required temporal and spatial scales. And emerging data systems will allow development of critical ecological understanding, while informing responsible use of marine natural resources. This will lead to continued, sustainable ecosystem services and the benefits we derive from them, benefits that are only possible through conserving biodiversity and managing human actions wisely.

In 2010, a group of scientists, managers, and agency representatives envisioned an operational Marine Biodiversity Observation Network (MBON) to catalyze increased and routine observations of life in the sea, to satisfy needs of society in a manner similar to what is done today for weather observations. Duffy et al. (2013) summarized recommendations for such a network. A year later, a series of MBON demonstration projects were funded and initiated across sites in the Florida Keys, Monterey Bay, Santa Barbara Channel, and the Arctic Chukchi Sea. These projects, designed to address key regional needs that could also contribute to national and international MBON endeavors, included state, local, and national governments as well as academic and private sector groups.

This special issue brings together some of the results of these demonstration projects. In this introductory paper, we provide perspectives from MBON sponsors, summarize the papers in the special issue, and provide thoughts about what future national and global observing systems for life in the sea might and should look like. It is as urgent as ever to implement this vision now.

THE ROLE OF GOVERNMENT AGENCIES AS SPONSORS AND PARTNERS

The MBON concept was born out of programs like the Census of Marine Life (2000–2010). The Census significantly increased the numbers of new species described and started projects like TOPP (Tagging of Pacific Predators) and OBIS (Ocean Biodiversity Information System). While investments have continued to develop a global ocean observing system focused on physics and biogeochemistry of the ocean, monitoring of biology remains localized and poorly organized. As a result, today there are no systematic and fully integrated US or global efforts to provide information about status, trends, and shifts in marine life over time. Importantly, we are not able to assess how humankind is impacting marine life and their habitats and, conversely, how these changes in biodiversity impact society. Current projections about impacts of global environmental change on living resources are based on physical and biogeochemical proxies developed from few direct biological observations. In short, there is no operational marine life observing system, even though human existence depends on having one.

In 2010, the National Oceanographic Partnership Program (NOPP), with support from seven US federal agency sponsors, engaged the science and management communities in a workshop titled "Attaining an Operational Marine Biodiversity Network." The workshop resulted in a solicitation and joint federal-industry investment to

From left to right. Giant kelp (*Macrocystis pyrifera*), Channel Islands National Marine Sanctuary (CINMS). *Photo credit: Claire Fackler, CINMS, NOAA.* A Christmas tree worm, *Spirobranchus giganteus*, on Elbow Reef, Florida Keys National Marine Sanctuary. *Photo credit: James Guttuso*. Orange stalked crinoid and octopus (*Graneledone boreopacifica*) at 1,973 m water depth, Davidson Seamount, Monterey Bay National Marine Sanctuary. *Photo credit: NOAA/Monterey Bay Aquarium Research Institute*. *Crossota* sp., a deep red medusa photographed in the deep waters of the Beaufort Sea, Alaska, north of Point Barrow. *Photo credit: Hidden Ocean 2005 Expedition, NOAA Office of Ocean Exploration*

initiate a US MBON. In 2014, three federal agencies, the National Aeronautics and Space administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), and the Bureau of Ocean Energy Management (BOEM), and Shell Oil partnered through NOPP to fund three comprehensive, five-year US MBON demonstration projects. The goal was to demonstrate that it is possible to have a single biodiversity observation system address the needs of multiple stakeholders, from local to national. The projects were challenged to work across sectors and disciplines; integrate new and existing biodiversity monitoring; address multiple temporal, spatial, and taxonomic scales; advance new approaches and technologies; and enable open access to data—all while addressing the needs of federal, state, local, private sector, and academic research partners for biodiversity information.

In 2016, MBON entered into a collaborative process and partnership with the Global Ocean Observing System (GOOS) and the Ocean Biodiversity Information System (OBIS), which are international networks sponsored by the Intergovernmental Oceanographic Commission. At the same time, the global Group on Earth Observations Biodiversity Observation Network (GEO BON), in support of its mandate to coordinate marine biodiversity observations around the world, incorporated MBON as a thematic node. Thus, MBON is the marine biodiversity program of the Group on Earth Observations. It contributes to GEO BON efforts to advance the development of Essential Biodiversity Variables. Similarly, US MBON contributes to the Intergovernmental Oceanographic Commission via GOOS (as part of the GOOS Biology and Ecosystem Panel), with OBIS, the Ocean Teacher Global Academy, and the Ocean Best Practices System, to advance standardized approaches and best practices for the collection of biology and ecosystem Essential Ocean Variables. Further, US MBON is a co-lead of the Marine Life 2030 Program of the UN Decade of Ocean Science for Sustainable Development and contributes significantly to other Ocean Decade programs, including the Ocean Biomolecular Observing Network, Ocean Practices for the Decade, Ocean Decade Research Programme on the Maritime Acoustic Environment (UN-MAE), and various GOOS initiatives.

