2021 2030 United Nations Decade of Ocean Science for Sustainable Development

The Ocean Decade

Vision 2030 White Paper

Challenge 9

Skills, knowledge and technology for all

Zero Draft - January 2024

unesco

Intergovernmental Oceanographic Commission

The Decade Coordination Unit of IOC/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 draft White Paper. The draft White Paper is a foundation for diverse stakeholders to provide comments and suggestions, and its contents will be refined and complemented following the public review process. A revised version of the White Paper will be presented and discussed at the 2024 Ocean Decade Conference in Barcelona, before being finalized and published as part of UNESCO's Ocean Decade Series of publications.

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VISION 2030 WHITE PAPER

ZERO DRAFT – JANUARY 2024

CHALLENGE 9: A VISION FOR CAPACITY DEVELOPMENT AND SHARING DURING THE OCEAN DECADE

Ensure comprehensive capacity development and equitable access to data, information, knowledge and technology across all aspects of ocean science and for all stakeholders.

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Acknowledgements

To be included after the review process

Acronyms

CDF	Ocean Decade Capacity Development Facility
CTD	Conductivity Temperature Depth sensor
ECOP	Early Career Ocean Professional
IOC	Intergovernmental Oceanographic Commission
LDC	Least Developed Countries
SIDS	Small Island Developing States
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization

1. Executive Summary

1.1. Overview of the Ocean Decade Challenge

Ocean science capacity in all its forms – including personnel, equipment, research vessels, funding, computing, and other research infrastructure, access to education and training, access to scientific publications, access to employment opportunities, and more – is unevenly distributed throughout the world's coastal regions. This unequal distribution hinders progress in ocean science and implies that governments in many coastal countries and island states are not getting adequate advice about coastal management issues. The goal of Ocean Decade Challenge 9: "Skills, knowledge, and technology for all" is to make significant progress in addressing these inequities by 2030.

1.2. Key Findings and Recommendations

Capacity development cuts across different sectors, with unique capacity needs for different users. The users identified here are scientists, resource users, educators/communicators, and managers/policymakers. Geographical, gender, cultural, and generational disparities, unequal distribution of funding, ocean observation equipment, laboratory infrastructure, and computing resources, technological and digital divide between the North and South, limited access to data and information, high cost of publishing open access, underrepresentation of global south scientists in international journals, meetings, language barriers in scientific sharing, advisory panels, and planning committees are among the key capacity challenges faced by ocean scientists globally. Additionally, knowledge about the state of marine resources, access to best practices in resource use and protection, and capacity to protect marine resources in the Global South are the key capacity needs identified for resource users. Educators, communicators, managers, and policymakers require equally important skills and tools to deliver their duties more effectively. It is recommended that the Ocean Decade strives to ensure comprehensive capacity development in ocean science across the world, with a particular focus on less scientifically-advanced regions and marginalized communities. The Ocean Decade should promote and expand existing Decade Actions, and endorse new Actions arising from the Decade ecosystem, that address inequalities in ocean science capacity, including actions that:

- Develop the skills required by scientists, resource users, educators, communicators, managers, and policy-makers to study, sustainably exploit, and manage the ocean.
- Promote equal representation of minority groups (women, early career ocean professionals, indigenous communities, and under-resourced countries) in the science, communication, management, and policy areas of the ocean.

- Ensure fair and equitable distribution of infrastructure and technology required to study, sustainably exploit, and manage the ocean.
- Remove barriers/restrictions including access and language on the sharing and movement of ocean data, knowledge, and information among different users of the ocean.
- Ensure equitable distribution of funding and encourage all countries to invest in ocean science.
- Encourage constructive, multi-directional partnerships.
- Encourage innovative solutions through fit-for-purpose technology.

