C-GRASS: Coordinated Global Research Assessment Of Seagrass Systems

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1. Summary

Seagrasses provide the foundation of submerged coastal grassland ecosystems around the world but are threatened worldwide by human activities, with almost 30% of seagrass global cover lost since the late 19th century. Seagrasses provide multiple ecosystem services, particularly in the developing world. Yet obtaining an accurate understanding of seagrass status, trends, and responses to global change has been challenging due to the fragmented nature of available data. The time is opportune for a new scientific synthesis and coordination of global seagrass research activities toward this goal. We propose a series of SCOR workshops to organize and synthesize existing data in a scientific analysis of seagrass ecosystems under global change and provide a framework for an ongoing observation program of seagrass cover and composition as an Essential Ocean Variable. Our Working Group engages a diverse community of scientists and stakeholders to (1) integrate existing seagrass monitoring and analysis efforts into a unified, global community of practice that incorporates diverse data types and informs diverse end users; (2) establish common protocols and best practices for seagrass data collection, curation, and sharing, collated in a multi-media handbook of accepted protocols and best practices; (3) integrate existing and ongoing seagrass data collection into international, open-access portals, with common frameworks for data vocabulary, metadata, management, and service to stakeholders; and (4) collate and analyze existing data on seagrass occurrence and composition to publish a scientific synthesis of current status, trends, and drivers of change in global seagrass systems as an open-access publication in the peer-reviewed literature.

2. Scientific Background and Rationale

2.1. Global status of seagrass ecosystems

Seagrasses provide the foundation of submerged coastal grassland ecosystems around the world. They are among the most productive natural habitats on land or sea [1], store substantial quantities of carbon, and provide humanity with fishery habitat, coastal protection, erosion control, and other services [2]. Seagrass nutrient cycling services alone have an estimated value of nearly $2 trillion per year [3], and Indonesian seagrass meadows provide fishery nursery areas that contribute an estimated 54% to 99% of daily protein intake for local communities [4]. Seagrasses also serve as early warning indicators of anthropogenic perturbations in the coastal zone due to their sensitivity to changing water quality and fishing activities [5].

These important habitats are threatened worldwide by human activities: the best available data indicates that almost 30% of seagrass global cover has been lost since the late 19th century [6] and 22 of the world's 72 seagrass species (31%) are in decline [2, 7], a trend widely considered a global crisis [8]. Recognizing their importance, the Global Ocean Observing System (GOOS) has proposed seagrass cover and composition as one of seven Essential Ocean Variables (EOVs). The EOVs are defined on the basis of societal importance as reflected in reporting requirements for the international conventions and agreements that shape policy responses to global change [9]. 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), among others.

Despite the importance of seagrasses to coastal ecosystems, economies, livelihoods, developing coordinated systems for observing their status and trends have been challenging for several reasons. First is the fragmented nature of available in situ data. Numerous local and regional monitoring programs collect data on seagrass cover and ecosystem characteristics, and several regional to global programs exist. The latter include Seagrass-Watch [10, 11], SeagrassNet [12], and the relatively new MarineGEO program led by the Smithsonian Institution. Together, these programs have engaged hundreds of scientists and thousands of citizens in collecting data relevant to assessing seagrass occurrence and composition. But such programs often have different objectives, employ a range of methods, and measure different variables, making inter-comparison and scientific analysis difficult. A second challenge is that field sampling is biased geographically, concentrated in North America and western Europe around major scientific organizations. As a result, existing syntheses of seagrass occurrence necessarily rely heavily on interpolation of expert knowledge and low-resolution point-based occurrence sampling, whereas seagrass extent is more difficult to quantify, and resolution is especially low in the regions where seagrasses are most diverse such as the western Pacific.

