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The Global Ocean Observing System

Ocean Observing Co-Design Workshop Report

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UN environment United Nations Environment Programme
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1. EXECUTIVE SUMMARY

The Ocean Observing Co-Design Programme, one of three transformational GOOS Programmes for the UN Decade of Ocean Science for Sustainable Development (Ocean Decade), aims to transform the ocean observing system assessment and design process, developing an integrated and agile system with a new framework for co-design involving observing, modelling, and key user stakeholders. A truly co-designed ocean observing system will enable us to better track the current state and future variability of the ocean, predict and warn more skillfully, manage ocean resources, empower society to adapt to change, and assess the impact of action towards a sustainable ocean.

To initiate this evolution the Programme hosted a first Co-Design Workshop in June 2022 to understand the lessons learnt from regional observing systems and co-design approaches taken to evaluate and respond to end-user needs in system design, across ocean observing and in other domains.

Key takeaways:

- A **paradigm shift** is needed to evolve the ocean observing system towards more user-focused outcomes. Co-design and user engagement can only be integrated if enough resources are provided for the time-intensive activities needed to effectively engage end-users, identify and incorporate their needs.
- Stakeholder engagement and the co-design process must be an **iterative practice** with processes established and matured to ensure that there are opportunities for feedback as part of the evaluation process.
- **Value-chain mapping** is an essential precursor to co-design that will articulate the key actors in the value chain and identify gaps.
- Co-design requires collaboration across the value chain from the **observing community, including the satellite community, to modelling, ocean prediction, and the end-users**. Existing trusted relationships, e.g. through intermediary stakeholders, can be leveraged for the co-design process.
- **Economic value assessment** is important to establish an economic case for ocean observations and to identify where observations can have the most significant impact on decision making.

2. OCEAN OBSERVING CO-DESIGN, A KEY TO SUPPORTING SUSTAINABLE SOCIETIES

The ocean stores heat and carbon, regulating our planet's climate and weather, and provides us with food, economic and recreational benefits, making it vital for supporting life on Earth and the stability of our society. Ocean observations are an underlying pillar that provides nations with the information allowing them to respond to common challenges and build sustainable economies and solutions. While communities around the world face increasing pressures due to climate change, a growing risk of extreme weather events and deterioration of ocean health, we struggle to adequately observe, understand and predict the ocean. To do this we need an uplift of our ocean observing system in key areas critical to address human safety and promote community resilience. The Ocean Observing Co-Design Programme will support the co-design of an integrated, fit-for-purpose ocean observing system, with input from key stakeholders (including end-users) and partners, and deliver needed information needed to maximise system value and return on investment to end-users.

The Ocean Observing Co-Design Programme identified six initial 'Exemplar Projects' (see Annex I and website for detail) - pilot projects to develop and refine co-design processes for their identified societal benefit areas. In order to achieve a co-designed observing system, the first critical step for the Exemplars is identifying key stakeholders, existing partners, needs, and gaps in the underlying observing system through e.g., mapping.

In recognition of this important need, on 7-9 June 2022, the Programme convened the first Co-Design Workshop to establish terminology, examine lessons learnt and best practices for co-design processes from across the ocean observing community, to look at examples of co-design from beyond the ocean observing community, and to explore how co-design of an effective fit-for-purpose ocean observing system can be progressed through the initial Exemplar Projects.

Days 1 and 3 of the Workshop were structured around a number of virtual sessions. High level questions about lessons learned and co-design best practices were addressed through talks and interactive opportunities with attendees and the diverse perspectives and contributions are outlined in the text below.

3. ESTABLISHING A COMMON CO-DESIGN TERMINOLOGY

As part of the Workshop discussions and input from participants, it was noted that a core precursor of the co-design process is to establish a common terminology ensuring the terms used have relevance and an agreed meaning for everyone. A common terminology among and across communities in the co-design process will help to manage expectations, avoid biases, and ensure a shared understanding. We start here by outlining some of the terms relevant to the Ocean Observing Co-Design Programme and those that are featured in this report.

TERMINOLOGY FOR THE OCEAN OBSERVING CO-DESIGN PROGRAMME:

OCEAN OBSERVING SYSTEM

The ocean observing system consists of a series of in-situ networks and assets, and a suite of air-borne and space-based remote sensing platforms and missions observing parts of the marine environment that observe the ocean and contribute to the .

OCEAN OBSERVING VALUE CHAIN

An ocean observing value chain represents the execution of observations, through forecasting, assessment, and data management to service and product delivery to users

STAKEHOLDER

Stakeholders refers to anyone with a vested interest, stake, or connected to the ocean observing value chain, including but not limited to projects, funders, researchers, data users, intermediary users, product and service providers, to the general public.

END-USER

End User/s are the users of the product or service at the end of the ocean observing value chain, i.e. the sector, group or individuals that use the information that was created from, with or using, ocean observations to make decisions or enhance knowledge.

INTERMEDIARY USERS

Intermediary users are intermediaries to the End Users. In the ocean observing value chain they are the entities that integrate the ocean observing data into forecasts, assessments, or other products and services for delivery of information products and services to the end users.

In the co-design of observing and forecasting systems, where an intermediary is present in a ocean observing value chain the co-design process would engage with the intermediary as the primary co-design focus, if an intermediary does not (yet) exist then the engagement would be with a representative selection of end users.

