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Editorial: Data acquisition and processing strategies for the development of ecological indicators in the exploration and monitoring of deep-sea ecosystems under natural and anthropogenic changes

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Editorial on the Research Topic

Data acquisition and processing strategies for the development of ecological indicators in the exploration and monitoring of deep-sea ecosystems under natural and anthropogenic changes

Over half a century ago, following the development and integration of the adequate technology, the deep sea transitioned from being the last frontier for exploration on our planet to the subject of industrial-level exploitation. While the main impacts in the deep sea are currently the product of large-scale fisheries and offshore energy production (mainly oil and gas), the expected transition of the global economy towards greener (or, in this case, bluer) solutions will likely include the use of the marine domain as a setting for renewable energy infrastructure (e.g., floating wind farms loosely anchored to the seabed) and seabed mining for rare minerals that are fundamental to the renewable energy technologies. Despite the risks posed by these impacts, the development of robust management guidelines for deep-sea habitats and resources has not kept pace with technological progress and growing economic forces. As a result, this highlights an opportunity to develop standardized methodologies, goals and overall strategies. To achieve this, it is imperative for scientists and managing authorities to reach a high level of consensus in both data acquisition and treatment, as well as in reliable ecological indicators to track both natural and human-induced ecosystem changes.

Efforts should focus on taking advantage of established and developing technologies for monitoring deep-sea ecosystems. To guarantee efficiency and flexibility/interoperability for any special case within a common approach, sensors should be combined in smart, interchangeable payloads built into intelligent platforms. These should, in turn, operate in tandem within coordinated missions that are tailored to characteristics of the monitored ecosystem. In addition, the establishment of ecological indicators that are reliable, informative, and comparable across different target ecosystems requires the development of holistic, Ecosystem-Based Management (EBM) approaches. These are encouraged by global initiatives under the Convention on Biological Diversity and EU policies (e.g., Marine Strategy Framework Directive, Maritime Spatial Planning Directive and EU Biodiversity Strategy 2030, among others). EBM approaches should also include the responsible allocation of resources in data acquisition strategies and data treatment methodologies. Both operational and theoretical/strategic aims should facilitate the ultimate objective of conservation programs, enabling well-informed management decisions.

Based on the principles summarized above, this Research Topic presents opinion/review contributions and a case study on how to approach these questions/requirements. In particular, EBM approaches and their principles are prominent and serve as the connecting link of the three manuscripts published in this special Research Topic. This is particularly highlighted, as the manuscripts cover a broad range of diverse ecosystems (i.e., shelf, slope abyssal and pelagic habitats, muddy and rocky bottoms, submarine canyons and artificial offshore sites in the Mediterranean, Atlantic and around the globe in Areas Beyond National Jurisdiction – ABNJ, among others), species, and data acquisition approaches.

Aguzzi et al. review the limitations of current stock assessment methodologies for a key target species for European fisheries, the Norway lobster *Nephrops norvegicus*, in the Atlantic and the Mediterranean. They argue that the uncertainties in the data generated by conventional UnderWater TeleVision (UWTV) surveys could be readily addressed by the complimentary and coordinated use of cameras on stationary (e.g., landers) and mobile (e.g., AUVs, crawlers, biomimetic robots, etc.) robotic platforms, combined with molecular (e.g., environmental DNA – eDNA), acoustic (e.g., tracking by telemetry) and other optic (e.g., laser-scanning) methods. They also argue that the development of Artificial Intelligence tools will accelerate data processing and enable monitoring to expand beyond *N. norvegicus*, and thus take into account the associated community and the relevant environmental variables within an EBM.

Maiorano et al. used experimental trawl surveys down to 800 m depth to assess the status and tendencies of benthic, demersal and benthopelagic faunal assemblages in the Ionian Sea. They detected two clearly distinguishable deep-sea faunal assemblages (i.e., epi- and mesobathyal), while also unveiling a reduction in biodiversity and species evenness in association with a growing dominance of some taxa between 2012 and 2020, at the expense of diversity and evenness. Furthermore, community structure of the demersal and benthopelagic fauna appears more stable than the less specialized benthic community that is characterized by generalists. The authors conclude that, due to the presence of Essential Fish Habitats for commercial species in that area, EBM spatial planning must be taken into account to optimize both marine environmental conservation and the exploitation of resources.

Finally, Bravo et al., review the state-of-the-art approaches in monitoring offshore energy-resource industry sites (gas, oil, wind, wave, thermal, hydrogen current and biofuel-based energy, among others). In addition, they discuss how novel technologies and data collection strategies can provide robust indicators of ecosystem services. The authors discuss the current management frameworks and how ecosystem services could be moving towards the direction of EBM through the collaborative work of the scientific community, industry and managing authorities. Finally, the authors wrap up their discussion identifying the ecological, technological, capacity, best practice, and activity coordination priorities for a more holistic approach in the management of offshore industry sites.

This Research Topic provides a step towards the integration of scientific and technological knowledge into a common strategy for deep-sea monitoring and management over an array of different habitats facing a wide-range of potential threats.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

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

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