OceanObs'19 Conference: 16-21 September, 2019 (Honolulu, Hawaii)
http://www.oceanobs19.net/
Breakout Session: Ecosystem Health and Biodiversity
Tuesday September 17, 2-4 pm local
Breakout Session Leads: Maury Estes and Gabrielle Canonico

Subject: Recommendations to the OceanObs'19 (OO19) Conference to integrate biological observations into ocean observing systems as a high priority to measure changing ecosystem and human health. Please provide comments to ***biodiversity@nsstc.uah.edu*** by August 31, 2019.

Draft Recommendations and Proposed Outcomes for Community Feedback

Instructions for community reviewers - This pre-conference document is part of a grass-roots effort to ensure that biology, biodiversity and ecology are fully integrated into regional and global ocean observing efforts as a high priority over the next decade to measure changes to ecosystem and human health. The draft "high level" recommendations and outcomes for the OceanObs'19 Conference will be discussed and agreed upon during the OceanObs'19 Conference, at the *Ecosystem Health and Biodiversity* Breakout Session. These discussions are synergistic with other OceanObs'19 Breakout Sessions (http://www.oceanobs19.net/breakout-sessions/), and we encourage the community to actively participate in amplifying the recommendations at the Conference and in post-conference activities. Additional detail on types of observations, platforms, and spatial and temporal resolution has been assembled by the Breakout Session organizers. This will be used to develop a decadal implementation strategy in the months following OceanObs'19. We seek volunteers to help lead and contribute to write sections of an implementation plan, engage with other elements of the observing system, and pursue financial and operational support.

Breakout Session Goal and Structure - The purpose of the session is to coordinate a standardized system for measuring Essential Ocean Variables (EOVs) that quantify biology and ecosystem status and trends and advance ecological forecasting efforts. The goal is to develop and publish a 10-year plan for implementation that outlines requirements for multidisciplinary information that satisfies end user requirements, promotes the use of best practices, and unites the ocean observing community on this major challenge. The session seeks consensus on this key recommendation for the OceanObs'19 Conference.

Rationale - The characteristic biodiversity and phenology of communities of organisms in different habitats determines regional to global capacity for productivity and resilience. The benefits that are derived from biodiversity and ecosystem characteristics are changing as the ocean changes. Simple proxies of biodiversity and ecosystem status and trends based on physical or chemical ocean variables alone are not sufficient to quantify these changes in life in the sea, including the diversity, distribution, abundance, and productivity of organisms. They are especially inadequate to assess the status and trends of benefits associated with particular communities of organisms. Observations of marine life and biodiversity from the surface to the deep sea, from microbes to whales, are therefore critical to understand and to monitor coastal and ocean ecosystem health. A sustained, fit-for-purpose ocean observing system needs to integrate biological, physical and biogeochemical observations to support ecosystem-based assessments and sound management of human activities, to maximize societal benefits, including a robust blue economy, and conservation of marine resources.

Outcomes - Biological and biodiversity measurements enable the quantitative assessment of critical ecosystem elements and realize societal benefit and the conservation of wild spaces. Select biological EOVs can be integrated today into ocean observing systems to improve on our dependence on physical and chemical proxies to infer ecosystem change. OceanObs'19 participants from all disciplines recognize the opportunities to work together to integrate biology and biodiversity into existing ocean observing systems and platforms in the short-term. We, the members of the ocean observing community, will develop a decadal implementation plan for further cross-discipline collaboration and integration of multidisciplinary biology and ecosystem observations and capacity building on the collection, curation, and use of this information.

High Level Recommendation to the Conference - The ocean observing community must advance a sustained, fit-for-purpose global observing system that integrates biology and biodiversity with physical and biogeochemical ocean observations to maximize societal and ecosystem health benefits. The integrated observing system should maximize access to biological data and information products to quantify and explain biological and biodiversity changes as the basis for ecosystem-based assessment, sustainable development, conservation, and sound management of the use of marine resources.