CO-DESIGN

Here, co-design is understood to be a continuous process, a collaborative and iterative effort involving various stakeholders, including observing system implementers, data managers, modellers, service providers, and end-users. An ocean observing co-design process provides a fit-for-purpose and responsive observing system that interconnects experts and stakeholders to ensure sharing of knowledge across disciplines, integration along the value chain, co-construction of solutions and innovative concepts, and the targeted production of products and services useful to stakeholders.
Co-design must be considered and practised from project inception. True co-design must consider what the processes should be to achieve transparency among stakeholders and to enable clear decision making.

EXEMPLAR PROJECT

In the context of the Ocean Observing Co-Design Programme, an ‘Exemplar Project’ is a use area or societal benefit area around which we pilot and refine the ocean observing system through establishing co-design processes.

FIT-FOR-PURPOSE

This concept recognises that it is essential to consider what purpose(s) and which end-user perspective(s) the system is being designed for. It is important that there is a continuous evaluation process to characterise/qualify how end-user needs are addressed through observing system changes, and how well the system is suitable for its intended purpose

BEST PRACTICE

A best practice is a methodology that has repeatedly produced superior results relative to other methodologies with the same objective; to be fully elevated to a best practice, a promising method will have been adopted and employed by multiple organizations[1].

4. CONSIDERATIONS FOR SUCCESSFUL CO-DESIGN

4.1 BUILD ON AND LEVERAGE EXISTING SUCCESSES IN CO-DESIGN

It is imperative that the Ocean Observing Co-Design Programme entrains and builds on previous observing system assessments and programmes to leverage successes and previous experiences in order to inform best co-design processes.

- Through focused attention to an ocean observing challenge, the advisory and science teams of Tropical Pacific Observing System (TPOS), Tropical Atlantic Observing System (TAOS), and the Indian Ocean Observing System (IndOOS) were able to formulate, through their processes, a transition from a vision of the observing system as the sum of disparate observing parts to a vision that is integrated and fit-for-purpose. By working through a list of active and prioritised requirements, planning and implementation teams, the projects developed an integrated vision of the systems - taking advantage of the complementarity of technologies and expertise. Bringing these disparate communities together often proves difficult. However, collaboration can be facilitated by an alignment with existing frameworks that can provide a common language and/or infrastructure for coordination, an example is the GOOS supported Framework for Ocean Observing (FOO[2]).

- Across the community it has been acknowledged that alignment with the FOO and its processes is highly effective in determining and prioritising Essential Ocean Variables(EOVs) to measure, and dissuade project members from prematurely jumping to technical solutions. However, somewhat similarly, the FOO does not provide much assistance when it comes to designing and drafting implementation plans. A rigorous exploration, discussion of platforms, and technology readiness are required for project members and experts. It has been determined that through the consideration of an optimal use of satellites, remote, and *in situ* platforms, as well as open and integrated data management techniques, along with regular interactions with stakeholders, sustained projects are better able to achieve system designs promoting optimal scientific purpose

[1] https://www.oceanbestpractices.org/

[2] http://www.oceanobs09.net/foo/FOO_Report.pdf

while meeting sponsor mission constraints and priorities. [These findings can be found in the 2019, FOO 2.0 System Report[3].

4.2 TIME AND FUNDING: AS ESSENTIAL TO BUILDING END-USER RELATIONSHIPS

Building trust may be a matter of establishing and maintaining personal relationships over multiple years. The short-term nature of research grants can make it challenging to manage the value of investing time to build relationships and it can be difficult to convey this value to programme managers whose focus is typically on deploying instruments and system servers. Interaction with users and sponsors, must be underpinned by a concerted, routine and iterative dialogue as part of the design process. The practice of starting community engagement early and often to ensure broad input and feedback, beyond the core observation community, must be incorporated in the design process. This practice is critical to ensure that the observing system remains responsive to weaknesses, incorporates positive advances, and is sensitive to new or changing needs.

- This development of trust and mutual understanding of needs and capabilities requires time and energy. Financing is essential to support time and resources for personnel, planning and meaningful engagement between scientists and non-scientists.

- Recognising and communicating both the priorities and constraints of sponsors helps to focus priorities and manage expectations.

- To incentivise investment it is beneficial to build value associated with the diverse needs of stakeholders that the observing system serves society, rather than focussing on a single need.

- From a practical and cost perspective, engagement with 'intermediary stakeholders' can be a first step and an important link in the process.

- Additionally, the commonalities between different regions' problems and solutions can potentially be leveraged to optimise for system efficiency For example, effort and learnings might be shared between island states and coastal African countries where challenges may be similar.

- A paradigm shift is needed, away from the traditional academic measures of success such as number of publications towards more valued user-focused and user engagement metrics. A mechanism may be needed to formally recognise time-consuming stakeholder engagement efforts in the same way scientific publications are recognised.

- Tracking and measuring of success that includes:

[3] https://www.goosocean.org/index.php?option=com_oe&task=viewDocumentRecord&docID=32427

- Delivery of products or tools that translate observations into information that address user needs;
- Evidence of the successful use of products by the target community, e.g. to inform policy, implement conservation measures, manage resources;
- Evidence of user satisfaction with societal ;impacts that include an increase in human capacity / self sufficiency / ownership and empowerment within coastal user communities: numbers of communities with reduction in hunger, poverty, conflict, migration.

