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Food for Thought

Co-designing a multidisciplinary deep-ocean observing programme at the Mid-Atlantic Ridge in the Azores region: a blueprint for synergy in deep ocean research and conservation

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Under the umbrella of the Deep Ocean Observing Strategy (DOOS) and the All-Atlantic Ocean Observing System (AtlantOS), researchers at the Okeanos—University of the Azores, local stakeholders and authorities, and the deep ocean science community are adopting a co-design approach [which, as highlighted by the Global Ocean Observing System (GOOS), the co-design concept aims to combine the knowledge of diverse experts and stakeholders to create innovative approaches to meet stakeholder needs in ways beyond what could be achieved by any one of those involved working alone] to create a deep-ocean observation project to strengthen deep ocean observing capacities in accordance with users' and societal needs. The demonstration project discussed below builds on decades of co-design in collaborative efforts in the Azores Archipelago between science, private entities, governmental institutions, and local authorities for science-based management (Santos *et al.*, 1995). Already in the 1980s, several Marine Protected Areas (MPAs) that impose fishing limitations to promote the sustainable use of marine resources were established by this collaborative effort (Santos *et al.*, 1995). During the 2000s, the joint effort between the Regional Government of the Azores and the University of the Azores resulted in the inclusion of 11 sites in the Oslo Paris Convention for the Protection of the North Atlantic (OSPAR; https://www.ospar.org/) MPAs' network. This made Portugal, and particularly the Azores, a pioneer in the protection of marine biodiversity at an international level (Ribeiro, 2010), and an important progressive player in the ground-breaking OSPAR high-seas MPAs process (Abecasis *et al.*, 2015).

The initial local efforts to establish these protected areas were based on the appraisal of benthic ecosystems by extensive mapping of invertebrate and fish communities. Soon it

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was realized that the focus needed to be extended beyond communities to the entire ecosystem to allow for systematic conservation planning and area-based policies that promote the conservation and sustainable use of deep-sea natural resources. An improved understanding of how oceanographic processes and water masses shape the diversity, composition, connectivity, and distribution of benthic communities, for present and future ocean conditions, was identified as a key knowledge gap. This calls for integration of community mapping with continuous observations and numerical modelling simulations of physical, biogeochemical, and ecological variables, and would require a wide range of monitoring platforms, approaches, and programmes. Additionally, understanding social and economic impacts requires transdisciplinary work that engages local and international users of these resources.

In order to address these challenges, the Okeanos—University of Azores engaged with DOOS, a GOOS project and a UN Ocean Decade-endorsed programme (https://www.oceandecade.org/actions/deep-ocean-observing-strategy) to extend the local co-design focus to a wider ocean observing community. It was agreed to co-develop a "deep ocean demonstration project" that serves the local stakeholder needs and, at the same time, showcases the feasibility and benefit of multidisciplinary ocean observations and thus facilitates the implementation of a deep-sea observing system on larger scales (Levin *et al*., 2019). DOOS connected with the NOAA Ocean Exploration and Research team to implement deep-ocean observation targets for the "Voyage to the Ridge 2020" mission with RV Okeanos Explorer that had to be postponed due to the COVID-19 pandemic. To keep the momentum, DOOS and the Okeanos—University of the Azores engaged in several initiatives in the field of ocean observation to explore possible collaborations to advance the Azores demonstration mission, including AtlantOS, GOOS, and the Marine Biodiversity Observation Network (MBON), and sought to advance the co-design with the Atlantic International Research Centre (AIR centre), also located in the Azores.

As a first step, DOOS and AtlantOS held a joint community workshop in June 2021 to work towards a joint Azores deep ocean observation project that combines the DOOS demonstration project with the AtlantOS Use Case (http://www.atlantos-ocean.org/page22.html) approach. The workshop discussed co-design strategies for an integrated deep-ocean observation project to address local needs and develop a blueprint for future implementation on a larger scale. Workshop participants represented existing and planned observation programmes as well as global initiatives to integrate and standardize ecosystem observations and modelling approaches. Discussions converged towards a project theme that focuses on communities of deep-sea organisms in a changing and heavily used oceanic area, with emphasis on the drivers of their spatial distribution and potential future trends, including biogeochemical and oceanographic modelling. During the iDOOS 2022 Annual Meeting (https://www.deepoceanobserving.org/pages/annual-meeting-2022), a follow-up workshop organized by a DOOS working group that includes scientists from the Azores and deep-ocean observing community members, identified the observation needs, gaps, and priorities, and discussed implementation means and opportunities.

In the coming years, DOOS and AtlantOS will facilitate the growth of this co-design effort and the engagement of stakeholders, including policy makers, business, society, and relevant UN bodies, to promote science-based decision-making (Levin *et al*., 2022). Much more than traditional metrics of success, such as funding and publications, the ultimate success of this effort will be in a process, and perception shift. This includes the creation of processes for resource and knowledge sharing that can be perpetuated into the future, where data from international programmes are freely shared in interoperable formats, and communication lines remain open to share resources—for example, ship berths and deck space for instrumentation deployments. Examples of this open communication and resource sharing that have already emerged from discussion at the workshops are (1) integration of the European Multidisciplinary Seafloor and water column Observatory (EMSO)–Azores to improve the understanding of the dynamics of hydrothermal ecosystems and the assessment of anthropogenic impacts, for example, pollution and mineral resource exploitation (Sarradin *et al*., 2021); (2) collaboration with global initiatives and programmes [e.g. Argo network (Roemmich *et al*., 2019)] as well with the industry [Joint Task Force (JTF) SMART Cables (Howe *et al*., 2019)] and the Regional Government of the Azores (oceanographic multiparametric buoys from LIFE-IP CLIMAZ and PO Azores 2020) to provide long-term oceanographic data to understand the diversity and distribution of deep-sea ecosystems and their fate under future ocean conditions; (3) collaboration with ocean technology programmes (e.g. EU Glider network), as well as private companies, to provide necessary tools for the collection of these physico-chemical, biological, and environmental data; and (4) connection to global initiatives (e.g. Marine Life 2030, MBON, the Ocean Biodiversity Information System/OBIS, and the Ocean Best Practices System/OBPS) to facilitate alignment with international standards and procedures. Ultimately, this co-design will help create informed strategies for the sustainable management and conservation of the deep ocean ecosystem.

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Conflict of interest

The authors declare that the work was conducted in the absence of any commercial or financial relationships that could be considered as a potential conflict of interest.

Author contributions

MP led the preparation of the manuscript. All co-authors provided significant input to the manuscript text.

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Data availability statement

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