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INFORMATION DOCUMENT

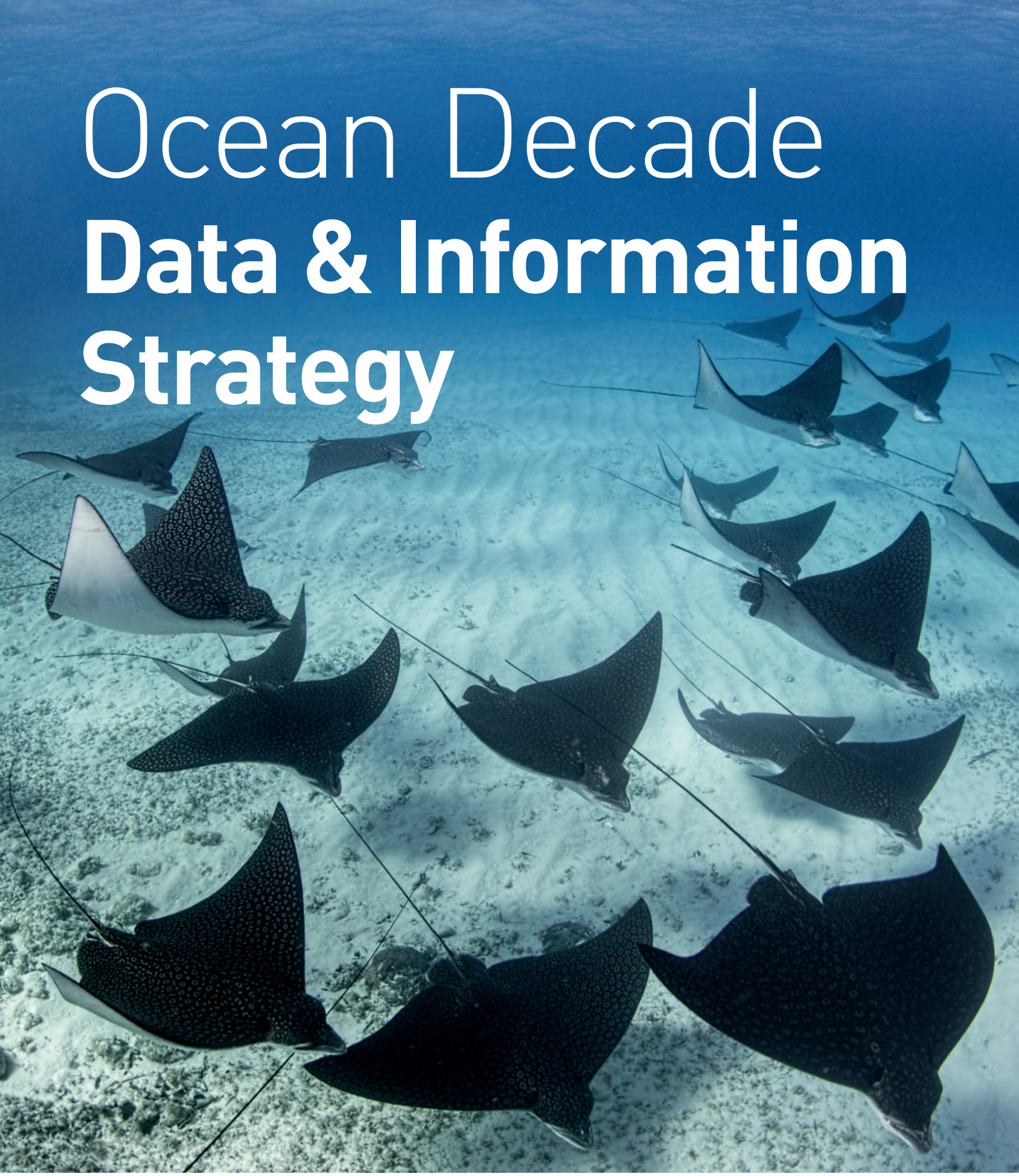
OCEAN DECADE DATA AND INFORMATION STRATEGY

Summary

This document presents the Ocean Decade Data and Information Strategy that was prepared by the Data Coordination Group, coordinated by the Decade Coordination Unit, in a participatory process between April 2022 and May 2023. The Strategy sets out the vision and mission for the creation of an interconnected ocean data and information ecosystem that is actively used for decision making to support sustainable ocean management in the context of the Ocean Decade. It identifies strategic objectives and enabling factors for Strategy success and sets out the process to transform the Strategy to an action plan for its effective operationalization. The attached document is also published in the IOC Ocean Decade Series under number 45.

The IOC's Ocean Decade Series provides 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.

Ocean Decade
Data & Information Strategy



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

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

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Table of contents

1 Context: Data and the Ocean Decade

1.1 Preamble

The United Nations Decade of Ocean Science for Sustainable Development (the 'Ocean Decade') seeks to transform humanity's relationship with the ocean, applying the full range of ocean science and knowledge to diagnose problems and generate solutions. This encompasses a wide array of data, information, and technology, including natural and social sciences, local and Indigenous knowledge, global sensor networks, community-driven research programs and citizen science.

While we are making progress with incremental improvements, we need to drive a step change in our digital capabilities; and **the Ocean Decade is the transformational opportunity**. Through the Ocean Decade, and through this strategy, we have a unique opportunity to transform the way ocean data and information are produced, shared, managed and used globally and equitably.

With the rapid development of new sensors, autonomous platforms and diverse techniques to measure and monitor the ocean, the number of data sources is growing rapidly, which is making the landscape increasingly complex. Despite the multiplication of data from diverse sources **we still have major data gaps to fill**. Common standards, increased interoperability, and enhanced partnerships are essential. The tools to manage, share and interact with our expanding range of digital resources require a similar transformation to ensure we maximise information value and its benefit to society for the investment in the observations themselves.

A note on terminology - Data, information and knowledge:

The Ocean Decade Implementation Plan refers to ocean "knowledge" as a key component of the Decade's objectives and measures of success.

With this strategy, we seek to guide the development of a digital ocean ecosystem capable of supporting the preservation and sharing of a wide array of data, knowledge and information products, while still respecting frameworks and guiding principles to grant their custodians the authority to control them. However, in this document we refer primarily to 'data and information', while frequently grouping them with other digital resources such as software and digital representations of knowledge. The terms 'data', 'information products' and 'digital knowledge' are further defined in the 'Glossary' included in the appendix of this document.

Additionally, included within the scope of this strategy, we note there are other Ocean Decade efforts focused on Indigenous and Local Knowledge (ILK) management, as well as engagement with Indigenous Peoples and Local Communities (IPLC). For example, IOC-UNESCO has drafted a concept note that defines the growing role ILK and IPLC are expected to play in the development of the Ocean Decade. See draft overview included in **Annex 1.**

In support of the Ocean Decade's work, the Data Coordination Group has been charged with developing the Data and Information Strategy described in this document, enabling the exchange of interoperable, reliable, accessible, and timely ocean data and other digital resources. Through the Ocean Decade, and through implementation of this strategy, we have a unique opportunity to transform the way ocean data and information are produced, shared, managed and used globally and equitably. We can no longer accept that valuable data and information resources necessary to

sustainably manage the oceans are stored on inaccessible, unconnected systems, invisible to science and society at a time of planetary crisis.

1.2 The Ocean Decade and the Data Coordination Group

In 2020, the United Nations General Assembly proclaimed the United Nations Decade of Ocean Science for Sustainable Development (2021-2030) ('the Ocean Decade'). During the Ocean Decade, partners around the globe will stimulate ocean science and knowledge generation to reverse declines in ocean health, while catalysing new opportunities for sustainable ocean uses, to achieve SDG14 and the 2030 Agenda.

Under the Ocean Decade Implementation Plan and its vision of '*the science we need for the ocean we want*', partners propose programmes, projects, contributions or activities for endorsement as Decade Actions. One of the criteria for endorsement is how each Action will ensure their data, information, and knowledge will be managed, shared, and made accessible.

The Ocean Decade Implementation Plan recognises that: *"Data and information will be key enablers of the Ocean Decade Outcomes. [...] Implementing a 'digital ocean ecosystem' to support the Ocean Decade will be a dynamic and continuous process, incorporating established approaches and technologies as well as those that are only just emerging."*

Acting in an advisory role, the Data Coordination Group was created to inform and guide the progress towards this digital ocean ecosystem. This Data and Information Strategy provides a vision for achieving the Ocean Decade Implementation Plan's data, information and knowledge management goals. The aim is not to create something new, but to leverage existing, infrastructures, systems and capacities. Today we have a myriad of ocean science and social projects already ongoing and underway in all parts of the world – including hundreds of Decade-endorsed Actions – each with their own datasets and interconnected to various degrees. This means that many of the required elements of a coordinated digital ocean ecosystem already exist. The strategy does not stand on its own either, but also builds on existing data strategies and policies from UN agencies such as IOC, GOOS, WMO among others, and seeks to link these into a globally comprehensive framework.