2. Introduction

2.1. Background and Context of the Challenge

The development of skills, technology, and exchange of knowledge is important for advancing ocean science and deepening our understanding of the challenges faced by the ocean globally. While some capacities in this regard exist within the global ocean science community, they are not equitably distributed among nations and coastal areas. The 2017 and 2020 Global Ocean Science reports (UNESCO-IOC, 2017, 2020) highlight the need to act and bridge ocean science capacity gaps that exist within the global community to effectively tackle the adverse impacts faced by the ocean. Both reports identified key inequities in human resources, infrastructure, technology, and data needs among the global ocean science community. As an illustration, the human resources propelling ocean science exhibit disparities across countries and show global variations in terms of age and gender. On average, women constitute approximately 38% of researchers in the field of ocean science. The availability of technical infrastructure essential for ocean science also is unevenly distributed, particularly by countries in the Southern Hemisphere which experience limited access to such resources. Globally, 63% of data centres limit access to specific data formats, while 40% impose restrictions and embargoes. Inequalities in the distribution of skills, infrastructure, knowledge, recognition, representation, and resources hinder the progress of ocean science. As a result, many coastal nations and communities are unable to participate fully in global ocean science discourse, implying that many regions of the world ocean are largely unexplored. Notably, the existing collaboration, capacity development activities, and sharing of data and technology tend to be ad hoc and not coordinated across different countries and institutions.

Ocean science is often understood as natural scientific research, which limits the representation of different approaches to understanding ocean systems and human-ocean interactions, particularly from social sciences and humanities, and marginalizes traditional knowledge systems. Underlying this are large differences in acknowledging the ocean's value (and the need for ocean science) from the general public, and educational

systems, up to the higher echelons of government. This contributes to the difference among countries in investing in ocean science and conservation.

The recognition of these inequities is the basis for the development of UN Ocean Decade Challenge 9, which seeks to ensure comprehensive capacity development and equitable access to data, information, knowledge, and technology across all aspects of ocean science and for all stakeholders. This white paper sets the strategic ambition to tackle Ocean Decade Challenge 9, to ensure that key inequalities in ocean science are largely resolved by the end of the Ocean Decade.

2.2. Overview of Current Work in the Ocean Decade

The Ocean Decade has endorsed a large number of programmes, projects, and other activities seeking to support skills development for women, early career ocean professionals and marginalized communities, to promote findability, accessibility, interoperability, and reusability of ocean data, and to promote access to the ocean by all. At present, roughly 15 percent of the Decade Actions within the UN Ocean Decade relate primarily to Challenge 9, though all endorsed programmes must demonstrate how they address capacity development, and systematically report on capacity development initiatives.

A Capacity Development Facility (CDF) was established in 2023 to identify and address the capacity development needs of partners involved in Ocean Decade Actions by building on the strengths and expertise of IOC-UNESCO in capacity development. Through this work, the CDF will serve to build connections among experts across the globe with a special emphasis on stimulating engagement and strengthening support to ECOPs, SIDS, and LDCs. The establishment of the CDF highlights the foundational nature of Challenge 9 and the importance of supporting capacity development to achieve all other challenges within the Ocean Decade.

2.3. Importance and Relevance of the Challenge for Sustainable Development

Sustainable use and development of ocean resources requires an understanding of the past, present and future state of the ocean. This includes advocating for actions that make the ocean beneficial to all generations with the overarching goal of enhancing the health and resilience of the ocean. To achieve this, it is important to address capacity needs across scientific, technological, institutional, financial, societal, and educational domains. Establishing equitable capacity for knowledge across all sectors and geography is therefore essential for sustainable development.

2.4. Methodology for Strategic Ambition Setting

To identify and map what needs exist to achieve the goal of Challenge 9 of the Decade, the Working Group conducted numerous discussions and consultations. Working Group 9 is composed of people from diverse backgrounds (natural sciences, social sciences, policy, law, technology, etc.), geographic areas, genders, ages, and career stages. The Group's varied background is a core element of its methodology, as the Group recognizes that many of the challenges that fall under Challenge 9 of the Decade stem from a lack of representation and opportunities for participation in global ocean sustainability initiatives.

Throughout the process of creating this white paper, members of Working Group 9 met regularly to discuss potential needs and solutions for Challenge 9. The suggested solutions were based on the collective expertise of the group. Following this internal discussion process, the reflections and proposed priority areas of the white paper were shared with the Decade's Capacity Development Facility. Insights from past surveys, including the 2017 and 2020 Global Ocean Science Reports, the 2020 and 2022 IOC capacity assessment survey reports, and from the Capacity Development Facility were used to compare and verify the reflections of this white paper. Furthermore, the co-chairs sought the views of co-chairs from other working groups, ensuring alignment between all working groups.

