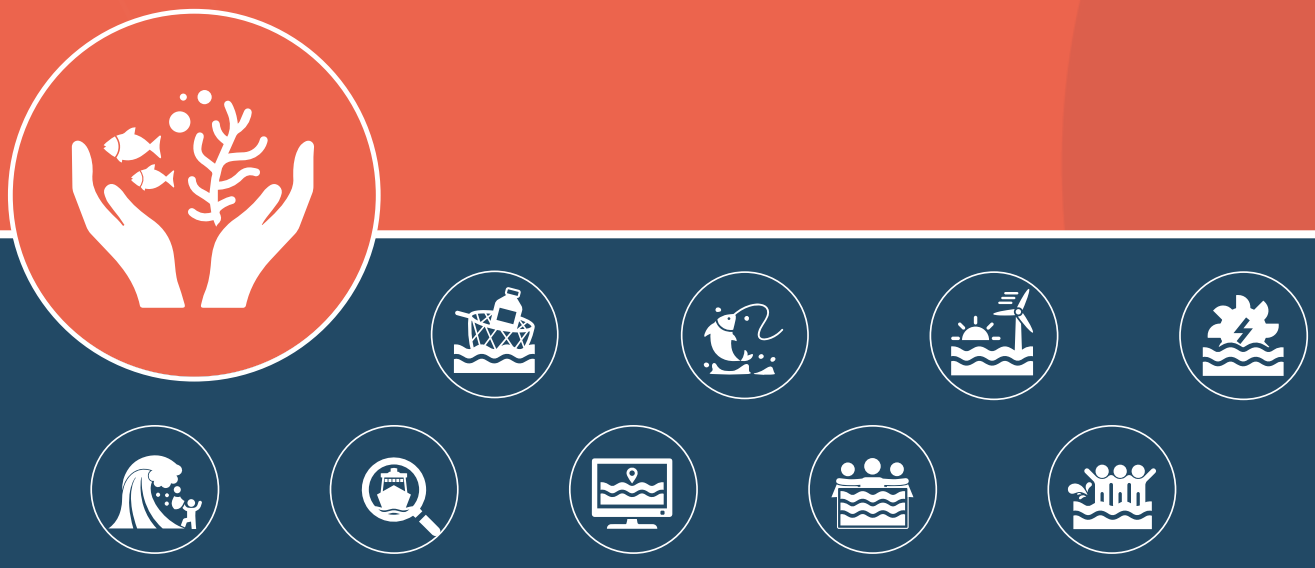
Ocean Decade

Vision 2030

White Papers

Challenge 2:

Protect and restore ecosystems and biodiversity



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

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

Published in 2024 by the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization

7, place de Fontenoy, 75352 Paris 07 SP, France

For bibliographic purposes, this publication should be cited as follows:

Muller-Karger, F. E., Tan, A. S. H., Allcock, L., Appeltans, W., Barón Aguilar, C., Blanco, A., Bograd, S. J., Buttigieg, P., Costello, M. J., Darnaude, A., Dupuis, B., Evaux, L. M., Friedman, K., Goodwin, K., Jungbluth, S., Leinen, M., Levin, L., Mahapatra, P., Martone, R., Mtwana Nordlund, L., Ndah, A. B., Pante, E., Pearlman, J., Pelletier, D., Pendleton, L., Relano, V., Rogers, A. D., San Diego-McGlone, M. L., Seeyave, S., Sequeira, A., Soares, J., Stiasny, M., Taylor, S. & Vavia, A. (2024). *Ocean Decade Vision 2030 White Papers – Challenge 2: Protect and Restore Ecosystems and Biodiversity*. Paris, UNESCO-IOC. (The Ocean Decade Series, 51.2). https://doi.org/10.25607/y60m-4329

Graphic design: UNESCO

(IOC/2024/ODS/51.2)

Ocean Decade Vision 2030 White Papers

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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The Intergovernmental Oceanographic Commission (IOC) of UNESCO, extends its sincere appreciation to the co-chairs and members of the Working Group for their leadership and commitment in the process of drafting and authoring the present document.

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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), the UN Ocean Decade (Barcelona, Spain, April 2024), 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.

Contents

Acronyms

ABNJ	Areas Beyond National Jurisdiction
AI	Artificial Intelligence
BBNJ	Biodiversity Beyond National Jurisdiction
BOLD	The Barcode of Life Data System
CBD	The Convention on Biological Diversity
GBF	Global Biodiversity Framework
GBIF	Global Biodiversity Information Facility
GOOS	Global Ocean Observation System
G3W	Global Greenhouse Gas Watch
FAO	Food and Agriculture Organization of the United Nations
ICES	International Council for the Exploration of the Sea
IOC	Intergovernmental Oceanographic Commission
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
mCDR	marine Carbon Dioxide Removal
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	United Nations Educational, Scientific and Cultural Organization

1. EXECUTIVE SUMMARY

1.1 Introduction and Scope of the White Papers

This 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 White Paper is one of a series of ten White Papers all of which have been authored by an expert Working Group. Accompanied by an Outcomes Report authored by the Decade Coordination Unit, this white paper was discussed at the 2024 Ocean Decade Conference (Barcelona. Spain). Input received from diverse groups through public consultation and at the Conference was reviewed and incorporated as relevant.

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 (positive and negative), 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 develop 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 at sea and on land that affect coastal and ocean biodiversity and include areas beyond national jurisdiction which represent most of the ocean.

Success in establishing 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 must deal with. This includes continuous monitoring and developing the understanding of:

- coastal, open ocean, deep-sea biodiversity and ecosystem change from the tropics to high latitudes,
- connectivity between marine populations, habitats and depths, and of the links between activities on land and at sea, water quality and freshwater availability, upstream ocean processes and marine ecosystem and biodiversity changes,
- the vulnerability of deep benthic, polar, and critical coastal and estuarine habitats,

- drivers of positive and negative change in biodiversity, ecosystems, and ecosystem services
- possible biodiversity and ecosystem change caused by aggressive geo-engineering efforts, including marine Carbon Dioxide Removal (mCDR) and other schemes,
- addressing the cumulative effects of human activities and climate change on biodiversity and ecosystems,
- co-designing place-based ecosystem approaches to management, explicitly considering biodiversity and connectivity at relevant scales, and including local people and their knowledge.

A major challenge is to rapidly implement the coordination, permanent funding, and infrastructure to scale from the current short term and small-scale studies of biodiversity and ecosystems to long-term national efforts that link science and management. This can and should be done in a way that helps nations understand their changing ecosystems in a regional and global context and helps justify and incentivize efforts in ecosystem management to conserve marine life for the benefit of future generations. Sustainable development will occur if the Ocean Decade provides the opportunities for individuals from different age, gender, cultures, and geographic backgrounds to have their views expressed and considered in the implementation of management actions. Social drivers weigh heavily in defining how societies everywhere will act to reverse the loss of marine biodiversity. Nations, local governments, the private sector, and non-governmental organizations should proactively implement place-based ecosystem approaches to management which consider the need of local communities to minimise and avoid the loss of local ecosystem services, even in the absence of complete information. These actions should include social, economic, and cultural perspectives.