A detailed Action Plan to implement the Data and Information Strategy will be developed in 2023. It will provide a list of concrete actions to be followed to implement the strategy, building on existing initiatives and structures as much as possible. The strategy will be **implemented by the network of Ocean Decade partners**, with support from Decade Collaborative Centres and Coordination Offices, under the guidance of IOC and the Decade Coordination Unit.

2 Strategic Elements

2.1 Purpose, scope, and intended audience

An online survey conducted in August-September 2022 with more than a hundred leaders of Decade-endorsed Programmes and Projects confirmed that ocean stakeholders still face significant challenges in finding, accessing and using ocean data.

From these inputs, we determined that the purpose of the Ocean Decade Data and Information Strategy should be to orient stakeholders in the Decade to collectively address the following issues, which hinder our ability to address and overcome the Decade Challenges as a global community, while building on what already exists today:

- **Accessibility and usability of digital resources**:
  - Ocean knowledge professionals still experience considerable difficulties in submitting, finding, accessing and using existing ocean data
  - There is a lack of awareness of different data, information and other digital resources available and how to access them
  - It often remains difficult to identify and/or understand the quality and provenance of existing data and information
  - Data are rarely interoperable, hence are not easily or immediately useable between different existing oceans models, although there are notable examples in operational oceanography
- **Data and knowledge gaps**:
  - Significant gaps in ocean data remain, both by variable or data type, and in terms of spatial and temporal coverage, because the data do not exist or because they are currently held in hidden, inaccessible databases
  - There is an underappreciation of the knowledge held by diverse communities about the ocean, most of which - especially at local scale - has no digital presence
- **Resourcing and capacity**:
  - Data management planning and resourcing are not prioritised at the outset or are of insufficient quantity and quality, leading to loss or poor management of data, thus reducing the impact of investment
  - There are resource and capacity gaps to collect, curate, manage and share ocean data and information digitally, including a lack of data management trained personnel
- **Value and awareness**: there is a general lack of understanding of the socio-economic value of data and the benefits of open data sharing in a time of planetary climate crisis.

In the first instance, **the strategy and associated content in this document are intended to guide the Decade actors**: the UN Decade Advisory Board, Decade Coordination Unit, Data Coordination Offices and Centres, as well as ongoing or proposed Decade Actions. Specific guidance will be prepared for each Call for Decade Actions, depending on the Decade Challenges focus of the call, to ensure alignment of all Decade endorsed actions with the strategy (See example in **Annex 2**).

While the strategy is primarily designed and intended to serve the needs of the Ocean Decade; the transformation it aims to achieve must extend well beyond 2030. The wider and longer-term ambition of this strategy is thus to **help align the digital efforts of the wider ocean community**, including all stakeholders concerned with or dealing with data, information, software, or other digital assets for sustainable ocean management.

2.2 Vision and mission

Our vision is that by 2030, we will have:

> **A trusted, inclusive, and interconnected ocean data and information ecosystem that is actively used for decision making to support sustainable ocean management.**

This digital ecosystem must also allow for new data sources, information networks and solutions to be integrated as the Ocean Decade needs evolve (see **Annex 3** for an explanation of a digital ocean ecosystem).

Our mission to achieve the stated vision by 2030 is:

> **To catalyse a solution-oriented, global digital transformation for the digital ecosystem we need to overcome the Decade Challenges.**

2.3 Strategic objectives

To pursue our vision and accomplish our mission, we identified the following five strategic objectives, which also align with and complement the ambition set out in the Decade Implementation Plan. These objectives are interdependent: achieving one will contribute to achieving another. The Strategic Objectives are elaborated upon in Section 3:

1. **Develop an ocean digital ecosystem that encourages the sharing and equitable access of multidisciplinary data, information and knowledge by all**
2. **Improve data discovery and usability across the ocean digital ecosystem**
3. **Build trust in data and information shared across the ocean digital ecosystem**
4. **Prioritise digital solutions that support decisions for sustainable ocean management**
5. **Expand, empower, and mobilise global communities to advance and maintain the ocean digital ecosystem**

2.4 Strategy

Communities and individuals working towards the vision of a digital ocean ecosystem in support of the Ocean Decade will strive to **establish and maintain meaningful, open cooperation** across regional, economic, sectoral, cultural, disciplinary, and other divides.

This digital ecosystem will **build on what already exists**, including ongoing data strategies and existing infrastructures, while supporting new digital sources of data and information focused on the Ocean Decade's Challenges. It will guide Decade contributors towards **co-developing the global digital capacity needed** to meet the Decade Challenges and contribute to a better understanding of the ocean, by interlinking their systems, pooling their assets and resources, and coordinating their capacity development efforts to form a globally distributed ocean digital ecosystem.

While addressing their local and regional priorities in a global context, contributors will **work with the Decade's coordination bodies** – specifically the Decade Coordination Offices, Collaborative Centres and Implementing Partners – to robustly, yet flexibly, interlink their systems and pool their assets and resources to contribute to a fit-for-purpose ocean digital ecosystem.

Partners will allocate resources towards co-development of conventions which simultaneously support autonomy alongside rapid, nimble digital exchange and interoperation. Together, this partnership will collectively engineer a system capable of responding to existing, emerging, and unexpected challenges to, and opportunities for, sustainable ocean management.

To power a global digital transformation and cultural change aligned to the Decade Challenges, implementers of the Decade's digital vision will also **coordinate their capacity development efforts** to secure a globally distributed enabling environment - including aligned frameworks, infrastructure, tools, training, and other resources - to advance the growth and evolution of the ocean digital ecosystem.

In all their efforts, the implementers of the ocean digital ecosystem will focus on **creating lasting change**, with advancements capable of being reused by all and extended beyond the Decade's 2030 timeline, providing technical and human capacity for the benefit of sustainable ocean management for years to come.

The strategy house diagram below provides an at-a-glance representation of the core components of the Ocean Decade Data and Information Strategy and how they support each other.

Figure: At-a-glance depiction of the Data & Information Strategy for the Ocean Decade.

3 Description of Strategic Objectives

3.1 Objective #1 - Develop an ocean digital ecosystem that encourages sharing and equitable access of multidisciplinary data, information and knowledge by all

This first and fundamental objective involves the **identification and implementation of the specifications and resources needed** to develop a federated ocean digital ecosystem that allows users to easily find, access, use, and contribute ocean data, information and knowledge openly through multiple pathways, tailored to their needs and capacities. Users must be able to easily combine data from diverse sources, across disciplines and geographic boundaries to properly address the Ocean Decade's challenges and address priority gaps in ocean data and observations - not only through new data collection, but also by unlocking existing, inaccessible datasets.

Potential providers need the necessary support tools and **incentives to openly share their data and information**. Many sources of ocean data and information are not easily discoverable and/or accessible; some are not made available at all for a variety of reasons - from protecting cultural and economic interests to reasons of national security. The ocean digital ecosystem should be able to accommodate for these scenarios and demonstrate the value of sharing data and information.

Just as the ocean digital ecosystem needs to connect a wide array of multi-disciplinary inputs, so too must it provide access and outputs to stakeholders with **varying levels of digital infrastructure**, analytical capacity, and data literacy. Each existing or emerging user or provider of ocean data and information - including non-traditional data and information, such as local and Indigenous knowledge or citizen science - should be able to fully participate in and shape the ocean digital ecosystem. This will ensure meaningful engagement with the widest variety of stakeholder groups, and facilitate geographic representation, inclusiveness, and a balance of interests. **Investments** in digital infrastructure, human capacity, and data policies will support a more complete, robust and equitable digital ecosystem.

Key considerations for objective #1

The following elements will need to be considered to achieve this ambition and strategic objective:

1. **Specify and implement technology** underpinning the ocean digital ecosystem that will allow broad and managed participation, encompassing and adapted to diverse data types, practices, and software applications.
2. **Make data sharing and usage as frictionless as possible** by co-developing clear and effective routes to share and/or use relevant data, information, and services. Where relevant, the DCCs/DCOs should support effective participation through coordination and capacity exchange actions.
3. **Encourage and incentivise sharing**: promote mechanisms, policies and frameworks to incentivise, support and encourage participants to share their data and information:
    a. Demonstrate the value of sharing data and information to build awareness of benefits (e.g. for sustainable ocean governance, management, ocean research, and fostering socio-economic benefits, and corporate responsibility).
    b. Provide guidance, mechanisms, tools, assistance and/or relevant capacity development to facilitate effective sharing of data and information (see Section 4 on Enablers and cross-cutting issues).

c. Promote substantive recognition and incentives for high-quality data sharing across the ocean digital ecosystem - e.g. scientific credit, environmental, social and governance (ESG) incentives, etc.

4. **Identify and address priority data gaps** in data types, geographic location and spatial and temporal coverage. Implement frameworks and mechanisms to fill these gaps, through new acquisitions, as well as unlocking existing, hidden or inaccessible datasets (e.g. in the private sector, in some national jurisdictions).
5. Ensure **accessibility to all**: encourage the development of low-threshold user access points/user services that facilitate access to data, information and digital solutions (see Objective #4), adapted to global, regional or local needs.

