2021 2030 United Nations Decade of Ocean Science for Sustainable Development

The Ocean Decade

Vision 2030 White Paper

Challenge 2

Protect and restore ecosystems and biodiversity

Version 1.0 - April 2024

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Intergovernmental Oceanographic Commission

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VISION 2030 WHITE PAPER

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CHALLENGE 2: PROTECT AND RESTORE ECOSYSTEMS AND BIODIVERSITY.

Understand the effects of multiple stressors on ocean ecosystems, and develop solutions to monitor, protect, manage and restore ecosystems and their biodiversity under changing environmental, social and climate conditions.

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Acknowledgements

Working Group 2 included subject experts, representatives from Ocean Decade Actions, users of information and ocean resources, Early Career Ocean Professionals (ECOPs), members from local and indigenous communities, and policy-makers from many different countries. Input from the public and user communities was obtained at the 6th World Conference On Marine Biodiversity (WCMB; Malaysia, July 2023), and through co-design focus groups organized by the Marine Life 2030 UN Ocean Decade Programme in collaboration with the Ocean Knowledge Action Network (Ocean KAN). We thank the staff of the UN Ocean Decade Coordinating Unit and many other people for their contributions through guidance, reviews, surveys, workshops, and direct and personal comments that helped craft the White Paper.

Acronyms

AI	Artificial Intelligence
CBD	The Convention on Biological Diversity
GBF	Global Biodiversity Framework
GBIF	Global Biodiversity Information facility
GOOS	Global Ocean Observation System
FAO	Food and Agriculture Organization
IOC	Intergovernmental Oceanographic Commission
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPLC	Indigenous People and Local Communities
MBON	Marine Biodiversity Observation Network
NBSAP	National Biodiversity Strategy and Action Plan
OBIS	Ocean Biodiversity Information System
OBON	Ocean Biomolecular Observing Network
SEEA	UN System of Environmental-Economic Accounting
SIDS	Small Islands Developing States
UN	United Nations
UNEP	United Nations Environment Programme
UNESCO	UN Educational, Scientific and Cultural Organization

1. Executive summary

1.1. Introduction and Scope of the White Papers

This draft White Paper has been prepared as part of the Vision 2030 process being undertaken in the framework of the UN Decade of Ocean Science for Sustainable Development. The Vision 2030 process aims to achieve a common and tangible measure of success for each of the ten Ocean Decade Challenges by 2030. From a starting point of existing initiatives underway in the Ocean Decade and beyond, and through a lens of priority user needs, the process determines priority datasets, critical gaps in science and knowledge, and needs in capacity development, infrastructure and technology required for each Challenge to ensure that it can be fulfilled by the end of the Ocean Decade in 2030.

The results of the process will contribute to the scoping of future Decade Actions, identification of resource mobilization priorities, and ensuring the ongoing relevance of the Challenges over time. The process identifies achievable recommendations that can be implemented in the context of the Decade, or more broadly before 2030 to achieve the identified strategic ambition and indicators that will be used to measure progress.

This draft White Paper is one of a series of ten White Papers all of which have been authored by an expert Working Group. Accompanied by a synthesis report authored by the Decade Coordination Unit, it will be discussed at the 2024 Ocean Decade Conference before being finalized and published.

1.2. Strategic Ambition of Ocean Decade Challenge No. 2

By 2030, the success of Ocean Decade Challenge No. 2 will be measured by the timely and widespread availability of scientific information about biological, ecosystem, and other biodiversity change, the human and natural drivers of change, and the local capacity to generate and use this information to advance sustainable development. Ocean Decade Actions should include local, indigenous, academic research, Non-Governmental Organizations (NGOs), and private sector approaches to develop this information. Ocean Decade Actions should also synergies with the Decade for Ecosystem Restoration to support the effective conservation and restoration of ecosystems and biodiversity with a view that goes beyond 2030. Success is a concerted effort to understand and monitor ecosystem and biodiversity changes in national waters, address issues on land that affect coastal and ocean biodiversity and include areas beyond national jurisdiction which represent most of the ocean.

Success in developing the scientific framework for sustainable development will rely on convergence on a practical set of essential ocean biology and ecosystem variables from among those defined by the Global Ocean Observing System (GOOS). This will require significant improvements in the methods and capacity to collect, curate, interpret, and access quality biological, environmental, social, economic, and cultural information. Of particular importance is addressing science and knowledge gaps about biology, biodiversity, and ecosystem changes that are pervasive everywhere, recognizing the urgency to act, and the broad variety of geographic, social, and other issues we have to deal with. This includes continuing monitoring and understanding of:

- coastal, open ocean, deep-sea biodiversity and ecosystem change from the tropics to high latitudes,
- connectivity and habitat interdependencies within ocean, land, and atmosphere ecosystems,
- the vulnerability of deep benthic, polar, and critical coastal and estuarine habitats,
- identifying drivers of change,
- addressing the cumulative effects of human activities and climate change on biodiversity and ecosystems,
- co-designing ecosystem-based management approaches, including conservation and restoration.

