Deepening the Decade: Collaborative Action for Advancing Deep-Ocean Science and Policy in the United Nations Decade of Ocean Science for Sustainable Development

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Deepening the Decade: Collaborative Action for Advancing Deep-Ocean Science and Policy in the United Nations Decade of Ocean Science for Sustainable Development

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Abstract

The current United Nations Decade of Ocean Science for Sustainable Development (2021–2030; hereafter, the Decade) offers a unique opportunity and framework to globally advance ocean science and policy. Achieving meaningful progress within the Decade requires collaboration and coordination across Decade Actions (Programs, Projects, and Centres). This coordination is particularly important for the deep ocean, which remains critically under-sampled compared to other ecosystems. Despite the limited sampling, the deep ocean accounts for over 95% of Earth's habitable space, plays a crucial role in regulating the carbon cycle and global temperatures, and supports diverse ecosystems. To collectively advance deep-ocean science, we gathered representatives from 20 Decade Actions that focus at least partially on the deep ocean. We identified five broad themes that aim to advance deep-ocean science in alignment with the Decade's overarching 10 Challenges: natural capital and the blue economy, biodiversity, deep-ocean observing, best practices in data sharing, and capacity building. Within each theme, we propose concrete objectives (termed Cohesive Asks) and milestones (Targets) for the deep-ocean community. Developing these Cohesive Asks and Targets reflects a commitment to better coordination across deep-ocean Decade Actions. We aim to build bridges across deep-ocean disciplines, which encompass natural science, ocean observing, policy, and capacity development.

Deepening the decade of ocean science: Introduction

The United Nations has declared 2021–2030 the Decade of Ocean Science for Sustainable Development (hereafter, the Decade), with a clear mission of supporting "the science we need for the ocean we want" (oceandecade.org). The Decade has provided a framework for researchers, policymakers, and other stakeholders to build new networks, convene collaborative platforms, generate knowledge, and ensure sustainable ocean use for the future. The Decade has identified 10 "Decade Challenges" (oceandecade.org/challenges/), which include protecting and restoring biodiversity, enhancing climate regulation, expanding the global ocean observing system, and developing an equitable and sustainable blue economy. Decade-endorsed Actions (examples shown in Table 1), are centered around these major challenges. Key to the Decade's success are collaborative and coordinated efforts across Actions that are working on similar topics or themes within the Decade framework.

The deep ocean, that is, waters below 200 m depth, cuts across all the Decade Challenges and is less accessible than coastal or shallow waters, making the collaboration

TABLE 1. Descriptions of Decade-endorsed Actions (Programs, Projects, or Centers) that have contributed to "Deepening the Decade" efforts

Name	Program, Project, or Center?	Description	Website
DCC—Northeast Pacific	Center	The Decade Coordination Center (DCC) supports and facilitates co-designed and co-produced knowledge for collaborative solutions to ocean challenges in the Northeast Pacific region.	https://oceandecadenortheastpacific.org/
Ocean Visions	Center	The Ocean Visions—UN Decade Collaborative Center for Ocean-Climate Solutions leads and supports processes to co-design, develop, test, and ultimately help deliver scalable and equitable ocean-based solutions to mitigate and reverse the effects of climate change.	https://oceanvisions.org/undcc/
DCO—Ocean Observing	Decade Coordinating Office	The Decade Coordination Office (DCO)—Ocean Observing will ensure connection between the numerous Decade Actions addressing Challenge 7, ensure such Actions are built for the future. This coordination is supportive of, but goes beyond the Global Ocean Observing System's (GOOS) existing scope. DCOs work to support Actions through capacity development, communications, tracking of progress and resource mobilization, as well as catalyzing new partnerships and initiatives as part of the Decade.	https://oceandecade.org/decade-collaborative-centres/
DOSI	N/A (supports Challenger 150)	The Deep-Ocean Stewardship Initiative (DOSI) is a global network of experts which integrates science, technology, policy, law, and economics to advise on ecosystem-based management of resource use in the deep ocean, and on strategies to maintain the integrity of deep-ocean ecosystems within and beyond national jurisdiction.	https://www.dosi-project.org
Challenger 150	Program	Coordination of global deep-sea research and advance our understanding of deep-sea marine life. Challenger 150 focuses on building capacity for deep-sea research, expanding biological observations, building ecological knowledge, increasing the use of deep-sea knowledge in management in decision-making.	https://challenger150.world/
Digital DEPTH	Program	To generate a digital deep-ocean habitat atlas, to improve the scientific understanding of material and energy connectivity across deep-ocean habitats, to develop key technologies for intelligent observation and numerical modeling of deep-ocean habitats, to deliver predictability of deep-ocean habitats and biodiversity in response to disturbances, and to provide area-based management tools based on habitat predictability.	https://digitaldepth.ndsc.org.cn
DITTO	Program	The Digital Twins of the Ocean (DITTO) program will establish and advance a digital framework on which all marine data, modeling and simulation, along with Artificial Intelligence algorithms and specialized tools will enable best practices and shared capacity to access, manipulate, analyze, and visualize marine information. It will enable practioners to evaluate scenarios addressing issues such as energy, mining, fisheries, tourism, and nature-based solutions. Digital twins can quantify environmental change, benefits of ocean observing withe powerful visualizations and future scenarios.	https://ditto-oceandecade.org