In 2019, NOAA, NASA, BOEM, and the Office of Naval Research, again through NOPP, awarded six new three-year US MBON projects covering the Arctic; the northern, central, and southern California Current; the Pacific Northwest; the Gulf of Maine; and subtropical waters around South Florida. These projects are now addressing specific needs of their federal, state, philanthropic, and private sector partners. A third round of US MBON awards are anticipated to get underway in 2022 following another competitive selection process, evidence of the US commitment to maintain, and build on, MBON activities to date.

With federal agencies supporting US MBON, our confidence in its ability to succeed at the admittedly ambitious goal of characterizing ocean life and capturing changes through time arises from several concurrent factors.

First, we are now in a period of unprecedented development of observation tools and methods that will enable us—for the first time—to observe life across the entire globe at a wide range of spatial and temporal scales. New in situ observation techniques include environmental DNA (eDNA) and other molecular approaches, high-resolution imaging of megafauna to very small particles in the water column, rapidly improving acoustic sensors and telemetry devices, and active in-water sensing with sonar and lidar. Coupling these in situ techniques with a wide range of autonomous surface and underwater vehicles and other observing platforms increases our reach throughout the vast volume of the world ocean. Coordinating in-water observations with airborne instruments on drones, piloted aircraft, and satellite sensors in space allows scaling out from microscopic to local to regional to global scales. The next decade will witness a range of new satellite sensor technologies operating globally, including hyperspectral (full spectrum) imaging spectrometers for much-improved surface characterization and laser-emitting devices (lidars) for shallow benthic habitat discrimination and capturing small particles (including zooplankton) in the photic zone that work alongside new radars capturing surface physical features.

Second, these new observing systems will generate vast amounts of data. Fortunately, computational and data systems have kept pace with the observational approaches so can handle the volumes of information being produced. Enhanced processing capacity, and improvements in the ability to move and store petabytes of products, allows users to zoom from very fine-scale understanding to global knowledge.

A third factor is the improvement in ecological modeling with which we can (1) test our understanding of biological processes, (2) explore the processes driving the patterns seen in the observations, and (3) forecast changes in marine life and in ecosystem services. These models are vital tools in getting to the "whys" behind the status and trends detected in observations of marine ecosystems.

A fourth factor lies in the growth of international partnerships dedicated to supporting these advances at national and international levels. GEO BON and GOOS engagement in MBON, and vice versa, is indicative of the value of growing international collaboration to understand biodiversity and its changes over time.

The future of scientific collaboration looks even brighter as we embark on the UN Decade of Ocean Science for Sustainable Development. Marine Life 2030 is a very important part of this global endeavor and provides a launching pad for building on the factors above—as documented by the papers in this special issue—to learn what we need to know to ensure a healthy and thriving living ocean for generations to come. Marine Life 2030 represents a large global consortium across sectors and disciplines and is building strong partnerships with other components of the Ocean Decade, including the Deep Ocean Observing Strategy, the Ocean Biomolecular Observing Network, Ocean Decade Research Programme on the Maritime Acoustic Environment (UN-MAE), and a host of other programs and activities emphasizing marine life science and stakeholder needs.

ARTICLES IN THE SPECIAL ISSUE

The papers in this collection provide examples and stories that illustrate the uses and value of an operational MBON. The collection highlights the success of partnerships, of developing new methods, of documenting best practices, and of advancing data and knowledge systems that produce information for a wide variety of stakeholders. Each of the contributions emphasizes the need for continual monitoring of coastal and marine ecosystems.

