



Transferring Complex Scientific Knowledge to Useable Products for Society: The Role of the Global Integrated Ocean Assessment and Challenges in the Effective Delivery of Ocean Knowledge

Karen Evans^{1*}, Tymon Zielinski², S. Chiba³, Carlos Garcia-Soto^{4,5}, Henn Ojaveer⁶, Chul Park⁷, Renison Ruwa⁸, Jörn Oliver Schmidt^{9,10}, Alan Simcock¹¹, Anastasia Strati¹² and Ca Thanh Vu¹³

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*Correspondence:

Karen Evans
karenevans@csiro.au

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¹CSIRO Oceans and Atmosphere, Hobart, TAS, Australia, ²Institute of Oceanology Polish Academy of Sciences, Sopot, Poland, ³Japan Agency for Marine-Earth Science and Technology, Yokosuka, Japan, ⁴Spanish National Research Council, Santander, Spain, ⁵University of the Basque Country, Plentzia, Spain, ⁶Pärnu College, University of Tartu, Pärnu, Estonia, ⁷Department of Oceanography, Chungnam National University, Daejeon, Korea, ⁸Marine and Fisheries Research Institute, Mombasa, Kenya, ⁹Science Committee, International Council for the Exploration of the Sea, Copenhagen, Denmark, ¹⁰Center for Ocean and Society, Kiel University, Kiel, Germany, ¹¹Independent Researcher, Richmon-Upon-Thames, Richmond, United Kingdom, ¹²Ministry of Foreign Affairs, Athens, Greece, ¹³Faculty of Environment, Ha Noi University of Natural Resources and Environment, Ha Noi, Vietnam

The ocean provides essential services to human wellbeing through climate regulation, provision of food, energy and livelihoods, protection of communities and nurturing of social and cultural values. Yet despite the ocean's key role for all life, it is failing as a result of unsustainable human practices. The first global integrated assessment of the marine environment, produced by the United Nations under The Regular Process for Global Reporting and Assessment of the State of the Marine Environment, including Socioeconomic Aspects (the World Ocean Assessment), identified an overall decline in ocean health. The second assessment, launched in April 2021, although recognising some bright spots and improvements, stresses ongoing decline in the ocean as a result of many unabated anthropogenic stressors on the ocean. This highlights that society, as a whole, does not fully recognise or value the importance of the ocean to their lives and impacts on the ocean caused by human activities. Further, recognition of the need for immediate and effective solutions for mitigating impacts and enabling ecosystem recovery, and the associated societal changes required is lacking. The United Nations 2030 Agenda for Sustainable Development and the United Nations Decade of Ocean Science for Sustainable Development 2021–2030 both recognize that sustainability is both a desired and essential pathway for ensuring the ocean can continue to provide the services society depends on. The World Ocean Assessment has an important role to play in increasing awareness of the ocean, the changes occurring in the ocean, the human activities causing those changes and the progress being made in reducing and mitigating the impacts of human activities on the marine environment. This paper outlines the

knowledge brokering role that the Regular Process provides on ocean issues to all aspects of society from policy makers, ocean managers, ocean users to the public. It identifies the challenges faced by the Regular Process in successfully carrying out that role and lessons learned in achieving widespread uptake and recognition. Within the Decade of Ocean Science for Sustainable Development, solutions in the form of instructions or guidelines for the use of the assessment can be developed and implemented.

Keywords: world ocean assessment, ocean literacy, science-policy interface, sustainable development goals, ocean management

INTRODUCTION

Background to the World Ocean Assessment

The ocean supports all life on Earth. It provides essential services to the wellbeing of all of humankind by regulating our climate, storing carbon, producing oxygen, providing food, mineral and energy sources and nurturing social and cultural values (Pendleton et al., 2020). It has facilitated global economies for centuries *via* trade routes and is the basis for the fastest growing economy—the blue economy—expected to contribute over US\$3 trillion to the global economy over the next 10 years (OECD 2016). However, an important constraint on this growth is the ongoing deterioration of the ocean caused by the pressures already being placed on it through human use (United Nations 2017; United Nations 2021).

In 2002, leaders from government, non-governmental organisations, business and other international organisations attending the World Summit on Sustainable Development recognized that significant gaps and challenges existed in the understanding of ocean processes and trends, and in achieving sustainable outcomes for the ocean within the context of increasing populations and associated demands on its services (United Nations 2002). They agreed to increase scientific and technical collaboration, including expanding ocean-observing capabilities for the timely prediction and assessment of the state of marine environment and in doing so, establish a regular process for global reporting for an integrated assessment which should include socio-economic aspects (United Nations 2002). Importantly, it was recognized that prior to this point there had been no framework or process for providing an integrated view of the global state of the ocean (Feary et al., 2014). In initiating the Regular Process, the United Nations (UN) General Assembly launched an “Assessment of Assessments” in 2003 (UNEP and IOC-UNESCO, 2009) and by 2009 a framework for a Regular Process for Global Reporting and Assessment of the State of the Marine Environment, including Socioeconomic Aspects was adopted (United Nations 2010).