(Continues)

TABLE 1. Continued

Name	Program, Project, or Center?	Description	Website
DOOS	Program	The Deep Ocean Observing Strategy (DOOS) is an international, community-based group that coordinates deep ocean observing to understand the state of the global deep ocean with respect to baseline conditions, response to climate change, and response to human disturbance.	www.deepoceanobserving.org
JETZON	Program	Joint Exploration of the Twilight Zone Ocean Network (JETZON) acts as the international coordinator and focal point of Twilight Zone studies and projects. JETZON aims to provide the scientific understanding necessary to inform a sustainable approach to the management and conservation of the Twilight Zone ecosystem.	https://noc.ac.uk/projects/jetzon
Marine Life 2030	Program	Marine Life 2030 will establish the globally coordinated system to deliver actionable, transdisciplinary knowledge of ocean life to those who need it, promoting human well-being, sustainable development, and ocean conservation. The Marine Biodiversity Observation Network (MBON) is the platform to build the community of practice needed to implement Marine Life 2030.	https://marinelife2030.org/
OBON	Program	The Ocean Biomolecular Observing Network (OBON) is an endorsed program of the UN Decade of Ocean Science for Sustainable Development that will monitor, research, and understand ocean life by analyzing biomolecules.	https://obon-ocean.org/; https://oceandecade.org/actions/ocean-biomolecular-observing-network-obon/
Ocean Census	Program	The Nippon Foundation-Nekton Ocean Census Program aims to accelerate the discovery of species in the ocean. The program aims to achieve this through a variety of strategies including the use of digitization to enhance cybertaxonomy, the adoption of new technologies to accelerate species discovery, including sample collection technologies, high-throughput 3rd-generation DNA sequencing, high-resolution 2D and 3D imaging and machine learning, and capacity development targeted at low- and middle-income countries. The program is expedition led, whereby regions of the ocean that are poorly sampled are targeted for sampling. Expeditions are followed by taxonomic workshops to sort and identify specimens and samples.	https://oceancensus.org/
Ocean Voices	Program	The Nippon Foundation University of Edinburgh Ocean Voices Program aims to fill gaps in capacity and knowledge to address global and climate global challenges through connected networks and values and make sure that everyone has a space in ocean science to policy decision-making space to create an equitable ocean for all. It does this in a number of ways: supporting fellowship, safe spaces to connect, exchange knowledge, share perspectives, and collaboration among others. Ensure people have access to decision-making spaces and have a voice and active role through accreditation, financing, or support while they are there.	https://ocean-voices.ed.ac.uk/

(Continues)