4.3 THE IMPORTANCE AND COMPLEXITY OF ENGAGEMENT WITH USERS

Throughout the Co-design Workshop discussions, it was stressed that it is important to keep in mind the range of different types of stakeholders: from those that are typically connected to well-represented networks, to members of hard-to-reach groups or from more remote areas. It is important to recognise that not all stakeholders/end-users are interested in engaging in co-design, but may want to stay informed. It was noted that an over-reliance on a few stakeholders may result in the potential for stakeholder fatigue, as the same individuals or organisations receive too many requests for engagement. Some considerations for achieving effective engagement include:

- Existing trusted collaborations, relationships and networks provide a foundation of established trust that can be built on, while remaining mindful of power and political relations, especially between different stakeholders in the value-chain and where relevant indigenous and local communities should be involved to ensure the best outcomes are achieved for all stakeholders;

- Leveraging relationships between upstream and downstream stakeholders will help with the downstream engagement;

- A circular flow of information between all parties requires talking 'with', not 'to' stakeholders to understand needs and harness information to produce sustainable solutions. Scientists shouldn't assume that they know what end-users want;

- Platforms like OceanExpert (Global Directory of Marine and Freshwater Professionals) or the Ocean Decade Network[4] could potentially be leveraged to build and maintain a sustained and open community for some stakeholder groups;

- Prioritising which end-user needs are most important may be subjective. It should be clear how consensus will be reached and what interests shape it. There should be transparency about the processes for incorporating different requirements and an understanding of constraints to achieve alignment with expectations;

[4] https://forum.oceandecade.org/page/welcome

- Engagement with potential stakeholders may require incentives for collaboration (this may be a shared common goal) and a return on investment for stakeholders who invest time and input.

- There must be flexibility to change the direction or prioritisation of project outcomes if, according to feedback, the desired products or services are not being delivered.

- A social ecological approach, including working with social scientists and practitioners, will help to understand competing interests and prioritise all societal needs.

Example: Stakeholder Driven Process

Three important facets of engaging with users, as defined by [Iwamoto et al., 2019] and illustrated in Figure 1 below:

1. Tailor engagement to identify user needs. This requires relationship building and interaction. The product that end-users need may differ from how scientists typically represent data.
2. Design and refine data products with users to provide the scale needed. This process is an iterative loop and products may require numerous renditions.
3. Continue the iterative engagement to build trust in the products/models/data.

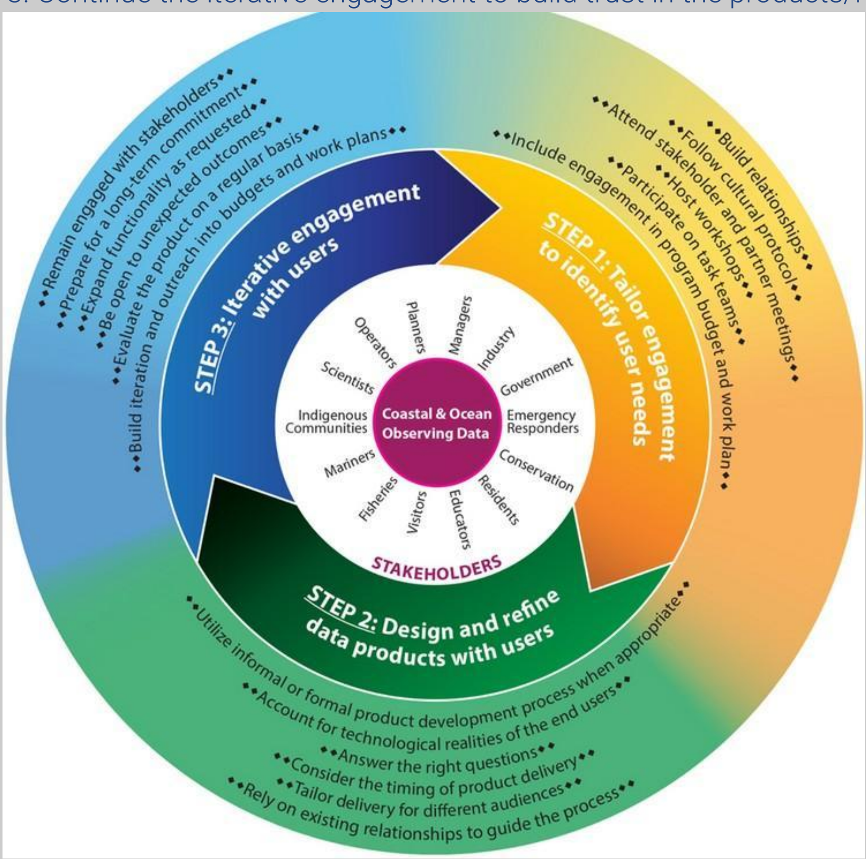


FIGURE 1: Graphic from Meeting Regional, Coastal and Ocean User Needs With Tailored Data Products: A Stakeholder- Driven Process, Iwamoto et al., 2019

4.4 INTEGRATING COMMUNITY STAKEHOLDERS AND INDIGENOUS KNOWLEDGE

Equity and inclusion are essential to produce successful outcomes for community stakeholders and co-design leads. Co-ownership and co-responsibility are essential for the successes, failures, continuous engagement, and the generation of future designs. Some insights related to the engagement with communities and indigenous knowledge holders are included here:

- In some areas and contexts, there can be a difference between stakeholders and right-holders. It is important to recognise the rights of indigenous peoples and Small Scale Fishery communities, their tenure and access to marine resources;
- Co-design must recognise that knowledge of biodiversity can come from two sources: science and traditional knowledge of coastal communities;
- Scientists should not assume that they know what users want, as the priorities for different 'users' will vary. An example presented by Coope-Solidar (Example below) during the workshop described how the conservation and human rights group working with fishing communities in Costa Rica recognise the priorities of indigenous stakeholders they work with;
- When designing a system related to Marine Protected Area management, introduction of governmental action and responsibility may upset historical protections and management practices of indigenous peoples who prioritised protections of natural resources.Targets, such as the Kunming-Montreal Global Biodiversity Framework's (GBF) goal to achieve effective conservation and management of at least 30% of the world's lands, inland waters, coastal areas and oceans by 2030, can favour large-scale industrial fisheries rather than Small Scale Fisheries (SSF) who may not have formal 'rights' to fish.
- To achieve real diversity in co-design, equity mechanisms are needed to ensure inclusion and avoid tokenism. (As a note: within local communities, a single meeting risks creating gender imbalances.)

