# OARS Outcome 3 White Paper

## OARS Outcome 3: Co-design and implement observation strategies

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Building upon efforts of the Global Ocean Acidification Observing Network (GOA-ON), the Ocean Acidification Research for Sustainability (OARS) programme, endorsed by the UN Decade of Ocean Science for Sustainable Development, further enhances ocean acidification capacity, increases observations of ocean chemistry changes, identifies the impacts on marine ecosystems on local and global scales, and provides society and decision makers with the information needed to mitigate and adapt to ocean acidification. GOA-ON and its partners propose to broaden the network's scope and expect to achieve a set of seven outcomes (Figure 1, see: http://www.goa-on.org/oars/overview.php) through OARS by 2030. Collectively, this will help regions and national governments better understand the dynamics of climate related ocean changes across different geographic and spatial scales, which is essential for improving understanding of key vulnerabilities and adaptation potential to climate change. While mechanisms are being established to strengthen ocean acidification mitigation and adaptation measures across relevant UN and international conventions, capacity for generating tailored information for local management, policy response and preparedness remains a significant barrier to advancing necessary adaptation efforts.

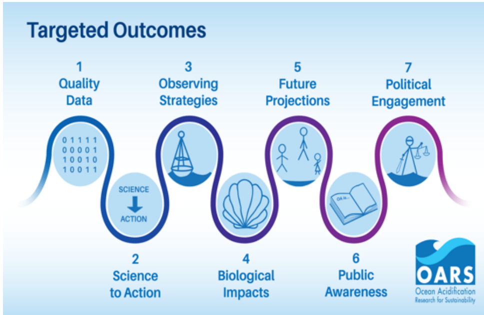



Figure 1: OARS seven targeted outcome. *Source: GOA-ON.*

To help break down this barrier, OARS Outcome 3 will contribute to the co-design and implementation of observation strategies in collaboration with data/information producers and end-users. These initiatives will be supported by capacity building, to ensure vulnerable areas are adequately monitored and strong baseline information exists throughout the world, which is particularly critical for the implementation of newly developed carbon removal strategies. Effective co-design of activities, requires that all interested stakeholders involved in that co-building of observing systems have a strong foundational knowledge. Stakeholders need to understand how the natural and human systems work and how they interact. Without this key understanding, there will actions will be hindered. We witness a current plethora of individual monitoring activities operating over different spatial and temporal scales, all with different objectives and approaches. Only targeted co-built observation strategies will guide successful coral reef restoration, fisheries and aquaculture resilience strategies, innovative nature-based projects, carbon removal strategies, land-based pollution controls and climate responsive marine spatial planning and conservation efforts (Fig 2).


Figure 2: Integrated programs are recommended to better understand present day carbon cycle dynamics. *Source: OARS Outcome 3.*

Interdisciplinary and integrated programs based on ship-based hydrography, Voluntary Observing Ship (VOS) lines, time-series moorings, floats, gliders, and autonomous surface vessels with sensors for $pCO_2$, pH, and ancillary variables (Fabry et al., 2008) are recommended to better understand present day carbon cycle dynamics, quantify air-sea $CO_2$ fluxes, and determine future long-term trends of $CO_2$ in response to global change forcings (changes in river inputs, hydrological cycle, circulation, sea-ice retreat, expanding oxygen minimum zones (Borges et al., 2010).

The success of OARS Outcome 3 will depend on close communication will all of the other OARS Outcomes 3. Outcome 3 will strive for engagement with activities conducted under OARS Outcomes 6 (Public awareness) and 7 (Political engagement). Collaboration between actions under OARS Outcomes 1 (Quality data) and 3 is indispensable since focusing the scientific community to provide ocean acidification data of known quality via capacity development, mentorship of early career researchers, and data sharing are fundamental steps to implement fit for purpose observation strategies (Outcome 3). A close collaboration with Outcome 4 will allow us to design observation strategies that are relevant for the forecasting of biological impacts, and with Outcome 5 to provide appropriate data and information necessary for the development of societally relevant predictions and projections.

OARS outcome 3 embraces the three pillars of the Framework for Ocean Observing (FOO, 2012), namely: Requirements, Observations, and Data science to ensure the completion of the "ocean observing value chain". To do so, OARS Outcome 3 specifically aims to build capacity for the people responsible for funding/commissioning monitoring/observations ('funders'), and for those people who could contribute to the application of monitoring on the ground (e.g. environmental managers, related industries such as aquaculture fishing, NGOs) (the 'practitioners'). Targeted capacity development activities for these stakeholders will be key since they constitute the missing links in the value chain despite the significant role they have to play in realizing integrated, sustainable, long-term observing activities.

