

Learning from experience: what the emerging global marine assessment community can learn from the social processes of other global environmental assessments

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Abstract: In recent decades, international assessments of the ocean have evolved from specialized, technical evaluations of the state of the marine environment to more integrated and thematically extensive science-policy platforms. As assessment programmes such as the UN Regular Process blossom on the global stage and subsume responsibility for tracking progress on sustainable development, there is a need to consider how their processes wield influence and effectively translate knowledge into action. In the present paper, we undertake a comprehensive review of the literature on global environmental assessments (GEAs) and extract key principles that can be applied to global assessments of the marine environment. We were particularly inspired to identify how social processes could be arranged to best distill, communicate, and produce actionable knowledge. While we look to the advice of experts in the literature, we highlight specific examples from the Intergovernmental Panel on Climate Change (IPCC), Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), and the Global Environment Outlook (GEO). From this review, knowledge coproduction, multilevel collaboration, and futures thinking emerged as the dominant principles of influential and action-oriented assessments. We conclude the paper by contextualizing how these principles may be operationalized for Global Marine Assessments in the future.

Key words: global environmental assessments, marine assessments, coproduction, multilevel collaboration, futures, sustainable development.

1. Introduction

The emergence of complex, transboundary environmental challenges in the second half of the 20th century prompted the international community to develop a global environmental governance system (Jabbour and Flachsland 2017). Central to this system was cooperation and information provision (De Vos et al. 2013). By the 1980s, formalized processes called Global Environmental Assessments (GEAs) tackled these needs by compiling,

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analyzing, communicating, and generating knowledge on environmental challenges through complex social processes involving decision makers and experts in the international arena (Farrell et al. 2001; Miller 2001; Clark et al. 2006; Rothman et al. 2009; Kowarsch et al. 2016; Garard and Kowarsch 2017a) (Fig. 1). Through this distillation and repackaging of information, GEAs aim to inform decision making and influence action (Farrell et al. 2001). While these can be time-consuming and resource-intensive processes, they have surfaced as the most structured, powerful, and influential platforms¹ at the science-policy interface (Alcamo 2017; Kowarsch et al. 2017a; Rioussel et al. 2017)².

As the global environmental governance system has contended with deepening economic globalization, accelerating environmental degradation, and the proliferation of sustainable development thinking in recent decades, GEAs have evolved to adopt more integrated problem framings and progressively more elaborate process operations (Mitchell et al. 2006; Jabbour et al. 2012; Kowarsch and Jabbour 2017). First-generation GEAs such as the 1977 assessment of Long Range Transboundary Air Pollution (LRTAP), which were characterized by their narrow scope, scientific focus, and direct connections to policy makers, have provided the background for extensive, complex assessment processes such as the Intergovernmental Panel on Climate Change (IPCC) (Farrell et al. 2001; Jabbour and Flachsland 2017). These later assessments generally maintain wider scopes, increasingly divergent objectives, larger and more diverse contributor teams, and exceedingly voluminous output reports (Kowarsch et al. 2014). Alongside their broadening processes, GEAs have also embraced sustainable development as a description of human progress and environmental protection. Subsequently, GEAs have expanded into the realm of the solution space — discussing, evaluating, and even creating potential solutions for environmental challenges (Jabbour and Flachsland 2017)³.

These changes to the political landscape of GEAs have been reflected by an evolving and globalizing marine assessment community. Sustainable Development Goal (SDG) 14, the UN Decade of Ocean Science for Sustainable Development, and the ongoing negotiations for a legally binding instrument on Biodiversity Beyond National Jurisdiction (BBNJ), all enunciate the need for integrated problem framing and solution-oriented knowledge (Drakou et al. 2017; Arbo et al. 2018; IOC/UNESCO 2018; Virto 2018; Visbeck 2018; Ryabinin et al. 2019; Claudet et al. 2020). To address these needs, the marine assessment community has begun to move beyond the technical and thematically bounded assessments that characterized their traditional efforts, such as regional fish stock assessments or state of the environment reports for regional seas programmes. With the establishment of the United Nations Regular Process in 2010 and the Transboundary Water Assessment Programme (TWAP) in 2013, this community seems to be converging on holistic, integrated, and global assessment processes. With these advances, there is an opportunity to progress the sustainable development agenda for the oceans and thereby contribute to societal transformations for sustainability.

However, it remains unclear as to how these assessments can most effectively realize this opportunity. The 2009 Assessment of Assessments, orchestrated by the United

¹Science-policy platforms are social structures that house a communication interface between scientific and political communities. Such two-way information movements and influence between these communities have been described as the scientization of politics and politization of science (Wesselink et al. 2013).

²Some experts have pointed to the role of the GEO series in establishing the Sustainable Development Goals (SDGs) and the IPCC in forging the Paris Agreement as examples of how modern GEAs are influencing solution implementation (Kowarsch et al. 2016; Rioussel et al. 2017).

³Modern GEAs are delving into discussions of public policy response, future development trends and political opportunities for addressing environmental concerns more vigorously and more often than GEAs of the 1990s or 1980s (Jabbour and Flachsland 2017). The IPCC and its chair Hoesung Lee have, in particular, been explicit about their intention to devote even more focus to solution development moving forward (Lee 2015; Provost 2019).

Nations Environment Programme (UNEP) and the Intergovernmental Oceanographic Commission of the United Nations Education, Scientific, and Cultural Organization (IOC/UNESCO), stated that the “most important finding” from their review was that global marine assessment communities lacked “an awareness of how the design of an assessment process fundamentally affects the influence of its products, that is, their perceived relevance, legitimacy and credibility” (UNGA 2009). Additionally, “in many regions there [was] no clear link between an assessment and the relevant decision-making body” (UNGA 2009). Such conclusions suggest that the structures and operations of subsequent global marine assessments (GMAs) were developed with limited knowledge of how social processes between experts and decision makers might motivate knowledge mobilization. It also raises critical questions as to how marine assessments should be convened in the future to successfully translate knowledge into action.

In this paper, we look to the general GEA literature for guidance. We provide a comprehensive review of the general GEA literature and analyze expert advice on the social processes that underlie GEAs and enable them to wield actionable influence. To pragmatically anchor this general review, we explore and highlight the procedures of three particular GEA processes⁴: the Intergovernmental Panel on Climate Change (IPCC), the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services (IPBES), and the Global Environmental Outlook (GEO) assessment series. We were particularly inspired to identify the principles by which the social processes in marine assessments could be arranged to best distill, communicate, and produce actionable knowledge (Future Earth Oceans 2016; Kowarsch et al. 2016; Future Earth Coasts 2018). In other words, what are the guiding tenets that assessment practitioners have used to arrange participation, information gathering, contributor interactions, scoping activities, and other aspects of assessment compilation to maximally fulfill assessment objectives and contribute to decision-making efforts? Finally, we conclude the article with a discussion on how the identified principles could be effectively fostered in the context of GMAs. Importantly, this section reflects on the lessons learned from the IPCC, IPBES, and GEO series. Through this review, we aim not to establish mandatory criteria or prescribe procedures for effective GMAs, but rather to begin a conversation on the guiding principles for building influential and action-oriented GMAs.

1.1. Global environmental assessments

GEAs differ from national or sub-national assessments by (i) addressing environmental issues that impact more than one country, (ii) addressing environmental issues that are caused by more than one country, or (iii) including experts from more than one country (Clark et al. 2006). The effectiveness of a GEA may be conceptualized as its ability to wield influence within a particular environmental issue domain (Eckley 2001). At its highest level, this may involve bringing about positive changes to a certain aspect of the environment and increasingly orienting patterns of human development along sustainable trajectories (Alcamo 2017; Kowarsch and Jabbour 2017). Achieving such improvements requires influencing specific actors and audiences to implement solutions (Clark et al. 2006). The mechanisms by which this influence may occur are extremely complex and can arise in a temporally variable manner (Clark et al. 2006). Influence can be quick and explicit, such as when GEA findings are found to have motivated policy development. However, it can also be slow and subtle, such as when GEA discourses diffuse slowly into public and political arenas to reshape beliefs, interests, and behaviours (Clark et al. 2006; Riousset et al. 2017).

⁴A GEA assessment may be produced by an assessment process or programme such as the IPCC, or alternatively it may be produced in a standalone individualized compilation of information.

