U.S. Marine Biodiversity Observation Network
All-Hands Meeting

Friday, April 27, 2017, 8:30 a.m. - 4:30 p.m. ET
Hilton Embassy Suites, 900 10th St NW, Washington, DC 20001

I. Welcome and Introductions (Woody Turner and Gabrielle Canonico)

Gabrielle called the meeting to order at 8:30am. Introductions were made around the room.

II. Kickoff and Welcome (Derrick Snowden)

Over the past few years, the Marine Biodiversity Observation Network (MBON) has been a motivating source of change for the U.S. Integrated Ocean Observing System (IOOS) program. The IOOS Program Office realized the great work happening at MBON and came to understand the importance of biological observations. As a result, new staff members were introduced and changes were made to program organization, staff collaborations, and division structure.

IOOS is an interagency partnership that develops a community of practice by gathering similarly minded agencies to increase the efficiency of each agency's resources. Since its inception, IOOS has traditionally been rooted in the field of physical oceanography but has now broadened its focus to include biological observations. More specifically, IOOS aims to address interdisciplinary needs by joining physical and biological observations into a product, such as harmful algal bloom forecasting, that informs management – in this case razor clam fisheries.

As a program that has long supported physical observations, IOOS recognizes the steps MBON is taking to build an effective observing system. IOOS supported the working group on high frequency radar, which established standard practices and created the foundation for a global effort. Along with the U.S. Army Corps of Engineers, IOOS supported the wave coastal buoy system, which was a testing center for standard operations and became the basis for a global structure. IOOS, in partnership with the Interagency Ocean Observing Committee (IOOC), supports workshops to discuss community practices to outline standards for data exchanges, technology sharing, and overarching global practices surrounding the new system of gliders. These successes in creating global structures show that, while complex, a global marine biological observation system is attainable.

In support of creating standards for the biological observing community, IOOS is advancing data stewardship and management approaches consistent with the international biological observation governance structure being crafted by the Intergovernmental Oceanographic Commission (IOC), including the Ocean Biogeographic Information System (OBIS). IOOS is advocating alignment of biological data to the Darwin Core standard for data as well as appropriate metadata standards (Ecological Metadata Language, ISO) to ensure data can be shared more easily and support an effective global observing structure.

Future plans for IOOS include transitioning to cloud computing and rethinking coastal ocean modeling strategies. Specifically, they will focus on how models can be designed to be multi-disciplinary from the beginning. With the creation of common standards and platforms in the ocean observing world, MBON data can be used by IOOS in the future.

In addition, IOOS is embracing a shift away from a focus on basic science research to and increased focus on stakeholder engagement, which is also the theme of the next OceanObs conference.

III. MBON Status Updates

A. Sanctuaries MBON (Frank Muller-Karger)

Along with fourteen institutions including the Florida Keys and Monterey Bay National Marine Sanctuaries (NMS), and in partnership with U.S. IOOS and NASA, the Sanctuaries MBON project continues to work toward increasing our broader knowledge of biodiversity. Efforts to expand knowledge include integrating biological measurements with more traditional measurements of climate variables, and developing comparable observation standards to those used for climate variables in global ocean observations in order to create a biological community of practice. An ultimate goal is to use this knowledge to enable sustainable development and to conserve ocean resources.

To fulfill the project's goals, Sanctuaries MBON is using the NMS network as a pilot program to develop a successful biodiversity observing structure. This structure is being expanded to include other marine protected areas, both in NMS and worldwide. Efforts are being expanded through the X-MBON activity across the MBON projects to include the Channel Islands Sanctuary, Flower Garden Banks Sanctuary, Olympic Coast Sanctuary, and MarineGeo.

The activities of the Sanctuaries MBON team center around data collection and branding of a global MBON. Data collection activities include MBON team members collecting data in the field, as well as identifying and assembling data sets collected by other federal or state entities. Data is then transferred into the U.S. IOOS and transformed for input into OBIS in collaboration with USGS, which manages the OBIS USA node. Branding efforts for a global MBON include the creation of infographics from MBON data, and the integration of both derived products like Seascapes as well as NASA and NOAA satellite observations into an online application of global scope (the MBON Portal) that informs users including NMS, the Group on Earth Observations Biodiversity Observation Network (GEO BON), and the United Nations.

New data collection methods, specifically eDNA methods, are also being developed and refined by four groups within Sanctuaries MBON. After 42 cruises in Monterey Bay and 14 in the Florida Keys, eDNA methods have been found to detect more

species than traditional methods. A paper written by the Sanctuaries MBON team describing eDNA standard methods has been published.

