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Editorial: The ecological function of mariculture

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Editorial on the Research Topic
The ecological function of mariculture

FAO reported that about 90% of the world's commercial marine fishes have been overfished or are on the collapsed verge (maximum production) (FAO, 2020). The continuous increase in consumption of seafood is in contradiction with the seafood supply, especially capture fisheries. The aquaculture production is steadily increasing and surpassed the production of capture fisheries from 2014 (FAO, 2016). It was 57% (122.6 million tons) of the world aquatic production (214 million tons) in 2020 (FAO, 2022). The aquaculture production in the marine environment (mariculture) was 33 million tons in 2020 (FAO, 2022). Mariculture is increasingly seen as an alternative to capture fisheries to provide a growing human population with high-quality protein (Costello et al., 2020).

Aquaculture of fed species (e.g., fish in cages) relies on external food supplies, causing possible associated impact on environment (Tacon and Forster, 2003). Shellfish aquaculture can accelerate the turnover of phytoplankton to reduce eutrophication and play a role in carbon sink processes (Bricker et al., 2018). Seaweeds aquaculture, which can reduce nutrient loadings to the environment from fed species aquaculture, has not yet been attractive in many countries as algal products typically have a low value (Stedt et al., 2022). It is well known that combining different species in aquaculture systems or applying proper aquaculture methods and managements could provide more profit and have concomitant ecological benefits (Fang et al., 2016; Strand et al., 2019).

Sustainable aquaculture will be an eternal theme of the development of aquaculture. The ecosystem approach has emerged as concept in assessments of sustainability of aquaculture development, also through analysis of ecosystem goods and services (Smaal et al., 2019). This can provide methods to integrate environmental, economic and social aspects. Zhou et al. performed a systematic literature review of studies with the aim of understanding the ecosystem goods and services of mariculture in China. The ecosystem services of mariculture in China, not only in China, includes five main ecosystem functions: food supply, nutrient extraction, carbon sequestration, biodiversity conservation, and stock enhancement. Mariculture is closely relative integrated with coastal ecosystems. The inter-connections among mariculture production systems, the surrounding environment and local organisms must be thoroughly understood. As a result, interest in exploring the potential for ecological function of aquaculture in marine ecosystems is growing (Fang et al., 2016; ICES, 2020; Khanjani et al., 2022). The innovations of sustainable mariculture theories, methods, systems, technologies etc., are developing fast. Mariculture provides high quality seafood, and at the same time plays important ecological functions.

The ecological function of seaweed aquaculture

Macroalgae play an important role in nutrient extraction in coastal environments, and their role in carbon sequestration resisting global warming are promoted. At the same time they are affected by the environmental factors impacted by climate change. Zhang et al. found *Sargassum fusiforme* cultivation could increase DO and pH levels and decrease nitrogen and phosphorus levels in addition to enhancing phytoplankton community biodiversity, which was an effective approach for mitigating environmental problems in marine ecosystems. Broch et al. used a high resolution coastal and ocean hydrodynamic model system to investigate the transport and deposition patterns of Particulate Organic Matter (POM) from kelp farm. They underscore the dispersal and deposition of detritus from kelp cultivation associated environmental risks posed by organic loading, and the potential for seafloor carbon sequestration by kelp farming as a nature based climate solution. Endo and Gao reviewed the interactive effects of warming and nutrient enrichment on macroalgae production. They predicted that global warming would enhance bottom-up effects on primary production in cold seasons and areas, and there would be a negative warming effect on production in hot seasons and areas, but it might be possible to mitigate this effect by appropriate levels of nutrient enrichment.

The ecological function of shellfish aquaculture

Shellfish aquaculture interacts with marine ecosystems through processes like nutrient cycling, trophic recourses, substrate engineering etc. Sean et al. proved that the mussel farm enriched benthic communities at line- and bay-scales Îles de la Madeleine, eastern Canada. Spatial structure in the distribution of macrofauna was evident within the aquaculture lease as most species were more abundant directly below and close to mussel lines and anchor blocks. At the same time, oyster farm can provide habitat for marine organisms and increase the biodiversity of microbenthic animals. Chan et al. assessed the biodiversity associated with an abandoned benthic oyster farm. The oyster farm provided habitat and trophic support for associated benthic macrofauna. It showed that oyster aquaculture could improve the restoration potential of oyster reefs. There is also other impacts of aquaculture on the wild animals. Drolet et al. found the aquaculture-related diets from shellfish farm and salmonid farm had different effects on the long-term performance and condition of the rock crab (*Cancer irroratus*). The mussel-only diet impact little on the crabs, whereas the salmonid feed diet resulted in negative impacts on condition. However, the impacts should be investigated in wild environment in the future.

Bivalve aquaculture plays a role in nitrogen extraction. Guyondet et al. used coupled hydro-biogeochemical modeling to integrate all relevant interactions in the assessment of bivalve culture as a nitrogen extraction solution, which provided a new method to assess the eutrophication mitigation. Bivalve culture was shown to provide a net nitrogen removal in the majority of the tested scenarios. Mussel rather than oyster farming provided the strongest potential for nutrient loading mitigation.