All coastal communities, including indigenous and Small Island Developing States (SIDS) are vulnerable to marine biodiversity loss and ecosystem change. Management efforts need to recognize the contribution of these communities to knowledge and engage them in the implementation of place-based ecosystem approaches to 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. Researchers, stakeholders, and rights holders also need to recognize that not all biodiversity and ecosystems can be restored - thus, a high priority is to avoid and minimize harm to biodiversity in specific areas including the deep sea and coastal areas from tropical to high latitudes, from islands estuaries. Rapid identification of these vulnerable areas is a priority to avoid potentially irreversible loss of marine biodiversity and ecosystem services (Campagne et al., 2023)

Ultimately, because we cannot measure everything, everywhere, all the time, the process of the Ocean Decade needs to point to developing tools to forecast, preserve, and sustainably use biodiversity, not just in historically data-poor areas and in poorly known settings, but everywhere.

1.3 Key Recommendations to Achieve the Strategic Ambition

To ensure success in the context of all Challenges beyond 2030, the Ocean Decade should advance the following activities:

- Implement Actions around marine life and the ocean that help everyone imagine a positive future.
- Foster public-private partnerships focused on incentives to promote ocean science, innovation, monitoring, and education focused on sustainable development. For example, governments may establish incentives attached to key performance indicators in financial and tax structures and tools for biodiversity outcomes.
- Implement a co-design approach to ecosystem and biodiversity observation networks to understand the many impacts of human activities to biodiversity and to enable local, place-based ecosystem approaches to management actions; this process should highlight partnerships with local and indigenous communities.
- Coordinate with nations to conduct gap analyses for the data needed to detect trends in representative aspects of biodiversity, and to address these gaps.
- Support existing networks for biodiversity observation (e.g., elements of GOOS, OBIS, GBIF, BOLD, MBON, OBON, G3W, ICES, IUCN and others, and relevant UN programs of UNESCO, UNEP, FAO, WMO and others) and build on them to integrate biological observations with physical and biogeochemical ones in observing networks guided by the requirements of assessment programs including the CBD GBF, IPBES, and IPCC.
- Urge nations to agree on and promote a minimum set of operational and interoperable biodiversity observations, including indigenous scientific knowledge, to support decisions and actions to inform management and mitigate biodiversity loss.
- Deploy biological observing systems in under-sampled regions and regions vulnerable to climate change and anthropogenic stressors.
- Develop a strategy to lower the cost of high-quality biodiversity and ecosystem observations and promote broader geographic coverage.
- Fully integrate biodiversity and ecosystem change research into geo-engineering studies and implementation efforts, including mCDR and other schemes.
- Expand and coordinate capacity building among institutions nationally and internationally to implement place-based ecosystem approaches to management, including observing, monitoring, and information management, as well as capacity in governance to support conservation and restoration.
- 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 scales and government levels.
- Proactively implement place-based ecosystem approaches to management designed to minimize and avoid impacts on biodiversity and ecosystem services even in the absence of complete information.

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 that are essential for sustainable development within and beyond national jurisdictions and has worked with local communities and agencies to initiate monitoring.

- 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, 2026: The UN Ocean Decade has helped the private sector, governments, and research groups to have a dialogue on financial and tax structures and tools (such as blue bonds) for key biodiversity outcomes and educate these communities on their broad implementation.
- By July 1, 2027: Every National Decade Committee has developed messaging outlining the justification for conserving, restoring, and protecting marine biodiversity and ecosystem services in a way that helps decision makers to quantify the costs (and overall benefits) of restoration and conservation actions.
- 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. This process should align national targets with global targets and highlight the need for observations to produce indicators relevant to the GBF. The process should also include consultation and pathways for long-term collaboration with local and indigenous communities, with their free, prior and informed consent, in accordance with national legislation.
- By January 1, 2027: Sponsors, researchers, and implementers of geo-engineering efforts including mCDR and other schemes, have engaged in the co-design of biodiversity and ecosystem change studies and action plans to minimize and avoid biodiversity and ecosystem impacts.
- By January 1, 2028: Every National Ocean Decade Committee or regional group has collaborated with local and indigenous communities with their free, prior, and informed consent, and in accordance with national legislation, on developing strategies on two-way incorporation of Essential Ocean Variables (EOV) and Essential Biodiversity Variables (EBV) into their understanding and place-based ecosystem management. This includes facilitated two-way exchange as agreed between communities and existing, interoperable, international information systems, such as the Ocean Biodiversity Information System (OBIS) and Global Biodiversity Information facility (GBIF).
- 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 2028: The Ocean Decade Coordinating Unit is actively engaged in the planning for full and visible participation of the Ocean Decade in the OceanObs'29 Conference, to be hosted by China in 2029, to ensure that biology and ecosystems research and applications are fully linked into the framework for ocean observing.
- 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, including resources to advance the work and knowledge of indigenous partners

with their free, prior, and informed consent.

Indicators:

- Number of countries advancing their capacity to generate and use scientific data on marine biodiversity and ecosystem change.
- Density of biodiversity data (i.e. the volume of data in a geographic area such as an EEZ, over regular time periods: e.g. TB km^{-2} $year^{-1}$) collected and published in interoperating marine biodiversity databases (e.g., in OBIS, GBIF, nucleotide databases linked to curated museum data, such as BOLD).
- Number of reference DNA sequence data ideally paired with museum voucher specimens, available for global indicator species.
- Number of Ocean Decade Actions that explicitly include biodiversity, ecosystem change, ecosystem functioning, and scientific measures of effectiveness of conservation and restoration.
- Number of countries and regions with biodiversity climate risk assessments.
- Number of Actions that explicitly include co-design efforts with and leadership from local and indigenous communities to support biodiversity and ecosystem protection and restoration.
- Number of global networks and international coordination mechanisms that integrate biology and ecosystems Essential Ocean Variables, incorporating capacity sharing and local and indigenous knowledge.
- Number of sustained funding sources for securing midterm or long-term connections between research and operations that support biodiversity and ecosystems protection and restoration.

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, relevant socio-economic and human use data, 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, indigenous, and government agencies at every level to collaborate on generating the knowledge we need for sustainable development (Ryabinin et al., 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 rights holders (Fischman et al., 2023). Incentives for collaboration are critical in shaping a culture

around standards and best practices and capacity exchange to improve outcomes for conservation and restoration (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

The Ocean Decade hosts multiple Programmes each designed to coordinate dozens of Projects, many of which have a strong focus on Challenge 2. 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 (Jouffray et al., 2020). These changes include increased fishing, more pollution, increased shipping, and human development, 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 and 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 webs, 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, productivity, species interactions, and distribution of living communities and ecosystems) are alarming, and is what people refer to as "biodiversity loss". These 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 communities 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 National Biodiversity Strategy and Action Plans (NBSAP) in signing the Convention on Biological Diversity (CBD). Voluntary plans and sub-national and regional (supranational) biodiversity strategies and action plans may also be developed by nations and groups that are not formally part of the Convention (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 processes require participation of all sectors of the economy (Gerber et al., 2023, OECD, 2019).

