Coordinating the Implementation of Mangrove and Seagrass Essential Observations – A joint GOOS/MBON community outreach workshop to implement EOV/EBVs

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WORKSHOP REPORT

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I. SUMMARY

In many nearshore waters around the world, the dominant primary producers and foundation species are seagrasses and mangroves, which provide habitat and food for diverse organisms and valuable ecosystem services to people. These habitats are threatened by multifarious human pressures, yet assessing their status and trends is challenged by lack of coordination and standardization. To advance coordinated international observations of seagrass and mangrove systems, a multidisciplinary community of scientists and stakeholders recently convened to focus on (1) observing capabilities, (2) technology and innovation, (3) coordination and data management, and (4) products and deliverables.

Current seagrass monitoring networks (e.g. SeagrassNet, SeagrassWatch) use similar low-cost in situ protocols, offering promise for standardizing best practices. A central challenge is that most data are not open nor accessible. Recommendations for seagrass observing include leveraging and linking existing capacity; simple protocols to support broad use and interoperability; maintaining relevance to stakeholder and societal needs; ensuring continuity through training and succession; promoting rigorous taxonomy; and adopting an ecosystem approach. Promising technologies include artificial intelligence for image processing; integration of remote sensing with in-situ data; deployments of AUVs and hydro-acoustic sampling in inaccessible areas; and genomic and eDNA applications.

Mangrove monitoring involves both in-situ sampling and remote sensing. The Global Mangrove Watch (GMW) is an international collaborative project mapping mangrove extent and change over time using satellite data. GMW has assessed over 53,000 sites/pixels in 20 regions, documenting a 5.8% decline in global mangrove extent since 1996. In-situ sampling efforts are essential for validating satellite models and assessing species composition, yet in-situ mangrove sampling is not coordinated.
Recommendations to improve mangrove observations include developing best practices for linking in-situ data, including species composition, to satellite data to validate maps; and identifying existing in-situ and drone sampling capacities and gaps. In-situ sampling is resource-intensive and requires capacity development. A key goal is to link national data and in-situ observations toward an integrated picture of global mangrove change through time.

For both ecosystems, coordinated observations will benefit from standardizing the plant parameters measured as indicators of ecosystem health and condition; adopting good data management practices based on FAIR principles, organizing disparate data, and linking data systems to the Ocean Biogeographic Information System (OBIS) and World Conservation Monitoring Centre (WCMC). Standard Operating Procedures for Ocean Best Practices could be developed from the Blue Carbon Manual (mangroves) and protocols of SeagrassNet and Seagrass-Watch.

Overall, success of coordinated global seagrass and mangrove observations will require strengthening engagement between the observing community, workers in the field, and remote sensing, and nurturing diverse partnerships including with developing countries. Coordination and governance can be facilitated by system-specific groups such as the International Seagrass Experts Network and GMW, and by the Global Ocean Observing System and Marine Biodiversity Observation Network, which are working to define Essential Ocean Variables, including seagrass and mangrove cover, to strengthen global observing, conservation, and sustainable development.

More information and the presentations can be found at the Global Ocean Observing System workshop’s website: http://www.goosocean.org/index.php?option=com_oe&task=viewEventRecord&eventID=2491

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II. WORKSHOP BACKGROUND: rationale, goals, expected products and relevance to NASA

Background. Coordinated international monitoring of marine biodiversity and ecosystem processes is critical to document trends in the world ocean’s living resources, identify ecological thresholds and to support management that builds resilience, promotes recovery, and manages for sustainable development [1].

Seagrasses and mangroves are foundational species of shallow coastal ecosystems around the world. These habitats are amongst the most productive natural habitats in the world. They store substantial quantities of carbon, and provide critical fish habitat, support important biodiversity, coastal protection, erosion control, and a range of other ecosystem services that provide economic value and support livelihoods, particularly in the developing world including SIDS. Despite growing appreciation for the economic value of these habitats, both are severely threatened by human activities. Mangrove areas are being destroyed at a rate of about 1% each year [2,3]. Some estimates suggest that about 30% of seagrass global cover has been lost since the late 19th century, which is a serious crisis of global proportions [4].

Recognizing their importance, the Global Ocean Observing System (GOOS) proposed seagrass cover and composition and mangrove cover and composition as two of eight biological Essential Ocean Variables (EOVs). The EOVs were defined on the basis of societal importance as reflected in
reporting requirements for international conventions and agreements [1]. These include the Ramsar Convention on Wetlands, the Convention on Biological Diversity, and the UN Sustainable Development Goals (particularly SDG 14, Conservation and sustainable use of the oceans and marine resources and SDG 6.6 on water related ecosystems). These EOVs are linked with the Essential Biodiversity Variables (EBVs) of the Group on Earth Observations - Biodiversity Observation Network (GEO BON), particularly those related to primary productivity, species distribution, population abundance and ecosystem extent and composition [5].

Despite the importance of seagrasses and mangroves to humanity and to coastal ecosystems, developing coordinated systems for observing their status and trends has been challenging. Historically, available in situ data are few and fragmented internationally. Numerous local and regional monitoring programs collect data on mangrove and seagrass cover and some ecosystem characteristics. The Global Mangrove Watch formulated by the Kyoto and Carbon Science Team supported by the Japan Aerospace Exploration Agency (JAXA), and the GEO-Wetlands work programme of the Group on Earth Observations have assembled some global datasets. For seagrasses, Seagrass-Watch [6] and SeagrassNet [7] have develop regional to global observing networks and assembled datasets, with the Smithsonian-led MarineGEO program joining this effort in the last few years. Together, these programs have engaged hundreds of scientists and thousands of citizens in collecting data relevant to assessing mangrove and seagrass occurrence and composition. But such programs often have different objectives, employ a range of different methods, and measure different variables. This makes inter-comparisons between groups and regions, and any scientific analysis, challenging.

For mangroves, the first study applying a globally consistent and automated method for mapping mangroves was primarily based on the classification of ALOS PALSAR and Landsat sensor data, with annual maps of mangrove extent made publicly available [8]. While these maps provide ground validated information on mangrove cover/extent at the regional to global scale, they do not provide details related to mangrove composition, which requires more detailed local information. A national mangrove monitoring system based on the collection and interpretation of data by a team of local experts, is necessary but often constrained by financial and staff resources, and only a limited number of such systems exist nationally around the world (e.g. in Mexico and Australia). For seagrasses, the principal challenges are that remote sensing generally cannot detect seagrasses deeper than a few meters and that field sampling has been biased geographically, concentrated in North America and western Europe. As a result, existing syntheses of seagrass occurrence rely heavily on low-resolution point-based sampling. Seagrass extent is thus difficult to quantify, and resolution is especially low in the regions where seagrasses are diverse, such as in the western Pacific. Seagrass mapping using remote sensing is possible but quite complex, and currently, on-ground verification is still required [9,10]. Finally, as is true of most biodiversity observing, the lack of standardized vocabularies and metadata standards for the description of the sampling methods, instruments and units makes comparisons of existing data difficult, even if stored in global repositories like OBIS.