Sanctuaries MBON continues to work with other sanctuaries to develop regional and global Seascapes based on satellite observations to address the needs of NMS. The Seascapes are being compared to ground observations of microbes, plankton, fish, and mammals to document their relevance and dynamics. Data from MODIS, VIIRS, and Landsat satellites are being gathered for integration into Seascapes. A new partnership has been created with NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) to operationalize Seascapes data. Work is also being done with the IOOS Program Office and Axiom Data Science to create tools and products to further integrate and visualize large amounts of data within the MBON Data Portal. Products that have been developed in collaboration with IOOS include the MBON Explorer and Infographics Tools. The Explorer is an open-source application prototyping platform intended to design, implement, and test applications before they are moved to the IOOS-hosted MBON Portal. The applications take variables, including satellite data and biodiversity queries from OBIS, and extract them for specific jurisdictions such as EEZs, allow visualizations on a map, and plot summary results for use by the scientific community and governments around the world. The Infographics convey a simple story to the public with picture representation of organisms or environmental variables.

On the international level, Sanctuaries MBON is collaborating with the UNEP Regional Seas Programme, the UNESCO IOC'S Ocean Best Practices group, and the IOC's IOCARIBE program. Work is being done to harmonize the Essential Ocean Variables created by the IOC Global Ocean Observing System (GOOS) partnership and the Essential Biodiversity Variables developed by the GEO BON partnership. The Sanctuaries MBON team has mapped linkages between complementary EBVs and EOVs and published this mapping in a peer-reviewed article, as part of a larger effort to the importance of these variables to the oceanographic community. The Sanctuaries MBON is working with the IOC's Best Practices group and the National Science Foundation's OceanObs Research Coordination Network to reach out to the community and ensure that best practices for ocean observing and resource management are documented and submitted to the IOC's Best Practices repository. The ultimate goal is to help standardize methods on an international scale. Additional work is being done with the Pole-to-Pole MBON of the Americas to introduce the MBON framework to other regions and to collect more data for use in OBIS.

The Sanctuaries MBON project continues to face several challenges. Specifically, Sanctuaries MBON is tackling how to operationalize the system developed by the demonstration project and keep the system sustainable after current grants have ended.

In the upcoming year, Sanctuaries MBON is planning to continue working on eDNA collection, interpreting previously collected data, and integrating all data into

the MBON Data Portal. Developing indicators for the U.N. Sustainable Development Goals (SDGs), specifically SDG 14, continue to be a priority. Sanctuaries MBON plans to move Seascapes into an operational system within NOAA NESDIS and package it for public consumption. Sanctuaries MBON will also continue to lead efforts to globalize MBON, under GEO BON auspices, and support the other MBON projects. There is also interest, with the help of the Animal Telemetry Network and the Nature Conservancy, in including animal movement and behavior data to construct biodiversity hotspots of migration and then integrating this data into the framework.

B. Santa Barbara Channel MBON (Bob Miller)

The Santa Barbara Channel MBON (SBC MBON) project is based at the University of California Santa Barbara, with support from NASA, BOEM, NSF, and NOAA, among others. Their goal as an MBON prototype is to provide data to inform managers and society about patterns of biodiversity across taxa, space, and time. This involves both integrating data from existing monitoring programs and developing new methods and products to fill in any data gaps. Another goal of the project is to build a replicable framework to allow the reproduction of MBON under diverse circumstances, both nationally and internationally.

A good deal of focus in this project has been given to data integration and delivery. So far, 13 data packages have been published that can be used to calculate indicators and fed into ecological forecasting models. The data from the project have also been utilized to create products targeted for specific users. BOEM has used SBC MBON data on fish biomass and abundance to inform spatial management plans for oil and gas development, especially for decommissioning offshore oil platforms. The Channel Islands NMS is using SBC MBON data to inform their condition reports, and is interested in the project's development of species archetype modeling. The data from the project is also helping to uncover the complex and multiscale drivers of kelp forest communities, which can be useful for planning monitoring efforts.

New products are being developed by the project for several specific applications. Deep learning is being used to accelerate species identification and substrate classification for images collected by autonomous underwater vehicles (AUVs) and diving missions. Acoustic products are being used by regional managers for marine mammal detection, as well as by BOEM and NOAA for a variety of purposes. Remote sensing products are being used to classify phytoplankton functional diversity from pigment communities, which then informs bio-optical models that can extend valuable time series. Remote sensing products are also being used to monitor kelp forest condition, age, and extent, and build demographic models to inform gaps in data. New genomics products are being used to study microbial diversity and community structure, with the ultimate goal of linking genomic data with the bio-optical data available at larger scales (e.g., from satellites).