These plans require information about biodiversity and ecosystems, causes of biodiversity change, risks of losses of species and ecosystem services, and effective protection and restoration approaches. Mitigating or eliminating stressors from the vast and inherently interconnected marine environment requires addressing multiple stressors at the location where human activities take place and often also outside the immediate area where the resources or

protected areas are located. Examples of the latter include region-wide heat waves or other temperature extremes, transport of nutrients and sediment delivered by rivers or currents, noise and pollution from shipping, the migration of populations, and the spread of invasive species. Effective actions to solve problems require broad, cross-border, and transdisciplinary perspectives, bringing together knowledge holders from many disciplines and stakeholders and rights holders from multiple sectors (Lindstrom et al., 2012, Tanhua et al., 2019). It requires increasing the knowledge and ability to forecast marine biodiversity, ecosystem changes, and impacts of human activities (both at sea and inland) in a developing world. This comes through the systematic, sustained, and coordinated observation of marine life around the world, and through the management, publication, and collaborative analysis of biodiversity, environmental and socio-economic 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, social, and economic scientists, resource managers, engineers, and private sector, non-governmental organization (NGO), and philanthropic organization 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, few if any solutions that could lead to positive impact at large scales (either geographic or long-time scales) have been implemented. Just as relevant, the international community is not yet sufficiently 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, habitat destruction, and unsustainable practices, including fisheries, aquaculture and tourism (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 placed in areas without the input and buy-in of local communities or placed in remote areas with reduced conservation benefits. This all limits the positive ecosystem outcomes of these actions while complicating and diminishing the social and economic impacts of conservation and restoration efforts.

One recurring theme is the limited availability of information about marine biodiversity and a very limited ability to forecast changes in ecosystems and at all taxonomic, temporal, and spatial scales (GOOS, 2023). There are some 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.

However, the usefulness of much of the historical knowledge is hampered by the limited digitization and publication of data and metadata and by the very limited harmonization between methods and between data storage formats (Dornelas et al., 2018, Muller-Karger et al., 2018a, Miloslavich et al., 2018a, Miloslavich et al., 2018b; Hughes et al. 2021; Sequeira et al., 2021).

Major gaps in knowledge about how and why biodiversity and ecosystems are changing in different regions also remain; gaps are unavoidable. Observations have historically been concentrated around developed nations in the northern hemisphere, along coasts, and in shallow areas. Filling gaps will require a quantum jump in our ability to forecast marine life and ecosystem status. 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 video and imaging, remote sensing, 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, remote sensing). And it requires investing in and coordinating the capacity to monitor and use this information. Still, there is a major gap in our knowledge about functional processes that support biodiversity resilience towards climate change and human stressors, and that help us implement initiatives. This includes our limited ability to forecast the outcome of restoration, conservation, protection and development actions.

Other issues that need immediate attention are interoperability of observations across projects at all scales, the need to link marine life databases and environmental and socio-economic databases, and providing opportunities for dialogue among stakeholders, rights holders, and natural and social scientists to inform governance and management. Investments in making data interoperable and comparable spatially and temporally, for example through intercalibration between different biodiversity measurement techniques (acoustic, video, nets, biomolecular), integrating across scales with remote sensing and models, 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. Both observations and predictive models are needed at a sufficient spatial resolution to match biological and environmental processes with specific management needs and must 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). 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, satellite and other remote sensing, 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 on ecosystem and biodiversity changes (positive and negative) and their causes, and sufficient local will and capacity to generate and use this information to advance sustainable development. The goal is to enable effective conservation and restoration of ecosystems and biodiversity. Getting there requires that everyone imagines a positive future. Place-based ecosystem approaches to management should allow for decisions to be taken even if information is incomplete, and identify possible negative consequences and impacts on current benefits if other actions are taken. *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, as well as opportunities to mobilize this knowledge to inform policy and management* (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.

Achievement of 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 adequately and without interruptions. Coordination of local projects can lead to data that are findable, interoperable, reusable, and comparable across national and regional scales. The uncertainties in the data must 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, including assessment of effective management, conservation, and restoration approaches. Coordination and capacity sharing between these groups is a fundamental requirement for sustainable development.

Investments are needed to support the coordinated monitoring of the data necessary to calculate 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 place-based ecosystem approaches to management. Aggregation of these observations into gridded maps and time series may be viewed as Essential Biodiversity Variables (EBVs). 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) with attention to Biodiversity Beyond National Jurisdiction (BBNJ).

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.
- Convergence on observations to enable the Kunming-Montreal Global Biodiversity framework (GBF), promoting agreement on a minimum set of operational biodiversity observations that can be compared between places and over time, and use of interoperable observing systems.
- Consistent and high-priority policy recommendations on ocean biodiversity knowledge and management from the watershed to deep ocean habitats by linking the World Ocean Assessment, Convention on Biological Diversity (GBF and 30x30), BBNJ Agreement, UNFCCC, ISA, IPBES, and deep and national ocean fisheries policies.
- Deployment of biological observing systems in under-sampled regions and those most vulnerable to climate change and anthropogenic stressors.
- Improved understanding of connectivity between marine populations, habitats, and depths, and of the links between activities on land and at sea, water quality and freshwater availability, upstream ocean processes and marine ecosystem and biodiversity changes.
- 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, Intergovernmental Organizations (IGOs), 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 among human societies, climate change, the interplay of multiple stressors, ecosystems, and biodiversity. As not all data can or should be available freely and openly, a minimum set of "fit for purpose" biodiversity and ecosystem observations should be agreed on under the Essential Ocean Variable framework for specific operational monitoring and assessments and to be openly published,

similar to what is done for weather forecasting among nations of the world. This requires biological ocean observations coupled with data on - among many other variables - physical and biogeochemical EOVs and socio-economic data. 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. Any and all data collection and information publication should follow the FAIR principle on data sharing and management and respect the rights and intellectual property of the observers, be they from local, indigenous, academic researchers, government, private sector, or other groups (e.g., Tanhua et al., 2019).

The need to mobilize data, information, knowledge, and technologies is at the core of all relevant international treaties, monitoring, and policy implementation efforts. Information is fundamental for a vibrant Blue Economy. The international science and operations communities have already developed frameworks for observing Essential Ocean Variables (EOV), Essential Biodiversity Variables (EBV), and Essential Climate Variables (ECV) (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 (i.e., publication of the observations). We also call for closer coordination between all essential variable frameworks (EVs) to avoid decoupled data flows and diverging frameworks (i.e., data flowing as biological and ecosystem EOVs should be used to assemble marine EBVs, as equivalent variables, or alternatively to accept the concept that EBVs are simply time series of EOV observations at a location, or time series of maps of biodiversity data or information).

Scientific observations should be designed to better understand important ecological and biogeochemical processes, plan conservation and restoration programs, and 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 share or publish data, and this requires incentives and clarity in benefits to those who collect observations and benefits to society in general. This should be informed by the Data and Information Strategy and its Implementation Plan being developed under the Ocean Decade (IOC-UNESCO, 2023). This is a particularly relevant link between Ocean Decade Challenges 2, 8 and 9.

