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Editorial

New Techniques in Marine Aquaculture

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In recent years, the importance of marine aquaculture has been increasing globally, and new technologies are playing a significant role in this trend [1,2]. Marine aquaculture (i.e., mariculture) is the practice of farming aquatic organisms in the ocean or other marine water bodies. The practice has become increasingly important in meeting the growing demand for seafood as wild fish populations continue to decline due to overfishing and environmental degradation. Marine aquaculture has been practiced for centuries, but new technologies have recently revolutionized the industry. These technologies have enabled the farming of a broader range of species in larger quantities and with greater efficiency. They have also made it possible to reduce the environmental impact of aquaculture, making it a more sustainable practice.

The development of aquaculture technology for tuna and similar large ocean species has become increasingly important in recent years. As wild fish stocks continue to decline, the need for sustainable and efficient aquaculture practices has grown. Tuna, in particular, is a fish highly sought-after for its nutritional value and culinary versatility, making it a prime candidate for aquaculture development [3,4]. Advancements in aquaculture technology have allowed the successful farming of tuna and similar species in controlled environments. These technologies include advanced water filtration systems, specialized feeding techniques, and optimized breeding programs. These developments have increased the availability of tuna for human consumption and reduced the pressure on wild populations. Additionally, innovative monitoring and data collection systems have allowed the better management of aquaculture operations. Other emerging technologies include real-time water quality monitoring, tracking fish growth and health, and predictive analytics for optimizing feeding schedules and environmental conditions.

Another critical technology in marine aquaculture is the use of genetically modified organisms (GMOs) [5,6]. GMOs are organisms that have been genetically altered to exhibit certain traits, such as fast growth and disease resistance. In aquaculture, GMOs can be used to produce fish and other aquatic organisms that are more efficient to farm, require less feed, and are less susceptible to disease. Other new technologies in marine aquaculture include the use of automated feeding systems, advanced monitoring and control systems, and the use of renewable energy sources such as solar and wind power. These technologies are helping to make marine aquaculture more efficient, cost-effective, and environmentally sustainable.

The importance of these new technologies is not limited to meeting the growing demand for seafood. These novel technologies have food security, environmental sustainability, and economic development implications. Oceanic fish farming serves as a pivotal solution to alleviate the strain on natural fish stocks, supplying a sustainable source of superior protein to meet human dietary needs and fostering economic revitalization in shoreline locales. Advancements in aquaculture technology are instrumental in satisfying the escalating appetite for seafood, mitigating the exploitation of wild fish resources, and championing ecologically responsible practices. As the global population continues to

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grow and demand for seafood increases, marine aquaculture and new technologies will play an increasingly important role in meeting these challenges.

It is the basic requirement of the modern fishery to ensure the supply of high-quality aquatic animal protein and meet the increasing consumption demand. China has the longest history, the richest experience, and the most varieties and modes of comprehensive aquaculture in the world. The advent of innovative methodologies has been a catalyst for the swift expansion of the aquaculture sector on a global scale. The focal point of this Special Issue is to provide a comprehensive overview of the latest advancements in Chinese aquaculture. It encompasses a spectrum of cutting-edge fields, such as biotechnological applications, ecological management practices, nutritional tech innovations, and sustainable environmental technologies. Through this, we aim to offer insights into the technological progression that is shaping the future of aquaculture within the region. In this Special Issue, the farmed species include yellowfin tuna (*Thunnus albacares*), mackerel tuna (*Euthynnus affinis*), greater amberjack (*Seriola dumerili*), yellowtail kingfish (*Seriola aureovittata*), humphead wrasse (*Cheilinus undulatus*), bluestripe snapper (*Lutjanus Kasmira*), golden pompano (*Trachinotus ovatus*), yellow croaker (*Larimichthys crocea*), coral trout (*Plectropomus leopardus*), shrimp (*Penaeus monodon*), sea cucumber (*Apostichopus japonicus*), sea urchin (*Strongylocentrotus intermedius*), and microalgae (*Isochrysis zhanjiangensis*). The research contents and main findings in this Special Issue are as follows:

Contribution 1 conducted a preliminary study on an innovative concept that combines a floating offshore wind turbine with a fishing cage in order to optimize the utilization of ocean resources, reduce the investment return period, and directly supply energy to the fishing cage. The outcomes of their study offer insights into the conceptual design, modeling, and simulation analysis of the integrated wind turbine-fishing cage system. However, further research is needed to perform detailed structural design optimizations, strength evaluations, and experimental tests on the integrated system in the future.

In contribution 2, Zhao et al. employed the RAD-seq technology to identify the whole-genome SNPs of *Lutjanus kasmira*, a fish species. Subsequently, these SNPs were utilized to investigate the genetic diversity and structure of this species. The findings from their study offer a solid theoretical foundation for the strategic development and preservation of the germplasm resources of *Lutjanus kasmira*.

In contribution 3, Le et al. successfully cloned the MKK4 cDNA from *Penaeus monodon*, a species of shrimp. They then examined the responses of this gene to bacterial infection and low-salinity conditions. Interestingly, they found that the PmMKK4 gene was activated in both the gill tissue and hepatopancreas tissue of *P. monodon* after experiencing low-salinity stress. However, the expression change of PmMKK4 in the gill tissue was particularly significant. These findings suggest that the PmMKK4 gene plays a crucial role in both the innate immune response after pathogen infection and the shrimp's ability to adapt in a low-salt environment.

