BIOGEOSCAPES Australian National Report (September 2023) by P. Boyd

We did not have a workshop but ran a series of 6 working lunches leading to the publication of the following Perspective in J. Plankton Res.

[Ongoing need for rates: can physiology and omics come together to co-design the measurements needed to understand complex ocean biogeochemistry? | Journal of Plankton Research | Oxford Academic (oup.com)]

below is the Title, Abstract and Conclusions

Title: The ongoing need for rates: can physiology and omics come together to co-design the measurements needed to understand complex ocean biogeochemistry?

Abstract:

The necessity to understand the influence of global ocean change on biota has exposed wide-ranging gaps in our knowledge of the fundamental principles that underpin marine life. Concurrently, physiological research has stagnated, in part driven by the advent and rapid evolution of molecular biological techniques, such that they now influence all lines of enquiry in biological oceanography. This dominance has led to an implicit assumption that physiology is outmoded, and advocacy that ecological and biogeochemical models can be directly informed by omics. However, the main modeling currencies are biological rates and biogeochemical fluxes. Here, we ask: how do we translate the wealth of information on physiological potential from omics-based studies to quantifiable physiological rates and, ultimately, to biogeochemical fluxes? Based on the trajectory of the state-of-the-art in biomedical sciences, along with case-studies from ocean sciences, we conclude that it is unlikely that omics can provide such rates in the coming decade. Thus, while physiological rates will continue to be central to providing projections of global change biology, we must revisit the metrics we rely upon. We advocate for the co-design of a new generation of rate measurements that better link the benefits of omics and physiology.

Conclusions and Future directions:

We conclude with recent field-leading examples from ocean sciences that seek to derive metabolic rates from omics, explored through the lens of biomedical sciences. Saito et al. (2020) conducted metaproteomic analysis on subsurface biota in the Tropical North Pacific to pinpoint commonly occurring enzymes. They reported that nitrite oxidoreductase associated with the bacterium *Nitrospina* was abundant in this stratum and explored whether they could estimate rates of nitrite oxidation using wide-ranging methods, including biochemistry (specific activity), physiology (Michaelis–Menten kinetics) and omics. Despite employing this innovative suite of approaches, derived rates ranged >200-fold, pointing to the need to develop targeted physiological assays (c.f. Fig. 4). There are also promising initial developments from the emergence of phenomenological models based on simple geochemical/taxonomic principles that yield phytoplankton growth rates assuming steady-state growth (McCain et al., 2021).

The latest developments in biomedical and model-system omics suggest that obtaining rates from omics is still under development. First, holistic investigations of well-characterized model organisms have tracked every metabolite and protein to generate enzyme-directed functional rates in the bacterium Escherichia coli (Taniguchi et al., 2010) and the yeast Saccharomyces cerevisiae (Ho et al., 2018), but this approach is restricted to the organisms for which the function of every gene and protein is known. Second, expression-fitness landscapes (linking enzyme expression with growth rate) have revealed that enzyme expression can have a “ripple” effect across layers of biological organization ranging from mechanistic, regulatory to systemic (Lalanne et al., 2021), which adds further complexity to deriving growth rates from enzymatic fluxes. Third, sophisticated microbiome studies (from cheese to the human gut) (Poceviciute and Ismagilov, 2019), which are more akin to oceanic microbial systems, reveal that there are still a high number of metabolic functions that remain uncharacterized (Price et al., 2018). Fourth, progress in tackling cell regulatory mechanisms using multiomic modeling has been made but requires complex computing using deep neural networks such as GEMS (Genome-scale metabolic models) (Okada and Kuroda, 2019).

These four categories of advanced well-resourced research point to challenges yet to be surmounted in obtaining physiological rates from omics for biomedical sciences. But, they also provide cautionary lessons for ocean sciences. In our opinion, it may be more straight-forward to co-design targeted physiological metrics that better link omics with marine biogeochemistry. We advocate for better communication across these research communities that could be readily facilitated through co-design workshops and other forums to ascertain the best ways to reverse-engineer a new generation of physiological metrics, in tandem with the development of high-throughput technologies to promote "co-measurement" (Fig. 4), that better exploit the power of molecular biology to answer the most pressing questions in ocean sciences.

Responses to Q2-4 (questions are below, for Q1 see above)

Question 2: *How would your nation best contribute to BioGeoSCAPES efforts?* – e.g. fieldwork, laboratory work, modelling, intercalibration efforts, project coordination, data management, bioinformatics

Voyages such as the forthcoming MISO 60 d t the S. Ocean which has a 5-person BIOGEOSCAPES team along with a GEOTRACES team. They will carry our 72 h hybrid stations to 'titrate' the status of the microbial assemblage.

Lab cultures – to look at polar and subpolar phytoplankton and to compare physiological metrics with molecular approaches

Question 3: *What science questions are most important to your nation within the broad scope of BioGeoSCAPES on a 10-year timeframe?*

Environmental drivers (Fe, light, temperature….) of microbes of the S. Ocean and how they will exert cumulative pressures in the coming decade. How will the community respond? Will the community alter? Also linking surface and subsurface biogeochemical processes in the upper twilight zone.

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

Training to help with capacity building. Development of co-designed metrics and discussion about whether we need 'biological' standards to cross-compare datasets between nations and voyages. Collaboration via participation on voyages.