3.2.2 Knowledge generation and sharing

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

Coordination:

- Support, build on, link and harmonize existing networks for biodiversity observation. A major gap in the present system is a lack of coordination in collection of field observation in relation to positive and negative change in biodiversity, ecosystems, and ecosystem services, drivers of change, and improving standardization of sampling methods, though some good examples exist (e.g., Continuous Plankton recorder, Reef Life Survey).
- Foster partnership between at least the eight following major observation coordination programs, which largely serve as communities of practice: GOOS, OBIS, BOLD, GBIF, the Marine Biodiversity Observation Network (MBON/GEO BON), the Ocean Biomolecular Observing Network (OBON), the Global Greenhouse Gas Watch (G3W), the International Council for the Exploration of the Sea (ICES), the International Union for Conservation of Nature (IUCN) and others, and relevant United Nations programs including those of the UN Environment Programme (UNEP),

UNESCO, Food and Agriculture Organization (FAO), World Meteorological Organization (WMO) and others. 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 to contribute to international targets and indicators as well as assessment of drivers of biodiversity change and effective conservation and restoration.
- Link existing portals and 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 and eRNA, acoustics, citizen science, ocean-freshwater-land, etc.).
- Increase efforts to fill gaps in biodiversity information needed for conservation and restoration efforts, building on studies such as Rogers et al. (2022) and Gignoux-Wolfsohn et al. (2024). All nations should prioritize efforts to fill information gaps, with efforts to assist SIDS.
- Fully integrate biodiversity and ecosystem change research into geo-engineering studies and implementation efforts, including marine Carbon Dioxide Removal (mCDR) and other schemes, and proactively implement place-based ecosystem approaches to management to minimize and avoid biodiversity and ecosystem service impacts even in the absence of complete information.
- Promote training in the use of information management practices for biodiversity data. 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).
- Facilitate development and adoption of additional standards that are needed and promote adoption by the international science community (e.g., formatting and processing of acoustics data, 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).

Interoperability:

- With bearing on the Challenge 8 white paper and the Ocean Decade's Data and Information Strategy (IOC-UNESCO, 2023), integrate biodiversity data and information into the Ocean Decade's digital ecosystem.
- Pursue alignment and interoperability across biodiversity data collection, formatting, curation, publication, and management, with a focus on interoperability and dissemination through open databases (Benson et al., 2021).
- Generalize the use of standardized vocabularies (Vandepitte et al., 2018) and harmonize information standards through coordination between Actions and international standards organisations such as the Biodiversity Information Standards (TDWG) and the Genomic Standards Consortium.
- Integrate biodiversity data with broader oceanographic data flows through interoperability-focused, global efforts such as the IOC Ocean Data and Information System (ODIS) and the Ocean Decade's Ocean Data 2030 Programme.
- Promote identification, verification, and cross-validation of best practices, and training in their use (Costello and Wieczorek 2014; Wilkinson et al., 2016; Woelfle et al., 2011; Vicente-Saez and Martinez-Fuentes, 2018; Pearlman et al., 2021; CARE Principles for indigenous Data Governance as outlined by the Global indigenous Data Alliance: GIDA-global.org).

Communication:

- Inspire young people and make sure future generations are fully aware of the central role of marine life in the functioning of the planet and their own lives.
- Communicate knowledge of biodiversity and ecosystem change and causes to policymakers, managers, stakeholders, and rights holders, in a co-design and co-delivery framework, coordinating with the IOC and other UN Member States.
- To the extend possible, describe and name at the species level and above, and understand the function of the new taxa, rather than leave it undescribed or simply as a genetic sequence, to facilitate comparative biology, evaluation of how rare a species may be, and facilitate communication among scientists and decision-makers (Pante et al., 2015).
- Coordinate formal education processes internationally to develop curricula on core ocean science concepts and to promote convergence on best practices and interoperability. Examples that can be built on and used to promote such coordination on curricula are the IOC-UNESCO Ocean Teacher Global Academy (OTGA) and the Network of European Blue Schools (NEBS).
- Establish national and regional communications channels and networks 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 widespread 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 only focuses on monitoring a limited number of species or variables. Without a list of standardized parameters and capacity sharing on best practices, it is difficult to understand what to protect and conserve or where to restore. Globally, or at least regionally coordinated approaches are needed 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 Section 3.2.5. These technologies need to be accessible and integrated into existing and new ocean observing networks.

Significant long-term 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, trait, and animal tracking databases). Sustaining infrastructure for the curation and publication of samples and information is critical. An important resource for this is worldwide natural history museums, universities, and institutional research centers 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 for 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.
- Support and highlight partnerships with and leadership by local and indigenous communities and include them in decision making processes.
- 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 place-based ecosystem approaches to management, conservation, and restoration 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.

Long-term biodiversity monitoring programmes are needed to make progress toward Challenge 2 because this is how evidence is collected to manage human activities that affect biodiversity and ecosystem function. Existing biodiversity and ecosystem assessment programmes should be supported, and additional efforts should be implemented to fill the geographic gaps and to understand change over time as needed for effective resource management.

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 place-based ecosystem 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 place-based ecosystem approaches to 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, and learning from them to inform these efforts in other regions.

One recommendation is that a concerted capacity sharing 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 place-based ecosystem approaches to management. Case studies should be developed that highlight effective approaches and the benefits of place-based ecosystem approaches to management, conservation, and restoration efforts. A curriculum element should be designed to insert these methods into educational programs, from schools to universities and workforce development 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 and RNA, eDNA/eRNA; Yates et al., 2021), acoustics, underwater video and imaging, remote sensing (airborne, satellite), animal tracking and bio-logging, data formatting standards, robotics and autonomous platforms, open datasets, internet of things, and artificial intelligence (AI) all provide new ways 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 and eRNA 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.

3.2.6 Traditional and Indigenous Ecological Science and Knowledge

Indigenous knowledge about marine biodiversity and ecosystems has been continuously developed over centuries and millennia. Indigenous science is disciplined and uses practices of observing, hypothesizing, etc. which all fit the definition of 'science'. The difference between indigenous science and academic science may be in the way indigenous wisdom keepers and knowledge keepers transfer their knowledge and wisdom. Indigenous communities therefore have a historic baseline and unique approaches for understanding ecosystem and environmental

change. Indigenous knowledge is not static and is the result of system level ways of knowing that have been time tested. This traditional knowledge reflects understanding, builds on experiences of past ocean conditions, adaptations to current changes, and is promoted by knowledge holders to address community needs. It reflects processes and conditions that change over time and between locations that these communities visit. How traditional ecological knowledge is curated differs across communities and cultures. The methodologies of traditional ways of knowing in the future will continue to evolve as indigenous knowledge holders adapt and refine their scientific approaches to reflect changes in ocean, climate, and terrestrial conditions. The knowledge will also adapt to evolving community needs and values. The communities can also benefit from new knowledge and technologies developed by other sectors of society. This process will require support and funding, and will require the academic science community to reexamine their shortcomings. Collaborations between Indigenous science practitioners, traditional knowledge systems, and academic science systems will only be effective if there is an openness to new ways of knowledge creation, and true co-development is done in full cooperation and co-design at the onset of any scientific endeavour.