3.2 Objective #2 - Improve data discovery and usability across the ocean digital ecosystem

Enormous amounts of ocean data, information and other digital resources are already available, and even larger amounts are being produced with the expansion of observing, analytical, and modelling capacities. These data are a vital resource to meeting the Decade's Challenges. However, it often remains difficult to discover and use relevant data and information to develop solutions and inform decision-making.

As expressed in the FAIR Principles (see **Annex 4** for description), once data and information are available and accessible online (ref. Objective #1), steps must be taken to make it easily **discoverable** (findable), openly **available** (accessible) and readily **usable** (interoperable, reusable, also machine-to-machine). To make this happen, participants in the digital ecosystem should have clearly defined internal **data management plans**, policies, procedures, and architectures for the generation, management, licensing, and sharing of data.

With the Ocean Decade, we have a unique opportunity to change the current, inefficient way of discovering, using and understanding ocean data and information. Given the proliferation of data sources, we need to transform how we think about using, managing and sharing data. In tackling the complex issues of today, datasets have limited value when analysed in isolation. Their value and potential impact multiply when used in the context of the broader data ecosystem.

> **Note on data and metadata:**
>
> Metadata refers to data about data. It does not include the data it refers to but may describe the content of the data and provide information about its usage, permissions and provenance. For example, metadata from a wave buoy could include a time and date stamp, purpose of the data collection, and location. Well-structured metadata is important for improving data findability and availability; metadata can do this while also protecting data privacy and sovereignty because it can be shared without sharing the underlying data. Data should always be provided with metadata, but some contributors may choose to provide *only* metadata to the ocean digital ecosystem. For this reason, we refer to 'data' to encompass both scenarios.

Key considerations for objective #2

Fundamentally, making data and information readily discoverable and usable across the ocean digital ecosystem requires continuous alignment and integration of both social and technological conventions across all partners. Any data system in the ecosystem should be able to pass on requests to other, independent data systems and receive actionable responses back, such that they can combine data outputs (with clear credit and provenance metadata) and give a user a meaningful response. The user should not have to go to many different portals; rather, portals should be able to discover and talk to each other to give a response wherever they are. Key strategic considerations include:

1. **Unlocking existing data:** implement actions to search and uncover existing, hidden or locked datasets in both public and private sector organisations, including citizen science data, making them openly accessible, preferably through existing local/national/regional long-term curated data repositories.

2. **Proactive data management planning**: ensure clearly defined internal plans, resources, procedures, and/or architectures for generating, managing, licensing, and sharing data and metadata from the outset.

3. **Data sharing and interoperability**: share data and metadata externally using a defined set of conventions and/or standards used in the digital ecosystem:

    a. For data that are protected, confidential, or otherwise sensitive, metadata should be shared - as far as possible - which describes data holdings without compromising privacy, security, cultural heritage, and so on (see also **Annex 4** on the CARE Principles).

    b. Licences and terms of use should be explicitly defined for all data shared in the digital ecosystem, including reference to national laws and requirements (e.g. the Creative Commons licences, the European Union's General Data Protection Regulation).

4. **Conventions and policies:** explore opportunities to develop conventions and policies to encourage more comprehensive data sharing.

5. **Machine to machine interoperability:** make data available through open-source, interoperable and community agreed machine-to-machine (M2M) protocols, such as APIs; tools and training should be developed to support this.

3.3 Objective #3 - Build trust in data and information shared across the ocean digital ecosystem

Rapid, meaningful and efficient use of ocean data and information requires trust in who generated it, how it was collected, for whom, and why.

Unless there is trust in the data and information shared and services provided, neither data contributors nor users will engage in any collective digital ecosystem. Practices must be implemented to ensure that the quality and provenance of the digital resources that users rely upon are known, and to ensure proper attribution. Similarly, systems and infrastructure to safeguard the long-term and curated archiving of data, information, software, digitised knowledge, or any other digital resource must be implemented, together with clear data policies and terms of use.

When appropriately attributed, credited and incentivised, shared data, information, software, and other tools can drive digital transformation across sectors.

Key considerations for objective #3

Key strategic considerations to successfully achieve this strategic objective include:

1. **Metadata requirements**: promote, assure and where possible enforce that data are always accompanied by metadata (as described in objective #2) that minimally includes provenance metadata describing data collection or observation and analysis methodology, quality control procedures, licence conditions and flags (even when aggregated into information products).

2. **Data and information verification and documented terms of use**: for data which cannot be released publicly (e.g. sensitive data, security constraints, etc.), there should be a metadata element to indicate that an independent third-party has verified the quality claims made by the provider.

3. **Long-term curated archival and access:** essential data sets need reliable archiving that allows for reuse over long time periods, allowing verification of analyses and application of new methods and models. This includes version control and maintained access.

4. **Data attribution**: establish mechanisms and practices to ensure data attribution (e.g. DOIs, PIDs) as data is exercised through various data flows, models and by users, as well as mechanisms for flagging and feedback from data usage.

3.4 Objective #4 - Prioritise digital solutions that support decisions for sustainable ocean management

End-users in the ocean community face a variety of questions to help them manage ocean resources more sustainably: Where should a local fisher go today? Where should a marine protected area be placed? Where should infrastructure (e.g. wind farms, resilient shorelines, deep-sea cables) be developed? Is it safe to go to the beach today? What routes should ships take to avoid cetaceans or use less fossil fuels? In all cases, good decisions must be made on accurate, reliable - and therefore trusted - data and information.

Unfortunately, existing valuable ocean (meta)data, information and knowledge are often not available to those that need them in a form that they can understand and act upon. Through careful **co-design** of digital solutions, we increase the likelihood that insights from data products and services will be relied upon to inform decision-making. The ocean digital ecosystem should be developed with the objective to support digital solutions (including metadata standards, software, models, analytics, artificial intelligence solutions, user experiences) that can be accessed and effectively used by decision makers at all levels - including politicians, businesses, scientists, and private citizens.

This will help society at large face and overcome the Ocean Decade Challenges and support local and global contributions to the Sustainable Development Agenda for 2030.

Key considerations for objective #4

Key strategic considerations to successfully achieve this strategic objective include:

1. **Develop long-term, trusted relationships** and equitable communication mechanisms between providers of digital solutions and the communities which they are intended to serve.

2. **Prioritise co-development of meaningful digital solutions** with the end-users who will rely on them for decision-making. Ensure that end-users can participate in the update and refinement of solutions that affect them.

3. **Support implementation of robust mechanisms** to bring users into the project definition from the outset; to identify and evaluate the fitness of science projects for *specific* purposes and needs, and their ability to deliver insights that are urgently needed to enhance decision making at all levels.

4. **Continuously monitor and integrate** new developments and innovations (technological, legal, societal) as appropriate to the solutions and their users.

3.5 Objective #5 - Expand, empower and mobilise digitally literate global communities, driving the culture change needed to advance and maintain the ocean digital ecosystem

The successful implementation of this strategy depends on a thriving human community that is digitally literate and committed to sharing data, information, and knowledge to co-design ocean solutions and enable ocean discoveries. The Ocean Decade provides an opportunity to effect an

enduring behavioural change towards a digitally fluent community of ocean data producers and users, who readily and openly share their data, insights and understandings.

The development of the digital ecosystem will also require specific actions to overcome existing barriers such as differing levels of capacity and access to technology and computing power. Furthermore, this objective aims to build bridges to, and relationships with non-traditional groups and data sources that may link to the ocean digital ecosystem. This will ensure that all stakeholders have the skills and can access technology needed to generate, interpret and use ocean data, information products and knowledge.

Key considerations for objective #5

The purpose of this objective in the short term is to build awareness, skills, capacities and drive alignment with the strategy as we roll it out. In the long term, in order to achieve this strategic goal, the following elements are necessary, aligned with the capacity development ambition and goals set out in the Decade Implementation Plan (ref. section 2.6 of the Implementation Plan):

1. **Ensure strategic alignment amongst those with influence in this ecosystem -** alignment with this strategy and its implementation among the Decade partners (DCCs, DCOs, Decade Actions, DCU, and others) as well as other data producers and consumers, through communication and engagement actions. Create visibility and awareness of the value of digital capacity via demonstrations and case studies.
2. **Raise digital literacy** among Decade data producers, managers and users and develop a future-ready workforce globally, through education and communication campaigns, educational resources, built into decade programmes. Re-enforce resource mobilisation, with adequate funding towards ocean data and information management skills.
3. **Increase connectivity and awareness** amongst users and producers, through workshops, targeted communication campaigns and engagement opportunities to understand needs and opportunities and ensure feedback loops between data providers, knowledge generators and consumers. Integrate expertise from social sciences and humanities disciplines to strengthen our messaging and outreach.
4. **Enable equitable access to data infrastructure and digital resources.** Prioritise Decade Actions which ensure equitable access to data, physical infrastructure, technology and computing resources. Support the development of systems, tools and interfaces to broaden access to data for those with various levels of technical capability and resources, starting where they are most needed, making the provision of data as frictionless as possible.
5. **Incentivise, regulate and reward data sharing and re-use for existing and new data,** to effect a culture change where sharing ocean data is recognised as essential to society and becomes ingrained in all ocean-related activities and communities through a combination of incentives and regulations.