The SBC MBON has also collaborated with the Monterey Bay NMS to analyze eDNA samples from the Santa Barbara Long-Term Ecological Research (LTER)

site, and compare the results to those obtained through visual SCUBA surveys. For the moment, eDNA seems to be most useful for targeted applications, such as invasive species monitoring. However, with more study and controlled experiments, it could prove to be a viable complement to traditional observations.

C. Arctic MBON (Katrin Iken)

The Arctic MBON (AMBON) project focused much of its efforts on field work and data collection over the last year. In 2017, an additional sampling line was added to the 2015 sampling schedule, allowing the first look at inter-annual variability conditions. Conditions found in 2017 differed from those found in 2015, and include a warmer and saltier ocean surface, an earlier blooming event, higher fish species richness, higher abundance of Arctic Cod, and fewer seabirds and copepods. Additional time-series are being incorporated to understand the variability of zooplankton and benthic macrofauna in the Chukchi Sea. This new zooplankton time-series will also be used in Maria Kavanaugh's recently-funded Seascapes project, which had its kickoff meeting in January 2018.

Great effort has been made to manage and utilize data collected by AMBON. In collaboration with Axiom Data Science, data has been published on the MBON Data Portal and all biological data is now in adherence to the Darwin Core standard. Data has also been linked to the National Centers for Environmental Information (NCEI). Principal investigators of AMBON have also contributed data to the Conservation of Arctic Flora and Fauna's 2017 State of the Arctic Marine Biodiversity Report. A paper written by the AMBON team titled, "Does One Size Fit All?" is currently in review and examines the idea of observational design and scale. Specifically, the paper compares fish and epifauna biodiversity and community structures between the Distributed Biological Observatory (DBO) three lines in the southern AMBON study area to the DBO four lines in the northern study area. Findings from this paper have opened discussion as to whether the DBO four lines are in the most advantageous area.

AMBON has continued to collaborate with other entities including the DBO, Chukchi Ecosystem Observatory (CEO), and Alaska Ocean Observing System (AOOS). Many of the needs, goals, personnel, measurements, and platforms overlap or are shared between these projects and discussions about how to keep each project informed on complementary activities are ongoing.

On the management side, AMBON participates in monthly meetings of the U.S. Interagency Arctic Research Policy Committee (IARPC), where federal agency managers meet to share information. IARPC has published the Arctic Research Plan FY2017-2021, which specifically calls out AMBON in performance element 4.1.2. and DBO in performance element 4.3., as tasks needed to satisfy larger research objectives. AMBON also works closely with BOEM and is in discussions to use AMBON as a template for observing oil and gas exploration in the Beaufort Sea. Finally, AMBON interacts with the local Arctic community through daily email

updates when at sea and presentations at the Alaska Eskimo Whaling Commission and Alaska Waterway Safety Committee.

Within the MBON projects, AMBON has assisted in eDNA analyzing efforts of the 16S, 18S, and eukaryotes IPS primer. More work is needed to expand the reference database used to identify species by primer regions and to understand which region of the primer is most reliable for positive species identification. AMBON is also a test case for transferring data sets into OBIS. The MBON Data Portal has now published data and metadata from AMBON, with six of the thirteen projects now able to be visualized on a customizable map.

Participants suggest possible further collaborations between AMBON and other groups. AMBON leaders agreed that more interaction could be pursued with Arctic BON within GEO BON and NOAA's Ocean Acidification Program (OAP). While ocean acidification was not a core goal when AMBON was originally crafted, links have been made to other groups who work on ocean acidification in the Arctic.

D. Smithsonian Institution/MarineGEO (Emmett Duffy)

The Smithsonian-led Marine Global Earth Observatory (MarineGEO) was started as an effort to better understand the functions of coastal ecosystems and how to sustain these functions. While the Smithsonian is the lead institution, the effort is truly a global partnership with extensive participation throughout academia and with other partners. The Smithsonian is uniquely positioned to lead this effort as it not only has extensive biodiversity expertise, but can also use its convening power to sponsor global collaborations. MarineGEO's niche within the larger community is building a biodiversity library, which is especially critical to emerging eDNA methods. The goal of this program is to connect environmental monitoring with biodiversity quantification and both to ecosystem processes.

To better understand ecosystem processes, MarineGEO enables coordinated experiments across networks that aim to identify the underlying mechanisms of ecosystem relationships. This experimentation is focused on the ways that predation and invasion interact across geographies. MarineGEO leaders are consciously simplifying field efforts to make them easily replicable without extensive training. They are currently looking for partners in the southern hemisphere and the Arctic to continue replicating these global experiments. There is interest within the program in developing remote sensing capabilities, including using drones for mapping efforts.