2.2. New opportunities in seagrass science and conservation

Several converging trends create a promising opportunity to assemble a more geographically comprehensive and highly resolved understanding of global seagrass status, trends, and drivers of change. These include innovations in remote sensing; engagement of citizen scientists in field data collection; and growing community consensus around the need for standardization of sampling protocols, data management, and sharing. Our proposed working group (WG) aims to integrate and coordinate remote sensing and in situ sampling programs toward a more powerful scientific synthesis of global seagrass distribution and ecosystem characteristics. The WG will build toward this goal by coordinating a global community of seagrass ecosystem researchers and managers toward consensus on standard approaches in collecting and organizing data on seagrass cover and composition, and a new analysis of those data. The WG will have the secondary benefit of providing a scientific foundation to advance seagrass cover and composition as an Essential Ocean Variable.

We propose a series of SCOR workshops to organize and synthesize existing data in a scientific analysis of seagrass ecosystems under global change and provide a framework for an ongoing observation program of seagrass cover, biodiversity, and ecosystem characteristics. Our Working Group engages a diverse community of scientists and stakeholders toward these goals to (1) integrate existing seagrass monitoring and analysis efforts into a unified, global community of practice that incorporates diverse data types (in situ sampling, remote sensing, etc.) and informs diverse end users, including decision makers, resource managers, educators, scientists, and the public; (2) establish common protocols and best practices for seagrass data collection, curation, and sharing, collated in a multi-media handbook of accepted protocols and best practices; (3) integrate existing and ongoing seagrass data collection into open-access portals, with common frameworks for data vocabulary, metadata, management, and service to stakeholders; and (4) collate and analyze existing data on seagrass occurrence and composition to publish a scientific synthesis of current status, trends, and drivers of change in global seagrass systems as an open-

access publication in the peer-reviewed literature. The proposed workshops will establish the community to continue the process into the future, and several participating institutions are committed to supporting achievement of the long-term goals.

2.3. Rationale for a SCOR working group

The time is opportune for a new global scientific assessment of the status, trends, and drivers of change in seagrass ecosystems, based on synthesis of the heterogeneous and fragmented existing data on seagrass occurrence and coordination of ongoing research and monitoring. Achieving such a synthesis requires engaging expertise in seagrass physiology, field ecology, remote sensing, database architecture, geospatial science and mapping, and social science. The proposed WG brings together a group spanning this expertise. We will organize and link existing seagrass data and field programs with global databases to improve accessibility and interoperability of seagrass data, and build a foundation for coordinated, global seagrass observations by establishing consensus on a common set of protocols and best practices for field sampling and data management. These activities will foster a new quantitative analysis of the drivers of change in seagrass systems and will have the secondary benefit of testing approaches to implement quantification of seagrass cover and composition as an Essential Ocean Variable.

Candidate protocols and best practices have been developed, vetted, and formalized by Seagrass-Watch, SeagrassNet, the Zostera Experimental Network [13, 14], and other programs, providing a set of demonstrated cases available as a foundation for a global community of practice. Application of satellite remote sensing [15, 16] and lightweight drone technology [17, 18] demonstrate the ability to obtain high-resolution maps of seagrass distribution and resolve variation in abundance, offering promise in linking regional and global-scale cover mapping with strategically sited *in situ* measurements. It will be important to understand the capabilities of present remote sensing efforts and technologies to conduct regional assessments on the health and cover of seagrass communities. Satellite images collected over the past 30 years provide an important basis for evaluating change. More satellite data are now available than ever before, yet it is not clear how this technology can be leveraged with new unmanned airborne systems and field efforts to evaluate scientific questions on seagrasses. WG Members Frank Muller-Karger and Heidi Dierssen bring experience in these areas to the WG.

Moreover, the accessibility of shallow-water seagrass meadows and their importance to local fisheries and ecosystems makes seagrass systems prime targets for application of citizen science monitoring, as done by Seagrass-Watch and the Seagrass Spotter phone app[1], co-developed by WG Associate Member Richard Unsworth. There is considerable potential to expand and integrate these activities, streamlining efforts and adding value to separate programs. This WG is poised to conduct a comprehensive synthesis of the changing distribution of global seagrass habitat, and the drivers of these trends. This process will also advance implementation of the seagrass EOV envisioned as part of GOOS.