In this position paper, we will describe our outcomes vision of OARS Outcome 3, then the anticipated impacts and benefits with respect to the UN Ocean Decade, the environment and society. We will then provide a tentative list of outputs and products to be delivered to reach the expected outcomes along with the engagement activities that will create the outputs and products. We will point to the funding needs from international bodies to support this work, indeed vulnerable areas need to be adequately monitored as part of a comprehensive climate preparedness and response. Finally key inputs and enablers needed along the road to support activities and to ensure success to deliver the outcomes will be presented.

**To be transformative, one needs to think differently.**

Scientists are used to setting up scientific questions, formulating and testing hypotheses, and carrying out the work. In the UN Decade of Ocean Science for Sustainable Development, we need to be transformative, meaning one has to change their way of thinking. We need to envision the whole value chain, this means identifying the stakeholders, investors, end-users, and co-building the research questions with these groups, identifying what are the potential factors limiting the collection of data or implementation of solutions, and ultimately delivering the relevant data bases and solutions (Figure 3). We can no longer promote the status quo and simply relabel existing initiatives, we need to change our perspective. The "Theory of Change" provides this framework. In Theory of Change, desired long-term goals are set, then, working backwards, one identifies all the conditions (outcomes) that must be in place (and how these relate to one another causally). These outcomes then provide the basis for identifying what type of activity or intervention will lead to the outcomes identified as preconditions for achieving the long-term goal. Through this approach, the precise link between activities and the achievement of long-term goals is more fully understood. This leads to better planning, in that activities are linked to a detailed understanding of how change actually happens. It also leads to better evaluation, as it is possible to measure progress towards the achievement of longer-term goals that go beyond the identification of program outputs. The new way of thinking is switching from the sequences “Root causes- Problem- Consequences” to those of “Means-Desire Result-Impact” to ultimately follow those of “Impacts-Benefits-Outputs-Outcomes-Activities-Engagement”.

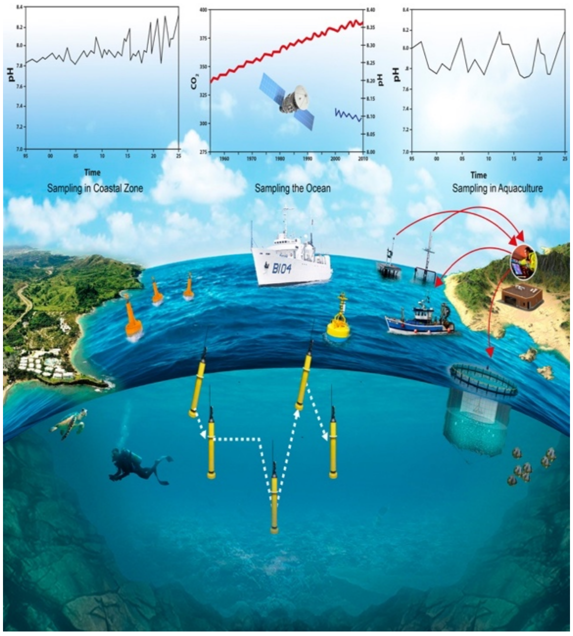



Figure 3: Co-design: Changing our way of thinking. *Source: OARS Outcome 3.*

**Vision of outcomes**

Despite the many IPCC reports, the impacts of ongoing ocean warming, acidification and deoxygenation are often under-recognized by policy and decision-makers, misunderstood or not incorporated across mainstream climate mitigation or adaptation priorities. This disconnect between science and policy responses pose a substantial risk to coastal community resources and seafood economies that humans depend upon. It also undermines the effectiveness of more mainstream ocean conservation and management tools like marine protected areas, ecosystem and habitat restoration efforts, nature-based solutions, and climate-resilient fisheries.

Ocean acidification, related biogeochemical changes, and other impacts are caused by human activities, therefore people must also be part of the solution. Educating people now should be a call to arms for engaging people in addressing this challenge of ocean change. While increasing ambition to reduce carbon dioxide emissions is paramount for mitigating OA, there are actions that governments and regional coordinating bodies can and should be taking now that will allow for increased adaptation and resilience of vulnerable ecosystems and species, further bolstering the ability of human communities to cope with future change. The way nations are investing as a consortium in the International Space Station to discover the origins of life should be duplicated for observing the ocean.