All local communities, including Indigenous and Small Island Developing States (SIDS) are vulnerable to biodiversity loss and ecosystem change. Management efforts need to recognize the contribution of these communities to knowledge and engage them in the implementation of ecosystem-based management. Management and planning need to incorporate biodiversity and environmental data into local, regional, and global ocean and earth system models to match specific management needs. Other issues that need immediate attention include interoperability of observations across projects, increasing collaboration between natural and social scientists and connectivity between marine life databases and environmental and socio-economic databases, and strengthening dialogue and collaboration among stakeholders and rights holders. High return in investments will come from making data interoperable and comparable spatially and temporally, sharing best practices to collect and manage information, and incorporating knowledge on biodiversity and ecosystem change in ecosystem-based management.

Based on the above strategic ambition, the formulation of the Ocean Decade Challenge could be modified as follows: Measure and understand marine biodiversity and ecosystem change to focus protection and conservation.

1.3. Key Recommendations to Achieve the Strategic Ambition

The Ocean Decade should advance these activities to ensure success in the context of all Challenges:

- Public-private partnerships focused on incentives to promote ocean science, monitoring, and education focused on sustainable development;
- Implement a co-design approach to ecosystem and biodiversity observation networks; this process should highlight partnerships with local and Indigenous communities.
- Nations should conduct gap analyses of biodiversity information and address these gaps;
- Support and build on existing networks for biodiversity observation (e.g., elements of GOOS, OBIS, GBIF, MBON, OBON, G3W, relevant UNEP and FAO programs). Biological observations should be integrated into physical and biogeochemical observing networks;
- Nations should develop a convention to promote a minimum set of operational, interoperable biodiversity observations;
- Biological observing systems should be deployed in under-sampled regions and those most vulnerable to climate change and anthropogenic stressors;
- A key goal should be to understand connectivity between different parts of an ecosystem, including links between activities on land, water quality and freshwater availability, upstream ocean processes, and ecosystem and biodiversity change;
- Develop a strategy to lower the cost of high-quality biodiversity and ecosystem observations and promote broader geographic coverage;
- Expand and coordinate capacity building among institutions nationally and internationally to implement ecosystem-based management, including observing, monitoring, and information management;
- Establish a coordination mechanism between actions of the Ocean Decade and the Decade on Ecosystem Restoration.
- Co-design methods to evaluate effectiveness of restoration and conservation programs;
- Communicate ecosystem and biodiversity status and change to prompt action across geographic, government scales.

1.4. Key Milestones and Indicators for the Strategic Ambition

Key milestones and indicators to be used to measure the fulfillment of the strategic ambition include:

Milestones:

- By July 1, 2025: Every National Decade Committee or regional group or agency has identified a core set of marine life and ecosystem variables to monitor that are essential for sustainable development within and beyond national jurisdictions.
- By January 1, 2026: The UN Ocean Decade has advanced a framework for global observation of biodiversity change and associated environmental, social, and climate conditions, data interoperability, and quality assurance, including developing the capacity to generate and use this information.
- By January 1, 2027: Every coastal nation has initiated a process to recognize and use scientific information about biodiversity and ecosystem change as part of its National Biodiversity Strategy and Action Plan (NBSAP) or equivalent efforts.
- By 2028: Every National Decade Committee or regional group has identified a process or strategy for collecting and publishing data on core marine life and ecosystem variables through existing, interoperable, international information systems, such as the Ocean Biodiversity Information System (OBIS) and Global Biodiversity Information facility (GBIF).
- By 2030, biodiversity and ecosystem health baselines and a systematic process to report changes to support sustainable development, including conservation and restoration efforts, have been established.
- Immediate and ongoing for the Decade and beyond: financial and logistical support by National Decade Committees or regional groups or agencies is secured to foster regular communication between all Decade Programmes and Actions.

Indicators:

- The number of countries that advance the capacity to generate and use scientific data on marine biodiversity and ecosystem change.
- The volume, geographic coverage, and monitoring observations collected and published in marine biodiversity databases (e.g., in OBIS, GBIF, nucleotide databases).
- Number of reference DNA sequence data available for global “indicator” species.
- Number of Ocean Decade Actions that explicitly consider biodiversity, ecosystem change, and scientific measures of effectiveness of conservation and restoration.
- Number of Actions that explicitly include co-design efforts with local and indigenous communities.
- Establishment of global networks and an international coordination mechanism that integrate biology and ecosystems Essential Ocean Variables, incorporating automated systems with Artificial Intelligence and Machine Learning (AI/ML), capacity sharing, and citizen science and local knowledge.
- Multi-annual funding is secured for Actions focused on Challenge 2.