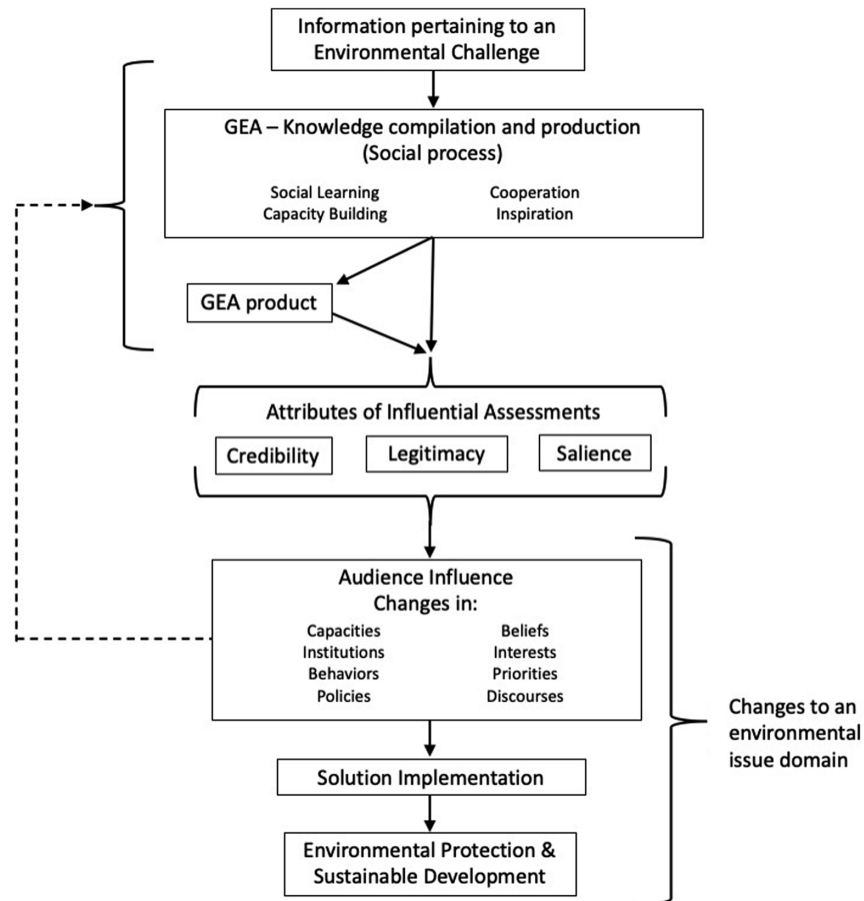
Such inconspicuous discursive seepage can restructure problem framings and subsequently provide perspectives on issue prioritization, resource allocations, and social connectivity for negotiations and policy-making processes (Kowarsch et al. 2017a). Influence may also arise when scientific considerations are “exposed” to political processes and policy agendas, thereby providing feedback to expert communities on the relevance of research agendas and the knowledge needs of policy makers (Riousset et al. 2017). The participatory and interdisciplinary nature of GEAs also has the potential to build the capacity of institutions and individuals across the science–society–policy interface (Riousset et al. 2017). Finally, GEAs are increasingly offering political bandwidth to explore solutions and convene discourses as well as analyses of policy options, which provides an opportunity for generating and disseminating new ideas about how to solve complex challenges (Edenhofer and Kowarsch 2015; Jabbour and Flachsland 2017). It would seem that influence is becoming more about the facilitation of knowledge to action as opposed to simply outlining and monitoring environmental challenges (Kowarsch et al. 2017a). By alluding to actionable knowledge in this manner, we are referring to “knowledge that people use to create the world” around them (Mach et al. 2020; Argyris 1993). This includes knowledge that influences the capacities, behaviours, priorities, beliefs, and ultimately the actions of its consumers (Fig. 1). To be actionable, knowledge should typically be customized to a particular context — be it culturally, geographically, or demographically.

Thus, through their complex impact mechanisms and transboundary scope, GEAs must span diverse communities, cultures, political systems, socio-economic conditions, knowledge capacities, and scientific paradigms (Cash et al. 2003; Siebenhüner 2003). They almost certainly confront an array of socially constructed knowledge types — or rather different ways of knowing something — as well as involve the interaction of those knowledge holders (Chapman and Schott 2020). Wielding influence, therefore, requires far more than an “objective”, technical evaluation of the environment. It requires legitimizing credible information in a manner that is relevant to an array of target audiences and their needs. In this light, GEAs are conceived as social processes that reconcile diverse strands of expertise, human perspectives, and environmental politics (Clark et al. 2006; Haas 2017). Their capacity to influence stems largely from participation, cooperation, social learning,⁵ and understanding that is forged between contributors within this process (Clark et al. 2006; Kowarsch et al. 2016; Yamineva 2017). Thus, as Mach et al. indicate, producing actionable knowledge requires motivating the users and producers of knowledge to interact, promoting power symmetries within these interactions, and “producing knowledge that is usable by decision makers” (Mach et al. 2020, p. 35).

Appraisals of GEA effectiveness are contextualized by the social processes and diverse pathways through which they wield influence as well as the constantly changing conditions in an environmental issue domain (Clark et al. 2006). The continual, independent evolution in the beliefs, ideas, behaviours, capacities, policies, solutions, and environmental conditions within an environmental issue domain means that identifying the influence of any single GEA is extremely challenging. To account for such dynamic processes, Alcamo (2017) suggests that these appraisals need to use holistic “programme evaluations” as opposed to simple product evaluations (Alcamo 2017). While the methods and tools used to make these evaluations have varied across the literature and between assessments, two general techniques have been identified: performance metrics and logic models (Alcamo 2017). Performance metrics focus on how audiences perceive and view an assessment

⁵Social learning in this capacity refers to “a change in understanding that goes beyond the individual to become situated within wider social units or communities of practice through social interactions between actors within social networks” (Reed et al. 2010, p. 10).

Fig. 1. A simplified overview of how global environmental assessments (GEAs) can promote the translation of knowledge to action and advance the sustainable development agenda. Audience perceptions of credibility, legitimacy, and salience contribute to determining how influential an assessment will be in motivating this action (Clark et al. 2006). The dotted line on the far left indicates the experiences, knowledge, and understanding that target audiences and decision makers can offer to help shape the knowledge production process and its outputs.



process and typically rely on specialized indicators that map out the level of credibility, legitimacy, and salience achieved among different audiences. Logic models, on the other hand, aim to identify, categorize, and track different strands of assessment influence from their origins in the GEA process to their subsequent outcome. Both evaluation methodologies are vital for analyzing the impact of actionable-knowledge processes (Mach et al. 2020).

1.2. Global marine assessments

Global marine assessments may be defined as GEAs that predominantly or wholly focus on marine environments or marine resources. While both assessments of global and regional scope fit within the definition of a GEA proposed by Clark et al. (2006), we differentiate between truly Global Marine Assessments (GMA) and those of a more regional nature (RMA). Generally, GMAs and RMAs are convened to fulfill reporting requirements under international conventions and agreements or mandates of intergovernmental organizations and NGOs (UNEP 2003). Both assessment types have varied considerably in their

processes, institutional structure, aims, and scale over the last few decades (UNGA 2009). In their 2003 review of global and regional marine environmental assessments, UNEP suggested that most of the early assessments were characterized by a limited thematic or geographic scope (Table 1) (UNEP 2003). Regional delineations were the dominant geographic framework for these assessments, with the northern hemisphere, especially the North Atlantic basin, being disproportionately represented (UNEP 2003). Despite substantial gaps and capacity differences between regions, UNEP found that RMAs, particularly the fish stock assessments conducted by the Regional Fisheries Management Organizations (RFMOs) and the marine pollution/ecosystem assessments by the Regional Seas Programmes (RSPs), provided “some of the required information” to support regional ocean governance decisions. The more pressing gap they suggested was at the global level, where only a smattering of sectoral and narrowly scoped scientific assessments existed (UNEP 2003).

By the early 2000s, subtle changes began to take shape in the global marine assessment landscape. In an era of emerging technology, international programmes for scientific data collection, information consolidation, and knowledge sharing have proliferated. Large scientific networks and systems such as the Global Ocean Observing System (GOOS), the Census of Marine Life and its Ocean Biogeographic Information System (OBIS), the Global Coral Reef Monitoring Network, and the UN Atlas of the Oceans, rapidly evolved to support the information needs of global assessments (Table 1) (UNEP 2003; Evans et al. 2019). At the same time, the United Nations primary advisory body on scientific aspects of the marine environment — the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) — underwent an extensive overhaul in operations with the aim of improving its participation from developing countries, extending its network, stimulating its engagement with the scientific and policy-making communities, and aligning its work to support the UN Commission on Sustainable Development (CSD) (Administrative Secretary of GESAMP 2005).