Example: Coope-Solidar (Costa Rica) recognise that priorities of 'people of the sea' are defined as Free Prior and Informed Consent (FPIC). This is a right of indigenous peoples, recognised in the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP), to give or withhold their consent for any action that would affect their lands, territories or rights.

For indigenous peoples, "Free" means that consent cannot be given under force or threat;

- Decent work (relate to social justice, fair markets);
- Value of women's work along the fisheries value chains;
- Active participation of Small Scale Fisheries in coastal management;.
- Protection of SSF communities from 'blue economy' industries and processes;
- Resilience-building of SSF communities to climate change and other environmental challenges.

4.5 DEVELOPMENT OF COLLABORATION ALONG THE VALUE CHAIN

Collaboration and breaking down of silos were recognised as critical to successfully implementing the Ocean Observing Co-Design Programme and to co-design more broadly. These collaborative practices and processes include:

- Modelling and data assimilation systems' active involvement to ensure sustained diagnoses of the observing system; these groups are critical to the production of the assimilated products for end-users;
- Fostering integration of offshore ocean observing systems into coastal regions that will require engagement with indigenous knowledge holders;
- Engaging with the World Meteorological Organization (WMO), meteorological services, and operational agencies to build connections to data simulation and prediction centres, and access funding and capacity for co-design;
- Engagement with the satellite community that goes well beyond the essential role of observations for calibration and validation, and comes to an understanding and integration of satellite resources that includes and complements their global coverage and recognises the global, spatial, and temporal observational data they provide.

4.6 THE IMPORTANCE OF ENSURING ACCESS TO DATA

Collaboration along the value chain is reliant upon access to data, products, and metadata, as well as other considerations highlighted below. Ultimately, these considerations must be a concerted effort and address access by end-users and other actors in the Exemplar value chain:

- Sharing of data and observations must be done in a Findable, Accessible, Interoperable, Reusable (FAIR) way, with regard given to principles of CARE (Collective benefit, Authority to control, Responsibility, Ethics);
- The smooth flow of data and information to custodians of the EOVs/Essential Climate Variables (ECVs) may arise because of the lack of a stable set of specifications to push or pull (meta)data to or from, as well as fragmentation of data supplied by observing systems and other sources;
- For some variables, the flow is quite clear, but for others not, and data may become lost to downstream synthesis/integration. The considerations mentioned above, cost due to incompatible methods, and lacking or non-interoperable (meta)data. To address this, the International Oceanographic Data Exchange (IODE) within the Intergovernmental Oceanographic Commission (IOC) has launched the Ocean InfoHub project, which is partnering with GOOS actors to co-develop a minimal (meta)data exchange package for the EOVs. Currently, this project is non-operational and very academic, as an unscalable effort in gathering, manually curating, and synthesising one-off analyses;

- Increasing numbers of data sets and products requires an understanding of what products end-users trust, and why. This means it will be critical to identify new routes to convergence of data standards;
- The modelling and data assimilation community must accommodate all measurement functionality to provide the glue that binds the disparate observations with physics;
- Access to data or data products must be done with consideration of the technical hurdles for end-users (in some cases, training may be needed to ensure equitable access and capabilities to interpret and understand the meaning of the data).

5. EXAMPLES OF METHODS, TOOLS, AND APPROACHES

5.1 EFFECTIVE MODELS FOR STAKEHOLDER MAPPING

Stakeholder mapping models have been developed for use by other industries and groups based on a concerted degree of interaction and influence (for example, from healthcare and User Interface / User Experience design). Some specific examples were shared by attendees. These are mapping approaches that have worked well in other instances and may provide a template that could be adapted to apply in an ocean observing / ocean science context.

Example. 1: Contextual and Organisational Support Mapping Of Stakeholders (COSMOS) mapping to understand agencies, capabilities and motivations in a healthcare setting.

Example. 2: Ojai Water Project 'wicked problem' mapping.An initial set of stakeholders get together to map wicked problems, the map is shared and tested back to identify the key leverage points for intervention. By Terry Irwin at Carnegie Mellon University, 2017

5.2 OBSERVING SYSTEM EXPERIMENTS (OSE) AND SIMULATION EXPERIMENTS (OSSE)

Across the observing system, investment will be required for Observing System Experiments (OSEs) and Observing System Simulation Experiments (OSSEs). These valuable tools help identify what observations and sampling frequency have the greatest impact related to the improvement in forecasts and analyses of specific key processes in regions of interest, changes in sampling scales, and the identification of gaps in observations. Workshop discussions included the following recommendations:

- This endeavour must go beyond the current scope of effort focusing on physical ocean variables to integrate biology and biogeochemical variables to address regional issues and requirements across spatio-temporal scales;
- Input from island and coastal states is needed to define appropriate metrics for OSSEs that will help to design the combined observation networks and aggregated global assessments to sustain ocean data uses, and guide baseline based decision making;
- OceanPredict hosts the Observing System Evaluation (OS-Eval) Task Team (TT) to provide consistent and scientifically justified requirements and feedback to observational

agencies. The Synergistic Observing Network for Ocean Prediction (SynObs) Decade project is an initiative of the OS-Eval TT that will identify the optimal combination of different ocean observation platforms through system design, assimilation, and evaluation;

- Coordination, interpretation, and distribution of the results are important for using OSSE and OSE results effectively. For this, a Rolling Review of Requirements approach may be particularly valuable.