TABLE 1. Continued

Name	Program, Project, or Center?	Description	Website
OneDeepOcean	Program	The One Ocean Network for Deep Observation (OneDeepOcean) program provides integrated knowledge on the functioning of deep-ocean ecosystems under global changes, to enhance efforts in mitigating natural disasters, and to engage citizens with a deep ocean increasingly under pressure due to human activities.	https://www.onedeepocean.org/
Seabed 2030	Program	The Nippon Foundation-GEBCO Seabed 2030 Project is a global, collaborative initiative with the mission to accelerate efforts to produce a definitive map of our ocean by 2030 and make it freely available to all. Through international cross-sector partnerships, integrating existing data, and encouraging new data collection efforts globally, Seabed 2030 aims to deepen our understanding of the deep ocean and its complex, interconnected communities.	https://seabed2030.org/
BORA Blue Ocean Research Alliance®	Project	BORA Blue Ocean Research Alliance® is an innovative relationship with a vision for marine scientists and the offshore industry to work together to improve the understanding of the world's ocean for a sustainable future. The alliance was initiated to enable energy transition stakeholders to support scientific observation during the UN Decade of Ocean Science for Sustainable Development. The alliance facilitates access to the deep ocean via a diverse fleet of industry offshore vessels and > 120 underwater vehicles operating to 3000 m depth, supporting projects from broad disciplines that can take place during operational time or through access to existing data.	https://www.blueoceanresearchalliance.com/
COBRA	Project	The Crustal Ocean Biosphere Research Accelerator (COBRA) is an international network-of-networks focused on the structure, function, resilience, and ecosystem services of the crustal ocean biosphere—the rocky parts of the seafloor—to inform decision-making for emergent human uses of the deep sea like deep-ocean mining and subseafloor carbon sequestration.	https://cobra.bigelow.org/
COESS	Project	Chemistry, Observation, Ecology of Submarine Seeps (COESS) is focused on studying the ecological importance of seeps, as well as their potential impact on climate, while fostering interest in students and local communities in these unique underwater habitats.	https://sites.google.com/view/coessproject/home
Quantifying gases in the ocean using acoustics	Project	This project will develop a cost-effective methodology to detect and quantify gas bubbles seeping from the seafloor using broadband acoustic technology.	https://oceandecade.org/actions/quantifying-gases-in-the-ocean-using-acoustics/
SMART Cables	Project	The Science Monitoring and Reliable Telecommunications (SMART) Cables Initiative is led by the ITU/WMO/UNESCO-IOC Joint Task Force (JTF) comprised of volunteers from government agencies, research and academic	https://www.smartcables.org/

(Continues)

TABLE 1. Continued

Name	Program, Project, or Center?	Description	Website
		institutions, and the private sector. SMART Cables is working to integrate sensors (temperature, pressure, and seismic motion) into undersea telecommunications cables. These sensors share the power and communications infrastructure of millions of kilometers of undersea fiber optic cable, enabling seafloor-based global ocean observing at modest incremental cost. They will provide climate and ocean data and improve global tsunami and earthquake warning networks.	

and coordination of initiatives among the community of preeminent importance. The deep ocean sustains diverse ecosystems and carries out critical ecosystem functions and services, such as climate regulation through carbon storage (Smith et al. 2022). Pollution, overfishing, and climate change, and impacts from emergent activities such as possible commercial seabed mining, biological resource extractions for commercial applications, and marine carbon dioxide removal (mCDR) are increasingly affecting the deep ocean (Smith et al. 2022. Levin et al. 2023). However, the deep ocean remains critically undersampled and largely unexplored compared to other marine or terrestrial ecosystems (Mayer et al. 2018; Hauck et al. 2020).

We gathered representatives from Decade Actions that focus (at least partially) on the deep ocean to address the coordination needs across the deep-ocean Decade community (Table 1). Together, we represent various disciplines in science, policy, and capacity building that altogether address aspects of each of the 10 Decade Challenges. The initial conversations about "Deepening the Decade" began in 2022, and accelerated in October 2023 with a workshop hosted by the Deep Ocean Observing Strategy (DOOS), a Decade-endorsed Action.

We began by gathering information about each Action's objectives, successes, challenges, and goals for the remainder of the Decade. We created network maps of keywords for each deep-ocean Action to establish areas of thematic connections among our respective groups (Fig. 1). The initial discussions, in-person workshop, and continued conversations at the Decade conference (April 2024) enabled us to identify gaps for potential new Decade programs/projects to cover and to build a collaborative deep-ocean Decade community with clear goals for the second half of the Decade (Fig. 2). From these discussions, five broad Themes for collective action emerged and are presented below. Within each Theme, we wrote concrete objectives (termed "Cohesive Asks") and associated milestones (Targets) for the deep-ocean community through 2030 and beyond. Each Theme cuts across several Decade Challenges and aims to identify and summarize deep-ocean priorities for each (Fig. 2). The timeline for Targets is the end of the Decade (2030), unless specified otherwise.

Concrete and cohesive asks for ocean stakeholders

Theme #1: The deep sea is critical to planetary health and wealth

Aligns with Decade Challenges 1, 2, 3, 4, 5, 6, 7, 8, 10

Cohesive Ask 1.1. *Characterize deep-ocean natural capital for ocean health and the new marine economy*. Natural capital is the stock of renewable and nonrenewable resources that combine to benefit individuals and societies. For the deep ocean, this will include benefits that encompass economic, social, environmental, cultural, spiritual, and well-being realms. Harmonizing multiple uses of the deep sea—which comprises 75% of all Exclusive Economic Zone areas and most of Areas Beyond National Jurisdiction—to maximize ocean health and human well-being remains a critical grand challenge.

Targets: (i) Develop ecosystem-based protocols for characterizing and quantifying the natural capital of the deep sea. (ii) Apply well-developed protocols to 100% of Areas Beyond National Jurisdiction to guide spatial planning.