Between 1999 and 2005, the Global International Waters Assessment (GIWA) was conducted, which provided for the first time a holistic picture of “transboundary aquatic resources in the majority of the world’s international river basins and their adjacent seas,” and particularly in developing regions (UNEP 2006). This technical, quantitative, indicator-based assessment brought together 2000 experts in 66 regional teams to evaluate the conditions of international water systems to inform the decision making of the Global Environment Facility (GEF) and UNEP (Hempel and Daler 2004; UNEP 2007). Alongside the GIWA, the United Nations system began preparations for convening a Regular Process for Global Reporting and Assessment of the State of the Marine Environment, including Socio-economic Aspects (UNGA 2005). Under the oversight of UNEP and IOC/UNESCO, a group of marine assessment experts conducted an Assessment of Assessments (AoA), which reviewed and critically evaluated the “scientific credibility, policy relevance, legitimacy, and usefulness” of past marine assessments in an attempt to identify potential modalities of operation for the Regular Process (UNGA 2009). The AoA was published in 2009 and offered a series of comprehensive recommendations for scope, financing, institutional structure, participatory arrangements, capacity-building efforts, and knowledge production procedures within a Regular Process (UNGA 2009).

By 2010, the marine assessment community was inching closer toward developing holistic, integrated, global science policy platforms. At this time, the Regular Process began its first cycle of assessment under the auspices of the United Nations General Assembly (UNGA), while UNEP and GEF — along with IOC/UNESCO, the International Hydrological Programme (IHP/UNESCO), UNEP-DHI, and the International Lake Environment Committee (ILEC) — commenced planning for the development of a Transboundary

Table 1. A timeline of the major developments in the evolution of global and regional marine assessments.

Year initiated	Assessment processes and institutions	Organization responsible	Geographic extent
1921	Compilation of international Bathymetric Surveys and Charts begins	International Hydrographic Organization (IHO)	Global
1954	Stock Assessment Process begins	Commission for the Conservation of Southern Bluefin Tuna (CCBST)	South East Pacific Ocean
1960	Fish Stock Assessments begin	North Atlantic Fishing Organization (NAFO)	North West Atlantic Ocean
1963	Fish Stock Assessments begin	North East Atlantic Fishing Commission (NEAFC)	North East Atlantic Ocean
1969	Monitoring Reports begin	International Commission for the Conservation of Atlantic Tuna (ICCAT)	Atlantic Basin
1972	ICES Environment Data Centre established	International Council for the Exploration of the Sea (ICES)	North East Atlantic Ocean
1974	Regional Seas Programmes launched	United Nations Environment Programme (UNEP)	Global with regional implementation
1980	Periodic Assessment of the State of the Marine Environment of the Baltic Sea Area begins	Helsinki Commission (HELCOM)	Baltic Sea
1982	State of the Marine Environment Reports begin	Joint Group of Experts on Scientific Aspects of Marine Pollution (GESAMP), UNEP & Intergovernmental Oceanographic Commission of the United Nations Education, Scientific and Cultural Organization IOC/UNESCO	Global
1984	Large Marine Ecosystem (LME) Program established	IOC/UNESCO, IUCN - International Union for Conservation of Nature, ICES, & University of Rhode Island	Global with regional implementation
1987	North Sea Quality Status Reports (QSR) begin	Convention for the Protection of the Marine Environment of the North East Atlantic (OSPAR) & ICES	North East Atlantic Ocean
1990	State of the Marine Environment (NOWPAP) Reports begin	Northwest Pacific Action Plan (NOWPAP)	East Asian Seas & North West Pacific Ocean
1991	Global Ocean Observing System established	IOC/UNESCO	Global
1994	Reports begin on the "Atlantic and Indian Oceans Environment Outlook"	UNEP	Western Indian Ocean and South East Atlantic Ocean
1995	Assessment Conducted on "Marine litter: an analytical overview"	UNEP	Global
1995	Global Coral Reef Monitoring Network (GCRMN) established	International Coral Reef Initiative	Global
1996	State of the Environment Report for the Black Sea 1996-2000 (SOMER) conducted	Black Sea Commission	Black Sea
1997	Conducted assessment on the "State and Pressures of the Marine and Coastal Mediterranean Environment"	UNEP & Mediterranean Action Plan (MAP)	Mediterranean Sea
1999	Global International Waters Assessment (GIWA)	Global Environment Facility (GEF), UNEP, National Oceanic and Atmospheric Administration (NOAA), the Finnish Department for International Development Cooperation, the Swedish International Development Cooperation Agency (Sida), and Kalmar University, Sweden.	Global

Table 1. (concluded).

Year initiated	Assessment processes and institutions	Organization responsible	Geographic extent
1999	UN Atlas of the Oceans commences	UN-Oceans	Global
1999	State of the Marine Environment Reports (ROPME) begin	Regional Organization for Protection of the Marine Environment (ROPME) - Kuwait Action Plan	Persian Gulf and Northern Indian Ocean
2000	Census of Marine Life (CoML) & Ocean Biogeographic Information System (OBIS) established	CoML network coordinated by (1) Secretariat based at the Consortium for Ocean Leadership and (2) a Scientific Steering Committee. Funded by Alfred P. Sloan Foundation. OBIS is now curated by IOC/UNESCO.	Global
2003	First State of the Cetacean Environment Reports released	International Whaling Commission (IWC)	Global
2005	Assessment of Assessments begins	Group of Experts, overseen by UNEP, IOC/UNESCO and United Nations General Assembly (UNGA)	Global
2006	State of the Environment Reports (PERSGA) begin	The Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA)	Red Sea and Gulf of Aden
2008	State of Fisheries and Aquaculture (SOFIA) Reports begin	Food and Agriculture Organization (FAO)	Global
2009	Assessment conducted on "Pollution in the Open Oceans: A Review of Assessments and Related Studies"	GESAMP	Global
2010	UN Regular Process commences	Overseen by Division for Ocean Affairs and Law of the Sea (DOALOS) and UNGA	Global
2010	First Outlook Report on the State of the Marine Biodiversity in the Pacific Island Region released	Secretariat of the Pacific Environment Programme	Western Pacific Basin
2012	Ocean Health Index established	University California Santa Barbara & Conservation International	Global
2013	Transboundary Water Assessment Programme (TWAP) begins	GEF & UNEP	Global
2015	West Indian Ocean State of the Coast Reports begin	Nairobi Convention & UNEP	Western Indian Ocean
2018	First Integrated Report on the Caribbean State of the Cartagena Convention Area released	UNEP and GEF	Caribbean
2019	Release of the Special Report on the Ocean and Cryosphere	IPCC	Global

Note: This table includes references to a range of one-off assessments, continual assessment mechanisms (e.g. The Regular Process), and institutional programmes devoted to environmental monitoring (e.g. The Regional Seas programmes). As such, it is worth noting that both assessment mechanisms and assessment-focused institutional programmes have the potential to produce multiple output reports over their lifetime. However, to simplify the table, these entries were organized by the year of their initiation and subsequent assessments that took place under their auspices were not included in the table. This table is not intended to serve as a comprehensive list, but rather a subset of the most thematically or geographically extensive and politically legitimate assessments. It is adapted from UNEP's Global and Regional Assessments of the Marine Environment Database (GRAMED). Finally, it is worth noting that the table only includes assessments and institutions that focus wholly or predominantly on the marine environment. Therefore, GEA processes such as the IPCC, which may include tangential chapters on the oceans, were not included.

Water Assessment Programme (TWAP) (UNEP 2011; United Nations 2016). Between 2013 and 2015, the TWAP carried out the “first global scale assessment of transboundary water systems” as a successor to the GIWA project (UNEP 2018b). In doing so, it aimed to serve as an information tool for the GEF and other international organizations to set funding priorities and establish connections between institutions to integrate transboundary considerations into other assessment programmes (UNEP 2018b). Based on the assessment of five broad transboundary ecosystem classifications: aquifers, lakes, rivers, Large Marine Ecosystems (LMEs), and open ocean, the TWAP utilized expert communities in each of these fields to perform an indicator-based assessment of the biophysical, socio-economic, and governance aspects for the state of water systems within each classification (McManus et al. 2016). The TWAP also conducted evaluations of the state of these transboundary water systems under the future scenarios of the shared socio-economic pathways developed by the climate change community (IOC/UNESCO and UNEP 2016). The Regular Process, on the other hand, was charged with the mandate to “regularly review the environmental, economic, and social aspects of the state of the world’s oceans, both current and foreseeable” (United Nations 2010). The first cycle of the Regular Process, known as the First World Oceans Assessment (FWOA), was tasked with establishing a baseline for ocean information (United Nations 2016). Completed in 2015, the FWOA assembled available knowledge across various marine sectors in support of global decision making for sustainable management of the marine environment (United Nations 2016). While many of the Regional Seas Programmes have already maintained recurring assessment processes, the establishment of the Regular Process ignited motivations for new assessments, especially integrated assessments framed in the context of sustainable development⁶ (UNEP 2003; UNEP 2018a). In April 2021, the Regular Process released the Second World Ocean Assessment (SWOA), which focused on reporting trends since the FWOA as well as identifying and closing gaps in ocean-related knowledge and capacities across the world (United Nations 2021).