5.3 ROLLING REVIEW OF REQUIREMENTS

Rolling Review of Requirements[5] (RRR) is a tool used by the WMO to inform 'High Level Guidance' documents for user requirements and observations that are compared with the capabilities of present and planned observing systems. This involves workshops every four years that culminate in a 'Statement of Guidance' and gap analysis prepared by experts for each WMO Application Area. Consideration is given to key characteristics of the WMO's Global Basic Observing Network and translating them into a set of proposed readiness criteria for expansion. The focus is on data and application areas deemed essential to services, and requires clarity and agreement among members, technical data requirements, and data exchange methodology.

5.4 TOOLS AND PRACTICES IN EVALUATING OBSERVING SYSTEM PRODUCTS

The community has in some instances adopted tools and practices that facilitate user engagement. The regular and widespread use of these tools is an expected outcome of co-design, these may include:

- Working groups focused on analysis and gaps;
- User surveys to collect metrics quantitatively of usage;
- Online analytics that show when a product is used (it was noted that such metrics need provoke the questions: Is it a bad product? Or is it that people are not aware of its availability?);
- A consolidated approach to broaden engagement evaluation to help avoid stakeholder feedback fatigue.

5.5 A SOCIAL ECOLOGICAL SYSTEM APPROACH

A 'social ecological' approach as part of co-design brings humans and societal concerns into the picture. This needs to involve social science expertise to help assist in the evaluation of priorities important to community partners. This will inform how ecological and ocean data are provided in a relevant and actionable way. Specific examples were presented based on experiences at different scales.

- **Example 1** - local scale: The Olympic Coast as a Sentinel integrated social-ecological vulnerability assessments.

[5] https://community.wmo.int/en/rolling-review-requirements-process-legacy-version

- **Example 2** - national scale: Australian IMOS. The focus is on five areas of societal benefit, and models are underpinned by engagement with nodes and jurisdictions and other partnerships to understand needs. These groups around the country work with end-users and stakeholders through research partnership with IMOS as a joint venture programme.

In this sociological ecological context considerations include:

- Inclusive and equitable spatial planning and coastal management;
- Implementation of Free Previous Informed Consent when approaching territories of Indigenous Peoples;
- Focus on 'sustainable use' rather than 'preservation';
- Relationship establishment with local co-champions who may be scientists, policymakers, etc.

5.6 ECONOMIC VALUE ASSESSMENT

Economic assessment of return on investment in ocean observations is a potentially valuable tool that can form part of the co-design process by providing decision makers with insight into the value of observations and on what will provide the greatest return on investment. Two examples were presented to outline approaches for understanding the economic assessment of the impact of ocean observations on economies.

5.6.1 ECONOMIC VALUE ASSESSMENT CASE STUDY: IMOS COST-BENEFIT ANALYSIS

Based on study for Australia's Integrated Marine Observing System (IMOS) by an economic consultancy, Lateral Economics, presented by Gene Tunny, economist. Findings here.

Lateral Economics (LE) shared the process and results of a study that assessed the extent to which Australia receives net benefits from its investment in IMOS. The study interpreted the Return On Investment (ROI) broadly to mean the project yield or Internal Rate of Return (a percentage per annum). The first part of the assessment required engagement with a range of stakeholders in Australia including users of data and IMOS partners to understand and quantify the 'benefits' of IMOS to Australia:

The identified benefit areas were:

- Better management of commercial fisheries in terms of preventing overfishing and avoiding damage to aquaculture from ocean acidification;
- More accurate weather forecasting from the use of IMOS data via Bureau of Meteorology and more targeted and accurate measurements of ocean temperatures;
- Natural disaster preparedness, including coastal adaptation;
- Improved policy responses to environmental challenges from more accurate data about the oceans, resulting, for example, in avoided GDP loss due to climate change;

- More accurate forecasting of ocean currents which, among other things, aids in navigation and helps oil and gas companies regarding their offshore operations;
- Public good value of better knowledge of the ocean (e.g. value of scientific publications), largely unquantifiable but which could be included in assumed 'long-tail' of benefits;
- Oil and gas industry benefits, e.g. efficiency, capital investment savings;
- Potential benefits to the Royal Australian Navy from a better understanding of how ocean conditions affect sonar soundings.

Lateral Economics then developed an indicative Cost-Benefit-Analysis based on a number of assumptions. Table 1 below, provided by Lateral Economics, outlines the assumptions and justifications that were based on consultations with stakeholders and literature review.

TABLE 1: Cost-Benefits Analysis assumptions - table from Lateral Economics presentation

Assumptions	Value	Justification
Discount rate	7%	OBPR
Real funding growth p.a.	3.0%	GDP growth
Long-tail benefits	25%	(i.e. the 20 in the 80:20 principle)[36]
Fisheries management ($m p.a.)	40	Zhang and Wang (2011)[37]
Weather forecasting total benefit p.a. ($m)	3,829	Based on London Economics (2016, Table 12, p. 61)[38]
Weather forecasting improvement due to IMOS	1.0%	Based on LE consultations with BoM
Growth rate of forecasting benefits p.a.	1.30%	Long-run population growth assumption in Intergenerational Report 2015
Cost of extreme weather events (2030, $m)	85,000	Climate Change Council (2019, p. 7)
Cost of extreme weather events (2050, $m)	91,000	Climate Change Council (2019, p. 7)
Percentage of risk of extreme weather cost mitigated	0.2%	Conservative assumption based on LE consultations and research
Cost of unchecked climate change - Aus. GDP loss (PV, $m)*	1,500,000	Deloitte Access Economics (2020, p. 5)[39]
Percentage of cost of GDP loss mitigated by IMOS	0.2%	Conservative assumption based on LE consultations
Oil and gas industry annual benefit ($m)	20	Consultations with oil and gas industry
Deadweight loss from taxation	24%	Based on Treasury analysis used in previous LE studies for ABS, PHRN, and AuScope.