Teaching people about the value of the ocean for human wellbeing, how to preserve our ocean, and remaining curious will hopefully direct humans towards inventing a route for a habitable planet in the future. The human biogeochemical footprint on the planet is now so large that the future quality and sustainability of environmental resources will be determined by societal choices rather than natural variability. At the same time, it is critical to understand how natural Earth Systems will respond to this anthropogenic forcing. Understanding the interactions between the pressures of humans and natural changes in marine ecosystems will be the basis for society to make educated decisions, and to be able to maintain, manage, and improve ocean and human health. Only when acknowledging that human activity is driving the delivery of ocean services, will their provision be maintained. Therefore, an envisaged outcome of co-designing ocean acidification observation is to provide data and information tailored for educational use, the implementation of marine management and policy action. While the academic sector is required to engage in developing knowledge that is "co-designed and co-produced" with those who use research in governments, business, and civil society, keeping a high profile on the rules of ethics and maintaining principles of bottom-up inspiration and scientific excellence is indispensable. Credibility and independence of the OARS research community are important attributes and so should remain.

In order for co-development and co-building to work better, it needs to be a cycle i.e. by co-developing observing systems alongside other key groups (other academics from different disciplines, funders, industry, public, decision makers, etc.), we will build these other stakeholders' knowledge of ocean acidification. By growing this knowledge then these groups will be better equipped to engage in future co-development systems, creating better outcomes with more learning opportunities, and the cycle goes on gaining strength with every cycle. Communicating a co-design blueprint, capacity training and educating people about the facts of ocean acidification science and policy will be fundamental priority tasks for our OARS Outcomes 3.

Most of the capacity for conducting ocean research and observations is concentrated in developed countries and in the Northern Hemisphere (IOC-UNESCO, 2020), and many of the best practices for conducting ocean acidification research were developed assuming access to a robust laboratory and costly equipment. In recent years ocean acidification expertise has been greatly enhanced through the work of many partners, including the International Atomic Energy Agency Ocean Acidification International Coordination Centre (IAEA OA-ICC), GOA-ON and The Ocean Foundation.

To improve accessibility of conducting research a group including the IAEA OA-ICC, GOA-ON, The Ocean Foundation, and IOC developed recommendations for creating a low-cost kit capable of collecting "weather quality" OA measurements as defined by GOA-ON. The Ocean Foundation, with funding support from the U.S. Department of State and the Government of Sweden created a kit list based on these recommendations. This kit, nicknamed "GOA-ON in a Box", enables users to obtain pH and alkalinity data through sensor deployment and analysis of discrete samples. To date, The Ocean Foundation has procured and shipped out 17 kits to 16 countries.

Another program key to expanding capacity is the Pier-2-Peer program which pairs scientists new to studying ocean acidification with more experienced scientists. The Ocean Foundation administers a small grants fund in support of this program to enable mentor and mentee pairs to collaborate on research and develop the skills and capacities of mentees and their institutions.

More than 500 scientists have also participated in hands-on training courses hosted by The Ocean Foundation, the IAEA OA-ICC, and IOC. Training in ocean observations has also been provided since 2001 by the Partnership for Observation of the Global Ocean (POGO) and the Scientific Committee on Oceanic Research (SCOR) through the provision of fellowships allowing early-career scientists from developing countries to receive training in practical skills and methods for ocean observing, data processing/management and modelling (see https://pogo-ocean.org/capacity-development/pogo-scor-fellowship-programme/). Of course, training in itself is not sufficient, and a long-term vision, sustained funding and the development of international partnerships and collaboration are required to truly develop the capacity (human resources/expertise and infrastructure) for long-term, routine OA monitoring in coastal developing nations worldwide.