2. Methods of the literature review

To inform the future development of GMAs, we reviewed the general literature on GEAs. This review was coupled with focused, case-study investigations of three prominent GEA processes: the IPCC, the IPBES, and the GEO series. While the findings of the general GEA literature review drove the primary conclusions of this article, these case studies enabled us to offer practical and detailed examples to support these results. We chose to review the function of the IPCC due to its prolific history and widespread recognition, the IPBES due to its emerging and innovative practices, and the GEO series because of its wide thematic scope (for more information, please see the Supplementary Material, File S1⁷).

The review was performed using a combination of Google, Google Scholar, and library catalogs. Search terms included: (i) “global environmental assessment”, (ii) “global environmental knowledge”, (iii) “Intergovernmental Panel on Climate Change” or “IPCC”, (iv) “Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services” or “IPBES”, and (v) “Global Environment Outlook” or “GEO”. We considered the top 50

⁶These modern state of the environment reports have included: the Caribbean State of Convention Area Report (2018), the Pacific State of the Environment Report (2017), HELCOM’s State of the Baltic Sea (2011–2016), the Mediterranean Quality Status Report (2017), OSPAR’s 2017 Northeast Atlantic Intermediate Assessment, West Indian Ocean State of the Coast Report (2015), Red Sea and Gulf of Aden State of the Marine Environment (2015), and Northwest Pacific State of the Marine Environment Report (SOMER) (2014) (UNEP 2018a). In addition to these assessment outputs several of the RSPs maintain monitoring programmes and indicator suites to support individual countries in the scientific evaluation of their coasts (UNEP 2018a).

⁷Supplementary material is available with the article through the journal Web site at <http://nrcresearchpress.com/doi/suppl/10.1139/anc-2020-0018>.

results in each search and selected literature where the aforementioned search terms were included in the title. This systematic entry point was complemented with a “snowball” technique, where additional texts were identified from the reference lists of articles within the initial search. There were often overlaps in the texts identified by each search.

The general literature review involved exploring expert commentaries, critical evaluations, and theoretical analyses that addressed GEAs, while the case-study investigations involved analyzing output assessment reports, gray literature that described assessment processes (often published by hosting or partner institutions for each GEA), and evaluative literature that analyzed particular assessment processes or their outputs. In total, we reviewed 127 texts (see File S2⁷).

We considered what experts identified as effective GEA functions⁸ as well as what evaluators recommended would need to be improved or implemented for future assessments. This involved examining both the technical mechanisms and procedures of GEAs, as well as the advertised principles of their operations. Our search was primarily guided by an interest in how GEA processes ought to organize their social interfaces to optimally wield influence in their respective domains. Moreover, we wanted to know how assessment experts advise practitioners to arrange participation, information gathering, contributor interactions, scoping activities, and other compilation proceedings to support compelling and motivational discourse, rich opportunities for social learning, institutional connectivity, and transdisciplinary capacity building, in a way that maximizes the perceived credibility, legitimacy, and salience of the assessment and effectively influences the beliefs, behaviours, priorities, decision making, and policies of the audience (see Fig. 1). In essence, we distilled the recommended operational principles of the GEA processes that promote the production of actionable knowledge. This line of inquiry was ultimately driven by the desire to inform the development of future marine assessments.

While we identified many approaches and methods that had either contributed to structuring influential social processes or were recommended in the literature, their prominence was often specific to a particular GEA context. For instance, many experts have discussed the need for more transparency in the IPCC process (Hulme and Mahony 2010; Vardy et al. 2017). However, outside of the literature on the IPCC, transparency generally did not surface in recommendations or was considered as an outcome of other guiding approaches (e.g., Coproduction). We also searched for the most quantitatively dominant principles in the literature. In other words, the principles that appeared or were exemplified the most in a numerical sense within the literature. For instance, a handful of experts advocated the development of more rapid and targeted assessments, such as the recent IPCC special reports (Beck et al. 2014; Rowe et al. 2014; Carraro et al. 2015). While potentially relevant to multiple GEA processes, support for this strategy was quantitatively weak and overshadowed by expert advocacy for other principled interventions. Therefore, we sought to distill the broadest and most transferable principles that were also quantitatively distinguishable in the literature.

3. Results

Bounded by the aforementioned methods and search criteria, we identified three principles that emerged from our review of the literature: the coproduction of knowledge, adopting a multilevel framework, and embracing futures thinking (Table 2). It is worth noting that these principles were often not overtly labeled as guiding ideas for the operations of

⁸Effectiveness in this capacity refers to the ability of a GEA to influence the beliefs, behaviours, priorities, decision making and policies of the audience (see Fig. 1).

Table 2. Prospective merits of operationalizing the three principles: knowledge coproduction, multilevel approach and futures thinking.

Coproduction	Multilevel approach	Futures thinking
<p>Participatory composition Support perceived legitimacy through wide ranging of participation Build social connections between different participants</p>	<p>Direct engagement at global level Build the capacity of participants at more local levels</p> <p>Contextualize information and assessment to local needs Construct linkages to more local decision-making arenas</p>	<p>Scenario development Collaboratively setting the scope for future societal development Setting goals for future societal development</p> <p>Improving adaptive capacity</p> <p>Supporting institutional organization</p>
<p>Inclusion of knowledge types Promote shared understanding between diverse actors Tailor the scope and details of assessments to particular contextual needs New, integrated and synergistic knowledge production</p>	<p>Engagement of sub-global institutions Build the capacity of institutions at more local levels</p> <p>Resource efficient spanning of geographic levels</p> <p>Contextualize information and assessment to local needs Construct linkages to more local decision-making arenas</p>	<p>Detailed mathematical predictions Further hone predictive capabilities</p> <p>Building individual capacities of assessment participants</p>
<p>Participant engagement structure Equalize power dynamics Build institutional and individual capacities</p> <p>Support uptake into decision making arenas</p>		<p>Policy appraisal Tailoring assessment to policy-relevant topics Supporting robust decision making with empirical analysis and prediction</p>

Note: The table organizes these according to discrete procedural considerations for each principle.

GEAs. However, they were typically hailed by evaluators, commentators, and academics as capacious concepts that, when manifested, grown, and furnished, would contribute to generating actionable influence. Furthermore, when looking at GEAs on a more functional level, the existence and implementation of these three principles is best exemplified by mechanistic and procedural features that subscribe to the objectives of these principles or have the effect of advancing toward their aims. The following results section defines each of these three principles and then uses examples from the IPCC, IPBES, and GEO to elaborate on procedural considerations for each principle's practical enactment (Table 3).

3.1. Knowledge coproduction

In the context of sustainability, coproduction may be defined as “iterative and collaborative processes involving diverse types of expertise, knowledge, and actors to produce context-specific knowledge and pathways towards a sustainable future” (Norström et al. 2020, p. 183). In a simplified manner, it involves the joint production of knowledge among a group of individuals. Central to the concept of coproduction are balanced power structures across these participatory arrangements (Van Kerkhoff & Lebel 2015; Norström et al. 2020). As such, coproduction requires crafting an environment that enables inclusive and transparent opportunities for knowledge exchange, social learning, collaboration, and capacity building (Fig. 1) (Clark et al. 2016). The construction and influence of this collaborative habitat ultimately hinges on the nature of participation, the acceptance of different knowledge types, and the structural characteristics of the engagement platforms (Table 2).