Cohesive Ask 1.2. *Characterize carbon sources and sinks for global carbon budgets and the evaluation of mCDR impacts*. There is increasing global interest in mCDR technologies that seek to increase the capacity of ocean carbon storage, along with many uncertainties associated with these technologies and their impacts on the ocean and deep-ocean ecosystems in particular. The ocean is a critical component of global carbon cycling, having absorbed approximately one-third of anthropogenic CO_2 (Friedlingstein et al. 2019). International efforts have attempted to quantify ocean carbon reservoirs and the fluxes between them, but many uncertainties remain due largely to observational gaps, particularly in deep-ocean systems (Hauck et al. 2020). Better understanding of natural ocean carbon sources and sinks is essential to understand the potential environmental impacts and risks of proposed mCDR technologies.

Targets: (i) Double the available deep-ocean physical and biogeochemical data (*see* Cohesive Ask 3.1). (ii) Synthesize current understanding of environmental impacts of mCDR techniques. (iii) Ground-truth the efficacy of mCDR technologies for sequestering carbon.

Cohesive Ask 1.3. *Map the seafloor*. Knowing the seafloor's shape is fundamental for understanding the ocean. This knowledge forms the foundation for ocean

circulation, tsunami forecasting, and climate models as well as offshore infrastructure and renewable energy, such as cables, pipelines, and wind farms. Moreover, accurate seafloor maps are indispensable for habitat characterization, sustainable resource management, and the establishment and maintenance of protected areas. Despite its significance, the comprehensive mapping of the ocean floor is still incomplete, with direct measurements covering only 26.1% of the global ocean (sonar, lidar, seismic, etc.; seabed2030.org). To achieve this goal, it is imperative to leverage existing mapping efforts and promote the sharing of privately held data, all while upholding principles of data accessibility and equity.

Target: Map 100% of the seafloor to modern standards. This work is currently being led by The Nippon Foundation–General Bathymetric Chart of the Oceans (GEBCO) Seabed 2030 Project (seabed2030.org), a Decade-endorsed program with the goal of publishing, and making publicly available, the most authoritative map of the world ocean floor. This initiative unites a wide spectrum of ocean stakeholders within the ocean community—explorers, academics, government agencies, and educators—to engage and contribute, collaboratively advancing science-based knowledge of our ocean floor.

Theme #2: Deep-ocean ecosystem function depends on biodiversity

Aligns with Decade Challenges 2, 4, 5, 7, and 10

Cohesive Ask 2.1. *Monitor biodiversity for conservation and management of the deep sea.* Biological diversity in the deep ocean is estimated to be high but is poorly documented compared to other ecosystems. New unique habitats (such as vents, seeps, and seamounts), species, behaviors, and interactions are frequently discovered and the estimated numbers of undiscovered species are high for many taxa (Rabone et al. 2023). Baseline biodiversity assessments of the water column and seafloor have not been conducted for many deep-sea areas and ecosystems, particularly in certain regions (e.g., the South Atlantic; Bridges et al. 2023). Ecological functions and services of deep-ocean ecosystems at individual, population, and community levels remain largely unknown.

Targets: (i) Identify global deep-ocean exploration and biodiversity characterization priorities. (ii) Double the number of deep submergence assets and berths, and increase online access for exploration available to the Global South/developing nations. (iii) Improve the understanding, applicability, and implementation of eDNA technologies and platforms and recommend that eDNA data are submitted to existing repositories (e.g., Ocean Biodiversity Information System [OBIS]) with appropriate ecosystem tagging (aligned with goals of decade-endorsed Actions such as Digital DEPTH, Challenger 150, and Ocean Census).

Cohesive Ask 2.2. *Identify and characterize deep-ocean ecosystem vulnerability and resilience to climate change, climate intervention, and resource extraction.* Deep-ocean ecosystems and species are sensitive to environmental change, which can occur naturally or as a result of global warming and ocean carbon uptake. Warming, acidification, deoxygenation, changes in food supply, and circulation are impacting the functions and services provided by deep-ocean ecosystems (Bindoff et al. 2019). At scale, mCDR activities and the extraction of living and nonliving resources may exacerbate these changes in the deep ocean (Levin et al. 2023). Commercial activity such as seafloor mining at submarine hydrothermal vents and seamounts and hydrocarbon extraction near cold seeps could potentially disrupt species dispersal of larval forms of benthic species (Mitarai et al. 2016). This is especially important since vents, seeps, and seamounts are critical stepping-stones for dispersion and gene flow of deep-ocean organisms and thus, affect biogeography and ecosystem structure and functions (Xu et al. 2018). Recognizing and conserving distinct deep-ocean ecosystems, refugia, critical corridors, and carbon reservoirs will benefit biodiversity and our ability to curb anthropogenic climate change.

