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Reply to: Ecological variables for deep-ocean monitoring must include microbiota and meiofauna for effective conservation

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REPLYING TO J. Ingels et al. *Nature Ecology & Evolution* https://doi.org/10.1038/s41559-020-01335-6 (2020)

Meiofauna and microbes are key components of deep-sea ecosystem assessments and were included among the list of essential variables in our recent comprehensive assessment and prioritization of a global deep-ocean monitoring and conservation strategy[1]. Meiofauna ranked in the top three variables, whereas microbes (bacteria, and archaea) were reported as key variables for some aspects of monitoring the deep sea. However, larger components of the deep-sea fauna (such as macro- and megafauna) received the highest priority.

In their Matters Arising, Ingels and co-workers[2] criticized the ranking because, in their opinion, macro- and megafaunal components cannot be considered higher-priority variables than microbes and meiofauna. They concluded that this result reflects an unequal distribution of the competence of the authors and of the respondents to the elicitation survey. However, their criticisms are unjustified for conceptual, methodological and operational reasons.

On semantic and theoretical grounds, Ingels et al. confused the concept of priority with that of relevance/importance. Ingels et al. seem also to confound the concept of monitoring and protecting with the importance of research for advancing scientific knowledge; these are two partly related, but distinct, objectives. Indeed, recognizing the ecological importance of one biological component is one thing, but identifying the monitoring variables where capacity to deliver for conservation management globally is well established, is quite another. We cannot apply the same monitoring and conservation approach to all biological components because small organisms, such as prokaryotes, protists and meiofauna encompass massive numbers of undescribed species with largely unknown ecologies[3,4] and shorter turnover times, which may make them more resilient to disturbance than larger biota.

Even an ocean completely depleted of large fauna, for example, sharks and all predators, would remain flush with meiofauna and microbes. Yet, a deep-sea system with abundant meiofauna and prokaryotes would almost certainly function poorly without higher trophic levels. This well-known ecological principle is certainly one of the reasons there was a wide consensus among the 112 experts (including the microbiologists and meiofauna experts who participated in the expert elicitation) on censusing larger species to protect vulnerable habitats they inhabit or create. The much more limited evidence for microbial and meiofaunal endemicity, the great proportion of unidentified species and the lack of life-history information, greatly compromise any proposal to use these components as proxies for monitoring and mapping conservation areas. Thus, the results of the expert elicitation, on the one hand, reflect the maturity of the disciplines and the capability to deliver indicator information and, on the other hand, recognize the role of larger organisms in current conservation priorities, while acknowledging fundamental roles of all groups.

Another important aspect overlooked by Ingels et al. is that deep-sea biodiversity was only one of the five main research areas addressed by the study. In the second research area we considered, which was dedicated to ecosystem functions, benthic faunal biomass and benthic faunal production were ranked as top variables (see table 1 in Danovaro et al.[1]). Because meiofauna and microbes typically dominate benthic faunal biomass at abyssal depths[5,6], we took care to emphasize the functional role of microbial compo-

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nents: "microbes (primarily bacteria followed by archaea) largely dominate overall biomass and production. These microscopic components, essential for deep-sea ecosystem functions … we stress microbial heterotrophic and chemoautotrophic C production as two essential ecological variables needed for understanding the key processes sustaining the functioning of deep-sea food webs and biogeochemical cycles".

We also strongly disagree with the methodological criticisms of Ingels et al. As scientists, we endeavour to remove all potential sources of bias in the framework of standard good practices for data evaluation. Our study is based on expert elicitation, which is a procedure to find consensus on priorities, not an experiment with treatments and controls; thus, standard deviations cannot be treated as in ecological experimental designs. Our Perspective describes how we endeavoured to achieve an objective methodology (that is, coverage of different research fields and knowledge for each of the five main themes, scientists covered a broad range of geographic regions, different taxonomic expertise, academic qualifications and years of experience). These aspects, including statistical treatment, were discussed in detail using multiple rounds of enquiries, following rigorous procedures[7], and were presented transparently in the supplementary information of our paper[1]. To our knowledge, the 112 scientists participating in this elicitation make this study the widest deep-sea community ever to participate in defining priorities based on standardized questions.

Ingels et al. assumed that microbial and meiofaunal components were not prioritized because most of the respondents were macrofaunal or megafaunal experts. However, this is not evident in our data, because a large fraction of respondents covered multiple fields of expertise (note that the supplementary information[1] reported only one main topic per scientist). Their criticism suggests that deep-sea scientists are divided into two groups: micro- meiofaunal experts competing against macro- megafaunal experts, fighting to prioritize their own work, rather than a community working together towards a common objective. Obtaining expert opinions for comprehensive deep-sea management, as we did, requires the involvement of scientists working in different sectors (such as deep-sea technologies, conservation biology, biological oceanography, biogeochemistry, policy and management), thus participants cannot simply be classified as experts by faunal size category. The fact that many scientists, in responding to the questionnaire, did not automatically prioritize their own research specialty for deep-ocean monitoring, conservation and impact assessment suggests that this is a false and non-productive dichotomy. Accordingly, we reaffirm that the expert elicitation reported in Danovaro et al.[1] is robust, accurate and balanced, and simply reflects the prioritization of the groups of organisms/habitats and associated variables to monitor in light of anthropogenic impacts, conservation needs and currently available technology, feasibility and knowledge.

In operational terms, environmental monitoring, especially in the deep sea, requires ready-to-use technologies and methods that are employable, which greatly influences the choice of monitoring priorities and rankings of the consulted experts. Our paper innovatively coupled this need with the readiness levels of the described technologies. We agree that the scientific community should do more to document the importance of small organisms, to establish and disseminate the best standardized practices for collecting such observations and to increase our knowledge of undescribed species and their ecological roles to use them more effectively in future monitoring plans, particularly in light of the ongoing effects of global change[8–10].

At the same time, no marine protected area (in both shallow waters and in the open ocean) or other conservation initiative anywhere targets the loss of meiofaunal or microbial diversity. The reference to the Marine Strategy Framework Directive (MSFD 2008/56/EC), designed to address the Good Environmental Status of marine ecosystems (including the deep sea), does not support the position of Ingels et al.[2] as the analysis of deep-sea biodiversity in the MSFD is, at present, limited to species of commercial interest and deep-water corals. None of the European directives prioritize meiofauna or microbes. Moreover, to the best of our knowledge, there is no single ongoing, nor planned, monitoring strategy of a national agency based on or prioritizing microbial or meiofaunal diversity in their standard protocols. Given the current limitation in the use of high-throughput sequencing (for example, for the identification of meiofauna[3]), further efforts are thus necessary to better integrate microbes and meiofauna in future monitoring and conservation programmes. To do this, the global deep-sea community must encourage joint efforts, share common goals and use standardized tools.

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Competing interests

The authors declare no competing interests.

Additional information

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