As a procedural starting point, coproduction relies on abundant participation. Access to opportunities for collaboration, as well as diversity in contributor identity and background, are of considerable value. Such inclusion, for instance, may encompass contributors that span political, geographic, cultural, and disciplinary bounds (Garard and Kowarsch 2017b). This wide-ranging involvement has the potential to bolster legitimacy by recognizing stakeholders across the spectrum (Table 2) (Mausser et al. 2013). It may also build social connections between researchers, policymakers, and stakeholders, which could leverage unforeseen utility in future situations (Djenontin and Meadow 2018). For instance, the extensive political and scientific engagement in the IPCC assessments, which occurs most notably through plenary, break-out, expert dialogue, and textual negotiation sessions, has been said to have provided a number of new professional connections between expert bodies and policy-making environments (Table 3) (Garard and Kowarsch 2017a). In addition, political engagement has helped to legitimize the findings of the assessments in an unofficial, but politically binding manner (Garard and Kowarsch 2017b; Rioussset et al. 2017; Mach et al. 2017). Meanwhile, the IPBES participation scheme has extended beyond the science-policy bifurcation to include local and Indigenous communities as well as civil society groups in assessment compilation (Table 3) (Futhazar 2016; Montana 2016). While IPBES fails to balance power structures between actors and equalizes representation across regions, genders, and disciplines, it does set a crucial precedent in GEA development by promoting inclusivity (Esguerra et al. 2017; Löfmarck and Lidskog 2017; Peterson et al. 2018; Timpte et al. 2018; Obermeister 2019). This has helped to extend IPBES' perceived legitimacy beyond expert communities and also provides these groups with a sense of ownership over the output assessments, both of which can affect the interests and priorities of individuals within these populations.

In addition, the recognition and inclusion of different knowledge types are of paramount importance for the realization of a coproduction approach. Traditional environmental knowledge production systems such as early GEAs and technical policy reports typically prioritize Western scientific knowledge above other forms, such as those used in Indigenous, local, and socio-economic spheres (Kowarsch et al. 2017a). However, by generating assessment

Table 3. Select examples showing how coproduction, multilevel approaches, and futures thinking are operationalized within the context of the IPCC, IPBES, and GEO.

	IPCC	IPBES	GEO
Coproduction	Plenary and break-out sessions Process to negotiate the Summary for Policy Makers Expert dialogue sessions with UNFCCC	Plenary and break-out sessions Process to negotiate the Summary for Policy Makers Task force on multi knowledge system integration Participatory opportunities for stakeholders: (i) chapter writing, (ii) stakeholder days, (iii) plenary session observation Conceptual Framework which recognizes diverse knowledge types, and perspectives	Plenary and break-out sessions Process to negotiate the Summary for Policy Makers Scenario development processes
Multilevel approach	Some regional involvement beginning (e.g. Observer organizations to plenary and AR5 chapters on regional adaption and mitigation)	Compilation of regional writing teams, engagement of local stakeholders in chapter writing & Technical Support Units (TSUs) Regional Workshops Expert group on integrating multilevel knowledge	Compilation of regional writing teams & their Technical Support Units (TSUs) Regional Workshops Regional Collaborating Centres and Communities of Practice
Futures thinking	Scenario development and Quantitative modeling at global level (e.g. Shared Socio-economic Pathways & Representative Concentration Pathways)	Regional Selections of global scenario archetypes	Visioning and scenario development workshops in GEO-6 and online contests for action plans to meet sustainable development targets ex post analyses on “case studies of policy options”

Note: The mechanistic and procedural features shown in the table may either subscribe to the objectives of these three principles or have the effect of advancing toward their aims.

products through a process that takes account of the diverse values, perspectives, and knowledge systems of contributors, coproduction systems can promote a shared understanding of the diverse challenges and interests at stake in environmental issues (Table 2) (Subramanian et al. 2019). Inclusion of such disparate knowledge types may also help tailor insights and findings to the particular contextual needs of decision makers and civilians in traditionally underrepresented or unique communities (Obermeister 2019). Finally, the integration, comparison, and discussion of various fields of expertise can generate new insights and problem framings as ideas are merged and conceptualized from different angles (Table 2) (Mauser et al. 2013; Djenontin and Meadow 2018). The IPBES Conceptual Framework (CF) is perhaps the most progressive example of such a pluralistic creation (Table 3). Often described as the heart of the IPBES process, the CF aims to provide coordination across the objectives, functions, and principles of IPBES and develop a common understanding between disciplines, knowledge systems, and stakeholders (Díaz et al. 2015a). Specifically, it identifies the central organizing paradigms of different knowledge systems and the relationships between these paradigms (Díaz et al. 2015a). This includes concepts such as “Mother Earth,” “Nature’s Gifts,” “Living in Harmony with Nature,” and “Quality of Life” (Vohland and Nadim 2015). By deliberating and disseminating this work, the IPBES CF contributes to bolstering the intellectual, theoretical, and conceptual capacities of the assessment participants and audiences (Díaz et al. 2015b; Dunkley et al. 2018).

In terms of engagement structure, the architectural composition of participatory arrangements is the final enabling aspect that allows cooperation and joint knowledge generation to flourish. Importantly, these platforms must be structured to navigate assessment development through power struggles, conflicting sets of values, and tendencies for participation to devolve into exclusive epistemic communities and isolationist roles (Mach et al. 2020). When designed in a way that facilitates synergistic collaboration, social learning, motivation, and capacity building can be forged (Table 2). The negotiations concerning the summaries for policy makers under the IPCC, for instance, have attracted wide participation, heated debates, and lengthy engagement (Table 3). In many instances, these features have contributed to improving the communication of the final document and facilitating the negotiation of common understandings (Garard and Kowarsch 2017b; Rioussset et al. 2017; Mach et al. 2017). Ultimately, this has helped strengthen the institutional capacities and policy outcomes of the process (Mauser et al. 2013; Djenontin and Meadow 2018; Obermeister 2019). Such interactions between producers and users of knowledge are also considered essential for generating actionable outcomes (Mach et al. 2020). In a slightly different light, IPBES has devised both a task force on traditional and Indigenous knowledge as well as the convening of periodic “stakeholder days” (Table 3). These developments contribute to orient stakeholders with the agendas and decisions of the plenary and may be beginning to address the asymmetrical balance in the capacity and power structures between assessment contributors (Montana 2016; Oubenal et al. 2017; Hill et al. 2020).

3.2. Multilevel approach

For the purposes of this paper, we define a level as a “unit of analysis” that demarcates a particular geographic extent (Cash et al. 2006). The way in which an assessment frames geography is fundamental for its scope as it dictates the problems, data, methods, and themes to be considered (Lebel 2006). Multilevel thinking bridges the divide between social-ecological systems nested in different geographic dimensions (Solé and Ariza 2019). For GEAs, a multilevel approach identifies critical cross-level environmental connections in a global context, while also generating and disseminating knowledge to action arenas at regional, national, and local levels (Mitchell et al. 2006). Despite the fact that assessment practitioners, decision makers, and the media often attempt to superficially extrapolate assessment findings across

levels, the translation of knowledge between spatial dimensions has particular difficulty in maintaining perceptions of credibility, legitimacy, and salience among the different audiences (Cash and Clark 2001; Lebel 2006). In addition, such inferences can inaccurately depict environmental problems and their socio-economic implications (Lebel 2006). Multilevel approaches, therefore, require moving beyond simple information provision. They require the active participation of stakeholders across levels to communicate and help formulate knowledge in ways that will reflect and take account of the unique realities and values of these stakeholders (Mitchell et al. 2006; Solé and Ariza 2019).

Multilevel engagement takes two primary forms in GEAs. On the one hand, it can involve the direct participation of lower-level contributors and the inclusion of associated information in the global assessment (Table 2). In some ways, the IPCC has attempted to implement this strategy by including research from across different levels in its all-encompassing global reports. However, the effectiveness with which it has actually enveloped, systematized, and emphasized that these more local perspectives have been scrutinized in the academic literature (Brooks et al. 2014; Beck et al. 2014; Carraro et al. 2015). Turning to the IPBES, it has perhaps more convincingly harnessed multilevel participation and information provision to conceptualize biodiversity and ecosystem services with a “view from everywhere” (Brooks et al. 2014; Borie et al. 2015). Its inclusion of local-level stakeholders, in particular, can be said to build the capacity of environmental caretakers, managers, and researchers at more local realms, as well as help influence the priorities and policies of more local action arenas for biodiversity governance (Table 2). At the same time, it has been acknowledged that widespread participation from the local level is a resource-intensive undertaking (Rowe et al. 2014; Soberón and Peterson 2015). Ultimately, IPBES will need to rectify this approach with the bounds of its financial resources in the future (Soberón and Peterson 2015).