Executive Summary Glossary and Resource List

Term	Explanation	Reference
Biodiversity	Biodiversity is the variety of life on Earth at all levels of biological organization, including ecosystems, species, and genes	Convention on Biological Diversity, 1992; Article 2 https://www.cbd.int/convention/articles/?a=cbd-02
Ocean science	"Ocean science" is used in this white paper to include knowledge derived from observation and synthesis from academic scientists and from Indigenous People and Local Communities (IPLC, as Traditional and Local Ecological Knowledge; (Berkes, 1993))	
UN Decade on Ecosystem Restoration	The UN Decade on Ecosystem Restoration aims to prevent, halt and reverse the degradation of ecosystems worldwide	UN A/RES/73/284 https://www.decadeonrestoration.org/
UN Ocean Decade	UN Decade of Ocean Science for Sustainable development. Mission: Transformative ocean science solutions for sustainable development, connecting people and our ocean.	https://oceandecade.org/
CBD	The Convention on Biological Diversity	https://www.cbd.int/
GBF	The Kunming-Montreal Global Biodiversity Framework, provides a pathway to achieve a world in harmony with nature by 2050	https://www.cbd.int/doc/decisions/cop-15/cop-15-dec-04-en.pdf
NBSAP	National Biodiversity Strategy and Action Plan	https://www.cbd.int/nbsap/ CBD/COP/DEC/15/12*
Primer for Biological Data Managers	Biological observations and data standardization recommendations	Benson et al., 2021. https://doi.org/10.6084/m9.figshare.16806712.v2

2. Introduction

2.1. Background and context of the Challenge

In promoting UN Agenda 2030 (UN A/RES/70/1), all nations agreed to work in a Global Partnership for Sustainable Development guided by 17 Sustainable Development Goals (SDG). This call for action to manage consumption and production of resources and to take action on climate change requires timely and accurate information so that present and future generations can enjoy prosperous lives “in harmony with nature”.

The UN designated two concurrent decadal processes (2021-2030) to meet broad sets of the SDG. One is the UN Decade of Ocean Science for Sustainable Development (the Ocean Decade). The other is the UN Decade on Ecosystem Restoration to prevent and reverse the degradation of ecosystems on every continent and in the ocean. Our current and future economies depend on natural capital. The global ocean economy is expected to grow to USD 3 trillion by 2030 relative to USD 1.5 trillion in 2010 (OECD, 2019). This growth depends on healthy marine life and ecosystems in sectors like fisheries and aquaculture, biomaterials, renewable energy, carbon accounting, recreation and tourism, and cultural and religious value (Estes et al., 2021). Ultimately, it depends on having a stream of timely and accurate information on the state of the ocean’s biodiversity and ecosystems and the capacity to use this information for management and policy (Spinrad, 2021; Urban et al., 2022; Miloslavich et al., 2022).

This intersection between concurrent UN decades is an unprecedented opportunity for private, academic, and government agencies at every level to collaborate on generating the knowledge we need to sustain development (Ryabinin et., 2019). Investments in marine conservation and restoration should be coordinated so that local projects can have beneficial effects at national and larger scales for stakeholders and right holders (Fischman et al., 2023). Incentives for collaboration are critical in shaping a culture around standards and best practices (Bell-James et al., 2024; Pearlman et al., 2021). These are fundamental elements of the Ocean Decade’s Challenge 2.

2.2. Overview of current work in the Ocean Decade

As of November 2023, seven Programmes with close to 80 Projects with a strong focus on Challenge 2 had been endorsed by the Ocean Decade. To make all these initiatives more effective, the Ocean Decade needs to organize support for them and coordinate their complementary efforts. Below, we provide some recommendations on how to focus funding and efforts to successfully address Ocean Decade Challenge 2.

2.3. Importance and relevance of the Challenge for sustainable development

We often take biodiversity for granted. Yet, marine ecosystems are changing within the span of our own lifetimes, driven by accelerating changes in human activities and climate change. These changes include more fishing, more pollution, rising sea level, more frequent extremes in weather, changes in water temperature, salinity, pH, and oxygenation, and other ecosystem alterations (IOC-UNESCO, 2022). These multiple stressors have already caused marked losses of marine habitats. They have led to changes in marine life from microbes to mammals. They have affected the physiology and health of many organisms, the geographic distribution and migration patterns of species, caused a dramatic decline in predators and large fish at the top of some ocean food chains, and changes in the productivity and size structure of plankton and microbial communities at their base. The resulting loss in marine life and other anticipated changes in biodiversity (the composition, abundance, and distribution of living communities and ecosystems) are alarming, and is what people refer to as “biodiversity loss”. The changes are affecting many ecosystem services on which the economy and well-being of many people depend (IPBES, 2019, IPCC, 2023). It is estimated that globally, natural capital stocks have already declined by about 40% per capita, compared to a global GDP per capita increase of more than 60% between 1992 and 2014 (OECD,

2019). People at all socio-economic levels and many industries are at risk of losing expected ecosystem services, with people with the least resources being most vulnerable.

How do we allow equitable development and simultaneously promote positive changes in coastal and marine ecosystems, including biodiversity? Sustainable development means that use of the ocean and its resources must be ecologically sustainable, and society and the economy need to operate within these limits. Countries have agreed to develop NBSAP in signing the Convention on Biological Diversity (CBD). Voluntary plans and sub-national and regional (supranational) biodiversity strategies and action plans are also being developed (CBD/COP/DEC/15/12*, 2023). The UN System of Environmental-Economic Accounting (SEEA) focused on the ocean (SEEA-Ocean) is an evolving concept to help organize ocean socio-economic and natural capital data (Gacutan et al., 2022, GOAP, 2023). These plans require participation of all sectors of the economy (Gerber et al., 2023, OECD, 2019).