The Ocean Decade should provide opportunities to develop strong relationships with coastal indigenous and other traditional maritime communities. The relationship with Indigenous peoples is critical to establishing trust given the history of the exploitation of Indigenous knowledge, which has been extractive without true benefits or credit given to Indigenous knowledge holders in academic, scientific and industrial studies and research. The United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) clearly outlines that governments and researchers must obtain the free, prior, and informed consent of Indigenous Peoples. In accordance with UNDRIP, collaborations can help communities use new technologies and concepts. Any strategies co-designed with indigenous communities should include clear guidelines on intellectual property, ownership of data, and protections against unfair leverage of that knowledge - just like the protections that are adopted by universities and the private sector. There must be clear benefits, articulated in the co-design stages, to the Indigenous communities who as partners contribute to the scientific work. This must include any monetary benefits, shared knowledge enhancement, benefits to the community, environmental and ecosystem benefits, technological benefits, and any other advantages afforded equally to other partners in the work. Research priorities of Indigenous communities must also be addressed within the co-design stages of the work plan. The pace of work must be flexible to adapt to community involvement, which may work at a different pace than that of the academic science community.

Similarly, with their consent, participation, and protection, many different indigenous ways of knowing could therefore inform other sectors of society about past ocean conditions or current issues. Education and clarity around indigenous science and traditional ecological knowledge (TEK) can help beneficial common understanding of different worldviews that acknowledge the self and others within a wider ecological context, and lead to key human-centered solutions in place-based ecosystem management. The scientific community must understand that Indigenous knowledge is derived from value systems and cultural norms of Indigenous peoples which inform their worldviews and may be unknown or unappreciated by governments and the academic research community. In this context, the use of the nomenclature of "western knowledge" is inaccurate geographically and culturally. Further, the common juxtaposition of "western knowledge" and TEK also continues to exacerbate negative perceptions by all involved. All ways of knowing are based on the application of the scientific method (imagine, ask, observe, synthesize, conclude, repeat).

The Ocean Decade must develop actions to ensure that indigenous communities and future indigenous knowledge holders have the financial, technical, and scientific resources to

allow their own practices to evolve and to implement and participate actively in place-based ecosystem management. Because interactions between sectors of society takes time and developing trust, the Ocean Decade needs to prioritize these Actions for indigenous communities to have fair and meaningful connections and collaborations.

The Ocean Decade must call on governments, the academic science, and industry research communities to invest in Indigenous peoples and Indigenous Knowledge Systems to address all the inequities that have taken place, rather than call on Indigenous Knowledge Holders to simply surrender their knowledge to be exploited "for the greater good". This act of reconciliation will ensure that Indigenous peoples will be able to co-design scientific research and be more effective and respected. Without this approach, the method of simply extracting knowledge from Indigenous peoples will continue to exploit knowledge holders and the Ocean Decade community will continue to struggle to truly benefit from Indigenous-led solutions.

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. Aquacultured 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 that are essential for sustainable development within and beyond national jurisdictions and has worked with local communities and agencies to initiate monitoring.
- 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, 2026: The UN Ocean Decade has helped the private sector, governments, and research groups to have a dialogue on financial and tax structures and tools (such as blue bonds) for key biodiversity outcomes and educate these communities on their broad implementation.
- By July 1, 2027: Every National Decade Committee has developed messaging outlining the justification for conserving, restoring, and protecting marine biodiversity and ecosystem services in a way that helps decision makers to quantify the costs (and overall benefits) of restoration and conservation actions.
- 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. This process should align national targets with global targets and highlight the need for observations to produce indicators relevant to the GBF. The process should also include consultation and pathways for long-term collaboration with local and indigenous communities, with their free, prior and informed consent, in accordance with national legislation.

- By January 1, 2027: Sponsors, researchers, and implementers of geo-engineering efforts including mCDR and other schemes, have engaged in the co-design of biodiversity and ecosystem change studies and action plans to minimize and avoid biodiversity and ecosystem impacts.
- By January 1, 2028: Every National Ocean Decade Committee or regional group has collaborated with local and indigenous communities with their free, prior and informed consent, and in accordance with national legislation, on developing strategies on two-way incorporation of Essential Ocean Variables (EOV) and Essential Biodiversity Variables (EBV) into their understanding and place-based ecosystem management. This includes facilitated two-way exchange as agreed between communities and existing, interoperable, international information systems, such as the Ocean Biodiversity Information System (OBIS) and Global Biodiversity Information facility (GBIF).
- 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 2028: The Ocean Decade Coordinating Unit is actively engaged in the planning for full and visible participation of the Ocean Decade in the OceanObs'29 Conference, to be hosted by China in 2029, to ensure that biology and ecosystems research and applications are fully linked into the framework for ocean observing.
- 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, including resources to advance the work and knowledge of indigenous partners.

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 National Biodiversity Strategy and Action Plans (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 and use scientific data on marine biodiversity and ecosystem change.
- The density of biodiversity data (i.e. the volume of data in a geographic area such as an EEZ, over regular time periods: e.g. TB km-2 year-1) collected and published in interoperating marine biodiversity databases (e.g., in OBIS, GBIF, nucleotide

databases linked to curated museum data, such as BOLD).

- Number of reference DNA sequence data, ideally paired with museum voucher specimens, available for global indicator species.
- Number of Ocean Decade Actions that explicitly include biodiversity, ecosystem change, ecosystem functioning, and scientific measures of effectiveness of conservation and restoration.
- Number of countries and regions with biodiversity climate risk assessments.
- Number of Actions that explicitly include co-design efforts with and leadership from local and indigenous communities to support biodiversity and ecosystem protection and restoration.
- Number of global networks and international coordination mechanisms that integrate biology and ecosystems Essential Ocean Variables, incorporating capacity sharing and local and indigenous knowledge.
- Sustained funding is secured for Actions focused on Challenge 2, with a particular emphasis on the connection between research and operations that support biodiversity and ecosystems restoration and protection.

References

Abarenkov K, Andersson AF, Bissett A, Finstad AG, Fossøy F, Grosjean M, Hope M, Jeppesen TS, Kõljalg U, Lundin D, Nilsson RN, Prager M, Provoost P, Schigel D, Suominen S, Svenningsen C & Frøslev TG. (2023). Publishing DNA-derived data through biodiversity data platforms, Vol. 1.3. *Copenhagen: GBIF Secretariat*. https://doi.org/10.35035/doc-vf1a-nr22.