**Goals of the workshop.** The goal of the workshop is to draft the implementation plans for a coordinated observing system of EOVs and EBVs associated to Seagrass and Mangrove ecosystems to support biodiversity and health status assessments of these fundamental coastal habitats. The workshop will bring together a multidisciplinary community of scientists and stakeholders including from the above-mentioned monitoring programs to identify requirements for a multi-year implementation of an observing and analysis system for this EOV/EBV alignment. The group will identify level of maturity of measurements in terms of requirements, coordination of observations,
address gaps in observation and user needs, and advance principles and design of data management and information products. These will build on the assessments done by the GOOS BioEco Panel [1], the Biological Integration and Observation Task Team (BIO-TT) [11], and the Marine Biodiversity Observation Network (MBON) [5].

**Expected outcomes of the workshop.** The major outcome of the workshop will be the collective drafting of implementation plans for a global system of seagrass and mangrove observing. The system is intended to represent a consensus of GOOS, GEO BON, MBON and the observing community, and will aim to begin operationalizing global coordination of seagrass and mangrove monitoring and data integration that reflects their status as combined EOV/EBVs.

The plan will include the following aspects:

1. The mission, and short and long-term decadal vision, for implementation, including a timetable
2. The scientific and societal requirements to support the UN Decade of Ocean Science for Sustainability’s goal of providing the science to help achieve Agenda 2030, as well as other critical international agreements and platforms that are related to climate change, biodiversity, and ecosystem services
3. Anticipated societal and scientific impacts of delivering this system, including stakeholder engagement, informing global assessments, plans to engage developing countries and developing capacity, transferring technology and managing and delivering data
4. Recommendations on actions for geographic expansion, technology development, global coordination, and integration across disciplines, networks and programs
5. Recommendations for a funding strategy for a full 10-year (2020-2030) period aligned with the UN Decade of Ocean Science for Sustainability

These implementation plans will benefit from the community white papers presented at OceanObs19, especially from the topics developed by Community White Paper #67 on Observational Needs: Macrophytes which touches on seagrasses. There are currently no community white papers focused on mangrove ecosystems, which emphasizes the urgent need for improved coordination and collaboration in this area.

**Relevance to NASA.** Remote sensing is a means to establish baselines and to monitor changes in spatial extent of nearshore habitats, potentially including seagrass and mangrove cover globally, over different time scales. Such information, derived from remote sensing can provide valuable information for policy makers and environmental managers, in particular where there is an absence of local information [8,9]. There are still many challenges to attain a global and coordinated observing system that generates useful and timely data around the EOV/EBVs of these two ecosystems. Some of these challenges are the lack of standardization of both remote and in-situ observing methods, making inter-comparability difficult, variability in data accuracy and resolution, and limited capability for large-scale in-situ measurements and verification, which are critical especially for seagrasses.

As the ocean observing community develops implementation plans for the EOV/EBVs of these ecosystems within the global observing system, satellite and remote sensing tools will become increasingly important. This implementation will require strengthening the engagement between
the scientific observing community, which for seagrasses involves in situ sampling almost exclusively, and the remote sensing platforms. These technologies and applications also need to be made accessible and usable for developing countries, which often requires significant capacity development [12].

The outcomes of this workshop will advance NASA’s mission of detecting and predicting changes in Earth’s ecosystems. The workshop will also support integration of remote sensing and international field studies and collaboration across science, engineering and technology for an improved and more comprehensive understanding of these valuable ecosystems.

III. WORKSHOP REPORT

1. Introduction and Welcome

Project chairs, Patricia Miloslavich, Emmett Duffy, and Nic Bax, welcomed all participants and introduced the main goals of the project (as mentioned in the Workshop Background). This brief introduction was followed by an “around the room” introduction of all participants who represented a diverse array of disciplines and sectors (science, policy, management) focused on global seagrass and mangrove initiatives.

2. Introduction to Working Group Structure

Following introductions, Emmett Duffy explained the structure of the working group which consisted of four (4) breakout groups centered around the topics of: observing capabilities, technological requirements and innovations, data management, and the products and deliverables associated with seagrass and mangrove global observing networks. In addition, all of the breakout groups addressed actions to address the cross-cutting issues of (1) priority needs/requirements, (2) technical and human capacity development needed and (3) strategy to secure funding for implementation. The overarching goal of the workshop was to move towards developing the implementation plans for global seagrass and mangrove observing networks. As such, a few suggestions were put forth to progress toward the development of these implementation plans: exploit existing models that work (such as GCRMN), focus on essential variables and data quality, not method details, adopt a nested/tiered structure, explicitly address incentives for data providers, start development with metadata and then incorporate raw data, build a community of practitioners and identify the incentives, identify ways to support people working together, and engage the public in the collection of data (i.e. through citizen science and local ecological knowledge).

3. Background on previous GOOS BioEco EOV Implementation

Patricia Miloslavich provided an introduction to the existing GOOS BioEco EOV implementation plans and how the existing frameworks support the implementation of the seagrass and mangrove cover and composition as GOOS EOVs and explained the EOVs connection to the Essential Biodiversity Variables (EBVs). The GOOS BioEco panel, under IOC, has been working for the past four years to implement the global ocean observing system. The goal of this global ocean observing system is to have a permanent global system for observations and modelling and analysis of marine and ocean variables which support real-time services in relation to information on worldwide marine
ecosystems health and climate. This consists of three parts: scientific oversight, observation coordination, and project development. The three focal areas are: climate, ocean health, and operational services. In order to achieve a global ocean observing system for biological variables we must identify the requirements for the EOVs, develop EOV implementation strategies and coordination of observations, and promote standards and interoperability of data and information products. Three years ago, the BioEco panel developed the process: EOVs should be variables that are the most feasible to measure and have societal relevance. The first step of this process was to host workshops on hard coral, phytoplankton and zooplankton, macroalgae, along with seagrass and mangrove. The workshops addressed the vision and mission, needs and requirements, capabilities, impact, funding, and governance of these observing networks. All of this fits into the GOOS 2030 Strategy which consists of eleven (11) goals within three focal areas: deepening engagement and impact, system integration and delivery, and building for the future (Figure 1). The most recent workshop focused on the scoping of all the biological EOVs to identify commonalities between the different EOVs and develop a common timeline for the various EOVs. A Q & A along with a discussion regarding the merging of data systems followed this presentation. A general conclusion that emerged from this discussion was that core data sets need consistent methods, sharing of data is a key factor, and that we must bring together people with technical experience in data architecture to support the integration of disparate data systems.

