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Editorial: Advances and Challenges in Microphytobenthos Research: From Cell Biology to Coastal Ecosystem Function

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Editorial on the Research Topic

Advances and Challenges in Microphytobenthos Research: From Cell Biology to Coastal Ecosystem Function

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The microphytobenthos are fascinating communities of microalgae and cyanobacteria that inhabit benthic habitats in marine and freshwater ecosystems. These often apparently barren landscapes are in fact a "secret garden", harboring an immense microbial diversity and intense photosynthetic and biogeochemical activity (MacIntyre et al., 1996; Underwood and Kromkamp, 1999). On the intertidal flats of estuaries and beneath shallow coastal waters, the microphytobenthos are dominated by pennate diatoms, the most recently evolved and most diversified of this important group of protists (Kooistra et al., 2007; Benoiston et al., 2017).

Microphytobenthos have mostly been studied in temperate estuaries, but they have a widespread distribution from polar regions (Woelfel et al., 2014) to the tropics (Underwood, 2002). Over the last decades, microphytobenthos have attracted considerable interest mainly due to their role as a main contributor to the productivity of estuarine and shallow coastal areas (Hope et al., 2019). With a global annual gross primary production estimated to be in the order of 500 Mt of carbon, these ecosystems can be responsible for up to 20% of the ocean gross primary production although occupying only 0.03% of the ocean surface area (Pinckney, 2018). For estuarine ecosystems, microphytobenthos primary production can be comparable to that of the phytoplankton and can provide up to more than 50% of total ecosystem-level carbon fixation (Underwood and Kromkamp, 1999). Best known for their high photosynthetic activity and carbon fixation, their contribution to sediment stabilization and the strong links with invertebrate and vertebrate consumers, microphytobenthos communities have in recent years become the focus of multiple and apparently disparate disciplines such as photonics, photophysiology, community ecology, biogeochemistry, microbiology, evolutionary science, remote sensing and molecular biology.

This Research Topic aimed to bring together contributions on microphytobenthos research, to update current knowledge and uncover exciting future directions of strategic value, including

new methods and approaches, ultimately contributing to link cell biology and functional traits of diatoms and cyanobacteria to emerging properties observed at the community and ecosystem-level. This ebook comprises a collection of 20 articles, covering a wide range of topics, from cell motility and photophysiology to ecosystem-level productivity, reflecting the current interest in microphytobenthos diversity and functional traits, as well as in their role in the ecology of estuarine ecosystems. Most contributions to the Research Topic present results of original research, but the ebook also includes one mini-review and one perspective article. The majority of the articles refers to microphytobenthos communities from estuaries, covering over 14 ecosystems in Europe, North America, Australia and New Zealand.

The contributions to this Research Topic can be divided in five different groups, based on the topics addressed: (i) microphytobenthos primary productivity and biogeochemistry in tidal estuaries; (ii) motility and vertical migration of benthic diatoms and cyanobacteria; (iii) interactions between microphytobenthos and consumers; (iv) microphytobenthos diversity; and v) emerging topics.

A large number of articles (eight) addressed questions related to the role of microphytobenthos as primary producers in tidal estuaries, centered on the characterization of the spatio-temporal variability in biomass and productivity, often showing complex patterns due to spatial patchiness and the influence of tidal regimes. Most studies refer to locations in the European Atlantic coast (France, Portugal, Spain) and one to estuarine areas in Australia. Haro et al. investigated the seasonal variability in microphytobenthos biomass and productivity in a southern European coastal system (Cadiz Bay, Spain) and explored the influence of multiple environmental factors on the observed patterns. Daggers et al. used remote sensing data from high resolution satellite sensors to obtain a detailed characterization the spatio-temporal variability in microphytobenthos biomass across intertidal areas of the Westerschelde (The Netherlands). The studies by Méléder et al. and Savelli et al. combined modeling approaches with remote sensing data to estimate areal rates of carbon fixation for intertidal mudflats in the French Atlantic coast (Pertuis Charentais Sea, France). Frankenbach et al. used chlorophyll fluorescence techniques to directly compare the spatial and temporal variability of the photosynthetic activity of microphytobenthos and phytoplankton of the Ria de Aveiro (Portugal), showing that the areal and ecosystem-level productivity of the microphytobenthos may more than double the contribution by the phytoplankton. Redzuan and Underwood addressed the effects of sediment resuspension by tidal currents on the redistribution of microalgal biomass in the Colne Estuary (UK), while Tolhurst et al., using a manipulative approach, investigated the role of light and nutrients on microphytobenthos biomass and on the biogeochemistry of intertidal flats in the Sydney Harbor estuary (Australia). Pniewski and Piasecka-Jedrzejak investigated the operation of photoacclimatory and photoprotective mechanisms in a benthic diatom species, photophysiological processes key to enabling high rates of productivity under the variable light conditions, characteristic of shallow and intertidal habitats.