3. Strategic Ambition Setting

3.1. Analysis of User Needs and Priorities

To set the strategic ambition, the Working Group identified a list of users and their needs and priority issues (Table 1). Through these categories, the group recognized the relevance of cross-disciplinary and -sectoral users. Education occurs within formal institutions and through local customs and traditional knowledge held and exchanged within local communities. Likewise, knowledge and labor contributions extend beyond ocean professionals to include community and voluntary organizations and activities, such as citizen science. For capacity building, it was important to recognize users and needs right down to the individual level, acknowledging the needs of early career ocean professionals, small-scale and recreational fishers, and young people who equally deserve access to the benefits that come from ocean literacy. These are broadly grouped into Scientists, Resource Users, Educators/Communicators, and Managers/Policymakers.

Table 1: Analysis of User Needs and Priority Issues

Needs	**Priority Issues**
Scientists (within academia, industry, and other sectors)	
•Representation. •Career development, job security, funding. •Networking, recognition. •Ocean observation and laboratory infrastructure (research vessels, boats, equipment), computing, and internet. •Membership in scientific bodies, subscription to journals and international networks, free access to research publications and best practices. •International partnerships.	•Geographical, gender, cultural, and generational disparities in ocean science. •Unequal distribution of funding, ocean observation, laboratory infrastructure, internet, and computing resources. •Technological and digital divide between the Global North and South. •Limited access to data and information. High cost of publishing open access. •Underrepresentation of global south scientists in international journals, meetings, advisory panels, and planning committees.
Resource Users (individuals and communities)	
•Knowledge about the state of ocean resources and sustainable resource use. •Skills in waste management. •Technology and infrastructure for sustainable resource use. •Conservation tools. •Education and awareness of the importance of marine resources. •Knowledge and access to best practices in use and protection. •Meaningful participation in decision-making. •Recognition of the value of community action and traditional knowledge. •Empowerment and confidence-building opportunities for marginalized communities.	•Limited knowledge about the state of marine resources among different users. •Limited capacity by users in the Global South to protect their resources. •Limited knowledge and access to best practices in resource use and protection.

Educators and Communicators	
•Communication skills, translation services, and publishing in multiple languages. •Digital and media literacy. •Cultural competence and awareness. •Access to best practices in education, knowledge of effective teaching methodologies, and curriculum development.	•Limited educational resources and opportunities in developing coastal states and Small Island Developing States. •Limited awareness of cultural needs. •Global Language divide and cost of translation. •Unrecognized biases that lead to unequal participation and representation of communities.
Managers and Policymakers (including government workers, international organizations, coastal managers, and investors)	
•Basic knowledge of ocean science. •Skills in policy formulation, analysis, and implementation. •Dialogue, negotiation, conflict resolution, and stakeholder engagement skills. •Knowledge of international laws and agreements. •Ocean financing and economic literacy. •Systems for monitoring and evaluating the effectiveness of policies and management strategies. •Understanding and use of traditional and Indigenous Knowledge in policy.	•Limited knowledge about the ocean. •Inadequate skills in policy formulation, analysis, and implementation especially in the Global South. •Limited understanding of priority areas to fund and invest in. •Inability to resolve conflicts among resource users. •Limited communication skills in dialoguing, negotiation, conflict resolution, and stakeholder engagement especially in under-resourced countries. •Limited knowledge of global ocean equity.

3.2. Definition of the Strategic Ambition for the Challenge

The strategic ambition for the challenge is to comprehensively develop and build the capacities required to deliver a globally robust and inclusive science and awareness needed to understand and address all other nine (9) challenges of the Ocean Decade. It is impossible to achieve the science we need for the ocean we want if the current existing gaps in skills, knowledge, and technology among the various users identified above are not bridged. The strategic ambition has several objectives:

- Develop the skills required by scientists, resource users, educators, communicators, managers, and policy-makers to study, sustainably utilize, and manage the ocean.
- Promote equal representation of all groups (including women, early career ocean professionals, indigenous communities, and citizens of SIDS and under-resourced countries) in the science, communication, management, and policy areas of the ocean.
- Create opportunities that promote career development, employment, networking, and recognition for scientists in the Global South.
- Ensure fair and equitable distribution of infrastructure and technology required to study, sustainably exploit, and manage the ocean.
- Remove barriers/restrictions including access and language on the sharing and movement of ocean data, knowledge, and information among different users of the ocean.
- Ensure equitable distribution of funding and encourage all countries to invest in ocean science.
- Encourage constructive, multi-directional partnerships to find common objectives that fulfil the needs of all parties involved.
- Encourage innovative solutions through technology for studying and sustainably managing the ocean.