The primary users of MarineGEO are the public, resource managers at local, state, national, and international levels, as well as the MBON community. To serve these users, MarineGEO has sponsored two "bio-blitz" events, in which specialists, students, and technicians work on biodiversity inventory campaigns. A third event will be held soon in the Chesapeake Bay area.

MarineGEO is working towards an integrated data system by developing streamlined and standardized data management protocols, collating heterogeneous

data from the past, standardizing data entry templates to handle different observation methods, and making material as accessible as possible. There are plans to expand the MarineGEO online portal and increasing its interoperability with other systems, and its developers are actively seeking input about best practices.

MarineGEO is currently developing a partnership with the National Estuarine Research Reserve System (NERRS). The approach has been bottom-up so far, and has not yet reached a national scale. The partnership is beneficial because NERRS observation coverage of the abiotic environment is substantial, while MarineGEO can help inform experimental approaches and provide animal diversity data.

MarineGEO is eager to work with MBON because it has the potential to find the key players and mechanisms that explain the influence of biodiversity on ecosystem processes. However, doing so will be labor intensive, expensive, and requires a sustainable business model.

III. Animal Telemetry Network (Bill Woodward)

The Animal Telemetry Network (ATN) is a multi-agency program that is hosted within the IOOS Program Office and is funded by BOEM, NOAA, and ONR. The ATN vision is to create an alliance among federal and non-federal, state, regional, tribal, and academic partners to maximize collaborations and access to telemetry data, improve data standards and sharing capability, and bring permanence to a U.S. national baseline telemetry network. A central component of the ATN is its operational Data Assembly Center (DAC). Serving as a national aggregation point, the DAC receives satellite, acoustic and archival data from telemetry researchers, enables data access and sharing among regional and global partners, and creates and expands telemetry data products.

Guided by the Animal Telemetry Network Implementation Plan 2016-2021, the ATN began a phased approach to implementation in 2016. Phase I included stimulating animal telemetry coordination efforts, crafting a governance structure (the ATN Steering Group), operationalizing the DAC, and convening regional workshops to identify telemetry assets, effort, needs, gaps and priorities. The execution of Phase II began in mid-2017 and will continue through 2018 and 2019 with a major focus on defining and funding regional baseline observations and required telemetry assets and infrastructure.

At their April 2018 meeting, the ATN Steering Group identified several initial candidate topics on high-priority national ATN Program Assets and Infrastructure for Phase II ATN funding in FY18. Candidate topics for FY19 funding will be chosen through an open competition, with an initial call for topic ideas concerning baseline observations and infrastructure scheduled for late summer 2018.

The operational implementation of the ATN DAC within Axiom Data Science began in early 2018. The DAC is being transitioned into a customer service-based center that will, among other things, provide tools to manage, analyze, and share data, standardize data/meta data formats, integrate tag data with oceanographic data, generate data products, and provide permanent archiving at NCEI. Funds provided by the National

Marine Fisheries Service (NMFS) will support a DAC Data Wrangler position, who will serve as the interface between the telemetry community and the DAC.

Regional tagging community members and stakeholders have so far met at five workshops held in different IOOS regions – MARACOOS, SECOORA, AOOS, GCOOS, and PACIOOS. Reports from these workshops will be published in early fall. Three more workshops are currently scheduled, including a joint ATN/MBON/OTN meeting on November 7-9, 2018 in Santa Cruz, California. The workshop will identify the stakeholder needs and priorities for animal telemetry and marine biodiversity observations in all three IOOS regions on the West Coast – NANOOS, CeNCOOS, and SCCOOS.

In collaboration with MBON, ATN continues to identify stakeholders who will increase the number of users of current products and communicate additional needs that could be met jointly by MBON and ATN. Increasing the visibility and significance of ATN and MBON among stakeholders makes them more likely to be vocal advocates for defining and implementing a sustained biological observing component in IOOS. Discussions for sustaining these separate national efforts are crucial, and it is imperative to begin to visualize how each effort should be joined to create a larger IOOS sustained biological observation system.

IV. Data Management Progress and Solutions (Gabrielle Canonico, Jennifer Bosch, Brian Stone, Frank Muller-Karger, Maria Kavanaugh)

A. Ocean Biogeographic Information System

OBIS USA focuses on integrating different data sets into the Darwin Core body of standards. Looking across different data sets enables the calculation of essential ocean variables, ultimately allowing for the production of trends that can be used as indicators for policy development. Much of the data that is now coming into the OBIS system includes metadata and is more than simple species occurrences. There are several groups working on algorithms to effectively use the data towards developing essential ocean variables.