Target: Conserve 30% of deep-sea habitats, combining biodiversity protection with conservation of carbon cycle services (in alignment with the '30x30' target in the Kunming-Montreal Global Biodiversity Framework).

Theme #3: Deep-ocean science requires an integrated observing system

Aligns with Decade Challenges 2, 6, 7 and 9

Cohesive Ask 3.1. *Enable a multidisciplinary, collective, deep-ocean observing system.* The deep ocean is highly connected with interacting physical, chemical, and biological features. Coordination of deep-ocean exploration, observing, and modeling across disciplines, temporal and spatial scales, and geographic regions can achieve a cohesive system capable of addressing current societal needs and those of future generations. Physical and biogeochemical variables in the deep ocean are under-observed, yet are a prerequisite for understanding broader ocean processes, interpreting and predicting climate impacts, and even for more skillful weather forecasting. Coordinated international efforts to integrate ocean observations and measurements into ocean and climate models for policy decision-makers are critical. Priority areas include sites with abundant data gaps in the Southern Hemisphere, including the Indian Ocean, and rapidly changing areas of the polar seas.

Targets: (i) Double the number of biogeochemical and physical properties sampled by global observing programs. (ii) Increase new research infrastructure and instrument deployments targeting priority areas/observational gaps (aligned with goals of decade-endorsed Actions, including those by Challenger 150, OneDeepOcean, and Ocean Census; Table 1).

Cohesive Ask 3.2. *Promote the use of multipurpose infrastructure to enhance deep-ocean observing, monitoring, and knowledge.* International communications (cables), offshore energy (hydrocarbons and renewables), fisheries, and nascent industries like mCDR and seabed mining, affect the deep ocean. Through collaborative efforts and data sharing, these industries should contribute to an integrated observing system that augments publicly funded scientific efforts and provides information about impacts in deep water.

Targets: (i) Identify and enable multiple sensing uses of each major deep observing network. (ii) Ensure deep-ocean observing data enter existing functional and Findable, Accessible, Interoperable and Reusable (FAIR) data facilities (e.g., Ocean Data Information System—*see* Cohesive Ask 4.1). (iii) Collaborate with the Decade-endorsed program Digital Twins of the Ocean (DITTO) to help optimize observations into model prediction engines that will guide the

