



The Global Integrated World Ocean Assessment: Linking Observations to Science and Policy Across Multiple Scales

Karen Evans^{1*}, Sanae Chiba², Maria J. Bebianno³, Carlos Garcia-Soto⁴, Henn Ojaveer⁵, Chul Park⁶, Renison Ruwa⁷, Alan J. Simcock⁸, C. T. Vu⁹ and Tymon Zielinski¹⁰

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*Correspondence:

Karen Evans
karen.evans@csiro.au

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¹ CSIRO Oceans and Atmosphere, Hobart, TAS, Australia, ² Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokosuka, Japan, ³ Centre of Marine and Environmental Research, University of Algarve, Faro, Portugal, ⁴ Spanish Institute of Oceanography, Santander, Spain, ⁵ Estonian Marine Institute, University of Tartu, Pärnu, Estonia, ⁶ Department of Oceanography, Chungnam National University, Daejeon, South Korea, ⁷ Kenya Marine and Fisheries Research Institute, Mombasa, Kenya, ⁸ Retired, Richmond, United Kingdom, ⁹ Hanoi University of Natural Resources and Environment, Hanoi, Vietnam, ¹⁰ Institute of Oceanology, Polish Academy of Sciences, Warsaw, Poland

In 2004, the United Nations (UN) General Assembly approved a Regular Process to report on the environmental, economic and social aspects of the world's ocean. The Regular Process for Global Reporting and Assessment of the State of the Marine Environment, including Socioeconomic Aspects produced the first global integrated assessment of the marine environment in December 2016 (known as the first World Ocean Assessment). The second assessment, to be delivered in December 2020, will build on the baselines included in the first assessment, with a focus on establishing trends in the marine environment with relevance to global reporting needs such as those associated with the UN Sustainable Development Goals. Central to the assessment process and its outputs are two components. First, is the utilization of ocean observation and monitoring outputs and research to temporally assess physical, chemical, biological, social, economic and cultural components of coastal and marine environments to establish their current state, impacts currently affecting coastal and marine environments, responses to those impacts and associated ongoing trends. Second, is the knowledge brokering of ocean observations and associated research to provide key information that can be utilized and applied to address management and policy needs at local, regional and global scales. Through identifying both knowledge gaps and capacity needs, the assessment process also provides direction to policy makers for the future development and deployment of sustained observation systems that are required for enhancing knowledge and supporting national aspirations associated with the sustainable development of coastal and marine ecosystems. Input from the ocean observation community, managers and policy makers is critical for ensuring that the vital information required for supporting the science policy interface

objectives of the Regular Process is included in the assessment. This community white paper discusses developments in linking ocean observations and science with policy achieved as part of the assessment process, and those required for providing strategic linkages into the future.

Keywords: marine environment, ocean observations, ocean-policy interface, ocean literacy, integrated assessment, sustainable development goals

INTRODUCTION

The ocean is vital to all life on Earth, providing countless benefits to humans, with these benefits termed “ecosystem services” (Costanza et al., 1997; Covich et al., 2004; Barbier, 2012). Some of the benefits provided by the ocean are delivered naturally and are known as regulating and supporting ecosystem services. Examples of these services include the functioning of the hydrological cycle, the absorption of carbon dioxide as part of the carbon cycle and the coastal protection offered by many coral reefs (Duke et al., 2007; Palumbi et al., 2009; Barbier, 2017). Other ecosystem services are obtained as a result of human activity to acquire the benefits and are termed provisioning ecosystem services. An obvious example of a provisioning service is the food provided by capture fisheries, which provides significant amounts of the animal protein in human diets – in some regions more than 50% (Hall et al., 2013; FAO, 2018). Globally, coastal and marine habitats have been estimated to provide over US\$14 trillion worth of ecosystem services per year (Costanza et al., 1997), however, the challenges in quantifying the value and economic benefits derived from such services mean that there are many varying values placed on services provided (see Barbier, 2012).