OBIS USA is also working to link previously unconnected information not originally part of its data sets, and using more comprehensive information to develop covariates for modeling purposes. When considering the data processing pipeline, some heterogeneity of data flowing into the international systems is permissible, as long as there are sufficient standards for interoperability. It is important to document and understand the protocols and methods being used at every step of the process.

OBIS USA is making an effort to develop and use technologies that are most accessible to the different groups inputting data into the system. They are using ERDDAP extensively, and are working with OBIS International to make ERDDAP a first-order provider. They will also be releasing software shortly to help convert data to the Network Common Data Form (NetCDF).

There are several international convergences between OBIS, the Global Biodiversity Information Facility (GBIF), Atlas of Living Australia (ALA), BIRDNET, and other groups working with Darwin Core. These groups are now considering the best way to create a shared global infrastructure of the same technologies to process various kinds of data into one overarching index.

OBIS is interested in fully incorporating all necessary aspects of animal tracking data, including both the derived and direct footprint of tracks through time. There are some difficulties, however, regarding the way data are grouped and the hierarchy of the structure. The newest version of OBIS currently in development will incorporate animal tracking data, and community input on necessary metrics would be helpful.

IOOS and OBIS recently hosted the first U.S. IOOS Biological Data Training Workshop on February 8-9, 2018 in Seattle, Washington. The biological data training workshop covered data standards and tools, web services for data access, and hands-on data exercises. Thirty people from regional IOOS associations, state and federal agencies, and the MBON community participated. There were several good outcomes from the workshop. The network of IOOS and OBIS collaborators was expanded, and there is now increased awareness of standards and best practices for handling marine biological data. Through the hands-on exercises, more marine biological data were published through IOOS and OBIS. These data now have increased availability to inform science, species conservation, and ecosystem-based management. For future reference, the collection of software and scripts from the workshop is available on GitHub, and the course materials are posted on OceanTeacher.

B. The MBON Data Portal

Development of the MBON Data Portal is a collaborative effort among the US MBON teams, the IOOS Program Office, Axiom Data Science, and core users and partners. The portal offers interactive visualizations and access to biological data, which are tailored to target different audiences. The infographics are geared toward the public, managers, and educators. The curated data views are targeted at advisory groups and researchers. The open data portal is intended to allow scientists and technical experts to create their own data views.

Jennifer Bosch and Brian Stone gave a demonstration of the MBON Data Portal. One participant suggested that it might be useful to offer a downloadable data template to help users create their own data sets. Participants also discussed the potential for the MBON portal to pull in data from outside sources, such as OBIS. Community-wide synthesis groups have been working on similar issues with data repositories in the past, and could provide valuable insight on the best way to move forward with that process. As more capabilities are added to the site, the navigation and interface might require more user skill, but shortcuts could be incorporated to ease use.

The MBON Explorer and Infographics tools were developed in cooperation with NMS, Integrated Ecosystem Assessment teams, state managers, and other partners to try to easily deliver information from local to global users. The Explorer tool creates plots in space and time, and is intended for scientists and managers. The Infographics tool chooses specific elements to plot, and is intended for the public. Both tools essentially allow the user to build their own story and share it easily. Some gaps in time and space still exist within OBIS and other data repositories, making the tools unable to measure change in real time. The early partnership with NMS in developing this tool may lead to a misconception that they were specifically designed only to inform sanctuaries condition reports. Moving forward, the developers are trying to better incorporate the needs of other users into the site.

C. Regional Seascapes

Seascapes are a remote sensing-based biogeographic framework within which observations can be embedded. Because ocean ecosystems move and are dynamic, the observation framework must also be dynamic. The development of seascapes enables rarefaction studies, ecosystem comparisons, and patch-scale studies. The framework can be used to conduct methodological comparisons for functional, taxonomic, and genetic diversity. Seascapes can also be used to develop ocean condition indicators to inform NMS condition reports. The methodology behind Seascapes involves a hierarchical, dynamic, relationship-preserving, probabilistic self-organizing map. This allows for the analysis of relationships that are non-linear and the tracking of water movements through space and time simultaneously.

Seascapes are being used by several MBON projects and other partners for diverse applications. In the Florida Keys NMS, Seascapes are being used to delineate plankton communities, comparing viral and phytoplankton community structures across different habitats. In the Gulf of Mexico, Seascapes are utilized to study larval habitat use within and across families. Developers of Seascapes are now building partnerships with The Nature Conservancy and ATN to inform migration and species distribution models. The analysis of Seascapes is being expanded to the Santa Barbara Channel, where it will allow for intra- and inter-management unit analyses of pelagic habitat representativeness and change. Seascapes analysis is also being expanded to the Arctic, where local and global input variables inform Seascape-species relationships and how they change in response to sea ice. Seascapes are also being operationalized for NOAA CoastWatch, which will use a classifier and near-real-time, high resolution input data to serve maps. Seascapes developers are collaborating with the NOAA Ocean Acidification Program to constrain parameterization of semi-analytical carbonate models.