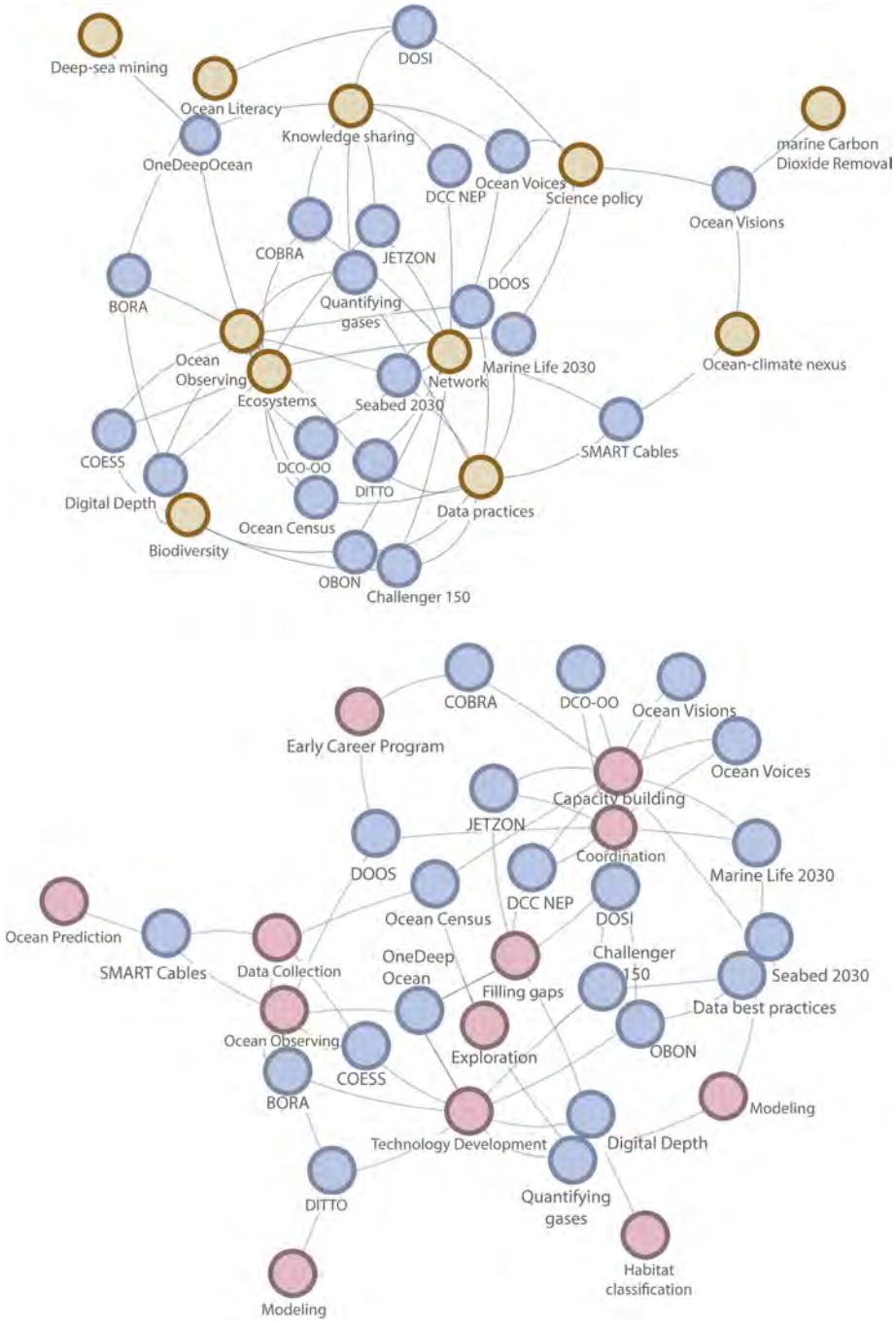

FIG. 1. Map of connections between Decade Actions, which include Projects, Programs, and Centers (blue circles), broad topics (top panel; tan), and efforts (bottom panel; pink). Each line represents a connection between a Decade Action and a broad topic or effort. See Table 1 for descriptions of each Decade Action.

design of ocean protection and conservation measures, ecosystem restoration, and ocean forecasting for public safety and all aspects of the blue economy. (iv) Use telecommunications infrastructure to accelerate deep-ocean data collection (aligns with the Decade-endorsed project Science Monitoring And Reliable Telecommunications [SMART] Cables).

Theme #4: Deep-ocean data are a world common heritage

Aligns with Decade Challenges 2, 8 and 9

"Trustworthy, robust, verifiable, reproducible, and open science is our responsibility and legacy for future generations" (American Geophysical Union Position Statement on Earth and Space Science Data, agu.org), and can only be achieved if data are openly shared and widely accessible. This vision will be fostered within the deep-ocean community by working toward the following:

Cohesive Ask 4.1. *Promote Open Science, FAIR, and CARE (Collective Benefit, Authority to Control, Responsibility, Ethics) principles worldwide.* To contribute to our knowledge and management of the deep ocean, data must be FAIR (Wilkinson et al. 2016), as well as open (freely accessible) (unesco.org/en/open-science). The FAIR data principles are clear, and the infrastructure to support a global discovery network is developing within the Decade (Smith et al. 2022). While FAIR and Open Science principles speak to characteristics of data, they do not consider the human context within which they were collected or how they are used. The CARE Principles for Indigenous Data Governance focuses on enhancing the well-being of people through responsible use of scientific data (Carroll et al. 2021). The deep-ocean Decade Actions collecting or curating data must meet FAIR, Open Science, and CARE principles. We will endorse and promote the CARE principles to respect and advance Indigenous innovation and self-determination within the data life cycle.

Targets: (i) Identify all Decade-endorsed deep-ocean Actions. (ii) Provide Decade-endorsed deep-ocean Actions with FAIR and CARE data training by 2025. (iii) Obtain endorsement and commitment of FAIR and CARE data from 100% of deep-ocean Decade Actions by 2028.

Cohesive Ask 4.2. *Promote accessibility and discoverability for deep-ocean biodiversity data.* With the larger goal of promoting FAIR and CARE principles, the deep-ocean community is well positioned to mobilize the accessibility of deep-ocean biodiversity data. A global repository, the OBIS (www.obis.org), already exists for these data. OBIS should be made more flexible and modular for hosting collection archives for deep-ocean surveys, in addition to deep-ocean biodiversity data. Several Decade-endorsed Actions (the Deep Ocean Observing Strategy, Digital DEPTH, Challenger 150, Ocean Census, and COBRA) have strong components of biodiversity data collection and aggregation,