The first cycle of the Regular Process was conducted over 2010–2015, during which the first global integrated marine assessment (the first world ocean assessment) was produced (United Nations 2017). This assessment constituted the first comprehensive global overview of the state of the ocean and the relationships between the ocean and humans, covering environmental, social and economic aspects. This first

assessment identified that parts of the marine environment, especially near the coast were seriously degraded and that there had been an overall decline in the state of the ocean. The assessment identified that the ability of the ocean to provide vital services to society, and the Earth as a whole, would continue to be reduced without an integrated, coordinated, proactive, cross-sectoral and science-based approach to coastal and marine management (United Nations 2017). The second assessment, launched in April 2021, although recognising some improvements in some sectors and some regions, also identifies ongoing decline in many aspects of the ocean as a result of the many unabated pressures humans are placing on the ocean (United Nations 2021). These findings are in line with other recent reports on the state of the Earth’s climate, ocean and biodiversity (IPBES net al., 2019; IPCC et al., 2019; CBD 2020). This highlights that society, as a whole, does not fully appreciate the role of the ocean in sustaining their lives or have full awareness of the impacts of current human activities and behaviours on the ocean. It also suggests that society does not fully understand the urgent need for innovative and effective solutions for mitigating impacts and the behavioural changes required to reduce stressors on the environment and facilitate a sustainable ocean future (McCauley et al., 2019; Kelly et al., 2021; Pendleton et al., 2020). The second world ocean assessment further highlights some of the current barriers to implementing such solutions, including significant constraints on resource capacity, including financial capacity, and technological capacity. The lack of access to the required knowledge, appropriate tools and skilled human resources needed for ocean management remains a significant constraint for the protection and conservation of the marine environment in many regions. Significant effort is needed in overcoming challenges to ensuring inclusive participation of countries in international instruments, strengthening intersectoral cooperation, ensuring coordination and information-sharing at all levels and developing new instruments to address emerging challenges in a timely fashion (United Nations 2021).

Relevance of the World Ocean Assessment to International Processes

The Regular Process is facilitated by the UN Division for Ocean Affairs and the Law of the Sea (DOALOS; <https://www.un.org/Depts/los/index.htm>) and therefore has direct linkages with the UN Convention on the Law of the Sea (UNCLOS) which sets out

the legal framework within which all activities in the oceans and seas must be carried out. It is recognized by the General Assembly in contributing to the provision of scientific information that supports the 2030 Agenda for Sustainable Development (<https://sustainabledevelopment.un.org/>), the development of an international legally binding instrument under UNCLOS on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction (<https://www.un.org/bbnj/>), the United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea (https://www.un.org/Depts/los/consultative_process/consultative_process.htm) and the United Nations Framework Convention on Climate Change process (<https://unfccc.int/>). In doing so, the Regular Process aligns with the activities of the Convention on Biological Diversity (CBD; <https://www.cbd.int/>), the Intergovernmental Panel on Climate Change (IPCC; <https://www.ipcc.ch/>) and the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES; <https://ipbes.net/>). Key outputs from processes such as those conducted by the IPCC and IPBES, as well as those produced through reporting mechanisms associated with various conventions such as those under the International Maritime Organisation (<https://www.imo.org/en/About/Conventions/Pages/ListOfConventions.aspx>) and international and regional commissions such as those of the International Union for Conservation of Nature (<https://www.iucn.org/about/union/commissions>) are integrated into the World Ocean Assessment and there has been an exchange of contributors across reports produced by each. Importantly, the Regular Process provides primary information specifically relating to the ocean that is either under-represented or missing from these outputs, particularly as a result of the interdisciplinary approach to the assessment and inclusion of social and economic aspects, and therefore provides a mechanism for informing initiatives carried out by these bodies.

Important outputs from the first cycle included three technical abstracts that distilled the content of the first assessment into useable information focused around climate change, biodiversity in areas beyond national jurisdiction and the sustainable development goals (SDGs), in particular, SDG 14 Life Below Water. The content of the first assessment itself and the series of technical abstracts raised the profile of the declining state of the ocean both within the UN and beyond and is recognized as informing action on SDG14 (Fawkes and Cummins 2019). This first assessment has been recognized as informing the development of a proposal to the UN General Assembly by the Intergovernmental Oceanographic Commission (IOC) for a Decade of Ocean Science for Sustainable Development (an “ocean decade”). This ocean decade was proclaimed by the UN in 2017, began in January 2021 and will run through to the end of 2030 (www.oceandecade.org). The implementation plan for the ocean decade identifies an overarching aim “to catalyse transformative ocean science solutions for sustainable development, connecting people and our ocean” (IOC-UNESCO 2020).

The World Ocean Assessment has the potential to provide a benchmark reporting mechanism for this ocean decade and the success of efforts conducted under the decade in reversing

declines in the state of the ocean and its ecosystems and transforming human use to sustainable practices. The second World Ocean Assessment provides an overview of the state of the global ocean at the start of the ocean decade, the third World Ocean Assessment to be delivered in 2026, has the potential to provide a mid-way report and the fourth World Ocean Assessment, to be delivered after the finalization of the ocean decade could provide an overview of change that might have occurred as a result of the efforts conducted throughout the decade. These assessments could also provide a mechanism for identifying where knowledge and capacity gaps remain and where efforts made during the decade need to be focused.

Here, we outline the knowledge brokering role that the Regular Process provides on ocean issues, the challenges faced by the Regular Process in successfully carrying out that role, lessons learned during the first assessment in achieving widespread uptake and recognition and potential solutions that could be implemented in future assessments.