4 Strategy Enablers

We identified the following critical enablers that cut across all strategic objectives and are considered key components to successfully implement the strategy.

1. Technological innovation
2. Partnerships
3. Sustained resourcing
4. Policy and regulatory frameworks

4.1 Technological innovation

The Ocean Decade's data, information and knowledge management ambitions require significant enhancement of digital infrastructure, filling major data gaps, and developing common technologies and approaches that enable interoperable data and information sharing and access. This will be a **dynamic and continuous process,** incorporating established approaches and both existing and new technologies as they emerge. Innovations across the ocean knowledge value chain will contribute to this process but will require steering and commitment towards key information technology goals that support all Ocean Decade Challenges and data strategy objectives.

This includes ensuring that the information technology development and investments are developed in flexible and adaptable frameworks, using open-source solutions, to **ensure equitable and sustainable technology sharing** and cost effectiveness. Technology advancements and new innovation should be monitored and integrated as appropriate. This strategy recommends the following considerations for aligning technological innovations with the Ocean Decade's data and information priorities:

- Establish mechanisms to identify, support and adopt technology developments that advance the strategic objectives, for example through specific Calls for Decade Actions
- Encourage innovative approaches for modular, scalable and flexible 'future ready' solutions
- Implement technology, incentives, education, and novel approaches to broaden access and participation

4.2 Partnerships

The Ocean Decade framework provides opportunities to create new collaborations across disciplines, geographies, political, and data boundaries, as well as opportunities to access new sources of support and develop collaborative mindsets. Indeed, to achieve the objectives of this Data and Information Strategy, we need to **establish vibrant, mutually beneficial partnerships** that will cover various needs in terms of funding, in-kind resources, access to networks and expertise, and enhanced collaboration between data providers, data managers, knowledge generators and consumers across the ocean knowledge value chain.

If done successfully, such novel partnerships will also help to drive change in digital culture to support broad data literacy and understanding of the importance and benefits of data stewardship and sharing. The ocean science community is not unique in its data challenges and knowledge requirements; engagement with other sectors and exchanging lessons learned is critical to developing a successful approach for the ocean digital ecosystem.

In seeking and developing partnerships, we will therefore have to consider and address the following key aspects:

- Partnering between the public, academic, and private sector around data sharing initiatives
- Strengthen partnerships and connections between evolving decade structures with a strong data and information component
- Strengthen government partnerships that align on digital ecosystem objectives, fostering partnerships with federal, state and local governments
- Strengthen regional partnerships, alliances and networks by connecting and empowering existing platforms and services with complementary capabilities to enrich the offer and reduce costs
- Establish new partnerships that increase collaboration with Indigenous peoples and local communities (IPLC).

4.3 Sustained resourcing

Sustained, **long-term resource mobilisation** to establish and maintain the various components of the ocean digital ecosystem will be essential to ensure the successful implementation of this strategy. To be successful, the paradigm for funding data management needs to change. Traditionally, data management has been funded as part of science projects, which limits the higher-level data management efforts required to truly improve interoperability. These efforts, which are best done by data science domain experts, deserve their own sustained funding streams that both provide basic data and information management within the scope of the project and also support sharing infrastructures and services connecting each project to the greater ocean digital ecosystem. **A shift is needed towards 'data-first' resource mobilisation**, i.e. not as an add-on for science projects, but to provide the baseline digital capacity for all.

Resource mobilisation actions and plans will therefore have to consider and address the following key aspects:

- Build awareness among funders of the critical nature of underlying infrastructure
- Mobilise political commitment and long-term, sustainable funding for stable and trusted open data sources and repositories
- Establish guidance and set requirements for each endorsed project/program to include appropriate resources for data and information management and sharing
- Request that funders support peer review and publishing of datasets or establishment of citable DOIs for ongoing, long-term monitoring datasets
- Develop mechanisms and provide financial support for 'retiring' data at the end of the project, making sure it is safely stored and remains accessible
- Sustained funding does not generate new silos and instead creates continuous integration.

4.4 Policy & Regulatory Frameworks

The flow of data and information across the ocean digital ecosystem spans multiple regulatory and policy frameworks, which may both help and hinder collaborative action towards the Decade's Challenges. The successful implementation of the Decade's data strategy will therefore be positively influenced by **promoting national, regional and international policies and frameworks** that advocate for free and open sharing of data and information and, where possible, **removing policy and/or regulatory frameworks which impose barriers**, while allowing for recognition of data ownership and institutional sources.

Actions to establish policies and regulatory frameworks should therefore consider and address at least the following key aspects:

- Promote policies that encourage and incentivize the sharing of data and information and establish regulations that enforce those policies
- Communicate on successful case studies that demonstrate the value of data sharing
- Leverage existing regulatory frameworks
- Incentivise the publication of data and information
- Consider aspects related to privacy laws (e.g. GDPR), as well as intellectual property law

5 Addressing the Decade Challenges

This strategy must be mission driven, enhancing our ability to address the Ocean Decade Challenges. For each Challenge, we must understand the key questions that users need answered, and their associated data and information needs to support development of sustainable ocean management solutions. Understanding this will also help validate that the strategy serves to address and overcome the Decade Challenges (see **Annex 5** for a detailed definition of all ten Decade Challenges).

Consultation with Decade Challenge subject-matter experts

To ensure that the data and information strategy serves the needs of the Ocean Decade community in addressing the Challenges, there is a need to conduct an in-depth assessment for each Challenge through a consultation process with relevant Decade subject matter experts and partners.

This assessment will be conducted as part of a broader ambition setting process for the Ocean Decade Challenges**,** known as the **Vision 2030 initiative,** which will be led by the Decade Coordination Unit and will involve the Data Strategy Implementation Group, which will be set up in May 2023. Vision 2030 will consult subject-matter experts and stakeholders involved in Decade Actions to obtain clear understanding of the following items for each of the 10 Challenges:

- What are the key questions to address for this Challenge?
- What are the priority data types, information products and/or insights required to answer these questions and tackle this Challenge?
- What are the capacity and resourcing needs? (i.e. infrastructure, people, etc.)
- How will the implementation of this strategy impact the community's ability to overcome the Challenge?

Early inputs inform strategic vision

Inputs gathered to date with global ocean data specialists, as well as through an online survey conducted with more than a hundred Decade Programme and Project leaders in August-September 2022, helped inform how the strategy should impact our collective ability to address the Decade Challenges.

From these early inputs, the Decade Coordination Unit established guidance for proponents of Decade Actions that was first published in October 2022, for the 4th Call for Decade Actions. These guidelines represent a first tangible step towards implementing the strategy (**Annex 2**).