These plans require information. Because the marine environment is vast and inherently interconnected, mitigating or eliminating stressors requires addressing problems outside the immediate area where a resource or a protected area is located. Examples are region-wide temperature extremes, transport of nutrients and sediment delivered by rivers or currents, the migration of populations, and the spread of invasive species. Effective actions to solve problems require broad, cross-border, and transdisciplinary perspectives, bringing together scientists, engineers, and knowledge holders from many disciplines (Lindstrom et al., 2012, Tanhua et al., 2019). It requires increasing the knowledge and ability to forecast marine biodiversity and ecosystem changes. This comes through the systematic, sustained, and coordinated observation of marine life around the world, and through the management, publication, and collaborative analysis of data. This is analogous to the international collection and sharing of meteorological data to improve weather forecasting for everyone's benefit.

2.4. Methodology for strategic ambition setting

To define a vision to address Challenge 2, the Ocean Decade convened a Working Group of natural and social scientists, resource managers, engineers, and private sector representatives. Input was collected from around the world through meetings, social media, and surveys on drafts of this white paper. The process sought to set an achievable ambition of broad societal benefit.

3. Strategic ambition setting

3.1. Analysis of user needs and priorities

The Working Group recognized that user needs and priorities relevant to Challenge 2 are well documented and captured in many publications, assessments, and international conventions (UN Agenda 2030, 2023, IPBES, 2019, CBD, 2022, UNCLOS, 2023). Yet, solutions that lead to positive impact at large scales have not been implemented. Just as relevant, the international community is not yet well organized to provide the information on ecosystem and biodiversity change required to design and to implement solutions. The UN Ocean Decade and the UN Decade for Ecosystem Restoration are intended to change this situation by expanding the geographic scales and ecosystem-level questions across which people can carry out critical collaborative science to inform governance.

3.1.1. Issues

The evidence continues to grow that we are in a global biodiversity crisis accelerated by pollution, climate change and some poor fisheries practices (IPBES, 2019). At present, national investments in collecting information about marine biodiversity and ecosystem services to guide effective conservation measures are insufficient (Canonico et al., 2019, Sala et al., 2021, Seidl et al., 2021, GOOS, 2023). Restoration projects are largely conducted in isolation and may not be planned or monitored for effectiveness. Conservation projects are rarely linked to sustainable development strategies and are often done where

they have the least impact on people. This all complicates and diminishes the social and economic impacts of conservation and restoration efforts.

One recurring theme is the limited availability of information about marine ecosystems and life at all taxonomic, temporal and spatial scales (GOOS, 2023). There are some limited data published from operational fisheries, aquaculture, and environmental monitoring programs, as well as long-term observations collected by academic researchers, non-governmental organizations, and civil society. But the usefulness of much of the historical knowledge is hampered by the limited digitization and publication of data and metadata and by a lack of harmonization between methods (Dornelas et al., 2018, Muller-Karger et al., 2018a, Miloslavich et al., 2018a, Miloslavich et al., 2018b; Sequeira et al., 2021).

Major gaps in knowledge about how biodiversity and ecosystems are changing remain. Observations have historically been concentrated around developed nations in the northern hemisphere, along coasts, and in shallow areas. There is a dearth of knowledge in the microbial realm (viruses, bacteria, archaea, protists and fungi), a group which constitutes around 90% of marine biomass and is at the core of biogeochemical cycling and the health of organisms, including our own. We still have limited abilities to assess and forecast ecosystem change in coastal areas where people are vulnerable, in the deep ocean including deep benthic habitats, in ecosystems that are frozen permanently or part of the year, and other remote places. Communities in SIDS, low-lying areas, and Arctic regions are particularly vulnerable to changes in coastal and marine habitats and biodiversity.

With the advent of new, non-invasive methods, including biomolecular tools and autonomous technologies, we can plan for monitoring marine life and environmental variables at synoptic scales. This requires investment in the deployment of such technologies and in the intercalibration with traditional methods. It requires a transformative increase in infrastructure for the analysis and handling of high volumes of new types of global biodiversity data (e.g., biomolecular, acoustic, video, tag data). And it requires investing in and coordinating the capacity to monitor and use this information.

Other issues that need immediate attention are interoperability of observations across projects at all scales, the need to increase connectivity among marine life databases and environmental and socio-economic databases, and providing opportunities for dialogue among stakeholders, rights holders, and natural and social scientists. Investments in making data interoperable and comparable spatially and temporally, for example through intercalibration between different biodiversity measurement techniques (acoustic, video, nets, biomolecular), and understanding how to use biodiversity information, are very high priorities.

Ultimately, management and planning require improving models to forecast biodiversity and ecosystem changes, including local and global ocean and earth system models. Models are needed at a sufficient spatial resolution to match biological and environmental processes with specific management needs, and yet also have to be available for use by managers and researchers everywhere.