Second, GEAs may engage with institutions at lower levels (Table 2). Regional involvement in this capacity is seen as a vital link between global and national levels. For instance, the IPBES global process is complemented by the regional networking and information gathering efforts of their technical support units (TSU) as well as their regional capacity-building workshops. Through a clear separation of responsibilities for TSUs and the broader platform, the TSUs have supported the production of four regional assessments: the Americas, Africa, Europe and Asia, and the Pacific (Futhazar 2016). Similarly, the GEO series maintained regional collaborating centres through its first four assessment iterations, and through all six iterations, it convened regional consultations with stakeholders (Table 3) (Kowarsch et al. 2014; Rowe et al. 2014). There may be some evidence to suggest that both the collaborating centres and the regional consultations operated as “boundary spanners” that helped to aggregate sub-regional level interests and information needs within the global assessment and build the capacity of contributors within the regions (UNEP 2004; Kowarsch et al. 2014; Rowe et al. 2014). In the case of the collaborating centres, it is also likely that they contributed to “cross-disciplinary interaction amongst contributors” (Rowe et al. 2014). Such spanning entities and their associated actions have been shown to have a high potential to encourage the successful translation of knowledge into action (Goodrich et al. 2020). In the terminal report for GEO-5, Rowe et al. (2014) specify that the regional, national, and sub-national levels are “where mitigation and adaptation decisions are made and increasingly those decisions are around what to do, not about whether to do something” (Table 2) (Rowe et al. 2014, para. 249, p. 75). Some experts have suggested that this institutional nesting for assessment compilation may motivate the commencement of regional and sub-regional levels to generate their own assessments, potentially bolstering institutional capacity building and the promotion of more local priorities (De Pryck and Wanneau 2017; Garard and Kowarsch 2017a; Rioussset et al. 2017).

3.3. Futures thinking

Futures thinking refers to the consideration of imagined futures (Hajer and Pelzer 2018). This may involve activities such as scenario building, where a range of potential futures are created; visioning, where a desirable future is depicted; or predictive modeling, where a likely future is mathematically anticipated (Wiek and Iwaniec 2014). GEAs have predominantly employed scenarios to promote discourse on the future and posit a range of plausible future development conditions (Retief et al. 2016). From a broad perspective, this pre-emptive style of thought ultimately enhances the adaptive capacity of society and supports institutional organization for a range of potential future conditions (Table 2). Scenarios can take many forms, including narrative storylines, robust mathematical models, wide-ranging explorations of futures, more detailed examinations of normative possibilities, forecasts of flourishing growth, or backcast investigations to determine what policy options and solutions will be required for direct development along various paths (van Vuuren et al. 2012).

From a developmental perspective, the first step in considering the future of a particular environmental domain is setting the scope of possibility (Table 2). In some cases, this has involved a more imaginative dimension with the use of perceptive tools such as narrative storylines, artistic explorations, and collaborative scenario design (van Vuuren et al. 2012). The GEO-6, for example, fostered a bottom-up approach to scenario construction by convening participatory workshops to co-create and co-envision transformational development pathways “based on local practices” with regional stakeholders (UNEP 2019a). The GEO-6 process also facilitated a “seed” approach that encompassed running an online contest where participants could assemble possible action plans to meet climate change and sustainable development targets (Table 3) (Pereira et al. 2019b; UNEP 2019a). IPBES took a slightly more structured approach by tasking regional writing teams to combine “existing scenario analyses [in] their respective regions with previously published archetypes” at the global level (Sitas et al. 2019, para. 6). The marriage of such top-down and bottom-up approaches was intended to provide cross-level connections, opportunities for regional contextualization, and inter-regional comparability (IPBES 2016; Obermeister 2019; Sitas et al. 2019). These interactive strategies for scenario development may stimulate motivation for sustainable transformations, explore how social-ecological systems function over long timelines, and establish collective goals and priorities for societal development (Biggs et al. 2007; Edenhofer and Kowarsch 2015; Oteros-Rozas et al. 2015; Bennett et al. 2016).

The extension of futures thinking beyond scenario development activities can also provide important benefits. For instance, mathematical emulations of environmental, social, and economic aspects can hone the predictive capacities of institutions and epistemic communities. In a somewhat backward and technocratic approach, the IPCC used an integrated modeling community to first establish potential “end points” for radiative forcing in 2100, and then Shared Socio-economic Pathways to contextualize, describe, and quantify several plausible pathways to these end points (Table 3) (Moss et al. 2010; Riahi et al. 2017; Beck and Mahony 2018). While this comprehensive “scenario matrix” provides a critical avenue to address the IPCC’s shifting solution-oriented agenda and the inherent uncertainty that characterizes society’s future climate challenges, many experts have criticized the scenarios as too unrealistic, technical, or narrow in scope (Kowarsch et al. 2014; O’Neill et al. 2014; Vaughan and Gough 2016; Beck and Mahony 2017; Vardy et al. 2017; Obermeister 2019). In a slightly different context, the mandates for GEO-5 and GEO-6 were extended to use the scenarios for ex post analyses on “case studies of policy options” at the global and regional levels (Table 3) (Kowarsch et al. 2016). This was incorporated within a three-part approach to their future outlooks, which included (i) using existing environmental treaties and goals to build a vision for a sustainable world in 2050, (ii) back casting to evaluate

existing scenarios in light of both this sustainable world vision and a conventional world vision, and (iii) identifying potential action and policy pathways to achieve sustainable world vision (UNEP 2012; van Bers et al. 2016). This remarkable departure from the strict anti-policy prescriptive motto that bound most GEAs narrowed the gap between expert knowledge and policy development and enabled GEO-5 to generate evidence and rationale for decision makers to implement solutions in the future (Table 2) (Rowe et al. 2014; Kowarsch et al. 2014). It also supported individual researchers' capacity to conceptualize such analyses and identified key gaps in the policy analysis literature (Jabbour et al. 2012; Kowarsch et al. 2014; Rowe et al. 2014). Despite the critical conjecture that suggests that the policy analysis in GEO-5 was irrelevant for decision-making purposes, the approach has opened the door for further exploration in the future (Rowe et al. 2014). With a more targeted effort on policy appraisal, the incorporation of SDGs within scenario development activities, and increased focus on generating connections with regional decision-making audiences, the GEO-6 seems well positioned to build upon the icebreaking path carved by the GEO-5 (UNEP 2019a).

4. Operationalizing action-oriented assessments in the Marine Domain

For the remainder of the paper, we discuss how coproduction, multilevel perspectives, and futures thinking may be mechanistically invigorated — in the context of global marine assessments — to best facilitate the refashioning of knowledge into action (Fig. 1). The discussion will draw from the results section and use the examples from the IPCC, IPBES, and GEO to reflect on procedural considerations for each principle's operationalization in the marine assessment domain. As such, the discussion will necessarily deliberate on established institutions, current governance trends, and past assessment experiences within the global marine domain. It will also examine relevant, ongoing efforts in the marine research community and speculate on the direction, opportunities, and challenges of future global marine assessment developments (Table 4).

4.1. Coproduction

Coproducing knowledge within global assessments is a delicate and demanding enterprise. For marine assessment practitioners, the challenge of growing influential participatory processes will entail reflecting on the social landscape of the ocean, including the institutional architecture of the ocean governance system, the knowledge systems that allow coastal peoples to interact with the ocean, and the relationships that tie ocean use and ocean management together.

Identifying who should be involved in joint knowledge production for global marine assessments is a challenging prospect. Both the IPCC and IPBES have global conventions and associated institutions to which they are closely tied, providing them with existing channels for communication and participation precedents (Soberón and Peterson 2015; Jänicke 2017). No equivalent policy implementation body exists for global marine governance. The UNGA may consider ocean affairs; however, the United Nations Convention on Law of the Sea (UNCLOS)⁹ delegates considerable authority to a myriad of policy-making arenas across global, regional, and national bounds. At the global level, the individual

⁹UNCLOS is recognized as the global constitution for the oceans. Garnering support from 168 contracting parties, it aims to “facilitate international communication” as well as “promote the peaceful use of the seas and ocean, the equitable and efficient utilization of their resources, the conservation of their living resources, and the study, protection and preservation of the marine environment”. It does this by providing standard definitions, procedures, and guidelines for resource allocation, territorial claims and dispute resolution. UNCLOS also establishes the jurisdictional structure for global ocean governance by articulating the bounds of authority for coastal and flag states as well as by delegating certain competencies to international sectoral organizations (UNGA 1984).

Table 4. Summary of avenues and opportunities for further operationalizing knowledge coproduction, multilevel approaches, and futures thinking in global marine assessments.