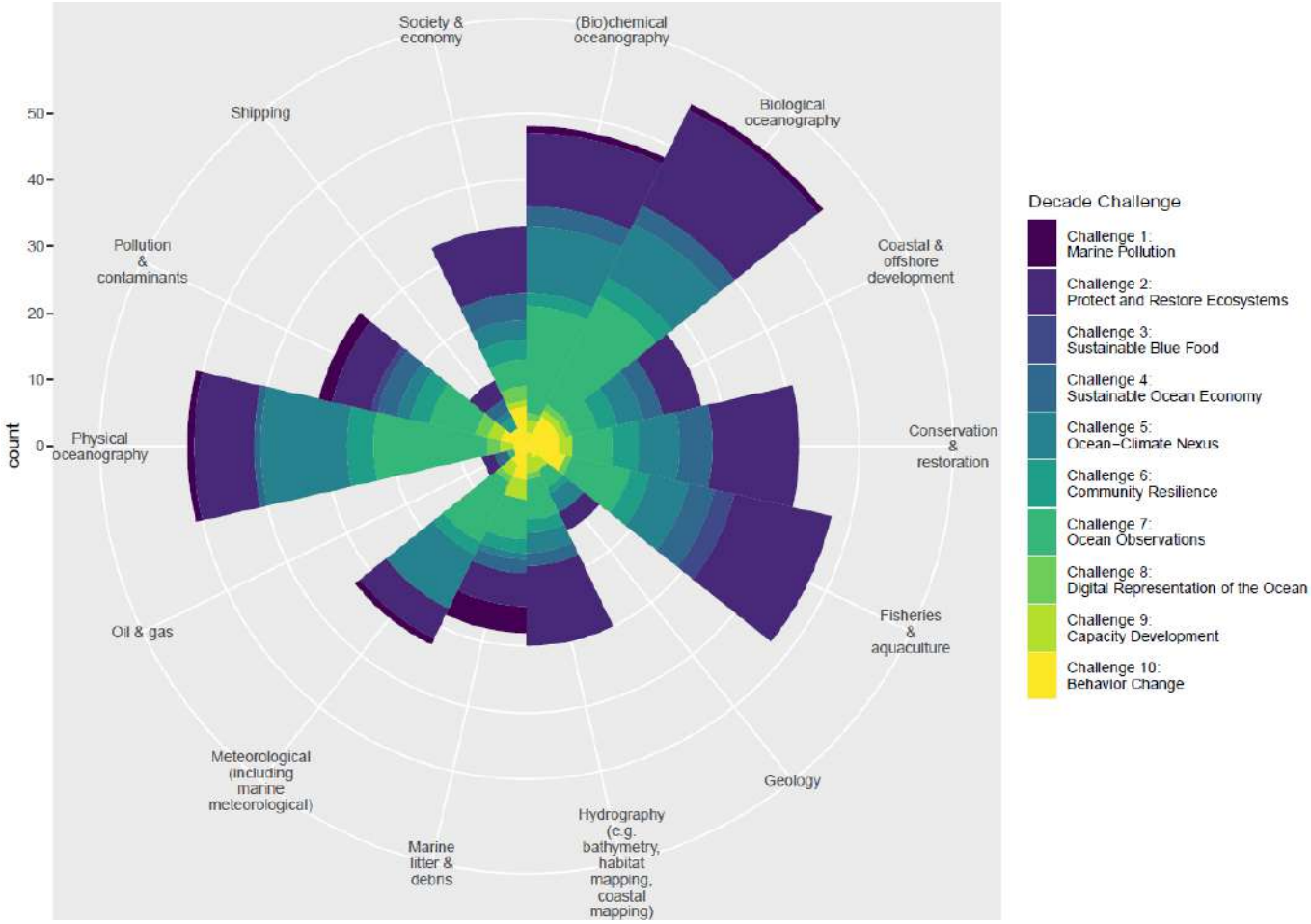
Aside from the need to develop a data ecosystem that delivers findable, accessible, interoperable and reusable ocean data of trusted quality, respondents also pointed to the need for the strategy to enable a culture change that will uplift data to be a first-grade research output to encourage timely data sharing - even influencing national data policies to make more ocean data openly accessible.

The survey also highlighted the need for the strategy to help **fill ocean data and information gaps** that have been identified in specific thematic Ocean Decade Challenges - from pollution, to biodiversity, to fisheries and climate change. The strategy should provide an enabling environment for the collection and observation of new data on essential ocean variables (EOV), or the discovery and unlocking of existing, hidden data that are of critical importance to overcoming the Decade Challenges. These datasets may cover temporal and spatial gaps, in particular data-sparse geographic areas, such as:

- Open ocean, specifically beyond national jurisdictions
- High latitudes, including the Southern Ocean

- Deep ocean, including seabed mapping
- Data-sparse continental coastal areas, particularly around Small Island Developing States (SIDS)
- Existing and future marine protected areas

The online survey provided early insights on the data needs and priorities. This is illustrated in the graph below, which shows the number of responses per data type used or required per Decade Challenge, based on responses from leaders of Decade endorsed Actions.



Capacity gaps in terms of infrastructure, access to internet, cloud storage, data security protocols and trained personnel are also critical elements and should be prioritised through the implementation of the strategy. The strategy should facilitate the mobilisation of funding and in-kind resources to support these infrastructure and training requirements.

The Ocean Decade data and information strategy should help avoid duplication of effort, to optimise resources where they are most needed. Decade Collaborative Centres (DCCs) and Decade Coordinating Offices (DCOs) will play an important coordinating role across Actions, Challenges and geographic regions to achieve this.

6 Implementing the Strategy

Successful implementation of the Ocean Decade and Data Strategy will require an iterative process of planning, execution, monitoring, review and revision at increasing levels of detail according to evolving needs as the Decade progresses and new insights are gained. To initiate this process, an

implementation group will be set up to work out a more detailed plan with guidance on the actions and steps needed to implement the strategy. This plan will need to consider the following elements, among others:

- Roll-out and communications
- Steps to implement the strategic objectives, with timeline and key milestones
- Resourcing and infrastructure needs
- Monitoring and reporting progress

Roll-out and Communications

The establishment and maintenance of the digital ecosystem will require dedicated communication and engagement to ensure continued involvement of, and support from all Decade partners. A communications task force with Data Coordination Group members, selected DCC and DCO leaders, and IOC communications experts will be convened to develop a communication plan with the following goals and desired outcomes:

- Raise awareness of the importance of data and information among Decade partners and participants
- Encourage buy-in for this strategy to ensure alignment
- Maintain engagement by promoting benefits, achievements and success stories
- Report on strategy implementation progress to Decade.

Steps to implement the strategic objectives

While this strategy document defines the initial high-level strategy and required enablers, a detailed Action Plan will be developed in the first half of 2023 that provides the roadmap with clear actions and instruction for successfully achieving the 2030 vision.

The Action Plan must also establish a review mechanism to update this Strategy as the Ocean Decade evolves and as new scientific insights and innovative technologies emerge.

In Q1 2023, the Data Coordination Group will convene a 'Data Strategy Implementation Group' through an open call for candidates. The goal is to form a group of up to fifteen ocean data experts that have both a strong technical understanding of digital data and information management, as well as experience managing implementation plans for new organisational and/or business processes, such as enterprise software rollouts. It will also include experts from social sciences and humanities backgrounds.

Resourcing and infrastructure needs

Once set up, the Technical Implementation Group will conduct a gap analysis to assess:

- What are the critical ocean datasets and information products needed to address the Decade Challenges?
- What are the data gaps in terms of ocean variables, data types, and spatial and temporal coverage?
- What are the gaps in terms of digital infrastructure required to achieve the distributed digital ecosystem proposed in this strategy?

- What the human capacity gaps, in terms of data literacy and digital capacity.

From this assessment, the Group will provide recommendations on the resourcing required to fill those gaps and use mechanisms such as targeted Calls for Decade Actions to mobilise additional partnerships and resources.

Monitoring and reporting progress

As with any strategy, it is essential to monitor progress and report on successes and lessons learned. The Action Plan will establish a set of Key Performance Indicators (KPI) that will be **integrated into the Ocean Decade Monitoring and Evaluation Framework** and allow us to track and report progress objectively and adjust the plan accordingly.

Among other considerations, monitoring of the Action Plan implementation should consider the following elements:

- Perform regular diagnostics, in addition to KPI tracking, to assess usage of the digital ocean ecosystem
- Ensure that digital capacities are properly coordinated (via DCCs and DCOs) and data and information flows are actively used and maintained.
- Ensure the digital ocean ecosystem is adapting towards the evolving needs of the Decade and the Challenges.

Glossary of Terms & Useful Links

Term	Gloss / Definition	Source	Comment
CARE Principles	Collective Benefit / Authority to Control / Responsibility / Ethics A set of data principles which, together with their sub-principles, provide guidance on how data and digital systems can address tension that Indigenous communities feel between (1) protecting Indigenous rights and interests in Indigenous data (including traditional knowledges) and (2) supporting open data, machine learning, broad data sharing, and big data initiatives.	CARE Principles	
Data	A set of values, symbols or signs (recorded on any type of medium) that represent one or more properties of an entity. For example, the numbers generated by a sensor, values derived from a model or analysis, text entered into a survey or the raw text of a document.	UN Ocean Decade Implementation Plan	
DCC	Decade Collaborative Centre, entity set up to coordinate Decade Actions having a primary focus on a particular challenge, theme or geographic area	UN Ocean Decade Implementation Plan	
DCO	Decade Coordination Office, entity emanating from a UN agency and set up to coordinate Decade Actions having a primary focus on a particular challenge, theme or geographic area	UN Ocean Decade Implementation Plan	
Digital knowledge	Knowledge that has been encoded in a machine-readable and actionable form. With Knowledge defined as: An abstract representation (i.e. a mental model) of an entity which: (i) is constructed from a substantial collection of information; (ii) grants its bearer reliable familiarity with that entity; and (iii) can be used to reason and take action about that entity. For example, an expert with knowledge about the salinity range of the Arctic Ocean (constructed from large amounts of information on the topic) would be able to reason that a salinity value of 43% is a likely error, rather than a real measurement.	UN Ocean Decade Implementation Plan	
Digital ecosystem	A **digital ecosystem** is a distributed, adaptive, open socio-technical system with properties of self-organisation, scalability and sustainability inspired from natural ecosystems.	https://en.wikipedia.org/wiki/Digital_ecosystem	

Term	Gloss / Definition	Source	Comment
FAIR Principles	Findability, Accessibility, Interoperability, Reusability A set of data principles which, together with their sub-principles, provide guidance on how data and digital systems can behave in a more collaborative way in networked systems.		
Information products	Products derived from data that lead to a greater understanding of an entity. For example, (i) the interpretation of a range of data from an array of conductivity sensors across the Arctic Ocean that informs us about that ocean's salinity range; or (ii) the narrative text of a report on harmful algal blooms that informs the reader on the timing of these blooms.	UN Ocean Decade Implementation Plan	
Principles	Basic assumptions, rules, or recommendations guiding behaviour.		
Interoperability (sensu FAIR)	The potential of agents to work together by referencing a digitised language of knowledge representation that follows the FAIR principles.		adapted from the gloss field in the Helmholtz Digitisation Ontology, drawing from: doi.org go-fair.org
Interoperability	The potential of two different agents - human or machine - to work together.		adapted from the gloss field in the Helmholtz Digitisation Ontology, drawing from: merriam-webster.com OBO Foundary WordNet
Value chain	A **value chain** is a set of activities that a firm operating in a specific industry performs in order to deliver a valuable product (i.e., good and/or service) to the end customer.	https://en.wikipedia.org/wiki/Value_chain	There are many value chains in operation. Thus, there is no single "ocean value chain" which serves all

Term	Gloss / Definition	Source	Comment
			stakeholders.

