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Editorial: Adaption, breeding and cultivation of seaweeds in the context of global climate change

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Editorial on the Research Topic
Adaption, breeding and cultivation of seaweeds in the context of global climate change

Seaweeds not only act as primary producers in marine ecosystems but also play an important role in mitigating climate change by providing potential solutions in overcoming or minimizing the impact of marine environmental problems, such as ocean acidification, eutrophication, hypoxia, and harmful algal blooms events and its potential as blue carbon. In addition, seaweeds are rich resources for food, medicine, chemical industry, animal feed and agricultural fertilizer. With the rapid development and progress of basic theoretical research, breeding technology, cultivation technology and engineering facilities, the cultivation scale of economic seaweeds has been expanded and the yield has been significantly increased. At present, the seaweed industry has become one of the most active fishery industries in the world, with an average annual production volume of more than three times the overall growth rate of the fishery. 36 million tonnes (wet weight) of seaweed were produced in 2020, of which 97 percent originated from aquaculture (FAO, 2022). However, with environmental changes such as seawater temperature warming, ocean acidification, and seawater pollution, the biodiversity, distribution, and cultivation of seaweeds have been significantly affected.

Variations of each seaweed in responding and adapting to environmental changes will affect the distribution, abundance, and diversity of seaweed populations in the future, and will subsequently affect the ecological functions of seaweeds. For economic seaweed, changes in the marine environment have led to frequent algal diseases, and the shortage cultivars with superior traits (fast growing, high biomass, climate and disease resilient), limiting the healthy development of the seaweed industry. Therefore, the understanding of the impact of global environmental change on the physiological ecology, mechanism of seaweed in responding and adapting to environmental changes is very important in helping to propose appropriate strategies by introducing new superior varieties of economic seaweed for cultivation, developing new germplasm, and optimizing culture technology. This information is crucial for the accurate assessment of changes in important algal biomes, effective resource utilization, scientific management, and sustainable human development in the context of global climate change.

Accordingly, this Research Topic collected six publications contributing to a better understanding on "the impact of global environmental change on the physiological ecology of seaweed, the mechanism of seaweed in responding and adapting to environmental changes, and research and development of high-efficiency cultivation technology in facing global climate change."

1 The impact of global environmental change on the physiological ecology of seaweed

Intertidal seaweeds have high carbon sink potential and are often subjected to hyposaline stress in their natural habitats. Chen et al. investigated the effect of hyposaline- and freshwater-stress on the release of dissolved organic carbon (DOC) from five common macroalgal species (*Pyropia haitaneisis*, *Gracilaria lemaneiformis*, *Sargassum thunbergii*, *Enteromorpha prolifera*, and *Ulva lactuca*). The results showed that the DOC release rate of five species increased overall with decreasing salinity. The tissue carbon contents of *P. haitaneisis*, *G. lemaneiformis*, and *E. prolifera* increased significantly with decreasing salinity, whereas that of *S. thunbergii* and *U. lactuca* were not influenced or were slightly decreased by low salinity. This study suggested that hyposaline stress substantially altered the carbon metabolism of macroalgae, especially increasing the DOC release rate from macroalgae, and this in turn may have a large impact on the carbon cycle in macroalgae enrichment areas.

Additionally, seaweed cultivation normally attracts beneficial bacterial species to colonize and inhibit pathogenic bacteria. Therefore, the interaction of seaweed and microbial is a key issue of the ecological benefits of seaweed under global environmental change. Study by Liang et al. investigated the spatio-temporal variations in composition, diversity, and functional properties of bacteria in seawater as well as the environmental variables of seawater in a large-scale laver farm in China. They found that laver cultivation was likely to be beneficial to maintain seasonal stability of microbial community richness and diversity in the laver farm ecosystem, and identified the keystone bacterial taxa basing on network analysis. Further mantel test and redundancy analysis showed that the hydrographic parameters (e.g. salinity, temperature, DO, pH) as well as the key carbon (e.g. POC, DOC) and nitrogen parameters (e.g. nitrate, DIN, DON, TDN) were crucial environmental variables to shape the bacterial community composition in the surrounding seawater of laver farm.

2 The mechanism of seaweed in responding and adapting to environmental changes

Zhang et al. investigated whether abscisic acid (ABA) is involved in the mechanisms of desiccation tolerance in *Pyropia haitanensis* by physiological studies and transcriptomics analysis. They suggested that ABA may have evolved as a signal to regulate stress tolerance in *P. haitanensis*. Exogenous ABA avoided photooxidation of thalli by reducing light capture and decreased carbon fixation to save energy. In addition, ABA treatment simultaneously activated repair mechanisms and the antioxidant system to allow for the rapid repair of macromolecular structures and avoid excessive accumulation of reactive oxygen species in thalli of *P. haitanensis*.

The distribution range of *Undaria pinnatifida* populations has been declining northward and now it is no longer found growing in Fujian province and southern Zhejiang province. They are confirmed to be distributed only on some small islands distant from the mainland, this is likely due to the anthropogenic threats such as habitat deterioration and marine heatwave. Therefore, to evaluate the genetic diversity and genetic structure of *U. pinnatifida* populations, Li et al. used the mitochondrial sequences of cox3 and tatC–tLeu regions, and 10 nuclear microsatellites to analyze the genetic diversity and genetic structure of three temporal *U. pinnatifida* populations from Gouqi Island and one *U. pinnatifida* population from Yushan Island. In this study, it showed high genetic diversity, shallow genetic structure and no signs of recent bottleneck in native populations of *U. pinnatifida* from southern China. The high genetic diversity will provide an advantageous basis for these populations to adapt to global environmental change. This study suggested that *ex situ* establishment of gametophyte stock will be prioritized to reduce the risk of possible devastating damage of extreme weather on the native populations of *U. pinnatifida*.

3 Research and development of high-efficiency cultivation technology in facing global climate change

Study by Sato et al. examined the effect of increasing the cultivation density of *U. pinnatifida* from 10 to 200 individuals m^{-1} on their survival rate, biomass production, profit, and morphological features related to quality as food. They found that biomass production increased with increasing density, indicating that the maximum density could possibly larger than 200 individuals m^{-1}. But the optimum condition of both the commercial profit and the quality as the food was estimated at 80–120 individuals m^{-1}, the best density to obtain the sporophylls was at 10–30 individuals m^{-1}. Therefore, these results provide data reference of the artificial control of the cultivation density adjustment of *U. pinnatifida* in future environmental changes.

Sun et al. studied the regulatory mechanism of tetraspore formation in *Gracilariopsis lemaneiformis* based on transcriptomic analysis. Results showed that *G. lemaneiformis* needed more energy by enhancing photosynthesis for tetraspore formation and release, and more material requirements by upregulating the synthesis of amino acids during reproductive development. Additionally, trehalose-6-phosphate may also act as a signaling molecule to induce tetraspore formation. These results are helpful to understand the transition from nutritional to reproductive development and the molecular mechanism of *G. lemaneiformis* tetrasporogenesis, which is crucial for the development of new

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germplasm and promoting the growth of the *G. lemaneiformis* culture industry.

Author contributions

WW was a guest associate editor of this Research Topic, acted as editor for two papers and wrote the paper text. TS was the guest associate editor of this Research Topic and acted as editor for two papers. PL was a guest associate editor of this Research Topic and revised the text. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Reference

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