A second group of articles (five) addressed questions related to cell motility and vertical migration in microphytobenthos biofilms. Cellular motility is recognized as a key factor for the optimal exploitation of resources in the sedimentary microenvironment, directly related to the environmental rhythmicity of intertidal habitats. Barnett et al. and Prins et al. present results on the role of light intensity and color on the control of vertical migratory behavior of benthic diatoms, and its coupling with the operation of photophysiological photoprotective processes. Lichtenberg et al. investigated the role of light in the vertical migration of the relatively less studied cyanobacteria-dominated biofilms. While these studies refer to manipulative studies carried out under controlled laboratory conditions, Kromkamp et al. presents data collected *in situ* on the short-term and micro-scale (< 1 m) variation of microphytobenthos biomass and photosynthetic activity during diurnal low tide periods. The ebook also includes a mini-review by Marques da Silva et al., consisting of a theoretical study on the long-standing question of the relative energetic costs of vertical migration and physiological photoprotective mechanisms in motile diatoms.

A third group of articles (three) address topics related to the interactions between microphytobenthos and consumers inhabiting estuarine intertidal areas. Using bird exclusion experiments carried out on an intertidal flat, Booty et al. explored the effects of the presence of shorebirds on key sedimentary parameters such as the critical erosion threshold, and the influx and efflux of nitrate and phosphorous. The connections between microphytobenthos and shorebirds were also addressed by Schnurr et al. who linked the seasonal variation in fatty acid composition of benthic diatoms, and associated nutritional value, to the regular visits of shorebirds to the Fraser River estuary, Canada, during their annual migration. The fatty acid composition of benthic diatoms was also studied by Hope et al., in the context of anthropogenic nutrient enrichment and turbidity increase, considering the implications for the populations of deposit-feeding bivalves.

The important, but often understudied, topic of the diversity of microphytobenthos communities is also covered in this ebook with two articles. Virta et al. investigated the seasonal and inter-annual variation of the taxonomic and functional composition of the communities of benthic diatoms in a non-tidal system in the Baltic Finnish coast. Ribeiro et al. explored alternative methodological approaches, as excluding abundance data or rare species, taxonomic resolution, or use of size-based metrics, to characterize the diversity of benthic diatom communities inhabiting intertidal flats of the Tagus estuary (Portugal).

The Research Topic also includes two articles on emerging topics in microphytobenthos research. One article refers to the first use of untargeted metabolomic techniques to microphytobenthos biofilms, here with the purpose of characterizing the metabolite composition of extracellular polymeric substance excreted by benthic diatoms (Gaubert-Boussarie et al.). The other is a perspective article on

the predictable but largely unstudied effects of light pollution on benthic microalgal communities (Maggi and Serôdio).

DEDICATION

We dedicate this ebook to Jacco Kromkamp, an inspirational scientist whose meticulous work was an exemplar to others in the field. Jacco will be missed in the community and more so by those that knew him for his science and for his kind and gentle nature. He was always supportive and constructive with a lively sense of humor and it was a pleasure to share fieldwork and laboratory studies with him.

AUTHOR CONTRIBUTIONS

JS, DP, VM, and WV organized this Research Topic and wrote the editorial. All authors contributed to the article and approved the submitted version.

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