In order to enable enduring capacity, partners are now seeking to establish regional training centers and use the regional hub structure of GOA-ON to ensure in-region support. For example, The Ocean Foundation and NOAA recently established the Pacific Islands OA Centre (PIOAC), hosted jointly by The Pacific Community and the University of the South Pacific. The Centre will host a spare parts inventory to enable quicker replacement of lab materials, maintain two GOA-ON in a Box kits for training purposes, provide data management and chemistry coaching to partners in the region, and support sensor repair and maintenance. The PIOAC was established in partnership with in-region partners and was specifically designed to meet community needs. POGO also supports regional and global projects that enable collaboration and sharing of best practices. On a regional scale, POGO supports a Working Group on ocean acidification monitoring in the Gulf of Guinea (https://pogo-ocean.org/innovation-in-ocean-observing/activities/biotta/), which is also collaborating with The Ocean Foundation and GOA-ON to provide training and OA kits to the participating countries. A global project on deoxygenation, ocean acidification and productivity, supported by POGO with funding from the Nippon Foundation (NF), and conducted by NF-POGO alumni, provides funding for bimonthly sampling of selected biogeochemical parameters in 17 countries (https://nf-pogo-alumni.org/projects/global/#participants). A partnership with GOA-ON and The Ocean Foundation could enable the expansion of the measurements to the full suite of OA parameters and their integration into existing global datasets.

**In brief, OARS 3 outcomes will include two main pillars:**

1) Identifying and supporting the people that should be part of the co-building process, their roles and their needs. One may question what are the specific development needs for the actual process of co-developing. Do participants need specific skills to be able to do co-building and what skills do they have in their chosen discipline? Is co-development a skill or expertise in itself on top of being a scientist, politician, stakeholder, funding manager? Targeted observations must be fit for purpose to ensure coastal managers, policy makers and climate advisors are equipped to advance meaningful and quantifiable adaptation strategies along the coastline that are responsive to human needs. This will require clear identification of stakeholder networks and providing accessible avenues for seeking their engagement and understanding their needs.

2) Identifying the barriers that prevent co-development, and what needs to be done to overcome these barriers in order to implement co-building to create a sustainable, effective observing system. It means understanding the factors that limit the collection of data such as access to instrumentation, appropriate maintenance, technological capacity, institutional capacity and financing–especially in developing countries or in regions that are more dependent on ocean and marine resources. There is a crucial need to strengthen policy commitments and increase awareness about the various applications for targeted OA data and information. This will help promote incentives for sensor developers and companies to reduce prices, actively encourage multiple producers of sensors to accelerate sensor distribution and minimize costs by easing the knowledge transfer, and collaborate to reduce maintenance costs and improve access to and sharing of monitoring opportunities.

These two pillars are the prerequisite foundation to create an enhanced OA observing global network by increased observing capability and geographic distribution of monitoring.

**Benefits and impacts**

The ultimate **benefits and impacts** will be increased observation capabilities in place globally to derive an improved understanding of global climatic trends, e.g. ocean pH and oceanic carbon uptake. This information is necessary to the development of societally relevant projections and will also enable the assessment of proposed carbon removal strategies.

Co-location of different observational parameters (physical, biological, chemical, environmental, social, economic) will provide us with a much more holistic appreciation of the fundamental processes, relationships and drivers which underpin marine socio-ecological systems and better understand the impacts of ocean acidification, in the context of other stressors (both climate driven and local human activity). For example, a methodological concept that serves as a basis for the development of alert systems for corrosive conditions for the fishing sector, for example where mollusk farming activities are carried out, will benefit this sector.

A breadth of data collection will also facilitate the creation and application of Digital Twins to better manage complex environmental challenges (e.g. creating and maintaining climate smart marine protected areas, managing fisheries, supporting marine spatial planning, etc).

An additional benefit will be a common and mutually agreed upon knowledge base to support international policy and science-based political vision to design a forward-looking climate decarbonization policy. By co-designing with stakeholders, common goals will be agreed upon, possibly increasing access to funding. Raising funds is critical in particular for vulnerable areas to plan their climate response.

Specifically, the increased collection of good/usable data respecting the "FAIR" (Findable Accessible Interoperable Reproducible) and "CARE" (Collective Benefit, Authority to Control, Responsibility, Ethics) principles and building of reliable databases with internationally agreed standard treatment (e.g., quality checks, quality flagging, adjustment procedures) will ease the comparison of results between international research groups to deliver globally consistent baseline information. Again, specific attention will be paid to proactively designing and implementing new observation strategies to ensure vulnerable areas are adequately monitored.

**Outputs for achieving co-designed ocean acidification observation by data producers and users**

Delivering the outcomes mentioned above requires a suite of key **outputs** to be produced. Some will be produced in synergy with outputs derived from other OARS outcomes.

