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CENTRE FOR THE SYNTHESIS AND ANALYSIS OF BIODIVERSITY

Project summary

FORCIS

Foraminifera response to Climatic Stress: evaluating biodiversity changes of calcifying zooplankton in response to multiple stressors

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The FORCIS project investigated the response of planktonic foraminifera to climatic stressors by analyzing global datasets dating back to 1910. Its objectives were to compile a comprehensive database, identify key environmental drivers, and model past and future responses of these organisms to global change.

Context and objectives

Planktonic foraminifera remain understudied in modern oceans for several reasons: they are scarce in the water column, difficult to maintain in laboratory cultures, and lack a comprehensive diversity database. Their intermediate size (63–500 µm) places them between two traditionally studied groups —nanoplankton and mesozooplankton— while research has historically focused on their

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geological applications. These factors have created a disconnect between three disciplines: marine biology, micropaleontology, and paleoceanography, each of which approaches these organisms from a different perspective.

Despite the challenges of studying living foraminifera under experimental conditions, the wealth of species-level census data available from plankton samples now allows for the investigation of their biodiversity across spatial and temporal scales within a coherent ecological framework.

Methods and approaches used for the project

Understanding the recent response of planktonic foraminifera to global environmental changes has been made possible by compiling a global census of their abundance based on historical plankton samples. The FORCIS database brings together information from scientific publications, dissertations, cruise reports, and archival sources, often digitized from legacy datasets. It includes samples collected using four main methods: plankton nets, water pumps, Continuous Plankton Recorders (CPR), and sediment traps, amounting to **over 188,000 samples**.

With this comprehensive dataset on abundance and biomass, FORCIS provides a solid framework for validating models that investigate the impacts of environmental stressors on plankton communities. These models, now supported by new empirical data, enable **more accurate predictions of how planktonic foraminifera may respond to future climate change**. They also allow for quantitative estimates of the production of shell carbonate and organic carbon by these organisms under various climate scenarios established by the IPCC.

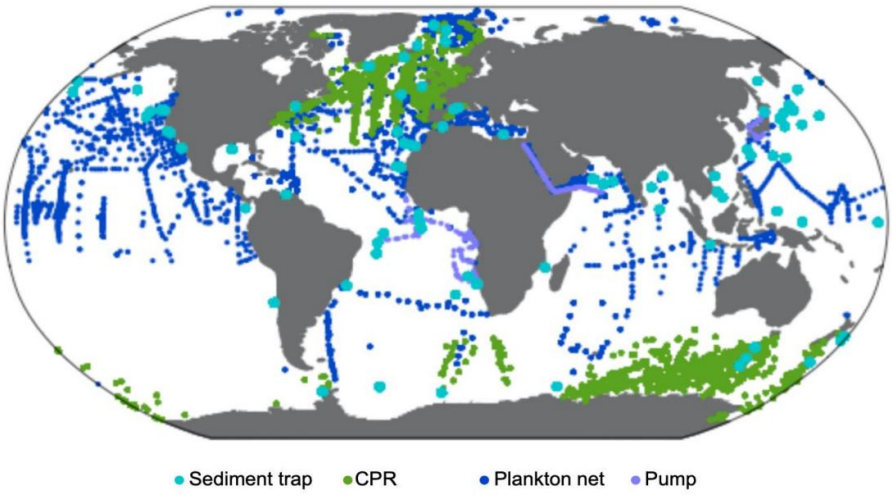

Fig. 1. Geographic locations of all records included in the FORCIS database.

Principal conclusions

The FORCIS database provides an initial overview of the global distribution patterns of planktonic foraminifera over recent decades. Overall, **a decline in abundance has been observed across nearly all species during the past decade**, likely influenced by various abiotic and biotic factors.
The response of planktonic foraminifera is species-specific, leading to a redistribution of their ecological niches and the emergence of new assemblages.

- **At low latitudes**, deep-dwelling spinose species lacking symbionts have exhibited both vertical and latitudinal migration toward higher latitudes, driven by the deepening of the thermocline.

- **At mid-latitudes**, species responses vary. Herbivorous symbiont-barren species have migrated northward following food availability, whereas omnivorous and carnivorous symbiont-bearing species have shifted to greater depths and higher latitudes. Some species, such as *P. obliquiloculata* and *G. ruber ruber*, appear unaffected by environmental changes and show no habitat shifts. Additionally, a decline in tropical and subtropical species has occurred in mid-latitudes, with a corresponding increase in species diversity compensating for losses in equatorial regions.

- **At high latitudes**, historical distribution shifts reveal **an increase in foraminifera abundance over the past 30 years**, with many species migrating poleward. **However, this poleward migration raises concerns, as seawater calcite saturation ($\Omega_{calcite}$) at high latitudes is predicted to decline to levels that may limit the ability of foraminifera to calcify their shells.**

Anticipated (or actual) impact of these results for science, society, and public and private decision making

More than 180,000 samples describing the distribution and diversity of modern planktonic foraminifera have been compiled globally in the FORCIS database. This compilation **enabled the development of an innovative normalization method**, preventing overestimation of concentrations in smaller size fractions and underestimation in larger ones. It thus allows for coherent comparisons between datasets derived from plankton nets with variable mesh sizes.

Analysis of these data has **improved understanding of planktonic foraminifera responses to climatic stressors since the early 20th century**. The FORCIS database now provides a robust tool to **refine predictions of the future evolution of these organisms under different climate scenarios**. Models based on these data will also allow **quantitative estimates of carbonate (shell) and organic carbon production in the context of global change.**

Finally, FORCIS establishes a crucial link between modern biodiversity datasets (genomics, imaging) and geological archives, **paving the way for an integrated approach to past, present, and future marine ecosystem dynamics.**

For any inquiries**, the database managers (Sonia Chabaane: chaaabane@cerege.fr and Xavier Giraud : giraud@cerege.fr) as well as the project leader (Thibault de Garidel Thoron) **can be contacted.

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