The following is a draft list of suggestions for how this high level recommendation can be implemented; these will be discussed at OceanObs'19. Please provide comments as appropriate.

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Blue Economy and Ecosystem Services

Marine Biodiversity is a fundamental pillar of our ocean for delivering ecosystem services to society and thus for supporting blue economic growth. The observation of variables useful for indicators of the links between biodiversity, ecosystem health, and the provision of ecosystem services under a 'blue economy' needs to be strengthened.

1) Provide more opportunities for the scientific community and end users to work together to identify and converge on major challenges and objectives in important areas, e.g. public health, food security, clean drinking water, aquaculture, sustainable fishing, tourism and recreation (Anderson et al. 2019, Stauffer et al 2019).

2) Make sustainable development needs and ocean observing fitness a priority (Anderson et al. 2019), including better use and integration of marine species as ocean observers (Harcourt et al. 2019).

3) Advance and improve cost-effective and sustainable ecological forecast systems that address the requirements of key end-users at global and regional levels (Anderson et al. 2019, Le Traon et al., 2019, Stauffer et al 2019).

4) Fill the essential need for sustained, and preferably automated, near real-time information from nearshore and offshore sites situated in biological hot spots and regions under peculiar threat (Anderson et al. 2019, Stauffer et al 2019, Queiroz et al 2019).

5) Increase communication between regions and multiple stakeholders to enable knowledge and data-sharing regarding best practices (Anderson et al. 2019), and to allow integration of multiple perspectives in decision making and policy development (Hays et al. 2019).

6) Encourage a systems approach for sustained ocean observing including:

    - Incorporate Earth Observations into monitoring and predictive efforts, including blended model-satellite products and data-assimilative models (Anderson et al. 2019, LeTraon et al., 2019; Fennel et al., 2019), as well as oceanographic and biological data ensembles collected by marine species (Harcourt et al. 2019).

    - Merge ecological models with existing Earth System Modeling Frameworks to enhance capabilities in forecasting and scenario-building (Anderson et al. 2019, LeTraon et al., 2019; Fennel et al., 2019, Harcourt et al. 2019).

    - Work toward providing seasonal to decadal forecasts to allow governments to plan and adapt to a changing marine environment while ensuring coastal industries are supported and sustained with minimal global impacts on marine life (Anderson et al. 2019, LeTraon et al., 2019; Fennel et al., 2019).

7) Address stakeholder needs while striving to attain and sustain climate-quality data for increased scientific understanding of marine biology, including long-term trends in HABs (Anderson et al. 2019) and animal behavior (Harcourt et al. 2019).

8) Encourage future research to focus on better elucidating relationships between multiple biological components of the ecosystem, including HABs, multi-species interactions, species-habitat interactions, and impacts of anthropogenic developments on marine megafauna with keystone roles in ecosystems.

9) Encourage the development of innovative techniques that will promote blue growth supported by biodiversity.

Indicators of Ocean Health

Important indicators of ocean health fall in four broad categories: 1) physical/chemical indicators (temperature, pH, salinity, nutrients, pollutants, and oxygen), 2) biogeochemical indicators (dissolved inorganic and organic carbon and nutrients, biomass proxies - particulate organic carbon, chlorophyll-a, light absorption and backscattering, etc.), 3) distribution/abundance/biomass indicators of biological communities and habitats (i.e., kernel densities, areas of biological importance), and 4) biodiversity measurements (i.e., species richness, behavioral activity hotspots). Biodiversity data should be categorized across a range of operational taxonomic units and functional traits to improve evaluation of the changing health global oceans. Essential ocean variables (EOVs) and essential biodiversity variables (EBVs) intersect, and physical and chemical parameters can be gross indicators of change, but they don't provide the information on biodiversity required to monitor abrupt or long-term changes that affect ocean and human health (Miloslavich et al., 2018; Muller-Karger et al., 2018a).