3.1.2. State of Play: Taking Stock

The growing recognition of the dependence of humans and life in general on the ocean provides an optimistic outlook that new management paradigms can be implemented. Many scientific assessments have been published over the past few decades that provide recommendations and examples on how to address effective conservation and restoration at local, national, and global scales (see Section 3.2.2. Knowledge generation and sharing). The goal of those recommendations is to stimulate a sustainable Blue Economy. This broad concept engages many sectors of the economy (Spinrad, 2021; Urban et al., 2022). It recognizes that sustained and equitable development is based on solutions that are informed by data about marine ecosystem change and, on the capacity, to use this information (Miloslavich et al., 2022). There are substantial efforts in the science community today to improve data collection, aggregation, synthesis, parameterizations, strategies to model biology and biodiversity, and to assess impacts of

change. Guidelines for best practices for biodiversity (genetic, taxonomic, functional, ecosystems) data collection and interoperability are also emerging or converging, allowing for more widespread use of new technologies (acoustics, imaging, biomolecular, optics, modeling). This outlook sets the stage for the strategic ambition to address Challenge 2 in this Ocean Decade.

3.2. Definition of the strategic ambition for the Challenge

The strategic ambition of Ocean Decade Challenge 2 is that there will be timely and widespread availability of scientific information about ecosystem and biodiversity change and its causes, and that there will be the local capacity to generate and use this information to advance sustainable development. The goal is to enable effective conservation and restoration of ecosystems and biodiversity. This process must identify possible negative consequences and impacts on current benefits if other actions are taken, even if information is incomplete. *Moving toward this vision requires convergence on a practical set of essential ocean biology and ecosystem variables, and significant improvements in the methods, collection, curation, and access to quality biological, environmental, social, economic, and cultural information* (Miloslavich et al., 2018b). Coordination to generate and share practical knowledge for managing uses of the ocean is the basis for better post-2030 scenarios.

To accomplish this strategic ambition requires harmonized national, regional and global marine biodiversity strategies and action plans that emphasize the co-design of ocean science and capacity development. The substantial current efforts in the science community, governments, international organizations, the private sector, and civil society to understand and address the biodiversity crisis need to be better coordinated and funded. Coordination of local projects can lead to data that are findable, interoperable, re-used, and comparable across national and regional scales. The uncertainties in the data have to be understood so that change can be detected over time. Many groups are improving strategies for biology and biodiversity data aggregation, synthesis, and modeling at scales spanning organisms to ecosystems. Coordination and capacity sharing between these groups is a fundamental requirement for sustainable development.

Investments are needed to support the coordinated monitoring of Essential Ocean Variables (EOVs; Miloslavich et al., 2018a), the recovery of historical baseline data and documentation of methods used for collection, and automated pipelines that mobilize data into internationally recognized data systems. The academic, government, and private sectors should agree on a minimum set of marine biodiversity metrics, prioritize investment in observation of EOVs that will support these, and facilitate data sharing to advance ecosystem-based management. Among the benefits would be availability of better information about marine life for larger numbers of people, better forecasts of possible outcomes of management scenarios, and more efficient uses of ocean areas while calibrating and timing protection, conservation and restoration decisions.

The requirement to collect data and improve forecasts of biodiversity and ecosystem change may be explicit in NBSAP or as other national contributions. These science-based strategies would contribute to a larger ocean policy framework to address development and conservation as necessary complementary efforts. For example, approaches may link inland and coastal research to guide management. Nations may also jointly plan to conserve and benefit from uses of national waters and Areas Beyond National Jurisdiction (ABNJ).

In this context, the Ocean Decade should advance:

- Public-private partnerships focused on incentives to promote ocean science, monitoring, and education focused on sustainable development;
- A convention on a minimum set of operational, interoperable biodiversity observations;
- Deployment of biological observing systems in under-sampled regions and those most vulnerable to climate change and anthropogenic stressors;

- Understand connectivity between different parts of an ecosystem, including links between activities on land, water quality and freshwater availability, upstream ocean processes, and ecosystem and biodiversity change;
- Capacity building to implement science-based management strategies;
- Coordination of Ocean Decade and Decade on Ecosystem Restoration Actions.
- Methods to evaluate effectiveness of restoration and conservation programs;
- Communication of status and change to prompt action across geographic, government scales.

Coordination and progress in these areas would benefit all nations and all people. The UN is in a unique position to engage Member States, Indigenous and local communities, researchers, Non-Governmental Organizations (NGOs), and the private sector to coordinate investments that directly support these recommendations focused on Challenge 2. Specifically, the Intergovernmental Oceanographic Commission (IOC) and other relevant UN bodies should be mandated and resourced by Member States to help harmonize the scientific design and implementation of ecosystem and marine biodiversity observing strategies across nested scales (local to global), with participation of all sectors. Organizations that should mandate such activities include the Convention on Biological Diversity (CBD) to enable the collection of observations for indicators of the Global Biodiversity Framework (GBF), the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) to conduct assessments of the state of biodiversity, and the Intergovernmental Panel on Climate Change (IPCC) to evaluate the impacts and linkages between climate change and life. Yet, more importantly, this information is required by individual communities, the private sector, and national governments.

