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# A decade to study deep-sea life

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**A Decade to Study Deep-Sea Life**

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*The UN Decade of Ocean Science for Sustainable Development represents a once in a generation opportunity to effect positive change in ocean use. We outline what is required of the deep-sea research community in order to achieve the ambitious objectives of the Ocean Decade and call for the development of a new ten-year research programme.*

The health of the global ocean, on which society is dependent, is in decline. The importance of sustainable use to ocean health has long been recognized[1]. The First World Ocean Assessment[2] highlighted increasing ocean pressures from accelerated expansion of human activities, including climate change, affecting all ocean regions, from the coast to the deep sea[3]. In response to this concern, and in keeping with several international policy commitments, the UN General Assembly proclaimed 2021-2030 the Decade of Ocean Science for Sustainable Development[4]. The Ocean Decade Roadmap recognizes the deep sea as a frontier of science and discovery, calling for research to advance understanding of deep-sea ecosystems, their functions, vulnerabilities, and services to society. Published in March 2020, the draft Implementation Plan for the Ocean Decade describes a framework to guide the design and implementation of 'Actions' throughout the Decade. These Actions underpin the move from the 'ocean we have' to the 'ocean we want'. Different levels of Actions are identified, and include programmes, projects, activities and contributions. The draft plan calls upon the scientific community to develop Actions to help deliver on four key objectives (see Fig. 1).
The deep-sea biology community responded to this call through working groups of the Deep-Ocean Stewardship Initiative (DOSI) and the Scientific Committee on Oceanic Research. In keeping with the Ocean Decade's focus on fair and equitable partnerships, these groups gather experts from developed and developing nations, representing diverse ethnic backgrounds, different genders and career stages. Together, these groups considered each of the Ocean Decade objectives in a deep-sea biology context, and the associated research needs. Here we present a series of recommendations under each objective to inform the development of deep-sea focused Ocean Decade Actions.

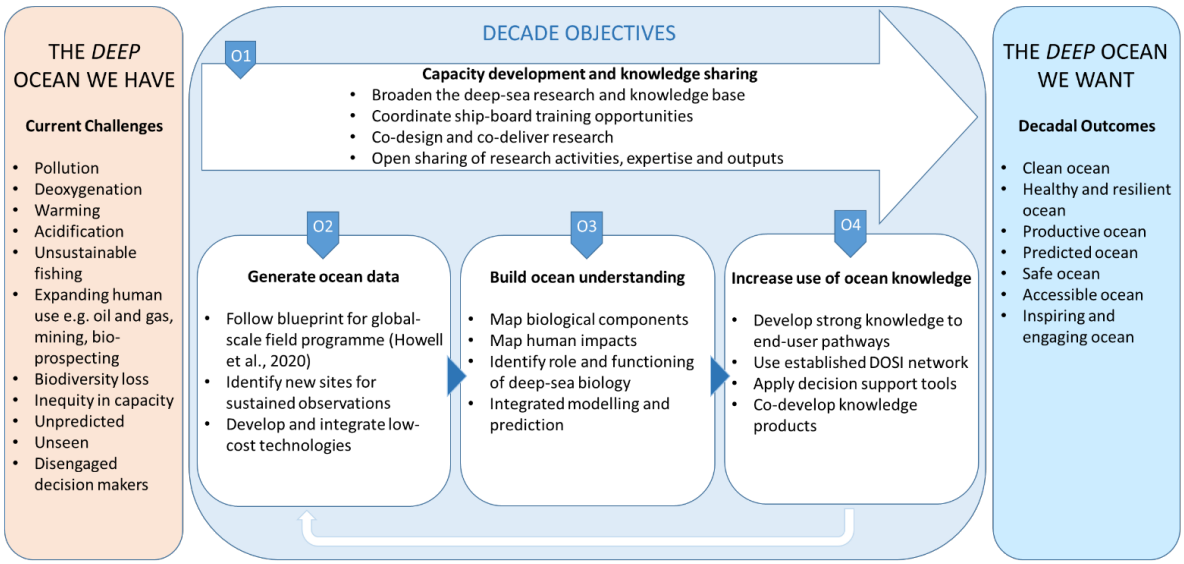


**Figure 1:** The Ocean Decade through a deep-sea biology lens, and our recommendations to support the development of Actions focused on achieving the Ocean Decade objectives.

*Objective 1: Increase*

Deep ocean science capacity among nations is unequal, where countries with developing economies face significant barriers to participating in deep-sea research, including access to technological capability and infrastructure, and specific expertise. Thus, although more than 70% of countries' Exclusive Economic Zones (EEZs) contain deep-sea environments, only a small subset of economically developed nations conduct most deep-sea research. Consequently, the least studied parts of the deep sea are within the EEZs of least economically developed countries (LDCs) and Large Ocean States (LOS a.k.a Small Island Developing States, SIDS). Availability of samples, data, and overall knowledge of deep-sea ecosystems reflect these biases. Even where such nations can participate, barriers to publishing in international journals often result in country-specific publications only.

Deep-sea focused Ocean Decade Actions must strive to expand capacity development by coordinating efforts across deep-sea research projects and regions to provide sea-going opportunities for researchers from those nations that have limited access to large-scale infrastructures. All Actions should commit to co-developing and co-producing transregional research at an early stage of design, partnering with local collaborators. Importantly, the planned research should value and build upon local / indigenous knowledge systems. This approach will bring new perspectives and approaches to deep-sea research[5], and encourage a new generation of deep-sea scientists and educators by highlighting a diversity of role models and opportunities. All Actions should facilitate open access to marine scientific research outputs, marine technologies, and ocean knowledge, using best practices. These should follow both the principles of being Findable, Accessible, Interoperable, and Reusable (FAIR) and the principles of Collective benefit, Authority to control, Responsibility and Ethics (CARE). Existing UN supported initiatives i.e. Ocean Biodiversity Information System (OBIS), and further developments under the Ocean Decade (for example the International Oceanographic Data and Information Exchange) should be employed. All actions should commit to sharing specimens (including whole animals, tissue, barcoding and environmental DNA samples), and invest in the deposition of specimens within established, regionally relevant, institutions with recognised charters to support permanent storage and care of archived specimens. We recommend open access publication of research and data where possible.