Other Useful Links

- The UN Ocean Decade website – www.oceandecade.org
- The UN Ocean Decade Implementation Plan
- IOC Oceanographic Data Exchange Policy (2019) - http://www.iode.org/policy
- Essential ocean variables, definitions and specifications (GOOS) - http://goosocean.org/eov
- OceanOPS integrated information, maps and tools on global ocean observation efforts - https://www.ocean-ops.org/board
- IOC Ocean Data and Information System (ODIS) - http://www.odis.org
- Ocean best practices - https://www.oceanbestpractices.org
- FAIR digital data principles - https://www.go-fair.org/fair-principles/
- TRUST principles (data repositories) - https://www.nature.com/articles/s41597-020-0486-7
- CARE principles for indigenous data governance - https://www.gida-global.org/care

ANNEX 1: Embracing Indigenous Local Knowledge in the Ocean Decade – Overview

unesco
Intergovernmental Oceanographic Commission

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

OVERVIEW

Embracing Indigenous and Local Knowledge in the United Nations Decade of Ocean Science for Sustainable Development

[VER. 28.04.2022]

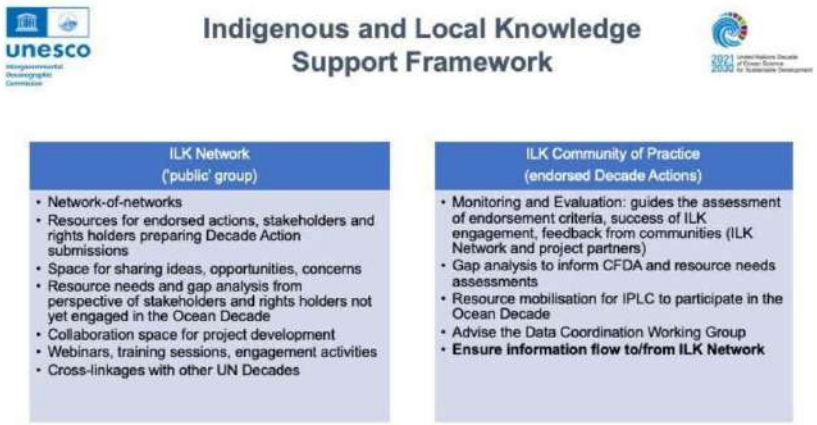
Purpose

The Ocean Decade Implementation Plan emphasizes that indigenous and local knowledge (ILK) is an integral part of the co-designed ocean science that the Decade aims to deliver. Therefore, it is important that the Ocean Decade establishes an enabling environment and framework for ethical engagement and equitable capacity exchange with indigenous peoples and local communities (IPLC), where different knowledge systems can be woven together and be respected equally valid. The Ocean Decade ILK framework will make use of the tools currently available to support the Ocean Decade ILK initiatives and encourage all Ocean Decade participants and partners to do so. This will occur through two distinct but complementary structures: the ILK Network and the ILK Community of Practice, both housed on the Ocean Decade Global Stakeholder Forum platform. A soft launch of this process will occur throughout 2022, with an official launch proposed at IMPAC5 in February 2023. Resources are being identified to support full time coordination of the network. Further details are provided in the Concept Note.

Guiding Principles

The Ocean Decade is committed to an ethical approach for working with IPLC through establishing the following guiding principles:

1. **Free, Prior, and Informed Consent (FPIC):** To ensure that ILK is shared in a non-extractive and respectful way, the Ocean Decade will firmly adhere to the FPIC principle when it comes to working with knowledge holders and rights holders.
2. **Adherence to FAIR and CARE data practices:** The FAIR (findable, accessible, interoperable and reusable) and CARE Principles for Indigenous Data Governance (collective benefit, authority to control, responsibility and ethics) should be respected. Operationalizing the CARE principles contributes to the self-determination, rights, and innovation of IPLC.
3. **Co-design, co-production, and co-dissemination:** The Ocean Decade promotes the development of co-designed and co-delivered ocean science that encourages IPLC involvement, for relevant Decade Actions, through each phase of the project.
4. **Inclusive capacity exchange and benefit to IPLC:** Capacity exchange reflects the need to ensure that IPLC contributing to the Ocean Decade experience the benefit from it. The Ocean Decade capacity development efforts will also focus on supporting the Global South, including Small Island Developing States, in addition to ensuring gender and intergenerational equity.
5. **Minimizing duplication of efforts:** The Ocean Decade pays particular attention to ensuring that IPLC representatives are not overburdened by the various demands coming from multiple ocean science stakeholders. Therefore, all Ocean Decade participants are encouraged to join their requests and work together, where possible, to limit duplication of engagement efforts.
6. **Accountability:** The Ocean Decade is committed to establishing mechanisms to deliver on its promises to embrace ILK. This will occur through the Monitoring and Evaluation process, resource mobilization, gap analyses, and facilitating entry points into the Ocean Decade framework.



For more information or questions, please contact:
Chelsea Koch, Decade Coordination Unit, c.koch@unesco.org

ANNEX 2: Data & Information Guidelines for Call for Decade Actions

Principles for all submissions to a Call for Decade Actions

Scope and framework

This document has been developed to help proponents of all future Decade Actions (including Decade programmes and projects) prepare submissions.

is relevant both: (i) as a set of guiding principles relevant to all Decade Actions (programmes and projects) being submitted to the Call for Decade Actions No. 04/2022 and; (ii) to provide specific guidance to proponents of future data-focused Decade programmes that could specifically contribute to Ocean Decade Challenge No. 8 – Digital representation of the ocean.

It aims to ensure that future Decade Actions address the common issues that the Ocean Decade Data & Information Strategy is trying to address including:

- Difficulties in submitting, finding, accessing and using existing ocean data
- Difficulties in identifying and understanding the quality and provenance of existing ocean data and information
- Significant gaps in ocean data, both by variable or data type, and spatio-temporally
- Data are rarely interoperable, hence are not easily or immediately useable, for example into existing oceans models
- Data management plans are often not prioritised at the outset or are of insufficient quality, leading to loss or poor management of data.

Requests for endorsement of Decade Actions will be evaluated in line with the Decade endorsement criteria contained in the Implementation Plan. Amongst these criteria is the need for proponents to demonstrate alignment with the following criterion:

> 'Ensure that all data and resulting knowledge are provided in an open access, shared, discoverable manner in accordance with the provisions of UNCLOS and are appropriately deposited in recognised data repositories consistent with the IOC Oceanographic Data Exchange Policy or the relevant UN subordinate body data policy.'

Specifically, this guideline aims to provide additional practical guidance to support proponents to align with this evaluation criterion.

With the Ocean Decade, we have a unique opportunity to change the current, inefficient way of discovering, using and understanding data and information. We can no longer accept that existing and newly collected data and information are stored on inaccessible, unconnected systems, invisible to science and society at a time of planetary crisis.

By applying the guidelines outlined in this document, Decade Actions can participate in a global movement to greatly improve the way we search, find and use ocean data. This will allow the scientific community to focus more time and effort on the actual science and applications - and allowing us collectively to work towards the digital ecosystem we need.

Findable, accessible, interoperable and reusable ocean data of trusted quality

Decade Actions should establish data management processes that align with the strategy referenced in section 1. Where possible, submissions for proposed Actions should include a draft data management plan that addresses the following questions:

- What types of data and information products the Action will generate, and whether the source data will come from existing databases or will be newly collected or observed?
- How the 2019 IOC Oceanographic Data Exchange Policy[1] will be applied and, in general, how FAIR (Findability, Accessibility, Interoperability, and Reusability) and TRUST (Transparency, Responsibility, User focus, Sustainability and Technology) principles will be adhered to.
- How CARE (Collective Benefit, Authority to Control, Responsibility, Ethics) data stewardship and sovereignty principles shall be applied to Indigenous and local knowledge - e.g. sharing the existence of the data but not the data itself.
- What data and metadata standards will be used to ensure interoperability and to provide visibility and transparency on the data quality? For example, by following ISO/TS 19115-3 specifications and the latest version of the Climate Forecast Metadata Conventions, ensuring the relevant fields are populated. *Note: IOC-UNESCO can provide support with recommended data and metadata standards, if required.*
- What discovery and data access services will be provided for users, including, for example any registration requirements?
- How your proposed Action will ensure and secure the quality of the data and information products generated.