3.2.1. Priority datasets

The conservation and restoration of ecosystems and biodiversity must be based on accurate and timely information that helps quantify, understand, and model the relationship between climate change,the interplay between multiple stressors, and ecosystems and biodiversity. This requires biological ocean observations coupled with data on physical and biogeochemical EOVs. While the collection of scientific data happens at local and regional scales, programs should be coordinated so that data and metadata can be published, aggregated, and analyzed to understand local change in a regional and global context.

The need to mobilize knowledge, technologies, solutions, and applications is at the core of all relevant international treaties, monitoring, and policy implementation efforts. It is fundamental for a vibrant Blue Economy. The international science and operations communities have already developed frameworks for observing Essential Ocean Variables, Essential Biodiversity Variables, and Essential Climate Variables (GOOS, 2023, GCOS, 2022, GEOBON, 2023, Muller-Karger et al., 2018b). We recommend that the UN convene leaders in different sectors to identify high-priority variables for standardization and sharing.

The scientific observations should be designed to better understand important ecological and biogeochemical processes plan conservation and restoration programs, and to implement indicators of their effectiveness. Focus on a subset of essential variables can be done through programmatic mandates, incentives, and guidelines that promote publication and regional and global assessments (see Benson et al., 2021, for guidelines for biological data management). We also need to transform the way that we publish data, and this requires incentives and clarity in benefits to those who collect observations and benefits to society in general.

3.2.2. Knowledge generation and sharing

The recommendation is that the Ocean Decade support four areas for knowledge generation around ecosystem and biodiversity change to advance sustainable development: coordination, interoperability, communication, and infrastructure requirements, as follows:

Coordination:

- Support and build on existing networks for biodiversity observation. Specifically, we recommend a partnership between these major programs: Global Ocean Observing System (GOOS), the OBIS, the GBIF, the Marine Biodiversity Observation Network (MBON/GEO BON), the Ocean Biomolecular Observing Network (OBON), the Global Greenhouse Gas Watch (GGGW), and relevant United Nations Environment Programme (UNEP) and Food and Agriculture Organization (FAO) programs. This should also be guided by the requirements of assessment programs including the CBD GBF, IPBES, and IPCC.
- Implement a co-design approach to ecosystem and biodiversity observation networks that link social and natural science with local needs and that contributes to international targets and indicators.
- Link existing portals/databases (e.g., OBIS, GBIF, NCEI, BCO-DMO, Pangaea, WoRMS, NCBI-GenBank, NCBI-SRA, BOLD) for different types of biodiversity data (i.e., taxonomic, eDNA, acoustics, citizen science, ocean-freshwater-land, etc.), for example through the use of reciprocal tags in data schema.
- Conduct gap analyses of biodiversity information, building on studies such as Rogers et al. (2022) and Gignoux-Wolfsohn et al. (2023), in all nations and with efforts to assist SIDS.

Interoperability:

- Promote training in use of best practices (Wilkinson et al., 2016, GIDA, 2019, DISD, 2007, Woelfle et al., 2011, Vicente-Saez and Martinez-Fuentes, 2018, Pearlman et al., 2021). This includes data collection, formatting, curation, publication, and management, with a focus on interoperability and dissemination through open databases (Benson et al., 2021). It includes use of standardized vocabularies (Vandepitte et al., 2018) and implementing guidelines from the Biodiversity Information Standards (TDWG) organization. One example is the Darwin Core data schema, used for recording species occurrences, abundance, traits, movement, and genetic information (De Pooter et al., 2017, Sequeira et al., 2021, Abarenkov et al., 2023). Additional standards should be agreed on and adopted by the international science community (e.g., formatting and processing of acoustics, imaging data, etc.).
- Use the Ocean Best Practices System (OBPS) to promote convergence and endorsement of methods, data interoperability, and accelerate effective management (Pearlman et al., 2021).

Communication:

- Communicate knowledge of biodiversity and ecosystem change and causes to policymakers, coordinating with the IOC and other UN Member States.
- Coordinate formal education processes internationally to align curricula on core ocean science concepts and to promote convergence on best practices and interoperability.
- Establish national and regional communications channels to inform about best strategies to use status and change in biodiversity metrics and indicators for policy and management actions.

Much information is available that can be used to develop Ocean Decade Actions and for nations to implement Ecosystem-Based Management. Case studies are routinely compiled by the Open Communications for the Ocean group/OCTO (https://octogroup.org/) and through research publications (Rudd et al., 2018, Winther et al., 2020, Lombard et al., 2023, Olson and Dinerstein, 2002, Selig et al., 2014, Jefferson and Costello, 2020, Jefferson et al., 2021, Jones et al., 2020, Sala et al., 2021, Visalli et al., 2020, Zhao et al., 2020, and many others).