Figure 1. Strategic objectives of the Global Ocean Observing System 2030 strategy. Objectives marked with a green star were considered as priority through a consultation process.
4. Introduction to Working Group Dynamics
Patricia Miloslavich explained that the workshop dynamics would follow discussion more than a presentation format. Workshop participants split into two groups depending on their expertise, mangrove or seagrasses and discussed the same issues. They reported to the plenary where cross-cutting issues were discussed. The goals the workshop and end of the workshop were focused on process as well as the product, to build community, and to discuss ways to facilitate and further develop the observing communities to find ways to get people to work together to collect data that is interoperable.

5. Current Status of Monitoring Efforts and Trends
5.1 Overview
Emmett Duffy provided an update and recommendations from the recent paper entitled, “Toward a coordinated global observing system for marine macrophytes” as a framework for thinking about the coordination of the implementation of mangrove and seagrass essential observations. The EOVs consist of the EOV, sub-variables, derived products, and complementary variables. For example, for the seagrass EOV the EOV description consists of seagrass cover and composition. Simply knowing the cover of seagrasses or mangroves is not enough to know the health of the ecosystem, thus the sub-variables provide insight into the ecosystem health. In addition, derived products consist of services that the EOV provides that may be derived from measuring the sub-variables. The complementary variables consist of variables that are important to measure as context or support for the sub-variables.

There are two global seagrass networks, SeagrassWatch and SeagrassNet, which collect data from sites around the globe. In addition, the Smithsonian MarineGeo program has 12 core sites around the world which uses synoptic seagrass survey protocols similar to SeagrassWatch and SeagrassNet. In addition, the MarineGeo program is collecting sediment to get estimates of Blue Carbon storage in seagrass ecosystems.

In regards to the data collection of the seagrass EOV, there is a Proposed Data Quality model that prioritizes the variables of data collected into various levels depending on the resolution and detail of those variables, thus variable collection is optimized so data collection can be tailored to programs of varying capacity.

The data management workflow consists of data quality control, data standards, and data sharing. Data quality control includes standards for metadata, methods, and meta-database. Data standards includes taxonomic authority such as WoRMS (which is used by OBIS). Data sharing includes permanent repositories that are regional or thematic (e.g. OBIS), formalized formats (data as .csv and metadata as .eml), analysis and QAQC scripts to automate checks for all metadata, along with formalized data sharing and use agreements. DOIs can support the provenance of data.

The implementation of the seagrass EOV is at a relatively advanced stage: the EOV spec sheet is online, current monitoring platforms exist (i.e. SeagrassNet and SeagrassWatch), protocols are similar among major platforms, the cost of sampling is relatively low since sampling occurs in shallow water and is relatively low-tech, there is a general level of coordination between sampling entities, and there is an existing governance framework, the International Seagrass Expert Network.

Recommendations for future seagrass EOV work include continuing to leverage existing capacity and garnering support, keeping the measurements simple to support interoperability, keeping the information relevant to stakeholders and societal needs, focus on the contributors and the network
of people, ensure the continuity of the network through training, succession, and planning, support a data management model to ensure FAIR data standards, promote rigorous taxonomy, and adopt an ecosystem approach.

Following the presentation, a few key points and recommendations were brought up in the discussion that followed the presentation. These included: an agreement on sampling definitions is important to the success of the network (i.e. the definition of percent cover), there could be broader engagement of NGOs and countries in the EOV implementation process, in many cases countries don’t have capacity to get and collate data, a standardized data sharing agreement under the GOOS and MBON framework and as part of the SOP manual for seagrasses.

5.2 Current Status of Seagrass Monitoring – Fred Short

Fred Short presented on the expansion of SeagrassNet. SeaGrassNet is a global monitoring program that evolved out of SeagrassWatch. The goal of this program was to collect data that was more consistent around the world in order to detect change in the global seagrass system. This includes a strong sampling design which includes fixed transects, repeated measures, standardized protocol, synchronous sampling, a range of depths, compatible for all species. SeagrassNet consists of 139 sites around the world (Figure 2). The process consists of identifying a tropical island, identifying where seagrasses are present, laying down a 50m transect, and then observing seagrass in shallow, mid, and deep bins. Sites can be accessed via intertidal access or scuba diving. The sites are sampled once and then reused in a repeated measure design. Case studies of sites sampled were presented such as: Micronesia, Malaysia, Israel, Korea, Thailand, Columbia, and Belize. The trends overtime at each of the sites show differing conclusions depending on the location of the sites and species. For example, in some cases the percent cover is the same, but the species composition has decreased dramatically. The largest stressors to seagrasses include: global sediment loading (land clearing), nutrient loading (sewage), climate change and direct physical impacts from aquaculture. The Future of SeagrassNet resides in the Smithsonian Institute and WCMC-UNEP. Data gaps in some areas such as West Africa may be language barrier.
5.3. Seagrass Watch- Len McKenzie

Seagrass Watch is a seagrass monitoring program that links monitoring and assessment with engagement and science-based education (Figure 3). These efforts support policy and outreach and education. Seagrass Watch exists in 32 countries that started in August 1999 (Figure 4). The program responds to local needs with no active recruitment, voluntary process, data collection must be overseen by a qualified scientist or trained and competent participant. There are many levels of certification, baseline mapping exists at many different scales (i.e. site, location, region) using standardized field protocols. Percent cover was the metric that gave the best representation of the seagrass meadow. The design of the monitoring and assessment includes a standardized sampling strategy that includes sites nested in locations within regions. Quadrat size is the same across all sites. There is a rigorous QA/QC process which includes aspects before, during, and after. Results can be used for a variety of purposes including reporting for policy and management and scientific publications.