3.2.1. Knowledge and Data Sharing

To achieve equitable knowledge and data sharing, the community needs open-access platforms and databases where researchers from all regions can share their findings and data freely. Motivated by the recognition that different users have varying data requirements, the community should establish open-source databases to ensure that data sharing is not hindered by formalities, while also ensuring that data may be broadly accessed. For example, universally recognized standards for measuring and assessing coastal ecosystems should be established and promoted. Technology and knowledge transfer between higher-resourced and under-resourced regions can be facilitated through partnerships, collaborative projects, and the sharing of best practices in data collection, analysis, and interpretation, as well as by encouraging the participation of local scientists from under-resourced nations in joint research.

3.2.2. Partnerships

Challenge 9 is an overarching challenge that concerns all other UN Ocean Decade Challenges and all UN Ocean Decade Outcomes. Therefore, ensuring a variety of partnerships and resources, both financial and in-kind, is essential for achieving the strategic ambition for this Challenge. Below are the partnership types necessary for its achievement.

International cooperation

Inter-regional, sea basin, and international cooperation should be encouraged and supported. Cross-cutting capacity development connects diverse stakeholders to ensure a common effort in solving the UN Ocean Decade Challenges. However, collaborative, and transparent decision-making can only be ensured through guidelines and policies that address power discrepancies. Working groups should be created to facilitate the exchange of knowledge and practices among researchers at global and regional levels. The development of multilingual communication strategies bridges language barriers. The Decade should also continue to support regional advances and organizations in marine sciences.

Interdisciplinary cooperation

An interdisciplinary approach should be at the core of further development of the UN Ocean Decade to identify efficient solutions to the ten Challenges. For this, the UN Ocean Decade should foster partnerships among scientists, communities, and experts from different disciplines including traditional knowledge sectors.

Donor and funding bodies

The Decade should ensure cooperation between funding organizations and mechanisms and organizers of capacity development opportunities (training, workshops, courses, scholarships, participation in international conferences/networks) so that the latter group has easy access to funders. The UN Ocean Decade may take on the role of aggregator of such information.

Promoting Public-Private partnerships

The UN Ocean Decade should provide mechanisms for public-private partnerships to fund and/or foster capacity development, especially in the regions that lack such opportunities. For example, instrument manufacturers can support capacity development initiatives by providing instruments at a lower cost to under-resourced countries and working with them on joint projects. Also, the UN Ocean Decade must encourage funding agencies to pay special attention to projects that promote researcher participation from different regions or different countries within one region.

3.2.3. Approach to capacity development and exchanges

1. **Skills development**

This first requires an increased awareness of ocean science careers in diverse communities, then funding and resource-sharing programmes to minimize the financial barriers to skills development. Opportunities (such as outreach, recruitment, and mentorship programmes) can then be created and offered to under-represented groups, as well as to graduate and post-graduate students to enhance their academic experience

and prepare them for the job market (such as on-the-job training opportunities). The UN Ocean Decade should support the endorsement and implementation of programmes that promote the training and empowerment of early career ocean professionals, women, indigenous groups, and scientists from under-resourced countries.

2. Technology and Infrastructure

There is a need for the development of low-cost, easy to use, and easy-to-maintain instruments for coastal observations in under-resourced countries. Recent technological advances have created opportunities to develop reliable, low-cost sensors, platforms, and communications, driven by the decreasing cost of components, the availability of 3D printing technology, low-cost controller/data loggers based on embedded systems, and low/no subscription costs for communication systems (Marcelli et al., 2021). While there are a number of projects in this area, mainly by oceanographic research and engineering groups, relatively few projects are by commercial instrument manufacturers (see Annex 1). Mechanisms for technological advances have included competitions, research projects, partnerships with vessels of opportunity, and citizen science/educational initiatives. Such successful models should be scaled up to ensure that a wide range of technologies are easily available to under-resourced countries to purchase, deploy, maintain, calibrate, and even build themselves.

As many of these technology development projects have been implemented by under-resourced countries, there is a need to facilitate the exchange of technology and expertise between higher- and under-resourced regions. In addition, establishing local research equipment vendors and remote offices of well-resourced companies would empower regions to build their own equipment and reduce dependency on global north vendors. In the longer term, the Ocean Decade community should focus on the development of institutional and societal capacity, which is essential in the longer term to guarantee the sustainability of capacity development efforts.