OCEAN AWARENESS AND UNDERSTANDING AND THE ROLE OF THE WORLD OCEAN ASSESSMENT

The Need for Increasing Awareness and Understanding and Challenges

Key to achieving the targets of the SDGs and in particular, those of SDG14 and the aims of the ocean decade, will be improving societal overall awareness and understanding of the ocean. This will require all parts of society (from communities to business to government) understanding and being capable of discussing the role of the ocean in supporting life on Earth, the reliance of society on the ocean for provisioning services and wellbeing and the impacts of current human behavior on the ocean [i.e. improving ocean literacy; see Schoedinger et al. (2010), Kelly et al. (2021) for a comprehensive overview of current approaches to ocean literacy and steps for improving ocean literacy]. It will also require society to then utilise that understanding to undertake informed decision making and implement behavioural changes required to halt and reverse impacts on the ocean (Schoedinger et al., 2005; Fauville et al., 2019).

One of the key challenges in engaging society with the ocean, is a lack of connectedness to the ocean. Although nearly 2.5 billion people live within 100 km of the coast (UNDESA, 2019) and coastal regions are experiencing higher rates of population growth and urbanization than inland regions (Neumann et al., 2015), much of the world’s population only spend a limited part of their life experiencing ocean environments (Cigliano et al., 2015). Increasing urbanisation is resulting in reduced access to the ocean (Roy et al., 2018). Modern lifestyles and technologies are leading to people spending time indoors rather than outside in the natural environment (Basile, 2016; Truong and Clayton, 2020), leading to a movement away from and a loss of cultural practices that might connect people to the ocean (Komugabe-Dixson et al., 2019). This disconnectedness is strongly associated with poor awareness and understanding of ocean issues (McKinley and Fletcher 2010). Personal

connectedness builds a responsibility or value system that is crucial in the process of behavioral change since knowledge and awareness are usually not sufficient for establishing a change in attitudes (Stoll-Kleemann, 2019).

In order to address these challenges and create the societal behavioural changes required for a future healthy, productive and sustainable ocean, innovative ways to share information and build knowledge and connectedness are needed. Effective connections between knowledge generators, including those in formal areas such as researchers, engineers, scholars, as well as less formal areas such as traditional owners, indigenous and first nations peoples with business, industry, government and all sectors of society will need to be built (Pendleton et al., 2020). Overall ocean literacy needs to be raised across all parts of society, including those making decisions that affect the ocean (Kelly et al., 2021). Extending ocean literacy programs and integrating these into school curricula across the world, coupled with the inclusion and nurturing of natural spaces in schools will assist with building a generation that values the ocean. Importantly it will engender an increased awareness in the next generation of decision makers, business leaders and societal catalysers.

The World Ocean Assessment: Provision of Information

The main outputs of the Regular Process, the World Ocean Assessments, provide a pathway for the sharing of ocean information and knowledge with society and provide both a global perspective on the current state of the ocean as well as more focused regional perspectives. During each assessment cycle, teams of volunteer experts including ocean scientists (across the fields of natural sciences, economics and humanities), managers, regulators and policy makers are brought together to provide such perspectives on key topic areas ranging from the state of species and habitats, ocean industries and ocean science, ocean values and community connections and planning and management approaches. Each team is tasked with synthesising current published and publicly available information to provide the state and trends of important ocean features and values over time, use of ocean environments by society and impacts created by that use (Evans et al., 2019). Further input into information gathering and development of content of the assessment by a wider group of scientists, managers, regulators and policy makers is facilitated through regional workshops, a stakeholder dialogue, a peer review process and then review by the member states of the UN. Through this process, the assessment serves the purpose of distilling complex, technical information on a wide range of ocean topics from many sources, information that is often beyond the reach of decision makers and the majority of the public population, and present it in formats that can be utilized more broadly. Production of technical abstracts (produced in association with the first assessment) and policy-relevant briefs, webinars and a web series of short expert interviews (being produced in association with the second assessment) allow for information focused around topical issues to be further distilled and

provided in short formats for easier access and use. Through the production of regular assessments, with succeeding assessments focused on providing information on change since the previous assessment, the regular process provides information on how the ocean is changing, in what way and at what speed that is regularly updated through time.

Early assessments of the reach of the first world ocean assessment have identified that its' content has primarily been used for coastal and marine research, academic purposes, including input into curricula, policy development and awareness raising activities (Fawkes and Cummins 2019). Further, the workshops conducted as part of the first cycle have been identified as facilitating connections and collaborations between ocean disciplines (Fawkes and Cummins 2019). Information from the first World Ocean Assessment has been summarized across many media platforms and features on the websites of UN agencies (e.g. <https://ioc.unesco.org/our-work/first-world-ocean-assessment>), national, regional and international ocean focused programmes (e.g. <https://pipap.sprep.org/content/first-world-ocean-assessment-united-nations>), and ocean information and communication initiatives (e.g. <https://worldoceanobservatory.org/index.php?q=content/un-world-ocean-assessment>; <https://www.grida.no/publications/314>). At the time of writing, just after the launch of the second world assessment, information has already been distilled and featured by a number of research programmes (<https://www.futureearthcoasts.org/second-world-ocean-assessment/>), agencies (e.g. <https://ecos.csiro.au/second-world-ocean-assessment-is-a-float/>) and sustainability initiatives (e.g. <https://www.msc.org/media-centre/news-opinion/news/2021/04/21/5-things-we-learned-from-the-un-world-ocean-assessment-ii-report>).