The very fundamental output is to ensure a sustainable production and distribution system for Certified Reference Materials (CRMs) and for the development of secondary standards (OARS Outcome 1). The COVID pandemic with shortage of CRMs highlighted the need to have in place a fully sustainable production and worldwide distribution system.

The delivery of our outcomes also implies the advancement of sensor technology towards a lower cost of equipment and of instrument maintenance, a prerequisite to expanding OA observing in developing countries. The need to install low-cost underwater sensors with the ability to measure pH, temperature and salinity in conjunction with the analysis of historical data generated by coastal programs is highlighted. Such a tool could generate $CO_2$ system data and evaluate the potential impacts that acidification can have in natural systems as described by Alin et al. (2013).

Stakeholders of the fishing sector have expressed the need to have in place alert systems so that they can make decisions on their activities. An alert system should be based on a good performance with respect to improving data collection, data quality control, and verification of modeled results with algorithms. However, the system must be able to adapt to the problems identified by real world user feedback (National Science Foundation, 2007; Newman et al., 2012). This is where the coastal monitoring system should offer the oyster producer, for instance, information (visualizations of observed data and modeling tailored for a non-specialized audience through for instance a web interface) on environmental monitoring (pH, temperature, and aragonite saturation $\Omega_{aragonite}$), making it a potential tool in decision-making. These decisions can be translated into short-term actions, such as adequate control of the seawater use system, or they could impact medium- and long-term actions, for example, the adoption of practices to deal with suboptimal conditions for bivalve development. Considering that the success of these digital platforms is based on training for their proper use, which would provide useful feedback, it is necessary to evaluate the ability of potential users to adapt to this newly available technology (Dehnen-Schmutz et al., 2016). In addition, considering for example that the oyster farming industry in different parts of the world is potentially susceptible to the influence of cold, undersaturated, and acidic waters, either in the short term (for example, coastal upwelling on the West coast of the North Pacific), or in the long term (for example, OA), knowing the opinions and the degree of knowledge of oyster farmers on the potential effects of OA on their industry, is necessary to evaluate their potential use of the available information. The challenge is to identify the missing information this sector has on this topic, and thus be able to address this problem, but with appropriate strategies to promote community participation in this topic of OA among stakeholders.

Evaluating the openness of aquaculture producers (e.g. oyster farmers) in adopting new information technologies and their perception of the effects of OA in the aquaculture industry is also needed. The fishing sector has mortality problems and the causes of these problems are uncertain, they might be due to management problems or diseases. We should be aware that the issue of OA is another addition to their list of challenges, making the needs assessment of the fishing sector even more delicate.

Coordination of OA monitoring with other ocean and atmospheric observation systems should be favoured. This would allow us to better understand the key biogeochemical-physical interactions and feedback between the ocean and atmosphere which regulate climate and global change. Similarly, deploying observing platforms that couple OA monitoring with biological monitoring would harness the power of existing biological time-series (link with OARS Outcome 4). All Essential Ocean Variables (EOVs) from observing systems could be managed/stored in a way that allows us to access both types of data simultaneously. This will require an improved dialogue between siloed entities that are focussed on climate change monitoring on one hand and those focused on biodiversity monitoring on the other hand. One may call for a specific joint IPCC-IPBES report on the fate of our future oceans which would demonstrate these international bodies work de concert to yield useful joint products. Collaborating with other UN Ocean Decade programs (such as the Ocean Biomolecular Observing Network, OBON, Marine Life 2030, and others) would also facilitate the linkage between OA and biodiversity monitoring.

There should be wider, systematic access to community-approved best practices and calibration protocols. These products can be easily done by publishing guidelines, best practice peer-reviewed documents, and by making available open access training materials to build capacity in people to engage in co-development.

In line with stakeholder-oriented co-design, and linking to OARS Outcome 7, the requirement of co-development could become a legal requirement in statutory environmental monitoring. OA monitoring could be for instance a mandatory observing requirement of Marine Protected Areas and aquaculture activities. Similarly, in areas of potential marine intervention for carbon removal, there should be baseline OA observing activities to provide evidence-based guidance on the development and implementation of such projects. Another avenue of collaboration could be with Carbon Capture and Storage (CCS) initiatives, which carry out some monitoring for leakage from geological sub-sea CCS.