The buried bivalve could increase sediment mineralization process. However, they were adversely affected by decreased dissolved oxygen and increased hydrogen sulfide in the sediment induced by marine heat wave, which was proved by Liu et al. from the behavior and physiological metabolism aspects of Manila clam (*Ruditapes philippinarum*).

The ecological function of sea ranching

Artificial reefs are popularly used in the enhancement of sea cucumber (*Apostichopus japonicus*). Xu et al. found that the sea cucumber farm provided spawning and first-year nursery grounds for wild black rockfish (*Sebastes schlegelii*) in Bohai sea, China. The same time, the increased black rockfish could affect other organisms, including crustacea, mollusk and *Hexagrammos otakii*, in both positive and negative way. So, the interaction effects between sea ranching and wild organisms need further research.

The ecological function of polyculture

Polyculture is an important concept in acheiving sustainable development of aquaculture. The well known and successful polyculture example is the shellfish-macroalgae integrated multi-trophic aquaculture (IMTA) (Fang et al., 2016). Liu et al. found the macroalgae and shellfish-macroalgae aquaculture waters absorbed CO_2 from atmosphere by determined the carbonate system and pCO_2 in Sanggou Bay, China. Jiang et al. found that the presence of kelp in integrated aquaculture may help shield oyster from the negative effects of elevated seawater pCO_2, which was due to the kelp improving pHNBS in the enriched CO_2 experimental system, and then the oyster could keep a relevant normal clearance rate and scope for growth. In the polyculture pond, Feng et al. constructed three Ecopath models representing the early, middle, and late culture periods of a *Portunus trituberculatus* polyculture ecosystem, respectively. The results demonstrated that detritus was the main energy source in this polyculture ecosystem. *R. philippinarum* had a dominant influence on phytoplankton community dynamics which changed from nano- to pico-phytoplankton predominance, from the middle to the late period. The ecosystem stability was decreasing during the culturing period, but it can be optimized by stocking more *R. philippinarum* and involving macro-algae in the pond.

Author contributions

JF and FW wrote the editorial. ØS and DL contributed to review and correct the editorial. All authors approved the submitted manuscript for publication.

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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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References

Bricker, S. B., Ferreira, J. G., Zhu, C., Rose, J. M., Galimany, E., Wikfors, G., et al. (2018). Role of shellfish aquaculture in the reduction of eutrophication in an urban estuary. *Environ. Sci. Technol.* 52 (1), 173–183. doi: 10.1021/acs.est.7b03970

Costello, C., Cao, L., Gelcich, S., Cisneros-Mata, M.Á., Free, C. M., Froehlich, H. E., et al. (2020). The future of food from the sea. *Nature* 588, 95–100. doi: 10.1038/s41586-020-2616-y

Fang, J., Zhang, J., Xiao, T., Huang, D., and Liu, S. (2016). Integrated multi-trophic aquaculture (IMTA) in sanggou bay, China. *Aquacult. Environ. Interact.* 8, 201–205. doi: 10.3354/aei00179

FAO (2016). The state of world fisheries and aquaculture 2016: Contributing to food security and nutrition for all. (Rome: Food and Agriculture Organization). Available at: https://www.fao.org/publications/sofia/2016/en/.

FAO (2020). The state of world fisheries and aquaculture 2020. Sustainability in action. (Rome: Food and Agriculture Organization). doi: 10.4060/ca9229en

FAO (2022). The state of world fisheries and aquaculture 2022. Towards blue transformation. (Rome: Food and Agriculture Organization). doi: 10.4060/cc0461en

ICES (2020). Working group on environmental interactions of aquaculture (WGEIA). *ICES. Sci. Rep.* 2 (112), 187. doi: 10.17895/ices.pub.7619

Khanjani, M. H., Zahedi, S., and Mohammadi, A. (2022). Integrated multitrophic aquaculture (IMTA) as an environmentally friendly system for sustainable aquaculture: functionality, species, and application of biofloc technology (BFT). *Environ. Sci. Pollut. Res.* 29, 67513–67531. doi: 10.1007/s11356-022-22371-8

Smaal, A. C., Ferreira, J., Grant, J., Petersen, J., and Strand, Ø. (2019). *Goods and services of marine bivalves* (Cham: Springer), 591 p. doi: 10.1007/978-3-319-96776-9

Stedt, K., Pavia, H., and Toth, G. B. (2022). Cultivation in wastewater increases growth and nitrogen content of seaweeds: A meta-analysis. *Algal. Res.* 61, 102573. doi: 10.1016/j.algal.2021.102573

Strand, Ø., Jansen, H. M., Jiang, Z., and Robinson, S. M. (2019). "Perspectives on bivalves providing regulating services in integrated multi-trophic aquaculture," in *Goods and services of marine bivalves*. Eds. A. C. Smaal, J. Ferreira, J. Grant, J. Petersen and Ø Strand (Cham: Springer), p 209–p 230. doi: 10.1007/978-3-319-96776-9

Tacon, A. G. J., and Forster, I. P. (2003). Aquafeeds and the environment: policy implications. *Aquaculture.* 226 (1–4), 181–189. doi: 10.1016/S0044-8486(03)00476-9