The current state of routine information on marine biodiversity is fragmented and does not offer a coherent baseline. The advent of autonomous platforms such as animal telemetry (Harcourt et al. 2019), Argo floats (Roemmich et al. 2019, gliders (Testor et al 2019), animal telemetry and tracking (Harcourt et al. 2019, Hays et al. 2019), research vessels (Benway et al. 2019) and satellites (Muller-Karger et al., 2018b) augment the ability to observe, at (sub)mesoscales to global ocean scales, over hours to interannual time scales, from the coast to the deep sea and from the bottom of the ocean to the surface. Technology is available today to measure life in the sea through acoustics, tagging and tracking, imaging, bio-optics, omics, and more traditional methods. New platforms and sensors are required, and costs and maintenance have to be lower to enable widespread observations.

1) Determine through further research and evaluation the appropriate spatial and temporal scales for indicators to assess ocean health, which will help identify the gaps that new technology and sensors need to fill over the next decade.

2) Collect additional data on organismal distributions as well as observations on the physical environment eventually coincident with animal movements to evaluate health and usage of ecosystem habitats (Harcourt et al. 2019).

3) Target biological and biodiversity measurements in regions with limited historical data and valuable marine ecosystems that are suggested as priorities in the decadal strategy while continuing to collect time series of biodiversity observations in areas with historical data (Sequeira et al. 2018, Canonico et al. 2019).

4) Promote action towards the building of interoperable databases, essential data products, and data synthesis at the required resolution for ocean health assessment, model requirements, users' needs and management frameworks (Breitburg et al., 2018).

5) Support efforts towards the establishment of a truly integrated global-regional-coastal network for biogeochemical, biological, and biodiversity observations that are consistent, effective and efficiently aligned with the vision proposed by the GOOS framework (Johnson and Claustre, 2016, Miloslavich et al., 2018; Muller-Karger et al., 2018a; Roemmich et al. 2019; Anderson et al. 2019).

What to Measure

Multidisciplinary baseline information is needed on the status of current systems to deliver information for assessing biogeochemistry, biology, and biodiversity. Community consensus is needed on the best approaches to measure BioEco EOVs over the next decade and the types of data needed to implement such approaches (e.g. species, traits, genomics, etc.). Long term time-series of observations are required to separate the influence of natural patterns of large-scale climate variability (such as ENSO, PDO, NAO, etc.) from human-induced changes at short- and climate scales. Few observational and monitoring programs that track the chemical and/or biotic properties of marine (plankton) ecosystems have some continuity over several decades. Those that have been sustained into the present from the early to mid-1900s have proved invaluable to climate research (Lombard et al. 2019). The scarcity of combined *in-situ* biological, physical and biogeochemical measurements limits our data assimilation capabilities in ecological models, hinders improvements to model performance, and limits delivery of added-value services from ocean observations. This issue is even more critical in access to near real time information, which at the global level is currently limited to ocean surface chlorophyll data from satellite observations.

1) Generate novel data in a reasonable way, i.e., using common global standards for data generation, taxonomic identification, quantification of uncertainty, and comparison against standards (Lombard et al 2019, Harcourt et al. 2019, Sequeira et al. in rev, Bax et al 2019, Anderson et al. 2019).

2) Invest in efforts to harmonize BioEco Essential Ocean Variables (EOV) among national and international programs, and to inter-compare and inter-calibrate methods to ensure measurements can be integrated into a global observing system and modeling framework (Lombard et al. 2019). A series of important tools are available for the community to share ideas, methods, observations and strengthen their individual observing systems, including the Global Ocean Observing System (GOOS), which defines the EOVs and provides an operational link to established observing platforms; the Marine Biodiversity Observation Network (MBON), which serves as a networking entity and is engaged in the operational definition of Essential Biodiversity Variables (EBVs) as a complement to the EOVs; the Ocean Best Practices System; the Ocean Biogeographic Information System (OBIS) and the Darwin Core data schema; and partnering capacity building programs such as POGO and the Ocean Teacher Global Academy.