3. Funding

Lack of funding is a major obstacle to implementing research projects in regions that lack resources. Such funding should be prioritized, while ensuring that these projects address the specific needs of local communities. In addition to sustained support from the global north (e.g. funding agencies, philanthropy, and development banks) to under-resourced countries through funding, training, and capacity-building initiatives, there is a need to advocate for national/local policies that prioritize the funding of ocean science by under-resourced countries.

4. Knowledge and Data Sharing

Sharing knowledge and data through international cooperation and networking is essential. This can be achieved by advocating for policies that require international collaboration and data/knowledge sharing, and that incentivize researchers to work together across borders. We need to incorporate these ideas into policy frameworks, funding initiatives, and collaborative efforts to significantly reduce inequities in ocean science and foster a more inclusive and diverse research landscape. Cost is a major barrier to publishing in international journals, therefore financial support should be provided for authors (both ECOPs and non-ECOPs) in under-resourced countries.

3.3. Integration, Synergies, and Interdependencies with Other Challenges

Capacity development and access to technology are cross-cutting issues essential for the success of the Ocean Decade. Capacity development and access to technology are, in fact, the “enablers” of the other challenges. Without appropriate capacity development and access to technology, the other nine challenges will not be realized. Text from the white papers on the other 9 Ocean Decade Challenges that link to Working Group 9 is provided in a table in Annex 2.

4. Milestones and Indicators

4.1. Key Milestones to Measure Progress and Success

Success will be reached when resources and knowledge are shared equitably across all coastal communities so that all scientists and stakeholders can study ocean resources and share their information. While some dramatic changes are possible – such as focusing funding on under-resourced countries and diverse scientists (based on geography, gender, and years of practice) – shifts in established practices will take time. A practical way to identify milestones in progress toward equitable distribution of research and knowledge is to have policymakers measure their success, individually. Policymakers include governments (local and national), quasi-governmental organizations, and educational institutions, both public and private. Achievements in some areas will naturally diminish barriers in others. Four steps are recommended for policymakers to address global inequities related to knowledge and data sharing: establish a baseline; track data; weigh the data; and implement changes. Specific milestones are identified below.

4.1.1. Milestone 1: Equitable Representation

Ensure significant representation of under-represented groups (women, early career ocean professionals, indigenous communities, and scientists from under-resourced countries) in ocean science, communication, management, and policy.

- Promote the representation of women, early career ocean professionals, indigenous communities, and under-resourced coastal countries in ocean science, communication, and policy.
- Provide career development support and create jobs for scientists in the Global South, thus reducing that area's "brain drain".
- Increase networking, professional membership, and recognition opportunities for scientists for the groups described.

4.1.2. Milestone 2: Skill Development

Develop the skills required by scientists, resource users, educators, communicators, managers, and policy-makers to study, sustainably exploit, and manage the ocean. Develop and implement training programmes to:

- Enhance field and data management of ocean scientists.
- Enhance communication, negotiation, conflict resolution, and stakeholder engagement skills.
- Enhance cross-disciplinary skills to support holistic approaches to problems.
- Provide policy formulation, analysis, and implementation.

4.1.3. Milestone 3: Distribution of Infrastructure and Technology

Ensure the fair and equitable distribution of the infrastructure and technology required to study, sustainably exploit, and manage the ocean across regions and communities.

- Develop a plan for the equitable allocation of infrastructure and technology.
- Promote the involvement of underrepresented groups and communities in decisions regarding the distribution of infrastructure and technology.
- Implement initiatives to develop low-cost technologies/instrumentations in underrepresented areas and regions.
- Provide training programmes to build local capacity for the effective use of technology.
- Launch programmes to improve access to advanced technology, including cloud resources, especially in regions with limited resources.
- Establish a system to track the distribution of infrastructure and technology during the Ocean Decade.
- Provide regular reports on the status of infrastructure and technology distribution, identifying geographical areas requiring additional attention.

4.1.4. Milestone 4: Access and Language Barriers

Remove access and language barriers/restrictions on the sharing and movement of ocean data, knowledge, and information among different users of the ocean.

- Engage in policy advocacy efforts and awareness campaigns at local, national, and international levels to promote open access to ocean data and information.
- Promote collaborative user-friendly frameworks that facilitate data sharing among different ocean user groups.
- Develop and promote standardized data formats to enhance interoperability and ease of sharing.
- Launch initiatives to ensure language accessibility in ocean data and information sharing.
- Establish guidelines for responsible and ethical data governance.