The assessments carried out under the Regular Process, at this point in time, do not actively implement recognized drivers influencing ocean awareness and understanding [described in Kelly et al. (2021)], including education, cultural connections, technological developments and knowledge exchange and science-policy connections. However, they do provide key resource tools along with the associated abstracts and policy brief and web series, that can be employed as part of frameworks aimed at improving ocean awareness and understanding (i.e. provides an important component of the toolbox for ocean literacy outlined in Kelly et al., 2021). In providing such a resource, the Regular Process facilitates a bridging of the science-policy interface by collating and distilling technical scientific and industry knowledge into accessible and understandable formats (Bayliss-Brown and Ní Cheallacháin 2016; Fernández Otero et al., 2019).

IMPROVING THE VALUE AND REACH OF THE WORLD OCEAN ASSESSMENT—CHALLENGES AND LESSONS LEARNED

The Regular Process, having just launched its second World Ocean Assessment, can still be regarded as a relatively new

undertaking, particularly when compared to other global assessments such as those produced by the IPCC, established in 1988 [see Agrawala (1998)] and in the process of producing its sixth assessment report. The Regular Process has been constrained by many of the challenges faced by the IPCC across its first two assessments, including budgetary limitations (there was no specific budget assigned to the Regular Process in its first cycle), insufficient mechanisms for facilitating the assessment, differing levels of disciplinary and regional coverage and cohesion across chapters, and varying levels of community awareness and credibility (Agrawala 1998; Fawkes and Cummins 2019). As has been the case with the IPCC, there are lessons to be learned from both the first and second cycle of the Regular Process that can be used to further improve future assessments, particularly the contribution of the assessment to bridging the science policy interface and improving societal ocean awareness and understanding.

It is widely recognized that when assessments are carried out over recurrent processes, there are useful opportunities for learning from past experience to improve procedures and enhance the effectiveness of those assessments in bridging the science policy interface (Siebenhüner 2002). The Regular Process has built a process of capturing some of the lessons learned during each cycle in an effort to improve the process and subsequent assessments. In the first cycle this comprised input from Member States of the UN, participants in the Ad Hoc Working Group of the Whole (the body that oversees and guides the Regular Process comprised of UN Member State representatives), the Secretariat to the Regular Process (DOALOS) and the joint coordinators of the Group of Experts to the Regular Process (the group that coordinates and is responsible for the writing of the assessment). This was expanded in the second cycle to also include feedback from the writing teams and peer reviewers involved in the second World Ocean Assessment. Based on the feedback provided through this process, there are three areas where improvements could be made to enhance the role of the World Ocean Assessment in increasing overall societal ocean awareness and understanding and bridging science-policy gaps.

Strengthening of Credibility Within the Ocean Community

In linking scientific information to policy decision making, assessments must be both credible and relevant (Keller 2010). The broad scope of the World Ocean Assessment, particularly in providing an interdisciplinary approach that includes not only environmental, but also social and economic aspects of the global ocean combined with the voluntary nature of contributions presents clear challenges in attracting experts not only to identify themselves to the Regular Process, but also to actively contribute to chapters throughout the Process. The Regular Process also relies on Member States to identify and nominate experts. In many cases this is managed either by representatives to the UN or associated government agencies, many of which are not adequately linked to the scientific community or don't have sufficient understanding of the interdisciplinarity required for effective facilitation of the assessment. This has resulted a lack of

awareness of the Regular Process within the wide expertise it needs to engage with (scientists from many disciplines, economists, engineers, managers, regulators, policy makers) and a lack of clarity of the processes for input by these communities. As a consequence, writing teams contributing to both the first and second World Ocean Assessment have often been uneven in their disciplinary and regional coverage. An outcome of unbalanced contributions to writing teams is that chapters have varied in their scope, the degree to which they have covered the diverse range of topics and the extent to which complex scientific information was integrated across disciplines and delivered. This has led to varying perceptions of overall legitimacy and credibility amongst the ocean community (Fawkes and Cummins 2019). While similar variable contributions were noted in the first IPCC assessment (Siebenhüner, 2002; Hirst, 2014), other assessments such as IPBES have largely been successful in developing multi-disciplinary teams (Beck et al., 2014), particularly when well resourced.

Efforts to ensure greater participation in the writing teams have included an expansion of the number of workshops conducted throughout the process, the focusing of a proportion of the workshops around specific topics of the assessment and inclusion of a small number of meetings where writing teams were brought together to work on parts of the assessment. However, there is still insufficient participation in writing teams by experts from a number of disciplines, particularly in social sciences, public health, psychology, philosophy, economics and specialists directly involved in marine industries. Further, there is a lack of involvement of local, traditional and indigenous knowledge holders who can provide essential perspectives to many ocean issues and important inputs into assessments.

