Summary of the Netherlands BioGeoSCAPES scoping workshop for the International BioGeoSCAPES community

The Netherlands BioGeoSCAPES scoping workshop was convened at the University of Amsterdam on 22 February 2023 by Susanne Wilken (University of Amsterdam) and Rob Middag (Royal Netherlands Institute for Sea Research (NIOZ) and University of Groningen). In total, 19 participants joined from 5 different universities/institutions from across the Netherlands with diverse expertise in chemical and biological oceanography, biogeochemistry, (quantitative) microbial ecology and bioinformatics. Additionally, Martha Gledhill (Geomar, Germany) joined to provide a perspective on ongoing/planned European and international initiatives. As with other similar workshops in other countries, the workshop aimed to gather feedback from the Dutch scientific community on the preliminary BioGeoSCAPES Mission Statement and get input on the three questions as suggested by participants in an initial international meeting (Woods Hole (USA) in November 2018), for discussion during national meetings.

1. The preliminary BioGeoSCAPES Mission Statement is "*To improve our understanding of the functioning and regulation of ocean metabolism and its interaction with nutrient cycling within the context of a hierarchical seascape perspective*". Suggestion: "*To understand the functioning and regulation of ocean metabolism and biogeochemical cycling across all scales of the seascape*" or "*To understand the functioning of marine (micro-)organisms and their role in biogeochemical cycling across all scales of the seascape*"

Dutch participants felt the mission statement generated some confusion, particularly the 'hierarchical seascape perspective'. Furthermore, 'ocean metabolism' as such is not scientifically/technically correct and would need to be clearly defined (nevertheless the term can be used as it is compelling and catchy). In addition, the temporal aspect is not clearly part of the seascape. Metabolic pathways (ocean metabolism) are inherently part of biogeochemical cycles, so the current separation seems odd and feedbacks between nutrients cycling and microbial processes are not specifically mentioned; we suggest to specifically include feedback in any text explaining/detailing the mission statement. There was a preference for biogeochemical cycling rather than nutrient cycling (carbon was not thought of as a nutrient by all). This includes the link to climate (change) through changes in all aspects of the ocean carbon cycle

2. How could the Netherlands best contribute to the BioGeoSCAPES efforts (e.g., fieldwork, laboratory work, modelling, intercalibration efforts, project coordination, data management, bioinformatics)?

In the Netherlands, we expect the commissioning of a new oceanographic research vessel in about 3 years that would be ideally suitable for interdisciplinary cruises. It will be able to bring up to 30 scientists as well as a variety of mobile labs, large volume trace metal clean sampling system and incubation facilities. This infrastructure will be embedded within the Eurofleets program and provides ample opportunities for collaborative research, also with scientists from nations that do not have access to such infrastructure. Additionally, we have access to state-of-the-art laboratories and instrumentation, climate rooms, clean rooms, mesocosms, microbial cultivation facilities, and expertise in modelling, machine learning and artificial intelligence. Overall, there is strong expertise related to the BioGeoSCAPES research focus and tools.

There are coastal time series in the Netherlands that could be complemented with BioGeoSCAPES type measurements. Specifically, Rijkswaterstaat (Dutch Department of Waterways and Public Works) is monitoring stations in the North Sea in collaboration with NIOZ, but currently mainly for chemical measurements. NIOZ is maintaining a time series on the jetty near the institute at the border of the Wadden Sea and North Sea that could be expanded upon. The Netherlands typically performs multiple cruises to the North Sea and the North-Atlantic Ocean each year that could be used for the purpose of monitoring. In addition, models of ocean physics, biochemistry and nutrient cycling (such as Earth System Models) can a) help identify regions and timings of greatest uncertainty and thereby direct observational efforts, b) help understand the system, c) make future projections.

3. What science questions are most important that we could address within the broad scope of BioGeoSCAPES in a 10-year timeframe?

The Netherlands is home to a relatively small but active community of marine scientists that could contribute to and benefit from more national and international collaborations. Concerning science questions, it is important to connect across scales (from cells to ecosystem and from elemental concentrations to ecosystem-scale nutrient budgets), to connect structure and function, as well as make connections between ecosystems.