The lead paper of the special issue by **Santora et al.** reviews and provides results from NOAA's iconic Rockfish Recruitment and Ecosystem Assessment Survey (RREAS) anchored in central California. They show how marine life changed dramatically with a major marine heatwave in 2014–2016. MBON support enhanced modeling and synthesis efforts as well as the integration of new remote sensing products (seascapes) and methods (eDNA). This information has been incorporated into the Integrated Ecosystem Assessment program resulting in the generation of new user products. The paper is followed by one from **Mueter et al.**, who compare two years, 2015 and 2017, of observations by the Arctic Marine Biodiversity Observing Network over the eastern Chukchi Sea shelf. The warmer, more saline Pacific waters in 2017 led to decreases in the diversity and abundance of benthic species and increases in zooplankton and demersal fish, representing signs of "borealization" of the Arctic region. **Medina et al.** synthesize observations from the Reef Visual Census and other habitat monitoring programs in the Florida Keys National Marine Sanctuary. They note significant effects of the influence of habitat (reef morphology) and level of protection (take or no take) on community structure (abundance, biomass, biodiversity), and tracked changes in biodiversity in these areas over time. **Rognstad et al.** synthesize data from and model kelp forest communities in the Santa Barbara Channel, using species archetype modeling to identify species groups and corresponding indicator species that respond similarly to ocean conditions. **Kavanaugh et al.** discuss the challenges and opportunities of using remote sensing for marine biodiversity studies. They highlight the use of remote-sensing case studies and demonstrate the practical application of ocean seascapes to estimate temporal and spatial patterns of preferred habitats for key species. They conclude with recommendations for the future of remote sensing applications.

Montes et al. present the results from a unique pole-to-pole coastal monitoring network along the Americas. Collaborative observations of rocky shore habitats for macroinvertebrates and algae extending from close to 60°N to 60°S latitudes illustrate latitudinal biodiversity patterns. They provide recommendations regarding the number of samples required for these types of operational intercomparison studies. The study outlines challenges and especially the opportunities presented by collaborating as a "network." **Chavez et al.** review the use of eDNA for marine life studies for science, conservation, and management. They demonstrate how eDNA can be applied to understanding two very different biomes (cool West Coast upwelling and warmer Florida Keys). They argue for the benefits of automated eDNA analyses, potentially through UN Ocean Decade for Sustainable Development programs like Marine Life 2030 and the Ocean Biomolecular Observation Network for globally scaled-up observations. These technologies make it possible to observe marine life the way that we now measure ocean physics and biogeochemistry. **Sayre et al.** present a new global coastlines product that integrates remote sensing and a variety of in situ data. This data layer provides Coastal and Marine Ecological Classification Standard labels for coastal segment units (CSU) globally at ~1 km resolution. The CSUs are a valuable tool for scientific, conservation, and management purposes across a wide range of coastal habitat types. **Benson et al.** delve into the difficult but absolutely essential problem of data management for MBON. To further the timely sharing of data, they provide a series of steps that can help improve the production and distribution of reliable biological data. **Ruhl et al.** describe the use of ecosystem data in support of US National Marine Sanctuaries and NOAA Integrated Ecosystem Assessments along the west coast of North America, as an MBON collaborative effort among numerous partners. The delivery of routine biodiversity information targeted to management requirements is emphasized, as is the iterative "co-development" environment where the user and data provider work closely together.

OPPORTUNITIES AND CHALLENGES MOVING FORWARD

There is growing recognition of the need to establish operational marine life observation systems to help maintain a healthy and sustainable ocean. New observation methods promise to greatly reduce the costs of observing systems and provide information required for management. Global communities are working in concert to establish best practices, standards, and information management systems required to turn observations rapidly into routine products for the user community. In this regard, the future is bright.

However, significant challenges remain. Present levels of funding are woefully inadequate and poorly coordinated. The scientific communities are presently mostly organized by measurement type (i.e., molecular, visual, acoustic, etc.) rather than integrated into a common observing system. Regionally, programs are organized by institution or project, each with specific goals and working independently rather than within a well-coordinated network where the end result is much more than just the sum of the parts. The programs tend to be localized geographically, and many are of limited duration due to the difficulties in securing long-term funding. The hindrances that these traditional approaches place on the development of an integrated biological observing system are well recognized. Overcoming them will take significant effort and time.

MBON was established to advance this "integration." The demonstration projects have made inroads and catalyzed plans to integrate disciplines and local-to-regional observing projects. Synthesis and modeling efforts with specific goals of determining optimal observation systems in terms of time, space, and key biological parameters should be encouraged and funded. A coordinated US effort will encourage other international efforts and global networking. Integration and coordination efforts, together with funding for national infrastructure and observations in every maritime nation, would enable the operational MBON required to address serious and pressing societal needs globally.

The technology and approaches needed have been outlined in the prototype MBON projects, and the space-based component has a solid foundation, with plans underway for new platforms and sensors. Significant investment in in situ, underwater observation on the same scale would catapult MBON into a future where humankind actually knows how Earth's vital marine ecosystems are faring and changing. The future of the ocean, and of humanity, depends on it.

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