Recognizing that significant gaps exist in the understanding and management of ocean processes and trends, governments at the World Summit on Sustainable Development decided that a regular assessment of the oceans should be carried out (UNEP and IOC-UNESCO, 2009). The first Regular Process for Global Reporting and Assessment of the State of the Marine Environment, including Socioeconomic Aspects (known as the first World Ocean Assessment), approved by the United Nations General Assembly (see¹ for an overview of the process, its history and its outputs), reported that growing populations, economies and the agricultural and industrial requirements for feeding, clothing and housing the world’s population are seriously degrading parts of the marine environment, especially near the coast (United Nations [UN], 2016). For example, widespread development of coastal regions has resulted in habitat loss, pollution and overfishing (United Nations [UN], 2016; Frid and Caswell, 2017; FAO, 2018). In some cases, the utilization of marine ecosystems by humans and associated impacts have reduced the marine environment’s ability to provide the ecosystem goods and services we depend upon (Costanza et al., 2014; United Nations [UN], 2016). Further, activities on land and in river basins some distance from coastal zones have contributed to ocean

pollution and coastal habitat degradation. The assessment concluded that without an integrated, coordinated, proactive, cross-sectoral and science-based approach to coastal and marine management, the resilience of coastal and marine ecosystems and their ability to provide vital services will continue to be reduced (United Nations [UN], 2016).

The second World Ocean Assessment (WOA) is currently being prepared for delivery in late 2020. Given that baselines for many aspects of marine socio-economic and bio-geo-physical systems were provided in the first assessment, a key focus for the second WOA is to build on these baselines and provide an assessment of changes that may have occurred since the first WOA. A number of emerging and important topics that were not covered specifically in the first WOA have also been included in the second WOA (e.g., anthropogenic noise, cumulative impacts, marine spatial planning, management approaches) in an effort to provide a comprehensive update to the first assessment across the Drivers-Pressures-State-Impacts-Response framework (Smeets and Weterings, 1999) utilized by the Regular Process.

Central to being able to provide comprehensive assessments of the marine environment are two components. First, is the utilization of ocean observations, monitoring outputs and the research required to temporally assess components of coastal and marine environments to establish their current state, impacts on them, responses that might be implemented and ongoing trends. Second, is the knowledge brokering of ocean observations and associated research to provide key information that can be utilized and applied to address management and policy needs at local, regional and global scales. Through identifying both knowledge gaps and capacity needs, assessments should also provide direction to policy makers for the future development and deployment of sustained observation systems required for supporting national aspirations associated with the sustainable development of coastal and marine ecosystems.

Here, we provide an overview of the vital information relating to ocean observations that supports the science policy interface developed and provided by the Regular Process. We detail the requirements for supporting the ongoing improvement and development of assessments conducted by the Regular Process, and for providing strategic linkages between the science community and end-users into the future. Finally, we detail the utility of the Regular Process in helping to guide planning for the activities of the United Nations (UN) Decade of Ocean Science for Sustainable Development².

¹<https://www.un.org/regularprocess/>

²<https://en.unesco.org/ocean-decade>

ROLE OF OCEAN OBSERVATIONS IN THE WORLD OCEAN ASSESSMENT

Responding to changing and increasingly modified coastal and marine environments requires sufficient monitoring on relevant temporal and spatial scales, and an adaptive approach to management (Nicol et al., 2015; Constable et al., 2016). Adaptation of industries and activities to future environments and mitigation of possible impacts requires a capability to assess:

- the dynamics of coastal and marine ecosystems in response to variability in the marine environment over short, medium and longer time scales, including the key environmental drivers that influence the functional components of ecosystems;
- the responses of coastal and marine ecosystems to projected future changes to the Earth system and;
- the nature and extent of human activities occurring in coastal and marine environments and the sensitivity of coastal and marine ecosystems to singular and cumulative impacts of the activities interacting with them.