OPBR = Office of Best Practice Regulation

The **Cost-Benefit-Analysis was based on a 50-year time period** to account for benefits that may not have an immediate effect but are significant in terms of long-term adaptation and coastal resilience. The summary of this analysis is outlined in these key estimates:

- **Conservative indicative estimates:** $4.70 of benefits are generated for each $1 of cost;
- The **benefit-cost ratio is 12:1 as an upper-bound estimate**, assuming all the co-contributions by partners are stimulated by IMOS. This illustrates the extent to which IMOS funding can be leveraged to encourage additional investment from partners. An upper end cost-benefit ratio for the Australian Government;
- **The benefit-cost ratio is 7.6:1 on a lower-bound estimate**, assuming only 50% of observed co-contributions would have been made anyway (i.e. equivalent money or resources would have been invested in similar activities). A more conservative benefit-cost ratio for the Australian Government;
- **The fiscal return is $1.06 to $1.50 of taxation for every $1 of spend** over the long-term.

SLIDES LINK presented by Gene Tunny, Lateral Economics

5.6.2 ECONOMIC VALUE ASSESSMENT USE CASE: REVEALED VALUE IN USE

Based on a paper being developed through a collaboration between GOOS, OECD and environmental economists from the University of New Mexico to assess the value of marine science to inform marine policies and use decisions to sustainably manage ocean resources, presented by Richard Bernkopf, University of New Mexico.

The 'revealed value in use' approach is a quantitative impact assessment outlined as a schematic in Figure 2 below. The approach is based on an applied economic model that can be used to evaluate expected revenue for market goods plus the value of ecosystem services, and to compare how different decisions (e.g. management practices, environmental policies, development preferences) and the use of Essential Ocean Variable (EOV) data in these decisions, affect the outputs and return, given varying ocean conditions and spatio-temporal parameters.

The evaluation can apply at the scale of regional or national economies. This approach can be used to demonstrate the benefits of EOV observations to reduce uncertainty about the state of the ocean under different parameters. The estimated 'value of information' is calculated based on the difference in total costs with or without EOV data. This demonstrates the value of EOVs for decreasing uncertainty and informing more cost-effective decisions, relating, for example, to policy interventions or blue economy industry decisions.

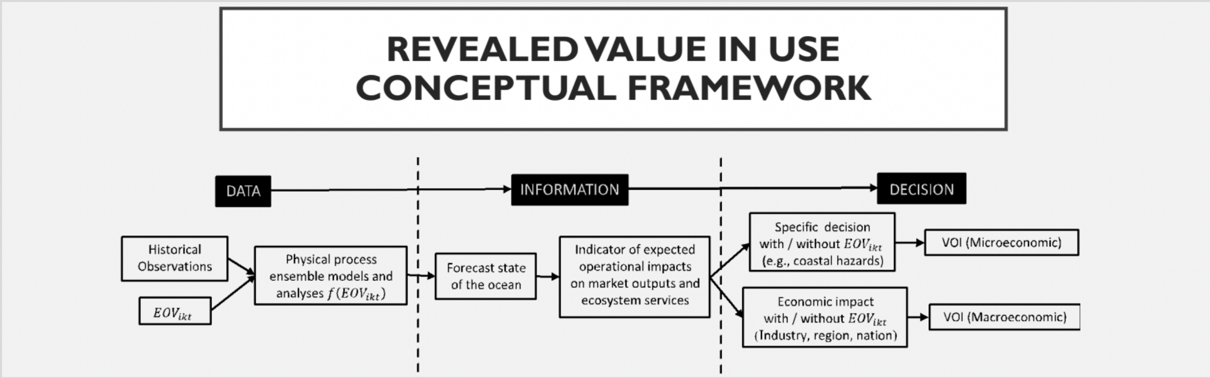


FIGURE 2: Schematic of the 'revealed value in use' conceptual framework where EOV = Essential Ocean Variable, f = VOI = Value of Information

Ecosystem services are categorised under a number of headings: Regulating, Provisioning, Habitat and Supporting or Cultural and the conversion of EOV information into these ecosystem services is based on local, regional and biogeographical oceanic effects of the EOVs. This conversion process is illustrated in Figure 3 below.