Infrastructure Requirements

Implementing conservation and restoration strategies that are coherent from local to global scales will require agreement and access to education, data collection, information management, and forecasting infrastructure that at present is not coordinated. Often, evaluation of the success or failure of conservation and restoration focuses on monitoring a limited number of species or variables. Without a list of standardized parameters, it is difficult to understand what to protect and conserve, or where to restore. Without globally coordinated standard approaches, it is not possible to assemble regional or global indicators of biodiversity and ecosystem change, to understand drivers of change, or forecast impacts of possible management scenarios.

New autonomous technologies are now available that allow us to monitor multiple species and ecosystem status at the same time, repeatedly, and over a long time in a way that helps detect change and compare between locations. Some key innovations are listed in the Technology and Innovation Section (3.2.6). These technologies need to be accessible and integrated into existing and new ocean observing networks.

Significant investments are required by governments, academia, and the private sector in engineering and manufacturing to maintain the infrastructure and capacities that exist, to bring down the cost of data collection and processing technologies, invest in method validation laboratories, and maintain and further develop databases that help anchor observations in reality (e.g., voucher specimens, and taxonomic, bio-optical, and animal tracking databases). Sustaining infrastructure for the curation and publication of samples and information is critical. An important resource is Natural History Collection Museums, whose efforts to digitize collections and preserve voucher specimens are fundamental to understanding biodiversity change and evolution. From this infrastructure, an industry can emerge to provide services, from mobilizing data to generating value-added products.

Ultimately, sustainable development needs to include ecosystem and biodiversity forecasting. Developing the infrastructure that ingests observations, allows modelling at the spatial and temporal scales needed by management, and facilitates model validation in a way that is accessible to nations and groups around the world is of fundamental importance.

3.2.3. Partnerships and resources

Coordinating and strengthening co-design among the existing networks of academics, policymakers, governments, coastal communities, Indigenous groups, industry, NGO's and others is a requirement for positive outcomes on Challenge 2. An inclusive approach that increases engagement with stakeholders and rights holders would lead to a broader range of perspectives in research and management. This increases transparency and trust in science, thus likely increasing the uptake of scientific information in decision-making at all levels. Actions focused on biodiversity and ecosystem science that address these issues include:

- Identify and link groups already engaged in restoration and conservation in a region.
- Identify opportunities to leverage efforts under other UN Ocean Decade Challenges.
- Facilitate dialogue and partnerships to address knowledge gaps and share capacity.
- Highlight partnerships with local and Indigenous communities.
- Engage Early Career Ocean Professionals (ECOPs) in decision-making processes.
- Develop processes that look beyond 2030.

3.2.4. Capacity development and exchange needs

Challenge 2 is closely linked to Challenge 9 (capacity development) and Challenge 10 (changing humanity's relationship with the ocean). The Ocean Decade and the Decade for Ecosystem Restoration are

opportunities to coordinate international capacity sharing around efforts to understand and monitor linkages between land, freshwater, coastal, and marine ecosystems. This coordination would facilitate common approaches to monitoring, forecasting, and implementing ecosystem-based management approaches that include upstream activities. A primary goal is to develop the capacity to collect and publish data and for people to easily understand, use, and apply information about marine life and ecosystems.

The UN Ocean Decade should stimulate investment by governments, philanthropy, and development banks to support the capacity development work undertaken by the Decade Actions. The Ocean Decade should help its Programs and Projects share core strategies for supporting ecosystem-based management. This includes education on the value of biodiversity and ecosystems to an individual and to society. Actions should focus capacity sharing on posing the scientific questions, monitoring, and forecasting to advance sustainable development. Coordination, collaboration, and networking among existing data generators and users is fundamental to leverage existing capacity.

The capacity to implement ecosystem-based management should be developed at the local level, or at least coordinated between the local and regional or national level. It should engage local and indigenous communities in addressing their local needs, including protecting, conserving, and restoring local habitats and biodiversity in the context of their own sustainable development.

Our recommendation is that a concerted capacity development effort be organized under the Ocean Decade (Challenges 7, 9 and 10) to advance methods for a minimum set of biology and ecosystem EOV observations, data management concepts, and applications. The framework of the Essential Ocean Variables (EOV) is useful to focus on specific sets of measurements needed to implement ecosystem-based management. Case studies should be developed that highlight the benefits of ecosystem-based management. A curriculum element should be designed to insert these methods into university and workforce development core courses, rather than as elective courses. This concerted effort should address national waters as well as areas beyond national jurisdiction, which includes most of the ocean and is where many industrial developments are taking place, often without clear conservation management elements.

Biodiversity-positive ambition and action are elements that require capacity development for the design and implementation of UN instruments, including those specifically addressing climate, pollution, fishing, and social issues like conflict and migration. The capacity development and technology transfer elements in different treaties and conventions should all include biodiversity and habitat monitoring, restoration, and protection as tools for sustainable development.