V. Global Updates (Enrique Montes, Maria Kavanaugh, Laura Lorenzoni, Frank Muller-Karger, and Gabrielle Canonico)

A. Global Seascapes

Similar to the regional scale, global Seascapes dynamically classify multiple physical and biological assets in both space and time. Characterizing both regional and global

variability involves a strategic downscaling exercise, which is now underway. The classifier used in the system is hierarchical, so it does lend itself to the process of zooming down.

Part of developing global seascapes is comparing and calibrating them with Ecological Marine Units (EMUs), which are static 3D classifications of ocean volumes using physical and chemical data archived in the World Ocean Atlas (WOA). Inter-comparisons between Seascapes and EMUs will highlight variability at depth, which is not well-observed by satellites. This will then uncover changes in habitat quality and extent that weren't apparent before. As part of this calibration, more comprehensive data have been incorporated into global Seascapes, including sea surface temperature, sea ice, sea surface salinity, sea surface height, ocean color, and winds. It is important when comparing seascapes and EMUs to consider both the hierarchy and topology of the methods used.

The current Seascape system uses a dynamic range of the sea surface height field, which doesn't necessarily resolve mesoscale eddies. However, some of the classifications include both absolute dynamic height, which is indicative of geostrophic flow, and sea level anomalies. This has been very informative, as it's shown that water masses with different classifications are being affected differently by environmental forces.

While developers are trying to incorporate as much data as possible into these Seascapes, they must also consider the risk of collinearity. If too much data is added, a suite of variables could come to dominate the classification more than they should.

In regions like Florida and California that have *in situ* imaging spectrometer data, there has been some investigation into how spectroscopy might affect Seascapes. This could potentially prove useful for investigating phytoplankton functional types and the community structure aspect of biophysical response envelopes.

A new Arctic case study using Seascapes to look at habitat-species relationships was recently awarded in response to the NASA ROSES A.50 GEO Work Programme solicitation.

B. Pole-to-Pole MBON of the Americas

The Pole-to-Pole MBON of the Americas has the ultimate goal of creating a community of practice that helps countries develop sustainable and robust strategies for conserving marine resources, while also informing the larger scientific community and stakeholders from a local to international scale. The specific objectives of the project revolve around capacity building in the areas of field data collection, Darwin Core standards, access to OBIS, and use of dynamic Seascapes derived from satellite data. The idea for this multinational effort was born at a workshop in Mexico in 2016, and was recently funded through 2020 by a NASA ROSES grant.

The project has a very ambitious geographic scope, from the Arctic to Patagonia, and is involving PIs from countries all over the Americas. The group is leveraging existing monitoring infrastructure and resources from the South American Research Group on Coastal Ecosystem as a jumping off point. The group is also leveraging AmeriGEOSS resources to distribute satellite Seascape data to regions of interest for tracking changes in oceanographic conditions and the biogeography of the ocean. This is part of a larger effort to understand what Seascapes mean in terms of phytoplankton communities, and how lower trophic levels respond to large-scale forcing.

The team is organizing a workshop for the Pole-to-Pole MBON project to be held in August 2018 in Brazil, which will include both a field and lab component. Some of the participants coming to this workshop have experience gathering data for the Census of Marine Life, which has a history of capacity building in marine observations.

AtlantOS is a European group conducting monitoring in the eastern Atlantic. While there is some overlap between the objectives of AtlantOS and MBON, AtlantOS is scheduled to conclude in June 2019. There is interest among many European organizations in continuing coordinated marine biological observing efforts, but it is still unclear how these groups might best come together in moving forward.

C. G7 Future of Seas and Oceans Working Group

The G7 has been paying more attention to ocean issues since the 2015 Summit, when Germany raised the issue of plastics and marine debris. At the Japan Summit in 2016, five main action areas were identified to support the achievement of the UN Sustainable Development Goal 14. These action areas are: 1) supporting ocean observation that monitors climate change and biodiversity, 2) supporting ocean assessment to develop a consensus view of the state of the ocean, 3) promoting open science and data sharing, 4) strengthening collaboration in regional observing networks, especially in developing countries, and 5) promoting political cooperation by identifying actions needed to enhance observations. In addition to defining these action areas, G7 leaders formed the Future of the Seas and Oceans Working Group, and released the Tsukuba Communique, which highlights the need to better understand ocean issues and work collaboratively for healthy oceans.