Central to the capability required for undertaking assessments of the marine environment and the impacts caused by human stressors is the collection of long time-series data from locations dispersed throughout the marine environment. This includes measurements of oceanography, biogeochemistry, marine soundscapes and species, communities and habitats, the varied means by which ocean resources are used and the cultural role that the ocean provides to human society (e.g., Nicol et al., 2012; Moore and Gulland, 2014; Addison et al., 2015; Erbe et al., 2015; Lynch et al., 2014; Evans et al., 2018). Also key to supporting the coordination of activities are data management systems that make such time series publicly available (e.g., the Ocean Biogeographical Information System (OBIS³) and systems for modeling and analyzing marine variables to support the investigation of future potential states, the interactions between marine activities and development of appropriate management strategies (e.g., Fulton et al., 2011; IPCC, 2014; Plagányi et al., 2014; Ortiz et al., 2016; Gattuso et al., 2018). Importantly, a capacity to then transform those sustained ocean observations into information that can support decision-making is needed.

The Regular Process provides an important pathway for the transformation of ocean observations into information that can be useful for decision makers at local, regional and global scales. It does this predominantly by tasking expert teams comprised of ocean scientists (across the fields of physics, chemistry, biology, socio-economics and humanities), managers, regulators and policy makers to synthesize published open access information to provide the state and trends of important environmental features and values over time, current use of the ocean environments and impacts created by that use. Further input to the process by the wider community is facilitated through regional workshops, a stakeholder dialogue and a peer

review process. The finalized assessment is provided in two formats, the first a detailed summary of the current global state and the second a series of technical abstracts detailing topical domain areas that are specifically aimed at policy makers. The first WOA produced technical abstracts that were focused on findings relevant to climate change, biodiversity in areas beyond national jurisdiction and the UN Sustainable Development Goals (SDGs)⁴.

Extensive work has been undertaken over the last couple of decades expand and better focus sustained observations of coastal and marine environments under formal frameworks at local, regional and global scales (e.g., Meredith et al., 2013; Lynch et al., 2014; Miloslavich et al., 2018a; POGO, 2018). In association, substantial work has been put into providing the supporting frameworks and mechanisms for providing access to those observations (e.g., Claustre et al., 2010; Proctor et al., 2010; Costello and Wieczorek, 2014). These efforts have contributed substantially to the capacity of those involved in the Regular Process to access datasets required for assessments included in the WOA. Further, the substantial progress in synthesizing observations at global scales into scientific understanding of ocean processes, (e.g., Dickey, 2003; Keeling et al., 2010; Chavez et al., 2011; Cheung et al., 2013; Harrison and Chiodi, 2015; Pecl et al., 2017) and activities (e.g., Halpern et al., 2008, 2017; OECD, 2016; FAO, 2018), particularly through modeling frameworks, has significantly supported the capacity of the Regular Process to provide a global perspective on the state of the ocean and the impacts of current activities. In addition, scientists and society have created an avenue for open dialogue with the emergence of citizen science⁵. In many regions, citizen science is providing support to scientific programs using technological advancements, state-of-the-art observation systems and analytical tools, as well as open sharing and exchange of information, further expanding ocean observations and understanding of ocean processes (e.g., Stockmayer and Bryant, 2012; Trouille et al., 2019).

IMPROVEMENT AND DEVELOPMENT OF THE WORLD OCEAN ASSESSMENT

The number of components or processes that can be monitored in the marine environment, however, is endless, particularly when considering the ocean from a whole of system perspective (that is it's physical, chemical, biological, socio-economic and cultural elements). Despite significant progress in the establishment of ocean observation networks, associated capacity development and improved modeling and reporting processes, there are still fundamental gaps in observations and significant limitations in accessing comprehensive and timely ocean information. These continue to limit our understanding of ocean processes and activities across multiple spatial and temporal scales. Many of these gaps and limitations were detailed in the first WOA (see United Nations [UN], 2016) and similarly, these continue to be identified under other assessments across local, regional and

³<http://www.iobis.org/>

⁴<https://www.un.org/regularprocess/content/technical-abstracts>

⁵<https://www.citizenzenice.org/>

global scales (e.g., BOBLME, 2014; UNEP-NAIROBI Convention and WIOMSA, 2015; IOC-UNESCO and UNEP, 2016; Ministry for the Environment and Statistics New Zealand, 2016; Evans et al., 2017).