*Objective 2: Identify and generate required ocean data,* information and knowledge

Physical and biogeochemical observing programmes in the deep ocean have expanded recently at local, regional, and global scales. However, sustained biological observing programmes have lagged, with only a handful of long-term study sites[6]. Spatial bias occurs in biological ocean observations, with undersampling of equatorial and polar regions, and the southern hemisphere more generally[7]. Globally, sampling effort decreases with depth[8]. Although recent technological advances allow every part of the deep ocean to be accessed, the capacity to deploy assets remains restricted worldwide because of the high cost of suitable vessels and limited available infrastructure.

A coordinated international effort is needed to expand deep-sea biological observations and sampling in all ocean basins, specifically focusing on underexplored regions. A blueprint for a global-scale field programme using standardized methods, stratified by latitude, biogeographic region and depth, among other key variables, has recently been prepared[9] that addresses this issue specifically. We recommend that Ocean Decade field survey Actions follow this blueprint to support completion of a global sampling jigsaw puzzle, designed to collectively advance scientific knowledge in all ocean basins to deliver comparable information on deep-sea ecosystems that can address the Ocean Decade objectives. The blueprint also highlights the need to identify biogeographically representative sites to initiate a globally comprehensive sites network for sustained observations.

Expanding both spatial and temporal biological observations in the deep ocean will require both smaller and lower-cost technologies to enable broader participation[10,11]. Ocean Decade Actions should build on existing efforts within our deep-sea research community to develop and apply such novel approaches under a standardized framework, with the aim to extend and accelerate spatial and temporal ecological knowledge acquisition globally.

*Objective 3: Build comprehensive understanding* of the ocean and its governance systems

Despite increased research efforts in recent years, fundamental biological, ecological and taxonomic information for much of the deep ocean is urgently needed to improve predictions, forecasting and modelling that will generate knowledge for decision-making, policy, management and innovation. Accurate prediction of how biodiversity will respond to future climate change and other anthropogenic pressures requires data on existing species, their biotic and abiotic tolerances and interactions, in addition to better characterization of climate stressors at deep-sea habitat-representative spatial and temporal scales. Effective ocean management and sustainable use also critically depend on understanding linkages among deep-sea ecosystems, communities, species, and populations, collectively termed *connectivity.* Finally, a clear understanding of the role of the deep ocean in the provision of ecosystem services at regional and global scales is needed.

Ocean Decade Actions must expand knowledge of offshore and deep-sea ecosystems and associated anthropogenic impacts. Mapping the biological components of the deep sea, describing what we have, where and how it lives is critical to achieving this objective. We recommend Actions look to map ecosystem services delivered by the deep seas, and flows of benefits to society. Mapping of human impacts across temporal and spatial scales, following standardized methodologies and a dynamic stratified design is also needed in order to understand current baselines. Through targeted sampling and experimentation, Actions should identify the role and functioning of deep-sea biology, including those systems essential to ocean and human health. The acquired information can then be used to map and quantify human impacts in the deep sea and assess the feasibility of future restoration actions[12]. Collectively, this knowledge will facilitate improved modelling and predictive capacity to deliver relevant and timely societal services that can inform sustainable management of our future ocean. These results can feed into UNGA processes, and more regional management bodies (e.g., through FAO, ISA), as well as contribute to national management options.

*Objective 4: Increase the use of ocean knowledge*

Decision-making processes to ensure sustainable use of the marine environment require synthesis of multiple streams of knowledge to reach evidence-based choices. While researchers have developed many decision-support tools that have already been applied to marine spatial planning (see review by [13]), few have been applied specifically to the deep sea[14].

Ocean Decade Actions should strive to inform ecosystem-based management to support global, regional and local decision-making in the deep ocean. Working with the UN, and relevant regional and national bodies, Actions should further develop and trial decision-support tools and scenario-based systems for informed decision-making and adaptive management at local to global scales. Actions should foster the development of effective “knowledge to end-user” pathways, building on already successful community initiatives, for example the DOSI.

*A call for a new ten-year research programme*

The Ocean Decade begins on the 1st January 2021. Our recommendations provide a resource for deep-sea biologists seeking to engage with the Ocean Decade through developing their own Actions. However, they also provide the basis for the development of a deep-sea focused Programme level Action designed to coordinate and monitor deep-sea research effort over the Decade, in order to accelerate knowledge generation and understanding of the deep ocean. Such a Programme could build on previous global decadal efforts, most recently the Census of Marine Life (CoML) (2001-2010). The CoML brought together more than 2700 researchers from around the world to evaluate the diversity, distribution, and abundance of life in the global ocean. Of the 17 major projects under the CoML, five specifically focussed on deep-sea ecosystems, and these provide an important reference point. A new Programme, designed around the Ocean Decade objectives, could result in a more significant advance in knowledge to support high-level policy processes, including the Sustainable Development Goals and Aichi 2030 Targets, than individual Project level Actions could achieve in isolation. We contend that a new ten-year programme to enact our recommendations is essential if we are to move to a more sustainable future for our deep ocean. This Ocean Decade is the time, and we must all seize the opportunity.

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