Editorial

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Phylogeny and ecology of the green seaweed *Ulva*

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Algae of the genus *Ulva* are of central importance in both applied and basic research, as they present a fascinating mix of biological, ecological, evolutionary, physiological, and genetic research priorities (Blomme et al. 2023; De Clerk et al. 2018; Wichard et al. 2015). Due to their crucial role in coastal ecosystems and their burgeoning commercial use for aquaculture, *Ulva* spp. have become the focus of many (applied) scientific studies (Bolton et al. 2016; Simon et al. 2022; Steinhagen et al. 2021; Wichard 2023). The cultivation of seaweed for food, feed and useful chemicals has the potential to increase significantly and sustainably. It could provide alternative protein sources, alleviate food shortages and meet increasing demand by utilizing the largely untapped aquatic environment (Barbier et al. 2020; Buck and Shpigel 2023). In any case, the reliable identification of the morphologically variable species and ecotypes of *Ulva* remains of particular interest and a prerequisite for many applications (Steinhagen et al. 2019).

Despite their paramount importance, a comprehensive understanding of the ecology, phylogeny, and key characteristics across various *Ulva* species remains elusive. Advancements in cutting-edge technologies and sophisticated molecular techniques have propelled scientific research, unlocking some of the mysteries of this ecologically and economically significant genus. The quest to unravel the complexities of *Ulva* continues. This Special Issue consolidates pertinent scientific contributions spanning species-specific ecological traits, intricate phylogenetic aspects, and insightful aquaculture case studies.

Acknowledging the considerable interest and commitment demonstrated by all contributors to this Special Issue, we express gratitude for their valuable research. This collection delves into diverse aspects of *Ulva* and showcases the advancements in the field made by these research contributors. Notably, this Special Issue is presented in two volumes, reflecting the extensive coverage of the multifaceted topics explored and the increasing interest in *Ulva* research.

The article collection is dedicated to our friend and colleague, Prof. Dr. Klaus Lüning, who unfortunately passed away last year. With profound sorrow, we announce the passing of a stalwart in the wide field of phycolgy, whose invaluable contributions have left an indelible mark on the scientific community. Prof. Lüning, a distinguished biologist and marine botanist, dedicated his life to unravelling the intricacies of marine macroalgae. Throughout his illustrious career, he held a professorship at the University of Hamburg and was the head of the Department of Marine Botany at the Biologische Anstalt Helgoland (later part of the Alfred-Wegener-Institut, Bremerhaven, Germany). His research spanned diverse facets of seaweed ecology, focusing on the ecophysiology of marine macroalgae, the regulation of algal development, biogeography and macroalgal cultivation for commercial applications. As a result of his research activities, Prof. Lüning has published more than 100 scientific articles as well as the book *Seaweeds: their environment, biogeography, and ecophysiology* (Lüning 1990) and successfully implemented his scientific work by founding the company Sytler Algenfarm GmbH & Co.KG, for the biomass production of macroalgae. As we reflect on his remarkable life and legacy, let us honour Prof. Dr. Klaus Lüning’s enduring contributions to phycology, and especially his contributions to the genus *Ulva*, which will continue to shape the future of marine science for years to come. Notably, Prof. Lüning’s contribution intended for this Special Issue was published in advance in *Botanica Marina* (Lüning 2023).

The EU-funded Cooperation in Science and Technology (COST) Action SeaWheat (CA20106) “Tomorrow’s ‘wheat of the sea’, Ulva a model for an innovative mariculture (sea-wheat)” has brought together macroalgal researchers to build up a new network dedicated to macroalgal research and its applications (https://www.cost.eu/actions/CA20106/; 04/10/2021–03/10/2025). The COST Action aims to integrate *Ulva* into various aspects of industry and daily life, from food production to biotechnology, focusing on sustainability and...
environmental considerations. It seeks to leverage European expertise, quality standards, and dietary habits to facilitate the adoption of Ulva-based products. Inspired by this newly launched network coordinated by Prof. Dr. Muki Shpigel (University of Haifa, Israel), we developed the concept for a Special Issue focused on the ecology and phylogeny of Ulva.