Bell-James, J., Foster, R., Shumway, N., Lovelock, C. E., Villarreal-Rosas, J., Brown, C. J., Andradi-Brown, D. A., Saunders, M. I., Waltham, N. J., & Fitzsimons, J. (2024). The Global Biodiversity Framework's ecosystem restoration target requires more clarity and careful legal interpretation. Nature Ecology and Evolution. https://doi.org/10.1038/s41559-024-02389-6

Benson, A., LaScala-Gruenewald, D., McGuinn, R., Satterthwaite, E., Beaulieu, S., Biddle, M., deWitt, L., McKinzie, M., Montes, E., Moustahfid, H., Muller-Karger, F., Murray, T., Van de Putte, A., & Cluster, E. B. D. S. (2021). Biological Observation Data Standardization - A Primer for Data Managers. ESIP. https://doi.org/10.6084/m9.figshare.16806712.v2

Campagne, C.S., Roy, LA., Langridge, J., Claudet, J., Mongruel R., Beillouin, D., Thiébaut E. (2023) Existing evidence on the impact of changes in marine ecosystem structure and functioning on ecosystem service delivery: a systematic map. Environmental Evidence 12, 13. https://doi.org/10.1186/s13750-023-00306-1

Canonico, G., Buttigieg, P. L., Montes, E., Muller-Karger, F. E., Stepien, C., Wright, D., ... et al. (2019). Global observational needs and resources for marine biodiversity. Frontiers in Marine Science. https://doi.org/10.3389/fmars.2019.00367

Convention on Biological Diversity (CBD). (2022). Final text of the Kunming-Montreal Global Biodiversity Framework. https://www.cbd.int/article/cop15-final-text-kunming-montreal-gbf-221222.

Costello M.J., & Wieczorek J. (2014). Best practice for biodiversity data management and publication. Biological Conservation, 173, 68-73.

CBD/COP/DEC/15/12*: Subnational and Local Biodiversity Strategies and Action Plans (cbd.int); Regional Biodiversity Strategies and Action Plans (cbd.int)

De Pooter, D., Appeltans, W., Bailly, N., Bristol, S., Deneudt, K., Eliezer, M., ... et al. (2017). Toward a new data standard for combined marine biological and environmental datasets - expanding OBIS beyond species occurrences. Biodiversity Data Journal, 5, e10989. https://doi.org/10.3897/BDJ.5.e10989.

Dornelas, M., Antão, L. H., Moyes, F., Bates, A. E., Magurran, A. E., Adam, D., Akhmetzhanova, A. A., Appeltans, W., Arcos, J. M., Arnold, H., Ayyappan, N., Badihi, G., Baird, A. H., Barbosa, M., Barreto, T. E., Bässler, C., Bellgrove, A., Belmaker, J., Benedetti-Cecchi, L., . . . et al. (2018). BioTIME: A database of biodiversity time series for the Anthropocene. Global Ecology and Biogeography, 27(7), 760–786. https://doi.org/10.1111/geb.12729

Estes, M. G., Anderson, C. R., Appeltans, W., Bax, N. J., Bednaršek, N., Canonico, G., Djavidnia, S., Escobar, E., Fietzek, P., Grégoire, M., Hazen, E. L., Kavanaugh, M. T., Lejzerowicz, F., Lombard, F., Miloslavich, P., Möller, K. O., Monk, J., Montes, E., Moustahfid, H., . . .et al. (2021). Enhanced monitoring of life in the sea is a critical component of conservation management and sustainable economic growth. Marine Policy, 132, 104699. https://doi.org/10.1016/j.marpol.2021.104699

Fischman, R. L., Ruhl, J. B., Forester, B. R., Lama, T., Kardos, M., Rojas, G. A., Robinson, N. A., Shirey, P. D., Lamberti, G. A., Ando, A. W., Palumbi, S. R., Wara, M., Schwartz, M. W., Williamson, M. A., Berger-Wolf, T. Y., Beery, S., Rolnick, D., Kitzes, J., Thau, D., . . . et al. (2023). A landmark environmental law looks ahead. Science, 382(6677), 1348–1355. https://doi.org/10.1126/science.adn3245

Gacutan, J., Pınarbaşı, K., Agbaglah, M., Bradley, C., Galparsoro, I., Murillas, A., Adewumi, I. J., Praphotjanaporn, T., Bordt, M., Findlay, K., Lantz, C. A., & Milligan, B. (2022). The emerging intersection between marine spatial planning and ocean accounting: A global review and case studies. Marine Policy, 140, 105055. https://doi.org/10.1016/j.marpol.2022.105055

Gerber, L. R., Schwartz, M. W., & Dreiss, L. M. (2023). The U.S. needs a National Biodiversity Strategy. Conservation Science and Practice, 5(11), e13028. https://doi.org/10.1111/csp2.13028

Group on Earth Observations Biodiversity Observation Network (GEOBON). (2023). The Group on Earth Observations Biodiversity Observation Network. Essential Biodiversity Variables. https://geobon.org/ebvs/what-are-ebvs/.

Global Indigenous Data Alliance (GIDA). (2023). CARE Principles for Indigenous Data Governance. Research: Data Alliance International Indigenous Data Sovereignty Interest Group. https://www.gida-global.org/care

Gignoux-Wolfsohn, S. A., Dunn, D. C., Cleary, J., Halpin, P. N., Anderson, C. R., Bax, N. J., Canonico, G., Chaniotis, P., DeLand, S., D'Iorio, M., Gaines, S. D., Grorud-Colvert, K., Johnson, D. E., Levin, L. A., Lundquist, C. J., Manca, E., Meta×As, A., Monaco, M. E., Morgan, L. E., . . . et al. (2024). New framework reveals gaps in US ocean biodiversity protection. One Earth. https://doi.org/10.1016/j.oneear.2023.12.014

The Global Climate Observing System (GCOS). (2022). The 2022 GCOS Implementation Plan. https://library.wmo.int/records/item/58104-the-2022-gcos-implementation-plan-gcos-244.

Global Ocean Accounts Partnership (GOAP). (2023). Detailed Technical Guidance on Ocean Accounting. https://oceanaccounts.atlassian.net/wiki/spaces/DTGOOA/overview.

Global Ocean Observing System (GOOS). (2022). Alarming knowledge gaps in the global status of marine life. https://stag.goosocean.org/news/alarming-knowledge-gaps-in-the-global-status-of-marine-life/

Hughes, A. C., Orr, M. C., Ma, K., Costello, M. J., Waller, J., Provoost, P., ...et al. (2021). Sampling biases shape our view of the natural world. Ecography, 44, 1259–1269. https://doi.org/10.1111/ecog.05926

IOC-UNESCO. (2022). Multiple Ocean Stressors: A Scientific Summary for Policy Makers. P.W. Boyd et al. (eds). Paris, UNESCO. 20 pp. (IOC Information Series, 1404) https://doi.org/10.25607/OBP-1724

IOC-UNESCO. (2023). Ocean Decade Data & Information Strategy. Paris, UNESCO. (The Ocean Decade Series, 45)

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES Secretariat. Bonn, Germany. 1148 pages. https://doi.org/10.5281/zenodo.3831673

Intergovernmental Panel on Climate Change (IPCC). (2023). Summary for Policymakers. In Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on

Climate Change (pp. 3–34). frontmatter, Cambridge: Cambridge University Press.