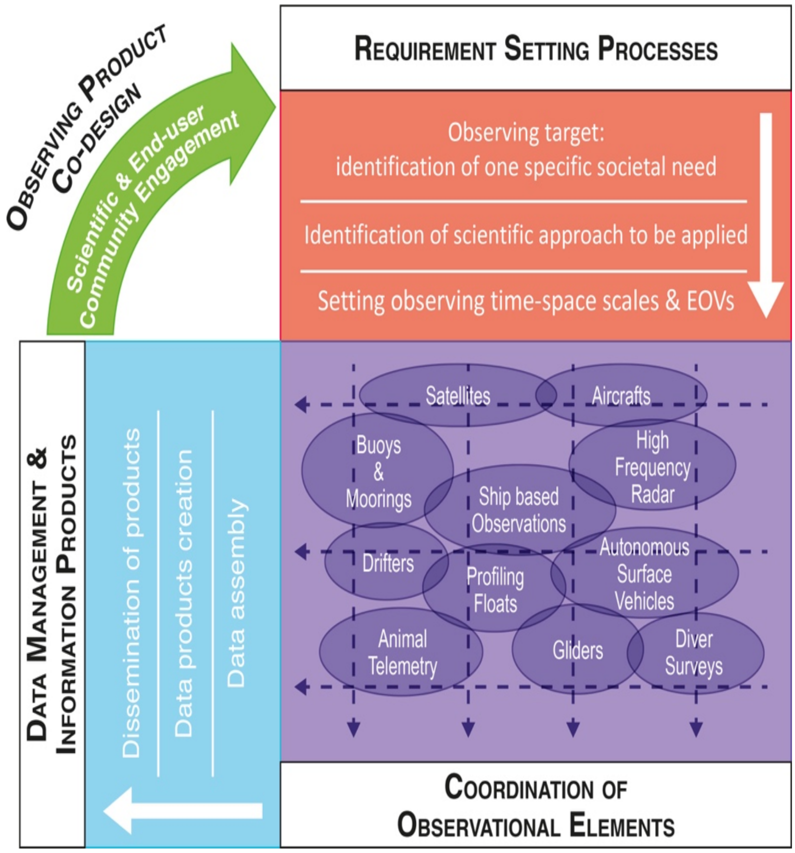
Finally, all observations/research based informational products useful for decision making, e.g. time series analysis tools and mechanisms visualizing the impacts of OA on marine life are instrumental to deliver the desired outcomes. Visuals are the backbone of efficient messaging to society so we should aim to always deliver high quality informative visuals to communicate and capture society's attention.

**Planned engagement activities**

As was mentioned before, OARS outcome 3 embraces the three pillars of the Framework for Ocean Observing (FOO). The three pillars include Requirements, Coordination of observations, and Data management and information products (Fig. 4). The FOO is the ideal framework to structure engagement activities and it provides valuable guidelines for assessing ocean observing problems. The "loop" that is executed when applying the FOO principles to a certain observing objective (e.g., seasonal cycle of coastal pH off California) is also called the "ocean observing value chain". The value chain is a concept adopted from economics that describes a process in which a system is organized through subsystems, each adding value with inputs, transformation processes, and outputs.

Some activities come under only one pillar while others fall under the combination of two pillars. Here is the list of planned engagement activities:

- It is paramount to support the enhancement of networks tackling local, national, regional, and global specific OA issues.
- The development of autonomous, programmable, low-cost instruments with the necessary electronics and sensors to measure pH and temperature of seawater.




- The development and strengthening of the capacity to monitor, document, and analyze the changes in pH and $\Omega_{aragonite}$, in the effects on the coastal ecosystem through the development of an underwater pH, salinity, and temperature sensor.

Figure 4: Conceptual structure for an ocean observing value chain designed to match the original structure of the Framework for Ocean Observing (FOO). *Adapted from the FOO, 2012.*