Prioritizing what, when and how components of the marine ecosystem are monitored is essential if scientific data are to support marine managers in the changing and increasingly complicated environment they find themselves in. Initiatives such as the Framework of Ocean Observing (FOO; UNESCO, 2012) are assisting this prioritization process through three Global Ocean Observing System (GOOS) panels (the Climate and Physical Oceanography panel, the Biogeochemistry panel and the Biology and Ecosystems panel). These panels have been tasked with identifying a number of environment and ecosystem focused Essential Ocean Variables toward which global monitoring efforts should be focused over sustained time frames. This identification process has been based on the extent of societal importance of each variable and feasibility in implementation of observation. International observation networks, such as the International Quiet Ocean Experiment (Boyd et al., 2011) and Global Ocean Acidification Observing Network (Newton et al., 2015) are also developing frameworks for identifying variables for monitoring. Further, a number of targeted activities aimed at identifying environmental variables for various scientific and management purposes have been conducted globally (e.g., Cury and Christensen, 2005; Fabricius et al., 2012; Hayes et al., 2015). These networks and activities are specifying the methods associated with monitoring of variables, with the objectives of supporting assessments of the marine environment and informing management of the use of the marine environment. Continued development of these observation frameworks will provide ongoing opportunities for uptake into the assessments conducted under the Regular Process and in association, continued improvement of the WOA.

One of the main aims of the FOO is the international integration and coordination of interdisciplinary ocean observations. This is being facilitated through the streamlining of processes associated with the identification of societal demands, the collection of ocean observations, the analyses and assessment of those data and the sharing of information with policy makers, thereby building a pathway for the transfer of the knowledge created through observations to society. At present however, while great efforts have been placed into ocean observations and their analyses, including building global models from the integration of point sources of data, a clear protocol linking data outputs to policy development and implementation remains unidentified. By providing a clear avenue for delivery of ocean observations to policy makers, the WOA can play a role to assist with this key knowledge brokering component of the FOOs aims: data to information for policy needs. Strengthening the communication links and opportunities for input into the Regular Process would serve to ensure that these pathways are identified and established. One potential avenue for facilitating a strengthening of communication links and opportunities is through UN Oceans⁶, an inter-agency mechanism that

aims to strengthen and promote coordination and coherence of UN system activities related to ocean and coastal areas. Embedding the Regular Process as a mechanism for linking data outputs to policy development and implementation within UN Oceans would assist in achieving the FOOs aims, whilst also ensuring that data inputs into the assessment process are maximized.

Most observation networks however, do not extend into economic, social and cultural aspects of the ocean and as a consequence, focused, sustained and publically accessible observations of these aspects of marine systems in standardized formats at regional and global scales are lacking (noting that some socio-economic indicators have been developed for specific locations and management purposes – see for example Rey-Valette et al., 2005; Foley et al., 2014). One area in which there are exceptions is fisheries and aquaculture, where regular reporting of some aspects of the socio-economics of these activities occurs at regional and global scales (e.g., FAO, 2018). Compiling economic, social and cultural information into useable formats for inclusion within an assessment framework (including extracting ocean based components from overall reporting across terrestrial and marine systems) for synthesizing at global scales requires considerable effort, often beyond the ability of those individuals or groups of individuals involved in contributing to assessments under the Regular Process. This is a clear area where extension of current observation frameworks to incorporate sustained and standardized monitoring of economic, social and cultural aspects of the ocean would significantly improve assessments undertaken under the Regular Process. There is an aim for variables being developed under the Biology and Ecosystems panel to extend to pressures placed on marine ecosystems by human activities (in the first instance this might include ocean noise and marine debris including plastics). The outputs from the Regular Process could assist in guiding the process for identifying such variables, and in doing so, can provide a pathway for further improvements to the observations contributing to the WOA.