Jefferson, T., & Costello, M. J. (2020). Hotspots of marine biodiversity. In Elsevier eBooks (pp. 586–596). https://doi.org/10.1016/b978-0-12-409548-9.11952-9

Jefferson, T., Costello, M. J., Zhao, Q., & Lundquist, C. J. (2021). Conserving threatened marine species and biodiversity requires 40% ocean protection. Biological Conservation, 264, 109368. https://doi.org/10.1016/j.biocon.2021.109368

Jones, K. R., Klein, C. J., Grantham, H. S., Possingham, H. P., Halpern, B. S., Burgess, N. D., Butchart, S. H. M., Robinson, J. G., Kingston, N., Bhola, N., & Watson, J. (2020). Area requirements to safeguard Earth's marine species. One Earth, 2(2), 188–196. https://doi.org/10.1016/j.oneear.2020.01.010

Jouffray, J.-B., Blasiak, R., Norström, A.V., Österblom, H., Nyström, M. (2020) The blue acceleration: The trajectory of human expansion into the ocean. One Earth, 2(1), 43-54. https://doi.org/10.1016/j.oneear.2019.12.016

Lindstrom, E., Gunn, J., Fischer, A., Mccurdy, A., Glover, L. K., Alverson, K., Berx, B., Burkill, P., Chavez, F., Checkley, D., Clark, C., Fabry, V., Hall, J., Masumoto, Y., Meldrum, D., Meredith, M., Monteiro, P., Mulbert, J., Pouliquen, S., … et al. (2012). A Framework for Ocean Observing Prepared for the Task Team for an Integrated Framework for Sustained Ocean Observing (IFSOO). https://doi.org/10.5270/OceanObs09-FOO

Lombard, A. T., Clifford-Holmes, J. K., Goodall, V., Snow, B., Truter, H., Vrancken, P., Jones, P. J., Cochrane, K. L., Flannery, W., Hicks, C. C., Gipperth, L., Allison, E. H., Diz, D., Peters, K., Erinosho, B., Levin, P. S., Holthus, P., Szephegyi, M., Awad, A. M., . . . et al. (2023). Principles for transformative ocean governance. Nature Sustainability, 6(12), 1587–1599. https://doi.org/10.1038/s41893-023-01210-9

Miloslavich, P., Bax, N. J., Simmons, S. E., Klein, E., Appeltans, W., Aburto-Oropeza, O., Garcia, M. A., Batten, S. D., Benedetti-Cecchi, L., Checkley, D. M., Chiba, S., Duffy, J. E., Dunn, D. C., Fischer, A., Gunn, J., Kudela, R. M., Marsac, F., Müller-Karger, F. E., Obura, D., & Shin, Y. (2018a). Essential ocean variables for global sustained observations of biodiversity and ecosystem changes. Global Change Biology, 24(6), 2416–2433. https://doi.org/10.1111/gcb.14108

Miloslavich, P., Seeyave, S., Müller-Karger, F. E., Bax, N. J., Ali, E. M., Delgado, C., Evers-King, H., Loveday, B. R., Lutz, V. A., Newton, J., Nolan, G., Peralta, A. C., Traeger-Chatterjee, C., & Urban, E. R. (2018b). Challenges for global ocean observation: the need for increased human capacity. Journal of Operational Oceanography, 12(sup2), S137–S156. https://doi.org/10.1080/1755876x.2018.1526463

Miloslavich, P., Zitoun, R., Urban, E., Karger, F., Bax, N. J., Arbic, B. K., Lara-Lopez, A., Delgado, C., Métian, M., Seeyave, S., Swarzenski, P. W., Uku, J., & Valauri-Orton, A. (2022). Developing capacity for ocean science and technology. In Blue Economy (pp. 467–504). https://doi.org/10.1007/978-981-19-5065-0_15

Muller-Karger, F. E., Hestir, E., Ade, C., Turpie, K., Roberts, D., Siegel, D., … et al. (2018a). Satellite sensor requirements for monitoring essential biodiversity variables of coastal ecosystems. Ecological Applications. https://doi.org/10.1002/eap.1682

Muller-Karger, F. E., Miloslavich, P., Bax, N., Simmons, S., Costello, M. J., Sousa Pinto, I., … et al. (2018b). Advancing marine biological observations and data requirements of the complementary essential ocean variables (EOVs) and essential biodiversity variables (EBVs) frameworks. Frontiers in Marine

Science. https://doi.org/10.3389/fmars.2018.00211

Organisation for Economic Co-operation and Development (OECD). (2019). Rethinking Innovation for a Sustainable Ocean Economy. OECD Publishing, Paris. https://doi.org/10.1787/9789264311053-en

Olson, D. M., & Dinerstein, E. (2002). The Global 200: Priority ecoregions for global conservation. Annals of the Missouri Botanical Garden, 199-224. [AKA, WWF Global 200].

Pante, E. Schoelinck, C., Puillandre, N. (2015) From Integrative Taxonomy to Species Description: One Step Beyond, Systematic Biology. 64(1) 152–160. https://doi.org/10.1093/sysbio/syu083

Pearlman, J., Buttigieg, P. L., Bushnell, M., Delgado, C., Hermes, J., Heslop, E., Hörstmann, C., Isensee, K., Karstensen, J., Lambert, A., Lara-Lopez, A., Müller-Karger, F. E., Mas, C. M., Pearlman, F., Pissierssens, P., Przeslawski, R., Simpson, P., Van Stavel, J., & Venkatesan, R. (2021). Evolving and sustaining ocean best practices to enable interoperability in the UN Decade of Ocean Science for Sustainable Development. Frontiers in Marine Science, 8. https://doi.org/10.3389/fmars.2021.619685

Rogers, A. D., Appeltans, W., Assis, J. F., Ballance, L. T., Cury, P., Duarte, C., Favoretto, F., Hynes, L. A., Kumagai, J., Lovelock, C. E., Miloslavich, P., Niamir, A., Obura, D., O'Leary, B. C., Ramírez-Llodra, E., Reygondeau, G., Roberts, C. M., Sadovy, Y., Steeds, O., . . . et al. (2022). Discovering marine biodiversity in the 21st century. In Advances in Marine Biology (pp. 23–115). https://doi.org/10.1016/bs.amb.2022.09.002

Rudd, M. A., Dickey-Collas, M., Ferretti, J., Johannesen, E., Macdonald, N., McLaughlin, R. J., Rae, M., Thiele, T., & Link, J. S. (2018). Ocean Ecosystem-Based Management Mandates and Implementation in the North Atlantic. Frontiers in Marine Science, 5. https://doi.org/10.3389/fmars.2018.00485

Ryabinin, V., Barbière, J., Haugan, P. M., Kullenberg, G., Smith, N., McLean, C., Troisi, A., Fischer, A., Aricò, S., Aarup, T., Pissierssens, P., Visbeck, M., Enevoldsen, H., & Rigaud, J. (2019). The UN Decade of Ocean Science for Sustainable Development. Frontiers in Marine Science, 6. https://doi.org/10.3389/fmars.2019.00470

Sala, E., Mayorga, J., Bradley, D., Cabral, R. B., Atwood, T. B., Auber, A., Cheung, W. W. L., Costello, C., Ferretti, F., Friedlander, A. M., Gaines, S. D., Garilao, C., Goodell, W., Halpern, B. S., Hinson, A., Kaschner, K., Kesner-Reyes, K., Leprieur, F., McGowan, J., . . . et al. (2021). Protecting the global ocean for biodiversity, food and climate. Nature, 592(7854), 397–402. https://doi.org/10.1038/s41586-021-03371-z