Could protocols used for seagrass monitoring be deposited into the ocean best practices portal. Data can be open at higher resolutions, but at the quadrat, transect, and site level it is a lot harder to get researchers to provide open access data.
Figure 3. Seagrass-Watch working scheme: from monitoring and assessment to engagement and science-based education
5.4 Current Status of Mangrove Monitoring - Lisa Maria Rebello

Lisa Maria Rebello provided an update and recommendations associated with the Bunting et al. paper entitled, “The Global Mangrove Watch – A new 2010 Global Baseline of Mangrove Extent”. Regarding the in-situ data collection for mangroves, there is a large amount of in-situ data collected but there is not a common place for data. Regarding remote sensing of mangroves, mangroves are different than most other wetlands in the active remote sensing community since there are a few aspects of mangroves that make them identifiable via remote sensing. Thus, Global Mangrove Watch is an international collaborative project through JAXA and K&C with the goal of mapping mangrove extent (baseline data) and the change over time using satellite data (Figure 5). The objective of Global Mangrove Watch are to: map extent and change of global mangroves using satellite data at a resolution of 25-30m, generate an updated baseline map of the global mangrove extent (updated from the Global Atlas on Mangroves), and to generate maps of annual changes in global mangrove areas. To achieve these objectives, Global Mangrove Watch has assessed ~53,800 randomly sampled sites/pixels in 20 regions with an accuracy of 95.25%. The Global Mangrove Watch dataset provides an interactive 20-year snapshot of changes in mangroves and is being accepted as the data for SDG 6.4.1 on wetlands. Overall, there has been a 5.8% decline in global mangrove extent from 1996. The largest area is in SE Asia which represents a majority of the mangrove extent. The mangrove losses have slowed down relative to the 1996-2007 period. A limitation of the data is that it is a global dataset that doesn’t capture everything, such as some SIDs. Future goals include bringing together national data and in-situ sensing to get a more holistic picture.
of global mangrove change overtime and to bring in other parameters of mangrove data (such as height, structure, biomass) to get a sense of the health and condition of mangroves.

Figure 5. 2010 Global mangrove baseline (v2.0) released in October 2018

6. Observing capabilities of Seagrasses and Mangroves (Breakout Topic 1)

6.1 Overview
The goal of the first concurrent breakout discussion sessions were to identify the current observing and analysis capabilities and data sources for seagrass and mangrove monitoring and discuss their integration into a unified, global community of practice that incorporates diverse data types (in situ sampling, remote sensing, etc.).

Discussion topics included:

- What are the current capabilities?
- What needs to be improved, improvements?
- What supporting variables (e.g. physics, biogeochemistry) are needed?
- Are the methods and data inter-operable – are the standards and best practices documented?
- Gap assessments – what areas require more observations – what would it take to expand to those?
- What are the costs, what are the funding options to improve current capabilities?
- What capacity development is needed?

6.2 Observing capabilities: Seagrasses
The observing capabilities of the seagrass EOV will be set within the context of the decadal goals focused on sustainable development and the Ocean Observation 2019 conference. Currently, a tiered approach exists for sampling seagrasses which includes: presence/absence, Percent cover/density (abundance), composition (diversity), aerial extent (using satellites, drones, and hydroacoustic), reproduction (seed banks, reproductive shoots), and blue carbon. The “Supporting variables” include: turbidity (from Secchi Disk measurements or satellites), depth, Kd (light attenuation), nutrients, temperature, and salinity.
The in-situ measurements of seagrass ecosystems is very well established and exists, yet the question remains on how to integrate in-situ measurements with remote sensing. Global capacity development for seagrass sampling must target scientists, governments, and citizens by providing Currently, there are a diversity of different databases, but the question remains on how to organize disparate sources into a single common portal/map. The existing databases will need to be migrated and collated and old data needs to be identified (data archaeology). In addition, barriers to data sharing were an important part of the discussion. Barriers may include historical and cultural barriers. In addition, there are incentives for people to engage in data sharing practices, and these include incentives centered around data hosting, publishing, curation, credit/DOI.

Funding sources for seagrass and coastal habitat monitoring include philanthropic organizations, endowments, non-governmental organizations, and governmental agencies. In addition, the idea to establish a network of networks (ISEN/WSA) using the formation of the Mangrove Alliance as an example and developing a metadata portal (GEO) using the World Database on Protected Areas as a metadata example (www.protectedplanet.net)

Discussion on the EOV spec sheet identified a few areas which were adjusted on the EOV spec sheet. These include needs: (1) EOV needs to be changed to distinguish between cover and extent (2) retitle “Seagrass cover and composition” (3) Develop standardization methods.

6.3 Observing capabilities: Mangroves
The current monitoring capabilities of mangroves include three main methods: remote sensing, drones, and in-situ sampling. The breakout discussion focused on derived products such as: mangrove extent and change, canopy height (from year 2000 onward), carbon & biomass estimates, restoration potential, global canopy, drivers of mangrove loss (i.e. aquaculture, agriculture etc.), ecosystem services and coastal protection, and tourism. Some of the supporting variables needed for the seagrass EOV include: salinity & freshwater inflow, geomorphology, tidal, sea level height, storm events (rain, lightning, hurricanes), porosity of land-ward border (aka location of coastal infrastructure.

The methods and data for the Mangrove EOV are inter-operable since the standards and best practices are documented. From a remote sensing perspective, satellite methods include standard protocols and the remote-sensing community is well established and communicative. Consequently, coordinated remote sensing efforts are occurring for mangroves. For drones, everyone is collecting data differently but there is a Drone Monitoring Protocol in progress. For in-situ data there is no coordination but the Blue Carbon protocol and the Kauffman and Denado handbook could serve as a starting point for developing an in-situ Standard Operating Procedure (SOP).

Improvements to the mangrove EOV could incorporate: including species composition measurements in remote sensing data, satellite data verification using in-situ data, a best practice or formal process by which in-situ data can inform the maps made from satellite data, best practice and work-flow for how to map mangroves (publications exist for this but there is no one “manual” or best practice document), and a scoping process to identify the existing in-situ and drone sampling and to identify the current gaps in in-situ and drones data. The gaps in remote sensing data include certain islands, especially small islands. In addition, drone and in-situ data is very patchy and there is a strong need to first identify who is doing what and where in order to begin coordinating efforts. In-situ sampling is extremely resource intensive, so capacity development may focus on this...
sampling method. In addition, there are opportunities exist to partner with groups such as the Mangrove Alliance and Blue Carbon initiatives as possible ways to share existing resources.

7. Technological requirements & innovations of Seagrasses and Mangroves (Breakout Topic 2)

7.1 Overview
The goal of the second concurrent breakout discussion sessions were to identify the technological requirements and innovations to maximize and automate observations and improve current coverage, platforms and infrastructure.

Discussion topics included:
- What actions are needed to improve current platforms and infrastructure?
- Identify near-term innovation priorities for observing platforms and sensors, data and modeling to enable multi-disciplinary observations.
- What are the costs, what are the funding options to improve current technologies?
- What capacity development is needed?

