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EDITED AND REVIEWED BY
Yngvar Olsen,
Norwegian University of Science and Technology, Norway

*CORRESPONDENCE
Sílvia Lourenço
slourenco2@gmail.com

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Editorial: Aquaculture of emergent marine invertebrates: Advances in nutrition, rearing technology and end-product quality

Sílvia Lourenço[1]* and Luísa M. P. Valente[2,3]

[1]MARE –Marine and Environmental Sciences Centre/ARNET – Associated Laboratory, ESTM, Polytechnic of Leiria, Peniche, Portugal, [2]CIIMAR/CIMAR, Centro Interdisciplinar de Investigação Marinha e Ambiental, Universidade do Porto, Terminal de Cruzeiros do Porto de Leixões, Matosinhos, Portugal, [3]ICBAS, Instituto de Ciências Biomédicas de Abel Salazar, Universidade do Porto, Rua de Jorge Viterbo Ferreira, Porto, Portugal

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Editorial on the Research Topic
Aquaculture of emergent marine invertebrates: Advances in nutrition, rearing technology and end-product quality

The growing demand for nutritious healthy seafood with high safety standards drives the aquaculture future. While farmed species of high trophic level are still highly dependent on fishmeal and fish oil that may limit its production growth, marine invertebrates are often species of low trophic level with high market value and high potential to expand. Sea urchins, sea cucumbers and the european clam (*Ruditapes decussatus*) have been extensively investigated, but other species recently emerged as potential candidates for aquaculture diversification, including gammarid crustaceans, jellyfish, tunicates (ascidians) and limpets.

This Research Topic on "Aquaculture of emergent marine invertebrates - Advances in nutrition, rearing technology and end-product quality" gathers nine research articles and a systematic review dedicated to the physiology, nutrition, and rearing technology of marine invertebrate species emergent for aquaculture. The articles addressed key nutritional requirements of various species; novel feed formulations and their implication in specific physiological functions, including the quality of end-product; the impact of climate change related factors in species survival; as well as production technologies to maintain healthy broodstock and improve larvae and juvenile production.

Sea urchins and sea cucumbers have long been identified as candidates to aquaculture diversification. In their work, Suckling et al. analysed the market potential of *A. punctulata* gonads, a common but still unexplored sea urchin in the western Atlantic Ocean. Various diets were tested and shown to be able to promote gonad size with some individuals exhibiting gonads with acceptable colours for European market. Grosso et al. focused on trophic requirements of different life stages of *Paracentrotus lividus*, to help defining suitable and cost-effective diets maximizing somatic growth and gonadal production depending of life cycle stage. A general growth model covering the full post-metamorphic *P. lividus* life cycle was defined for each dietary condition, evidencing a consequent variation of trophic requirements and food energy allocation with increased size. Complementarily, the work conducted by Zuo et al highlighted that lipid dietary sources affect the reproductive performance and early larvae development in *Strongylocentrotus intermedius*. Fish oil was considered the best lipid source based on growth, reproductive performance, survival rate and quality of larvae. Altogether, these results highlight the need for adopting efficient feeding strategies to promote the reproductive performance and gonad quality of sea urchins.

Li et al. investigated the long-term effects of historic diets on the digestive enzyme activities in regenerated intestines of *Apostichopus japonicus* after evisceration (characteristic behaviour of sea cucumber in stressful situations). The results showed that diets provided in earlier stages of sea cucumbers life cycle can affect their digestive physiology and can persist in regenerated intestines producing long-term effects on the growth and metabolism.

The study conducted by Rato et al. evaluated the combined effect of temperature and salinity on mortality and feeding behaviour of European calm, *Ruditapes decussatus*, showing that abrupt reductions in salinity and sharp increases in temperature leaded to high mortality. Juvenile clams were shown to be more sensitive to the increase of temperature in a less saline environment, resisting more to extremely high temperatures under more saline conditions. These results are particularly important under climate change scenarios that predict extreme events of high temperatures and heavy rainfall in the south of Europe, that may compromise the recruitment of European clam.

Castejón et al presented a methodological article with major advances in limpets' larval culture, settlement, and juvenile growth. This research work introduces, adapted and optimized methods to produce, at experimental scale, the native species of the Macaronesia region, *Patella aspera* and *Patella candei*, two limpet species with relevant cultural, gastronomic, and economic importance.

Ribes-Navarro et al. explored the combined effects of diet and environmental factors, on survival, growth, and LC-PUFA content of *Gammarus locusta*. The effects of temperature on the gammarid fatty acids were not evident, with diet being the main modulator of the profiles. The results suggest an ability of *G. locusta* for LC-PUFA biosynthesis (trophic upgrading) and/or retention, making this species a promising source of high-value ingredients for aquafeeds.

Ballesteros and colleagues have focused on the production potential of jellyfish for a variety of applications including biomedical, cosmetic, and pharmacological industries. Ballesteros et al. designed and set up an effective rearing system to produce the early planktonic stages of *Pelagia noctiluca* in both flow-though and closed systems. Moreover, Ballesteros et al. defined optimal feeding conditions for *P. noctiluca* culture. They have guaranteed the culture durability by obtaining a third generation of the species and validated the use captive-bred specimens to produce the toxins of biotechnological interest. Both studies highly contributed to the improvement of breeding techniques, nutrition and production in aquaculture of the most important jellyfish in the Mediterranean Sea.

Finally, a thorough systematic revision was conducted by Marques et al on the potential contribution of tunicates as extractive species, further exploring its potential as sources of nutrients and bioactive compounds for aquafeed. The review showed that ascidians present high filtration and fast growth rates, performing well under an integrated multitrophic aquaculture system framework. They also hold great potential for aquafeed formulations and dietary supplements as sources of n-3 LC PUFA.

Overall, the ten articles included in the Research Topic in Aquaculture of emergent marine invertebrates mirror the high diversity of species candidate for aquaculture; the technological challenges behind their full-life cycle production; the need to identify species nutritional requirements, and to understand the diversity of species physiologic responses to climate change scenarios. But foremost, this collection of manuscripts shows that emergent marine invertebrates have the potential to expand the aquaculture sector and produce high-value products for gastronomic niche markets. The wide range of species considered can also contribute with valuable novel raw materials for the aquafeed industry, but also for a variety of biotechnological, pharmacological and nutraceutical industries.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it 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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