Where a proponent cannot provide a draft data management plan at the time of submission, this plan will likely be requested either as supplementary information during the review process or as a condition of endorsement. Proponents are therefore strongly encouraged to consider the above issues from the outset of development of their future Decade Actions.

Further details and guidelines on developing a data management plan are included, among others, in the 'Manuals & Guides 73 - Guidelines for a Data Management Plan' document published by IOC-UNESCO in 2016. Several regional and national programmes also provide guidance on how to develop and implement a data management plan.

Addressing the entire value chain, from observations to end-user applications

Proposed Actions should articulate how it addresses the Decade Challenges and the specific element(s) of the value chain that it applies to, from the initial ocean observations to the end-user's application. We therefore encourage initiatives that address the following:

- How the Action will deliver information products and/or applications and solutions through data processing, modelling and prediction, among others.
- Which end-users (i.e. decision makers, policy makers, local and Indigenous communities, etc.) and what decision-making processes the Actions' expected outcomes will support.
- How the Action supports inter-disciplinary and/or cross-regional applications, including use of non-oceanic data, such as socio-economic data.

Data gaps to be addressed

Proposed Actions should address data and information gaps that have been identified in the specific value chain and end-user knowledge requirements they are addressing.

[1] This data policy is currently being revised and will be submitted for adoption to the IOC Assembly in June 2023.

We also encourage submissions that will propose collection, discovery, or optimisation for usability of data on essential ocean variables (EOV) in certain underrepresented, data-sparse geographic areas, such as:

- Small Island Developing States (SIDS), across their entire EEZ
- Open ocean, specifically beyond national jurisdictions
- Southern Ocean
- High latitudes
- Deep ocean, including seabed mapping
- Underrepresented continental coastal areas
- Existing and future marine protected areas, including marine World Heritage Sites

Existing data frameworks & infrastructure

The Ocean Decade seeks to avoid duplication of effort and to optimise resources where they are most needed.

Proposed Actions should focus on complementing existing data and infrastructure and therefore should assess what existing infrastructure, platforms and systems can be leveraged, before developing new ones.

Submissions should describe:

- How the Actions' resulting quality-controlled data and information products will connect to existing, open and free national and international data systems - to make the data discoverable, openly retrievable and quality controlled.
- At the national level, preference should be given to using data centres linked to the IOC Ocean Data and Information System (ODIS) as repositories for oceanographic data and associated metadata.

For further guidance on where and how to connect to existing data platforms and systems, please contact the Decade Coordination Unit at oceandecade@unesco.org.

Resourcing & capacity development

The Ocean Decade is committed to both advancing the generation and application of ocean observations and data, as well as the expansion of capacity.

Applying the recommendations set out in this document requires the investment of significant resources, including staff time and computing resources that are often overlooked or underestimated.

We encourage submissions that:

- Demonstrate what resources will be dedicated to data management within the context of your Action.
- Foster capacity development for ocean data management and data literacy, including in SIDS and LDCs

In addition, we encourage submissions that provide education on data acquisition, processing and management - to educate users about what data and data systems exist, where and how to find and retrieve data, and how to use it.

ANNEX 3: Digital Ecosystems and Value Chains

Foundational components of a digital ocean ecosystem

A digital ecosystem is a complex system-of-systems, where technology and human communities interact in a wide and often unexpected variety of ways. When many such systems, originating in independent organisations or projects, begin to interact and form a larger, more open digital ecosystem, new behaviours emerge and the system's properties become defined by bottom-up, organic processes.

The collective digital ocean ecosystem that will advance and persist beyond the Ocean Decade is already emerging, with highly diverse initiatives exploring how to bridge digital divides and interoperate (i.e. work together) to meet - and overcome - the Decade's Challenges.

This strategic document intends to promote such activity, while ensuring all partners - across a wide range of digital capacity - can participate equitably and find value in this ecosystem. In doing so, we avoid being prescriptive, but provide a set of principles which will support collaborative implementations and continuous digital exchange.

We have identified several key components of the ocean digital ecosystem, noted below. The strategic considerations in this document have relevance across all of these components. However, implementation of these components and the strategy itself may vary.

Key components:

- Observation and data generation
    - Vast amounts of new ocean data and information are being generated each hour by observing systems
- Data management and sharing
- Data analytics, modelling and prediction
- End-user delivery and application

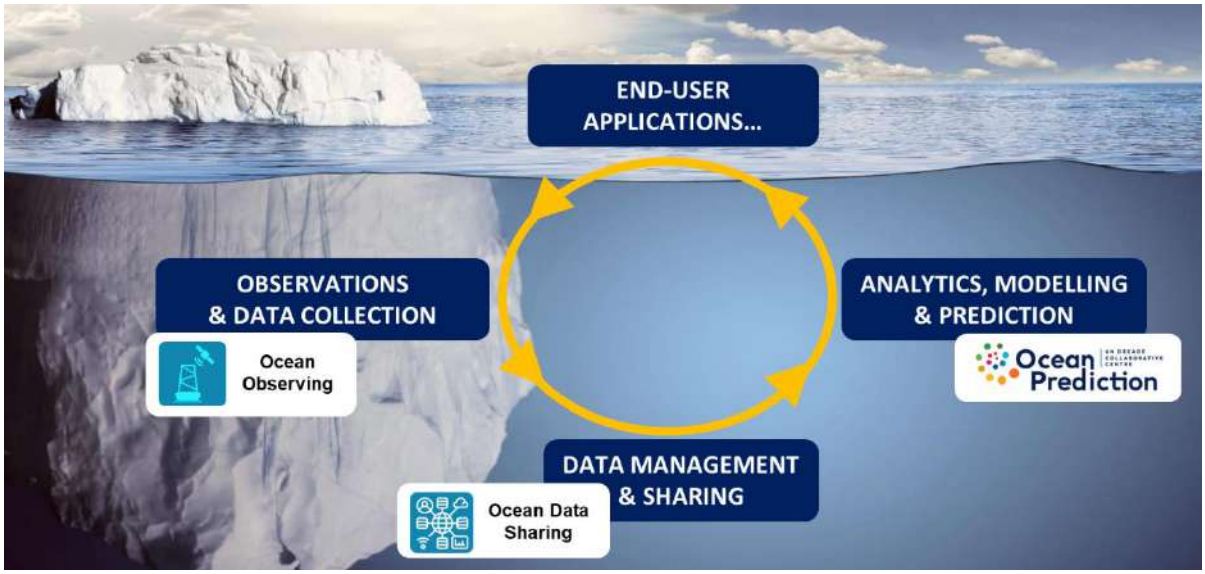


Fig: Foundational components of the ocean digital ecosystem. Digital Coordination Offices (DCO) for Ocean Observing and Data Sharing, as well as the OceanPrediction Decade Collaborative Centre (DCC), will work together to coordinate the research and support implementation of this strategy.

Digital value chains

Data, information, software, and other digital resources flow through many processes which change their form, meaning, and capabilities. During this journey, these resources have different value to different users: for example, while a traffic-light code for water quality provides high value to beach managers, the underlying, raw data about chemical concentrations and the presence of microbial species is of higher value to a scientist or an environmental monitoring agency. Among that data, a single, derived estimate of pathogen load may be of the highest value to a modeller during data assimilation.

To build an inclusive ocean digital ecosystem which delivers value to all, we must - collectively - **create and preserve digital supply chains** which reliably deliver data users value as our digital ecosystem grows and changes.

A **value chain** is a conceptual model which assists organisations understand how their activities interact to deliver value to its customers and/or stakeholders. The diversity of organisations and stakeholders in the ocean digital ecosystem will bring together many value chains, often embedded within different value systems.

In implementing the strategy outlined in this document, we recognise the need to support participants in the ocean digital ecosystem express and share what data and digital products they value, such that all can more rapidly and inclusively understand how the ecosystem serves different users.