- Identification of potential funders and development of diverse sources of funding (e.g. for instruments and maintenance and/or return to companies for maintenance) are critical to delivering the above-mentioned outputs. OARS should liaise with the corporate world through for instance the World Ocean Council or the Global Association of Risk Professionals to activate the private sector in "natural capital" so that they set up venture capital funds to invest in ocean climate solutions sourced from ocean science institutions. Insetting[1] is a way for companies to harmonize their operations with the ecosystems they depend upon and transition to a more sustainable business model. OARS could team up with companies to build Insetting projects along companies' value chains that are designed to generate GHG emission reductions and carbon storage, and at the same time create positive impacts for communities and ecosystems.
    - Present exemplars include the Ponant Science capacity building platform R/V Commandant Charcot icebreaker which sails in the Arctic and Antarctic, the Pier-2-Pier program run by The Ocean Foundation (TOF), the Partnership for Observation of the Global Ocean (POGO) to list a few. By engaging with these stakeholders, increased accessibility to funding is expected. Active participation of private sector partners (e.g. Aanderaa Data Instruments AS) in capacity-building events will certainly favour companies' awareness and potential reduction in the cost of equipment and in instrument maintenance for developing countries.
- To maximize the use of infrastructure, it is timely to stop breaking up all observing networks and to promote greater integration between the global OA observing network and other observing networks, focusing on related measurements.
- The development and validation of proxy algorithms of the aragonite saturation state using hydrographic data that is intended to be applied in sites where aquaculture is practiced.

[1] https://www.insettingplatform.com/insetting-explained/

- Generate relevant information to evaluate the changes and trends of ocean acidification on the coasts that are useful for the aquaculture sector.
- Provide advice and experience on these issues to other groups from different countries, starting in priority regions most vulnerable to acidification.
- Generate environmental information on vulnerable regions that will support future research related to the potential impacts of climate variability and change on natural and socioeconomic systems, know the degree of interest and availability of aquaculture producers (e.g. oyster farmers) around the world to adopt digital platforms to obtain environmental information (coastal monitoring system) and evaluate their perception of OA.
- A platform will be provided enabling continued communication and more open access between different stakeholders to ensure governmental, private, and UN support to OA observing efforts and the application of the produced data and information. Planned exemplars include for instance dissemination of an ad-hoc stakeholder questionnaire for aquaculture companies in Mexico, and increased production and dissemination of Chilean CEAZAmar Bulletin types to contribute to the education of the younger generation and general public globally.
- The development of cheaper and more readily available CRMs (increased access) should be undertaken along with the promotion of adherence to international standards (link with OARS Outcome 1)
- The development of capacity and mentoring of early career scientists (link with OARS Outcome 1), of the general public (link with OARS Outcome 6), of policymakers (link with OARS Outcome 7) and of stakeholders and funders (OARS Outcome 3) is definitely a transverse fundamental action within OARS.
- Upcoming exemplars include the GOOD/OARS International Summer School in Chile SS2023 in November 2023, and initiatives to be co-led with the Ocean Teacher Global Academy (OTGA), GOA-ON-TOF, and POGO.
- The world of databases needs to be reshuffled to ultimately build harmonized, interoperable, reliable and open access databases which can be used for climate science, and this means improving data infrastructure.
- Development of the capacity of countries to measure and report OA data as part of the SDG indicator 14.3.1 process and to achieve the SDG target 14.3 should be our UN Decade endeavor.

**Key inputs and enablers**

Key **inputs** to support these engagement activities will require intellectual resources (expertise and strategic vision), data and information, dedicated commitment from members of our scientific community and of the private sector, availability of equipment, infrastructure, and funding. We will have to consider possible strategies for implementation, e.g. either prioritize some key actions to lead globally, then when achieved, move on to others, or pragmatically push for certain actions in some parts of the world and others in other parts, making sawtooth plan progression. Pragmatism is key since actions need to be initiated **now** and produce results.

To achieve proper delivery of Outcome 3, key natural **enablers** include both OARS co-chairs, all OARS co-champions and their Working group members, the GOA-ON Secretariat, and all possible funders from the public and private sectors. Everyone is an ocean stakeholder so ultimately all nations should invest in ocean observation as a consortium, the way they do in the International Space Station. Humankind has been determined to understand the origins of life on planet Earth. Similarly, humankind should show an unwavering will to build the future trajectory of Earth's climate toward sustainability, habitability and well-being. It is not enough to know where we come from, we also need to shape where we go. And within a healthy and resilient ocean, sustainable and productive, clean and safe, predicted, transparent and accessible, inspiring and engaging, lies our future.

## Conclusion and perspective

Following this roadmap, WG OARS Outcome 3 efforts will be instrumental in meeting our ultimate challenge: contributing to designing policies for balancing the needs of human development with environmental protection to preserve the ocean from irreversibly turning sour.

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