Coproduction	Multilevel approach	Futures thinking
<p>Participatory composition Further integrate the polycentric constellation of decision-making bodies for the oceans</p> <p>More inclusion of Indigenous and local communities</p>	<p>Direct engagement at global level Use existing regional organizations (RSPs, RFMOs, LMEs) to facilitate the direct involvement of local-level actors in global assessment activity</p>	<p>Scenario development Establish ocean-specific scenarios at the global level</p> <p>Consider using more abstract, artistic approaches and ongoing efforts as part of the UN Decade of Ocean Science for a starting point in scenario development</p>
<p>Inclusion of knowledge types More recognition for knowledge types outside the realm of science (especially Indigenous knowledge)</p>	<p>Engagement of sub-global institutions Use the Regional Organizations to provide information and input on assessment design</p> <p>Foster regional organizations to coordinate assessment methods that can feed into global processes</p>	<p>Detailed mathematical predictions Integrate ongoing, academic efforts to develop detailed modeling practices within global scenario development</p>
<p>Participant engagement structure Use existing platforms such as the IPC and UN-Oceans to cultivate participation Utilize a boundary organization to help equalize power imbalances between participants</p>		<p>Policy appraisal Begin “exploring” options for integrating policy-relevant futures thinking</p>

agendas and lack of coordination between sectorally delineated intergovernmental organizations such as the International Maritime Organization (IMO), UNEP, the Food and Agriculture Organization (FAO), and IOC/UNESCO can create bureaucratic ambiguity and narrow, unilateral pursuits of policies, programs, and solutions (Grip 2017). Such a polycentric governance structure means that assessment processes must be designed in ways that enable participation and foster the creation of knowledge that relates to the interests of many distinct political audiences (Table 4). At the same time, this institutionally fragmented operating environment suggests that the marine governance system could have a great deal to gain from knowledge coproduction, with marine assessments potentially serving as a crucial platform for cultivating cross-sectoral learning, common understanding, shared visions for the future, and mutually practical solutions. Efforts to cultivate such participation should be built from existing coordinative frameworks such as the Informal Consultative Process (ICP) or UN-Oceans (Table 4)¹⁰. However, it should also

¹⁰The ICP and UN-Oceans are international mechanisms that help to advise and coordinate ocean governance strategies. The ICP was established as a way to support vertical coordination and capacity building between the UN and the entire global ocean governance community. Specifically, it aims to develop the capacity of permanent missions to the UN and forge communication pathways between the UN member states, the UN Secretariat and the plethora of international bodies concerned with ocean affairs (Simcock 2010). Under recommendations from the ICP, the UNGA and Secretary General established UN-Oceans to support the horizontal coordination between ocean-oriented international organizations. At a broad scale, UN-Oceans aims to foster cooperation between agencies, avoid duplication of efforts, support the transfer of knowledge, and “enhance the effectiveness of competent organizations of the United Nations system”, the International Seabed Authority, and relevant international treaty organizations (UNGA 2003; UN-Oceans 2019).

extend beyond these established mechanisms to transcend knowledge systems and include industry groups, NGOs, scientific networks, Indigenous bodies, and many others across regional, national, and local levels. Mechanisms to promote collaboration and social learning between societal, political, and expert communities also need to be encouraged and financially supported.

Examples of coproduced research, monitoring, and management activities are emerging in certain coastal regions (Thornton and Scheer 2012; Weiss et al. 2013; Ban et al. 2019). However, the operational principles of these processes have struggled to scale-up and pervade global governance systems in a substantial way (Berkes 2006; Thornton and Scheer 2012; Fawkes and Cummins 2019). In some cases, this may result from the widespread disconnect between science and policy (Cvitanovic et al. 2015). Yet in others, it may result from a narrow conceptualization of coproduction and the fact that marine science is often valued “above” other knowledge types (Aswani et al. 2018; Bennett 2019). Such perceptions seem to be reflected by concerns that traditional and Indigenous knowledge systems do not permeate global decision-making mechanisms for ocean affairs (Bhatia and Chugh 2015; United Nations Economic and Social Council 2016; De Lucia 2019; Bennett 2018). While the Regular Process and the TWAP have been successful, to some degree, at engaging diverse political actors in the governance realm, there has been little to no acknowledgement of the value of different knowledge systems in these assessments (Fawkes and Cummins 2019; UNEP 2018b). As alluded to in Section 3, such reliance on a single knowledge system can have large political implications as vulnerable groups are sidelined and thereby less likely to view subsequent solutions as legitimate (Bennett 2018; Bennett 2019). IPBES, for instance, avoided political turmoil in its Asia–Pacific assessment when “ILK holders brought up the issue of nuclear fuel waste, which had hitherto been ‘out of sight, out of mind’.”¹¹ It was reported that “that contribution changed the nature and focus of the assessment” (Obermeister 2019, p. 851). In this context, there is a critical need to recognize “the relationships between marine biodiversity and cultural diversity” within global marine assessments and the global marine governance system in general (Thornton and Scheer 2012, para. 40). The idea that scientific knowledge provides neutral input to global ocean governance must be abandoned (Beck et al. 2014). Decisions cannot be made based on technical indicators alone; social information requires qualitative explanations (Lebel 2006).

Aspirations to coproduce knowledge for marine assessments will need to be met with commitments for growing trust and institutional cooperation if they are to be fully realized. Resource competitions, territorial claims, negotiations, and economic opportunities, and in the global ocean, commons create particular power arrangements and social relationships between actors (Österblom et al. 2020). Contributions to assessments cannot be insulated from these digressing pressures and interests (Clark et al. 2016). Fostering equitable power arrangements to navigate these disagreements requires the establishment of trust. The inequalities, diverse value systems, and conflicting perspectives that underlie these political sensitivities will need to be acknowledged and addressed in order to build trust (Mauser et al. 2013; van Kerkhoff and Label 2015). Existing social relationships that promote sustainable management will need to be strengthened, and new relationships will need to be forged. This progress will need to occur alongside more direct efforts to (i) build the capacities of assessment contributors and practitioners, (ii) divide roles and responsibilities in a fair and equitable manner, and (iii) use a boundary organization,

¹¹Indigenous and local knowledge (ILK) is a term used to describe “dynamic bodies of integrated, holistic, social and ecological knowledge, practices and beliefs pertaining to the relationship of living beings, including people, with one another and with their environments.” (IPBES 2017).

knowledge broker, or social network to span gaps and facilitate communication between actors¹² (Table 4) (Treffny and Beilin 2011; Wyborn 2015; Djenontin and Meadow 2018). Most importantly, the selection of assessment participants needs to abide by systematic, logical, and transparent mechanisms (Kowarsch et al. 2014). Ultimately, these efforts will need to occur “through an evolutionary process, encouraging systematic learning from success and failures” (Garard and Kowarsch 2017a, p. 18).

4.2. Multilevel approach

In light of the transboundary and interconnected characteristics of marine ecosystem function, maritime activities, and ocean governance structures, the incorporation of cross-level considerations appears crucial for GMAs to wield influence within marine related decision-making fora (Sardá et al. 2014; Aswani et al. 2018; Solé and Ariza 2019). However, as discussed in Section 3, the IPBES and GEO show that building connections with audiences at different geographic levels is challenging. For instance, maintaining direct participation or networks of regional collaborators can be resource-intensive and time-consuming (Cash and Clark 2001). On the other hand, it can also be difficult to accommodate divergence in regional assessment mechanisms when aggregating matters at the global level.

However, the unique architecture of the marine governance system provides alternative opportunities for GMAs to link across levels (Table 4). The well-established regional management systems, in particular, offer a level of unparalleled coordination and organization for catalyzing cross-level knowledge generation and promoting the development of regionally tailored solutions (Sherman and Duda 2002; Glaser and Glaeser 2014; UNEP 2016; Mahon and Fanning 2019; Singh and Ort 2020). UNEP’s Regional Seas Programmes (RSPs), the FAO’s RFMOs, and GEF’s LMEs each facilitate information flows between global governance platforms and national policy implementation arenas by providing regional reporting, monitoring, and assessment activities. For instance, the RSPs have built on the strong history of their state of the coast reports to begin assembling SDG reporting mechanisms (UNEP 2018a). Such established regional platforms, therefore, have tremendous potential to support cross-level consideration in GMAs. For starters, their assessments may provide vital information and coordinated reporting protocols to inform global processes. Second, regional assessments offer exploratory opportunities for building and identifying the best practices in international marine assessment processes. Third, regional structures and their respective assessments could contribute capacity-building services for individual assessment practitioners to contribute to global processes more effectively. Fourth, the structures themselves could act as boundary-spanning agents to (i) facilitate and bolster cross-level participation in global processes and (ii) elaborate on how global assessment outputs would relate to sub-regional decision makers and stakeholders. Fifth, coordination with these centres presents opportunities to influence more local-level decision-making bodies and could facilitate information flows to local communities. Finally, if regional assessment mechanisms foster strong sub-regional participation schemes and project the values, perspectives, and opportunities in more local spheres, the regional systems could alleviate some of the financial burden for “widespread” participation in global assessment processes. This distributed style of assessment would require sub-regional participation at the global level as well, but it allows the global assessment to use the existing relationships and

¹²New knowledge-action networks such as Future Earth Coasts and the Ocean Knowledge-Action Network (Ocean KAN) are accelerating transdisciplinary research across national bounds and cultivating influential communities of experts to more effectively match decision-making needs with knowledge sources. These organizations may be ideally positioned to help orchestrate “cross fertilization” and coordination between institutions and researchers involved in assessments by using their existing connections and global reach to (i) identify relevant experts in a particular field and (ii) promote, translate and distill assessment findings for their broader community and beyond (Bennett 2018; Gerhardinger et al. 2018).

ongoing programmes at the regional and sub-regional level to cultivate a broad, bottom-up perspective as opposed to recreating such procedures within a single, top-down, centralized process (Cash 2000).