[1] See: https://seagrassspotter.org/

3. Terms of Reference

The objectives of the SCOR C-GRASS Working Group are:

Objective 1: Organize an interdisciplinary community of practice to synthesize data on status, trends, and drivers of global change in seagrass ecosystems, building on and integrating existing resources.

Objective 2: Produce a handbook of standard protocols and best practices for collecting, curating, and sharing data on seagrass ecosystems among scientists and stakeholder groups, building on existing experience of scientists and end-users in management and conservation, and contributed to the Ocean Data Standards and Best Practices Project of IODE.

Objective 3: Promote development of standardized vocabularies for variables and data schemes specific to seagrass ecosystems, and integration of existing and new data into the Ocean Biodiversity Information System (OBIS) using the EVENT-DATA schema [19].]

Objective 4: Produce a scientific synthesis of status and trends in global seagrasses and the systems they support, via a comprehensive review of peer-reviewed and gray literature on seagrass occurrence, ecosystem characteristics, and benefits to human well-being.

4. Working plan

4.1. Objective 1: Organize an interdisciplinary community of practice

A rigorous analysis of how and why seagrass systems are changing on a global scale requires a coordinated effort, structures to manage ongoing data input and access to maintain inter-comparability, and engagement of a group with diverse geographic origins, disciplinary expertise and knowledge of the needs of policy- and decision-makers. To begin, we will focus on linking the web portals of the Seagrass-Watch, SeagrassNet, the Ocean Data Viewer, and MarineGEO networks, leveraging resources already invested in them and the continuing support of their secretariat institutions. Working Group members, including the UN Environment World Conservation Monitoring Centre (UNEP-WCMC, with leadership from co-chair Weatherdon) will assist in engaging end-users of the information products from the policy community, and in developing a communications strategy. UNEP-WCMC's existing seagrass layer has been used for environmental sensitivity mapping, marine spatial planning, high-level screening of biodiversity risk [20], and blue carbon assessments, and its application to ecosystem-based adaptation to climate change is in progress.

4.2. Objective 2: Produce a handbook of standard protocols and best practices

A key component of coordinating monitoring across a distributed network is common protocols and best practices. Ensuring that seagrass data are comparable across space and time requires community consensus on the core measurements and protocols for collecting and integrating them. These include in situ survey methods [21], remote-sensing approaches [16], and sampling

designs for achieving data that is fit to purpose, with acceptable error variance. The Working Group will collate, analyze, and update existing seagrass-related protocols to produce a multi-media handbook, linked to training videos and other online resources, that includes accepted methods for field data collection, data management, and curation. Protocols will be structured hierarchically, with a small core set of variables that can be integrated with remote sensing data and allow for repeated measures. Major criteria for variables will include fitness for purpose, i.e., the ability to provide information of appropriate resolution, quality, and scale to capture seagrass trends relevant to reporting requirements of nations and decision-makers.

4.3. Objective 3: Promote development of standardized vocabularies and data schemas

Rigorous comparison of data among programs requires a common language. The new EVENT-DATA OBIS schema uses a standard Darwin Core set of terms and accommodates sampling descriptions, environmental data, and biodiversity records. But using it requires developing a standardized set of vocabulary terms for seagrass-related data. The WG will develop and compile this vocabulary in close collaboration with OBIS under leadership of WG Full Member and OBIS co-chair Eduardo Klein.

The WG will promote integration of a substantial body of records of seagrass cover and species composition into OBIS. WG Member Short will make available data from the SeagrassNet program he founded in 2001, which includes data from 33 countries. The Smithsonian-led MarineGEO program (led by co-Chair Emmett Duffy) networks 13 sites and counting worldwide and will contribute seagrass and environmental data from this effort. We will also work with Seagrass-Watch to integrate as much data as possible from its sources.