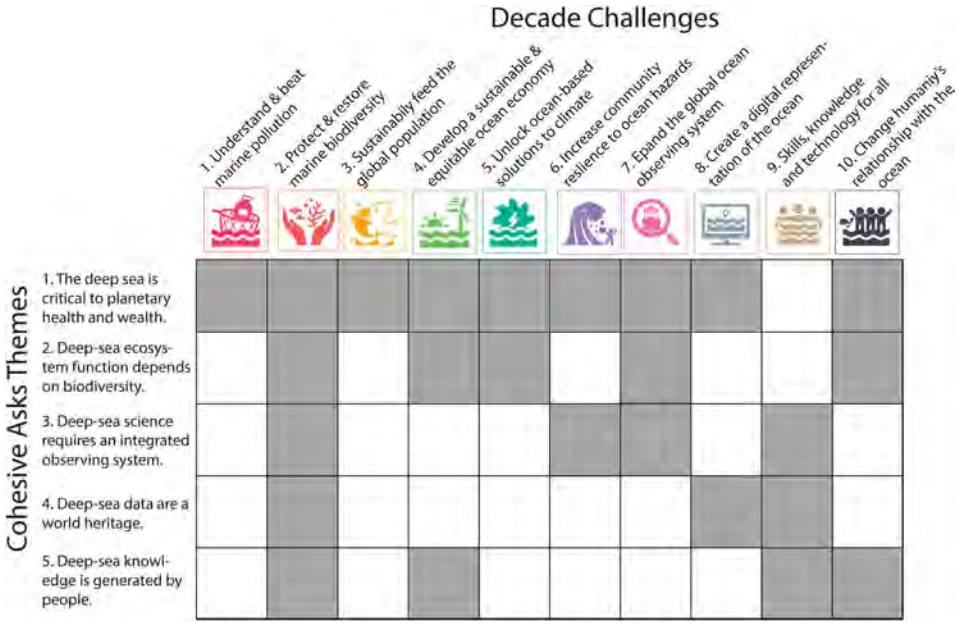

FIG. 2. Cohesive Asks are grouped into five main Themes, which are cross-cutting and each support numerous Decade Challenges. Boxes that are shaded gray indicate which Themes support each Decade Challenge.

as well as strong communication pathways to promote data sharing.

Target(s): (i) Provide Decade-endorsed deep-ocean Actions with OBIS training or resources by 2026. (ii) Double the amount of deep-ocean data that are discoverable and openly accessible online.

Theme #5: Deep-ocean knowledge is generated by people

Aligns with Decade Challenges 2, 4, 9, and 10

Cohesive Ask 5.1. *Train and empower the next generation of deep-ocean professionals*. Young people are the next generation of professionals that are already contributing to addressing ocean challenges. There are a variety of disciplines and efforts by Early Career Ocean Professionals (ECOPs) that address the visions of the Decade. Therefore, it is important to provide support for ECOPs so they are well equipped to perform their work and advance in their ocean-related professions. This support can be in terms of opportunities, training, resources, and networking.

Target(s): (i) Create a Deep ECOP task team by 2025. (ii) Connect Deep ECOPs with existing opportunities to engage with deep-ocean Decade Actions. (iii) Double the membership and participation in the Deep ECOP task team by 2027.

Cohesive Ask 5.2. *Break down barriers to communication across global communities and sectors*. Many stakeholders lack access to the deep-ocean knowledge that is needed to address the Decade's key challenges. Experts and Decade participants should strengthen their communication efforts, both learning from and sharing knowledge with the communities and sectors whose help is needed to restore ocean health.

Target(s): (i) Identify opportunities to leverage the framework of the Decade for strengthened cross-sectoral partnerships and strategic knowledge sharing. (ii) Coordinate among deep-ocean Actions (DOSI, DOOS, Digital DEPTH, ECOP program, and others; Table 1; *see* Cohesive Ask 4.1).

Cohesive Ask 5.3. *Translate knowledge to decision-makers*. The value of ocean data lies in its ability to be used in making predictions and informing decision-making. The extraction of knowledge from data is a critical part of the role of an ocean scientist. Such knowledge, when explained in the context of societal benefits and risks, will enable decision-makers to form policy and direct investment. Deep-ocean knowledge is becoming increasingly available and useful to decision-makers who rely on best available information to shape national and international ocean policy and regulation amidst unprecedented climate and human impacts. Co-design of processes that integrate science products with the needs of users in policy and decision-making arenas (Claudet et al. 2020) is essential for ensuring deep-ocean knowledge is available, actionable, and responsive in this critical time.