For the second WOA, the Regular Process has expanded opportunities for the exchange of information and input into the assessment by incorporating two rounds of regional workshops, held in 2017 and 2018, and a stakeholder dialogue and capacity building event held in 2019 (see⁷ for outputs from the workshops and⁸ for outputs from the stakeholder dialogue and capacity building event). These meetings have provided platforms for widespread regional input into the process by science, management and policy communities and facilitated increased awareness of activities and outputs of relevance across ocean regions. In particular, the workshops and dialogue event have highlighted the challenges associated with contributing to the assessments of the Regular Process within ocean regions, particularly in resourcing contributors and the coordination of local and regional inputs to the process for synthesis at the global level. Highlighting these challenges has provided

⁶<http://www.unoceans.org/>

⁷<https://www.un.org/regularprocess/content/second-round-regional-workshops>

⁸<https://www.un.org/regularprocess/content/multi-stakeholders>

clear guidance to the Regular Process on current gaps in ocean observations used to support assessments and where action is needed to develop global capacity for supporting the collection, analyses and interpretation ocean observations (summarized in the first WOA – see United Nations [UN], 2016). This adds to assessments of current capacity gaps in ocean observations and associated ocean science provided in the Global Ocean Science Report (UNESCO, 2017) and detailed in numerous publications (e.g., see Koslow and Couture, 2015; Buch et al., 2017; Bax et al., 2018; Ludwigsen et al., 2018; Miloslavich et al., 2018b; POGO, 2018).

Developing the knowledge to fill current gaps in ocean observations and the science supporting the assessment is an ongoing challenge. It will require coordinated efforts to identify and develop the capacity to meet scientific, technological, and communication needs across spatial and temporal scales relevant for assessment and sustainable management of the marine environment (United Nations [UN], 2016). It will also require current calls to support pathways for capacity building to be recognized and met by individual countries and their scientific, education and management agencies. The development of scientific, technological and communication capacity required to support sustainable marine management and processes such as the WOA, GOOS, the UN SDGs and others will require long-term, sustained partnerships, built on mutual commitment, trust and investment.

Achieving widespread understanding of the need and commitment to long-term, sustained partnerships that support capacity and capability building requires that all aspects of society has a clear understanding of the value of the services provided by the ocean, current impacts on those services and the strategies required to achieve a sustainable future. It is recognized that the science community needs to move beyond the collection of data and publication of their research results in peer literature, formats that are not easy to “digest” by most of society. Further, strengthening of the pathways for transformation of ocean observations into information that can be understandable and therefore useful for decision makers at multiple spatial scales, should consider how best to communicate the outputs of assessments to society.

Programs focused on developing frameworks for improving ocean literacy provide an avenue for formal and informal educators to engage and educate society on ocean system issues (see UNESCO, 2005; National Geographic Society [NGS] et al., 2005; Dupont and Fauville, 2017). These frameworks for ocean literacy serve as a platform for inspiring people in ocean research and beyond (Bray et al., 2012; Trouille et al., 2019). When particularly targeted at younger age groups, this promotes an increased understanding by those that will contribute to the next generation of scientists, managers, policy makers, and those involved in business and industry. This therefore provides the opportunity for facilitating a step change in the way in which the ocean is valued and used. Many initiatives have been launched in order to increase societal awareness of the ocean and ocean ecosystems. These include government led initiatives such as the European Commission

programs and projects Sea for Society⁹, Sea Change¹⁰ and MARINA¹¹, and those led by non-governmental organizations such as the Ocean Sanctuary Alliance¹², World Ocean Network¹³ and World Ocean Observatory¹⁴. Business associations focused on identifying and implementing sustainable practices and guiding future investment such as the UN Global Compact¹⁵, particularly through the Action Platform for Sustainable Ocean Business and the World Ocean Council¹⁶ also provide the opportunity for the development of direct communication pathways and avenues for engagement to better inform and engage society on ocean system issues identified by the Regular Process.