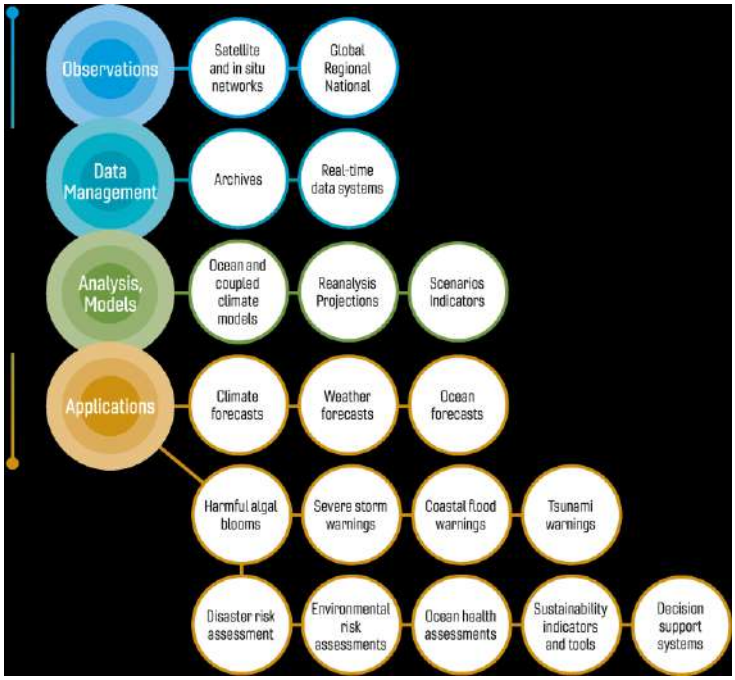


Figure A2.1: An illustration of how data and information flows through different processes, extracting insights that deliver differing value to different stakeholders. Where a given state of data (or digital assets like software) lies on a user's value chain depends on their priorities, objectives, and capacities.

ANNEX 4: FAIR and CARE Principles

The FAIR and CARE Principles provide high-level guidance on designing performant, interlinked, and ethical digital strategies and systems. However, the interpretations of these principles can vary widely, to the extent that 1) entirely FAIR-compliant systems are unaware of one another and unable to interoperate and/or 2) CARE-compliant systems have conflicting notions of ethical norms.

The FAIR Principles in the Ocean Decade

Findability

F1. (Meta)data are assigned a globally unique and persistent identifier

F2. Data are described with rich metadata (defined by R1 below)

F3. Metadata clearly and explicitly include the identifier of the data they describe

F4. (Meta)data are registered or indexed in a searchable resource

The Findability principle and its sub-principles are centred on unambiguous and efficient discovery of data by a community. The interpretation of sub-principles F1, F3, and F4 is primarily technical and straightforward. However, sub-principle F2 needs global alignment across multiple sectors and communities.

Regarding the former set of sub-principles, the key recommendation is the use of referenceable, globally unique, and persistent identifiers for digital assets. This technical requirement is well met by many ocean data systems, and capacities can be readily transferred and developed where needed given resourcing.

Sub-principle F2 must be approached with clear requirements from each FAIR implementation network, including that of the Ocean Decade. The "richness" of (meta)data must be determined against a set of competency questions agreed upon by a community of practice and its sub-communities. The Ocean Decade community must define a collective notion of "rich metadata" to address the Decade challenges. This is a formidable task, wherein input from the entire breadth of the ocean community must be synthesised and operationalised such that all can find what they are looking for, even if stored in systems they have never heard about.

Accessibility

A1. (Meta)data are retrievable by their identifier using a standardised communications protocol

A1.1 The protocol is open, free, and universally implementable

A1.2 The protocol allows for an authentication and authorisation procedure, where necessary

A2. Metadata are accessible, even when the data are no longer available

Satisfying the Accessibility principle is also largely a technical issue, which many web-enabled data systems are well-poised to fulfil. Virtually all such systems will use the Transmission Control

Protocol/Internet Protocol (TCP/IP) suite. If alternative systems are used, these must be well-documented and logged by the DCO.

However, the requirement that access is mediated through a dereferenceable, persistent, and globally unique identifier (F1) must be underscored: simply hosting data on the web is not sufficient for accessibility.

Further, many digital strategies neglect compliance to A2: metadata which pertains to data which has been deleted, superseded or otherwise lost (e.g. intermediate files generated during an analysis, temporary data, sensitive data, retired data) is rarely stored or shared. This can be detrimental to processes such as scientific reproducibility and provenance tracing, limiting trust and verification. The Ocean Decade communities and Actions building or using digital systems must carefully consider this sub-principle in their strategies and data management plans.

Finally, we must recognise that not all ocean communities will wish to host their data on the web. This will preclude them from identifying their data systems as FAIR-compliant, and other forms of access control must be explored and developed to build equity for a Transparent and Accessible Ocean.

Interoperability

I1. (Meta)data use a formal, accessible, shared, and broadly applicable language for knowledge representation.

I2. (Meta)data use vocabularies that follow FAIR principles

I3. (Meta)data include qualified references to other (meta)data

Arguably the most challenging of the FAIR principles, particular attention must be paid to securing, demonstrating, maintaining, and developing semantic interoperability between *independent* data systems participating in the Ocean Decade.

As noted in I1, interoperability hinges on using broadly applied knowledge representation languages. In the ocean community, these are dominated by vocabularies, glossaries, and thesauri with low-to-moderate expressivity, dubious semantic/logical rigour (limiting reasoning and automated inference), and varying compliance to I2. Regional, disciplinary, and sectoral variation is high, and the community lacks widespread expertise in knowledge representation to build coordinated strategies. A focused drive to align, harmonise, and enhance semantic interoperability is sorely needed. Further, ensuring interoperability between the knowledge representation languages used in the ocean community with those used in others (e.g. the biomedical community, the broader Earth and environment community)

Regarding I3, much of the ocean community does not use qualified references between their (meta)data, certainly not in a machine-readable and -actionable way. Consensus on these qualified references is essential to cross-system interoperability. Where the same qualification schemes cannot be agreed upon, authoritative mappings to readily convert between them must be maintained and highly visible.

While this principle focuses on semantic interoperability, the Ocean Decade's digital ecosystem - in order to evolve into a data space - must also aim for lower-level interoperability. That is, independent systems must be able to coordinate their actions based on the exchange of compatible serialisations and encodings of data and information products.

Reusability

R1. (Meta)data are richly described with a plurality of accurate and relevant attributes

R1.1. (Meta)data are released with a clear and accessible data usage license

R1.2. (Meta)data are associated with detailed provenance

R1.3. (Meta)data meet domain-relevant community standards

As noted in the section on Findability, the key strategic consideration is the creation of a collective definition of what is considered "rich" (R1) and for what purpose or set of competency questions. For the Ocean Decade, richness for reusability must include metadata required to understand where (meta)data came from, (if possible) how to reproduce it,

Referencing R1.1, licensing information (including that pertaining to embargoes or similar restrictions) is often included in metadata. Where this is not, the ocean community must normalise this practice, even (or especially) for data whose licence is taken for granted. Further, alternative licence or licence-like metadata (e.g. Traditional Knowledge Labels) must be made more machine-readable and actionable than it currently is (e.g. through deeper F and I compliance) to enable automated negotiations and appropriate usage. Naturally, the custodians of these licences should be the hosts of their machine-readable forms, and no parallel systems should be constructed without explicit permission.

Referencing R1.2, tracking the provenance of digital assets (e.g. data, information, digitised knowledge, code, software) is essential to securing trust. The origin and

Referencing R1.3 - can easily become a silo-generating criterion

The CARE Principles in the Ocean Decade

Collective Benefit

C1 For inclusive development and innovation
C2 For improved governance and citizen engagement
C3 For equitable outcomes

Authority to Control

A1 Recognizing rights and interests
A2 Data for governance
A3 Governance of data

Responsibility

R1 For positive relationships
R2 For expanding capability and capacity
R3 For Indigenous languages and worldviews

Ethics

E1 For minimizing harm and maximizing benefit
E2 For justice
E3 For future use

ANNEX 5: The Ocean Decade Challenges

Thematic challenges

Challenge 1: Understand and map land and sea-based sources of pollutants and contaminants and their potential impacts on human health and ocean ecosystems and develop solutions to remove or mitigate them.

Challenge 2: 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.

Challenge 3: Generate knowledge, support innovation, and develop solutions to optimise the role of the ocean in sustainably feeding the world's population under changing environmental, social and climate conditions.

Challenge 4: Generate knowledge, support innovation, and develop solutions for equitable and sustainable development of the ocean economy under changing environmental, social and climate conditions.

Challenge 5: Enhance understanding of the ocean-climate nexus and generate knowledge and solutions to mitigate, adapt and build resilience to the effects of climate change across all geographies and at all scales, and to improve services including predictions for the ocean, climate and weather.

Infrastructure challenges

Challenge 6: Enhance multi-hazard early warning services for all geophysical, ecological, biological, weather, climate and anthropogenic related ocean and coastal hazards, and mainstream community preparedness and resilience.

Challenge 7: Ensure a sustainable ocean observing system across all ocean basins that delivers accessible, timely, and actionable data and information to all users.

Challenge 8: Through multi-stakeholder collaboration, develop a comprehensive digital representation of the ocean, including a dynamic ocean map, which provides free and open access for exploring, discovering, and visualizing past, current, and future ocean conditions in a manner relevant to diverse stakeholders.

Foundational challenges

Challenge 9: Ensure comprehensive capacity development and equitable access to data, information, knowledge and technology across all aspects of ocean science and for all stakeholders.

Challenge 10: Ensure that the multiple values and services of the ocean for human wellbeing, culture, and sustainable development are widely understood, and identify and overcome barriers to behaviour change required for a step change in humanity's relationship with the ocean.

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