3) Encourage development of autonomous platforms to address observation, deficiencies by providing data that can be adequately assimilated in models in NRT and reanalysis mode (e.g. Fenne et al. 2019, Harcourt et al. 2019, Stauffer et al. 2019).

4) Encourage more coordinated Ocean Observing System Simulation Experiments (Ocean OSSEs) by designing new biogeochemical and biodiversity observing systems with maximal leveraging and impact to users (e.g. Le Traon et al. 2019)

5) Encourage a culture of data sharing and coordinated efforts to make the most of existing data at global and finer scales and highlight data gaps where sampling efforts should be a priority (Sequeira et al. 2018, Queiroz et al. 2019).

Stakeholder Requirements

Stakeholders and end users must be involved with the marine science and technology community in the early stages of new technologies to ensure that the data collected address societal needs (e.g., Hays et al. 2019). Methods for data access, formatting, and determining the types of data products needed are important topics that should be considered in consultation with end users. Biogeochemical and biodiversity variables are not used enough in the decision-making process (e.g. definition of marine protected areas, fisheries management) and actions are required to understand and change the process and to develop products and services fit-for purpose for a diverse community of users. Some regions (e.g. coastal, tropical, deep ocean) lack observations or have local observational systems that are disconnected from larger scale programs or have restricted data access.

1) Identify subsets of EOVs and data that can be shared with the purpose of facilitating local, national, and international assessments of local variations in resources in the context of regional change, without jeopardizing sovereignty or rights to publication and use of information.

2) Prioritize early involvement of stakeholders to facilitate contributions and influence data collection.

3) Encourage further development of The Marine Biodiversity Observation Network (MBON) as a network of observers, and the Ocean Biogeographic Information System (OBIS) as an interoperable user interface such that complementary biological and environmental datasets can be accessed by global user groups (Anderson et al. 2019, Benson et al. 2018, Martin Miguez et al. 2019).

4) Interact with modelers to derive and produce relevant outputs and indices, identify their needs (e.g., to ensure measurements target what models are sensitive to), and describe observation efforts (Lombard et al. 2019), including added value of the new measurements.

5) Organize summer schools and workshops, dedicated to students, early career and senior scientists, stakeholders and policy makers. Capacity building should transfer theoretical (e.g., ecology, diversity and taxonomy) and technical knowledge. It should enable consistency in data handling and processing (e.g., based on standardized formats and approaches), dissemination, and increased use of data collected. More outreach to developing nations is needed. Where appropriate, build on the existing MBON Pole to Pole, OBIS, and Ocean Teacher Global Academy approach for training ‘from field data collection to the cloud’ (Canonico et al. 2019). Document the material provided through the summer schools and workshops in a repository (e.g., videos of classes, PDFs of materials, etc.) to support long-term opportunities for training (Lombard et al. 2019).

6) Promote the exchange of expertise between countries through capacity building activities and direct engagement and technology sharing with scientists and students from developing countries, where the largest gaps in our knowledge persist, but where taxonomic expertise is still strong (Lombard et al. 2019).

7) Encourage opportunities to enhance use of ocean biodiversity and biogeochemical observations in management decisions; including data/products with uncertainty assessment and adequate resolution to meet space and time requirements.

8) Organize an international workshop to link ocean biology and biodiversity, and physics biogeochemistry with ocean health, fisheries and otyher social and economic needs.

9) Develop a roadmap for an international coordinated and sustainable observing system for high-quality biodiversity, biogeochemical and physical variables in support to management decision, societal needs, the implementation of the UN Sustainable Development Goals, the forecasting of the ocean, and the development of added-value products.