Improved outreach and stronger linkages with international and regional science organisations, regional seas management bodies and local, traditional and indigenous groups as well as greater engagement between member state representatives with the wider ocean communities within countries would likely assist in improving engagement in the regular process and filling these gaps. Enhanced opportunities for capacity development and mentorship of contributors from less developed regions and small island developing states through mechanisms such as internships (either through country partnerships or facilitated through regional organisations) would also serve to address current regional gaps in contributions to assessments, while also serving to increase awareness of the Regular Process throughout those regions, both within the scientific community and also more broadly. This will require a commitment from the member states to support and facilitate such mechanisms for engagement. Recognising that the majority of contributions made to the world ocean assessment are voluntary, greater support by research institutions and agencies in facilitating the involvement of experts across disciplines in assessments would assist in improving participation. Focusing the assessment process to take on more of a multi-stakeholder approach, an approach that has been central to the IPBES process [see Beck et al. (2014); Borie and Hulme (2015)], could serve to build multidisciplinary and

multisectoral teams, ensure that connections for delivery of interdisciplinary information from assessments are directed appropriately and that information is delivered in readily understandable formats. This would also serve to build improved internal accounting of content comprising each chapter of the assessment, complimenting more formal review processes undertaken through peer review and member state review and improving the credibility of the Regular Process. Understanding and implementing those processes that have been successful in bringing multi-disciplinary teams together would also go some way in addressing this challenge.

Enhanced Engagement of Managers, Policy Experts, Decision Makers and Member States in the Regular Process

Member states identified during the lessons learned process associated with the first World Ocean Assessment that the assessment should “provide a reference platform for facilitating practical implementation of ocean-related sustainable development goals (SDGs) of the 2030 Agenda for Sustainable Development, support policy development at national regional and global levels and provide knowledge to effectively manage human activities affecting the marine environments.” The broad scope of the World Ocean Assessment and the multi-disciplinary (physical, biogeochemical, biological, socio-ecological components) and multi-sectoral (industrial, societal, regulatory components) knowledge needed to provide a comprehensive assessment that addresses all of the needs identified by the member states poses multiple challenges to those involved in each assessment. Creating writing teams capable of comprehensively tackling each topic is one challenge (as outlined in *Strengthening of credibility within the ocean community*). Accessing relevant information at both global and at regional scales that captures current approaches, concepts, developments and understanding and then presenting that information in formats useful for decision makers is also a challenge. Most ocean observation networks do not extend into economic, social and cultural aspects of the ocean and as a consequence, sustained observations of these aspects of marine systems in harmonised formats are lacking (Evans et al., 2019). Further, much of the information associated with maritime industries is not made publicly available. Compiling economic, social and cultural information for synthesising at global scales requires considerable effort, often beyond the ability of those involved in contributing to assessments under the Regular Process (Evans et al., 2019). Identifying mechanisms for expanding ocean observing systems was highlighted by Evans et al. (2019), with the Regular Process taking on a guiding role in the development of essential (and practical) indicators that could then deliver this information through the World Ocean Assessment.

Co-development and delivery of assessments undertaken by writing teams with managers, regulators and holders of maritime industry and business data would assist not only in addressing these challenges, it would also increase awareness of the Regular Process with these sectors and assist in strengthening links

between assessments and decision makers and industry; i.e. those implementing the ocean-related SDGs. To achieve this would require agreement from member states that the role of stakeholders such as maritime industries, industry regulators and marine managers is enhanced and greater engagement by member states in identifying relevant contributors from these sectors, as well as facilitating access to currently unavailable datasets. This will require some consideration of trade-offs between a desire and need for broad participation and for scientific integrity and credibility (Beck et al., 2014), but is essential for strengthening assessments to deliver the information the member states themselves are calling for. Recent voluntary commitments made by governments to ocean issues (e.g. those made at the Our Ocean and UN Oceans conferences) and a commitment to identifying actions for ocean sustainability (e.g. through self-organised initiatives such as the High Level Panel for a Sustainable Ocean Economy; see <https://oceanpanel.org>) suggest an increasing awareness and commitment to ocean-related processes and initiatives (Neumann and Unger 2019). Further, there is greater awareness of the need to make all data and information collected on the ocean (including historical information and that collected by governments, industry and private companies) accessible (Evans et al., 2019). There are efforts currently being undertaken to recover historical information and digitize those data for use in ocean modelling efforts (e.g. the RECOVERY of Logbooks And International Marine (RECLAIM) data project, <https://icoads.noaa.gov/reclaim/>), independent efforts to harness and deliver ocean data across users (e.g. <https://www.oceandata.earth/>) and government driven efforts to ensure public availability of ocean data (e.g. <https://portal.aodn.org.au/>) that are improving the availability of ocean information. However, much more is needed in order to ensure that ocean knowledge is widely available and comprehensive and timely assessments of the ocean that are relevant and effective for decision making can be achieved.

Improved Information Delivery Mechanisms

The first World Ocean Assessment consisted of nearly 1,000 pages of information published in English and delivered at the UN Oceans Conference (United Nations 2017). A summary of the assessment was presented separately to the UN General Assembly in all of the official languages of the United Nations (available at <https://www.un.org/regularprocess/content/first-world-ocean-assessment>). At the time of its release, individual chapters of the assessment and a compiled group of its component chapters was made available electronically on the DOALOS website (<https://www.un.org/regularprocess/sites/www.un.org.regularprocess/files/woacompilation.pdf>). The full assessment was not available in languages other than English and an indexed, searchable electronic version of the assessment was not available, somewhat limiting the potential widespread distribution and use of the assessment. Utility of multiple electronic platforms for awareness raising and production of material in easily understandable and useable formats was lacking. This was largely a consequence of the limited resources available to the Regular Process that could be put

towards not only making the assessment more broadly available but also communicating the assessment beyond the UN (Fawkes and Cummins 2019; see also <https://undocs.org/A/70/418>). There were clear gaps in outreach and awareness raising that were raised in the lessons learned identified in relation to the first assessment.