A workshop for action area 4 (strengthening collaboration in regional observing networks) was held in May 2017 with the goal of designing a cost-effective, sustainable system for coastal ocean observing in developing countries. A workshop for action area 1 (supporting ocean observation that monitors climate change and biodiversity) was held in June 2017 to discuss using augmented observatories as sites for developing technology protocols. The implementation of these augmented observatories will follow the MBON model in using a common framework of methods and incorporating 'omics' data.

At the 2018 G7 Summit in Canada, there were three focus areas relating to oceans: coastal resilience, healthy oceans, and marine debris. The framework for action is to build stronger and more resilient coasts and communities through four priority areas.

Horizon 2020 is a large EU Research and Innovation program that is dispensing nearly $93 billion in research funding between 2014 and 2020. Although the program doesn't fund U.S. investigators directly, it can potentially fund infrastructure and services. There is also a potential for knowledge exchange, making it advantageous for U.S. researchers to explore the possibility of forming partnerships through the program.

D. Global Connections

On the international level, work is being done to link two frameworks of ocean variables; the Essential Biodiversity Variables (EBVs) and the Essential Ocean Variables (EOVs). During the OceanObs'09 conference, the EOVs were created by GOOS to guide the design of ocean observing variables and inform ocean observing. The EOV framework will be also be discussed during the OceanObs'19 conference. A paper was published in early 2018 that defined the EOVs through identifying variable stakeholders and collectors, outlining variable pressures and drivers, and determining what observing systems collect which variable. Work is now being done to link the EOVs to the separate but complementary EBVs created by GEO BON. A paper describing the connection between the EBVs and the EOVs has also been accepted for publication. In addition to the EOVs, GOOS is also looking for input on deep ocean essential variables for their deep ocean observing system.

Within GOOS, there is a proposal to add biological measurements to the GOOS community's separately operated ships, buoys, and drifters. MBON is coordinating this measurement effort and providing measurement standards. The data collected will then be placed into OBIS, to allow easy access to products.

There is an opportunity to connect a GEO portal to the MBON Data Portal. There will be a meeting in mid-2018 to discuss how to bring users to the GEO portal and how to incorporate data into the portal. Currently, the United States is not engaged in this effort. Connecting with the GEO BON portal is also a possibility, but resources are scarce and the current GEO BON portal only points to data.

'Omics' is beginning to receive greater attention from international entities. The G7 is supporting an 'omics observatory effort. GEO BON and GEO are interested in expanding their interests beyond biodiversity and organizing a larger health and 'omics' effort. They have also agreed to provide a home for the overall global 'omics' effort and GEO BON will have an 'omics' working group. The Belmont Forum, in collaboration with Future Earth, is currently scoping a call for proposals focused on Oceans, Climate, Environment, and Health. There is interest in the potential for ocean observations, including 'omics', to provide a predictive capability for certain aspects of human health.

MBON representatives will be attending several activities in 2018, including the Convention of Biological Diversity Subsidiary Body on Scientific, Technical, and Technological Advice, and the Pole-to-Pole Workshop. This will serve as an avenue to display MBON products on an international scale.

VI. Long-Term, Sustained Biological Observations (Group)

With the MBON demonstration projects entering their fifth and final year of funding, a discussion regarding ideas and strategies to sustain the MBON effort was had by the general group. Details of the discussion can be found below and are divided into six main topics areas.

A. Define Expectations

Participants stressed the importance of more clearly defining project expectations in any agency solicitations. From the beginning, expectations of using a common data protocol, with data being placed in an interoperable data system should also be clearly conveyed.

The concept of working within a network of other projects should be better communicated. This would allow for a more seamless partnership between projects from the start. The X-BON (cross-BON projects) concept was introduced at project kick-off and not as part of the funding announcement. Resources to support X-BON were not allocated in the beginning of the demonstration projects, and important projects including eDNA, Seascapes, and data management have struggled as a result. An operational framework and resources to facilitate communication and collaboration would be beneficial.

B. Identify and Connect with Stakeholders

Participants recommended a more focused approach to identifying and directly connecting to project stakeholders. Tailoring each project to the needs of stakeholders would increase project effectiveness and strengthen support for sustaining the effort.

There should also be an acknowledgement that each project will be supporting stakeholders specific to their region. Though commonalities will exist between all stakeholders, regional stakeholder differences should be recognized and a flexibility to support different needs should be encouraged. It is possible to support regional stakeholder needs while striving to join all stakeholders into a global network.

Resources should also be allocated to allow for a more robust stakeholder partnership with regional IOOS associations. It is a possibility that future solicitations could require a prospective project to collaborate with their local IOOS regional association.