4.1.5. Milestone 5: Equitable Funding Distribution

Establish the equitable distribution of funding; encourage all countries to invest in ocean science.

- Develop a framework for equitable distribution of funding in ocean science, considering geographical, economic, and research capacity needs.
- Advocate for an international agreement on principles that promote equitable distribution of funding.
- Establish equitable distribution principles for funding mechanisms.
- Facilitate the inclusion of under-resourced coastal countries and indigenous communities in international research consortia to ensure access to collaborative funding opportunities.

4.1.6. Milestone 6: Multi-disciplinary Partnerships

Incorporate multi-disciplinary partnerships in ocean science initiatives, to include scientists, policymakers, industry representatives, NGOs, traditional knowledge, and local communities in collaborative efforts.

4.1.7. Milestone 7: Innovation

Encourage innovation for ocean solutions.

- Establish innovation incubators or research centers to develop technological and interdisciplinary solutions for ocean-related challenges.
- Implement programmes to facilitate the transfer of technology from other sectors to ocean science or among research institutions.
- Implement incentive programmes, such as grants or awards, to motivate researchers and organizations to pursue innovative solutions.

- Strengthen collaboration with industry partners to leverage private sector expertise and resources for technological innovation.
- Monitor the adoption rates of innovative technologies within the ocean science community and relevant industries.

4.2. Indicators to Track Strategic Ambition Success

The strategic ambition for Challenge 9 will be achieved when career opportunities, research papers, funded research grants, major award recognition, research equipment, and computing resources in ocean science are proportionately distributed to coastal nations worldwide. To achieve true equity, the Ocean Decade must promote measurable progress towards long-term capacity development as measured by achieving the above milestones.

4.2.1. Indicators for Milestone 1: Equitable Representation

- Percentage of women, early career ocean professionals, indigenous communities, and scientists from under-resourced coastal countries in the science and policy areas of ocean management.
- Number of new ocean science jobs created in under-resourced coastal nations.
- Number of networking, professional membership, and recognition opportunities for scientists from the Global South and other underrepresented groups.

4.2.2. Indicators for Milestone 2: Skill Development

- Number of new or revised programmes, courses, or modules developed for training programs and infrastructure development.
- Number of scientists, resource users, educators/communicators, managers, and policymakers trained.

4.2.3. Indicators for Milestone 3: Distribution of Infrastructure and Technology

- Establishment of a tracking system of the distribution of infrastructure and technology.
- Percentage increase in relevant organizations' resource allocation to underrepresented areas and percentage adoption of the resource allocation plan by relevant organizations.
- Identification of low-cost technologies implemented, and the geographical coverage of, infrastructure development projects.
- Number of programs on technology use, including the impact of training programs.

4.2.4. Indicators for Milestone 4: Access and Language Barriers

- Number of policy advocacy campaigns initiated; identified new policies favoring open access; reach and engagement metrics of awareness campaigns.
- Number of collaborative agreements established and level of inclusion of diverse stakeholders in collaboration frameworks.
- Number of data repositories supporting standardized formats.
- Number of platforms launched after 2024 that share ocean data, knowledge, and information.
- Publication and dissemination of data governance guidelines.
- Adoption rates by relevant organizations of data guidelines and multiple language access to platforms.

4.2.5. Indicators for Milestone 5: Equitable Funding Distribution

- Equitable funding framework developed which identifies geographical, economic, and research capacity factors.
- Number of countries endorsing an agreement on principles to promote equitable distribution of funding.
- Level of equitable funding principles in international policies.
- Number of public-private collaborations established since 2024 to address equitable funding and the amount provided for ocean science projects to under-represented entities.
- Number of under-resourced coastal countries, and indigenous communities participating in international consortia.

4.2.6. Indicators to Milestone 6: Multi-disciplinary Partnerships

- Representation of diverse stakeholders in collaborative projects.

4.2.7. Indicators to Milestone 7: Innovation

- Number of innovation incubators and research centers launched since 2024, and participation in and collaboration by industry and government partners.
- Number of technology transfer agreements and successful implementation of transferred technologies.
- Number of incentive programs launched and recognition and acknowledgment of innovative contributions.
- Number of industry partnerships established and successful implementation of joint projects.
- Adoption rates of innovative technologies within the ocean science community and relevant industries using surveys and assessment of technology uptake.