Seidl, A., Mulungu, K., Arlaud, M., Van Den Heuvel, O., & Riva, M. (2021). The effectiveness of national biodiversity investments to protect the wealth of nature. Nature Ecology and Evolution, 5(4), 530–539. https://doi.org/10.1038/s41559-020-01372-1

Sequeira, A. M. M., O'Toole, M., Keates, T. R., McDonnell, L. H., Braun, C. D., Hoenner, X., Jaine, F. R. A., Jonsen, I. D., Newman, P., Pye, J., Bograd, S. J., Hays, G. C., Hazen, E. L., Holland, M., Tsontos, V., Blight, C., Cagnacci, F., Davidson, S. C., Dettki, H., . . . et al. (2021). A standardisation framework for bio-logging data to advance ecological research and conservation. Methods in Ecology and Evolution, 12(6), 996–1007. https://doi.org/10.1111/2041-210x.13593

Selig, E. R., Turner, W. R., Troëng, S., Wallace, B. P., Halpern, B. S., Kaschner, K., Lascelles, B., Carpenter, K. E., & Mittermeier, R. A. (2014). Global Priorities for Marine Biodiversity Conservation. PLOS ONE, 9(1), e82898. https://doi.org/10.1371/journal.pone.0082898

Spinrad, R. W. (2021). The new blue economy. Chapter 6. In: Preparing a Workforce for the

New Blue Economy. Editor(s): Liesl Hotaling, Richard W. Spinrad. Elsevier. Pages 87-111. https://doi.org/10.1016/B978-0-12-821431-2.00042-1.

Tanhua, T., Pouliquen, S., Hausman, J., O'Brien, K., Bricher, P., de Bruin, T., Buck, J.J.H., Burger, E.F., Carval, T., Casey, K.S., Diggs, S., Giorgetti, A., Glaves, H., Harscoat, V., Kinkade, D., Muelbert, J.H., Novellino, A., Pfeil, B., Pulsifer; P.L., Van de Putte, A., Robinson, E., Schaap, D., Smirnov, A., Smith, N., Snowden, D., Spears, T., Stall, S., Tacoma, M., Thijsse, P., Tronstad, S., Vandenberghe, T., Wengren, M., Wyborn, L. and Zhao, Z. (2019). Ocean FAIR Data Services. Frontiers in Marine Sciences. 6:440. https://doi.org/10.3389/fmars.2019.00440.

UN Agenda 2030. UN A/RES/70/1. Sustainable Development Goal 14. https://sdgs.un.org/goals/goal14

United Nations Convention on the Law of the Sea (UNCLOS) High Seas Agreement. (2023). Agreement under the United Nations Convention on the Law of the Sea on the Conservation and Sustainable Use of Marine Biological Diversity of Areas beyond National Jurisdiction (A/CONF.232/2023/4; https://www.un.org/bbnj/).

Urban, E.R., Ittekkot, V., Attri, V.N. (2022). Blue Economy and Ocean Science: Introduction. In: Urban Jr., E.R., Ittekkot, V. (eds) Blue Economy. Springer, Singapore. https://doi.org/10.1007/978-981-19-5065-0_1

Tanhua, T., McCurdy, A., Fischer, A., Appeltans, W., Bax, N. J., Currie, K., deYoung, B., Dunn, D. C., Heslop, E., Glover, L. K., Gunn, J., Hill, K., Ishii, M., Legler, D. M., Lindstrom, E., Miloslavich, P., Moltmann, T., Nolan, G., Palacz, A., . . . Wilkin, J. (2019). What we have learned from the Framework for Ocean Observing: Evolution of the Global Ocean Observing System. Frontiers in Marine Science, 6. https://doi.org/10.3389/fmars.2019.00471

Vandepitte, L., Vanhoorne, B., Decock, W., Vranken, S., Lanssens, T., Dekeyzer, S., Verfaille, K., Horton, T., Kroh, A., Hernandez, F., & Mees, J. (2018). A decade of the World Register of Marine Species – General insights and experiences from the Data Management Team: Where are we, what have we learned and how can we continue? https://doi.org/10.1371/journal.pone.0194599

Vicente-Saez, R., & Martínez-Fuentes, C. (2018). Open Science now: A systematic literature review for an integrated definition. Journal of Business Research, 88, 428–436. https://doi.org/10.1016/j.jbusres.2017.12.043

Visalli, M., Best, B., Cabral, R. B., Cheung, W. W. L., Clark, N., Garilao, C., Kaschner, K., Kesner-Reyes, K., Lam, V. W. Y., Maxwell, S. M., Mayorga, J., Moeller, H. V., Morgan, L. E., Crespo, G. O., Pinsky, M. L., White, T. D., & McCauley, D. J. (2020). Data-driven approach for highlighting priority areas for protection in marine areas beyond national jurisdiction. Marine Policy, 122, 103927. https://doi.org/10.1016/j.marpol.2020.103927

Wilkinson, M. D., Dumontier, M., Aalbersberg, I. J., Appleton, G., Axton, M., Baak, A., Blomberg, N., Boiten, J., Da Silva Santos, L. O. B., Bourne, P. E., Bouwman, J., Brookes, A. J., Clark, T. W., Crosas, M., Dillo, I., Dumon, O., Edmunds, S., Evelo, C. T., Finkers, R., . . . et al. (2016). The FAIR Guiding Principles for scientific data management and stewardship. Scientific Data, 3(1). https://doi.org/10.1038/sdata.2016.18

Winther, J., Dai, M., Rist, T., Hoel, A. H., Li, Y., Trice, A., Morrissey, K., Juinio-Meñez, M. A., Fernandes, L., Unger, S., Scarano, F. R., Halpin, P. N., & Whitehouse, S. (2020). Integrated ocean management for a sustainable ocean economy. Nature Ecology and Evolution, 4(11), 1451–1458. https://doi.org/10.1038/s41559-020-1259-6

Woelfle, M., Olliaro, P., & Todd, M. H. (2011). Open science is a research accelerator. Nature Chemistry, 3(10), 745–748. https://doi.org/10.1038/nchem.1149

Yates, M., Derry, A., Cristescu, M. (2021) Environmental RNA: A Revolution in Ecological Resolution? Trends in Ecology & Evolution, 36(7), 601-609. https://doi.org/10.1016/j.tree.2021.03.001.

Zhao, Q., Stephenson, F., Lundquist, C. J., Kaschner, K., Jayathilake, D. R., & Costello, M. J. (2020). Where Marine Protected Areas would best represent 30% of ocean biodiversity. Biological Conservation, 244, 108536. https://doi.org/10.1016/j.biocon.2020.108536

Annex

Glossary and Resource List

TERM	EXPLANATION	REFERENCE
Biodiversity	Biodiversity is the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.	Convention on Biological Diversity, 1992; Article 2 https://www.cbd.int/convention/articles/?a=cbd-02
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

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 thevision and mission of the Ocean Decade.

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