Target(s): (i) Create online training tools (e.g., short course and resources, including in collaboration with UNESCO International Oceanographic Data and Information Exchange's OceanTeacher) by 2026 that enable deep-ocean scientists to identify the potential policy relevance of their work, understand the relevant governance structures, and identify vehicles to engage in the science–policy interface. (ii) Double the number of scientists (and countries represented) contributing science to international policy negotiations relevant to the deep ocean (e.g., through DOSI, DOOS, or other Decade Actions).

Cohesive Ask 5.4. *Amplify traditionally underrepresented voices*. Access to deep-ocean knowledge and the capacity to generate it has historically been limited to those in a small number of geographies (Bell et al. 2022). This contributes to a "mismatch" between communities likely to have strong interest in deep-ocean science and policy and their ability to contribute to and use the growing body of knowledge about it. "Parachute Science," which creates dependency on external expertise, exacerbates the problem and hinders local research efforts. Recent efforts such as the Alliance of Small Island States' Declaration for the Enhancement of Marine Scientific Knowledge, Research Capacity, and Transfer of Marine Technology (2022) and the Decade-endorsed Global Deep Sea Capacity Assessment (Bell et al. 2022) exemplify the importance of increasing participation of historically underrepresented geographies in producing, accessing, and using knowledge. Co-design processes responsive to context-specific priorities can break down existing barriers to generation and communication of knowledge across geographic communities (Alliance of Small Island States 2022; Bell et al. 2022).

Target(s): (i) Support leaders from developing countries, especially those from Small Island Developing States (SIDS) and Least Developing States (LDCs) to lead science expeditions by increasing the number

of deep-ocean Decade projects, programs, collaborative centers, and actions that are co-designed by SIDS and LDCs and are aligned with their nations' research priorities. (ii) Leverage the Deep ECOP task team (*see* Cohesive Ask 5.1) to engage early-career researchers from the Global South in science and policy training and initiatives. (iii) Identify and advertise existing opportunities and resources that provide funding mechanisms for people from nations or regions historically poorly represented to attend high-level meetings.

Cohesive Ask 5.5. *Co-create with traditional and Indigenous knowledge*. Indigenous Peoples have been stewards of the land and sea since time immemorial. Yet, Indigenous knowledge has often been excluded from ocean science and policy decision-making. The implementation of marine protected areas, for example, should be evaluated in regards to the impact and reception by local small-scale fishing and/or Indigenous communities (Mascia et al. 2010). In addition to implementing the CARE principles across the data lifecycle (*see* Cohesive Ask 4.1), there is a need for ocean policy to be Indigenous informed and involve respectful partnerships between Indigenous Peoples and ocean scientists. This can be accomplished by using a "two-eyed seeing" approach (Leonard et al. 2022), which aims to combine Indigenous and Western knowledge in a way that can advance science and uplift Indigenous communities. Engaging with Indigenous communities at an early stage and building on-the-ground relationships are critical for avoiding parachute research practices at a time when Indigenous Peoples are increasingly being sought out for research partnerships that consider Traditional or Indigenous knowledge (Jennings et al. 2023). To uphold Indigenous Rights, and effectively partner with Indigenous communities to co-design and co-produce knowledge, researchers must recognize past and present colonial legacies, understand existing capacities and barriers to participation, and be advocates for change within the academic and research communities (Ignace et al. 2023).

Targets: (i) Create two-way conversations between Indigenous communities and representatives of traditional knowledge systems and all deep-ocean Decade Actions to explore linkages by 2025. (ii) Adopt co-designed and co-creation operating principles (building on the CARE principles) relevant to the deep ocean.

Conclusions

Collaboration and coordination are imperative for advancing ocean science and the Decade initiatives. This is particularly true for deep-ocean science, which is expensive and often inaccessible (Bell et al. 2022). In addition to writing the Cohesive Asks above, recent conversations within the deep-ocean Decade community have led to the creation of a deep-ocean task team within the global ECOP program. This task team will serve as a bridge between early career researchers eager to engage with the Decade and programs offering opportunities for ECOPs but lacking mechanisms to do so. Members of the deep-ocean Decade community also recently participated in the recent reviews of the Decade's Vision 2030 white papers (oceandecade.org/publications/ocean-decade-vision-2030-white-papers/) to ensure deep-ocean representation. While many Decade initiatives are in their early stages, we have identified the Cohesive Asks and associated Targets above as a roadmap for the deep-ocean community. Our collective efforts aim to enhance deep-ocean science for the remainder of the Decade and beyond. If you are interested in contributing to these Decade Actions, or if you are involved in a Decade Action that works on deep-ocean topics and would like to contribute to future activities, please contact deepoceanobserving@gmail.com or the corresponding authors.

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