Eight articles present a broad view of exciting topics (Figure 1), including studies on the main tasks of the COST Action SeaWheat project, such as the interconnected topics: (i) cultivation, (ii) ecology/biology, and (iii) evolution/biodiversity.

Several authors make use of molecular data to refine the taxonomy and nomenclature of Ulvaceae species and provide a more accurate understanding of their relationships and distribution. Hughey et al. (2024) highlight the importance of DNA sequencing for the type specimens of each species of Ulva to ensure the accurate application of names in repositories, which is essential for applied research. Following this approach, Maggs et al. (2024) reassign, for example, Ulva gigantea to Ulva compressa based on rbcL, tufA, and ITS sequences from the holotype. In field studies, Gabrielson et al. (2024) describe the foliose green seaweed flora of the Galápagos Archipelago, whereas Zhong et al. (2024) demonstrate the impact of dynamic environmental conditions and latitudinal gradients on phenotypic and genetic patterns of Ulva species in the North West Pacific.

Two studies in this issue have contributed to a better understanding of the cross-kingdom interactions between Ulva and its associated bacteria and fungi. The study of Noor et al. (2024) focuses on the isolation and biological evaluation of the under-investigated endophytic fungi found in Ulva spp. isolated from the Bay of Bengal (Bangladesh). Similarly, Hmani et al. (2024) suggest that Ulva-growth-promoting microbial traits can change with temperature, emphasizing the need for a comprehensive approach that combines microbiome analysis with functional examinations.

Green seaweed aquaculture is a small industry where optimal cultivation practices are being developed to scale up production. Ulva lactuca was identified by Gnayem et al. (2024) as a valuable source of high-value fatty acids depending on its specific harvest seasons. It underscores the significance of Ulva spp. as contributors to sustainable alternatives for essential fatty acids traditionally sourced from wild fish. Finally, Rautenberger (2024) explore the value and potential cost of using germanium dioxide as an antifouling agent against the bio-fouling diatoms in Ulva’s land-based aquaculture.

In conclusion, this Special Issue comprehensively explores diverse facets of Ulva, shedding light on its ecological, phylogenetic, and practical dimensions. Through collaborative and pioneering research, the collection significantly advances our comprehension of this fascinating

Figure 1: The highlights of Ulva research can be divided into three main research areas, which are reflected in this special edition.
References


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Sophie Steinhagen is a permanent researcher at the University of Gothenburg (Sweden). After conducting her PhD in molecular ecology (GEOMAR Helmholtz Centre for Ocean Research, Germany) she investigated the green seaweed biodiversity, their phylogenetic relationships, and species-specific traits. Her current research explores the interplay between environmental factors and genomic set up of seaweeds, unraveling the secrets behind the content of high-value compounds and setting baselines for breeding programs in European seaweed crop strains to support a sustainable seaweed aquaculture.
Thomas Wichard is a research group leader and lecturer in Analytical Chemistry at the Institute for Inorganic and Analytical Chemistry of the Friedrich Schiller University Jena (Germany). After being awarded a PhD in Biochemistry (Max Planck Institute for Chemical Ecology), he investigated the metal recruitment of nitrogen fixers at the Princeton Environmental Institute (USA). His team applies various analytical chemistry, chemical ecology, and molecular biology methodologies to understand the basis of eco-physiological processes in bacteria-macroalgae interactions (cross-kingdom interactions).

Jonas Blomme is a postdoctoral research fellow at Ghent University/Center for Plant Systems Biology (Belgium). He is affiliated to both the Phycology and Plant Genome Editing research group, headed by Olivier De Clerck and Thomas Jacobs, respectively. After focusing on the genetics of leaf growth during his PhD, he switched from the model organism Arabidopsis to Ulva. The major focus of his work is generating and optimising molecular tools that allow the creation of Ulva gain- and loss-of-function mutants. This work is complemented with research lines on characterising the molecular players involved in carbon capture and large-scale genomics of Ulva.