7.2 Technological requirements & innovations: Seagrasses
The desired technologies for seagrass monitoring include: AI/machine learning to process imagery of seagrasses, fishes, human impacts (i.e. BenthBox-AIMS), enhanced data storage capacity such as for imagery and videos, hyperspectral sensor (30-m resolution) and ISAT2 (bathymetry), cloud computing/storage for hi-res imagery, integration of remote sensing with in situ imagery in locations where this is possible, comparison of technologies at the same sites such as MarineGEO drone imagery on US West Coast combined with aerial imagery and satellite data, AUVs and hydroacoustics can be deployed broadly in places that are difficult to access or work in for people, genomics and eDNA methods to indicate status of seagrass habitats and measure species and genetic composition especially in murkier areas, concurrent sampling of habitat & fauna such as associated fish and inverts, and data curation tools.

The capacity development needed for technological progress associated with seagrass monitoring includes: linking modeling efforts (e.g. terrestrial or watershed models), citizen science efforts (e.g., Project Seagrass) and ecotourism as ways to collect data, standard protocol packages developed for programs with differing capacities, science communication (i.e. Blue Solutions, Ocean Teacher Portal). In addition, capacity development should include dataset and database integration since data are currently scattered in a non-standard format and can be easily lost. In addition, data can be integrated with other datasets such as climate, oceanographic, and terrestrial datasets. The possibility of remote sensing for seagrass at the regional scale but it is limited to shallow clear water.

The priority for funding efforts should be centered on data management, curation, storage, and analysis. There is a need for seed funding and a sustained funding source. A suggested approach is to contact cloud storage providers (e.g., Amazon) to provide storage & processing of imagery, possibly using the Gulf of Mexico as a test case.
7.3 Technological requirements & innovations: Mangroves

The actions needed to improve current platforms and infrastructure are slightly different depending on the sampling methods used for mangrove monitoring. For in-situ data there are currently is no monitoring network, no in-situ database. Existing platforms, such as the Coastal Carbon Atlas, GeoWetlands, and GloMIS, could be good examples to base the in-situ global mangrove sampling on. A challenge of in-situ data sampling is that it is difficult to maintain sampling sites. Drone sampling methods are more similar to in-situ data in terms of tradeoff between resolution and scalability. With regards to data obtained from drone monitoring of mangroves, drone data requires a data repository with a consistent format for the data. The GlobalArchive for global video transects could serve as a good example for the development of a platform.

The near-term innovation priorities include the following: a lot of the in-situ data exists but they are not coordinated, there is a need a platform and network for global in-situ mangrove data with a focus on long-term monitoring mangrove sites, video monitoring may be another method for monitoring but there are possible issues around the storage of images obtained from visual monitoring, there is a need for a data host or repository for data obtained from in-situ sampling, there is a need to identify the science questions or societal needs guiding the creation of platforms and interfaces.

The costs and funding options to improve mangrove monitoring efforts include: challenges for funding monitoring efforts and maintaining platforms and databases, drones are relatively expensive ($1500) but require about two to three trained people to operate per drone (pilot, watch, data organization).

The capacity development that is needed includes: developing standardized protocols for in-situ measurements. This could include working with the Ocean Best Practices (OBP) since there is existing capacity and effort supporting this initiative. In addition, there is a need to translate protocols and standards into many languages so can facilitate capacity development. A map of in-situ monitoring efforts of mangroves is needed to better understand the current monitoring efforts. This could include mangrove restoration and non-restoration sites. There is a need to scope the existing capacity supporting monitoring efforts to see how it could be redirected to areas that may need further funding and support.

8. Data management (Breakout Topic 3)

8.1 Overview

The goal of the third discussion session was to discuss approaches to consolidate existing data and associated metadata in a data system to ensure their discovery, accessibility, interoperability and re-use, and identify future priorities for management of data on seagrass and mangrove abundance under the principles of FAIR data standards (Findable, Accessible, Interoperable, and Re-useable). This session included a presentation on OBIS from Sky Bristol followed by a group discussion focused on the following topics:

- Mapping the data management network (who is doing what)
- Describing requirements for:
- data standards and best practices
- data processing (QA/QC)
- data archiving
- data provenance and traceability
- data access
- manuals and human helpdesk support

- Developing a concept for a data system architecture, 5-year roadmap and workplan, including resource (human, technical and financial) requirements.

8.2 OBIS- Sky Bristol Presentation & Data Management Discussion

Sky Bristol presented the Ocean Biogeographic Information System (OBIS). OBIS was created as a data repository and information dissemination for 16 projects of the Census of Marine Life. OBIS provides more than a central database in that it combines partners, nodes, and users. OBIS is a network of networks to provide data and capacity development across the system. OBIS is organized into country and in some cases thematic nodes and includes connection between the global north and global south.

Darwin Core is the body of standards for the data. OBIS provides a pipeline for 27 major tests for data. The features include taxonomy, geography, depth, completeness, data format, outliers. The OBIS platform includes API, map, and R tools. The reason to use Darwin Core is in order to make data comparable to other data. The event core is a standard used throughout the community. The observations and measurements can be encoded in standards for units of measurements, protocols, then they will be useful at a broader level by the community. Identifying the different types of protocols and methods for specific sampling methods (i.e. Plankton Net and CTD). Event Core can be used anytime physical or biological data is being collected.

These data standards (OBIS-ENV-DATA and Event Core) are being used in the marine sanctuaries, Marine Biodiversity Observing Network (MBON), and NOAA coral reef monitoring. OBIS-USA takes in source data in a variety of different organizations puts them into OBIS and Global Biodiversity Information Framework (GBIF). Science Base stores the original data (USGS platform) to API driven applications and then sends to OBIS and GBIF (Figure 6).
Some of the essential questions for the development of the community context include: developing a community and mapping the network (who has what data and where?), determining who is part of the broader knowledge network to develop consensus on vocabularies (ontology develop- NERC & BRDC), and develop consensus on protocols and methods (protocols or suitable alternative). This could include mapping between protocols to link different protocols that are similar enough and hosting protocols so that protocols can be linked to data. Another important aspect is to institutionalize sound data management practices.

A few important points came out of the Q & A session that followed the presentation: the only records that are fully brought into the index are ones that have a valid id in WoRMS, OBIS has many records for mangroves and seagrasses but they are likely not complete, the event schema can accommodate and inform standardization of data that needs to be brought into the global system, many groups (ESIP, USGS Community for Data Integration) work together on “data at risk” or data archaeology to identify data sets that if not they are not dealt with soon will lead to a loss of institutional knowledge, partnerships to work on data challenges are an important part of the community, data must be sound and structurally coherent and available online for use.

A couple suggestions were put forth for action items to discuss during the working group related to data management. Regardless of the data standard is that you are going to comply with, you need unique identifiers that are agreed on with linkage between other vocabularies. It is very important to take a look at the relevant vocabularies, identify those that make sense, and annotate terms that are those that apply. This may lead to building a more comprehensive ontology. Thus, it is important to identify relevant vocabs, adopt for data, adapt as necessary. Developing a consensus on protocols and methods is a key aspect of developing a sound data management plan. Otherwise, it is important to make the protocol explicit that is linked to the data so (protocol.io). There should be an active harmonization of vocabulary and documentation of protocols.