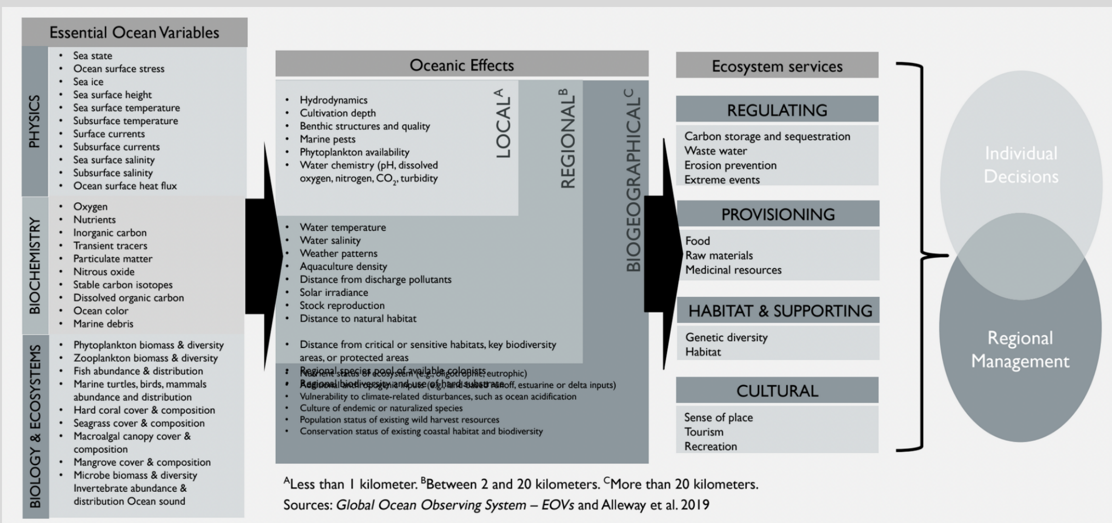


FIGURE 3: Process for converting an EOV to an Ecosystem Service

A Bayesian model can be applied to decision making as illustrated in the 'influence diagram' in Figure 4 (adapted from Economou et al. 2016). A decision maker is assumed to have a prior probability of the ocean condition, P (M), associated with the decision, d. The information of interest is how new information (from EOV observations) changes this distribution, P (M\EOV), and the cost of the action taken, C = (d, M). The higher the correlation between the state of nature and the decision then the more the more beneficial the EOV observations.

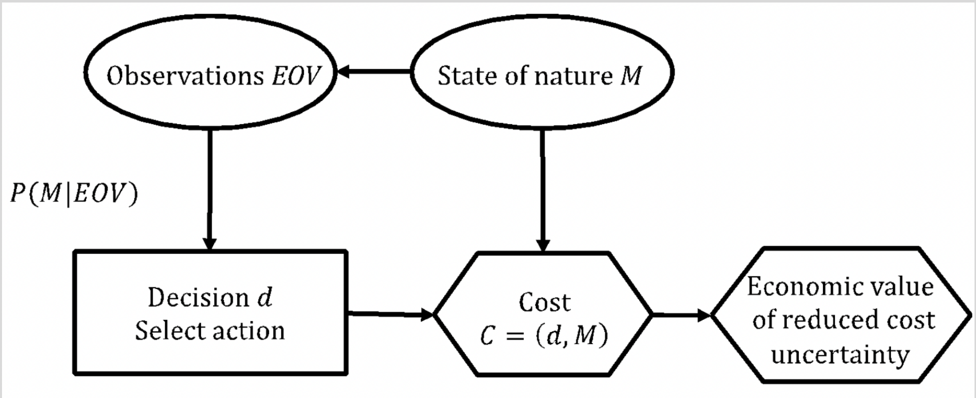


FIGURE 4 - Influence diagram illustrating a decision application (adapted from Economou et al. 2016)

The revealed value in use approach highlights how observations can be used to inform policy choices that minimise the societal cost. To apply this methodology, a sustained supply of baseline scientific data is essential to enable forecasts of impacts associated with different decisions. The model will be developed further and published as an OECD Technical paper in 2023 (in preparation Bernknopf, Jolly, Joliffe, Casy and Heslop , 2023)

SLIDES LINK presented by Dr Richard Bernkopf University Of New Mexico

APPENDIX I: THE FIRST CO-DESIGN EXEMPLARS

The first set of Exemplars are listed here in the context of their societal benefits. More information and contact details are available on the Ocean Observing Co-Design webpage.

The Ocean Carbon Cycle

Improving carbon data to inform climate targets, such as net zero.
To aim for net zero, it is essential to measure and report on ocean carbon uptake. A global ocean carbon observing network co-designed with key government users will provide an integrated view so that ocean carbon is counted alongside atmospheric accumulation and fossil fuel emissions, to better inform emission reduction targets and assess feasibility of carbon dioxide removal strategies.

Tropical cyclones ocean observations and forecasting

Advancing cyclone forecasting to save lives and property.
Tropical cyclone impacts are amplified by a warming ocean and rising sea levels, and disproportionately affect less developed countries and small island developing states. Enhancing ocean observing to improve forecasts and warnings will save lives and property, as well as promote equity and resiliency.

Marine Life 2030: developing knowledge for local action

Sustaining development and conservation of living marine resources.
There is an urgent need to better understand the needs of coastal communities and establish trusted information exchange regarding marine life to support sustainable development and conserve marine biodiversity. We will engage communities, indigenous peoples, industry and governments, in developing and developed nations, to understand their needs and establish sustained, trusted flows of information about ecological baselines, status and forecasts.

Storm Surge

Improving storm surge predictions to minimise impacts on vulnerable communities and natural resources. Sufficient lead-time and accuracy in forecasting storm surge is critical to minimise impacts on natural and human resources and assets. Forecasting capabilities will be developed at the local level for vulnerable communities.

Marine Heatwaves

Monitoring marine heatwave impacts on biodiversity and economies to ensure food security, protected areas management, tourism, climate and weather services. Global sustained monitoring of marine heatwaves and their impacts on marine biodiversity and coastal communities will support effective ocean management.

Fit-for-purpose observing systems with boundary currents

Observing key current systems to support search and rescue services, Marine Protected Area management, wind energy development, fisheries, tourism, shipping and weather forecasts. Boundary currents are critical drivers of the global climate system and fisheries productivity.