Observations and Deployment Technologies

The advent of hyperspectral satellites and active sensors (e.g., lidars) (Jamet et al. 2019) is promising delivery of synoptic-scale information on ocean surface Plankton Functional Types, detection of Harmful Algal Blooms, and benthic habitat mapping including for coral reefs. Robotic platforms will offer opportunities to map the deep seafloor (Boss et al. 2019, Anderson et al 2019). Many technological developments are expected to lead to new generations of tags for tracking animals and recording environmental and physiological measurements for many marine species (Sequeira et al. in rev) at several life stages. Omics approaches have been transferred from research to operational use for ocean observing. These technologies will measure activities such as illegal fishing and pollution, and their impacts. The combination of omics, marine robotics, image analysis, machine learning, new sensor development and the coordination of robotic platforms and satellite sensors constitutes a significant breakthrough in our knowledge of marine biodiversity that we are hardly realizing. Linked through MBON groups of observers will be able to compare methods and data on microbial, invertebrate, and vertebrate species and populations (Canonico et al. 2019). This integrated information is required to quantify ecosystem and human health and their dependence on primary productivity, energy transfer, and food web interactions.

1) Keep innovating and investing in the development of new sensors/ analytic tools and pipelines for the use of automated optical/imaging techniques for building new biodiversity indicators.

2) Take advantage of developments from other fields (e.g., computer science, optical and acoustical engineering, etc.) to improve our current sensing systems. Look for opportunities to reduce the costs of measurements without decreasing their quality (e.g., Wang et al., 2019), in such a way that future equipment could become standard tools on cruises and/or autonomous platforms (floats, gliders) (Lombard et al. 2019).

3) Promote a sustained, fit-for-purpose biological component of GOOS that leverages existing multi-disciplinary and multisectoral partnerships; integrates biology with physical and biogeochemical ocean observations; maximizes access to data and information products; and supports real-time needs for ecosystem-based assessment and management of marine fisheries, protected species, and special places. Link ocean observing in the context of GOOS and MBON, fisheries observations, and capacity development in a comprehensive ocean observing framework that allows all monitoring actors to work together, maximizing benefits of efforts (Schmidt et al. 2019, Harcourt et al. 2019).

4) Coordinate the collection of multidisciplinary biological and environmental information from all sources and the formation of EOVs and EBVs by linking all relevant organizations and stakeholders, including industry and communities, and better integration between researchers and their existing datasets (Martin Miguez et al. 2019).

5) Facilitate dialogue between data producers, data users, producers of intermediate products and end-users to continually assess monitoring objectives in light of policy and user needs.

6) Adopt a comprehensive data management framework (e.g. MBON, OBIS, EMODnet), including the consistent and sustained use of specific data repositories for specific types of information, implementing linkages of records between these repositories, promoting the use of common data and data exchange formats for interoperability, easy-machine-to-machine exchange, and use of open source tools.

7) Implement systematic data quality assurance and quality control processes for EOVs that will facilitate usage with EBVs.

8) Improve and facilitate access of data and metadata for science and products for the public, industry, resource managers, and policy and decision makers.

9) Improve modelling efforts for dynamical forecasting, including species distributions and abundance data, through ecosystem models to support management of human activities and conservation efforts.

10) Develop and implement coherent capacity development and training programmes, including analysis and visualization for users of varying levels of expertise through a joint ocean observing system governance framework.

Alphabetical List of Contributors

Clarissa Anderson/Scripps Institution of Oceanography
Emmanuel Boss/University of Maine
Gabrielle Canonico/NOAA/US IOOS/US MBON
Maury Estes/University of Alabama in Huntsville/NASA
Gary Geller/NASA Jet Propulsion Laboratory
Marilaure Grégoire/University of Liège Belgium
Frank Muller-Karger/University of South Florida
Margaret Leinen/Partnership for Observation of the Global Ocean
Frank Lejzerowicz/University of California, San Diego
Fabien Lombard/Sorbonne University
Mitchell Roffer/University of Miami
Jörn Schmidt/Kiel University
Ana Martins Sequeira/University of Western Australia
Brendal Townsend/Ocean Tracking Network Dalhousie University
Woody Turner/NASA

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