There has been active discussion on DOI and blockchain in the OBIS community. OBIS is not considered to be a primary repository for data. They assign DOIs to the USGS original source data,
but not to datasets that exist in other primary locations on the internet. The central location of OBIS is out of Belgium and provides a repository source for original data that doesn’t have an existing primary location. OBIS and other data systems have a responsibility to retain the datasets unique identifier. Thus, OBIS does not assign DOIs to datasets in OBIS that have another source location since the home repository would be where the DOI should link to. The GBIF community has started thinking about Dataset ID, DOIs and tracking primary sources. In addition, there are dataset metrics that are derived from citations and social media.

Other aspects of OBIS scope and capacity came up during the Q & A. The main points were that: OBIS can serve as a metadata repository depending on the context of the metadata included, the IUCN is linked to OBIS, OBIS is not currently in formal communication with the satellite community but this could be a valuable collaboration since in-situ data could provide ground-truthing for satellite models, OBIS is semantically linked through the species and taxon names and the terms in Data Core provide some level of semantic integration, there is important work in clarifying the event specifics like the measurement types in a way that can support semantic interconnecting. This would require clarifying the use of terms and to determine how closely aligned those terms are.

The group thought that it was important to map the data management network of mangroves and seagrasses to understand who is doing what and that this could be achieved in stages. The requirements for the data standards and best practices for mangroves could be modeled off of existing standard protocols that exist in the Brazil which measure DBH, height, number of stems within a plot. In addition, LIDAR is used for fractional vegetation cover and drones measure vegetation cover on the top of the canopy and on the understory and ground.

With regards to developing a data system architecture, Darwin Core is used as a common protocol. In addition, there needs to be a central database for seagrass data. Since In-situ data is part of the WCMC mandate, the WCMC has funding and staff to facilitate scoping process for the development of a data management system for mangroves and seagrasses, which workshop participants from both the seagrass and mangrove community were onboard with. It may be possible to combine OBIS and WCMC to serve complementary roles in the data management process. In addition, data sharing could be facilitated by supporting the use of DOIs and building a network such as the Coastal Carbon Research Network which was built with an NSF coordination grant effort.

8.3 Discussion of Seagrass EOV spec sheet
Following the data management discussion, workshop participants discussed the seagrass EOV spec sheet. One of the most important things that came from the discussion the previous day was that there are two measurements relevant to seagrass: (1) the real extent of seagrass meadow and (2) the landscape level extent (100s of meters) compared with the organism scale (meters).

The shoreline protection value depends on canopy height, leaf area index and width, and water depth. As mentioned the previous day, sampling efforts could be prioritized based on the tiered data quality model. In addition, since there is a relationship between percent cover and biomass and density then percent cover, canopy height, and species composition would be the priority variables to measure. In addition, the bulk density contributes to belowground carbon. Fluorescence (PAR) doesn’t give good estimates in the field. There isn’t a standard protocol for measuring seed production, but there is a need to develop this. In addition, since dissolved nutrients in water are
highly variable and don’t relate much to the seagrass plants, tissue nutrients may be a better estimate. Also, the presence of seaweeds in the system indicates an excess of nutrients because seaweeds are present only under high nutrient conditions.

The necessary frequency of sampling will depend on the phenomena you want to observe. All data should be included as raw data in the system. As mentioned in past sessions, it is important to identify the best variables to measure and ones that are not as priority. It also may be important to develop relational tables to keep the detailed information, but have the key parameters and observe those connections to make the data sets. Add fish abundance and composition, seagrass disease prevalence, and invasive species composition and abundance to the complementary variables to support the derived products.

9. Products & Delivery (Breakout Topic 4)

9.1 Overview
The goal of the fourth concurrent discussion sessions were to discuss ideas for the draft decadal implementation plans for a global observing system of mangrove and seagrasses that: engages stakeholders and informs global assessments, engages developing countries and develops capacity, transfers technology and manages and delivers data to inform diverse end users, including decision makers, resource managers, educators, scientists, and the public.

9.2 Products & Delivery: Seagrass
Jon Lefcheck reported on the discussion centered on the products and delivery associated with the Seagrass EOV. The seagrass monitoring networks have developed in an organic and ad hoc which may determine how we proceed in letting it develop. The seagrass network will leverage existing networks and regional governments as nodes. For example, SeagrassNet, Seagrass Watch, and MarineGEO could be nodes within the network. The monitoring networks associated with physical and chemical do not necessarily acquire or serve data in the same way as biological variables, such as seagrass monitoring. The monitoring occurs very nearshore and is an entirely different suite of variables. The parameters that are measured should be guided by the focal questions and could include: percent cover, composition, fish abundance, and carbon.

The deliverables and action items discussed during the breakout session on seagrass include the following:

- A global and temporal map of seagrass (WCMC)
  - Using valid data sources (e.g., government data sources)
  - Showcase the potential of a large-monitoring network
  - Demonstrate gaps in monitoring
- A review of the existing seagrass data to optimize sampling
- Expansion of seagrass monitoring using MBON Pole-to-Pole Network
- Two-page glossy publication for funders
- Short meeting report (AGU EOS newsletter)
- Update data on seagrasses to include more recent data by Ocean Obs 2019
- Reach out to the other seagrass networks to get their data into OBIS: coordinated effort with a targeted request
- Continue to submit proposals for workshops to further develop the EOVs. For example, Emmett Duffy submitted a proposal to SCOR related to hosting a series of workshops to advance implementation plans.
- Develop a seagrass specialist group through IUCN
- Understand how seagrass biodiversity links to EBVs (Essential Biodiversity Variables)
- Cross standardize EOVs and then link to EBVs since the Essential Variables are emerging under two entities: GOOS- Essential Ocean Variables; GEO BON (Marine BON) - EBVs

9.3 Products & Delivery: Mangroves
Lisa-Maria Rebelo reported on the discussion centered on the products and delivery associated with the Mangrove EOV. The mangrove EOV breakout group focused the initial discussion on the Mangrove EOV Spec Sheet and changes associated with terminology, such as mangrove fringe width and area, were made to the spec sheet (for changes see the updated spec sheet). In addition, root density may be an important variable to consider measuring. In-situ information on species composition is currently needed since data is dispersed or may be lacking in some regions. Currently, the information available is a snapshot in time and often spatially aggregated from regional or national studies. Thus, data often lacks high spatial and temporal granularity or an agreed upon sampling method. Mangrove height has now been derived from DEMs and LIDAR and a global map is available. For global extent, there are opportunities to improve the spatial detail of GMW using Sentinel-2 and VHR sensors. The current GMW mapping does not provide sufficient spatial details due to a rather coarse effective spatial resolution (approximately 1 ha). This is especially the case in areas with fragmented mangroves or small island states. Efforts must facilitate the collection of field data in a central location.

