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Geohistorical perspectives on functional connectivity patterns

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Across the marine environment, the movements of living organisms facilitate the flow of matter, genes, and energy at various temporal and spatial scales, and they are collectively referred to as Marine Functional Connectivity (MFC; Darnaude et al. 2022). Human activities and climatic change have strong impacts on MFC today, but the scientific community struggles to disentangle and evaluate them due to the lack of long-term, pre-impact monitoring data, and their unprecedented nature. Geohistorical data (i.e. data from Earth and human history) can be instrumental for identifying baselines and deciphering long-term trends and the variability of MFC, resulting from changes in the distributions, life histories, and migration of species, which may be due to natural or anthropogenic causes (Fig. 1).

Historical records include documents, paintings, museum collections and archaeological artifacts (i.e. evidence of human activities), and organismal remains (e.g. shell middens). These can be used to track the pathways, rates and consequences of species distributions and movements at decadal to millennial timescales. Additionally, they provide information on how human activities have contributed to functional connections and disconnections. For instance, the transport of non-indigenous species along shipping routes ("hitch-hikers" on wooden hulls), and for aquaria and aquaculture, has been documented from at least the 1200s (Hoffmann, 2023; Holm et al. 2019; Lotze et al. 2014), whereas the more recent construction of physical connections, such as the Suez Canal, has led to unprecedented rates of biological invasion (Por 1971).

Geological records, on the other hand, include fossils, sediments and the biogeochemical data that can be derived from them. These provide information about changes in species distributions and ecology and the consequences on MFC of natural environmental changes at millennial to million-year timescales. Sclerochronologic and genetic methods applied to fossil remains (e.g. mollusc shells, mammal bones and teeth, and fish otoliths) further offer high-resolution reconstructions of the life histories of marine organisms and can be used to identify evolutionary events and past environmental changes.

This workshop organized by the Q-MARE working group (pastglobalchanges.org/q-mare), brought together 20 scientists from 10 countries, covering a wide range of disciplines ranging from ecology and paleontology to archaeology and history (pastglobalchanges.org/calendar/134692). The aim was to draft a research roadmap that explores how to obtain and use geohistorical data in the study of MFC. Reiterating the definition of MFC for the workshop participants, the meeting started with the presentations of historical examples and case studies of MFC, and continued with discussion in groups, and altogether, around three main questions: 1) What geohistorical data could be used to understand MFC?; 2) What resources are available for such work?; and 3) How should these data be analyzed and interpreted?

The diversity of data types and resources echoed the multidisciplinarity of the group (Fig. 1). Fossils and their assemblages, historical archives, archaeological remains, ancient DNA, and biogeochemical data can give information on MFC at multiple different temporal and spatial scales. Both vertical and horizontal seascape connectivity can be inferred, as well as the role of long-term drivers of MFC. The group identified specific archives and resources that are available, openly accessible or not, and noted information on how to access them. For each data type, we described the information captured, and any challenges associated with its use and analysis. We highlighted the role of proper recovery and identification of fossil, historical and archaeological material in the correct interpretation of the results. For each of these different data types, we identified examples that illustrate their contribution to understanding MFC. Finally, we concluded with the goal to publish the roadmap in the upcoming months, so stay tuned!

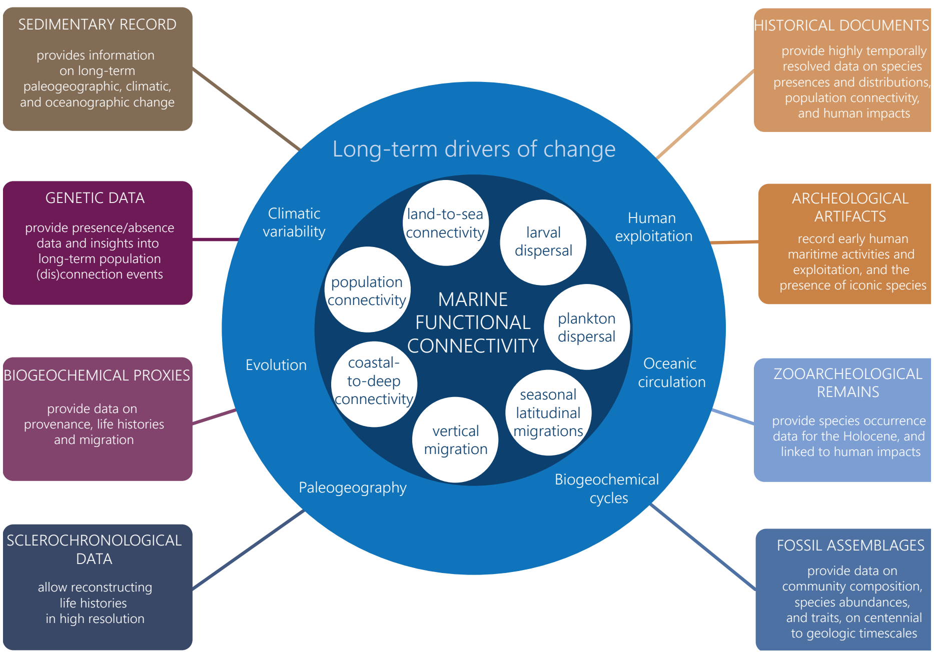

Figure 1: Overview of Marine Functional Connectivity (MFC) processes, their long-term drivers, and how geohistorical data can help unravel their changes over time.

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