

Euromarine BioGeoSCAPES workshop “Reconciling the impact of trace metal limitation on microbial metabolism and productivity”.

The workshop took place between 16th-17th June in Zagreb, Croatia. The workshop brought together researchers from across Europe and Israel to a) synthesis present knowledge and identify gaps, b) inform and engage European based researchers interested in BioGeoSCAPES and c) identify mechanisms to facilitate further networking/summer schools and training. The workshop was attended by 30 scientists from 11 different countries.

The state of the art was summarized by six keynote speakers that addressed the following topics – references to publications discussed in the presentations are provided where relevant. 1) C. Mark Moore. **Patterns of nutrient limitation in the Ocean**, 2) Noelle Held. **Responses to nutrient limitation at the level of the proteome**: (Held et al., Biogeosciences 17, 2020), 3) S. Hogle. **Responses of picocyanobacteria to iron limitation** (Hogle et al., ISME J, 16, 1636-1646, 2022), 4) C. Koedooder, **The effect of iron limitation on microbial metabolism – from the lab to the field**, (Koedooder et al., FEMS Microb. Ecol., 96, fiae, 2020) 5) D. Eviellard: **New insights from novel approaches to data analysis** ([Régimbeau](#) et al., 2022. Ecology Letters, 25, 1352-1364) and 6) A. Landolfi: **Top down controls on ecological niches** (Landolfi et al., 2021, Front. Aquatic Microbiol., <https://doi.org/10.3389/fmicb.2021.690200>).

Following the talks, we split into several groups for breakout sessions that addressed the following themes.

- A) **How do we link different kinds of metabolisms key to biogeochemical cycles to their demand for (trace) nutrients? How do we identify and measure key microbial processes that are poorly constrained?** Participants highlighted the complexity and breadth of this task - especially with respect to prokaryotic demands for trace nutrients and considering both assimilatory and dissimilarity processes. Challenges and opportunities arise throughout studies designed to address questions of complexity, dimension and scale of nutrient limitation in the ocean. To take an obvious example, photosynthesis and respiration are dominant processes driving the biological C cycle, nitrogen fixation and denitrification impact on C cycling, thereby linking N and C cycles through space and time in complex ways. The way in which biogeochemical cycles intersect thus becomes critical to the system as a whole. Participants identified the several factors that could be considered as BiogeoSCAPES develops:
- i. Split “the problem” into more manageable and focused sections, but be conscious of the dangers of compartmentalisation
 - ii. Identify major gaps in metabolic networks → particularly gaps that underpin microbial processes important in biogeochemical cycles
 - iii. Fully exploit mature technologies (e.g. water column chemistry, metaG, metaT) and expand role of newer approaches (e.g. metaP, metabolomics)
 - iv. Identify robust mechanisms for quantifying demand (rates and quotas)
 - v. Unravel links between community response and species/genus/family etc response (i.e. how is limitation “experienced” across a community and how does this impact the community as a whole?)

B) How do we integrate knowledge across different methods and approaches to deliver process understanding? BiogeoSCAPES aims to apply a diverse range of approaches in terms of experimental design and methodology. We therefore discussed how such a diversity of approaches can be combined to obtain novel understanding of the system. Key themes identified by participants in this breakout included

- i. Integration of knowledge across disciplines, approaches, career stages offers opportunities for novel understanding
- ii. The importance of standardisation, common protocols, reference materials and intercomparisons to ensure data quality and comparability.
- iii. Diversity in experimental design could provide complementary insights into processes
- iv. Laboratory experiments are important for mechanistic understanding, do not just do field work
- v. Leverage both quantitative and non-quantitative data for new understanding, but carefully consider how these types of data can be combined.

Finally we identified the following strengths within Europe:

- The existence of several time series stations in a range of habitats from coastal to open ocean
- The presence of multiple funding agencies from EU to national → potential for different levels of engagement.
- Solid framework for data products (e.g. Pangea, EBI, EMODnet).
- Tara Ocean, Atlanteco – large scale omics-based programs
- Participation in GEOTRACES

The workshop was organised by M. Gledhill (GEOMAR, Germany), S. Orlić (Institut Ruđer Bošković, Croatia), I. Obernösterer (France), Chris Bowler (France), A. Tagliabue (UK)