Though the importance of clearly identifying stakeholders at the onset was discussed, one participant mentioned a possible complication in focusing too intensely on one stakeholder's need(s) as this could lead to a narrow focus and limit the widespread

application of a project's services or products. Balancing stakeholder needs with a broad-use view will be important.

In reference to connecting with stakeholders, a suggestion was made to modify the MBON structure from research-based to applied sciences- or collaborative sciences-based. Requiring proposers to submit their project jointly with their stakeholders or end users and requiring a structure for collaboration would generate a more deliberate proposal that would increase the likelihood of a strong, long-lasting partnership and project.

A program within the National Ocean Service (NOS) – the NERRS Science Collaborative – has been executing the concept of collaborative sciences for over ten years and a representative from NOS offered to supply resources to learn more about this structure.

C. Link MBON with Ecosystem-Based Management Activities

Participants highlighted the need to involve organizations that focus on ecosystem-based management. These organizations could use MBON data to inform and define strategies for conservation and ecosystem management services. Currently, models that evaluate ecosystem services and global coastal vulnerability are not utilizing the biological observation data gathered by MBON. Programs such as NOAA's Integrated Ecosystem Assessment and other international programs could serve as important stakeholders and sustaining force for MBON. It is important that MBON bridge the gap between those in the ecosystem services field and oceanographers.

D. Support the Spread of Global Biological Observations

Participants discussed the goal of having MBON lead the effort to integrate biology as part of observation systems globally. More discussion detailing how to implement an observational framework on an international basis with limited resources is necessary. An international framework has been created through GEO BON, but the framework is lacking important inputs from certain stakeholders.

Suggestions were made to replicate the successful ARGO model when trying to determine a global biological observation model. Centering observations on hardware, i.e., an autonomous float, allows large amounts of data to be collected and shared in a cost-effective manner. This would allow any country to join for a nominal cost.

Other suggestions to expand biological observations globally include supporting citizen science projects, i.e., Australia's Reef Check Survey, and involving the international Regional Fishery Management Organizations (RFMOs). RFMO connections have been made but there are issues with proprietary data that are currently being discussed.

E. Revisit Foundational Questions

One participant brought up the need to refocus on the foundation of MBON and ensure that certain questions regarding the mission, core objectives, and priorities of MBON have been answered. Defining these clearly and presenting them to stakeholders and the public may help with visibility and funding issues.

F. Highlight MBON Products

Participants suggested highlighting a key product of MBON to users: the ability to integrate user data sets with other data sets. "Spatializing" data sets using physical variables and remote sensing allows for a better understanding of data that has yet to be collected, and data that needs to be rescued. This will help to create a broad geographic baseline. Difficulties related to the lengthy processing time of combining data sets, persuading users that MBON will continue to exist, convincing users of the importance of investing the time and energy required to submit their data, and challenges of remote sensing at coastlines were mentioned.

VII. Final Thoughts (Woody Turner and Gabrielle Canonico)

Woody and Gabrielle thanked everyone in attendance for their participation and valuable suggestions. The meeting was adjourned at 4:30pm.

Meeting Participants:

Name	Institution
Jim Price *Co-Chair*	BOEM
Woody Turner *Co-Chair*	NASA Headquarters
Gabrielle Canonico *Co-Chair*	NOAA/US IOOS
Brian Stone	Axiom Data Science
Jorge Ramos	Conservation International
Gael Fourget	Massachusetts Institute of Technology
Monique Messier	Monterey Bay Aquarium Research Institute
Keith Gettes	NASA/American Association for the Advancement of Science
Jay Skiles	NASA Biodiversity and Ecological Forecasting
Laura Lorenzoni	NASA Headquarters
Gary Geller	NASA Jet Propulsion Laboratory/GEO BON
Camrin Braun	NASA/Woods Hole Oceanographic Institute
Bill Woodward	NOAA/Animal Telemetry Network
Heather Bowman	NOAA Deep Sea Coral Research and Technology Program
Tom Hourigan	NOAA Deep Sea Coral Research and Technology Program
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Jennifer Bosch	NOAA/US IOOS

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Lisa Clough	NSF
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Allison Fleming	Smithsonian Institute/Marine GEO
Clarissa Anderson	Southern California Coastal Ocean Observing System
Katie Shamberger	Texas A&M University
Katrin Iken	University of Alaska Fairbanks
Bob Miller	University of California Santa Barbara
Margaret O'Brien	University of California Santa Barbara
David Siegel	University of California Santa Barbara
Lee Cooper	University of Maryland
Jackie Grebmeier	University of Maryland
Enrique Montes	University of South Florida
Frank Muller-Karger	University of South Florida
Sky Bristol	USGS/Ocean Biogeographic Information System
Carolyn Groves	NOPP Office
Katherine McKee	NOPP Office