Interfaces at different levels are crucial; what relevant processes occur at interfaces (redox, sediment-water, solid-solution, microbe-environment) and what is the role of extreme gradients at the small scale? Also, attention should be given to the micro-environments (e.g. shells, aggregates, local niches in sediment and water column): who does what and how fast? For example, how does the biogeochemistry of micro-environments (e.g., reducing conditions in sinking aggregates) influence biogeochemical fluxes and rates of climate relevant gases? An overall challenge is that such micro-environments are difficult to measure and thus to include in larger (global) budgets. Then, how do we scale up from observed variability across spatial and temporal scales, and how do we define 'borders' of 'systems' – how do we integrate disparate findings into a coherent understanding of the system? Scaling up of measurements (e.g. 'omics', rate measurements) across scales requires tight coupling with modellers and attention to physical processes, such as mixing. Directly linked to this is the question: how much complexity is needed to understand/predict a biological system using models? Another key question is: what processes (biological, chemical, physical) determine transformation and removal of nutrients?

The community felt that the science questions should be led by the processes we want to address/understand rather than be driven by new technology (e.g. trace element analyses, 'omics', etc). Additionally, modellers should be involved from the start, also to determine where uncertainties are largest and observations/insight are thus needed.

A specific interest of the Dutch community is understanding the microbial metabolic pathways/functioning that are affected by, and interact with, changing physicochemical properties in the ocean, as well as their contribution to climate change (e.g. by the production or fixation of greenhouse gases). Questions to focus on should be related to impacts of changing physicochemical parameters resulting from climate change, such as increasing temperatures, acidification, shifts in mixed layer depth, oxygen depletion, changes in nutrient supply etc. Furthermore, which biological players are involved, how active are they and are there tipping points in the climate feedbacks? A focus on ocean metabolism (microbial functioning) requires us to combine and integrate (eco)physiological experiments with 'omics' data from the field and to study physiological pathways within the microbial community. In this respect, the use of multiple stable isotopes is a powerful tool to measure rates within various elemental cycles simultaneously, providing additional insight into the processes and hence tell us more about trends in 'omics measured during transects in time and space.

BioGeoSCAPES should assess processes from lab systems to ecosystems, with attention for different types of ecosystems (ranging from coast to open ocean, from surface to deep, but also include margins and bathymetric features, benthic-pelagic coupling). Not everything is driven by micro-organisms only, larger organisms (e.g., zooplankton and filter feeders such as sponges) together with their microbial symbionts (i.e., the holobiont/metaorganism) can also play a key role in the cycling of carbon and nutrients.

4. Are there any impediments that the international community could seek to mitigate via training or collaboration?

Intercalibration and intercomparison experiments are needed for 'omics' (but we realise efforts are underway or planned). Especially within the field of 'omics', it was felt that a Best Practice guide for the BioGeoSCAPES community is desirable. This could entail protocols for DNA/RNA extraction, the use of internal spikes/standards, standardisation of bioinformatics tools etc. Sufficient data storage space is needed, and centralisation may be good with a need for databases that can integrate between the different data types to be collected and perhaps can provide access to computational facilities and pipelines. Additionally, the community feels there should be continuous efforts on getting more biological understanding out of 'omics' data, especially eventually translating 'omics' results to process rates.

To be most effective, it is important to have the chance to revisit field locations, i.e., test insights obtained under well-controlled conditions in the lab directly in the field and vice versa. Recurrent cruises (transects; at different time of the year) can contribute significantly to an improved understanding but are often not part of national oceanic programs. The relatively small Dutch community could benefit from increased international collaboration where hopefully a program like BioGeoSCAPES may offer some continuity.

BioGeoSCAPES might provide a good opportunity for capacity building by stimulating researchers at an early career stage or in a less-privileged position (regarding facilities) to develop research aligned with the aim of BioGeoSCAPES.

Participants (who agreed to have their name and contact details listed)

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