While financial constraints on the Regular Process remain and continue to be raised in lessons learned processes, efforts to improve information delivery to wider audiences implemented for the second World Ocean Assessment, include translation of the full assessment into all official UN languages and greater utilisation of electronic platforms for delivery of key messages, particularly through targeted short form webinars and web-series. In order to improve overall awareness and the utility of the World Ocean Assessment and in association transfer of knowledge for building ocean awareness, greater and expanded efforts beyond these are required and have been raised in the lessons learned from the second cycle of the Regular Process. Efforts to improve communication and outreach proposed for the third cycle include engaging specific communications expertise and development of an outreach and engagement strategy. Any strategy that is developed should consider moving beyond older models of learning such as the “knowledge deficit model” approach (i.e. which assumes that one-way communication of information infers uptake and application of such information) (Hecker et al., 2018). Creating experiential learning opportunities that can engender strong connections of society to the ocean through greater use of technologies and story-telling approaches (Kelly et al., 2021) would improve overall awareness of the content of assessments. These could take the form of for example short video vignettes (e.g. those produced as part of the I Live By The Sea International Youth Photo and Film Contest <http://www.todaywehave.com/CONTEST.html>), media commentaries (such as those published by The Conversation <https://theconversation.com/au>), exploratory games (e.g. the board game Ocean Limited <https://www.ocean-limited.de/>), modules for integration into school curricula (e.g. those provided by the Monterey Bay Aquarium <https://www.montereybayaquarium.org/for-educators/teacher-professional-development/teacher-programs/>) or components of art or museum exhibits (e.g. national science week <https://www.scienceweek.net.au/>). Ensuring the information delivery is tailored in such a way that it incorporates and is respectful of local practices and knowledge-making traditions (Weichselgartner and Marandino 2012) will be essential for expanding the reach of the assessment.

While the aim of the assessment is to provide a global overview, it is also essential that region specific information continues to be incorporated into the assessment so that it meets the needs of regional, national and sub-national decision makers and provides information that is relevant to local communities. This requires having a good understanding of the information needs of those decision makers across relevant scales. Delivery of information *via* platforms that are co-designed with decision makers, and therefore deliver information in formats that are readily interpretable and useable for developing policy and for marine management purposes, would also improve greater widespread uptake of information contained in assessments. This may require the World Ocean

Assessment partnering with specialist scientific knowledge translation and brokering agencies across a range of scales (regional, national sub-national) to facilitate effective transfer of information and ensure adequate communication and uptake of information products.

CONTRIBUTING TO A SUSTAINABLE FUTURE

With the recent delivery of the second World Ocean Assessment, planning for the third cycle and delivery of a third assessment has begun. In association, further improvements that might be implemented as part of the programme of work are being considered (some of those that have been identified and/or are in the latter stages of development have been detailed above). Achieving the improvements outlined here will no doubt be an iterative process (as it has been in other global processes elsewhere), but will require improved commitment to supporting the Regular Process as well as enhanced and engagement by member states in order to facilitate. This will require improved information flows between member state representatives and the greater ocean community in order to improve interdisciplinary engagement in assessments and delivery of outputs of the Regular Process. It will also require a commitment to facilitating Findable, Accessible, Interoperable and Reusable (FAIR) data practices across institutions, government agencies and industries to ensure transparency of information incorporated into assessments and that data and information considered is comprehensive. It may also require refocusing or adapting assessments to ensure appropriate delivery of relevant information for decision making, changes also undertaken in other global assessments [see (Beck 2011)]. Again, member states will need to be open to supporting adaptation of the Regular Process in order to facilitate the delivery of the platform they have called for as part of lessons learned. Finally, it will require a commitment to innovate delivery mechanisms to ensure that information from assessments reaches out to society and is effective in improving ocean awareness and understanding.

Over the next decade (2021-2030), the UN has proclaimed a Decade of Ocean Science for Sustainable Development as well as a Decade of Ecosystem Restoration (see www.decadeonrestoration.org), identifying that substantive improvements need to be made in relation to human use of the ocean and associated ecosystems if we are to continue to derive the benefits they provide to humankind and achieve the goals of the 2030 Agenda for Sustainable Development. Both of these calls to action provide an opportunity to improve understanding, innovate tools for assessing ocean environments both today and in the future, and identify solutions for mitigating pressures and repairing ecosystems. They also provide opportunities for expanding awareness of the ocean and the solutions (including behavioural change) needed to ensure a sustainable future. The knowledge brokering potential of the Regular Process in translating and transferring ocean information from generators to decision makers and to society has an essential role to play in expanding awareness of the ocean, delivering essential information that can be used for enhancing the sustainable

use of ocean. Establishing clear linkages between the Regular Process, the two UN decades and other global processes (e.g. such as IPCC and IPBES) will be essential for achieving this potential. As identified in *Relevance of the World Ocean Assessment to international processes*, the World Ocean Assessment has a potentially important role in communicating and delivering ocean understanding built during the UN decades, but also serving as a mechanism for tracking the implementation of changes needed in order to support future sustainability and identifying where knowledge and capability gaps remain. Much of the ocean understanding needed to support the commitments of the High Level Panel for a Sustainable Ocean Economy can be delivered through the World Ocean Assessment and similarly the World Ocean Assessment can provide a mechanism through which the success of the commitments made can be monitored through time. Strengthening linkages with other processes (such as IPCC and IPBES) would serve to ensure that each of the processes are informative to one another, resources such as access to experts are shared and in doing so the efficiency of support mechanisms for engagement is maximised, repetition of efforts are reduced, key messaging and directives for action are aligned and the potential for co-delivery of products and associated impact is enhanced.