STRATEGIC LINKAGES TO THE UNITED NATIONS DECADE OF OCEAN SCIENCE FOR SUSTAINABLE DEVELOPMENT

The United Nations’ General Assembly (UN-GA) decided that the Regular Process should not undertake any policy analysis or make any recommendations on policy or management. By approving the Summary of the Assessment however, the UN-GA, representing the world’s governments, has indicated that it accepts that the gaps in knowledge and capacity identified in the first WOA exist. Identifying a prioritization process for filling knowledge gaps and building capacity is an urgent task and one that the global community could be tasked with under the UN Decade of Ocean Science for Sustainable Development (the Decade) as a useful step in progressing the collection, analyses and interpretation of ocean observations.

Key to ensuring the uptake and utilization of the WOA in bridging science with policy will be the establishment of strategic linkages that not only provide pathways for access to and utilization of datasets for conducting analyses at global scales, but also provide for the establishment of networks amongst science, management and policy communities. Development of linkages and networks is critical for ensuring that key science-based information on marine systems can be accessed in useful formats by policy makers for future sustainable use of the marine environment. They are also key for ensuring that the resources required for supporting national aspirations associated with the sustainable development of coastal and marine ecosystems, including the sustained observation systems, are identified and implemented.

Just as the Census of Marine Life (see Williams et al., 2010), provided an opportunity to bring researchers together to facilitate

⁹<http://seaforsociety.eu>

¹⁰<http://www.seachangeproject.eu/>

¹¹<https://www.marinaproject.eu/>

¹²<https://www.oceansanctuaryalliance.org>

¹³<https://www.worldoceannetwork.org>

¹⁴<http://worldoceanobservatory.org>

¹⁵<https://www.unglobalcompact.org/>

¹⁶<https://www.oceancouncil.org/>

a step change in our understanding of the world's marine biodiversity, the Decade provides an opportunity to progress the development of a science policy interface for sustainable use of the global ocean. Implementation of infrastructure that supports the transfer of observations of the physical, biogeochemical, ecological, economic, social and cultural components of the oceans into planning and policy development formats will increase the likelihood that scientific evidence will be used in policy and management decision making. This will have the overall effect of increasing the success of those decisions in meeting their objectives, particularly in relation to the sustainable development of ocean resource and conservation of ecosystem services.

Planning for the Decade is underway with an initial roadmap developed to help guide the planning process (available at¹⁷). This document explicitly identifies the role the first WOA has had in identifying changes and losses in the structure, function and benefits obtained from marine systems and that action is clearly required in addressing these declines and losses. It also clearly articulates the role the Decade can have in significantly contributing to the understanding of ocean processes and activities and the way we manage cooperation and partnerships in support of sustainable development and a healthy ocean. Further, it details that the Decade should aim to address identified knowledge gaps and strengthen the conduct of the WOA, thereby identifying the potential improvements the Decade can provide to assessments under the Regular Process. Establishment of clear linkages between the Decade and the Regular Process, particularly during the planning process will ensure that these aims are achieved and future ongoing improvement of the WOA is facilitated.

¹⁷<https://en.unesco.org/ocean-decade/resources>

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CONCLUSION

By providing a global perspective on the current state of the marine environment, its use and impacts affecting its functioning, the WOA provides a key link for facilitating knowledge transfer across the science-policy interface for decision making on ocean issues. In providing this link, the WOA plays an essential role in assisting initiatives such as the FOO in achieving their aims. Strengthening of the knowledge brokering role of the WOA and in particular, addressing knowledge gaps will rely on building communication links and opportunities for input into the Regular Process. It will also rely on developing the capacity to meet scientific, technological, and communication needs across spatial and temporal scales relevant for the assessment. The UN Decade of Ocean Science for Sustainable Development provides an opportunity to progress the capacity development needed and strengthen the science policy interface required for sustainable use of the global ocean. Establishment of clear linkages between the Regular Process, the Decade and initiatives such as FOO will facilitate the enhanced understanding of ocean processes, activities and decision making required to support sustainable development, whilst maintaining a healthy ocean into the future.

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KE and SC developed the concept for the manuscript. All authors wrote the manuscript.

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