The MBON plankton workshops: "Plankton ecosystem function, biodiversity, and forecasting - research requirements and applications"

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Introduction

Plankton functional diversity is at the core of various ecological processes, including productivity, carbon cycling and sequestration, nutrient cycling [1], interspecies interactions, food web dynamics and structure [2]. Through these functions, plankton play a critical role in the health of the coastal and open ocean and provide essential ecosystem services. Yet, at present, our understanding of plankton dynamics is insufficient to project how climate change and other human-driven impacts affect the functional diversity of plankton. That limits our ability to predict how critical ecosystem services will change in the future and develop strategies to adapt to these changes.

The Marine Biodiversity Observation Network (MBON) [3], with the support of the Modelling Different Components of Marine Plankton Biodiversity team (MODIV) [4], organized four virtual workshops (first in November 2020, second and third in October 2021 and fourth in November 2021) titled: "*Plankton ecosystem functions, biodiversity, and forecasting - research requirements and applications*" [5]. The first workshop held in November 2020 was an initiative of the US-MBON and MODIV teams to bring together members of the ocean sciences community involved in plankton observing and modelling to meet, build rapport, and exchange expertise. The following workshops were organized by geography to accommodate time differences: one for South, Central, and North America; one for Africa, Europe, the Middle East, and India; and one for East Asia and Oceania. Each workshop was held for two consecutive days, and participation was limited to 20-25 participants per workshop to enable interactive discussions [5]. In total, 80 participants from 26 countries attended the workshops (Fig. 1). The United States of America and Australia were the countries with the most participants, followed by Canada, Germany, China, the United Kingdom and Argentina.

The objectives of the workshops were: (1) the identification of requirements with respect to the definition of Essential Ocean Variables (EOV) and associated measurements, as well as the compilation of the necessary data needed to address critical knowledge gaps related to the role of plankton biodiversity functions to provide ecosystem services; (2) discuss ways to better link empirical observations to theoretical concepts of plankton biodiversity and ecosystem dynamics; and (3) suggest methods to better communicate the value of plankton to peers and non-scientific audiences.

Data Requirements

The workshops reviewed some current empirical and theoretical methods to study plankton biodiversity. Discussions focused on ways to advance monitoring efforts, understand and use the concept of EOVs and Essential Biodiversity Variables (EBVs) to identify ecological processes that drive plankton diversity that can be studied with available data, and how observation networks such as MBON can help with model validation and forecasting. The main limitations highlighted in the workshops were:

1. The minimal use of existing standardized frameworks for data collection, taxonomy reporting, unit conversion, and reporting of uncertainties, the lack of global geographic coverage and data availability over time present major challenges for the community [6].
2. Most traditional plankton data are reported in global repositories and databases as bulk abundance (counts) or biomass (weight, carbon, or nitrogen content), without reports of traits or taxonomic identification beyond broad categories such as 'bacteria', 'phytoplankton', or 'zooplankton'. To better understand biodiversity and its link to ecosystem function, we need data that include species (or the highest taxonomic resolution available for each sampling and analysis method, such as Molecular Operational Taxonomic Units (OTUs), Metagenome-assembled genomes (MAGs) for novel metagenomic data or genus and family information for imaging data,

etc.), rates (e.g., growth, respiration, ingestion, evolution and acclimation rates as a response to environmental condition), stoichiometry and traits (e.g., lipid content, size, foraging mode, behaviour).

3. We also continue to have little or contradictory empirical data on how dissolved CO_2 impacts plankton diversity and marine carbon export. Earth System Models are sensitive to even small changes in rates (growth, grazing, remineralization, respiration), with substantial differences in carbon flux projections. Empirical data are fundamental to refine parameterizations and support more robust predictions.
4. Access to (historical) data varies based on countries; many have little to no available data, and many have data that are not openly available. However, since multiple international funding agencies have started to request that all project data become publicly available after the end of each funded project, this situation has been much improved in the recent decade.
5. Incentives are needed for observers to share data via existing databases and not to create new databases. Such incentives could include having the database destination (e.g., "OBIS" [7]) that provides qualified staff who will help scientists reformat, document and quality control their data and metadata and then assist the observer with attaining a Digital Object Identifier (DOI).
6. For model validation and testing hypotheses for biodiversity drivers, it is essential that plankton data - including plankton EOVs - are available together with physical and biogeochemical EOV data/metadata (environmental data along with physiological and functional trait data). International data archives should be used to generate lasting links between different data types measured during the same project.
7. Omics can help identify dominant genes expressed in the environment and can be related to important traits (e.g., nitrogen fixers; nifH gene). Still, the use of omics in modelling remains a challenge, especially for metazoans, as the data are often only an index of presence and not of absolute abundance, and at present, do not provide a direct quantitative estimate of rates included in models (e.g., respiration, photosynthesis, protein synthesis).
8. Trait-based or gene-based methods can bring new insights to ecophysiology and species distributions. Still, at present, they cannot be easily related to historical plankton abundance and biomass data that are expressed only in terms of bulk abundance or biomass.
9. Insufficient funding and training opportunities lead to a diminishing pool of skilled taxonomists and other plankton specialists and pose a substantial threat for the integration of future field observations, taxonomic work in the laboratory, data interpretation, analysis and synthesis.