Some of the products, deliverables, and action items arising from the
- Revision of the mangrove spec sheet
- A global assessment of mangrove cover (and composition) needs to be combined with a collation of data from long term in-situ monitoring sites
- A scoping study is needed to identify what databases exist, where, and what standards have been used. Offers of support have been provided by UCSD (Astrid will work with undergraduates to get a sense of what is out there with a metadata sheet), and WCMC to determine what databases exist, where they are, and where they are hosted, and the data collection standards.

9.4 United Nations Decade of Ocean Science for Sustainable Development Planning Meeting Recap- Erin Satterthwaite
Erin Satterthwaite gave a brief summary on the United Nations Decade of Ocean Science for Sustainable Development planning meeting in order to consider how the discussions from the seagrass and mangrove EOV working group could be integrated into the current and developing initiatives focused around the UN Ocean Decade. The Ocean Decade 1st Global Planning meeting was in Copenhagen, Denmark from May 13th to 15th, 2019 and included over 200 participants, from
research institutions and UN organizations, but also business, technology, NGOs, philanthropy and communication organizations. Erin attended the meeting representing the National Center for Ecological Analysis and Synthesis (NCEAS), Future Earth, and the Ocean Knowledge-Action Network (KAN).

The Ocean Decade is an initiative which provides a common framework that will ensure ocean science can fully support countries in creating improved conditions for sustainable development of the ocean. There were presentations and discussions around six main societal objectives arose during the meeting: a safe ocean, a sustainable and productive ocean, a transparent and accessible ocean, a clean ocean, a healthy and resilient ocean, and a predicted ocean. These goals align well with the work of the seagrass and mangrove monitoring communities and are set within the context of the Global Ocean Observing System (GOOS) framework. GOOS will play a key role in the Ocean Decade objective focused on a predicted ocean because GOOS plays a pivotal role in developing and maintaining the sustained and systematic global ocean observation systems. The main points from the meeting were that the Ocean Decade is a framework that is currently being facilitated by an executive planning team with IOC-UNESCO but it is clear that it will be a community driven process. The hope is that the Decade can leverage diverse partnerships to co-design mission-oriented research strategies in line with the sustainable development goals for the 2030 Agenda.

Continued involvement in the process includes attending the future planning meetings and developing initiatives that support the six societal objectives of the Ocean Decade. There will be a series of regional planning meetings to get involved in the process. There are also some initial projects such as developing a visual network of global organizations to better visualize the “landscape” of organizations involved in global ocean issues. In addition, Future Earth is developing a Network of Networks of Early Career Ocean Professionals as a way to communicate throughout the Decade. Lastly, a global policy engagement workshop for Early Career Ocean Professionals at Ocean Sciences Meeting 2020. Great opportunity exists to develop the biological global ocean observing system to provide evidence needed for the societal objectives for the Ocean Decade.

10. Conclusions and Action items

10.1 Overview

The action items that emerged from the meeting are centered on these focal areas: seagrass implementation plan, mangrove implementation plan, network map of mangrove and seagrass data providers, develop consensus on mangrove and seagrass vocabularies (possibly NERC), develop consensus on mangrove and seagrass protocols, institutionalize sound data management practices for mangrove and seagrass, EOS meeting report, seagrass 2-pager infographic, seagrass database and map, develop pipeline to bring existing databases together.

10.2 Action Items

The specific summary of actions, commitments, and assignments that were determined during the working group are as follows:

- Seagrass implementation plan (Emmett, Frank)
  - Edit and finalize specsheet
  - Edit and finalize tiered data quality model
  - Societal benefit matrix: link variables to benefits (Erin)
Incorporate emerging technological advances

- Map of seagrass monitoring locations across all networks (Erin)- Sep 2019 (Ocean Obs 2019)
- Mangrove implementation plan (Lisa Maria, Frank)
  - Edit and finalize spec sheet
  - Draft implementation plan
  - Draft before OceanObs, Sep 2019

- Data Network Map: seagrasses (Lauren, WCMC)
  - Map the network of data providers: who has what data, where
  - Develop consensus on vocabularies (e.g., NERC vocabulary system)
  - Develop consensus on protocols (protocols.io, Ocean Best Practices, Nic’s Australia prototype)
  - Institutionalize sound data management practices

- Data Network Map: Mangroves
  - Map the network of data providers: who has what data, where? (Astrid and students)
  - Develop consensus on vocabularies
  - Develop consensus on protocols
  - Institutionalize sound data management practices

- EOS meeting report (Emmett, Lisa Maria, Nic) - by August 2019

- Seagrasses: Draft 2-pager with infographics (Patricia, Jessie, Rich) - by Sep. 2019 (Ocean Obs 2019)

- Seagrass database (OBIS?) and map (Lauren, WCMC)
  - Draft concrete request and reach out to other networks
  - Work with providers to develop plan for data upload

- Assemble remote sensing protocols
  - Mangrove drone protocol: Astrid
  - Seagrass drone protocol: Margot

- Workshop reports (Patricia & Erin)

11. References


12. Links to Mangroves and Seagrass Networks

- GEO-Wetlands: http://geowetlands.org/
- Mangrove Watch/Australia: http://www.mangrovewatch.org.au/
- Blue Print: http://blueprints.ucsd.edu/blueprint/mangroves
- Datamares: http://datamares.ucsd.edu/eng/projects/mangroves/
- Seagrass-Watch: http://www.seagrasswatch.org/
- SeagrassNet: http://www.seagrassnet.org/
Smithsonian MarineGEO / Tennenbaum Marine Observatories Network:
https://marinegeo.si.edu/

13. Participants

Leadership and coordination

- Patricia Miloslavich (GOOS / UTAS)
- Emmett Duffy (MarineGEO and MBON)
- Lisa Maria Rebelo (IWMI and Ramsar STRP)
- Frank Muller-Karger (MBON, OceanObs RCN, USF)

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Appendix 1. Workshop agenda

Coordinating the Implementation of Mangrove and Seagrass Essential Observations – A joint GOOS/MBON community outreach workshop to implement EOV/EBVs

(Sea Plants Workshop)

Consortium for Ocean Leadership, Washington DC

10-11th June 2019

WORKSHOP AGENDA

Event website:
http://www.goosocean.org/index.php?option=com_oe&task=viewEventRecord&eventID=2491

Goals of the workshop:

(1) To identify the current observing and analyses capabilities and data sources for seagrass and mangrove monitoring and discuss their integration into a unified, global community of practice that incorporates diverse data types (in situ sampling, remote sensing, etc.)