Data access and ownership are key issues in the emerging networked data ecosystem. We will promote availability of as much seagrass data as possible, as close to open access as possible, while respecting needs of data providers. We will build on the experience of Seagrass-Watch, which provides a model for a tiered system of data sharing that respects the ownership of raw data, while making detailed summaries available via open access portals.

4.4. Objective 4: Produce a scientific synthesis of status and trends in global seagrass systems

A central goal of the Working Group will be to assemble the existing data on global seagrass cover, condition, and trends into an updated scientific assessment, building on previous assessments of global seagrass occurrence [22]. The data will be analyzed with ocean environmental data layers and data on human activities in an analysis of drivers of change in global seagrass occurrence. The results will be published in peer-reviewed paper(s) and integrated into the UNEP-WCMC Ocean+ initiative, which maintains a database of seagrass cover and produces maps and knowledge products that directly inform decision-making (available through Ocean Data Viewer[2]), including the *Global Distribution of Seagrasses*[3], curated on behalf of numerous contributors (including WG member Short). The synthesis will build on WG Member Muller-Karger's methods to map seagrasses using satellites [15]. And

[2] Available at: http://data.unep-wcmc.org.
[3] Available at: http://data.unep-wcmc.org/datasets/7.

recent progress and frontiers in quantification of seagrass ecosystem services [23, 24], and WG Member Unsworth's ongoing global synthesis of seagrass trends.

4.5. Timeline

Working Group meetings will be held in association with international conferences and we will work to leverage other funds to cover costs of participants; several participating institutions have offered financial or in-kind support. Possible venues for meetings include OceanObs19 in Honolulu, USA (2019); the 14th International Seagrass Biology Workshop (2020, venue not yet scheduled); regional symposium of the Blue Carbon Project in the Philippines (date not yet chosen).

Month 1: Working Group meeting 1. Hone goals, assignments of subgroups with leads for each of the four objectives. Begin identification of data sources (Objective 1), discuss and analyze standard protocols and best practices (Objective 2).

Month 1-12: Subgroups work on collation of data and assessment of needs for integrating into common framework (Objectives 1,3) and converge on best practices for handbook (Objective 2).

Month 12: WG meeting 2. Present draft of best practices document (Objective 2) and data schema (Objective 3) for discussion by WG. Review data assembled and outline synthesis paper(s) (Objective 4).

Month 12-24: Integrate sample data sets into OBIS using draft schema (Objectives 1,3). Continue work on best practices (Objective 2) and synthesis paper(s) (Objective 4).

Month 24: WG meeting 3. Complete best practices handbook (Objective 2) and synthesis papers (Objective 4). Report on data integration (Objectives 1, 3), challenges, and plans.

Month 24-36: Subgroups finish work on all four objectives.

Month 36: Meeting of selected WG members, lead authors, and data architects, to synthesize results toward the Objectives, finish products, and develop plans for long-term advancement.

5. Deliverables

(1) Hold a town hall meeting at the Ocean Sciences meeting (and potentially others) to announce the Working Group effort and solicit broad input. Contributes to delivering Objective 1.

(2) Produce a peer-reviewed handbook of standard protocols and best practices for seagrass field measurements and data management, published and contributed to the Ocean Data Standards and Best Practices Project of IODE. Delivers Objective 2.

(3) Integrate existing seagrass data, and ongoing monitoring data, into the Ocean Biodiversity Information System (OBIS) using a common data schema. Contributes to delivering Objectives 1 and 3.

(4) Produce a peer-reviewed scientific synthesis of status, trends, and drivers of change in global seagrasses and the systems they support, based on a comprehensive review of peer-reviewed and gray literature. Delivers Objective 4.