The importance and convenience of using these existing regional mechanisms for global processes have been acknowledged by the GIWA, TWAP, and Regular Process (UNEP 2006; UNGA 2011; McManus et al. 2016; United Nations 2016; United Nations 2021). However, how effectively these global assessments embrace regional bodies beyond the purpose of spatial delineations and information provision is highly questionable (UNEP 2018b; Fawkes and Cummins 2019). For the TWAP, strong engagement with regional actors was outside its mandate, while for the FWOA, funding limitations and political constraints contributed to its isolated development at the global level (Fawkes and Cummins 2019). Regional engagement has yet to be appraised in the context of the SWOA. While it is clear that these global processes need to commit more resources to empowering regional-level actors, such assessment mechanisms will undoubtedly encounter further challenges. For instance, multilevel assessment procedures do not automatically neutralize politics between organizations at different levels (Lebel 2006). It will take an ongoing process of negotiation to maintain trust and define the roles and responsibilities of these organizations. Vast differences in the capacity and mandates of regional organizations may also pose problems for the legitimacy of a global multilevel process, as some regions are extremely well equipped to participate, while others may be left without the appropriate resources or authority to equitably contribute (Rochette et al. 2015). Regional mechanisms also vary in their spatial extent. With no single organizational system covering the entirety of global coastlines or Areas Beyond National Jurisdiction (ABNJ) (UNEP 2016), jurisdictional gaps can appear to leave certain environments and communities underrepresented. In summary, it seems unlikely that regional bodies have reached their full potential to contribute to integrated, coproduced, solution-oriented global marine assessments. To support future multi-level approaches that maximize the use of regional mechanisms, substantial efforts will be needed to build the capacity of regional assessment processes and then integrate the social processes and assessment findings into global processes.

4.3. Futures thinking

In general, GMA processes seem rather unenthusiastic about considering plausible futures, especially when compared to the IPCC, IPBES, and GEO series. For instance, scenario development was outside the scope of the FWOA, despite recommendations for it in the 2009 Assessment of Assessments (UNGA 2009; United Nations 2016). While the SWOA includes certain outlook sections, it did not include a scenario development process (UNGA 2018; United Nations 2021). Similarly, the TWAP was more engaged with future-oriented thinking; however, it resorted to borrowing the Shared Socio-economic Pathways and technical predictions from the climate change community and discussed their possible implications for the ocean environment and development of coastal and marine spaces (McManus et al. 2016). As a result, the assessment never holistically addressed possible ocean futures in scenario building or visioning exercises. Overall, such mild involvement with futures thinking begs the question of how GMAs should more thoroughly explore the conditions of environmental and socio-economic development in the future?

Recently, there has been an emerging push in the academic literature to deploy both technical modeling and scenario construction approaches for the exploration of ocean futures (Planque et al. 2019; Olsen et al. 2018; Cheung et al. 2019a). This includes examinations of (i) fisheries economics on the high seas, (ii) changes in marine ecosystem services, (iii) the role of climate change in species distribution, (iv) future seafood consumption potential and trends, and (v) the future of fisheries conflicts (Cheung et al. 2019a). While

such expert analyses provide valuable quantitative insights for decision makers and GMA processes alike, some experts have cautioned against relying entirely on technical and tightly coupled model-scenario outlooks (Rosa et al. 2017; Trutnevyte et al. 2018). As discussed in Section 3, such detailed and specific interpretations of future development trends can prematurely risk, focusing on unrealistic or narrow outcomes. Integrating these models within policy-relevant globalized assessments is also challenged by the need to account for a wide range of variables, as well as the vast information gaps and uncertainties in the state of knowledge on marine socio-ecological systems. At the same time, such technical progress will be useful to further clarify ocean futures once there is greater effort and agreement at the global level for ocean-specific scenario development (Table 4).

While the GEO series and, to some extent, the IPCC have incorporated policy appraisal activities within their future outlooks (see Section 3), it seems unlikely that the political climate of the global marine governance arena would permit such value-laden and concentrated analyses within GMA processes at this time (Fawkes and Cummins 2019; UNEP 2019b). Similarly, it may be challenging to develop policy appraisals without first constructing ocean-specific scenarios in an intergovernmental context. Thus, GMAs currently have an opportunity to “explore” ocean futures by using “diverging assumptions” about technological innovation, marine resource allocation, and marine conservation to construct a broad spectrum of plausible outlooks (Table 4) (Van Vuuren et al. 2012). These open-ended conceptions have the potential to energize research communities and encourage cooperation in planning future ocean development. They also have the opportunity to inform the assessments’ methodology over time as new indicators, and problem framings may be gleaned from these explorations.

Some ocean-futures experts have proposed artistic approaches to these scenario development activities for the oceans. Merrie et al. (2018), for instance, advocated for a perspective that encompasses imagination, metaphor, and creativity (Table 4). By engaging with science fiction prototyping, they suggest that ocean scenario development “can loosen cognitive restrictions and stimulate a novel understanding of different trajectories and approaches” (Merrie et al. 2018, p. 23). Innovative and visionary processes may also (i) promote awareness of the complexity and uncertainty associated with future ocean conservation/development, (ii) integrate emotions and feelings into assessment processes and future outlooks, and (iii) support the assemblage of multiple knowledge types in GMAs (Pereira et al. 2019a). At the same time, it seems probable that more artistic impressions of ocean futures will have trouble traversing the political landscape of intergovernmental procedures and legitimization embedded within modern GMAs (Pereira et al. 2019a).

In this light, it is possible that the UN Decade of Ocean Science for Sustainable Development may provide an impetus for broader futures thinking (Table 4). For instance, IOC/UNESCO suggests that understanding plausible futures “will be a pre-requisite to the development of sustainable ocean economic policies and ecosystem-based management” (IOC/UNESCO 2018). In their roadmap for the decade, Claudet et al. (2020) go further and highlight the need for multilevel scenarios that emphasize the connections between humans, environmental change, and socio-economic challenges, as well as contributing to the assemblage of transdisciplinary knowledge (Claudet et al. 2020). Similarly, Pendleton et al. (2020) recommend the construction of a “digital twin ocean” to advance the UN Decade’s efforts to map future ocean trajectories (Pendleton et al. 2020). These ideas, guidelines, and principles generated by the momentum of the UN Decade of Ocean Science will need to be matched with the experiences and expertise of bottom-up participatory scenario development processes (see Planque et al. 2018; Cheung et al. 2019b; Garteizgogea et al. 2020; Gephart et al. 2020). Scaling-up ocean action is critical to the compilation of relevant and influential thinking on ocean outlooks. Blending this collaboration with imagination

could offer an opportunity to transform how society visualizes and plans for the future of the marine domain (Oteros-Rozas et al. 2015; Pereira et al. 2019a).

5. Conclusion

Knowledge coproduction, multilevel connections, and futures thinking have emerged from the literature as principles around which GEA processes may forge influential and action-oriented assessments. The newly developed GMA community has an opportunity to learn from past GEAs and operationalize these principles in future assessments. We have offered insights on how knowledge coproduction, multilevel approaches, and futures thinking may be achieved in the unique social, academic, participatory, and institutional realities of the marine domain. While we hope this provides guidance for future marine assessment practitioners, it will undoubtedly take further efforts on the ground to refine how marine assessments can maximize their credibility, legitimacy, and salience to become more influential. At a broad level, there is a need to re-conceptualize GMAs as large-scale learning platforms that mobilize knowledge into action and generate solutions from multiple perspectives, approaches, and knowledge types. Sustainable transformations cannot be realized through textual communication alone. Social interaction and collaboration are critical for achieving a sustainable future for all.

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