(2) To identify the technological requirements and innovations to maximize and automate observations and improve current coverage, platforms and infrastructure

(3) To recommend approaches to consolidate existing data and associated metadata in a data system to ensure their discovery, accessibility, interoperability and re-use, and identify future priorities for management of data on mangrove and seagrass abundance under the principles of FAIR data (Findable, Accessible, Interoperable, and Re-useable).

(4) To contribute ideas to draft decadal implementation plans for a global observing system of mangrove and seagrasses that: engages stakeholders and informs global assessments, engages developing countries and develops capacity, transfers technology and manages and delivers data to inform diverse end users, including decision makers, resource managers, educators, scientists, and the public.

(5) To facilitate the establishment of a community of practice that will continue the process into the future and support achievement of long-term goals

Monday, June 10
8:00: Breakfast at the Consortium for Ocean Leadership (venue)

8:30 – 9:30 am: Introductory presentations

- Welcome and round of introductions – institutions and expertise – Emmett Duffy and Patricia Miloslavich
- Introduction to the workshop – goals and expected outcomes – Emmett Duffy
- Introduction to GOOS BioEco EOV implementation plans – Implementation timeline - Seagrass and mangrove cover and composition as GOOS EOVs and their connection to EBVs - Patricia Miloslavich
- Explaining workshop dynamics – Patricia Miloslavich

We will have four breakout sessions. Each of them will have a different topic, but all of them to be focused on actions to address the cross-cutting issues of (1) priority needs/requirements, (2) technical and human capacity development needed and (3) strategy to secure funding for implementation.

Topics of breakout sessions will be:

1. **Observing capabilities**: How do we make the system global and sustained in time? What is needed to engage all networks, communities of practice and more developing countries?
2. **Technological requirements and innovations**: How can we improve current platforms and infrastructure to maximize and automate observations? What needs to be developed (at the system level, for sensors, for analyses and model interfaces, etc.)
3. **Data management**: How we can improve the information chain from sensors to users.
4. **Products and deliverables**: What products and deliverables are needed and for what purpose?

Workshop participants will split into two groups depending on their expertise, mangrove or seagrasses and discuss the same issues. They will report to plenary where cross-cutting issues will be discussed.

**Chairs and rapporteurs of all breakout sessions:**

- **Seagrasses**: Frank Muller-Karger (Chair) and Jon Lefcheck (Rapporteur)
- **Mangrove**: Lisa Maria Rebelo (Chair) and Erin Satterthwaite (Rapporteur)

9:30 – 10:30 am: Current status of monitoring efforts / technologies

- Seagrasses

- Update and recommendations from OceanObs19 paper: Toward a coordinated global observing system for marine macrophytes – Emmet Duffy (15 + 5 minutes)

- Towards the expansion of SeagrassNet – Fred Short (15 + 5 minutes)

- Mangroves
Update and recommendations from Bunting et al. paper: The Global Mangrove Watch – A new 2010 Global Baseline of Mangrove Extent — Lisa Maria Rebelo (15 + 5 minutes)

10:30 – 11:00 am: Morning break

11:00 – 12:30 pm: Breakout Topic 1: Observing capabilities

**Goal 1.** Identify the current observing and analysis capabilities and data sources for seagrass and mangrove monitoring and discuss their integration into a unified, global community of practice that incorporates diverse data types (in situ sampling, remote sensing, etc.)

Discussion topics include:

- What are the current capabilities?
- What needs to be improved?
- What supporting variables (e.g. physics, biogeochemistry) are needed?
- Are the methods and data inter-operable – are the standards and best practices documented?
- Gap assessments – what areas require more observations – what would it take to expand to those?
- What are the costs, what are the funding options to improve current capabilities?
- What capacity development is needed?

12:30 – 1:30 pm: Lunch break (provided at venue)

1:30 – 3:00 pm: Wrap up morning discussions and reports to plenary by session chairs and discussion from Breakout Session 1. **Moderator:** Daniel Dunn

3:00 – 3:30 pm: Afternoon break

3:30 – 5:00 pm: Breakout Topic 2: Technological requirements and innovations

**Goal 2.** Identify the technological requirements and innovations to maximize and automate observations and improve current coverage, platforms and infrastructure

Discussion topics include:

- What actions are needed to improve current platforms and infrastructure?
- Identify near-term innovation priorities for observing platforms and sensors, data and modeling to enable multi-disciplinary observations.
- What are the costs, what are the funding options to improve current technologies?
- What capacity development is needed?

5:00 pm ADJOURN FOR THE DAY

Dinner: you are free to make your own plans

Tuesday, June 11

8:00: Breakfast at the Consortium for Ocean Leadership (venue)

8:30 – 9:30 am: Reports to plenary by session chairs and discussion from Breakout Session 2. **Moderator:** Nic Bax
9:30 – 10:30 am: Breakout Topic 3: Data management

**Goal 3.** Recommend approaches to consolidate existing data and associated metadata in a data system to ensure their discovery, accessibility, interoperability and re-use, and identify future priorities for management of data on seagrass and mangrove abundance under the principles of FAIR data (Findable, Accessible, Interoperable, and Re-useable).

Discussion topics include:

- Mapping the data management network (who is doing what)
- Describing requirements for:
  - data standards and best practices
  - data processing (QA/QC)
  - data archiving
  - data provenance and traceability
  - data access
  - manuals and human helpdesk support
- Developing a concept for a data system architecture, 5-year roadmap and workplan, including resource (human, technical and financial) requirements.

10:30 – 11:00 am: Morning break

11:00 – 12:30 pm: Wrap up morning discussions and reports to plenary by session chairs and discussion from Breakout Session 3. **Moderator: Patricia Miloslavich**

12:30 – 1:30 pm: Lunch break (provided at venue)

1:30 – 3:00 pm: Breakout Topic 4: Products and delivery

**Goal 4.** Contribute ideas to draft decadal implementation plans for a global observing system of mangrove and seagrasses that: engages stakeholders and informs global assessments, engages developing countries and develops capacity, transfers technology and manages and delivers data to inform diverse end users, including decision makers, resource managers, educators, scientists, and the public.

3:00 – 3:30 pm: Afternoon break

3:30 – 4:30 pm: Wrap up afternoon discussions and reports to plenary by session chairs and discussion from Breakout Session 4. **Moderator: Nic Bax**

4:30 – 5:00 pm: Wrap up meeting – summary of actions, assigning tasks and follow up commitments and schedule – Emmet Duffy

5:00 pm ADJOURN

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Appendix 2. Workshop photos