Annex 1. Example list of low-cost instrumentation

Some examples of successful developments are provided below. Others can be found in, for example, Marcelli et al. (2021), in the "DIY Oceanography" section of Oceanography magazine, and on the "Oceanography for everyone" website.

- **Low(er)-cost instruments developed by research projects:** animal-borne CTD Satellite Relay Data Loggers developed by engineers at the Sea Mammal Research Unit of the University of St Andrews provide temperature and salinity profiles down to 2,000m depth while attached to animals, allowing the study of animal behavior while also filling gaps in data from remote locations.
- **Low(er)-cost instruments developed through competitions:** Wendy Schmidt Ocean Health XPRize (2013-15) for the development of "pH sensor technology to affordably, accurately and efficiently measure ocean chemistry from its shallowest waters to its deepest depths" (https://www.xprize.org/prizes/ocean-health). This competition satisfied two important requirements in advancing sensor technology: (1) testing new sensors against conventional methods under varied yet appropriate conditions, and (2) focusing on commercialization as a means of ensuring widespread adoption (Okasaki et al., 2017).
- **Low(er)-cost instruments developed for vessels of opportunity:** Partnerships with commercial or other entities operating vessels have enabled very cost-effective, long-term, and continuous deployment of instruments for collecting temperature profiles (e.g. Ocean Data Network projects).
- **Open-source hardware/software development:** the "Oceanography for Everyone" initiative provides a platform for developers to share their low-cost hardware and software developments via a Github community. A prominent example is the "DIY" Open CTD, where all build guides, 3D printer files and code are provided for the user to build their own CTD at a cost of ~300 USD. Another example is the plankton imaging device "Planktoscope". Many of these instruments take advantage of recent developments in open-source electronic boards, such as Arduino and Raspberry Pi.
- **Low(er)-cost instruments for educational purposes:** Audiomoth is a low-cost, full-spectrum, underwater acoustic logger. Although not a suitable replacement for science-quality hydrophones, this device does allow for the identification of different fish and marine mammal species, presenting a wide range of potential applications, including education and outreach.
- **Low(er)-cost instruments developed for citizen science:** the Smartfin project, developed at Scripps Institution of Oceanography, brings surfers and scientists together to collect surface temperature data (and more recently wave height) using

a surfboard fin that can passively collect the data and upload it to the cloud. A versatile low-cost smartphone-based environmental analyzer (vSEA) developed at Xiamen University□ its reliability, versatility, and analytical performance have been comprehensively optimized for nutrient and pH measurement in seawater (Li et al., 2022, 2023; Zheng et al., 2022). This lab-on-smartphone can be very attractive for citizen scientists-based water quality surveys.

Annex 2. Links to other Ocean Decade Working Groups

Working Group	*Text linked to Working Group 9*
1	*'Equally crucial is the necessity to present and communicate knowledge in a format that is relevant, digestible and transferable to all ocean users (REFS). Achieving this effort should be the result of a multi-stakeholder partnership aimed at bridging the science-policy gap, thereby supporting informed decision-making to ensure long-term ocean health and sustainability. This paper outlines several strategies to meet this goal.'*
	A key aspect of this effort involves leveraging the involvement of all users/stakeholders and amplifying the voices of coastal communities, marine-dependent populations, and indigenous groups often overlooked but potentially the most affected by marine pollution.
2	*Meeting Challenge 2 depends on advances in Challenge 9. Ocean Decade Actions need to have well-defined co-design and capacity development goals and activities. Of particular importance is the development of a coordinating framework for formal education in ocean observing that focuses on the interoperability of data and information management.*
3	*Mention of access rights and capacity building to overcome overfishing and other ocean management failures.*
4	*Strong mention of:* *Accessible and comprehensive knowledge* *Equitable management of knowledge and resources for all stakeholders, including indigenous communities, and current and future generations*
5	*Some mention the need for global partnerships and interdisciplinary cooperation to contribute to global peace, security, and the advancement of SDGs, and equitable access to resources.*
6	*[draft to be written]*
7	*Some mention of general capacity development needs by facilitating knowledge exchange, developing data sharing standards, access to information, and creative funding mechanisms. [needs to be expanded]*
8	
10	

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

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

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

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

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