3.2.5. Technology and innovation solutions

Emerging technologies are now demonstrating utility to simultaneously assess presence, abundance, genetic diversity, density, distribution, and health status of species and habitats. These measurements are critical for understanding the distribution and intensity of human activities, how to mitigate threats to biodiversity, and which actions may have a positive impact on biodiversity and ecosystems. For example, biomolecules (including environmental DNA/eDNA), acoustics, underwater video and imaging, remote sensing (airborne, satellite), animal tracking and bio-logging, data formatting standards, robotics and autonomous platforms, open datasets, and artificial intelligence (AI) all provide a new paradigm to help understand a complex world. Technological improvements have already increased data collection in understudied, difficult to access marine environments. The evolution toward low-cost sensors, available to all, including citizen scientists, would contribute to expanding interoperable observations globally. We also need low-cost sample processing, as for example the real bottleneck for eDNA samples is the cost of processing and analysis.

Ocean Decade Actions should help define and promote a minimum set of marine life observations to ensure proper indicators are available locally and for local action, equitably and in a way that observations can also be aggregated to monitor change at regional and global scales.

3.3. Integration, synergies and interdependencies with other Challenges

All the Ocean Decade Challenges are interconnected. Restoring and protecting ecosystems and biodiversity are key to feeding the global population, but this also relies on information that helps understand when marine ecosystems are changing and why. Tourism, artisanal fisheries, aquaculture, and general human health are challenged by pollution and changes in the ecosystem and its biodiversity. Aqua cultured species are increasing as a fraction of seafood consumed, and yet aquaculture impacts local ecosystems including the genetics of organisms and the spread of disease. A global, sustained ocean observing system, providing FAIR data for enhanced forecasting capability is necessary to understand the linkages between ecosystems, anthropogenic stressors, and climate change. Progress in generating knowledge and understanding, and using this knowledge, require coordinated capacity sharing. Ultimately, proactive and imaginative ocean management will come from societies living with the ocean and not just extracting from the ocean.

3.4. Key milestones to measure progress and success

The key outcome of the Ocean Decade is that science-based knowledge is accepted and used to sustain and improve social and economic well-being. Governments and private sponsors should focus on these core investments to achieve this outcome:

- By July 1, 2025: Every National Decade Committee or regional group or agency has identified a core set of marine life and ecosystem variables to monitor that are essential for sustainable development within and beyond national jurisdictions.
- By January 1, 2026: The UN Ocean Decade has advanced a framework for global observation of biodiversity change and associated environmental, social, and climate conditions, data interoperability, and quality assurance, including developing the capacity to generate and use this information.
- By January 1, 2027: Every coastal nation has initiated a process to recognize and use scientific information about biodiversity and ecosystem change as part of its NBSAP or equivalent efforts.
- By 2028: Every National Decade Committee or regional group has identified a process or strategy for collecting and publishing data on core marine life and ecosystem variables through existing, interoperable, international information systems, such as the OBIS and GBIF.
- By 2030, biodiversity and ecosystem health baselines and a systematic process to report changes to support sustainable development, including conservation and restoration efforts, have been established.
- Immediate and ongoing for the Decade and beyond: financial and logistical support by National Decade Committees or regional groups or agencies is secured to foster regular communication between all Decade Programmes and Actions.

3.5. Indicators to track the achievement of the strategic ambition

The Ocean Decade should align and progress ocean science and the recovery, collection, curation and publication of data, methods and information to support NBSAP or equivalent national voluntary strategies, contribute to the GBF even if not a formal party to the Convention on Biological Diversity, and to international assessments (such as by IPBES and the IPCC). Specific indicators to be used to track progress on the Ocean Decade Challenge 2 strategic ambition include:

- The number of countries that advance the capacity to generate scientific data on marine biodiversity and ecosystem change.

- The volume, geographic coverage, and monitoring observations collected and published in marine biodiversity databases (e.g., in OBIS, GBIF, nucleotide databases).
- Number of reference DNA sequence data available for global “indicator” species.
- Number of Ocean Decade Actions that consider biodiversity, ecosystem change, and scientific measures of effectiveness of conservation and restoration.
- Number of Actions that explicitly include co-design efforts with local and indigenous communities.
- Establishment of global networks and an international coordination mechanism that integrate biology and ecosystems Essential Ocean Variables, incorporating automated systems with Artificial Intelligence and Machine Learning (AI/ML), capacity sharing, and citizen science and local knowledge.
- Multi-annual funding is secured for Actions focused on Challenge 2.

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United Nations Decade of Ocean Science for Sustainable Development (2021-2030)

Proclaimed in 2017 by the United Nations General Assembly, the UN Decade of Ocean Science for Sustainable Development (2021-2030), provides a convening framework to develop the scientific knowledge and partnerships needed to catalyse transformative ocean science solutions for sustainable development, connecting people and our ocean. The Ocean Decade is coordinated by UNESCO's Intergovernmental Oceanographic Commission (IOC).

Established during the Preparatory Phase and to continue throughout implementation until 2030, the IOC's Ocean Decade Series will provide key documentation about this global initiative and aims to serve as a primary resource for stakeholders seeking to consult, monitor and assess progress towards the vision and mission of the Ocean Decade.

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

https://oceandecade.org/