Participants discussed possible actions to overcome these limitations. There was agreement that observations in natural ocean habitats are fundamental to the formulation and testing of new hypotheses and conceptual models. More active communication between data providers and users will benefit the data collection, interpretation and analysis, and usability. For example, data that allow quantifying relationships among species traits (e.g., size, stoichiometry) will help inform species responses to environmental conditions. Although participants agreed that there is a lack of standardization of methods, data formatting, distribution methods, in addition to information on data quality and uncertainty, they also recognized the challenges of establishing a global protocol for field practices considering the regional environmental differences. For example, a net with a smaller mesh size is needed in tropical regions because plankton body size generally declines with warming [8] or a net with a larger mesh size and towed faster is needed if the target is euphausiids rather than copepods. As a solution, they suggested the use, further expansion and explanation of existing protocols as best practices, and the set of minimum data and measurements required for data synthesis be laid out. Additionally, the creation of a community-driven unit conversion policy will help to normalize between datasets and allow a better understanding of variability and uncertainty. These approaches can help develop and validate models and minimize the uncertainty in data meta-analysis studies.

As a community, we need to build capacity at three levels: taxonomic ability, data science, and data management. We need to highlight the fundamental role of taxonomists in providing high-quality data, and of data scientists for data meta-analysis and synthesis. Databases should follow Findability, Accessibility, Interoperability and Reuse (FAIR) principles, credit and recognize the original data providers. Sufficient funds for the curation and archiving of project data should be included in future funding proposals at the national and international levels. The ideal scenario for data users is interlinked data repositories, standardized conversion tables, interoperable data collection protocols, and documented uncertainty levels. Each is a rather challenging task. As a first step, participants recommend an inventory of plankton databases with a summary of their holdings (e.g., the geographic area covered, time covered, types of plankton data included, information on data format and access [e.g., 9]).

The value of plankton

Plankton are valuable through their provisioning of ecological, biogeochemical services that enhance the cultural and economic value of the marine environment. They are responsible for approximately half of the Earth's oxygen production and photosynthetic carbon fixation [10] and play the fundamental 'bio' role in biogeochemical cycling of carbon, nitrogen, oxygen, and many other elements. They are linked through the food web to higher trophic levels and generate economic and recreational benefits for humans. Plankton are involved in feedback processes that affect the evolution and survival of all marine species [1] and promote marine biodiversity such as fish, benthic organisms, marine and even terrestrial birds and mammals. Yet, the value of plankton is mainly invisible and difficult to quantify, mostly because the public is aware of the ultimate ecosystem service delivered, but not the underlying ecosystem functions of organisms that deliver that service (e.g., the connection of plankton to fish and fisheries).

Many participants highlighted that public awareness of plankton is usually for negative reasons, such as blooms of pathogenic bacteria, harmful algae, or jellyfish. Quantifying in economic terms, and illustrating the link between plankton biodiversity and things we value (e.g., iconic species, recreational activities, water quality, carbon storage, nature conservation) will highlight the value of plankton to policymakers and the public. Citizen science, education, science-art projects, and outreach activities are important ways to raise this awareness. There are many plankton-related outreach activities for all ages, but as outreach is commonly the least-funded component of scientific projects, it is imperative that we find ways to advance them. Models, virtual reality, and artificial intelligence could also be further developed as a heuristic educational tool. One way to improve awareness is to integrate social scientists and those involved with science advice and policy into the development of research grants, approach mass media communication, and also consider the Decade of Ocean Science for Sustainable Development (2021–2030) proclaimed by the United Nations [11].

Next Steps

As we consider the challenge of monitoring the global ocean to understand and mitigate the negative effects of human activities and climate change on marine ecosystems, data remain the foundation for integrating empirical and theoretical approaches to deliver robust projections for policy and decision-making. The MBON plankton workshops provided an international space for data providers and data users to come together, discuss science and consider new collaborations. Participants agreed that data consistency, comparability and wider availability are necessary to move forward. They also highlighted the importance of better ways to communicate the value of plankton to scientists in various disciplines (e.g., fisheries, socioeconomics, policy) and to the public. As next steps, the participants decided to create two international groups to develop and publish:

(1) A synthesis paper on the current limitations in data collection, analysis and accessibility, recommendations to overcome them, and ways to create common standards for data harmonization.

(2) A perspective paper on the value of plankton, written by a coalition of peers from diverse fields (oceanography, education, economics, art, citizen science).

Authors contributions

All authors acted as chairs and note-takers during the workshops. MG, FKM, EM, AJR, JDE, EAT, CA, BC, CL, AP, FP, JR, SV, MV and SZ organized the workshops. EM designed the website. MG, FKM, AJR, JDE, CL, and JR wrote the manuscript with the contribution of all authors. All authors gave feedback on the manuscript before submission. The authors declare no conflict of interest.

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Figure 1: Global map depicting the countries of residence of the participants who joined the MBON "Plankton ecosystem function, biodiversity, and forecasting - research requirements and applications" workshops in November 2020, October and November 2021. The colorbar shows the number of participants per country. In grey: countries with no participants.