6. Capacity Building

The community of practice built through this series of working groups will be advanced into the future in several ways. First, we engage seagrass researchers and stakeholders from a diverse range of backgrounds, geographic regions, and disciplines in this common, collaborative effort. Second, we intend to develop courses with support from IODE Ocean Teacher Global Academy (OTGA) of the International Oceanographic Data and Information Exchange (IODE) to spread the protocols, best practices and synthesis tools in seagrass research to a global community. WG Member Eduardo Klein will liaise with the OTGA program to propose an OBIS course tailored for the seagrass community, with potential support from OTGA. Third, the several seagrass observation programs, including Seagrass-Watch, SeagrassNet, the Smithsonian-led MarineGEO program, and the MBON conduct training and outreach activities that will promote the best practices developed by the WG. Finally, development of the handbook and other products will also focus on feeding information into international targets such as the UN Sustainable Development Goals and Aichi Targets, as well as the post-2020 biodiversity agenda, with leadership by UNEP-WCMC.

7. Working Group Composition

Our Working Group brings together ten Full Members (5 female, 5 male), representing 9 countries, and a range of career stages and disciplinary expertise from seagrass biology to biogeochemistry, remote sensing, fisheries, social science, database architecture, and global conservation. Several Full and Associate Members are leaders in existing synthesis and coordination efforts in coastal marine and seagrass science. This diversity will help ensure that interdisciplinary products of the working group are effectively communicated to a wide audience and translated into practical applications.

7.1. Full Members

Name	Gender	Place of Work	Expertise
Emmett Duffy (co-chair)	M	Smithsonian Institution, USA	Marine ecology and biodiversity
Lauren Weatherdon (co-chair)	F	UN Environment World Conservation Monitoring Centre, UK	digital knowledge products, ocean biodiversity and spatial data

Rohani Ambo Rappe	F	Universitas Hasanuddin, Indonesia	Seagrass ecology, ecosystem services, seagrass restoration
Leanne Cullen-Unsworth	F	Cardiff University, Wales	Coupled social-ecological systems, seagrass ecosystem services
Miguel Fortes	M	University of the Philippines	Seagrass & mangrove ecology, blue carbon, policy & coastal resilience
Eduardo Klein	M	Universidad Simón Bolívar, Venezuela.	Marine ecology, data management, statistical/numerical methods for analysis of ecological data
Núria Marbà	F	Consejo Superior de Investigaciones Científicas, Spain	Seagrass ecology, global change
Frank Muller-Karger	M	University of South Florida, USA	Biological oceanography, remote sensing, global change
Masahiro Nakaoka	M	Hokkaido University, Japan	Coastal ecosystem dynamics, seagrass ecology
Jacqueline Uku	F	Kenya Marine and Fisheries Research Institute	Seagrass physiology, ecology, community development

7.2. Associate Members

Name	**Gender**	**Place of Work**	**Expertise**
Connolly, Rod	M	Griffith University, Australia	Seagrass ecosystem resilience, carbon pathways, fisheries food web
de la Torre Castro, Maricela	F	Stockholm University, Sweden	Social-ecological systems analysis, governance, gender, sustainable resource use, resilience
Dierssen, Heidi	F	University of Connecticut, USA	Remote sensing of seagrass extent, leaf area index, carbon

Fourqurean, James W.	M	Florida International University, USA	Ecosystem ecology, biogeochemistry of seagrass systems
McKenzie, Len	M	James Cook University, Australia	Seagrass status, management and sustainable use, founder Seagrass-Watch
Prathep, Anchana	F	Prince of Songkla University, Thailand	Seaweed and seagrass biodiversity and ecology; coastal climate change
Short, Fred	M	University of New Hampshire, USA	Seagrass ecology and restoration, founder SeagrassNet
Unsworth, Richard	M	Swansea University, Wales	Seagrass ecology, conservation, and ecosystem services, co-founder Project Seagrass

8. Working Group contributions

Emmett Duffy is a biodiversity scientist who founded the Zostera Experimental Network (ZEN) and is the first Director of the Smithsonian's Tennenbaum Marine Observatories Network and MarineGEO program. He is a member of MBON, the GOOS Biology and Ecosystem panel, and led development of the draft specification sheet for the GOOS seagrass EOV.

Rohani Ambo Rappe is a seagrass ecologist, studying ecosystem services and seagrass restoration, with expertise in the seagrass systems of the coral triangle region, the most diverse marine systems in the world.