APPENDIX II: LINKS SHARED BY PARTICIPANTS DURING THE DISCUSSIONS

Science for Nature and People Partnership https://snappartnership.net

Mapping a 'wicked problem' Ojai water shortage example
https://transitiondesignseminarcmu.net/wp-content/uploads/2017/01/Ojai-Mind-Map-TD-Seminar.pdf

Reimagining Ocean Stewardship: Arts-Based Methods to 'Hear' and 'See' Indigenous and Local Knowledge in Ocean Management
https://www.frontiersin.org/articles/10.3389/fmars.2022.886632/full

Meeting Regional, Coastal and Ocean User Needs With Tailored Data Products: A Stakeholder-Driven Process, Iwamoto et al., 2019
https://www.frontiersin.org/articles/10.3389/fmars.2019.00290/full

The Backyard Buoys project, a community-led ocean observing effort that unlocks key ocean insights for Indigenous communities in the Pacific Islands, Washington coast, and Alaska
https://www.sofarocean.com/posts/bringing-spotter-buoys-to-indigenous-communities-on-the-front-lines-of-climate-change

IODE's Ocean InfoHub project with GOOS - a minimal (meta)data exchange package for the EOVs

NVIDIA - a weather forecasting system based on machine learning:
https://arxiv.org/abs/2202.11214 that it is trained on the ERA5 atmospheric reanalysis.

FourCastNet: A Global Data-driven High-resolution Weather Model, short for Fourier Forecasting Neural Network, is a global data-driven weather forecasting model that provides accurate short to medium-range global predictions.

CSIRO marine heatwaves machine learning forecast:
https://research.csiro.au/cor/climate-impacts-adaptation/marine-heatwaves/forecasting-marine-heatwaves/

Forecasting Marine Heatwaves MetOcean (New Zealand) - machine learning forecasts for marine heatwaves and storm surges. Coasts & Ocean Research. The Project: Marine heatwaves in the Indo-Pacific region, their predictability and social-economic impacts.

Relevant paper on BGC OSSE: Ford, D.: Assimilating synthetic Biogeochemical-Argo and ocean colour observations into a global ocean model to inform observing system design, Biogeosciences, 18, 509–534, https://doi.org/10.5194/bg-18-509-2021, 2021.

APPENDIX III: WORKSHOP BACKGROUND AND AGENDA

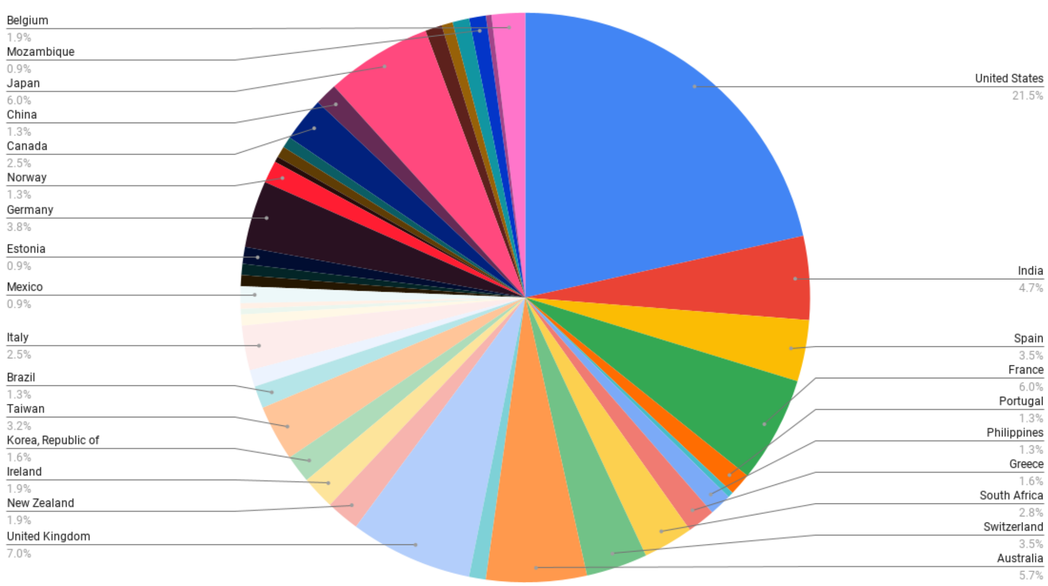
- Link to Workshop webpage with recordings here
- Download the Programme brochure here
- Detailed annotated agenda is linked here
- Ocean Observing Co-Design Programme webpage here

APPENDIX IV: WORKSHOP STATISTIC

The Workshop brought together various communities (Figure 1), including intermediary users for example service providers, see glossary), observation operators, and modellers to launch the process. This report highlights the key takeaways from the discussions and the next steps of the Programme to apply recommendations to the development of Exemplar goals and activities.

Figure 1: WORKSHOP ATTENDANCE AND GLOBAL PARTICIPATION

Total number of workshop attendees: 276
Number of countries represented: 41



List of countries represented:

Argentina	India	Poland
Australia	Indonesia	Portugal
Bahamas	Ireland	Réunion
Belgium	Italy	Romania
Brazil	Japan	Somalia
Canada	Kenya	South Africa

China	Korea, Republic of	Spain
Costa Rica	Malta	Switzerland
Denmark	Mexico	Taiwan
Egypt	Mozambique	Thailand
Estonia	New Zealand	Ukraine
France	Nigeria	United Kingdom
Germany	Norway	United States
Greece	Philippines	

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