REFERENCES

- Agrawala, S. (1998). Structural and Process History of the Intergovernmental Panel on Climate Change. *Climatic Change* 39, 621–642. doi:10.1023/a:1005312331477
- Basile, S. (2016). *Cool: How Air Conditioning Changed Everything*. New York, NY: Fordham University Press.
- Bayliss-Brown, G. A., and Ni Cheallacháin, C. (2016). *Knowledge Transfer with EU-Funded marine Science Research: A Viewpoint*. *Geophysical Research Abstracts* 18. Vienna, Australia: EGU General Assembly 2016.
- Beck, S., Borie, M., Chilvers, J., Esguerra, A., Heubach, K., Hulme, M., et al. (2014). Towards a Reflexive Turn in the Governance of Global Environmental Expertise. The Cases of the IPCC and the IPBES. *GAIA - Ecol. Perspect. Sci. Soc.* 23, 80–87. doi:10.14512/gaia.23.2.4
- Beck, S. (2011). Moving beyond the Linear Model of Expertise? IPCC and the Test of Adaptation. *Reg. Environ. Change* 11, 297–306. doi:10.1007/s10113-010-0136-2
- Borie, M., and Hulme, M. (2015). Framing Global Biodiversity: IPBES between Mother Earth and Ecosystem Services. *Environ. Sci. Pol.* 54, 487–496. doi:10.1016/j.envsci.2015.05.009
- CBD. (2020). *Secretariat of the Convention on Biological Diversity*. Montreal: Global Biodiversity Outlook 5.
- Cigliano, J. A., Meyer, R., Ballard, H. L., Freitag, A., Phillips, T. B., and Wasser, A. (2015). Making marine and Coastal Citizen Science Matter. *Ocean Coastal Manage.* 115, 77–87. doi:10.1016/j.ocecoaman.2015.06.012
- IPCC. (2019). “IPCC Special Report on the Ocean and Cryosphere in a Changing Climate,” in *Intergovernmental Panel on Climate Change*. Editors D. C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, et al. (Summary for Policymakers).
- Evans, K., Chiba, S., Bebianno, M. J., Garcia-Soto, C., Ojaveer, H., Park, C., et al. (2019). The Global Integrated World Ocean Assessment: Linking Observations to Science and Policy across Multiple Scales. *Front. Mar. Sci.* 6, 298. doi:10.3389/fmars.2019.00298
- Fauville, G., Strang, C., Cannady, M. A., and Chen, Y.-F. (2019). Development of the International Ocean Literacy Survey: Measuring Knowledge across the World. *Environ. Educ. Res.* 25 (2), 238–263. doi:10.1080/13504622.2018.1440381

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KE and TZ developed the concept for the manuscript. All authors contributed to the writing of the manuscript.

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- Fawkes, K. W., and Cummins, V. (2019). Beneath the Surface of the First World Ocean Assessment: An Investigation into the Global Process’ Support for Sustainable Development. *Front. Mar. Sci.* 6, 612. doi:10.3389/fmars.2019.00612
- Feary, D. A., Fowler, A. M., and Ward, T. J. (2014). Developing a Rapid Method for Undertaking the World Ocean Assessment in Data-Poor Regions - A Case Study Using the South China Sea Large Marine Ecosystem. *Ocean Coastal Manage.* 95, 129–137. doi:10.1016/j.ocecoaman.2014.04.006
- Fernández Otero, R. M., Bayliss-Brown, G. A., and Papanthassiou, M. (2019). Ocean Literacy and Knowledge Transfer Synergies in Support of a Sustainable Blue Economy. *Front. Mar. Sci.* 6, 646. doi:10.3389/fmars.2019.00646
- Hecker, S., Luckas, M., Brandt, M., Kikillus, H., Marenbach, I., Schiele, B., et al. (2018). Stories Can Change the World - Citizen Science Communication in Practice. in *Citizen Science - Innovation in Open Science, Society and Policy*. Editors S. Hecker, M. Haklay, A. Bowser, Z. Makuch, J. Vogel, and A. Bonn, London: UCL Press 445–462. doi:10.2307/j.ctv550cf2.37
- Hirst, D. G. (2014). Balancing Scientific Credibility and Political Legitimacy: the IPCC’s First Assessment Cycle 1988–1990. *Hist. Meteorology* 6, 79–94 .
- IOC-UNESCO (2020). Implementation Plan Summary. IOC/UNESCO. Available at: <https://oceanexpert.org/document/27348> (Accessed August 20, 2020).
- Keller, A. C. (2010). Credibility and Relevance in Environmental Policy: Measuring Strategies and Performance Among Science Assessment Organizations. *J. Public Adm. Res. Theor.* 20, 357–386. doi:10.1093/jopart/mup001
- Kelly, R., Evans, K., Alexander, K., Bettiol, S., Corney, S., Cullen-Knox, C., et al. (2021). Connecting to the Oceans: Supporting Ocean Literacy and Public Engagement. *Rev. Fish Biol. Fish.* 1. doi:10.1007/s11160-020-09625-9
- Komugabe-Dixon, A. F., De Ville, N. S. E., Trundle, A., and McEvoy, D. (2019). Environmental Change, Urbanisation, and Socio-Ecological Resilience in the Pacific: Community Narratives from Port Vila, Vanuatu. *Ecosystem Serv.* 39, 100973. doi:10.1016/j.ecoser.2019.100973
- McCauley, V., McHugh, P., Davison, K., and Domegan, C. (2019). Collective Intelligence for Advancing Ocean Literacy. *Environ. Educ. Res.* 25 (2), 280–291. doi:10.1080/13504622.2018.1553234
- McKinley, E., and Fletcher, S. (2010). Individual Responsibility for the Oceans? an Evaluation of marine Citizenship by UK marine Practitioners. *Ocean Coastal Manage.* 53, 379–384. doi:10.1016/j.ocecoaman.2010.04.012
- Neumann, B., and Unger, S. (2019). From Voluntary Commitments to Ocean Sustainability. *Science* 363, 35–36. doi:10.1126/science.aav5727