Leanne Cullen-Unsworth is a coupled social-ecological systems analyst focusing on seagrass ecosystem services, in particular seagrass fisheries and associated food security.

Miguel D. Fortes is a coastal Ecologist, and specialist on Biodiversity, ICZM and Blue Carbon, focusing on seagrasses and mangroves. His works are major additions to seagrass science and policy in the tropics and are having major impacts in applications and in development of coastal resilience in the face of climate change and other environmental uncertainties.

Eduardo Klein is a marine ecologist, with extensive experience in environmental impact assessment, database architecture and standardized vocabularies, and statistical/numerical analysis. He is coordinator of the Caribbean Regional Node for OBIS, OBIS co-chair of the Steering Group, country representative for the UNESCO/IOC Caribbean Marine Atlas,

and Resource Person for the Convention on Biological Diversity Marine Program (Ecological and Biological Significant Areas EBSA, and Sustainable Ocean Initiative SOI programs).

Núria Marbà is a seagrass ecologist focusing on assessing sustainability and integrity of coastal ecosystems and ecosystem services as well as the impact of global change.

Frank Muller-Karger is a biological oceanographer with expertise in marine biodiversity, marine policy, public outreach, in situ observing systems, and ocean color in coastal and pelagic systems. He is Co-chair of the Marine Biodiversity Observation Network (MBON).

Masahiro Nakaoka is a marine ecologist studying coastal ecosystem dynamics, including seagrass ecosystem in Eastern and Southeastern Asia and the West Pacific. He is a member of the IUCN SSC Seagrass Specialist Group, the World Seagrass Association, and of the Zostera Experimental Network (ZEN).

Jacqueline Uku is a marine ecologist working on seagrass systems in Kenya and recently engaged in community development projects along the Kenyan Coast. She is current President and member of the Western Indian Ocean Marine Science Association (WIOMSA), providing linkage to the member countries of the Western Indian Ocean.

Lauren Weatherdon leads development of digital knowledge products that contribute to a step-change in global access to, and use of, ocean biodiversity information and spatial data. These products help to support the delivery of global ocean goals and targets, and to support marine spatial planning, conduct environmental impact assessments, produce ecosystem assessments, and enhance ocean literacy; she is also a member of MBON.

9. Relationship to other international programs and SCOR Working groups

The proposed WG has important relevance to several other interdisciplinary global change science efforts, to the science-policy-society interface and communication initiatives, and to other SCOR groups. These other efforts are not specifically focused on seagrasses and would benefit from the research advanced by this SCOR WG on seagrasses. Among these are the following. The OceanObs Research Coordination Network is an NSF-sponsored effort to advance the integration of biological observations into ocean observing systems for societal benefit, co-led by WG member Muller-Karger. The OceanObs'19 Program Committee is processing community proposals for white papers in governance for the Global Ocean Observing System within the Framework for Ocean Observing v. 2.0, and determining user requirements for ocean observing, technology, and scientific approaches to solutions through the OceanObs'19 meeting in Honolulu, Hawaii, September 2019. The Marine Biodiversity Observation Network (MBON) is a thematic program under the Group on Earth Observations Biodiversity Observation Network or GEO BON to strengthen understanding of marine biodiversity and coordinate monitoring of associated changes over time by defining marine Essential Biodiversity Variables or EBVs. The Global Ocean Observing System (GOOS) Bio-Eco Panel seeks to improve the availability of existing core biological variables and identify and prioritize additional cross-cutting biological and ecosystem observation needs by defining Essential Ocean Variables or

EOVs for biology and to integrate these with physical and biogeochemical EOV and observing programs. The SCOR Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs Working Group (P-OBS) has the goal of identifying measurements that can expand the number of observations of biological stocks, diversity, and rates or fluxes of planktonic organisms). Several members of the proposed C-GRAAS WG are closely involved in each of these efforts and will work to integrate the]WG's activities with their goals.

10. Key References

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11. Appendix—5 key publications for full members

Emmett Duffy

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