- Neumann, B., Vafeidis, A. T., Zimmermann, J., and Nicholls, R. J. (2015). Future Coastal Population Growth and Exposure to Sea-Level Rise and Coastal Flooding - a Global Assessment. *PLoS ONE* 10 (3), e0118571. doi:10.1371/journal.pone.0118571
- OECD. (2016). *The Ocean Economy in 2030*. Paris: OECD Publishing. doi:10.1787/9789264251724-en
- Pendleton, L., Evans, K., and Visbeck, M. (2020). Opinion: We Need a Global Movement to Transform Ocean Science for a Better World. *Proc. Natl. Acad. Sci. USA* 117, 9652–9655. doi:10.1073/pnas.2005485117
- Roy, M., Shemdoe, R., Hulme, D., Mwangi, N., and Gough, A. (2018). Climate Change and Declining Levels of green Structures: Life in Informal Settlements of Dar Es Salaam, Tanzania. *Landscape Urban Plann.* 180, 282–293. doi:10.1016/j.landurbplan.2017.11.011
- Schoedinger, S., Cava, F., Strang, C., and Tuddenham, P. (2005). Ocean Literacy through Science Standards. *OCEANS* 1-3, 736–740 .
- Schoedinger, S., Uyen Tran, L., and Whitley, L. (2010). *From the Principles to the Scope and Sequence: A Brief History of the Ocean Literacy Campaign*. College Park: NMEA Special Report #3.
- IPBES. (2019). *Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Editors S. Díaz, J. Settele, E. S. Brondizio, H. T. Ngo, M. Guèze, et al. (Bonn: Germany: IPBES Secretariat). doi:10.5281/zenodo.3553579
- Siebenhüner, B. (2002). How Do Scientific Assessments Learn? *Environ. Sci. Pol.* 5, 411–420. doi:10.1016/s1462-9011(02)00050-3
- Stoll-Kleemann, S. (2019). Feasible Options for Behavior Change toward More Effective Ocean Literacy. *A. Syst. Rev. Front. Mar. Sci* 6, 273. doi:10.3389/fmars.2019.00273
- Truong, M.-X. A., and Clayton, S. (2020). Technologically Transformed Experiences of Nature: A challenge for Environmental Conservation? *Biol. Conservation* 244, 108532. doi:10.1016/j.biocon.2020.108532
- UNDESA. (2019). *Percentage of Total Population Living in Coastal Areas*. Department of Economic and Social Affairs. New York: United Nations. Population Division, Available at: https://sedac.ciesin.columbia.edu/es/papers/Coastal_Zone_Pop_Method.pdf (Accessed September 20, 2020).
- UNEP and IOC-UNESCO (2009). *An Assessment of Assessments, Findings of the Group of Experts. Start-Up Phase of a Regular Process for Global Reporting and Assessment of the State of the Marine Environment Including Socio-Economic Aspects*. Valetta: United Nations Environment Programme and Intergovernmental Oceanographic Organisation-UNESCO.
- United Nations (2002). *Plan of Implementation of the World Summit on Sustainable Development*. New York: United Nations.
- United Nations (2010). *Resolution Adopted by the General Assembly on December 4 2009A/RES/64/71*. New York: United Nations. Agenda item 76 (a) (Accessed September 20, 2020).
- United Nations (2017). *The First Global Integrated Marine Assessment: World Ocean Assessment I*. Cambridge: Cambridge University Press.
- United Nations (2021). *The Second World Ocean Assessment. World Ocean Assessment II*. United Nations. Available at <https://www.un.org/regularprocess/>.
- Weichselgartner, J., and Marandino, C. A. (2012). Priority Knowledge for marine Environments: Challenges at the Science-Society Nexus. *Curr. Opin. Environ. Sustainability* 4, 323–330. doi:10.1016/j.cosust.2012.05.001

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