In contribution 4, Lv et al. conducted an evaluation on the impact of various LED colors on the productivity, chlorophyll (Chl-a, Chl-b, and total Chl), protein, and carbohydrate content of *Isochrysis zhanjiangensis* in indoor culture. The findings of their research indicate that the productivity of Chl (a, b, and total), as well as the protein and carbohydrate content of *Isochrysis zhanjiangensis*, can be effectively regulated by different light wavelengths. This study holds great significance in terms of selecting the appropriate light color (wavelength) to maximize the production of desired organic compounds in indoor cultures, potentially paving the way for commercially viable practices.

Contribution 5 conducted a study aimed at investigating the potential positive effects of curcumin on the ammonia nitrogen stress tolerance ability of greater amberjack (*Seriola dumerili*). The results obtained from their research demonstrated that the inclusion of curcumin in the diet of the greater amberjack can enhance their tolerance to ammonia nitrogen stress. These findings provide strong support for the promising application prospects of curcumin in promoting the well-being and stress resistance of this fish species.

In contribution 6, Liu et al. conducted an investigation to assess the impact of acute high-temperature stress (34 °C) on the physiological reactions of juvenile yellowfin tuna (*Thunnus albacares*). By measuring changes in the biochemical indexes of serum, liver, gill, and muscle, the researchers compared the experimental group under high-temperature stress with a control group (28 °C) at different time points (0 h, 6 h, 24 h, and 48 h). The findings of the study revealed that the elevated temperature negatively affected the antioxidant enzymes and metabolic indexes of the yellowfin tuna, leading to a decline in physiological indexes. These results highlight the susceptibility of juvenile yellowfin tuna to acute high-temperature stress.

Contribution 7 conducted a comparative study on the survival, growth, and behavior performances of sea urchins and sea cucumbers in an integrated multi-trophic aquaculture (IMTA) system. In the IMTA system, the experimental group (group M) consisted of *S. intermedius* and *A. japonicus* per 10,638 cm^3 of stocking density, while the control group for sea urchins (group U) had *S. intermedius* per 10,638 cm^3 of stocking density, and the control group for sea cucumbers (group C) had *A. japonicus* per 10,638 cm^3 of stocking density. The results of the study indicate that the implementation of the IMTA system significantly enhanced the feeding behavior, body growth, and survival rate of cultured *Strongylocentrotus intermedius*. This innovative aquaculture system shows great potential in improving the production efficiency of juvenile *Apostichopus japonicus* (as the primary species) and *S. intermedius* (as the subsidiary species) in China.

In contribution 8, Li et al. conducted a study on a clone of *Penaeus monodon* NHE cDNA, known as PmNHE, and assessed its effects on high-concentration ammonia nitrogen stress. The significant expression of PmNHE was observed in the intestine of *P. monodon* under high-concentration ammonia nitrogen stress. Additionally, the survival times of *P. monodon* were found to be noticeably shorter when exposed to high levels of ammonia nitrogen stress compared to the control groups. These findings suggest that PmNHE may play a crucial role in environments with elevated levels of ammonia nitrogen.

In contribution 9, Liu and colleagues performed a comprehensive DNA barcoding study on the Scaridae, a family of parrotfish, in the Hainan region. Their investigation included the analysis of 401 DNA barcode sequences, with 51 of these sequences obtained from newly collected specimens. These sequences were derived from a specific 533 base pair segment of the CO I gene, known to be a reliable marker in genetic identification. The findings from this study suggest that DNA barcoding is a valuable molecular approach for the monitoring and conservation of fishery resources. Additionally, it serves as a critical tool for resolving complex taxonomic issues, highlighting areas in need of further scientific exploration.

In contribution 10, Zhao and colleagues meticulously identified a dozen pairs of polymorphic microsatellite markers. Leveraging these genetic indicators, they engineered a duo of multiplex PCR (polymerase chain reaction) protocols to facilitate the genetic scrutiny of 30 humphead wrasse (*Cheilinus undulatus*) specimens. The implementation of these advanced multiplex PCR systems has laid the groundwork for critical applications in the realms of genetic stock identification, the evaluation of genetic variability, and the monitoring of population dynamics following the introduction and propagation of *C. undulatus*. This innovative approach promises to enhance conservation efforts and sustainable management strategies for this species.

In contribution 11, Wang and colleagues explored the impact of varying sunlight exposure—sunny versus cloudy weather—on the pattern of gene expression in the liver of the mackerel tuna (*Euthynnus affinis*). Their findings revealed a consistent daily pattern among a broad set of genes, including those governing circadian rhythms (such as CREB1, CLOCK, PER1, PER2, PER3, REVERBA, CRY2, and BMAL1), metabolism (SIRT1 and SREBP1), and immune function (NF-kB1, MHC-I, ALT, IFNA3, ISY1, ARHGEF13, GCLM, and GCLC), regardless of the weather conditions ($p < 0.05$). The study concluded that the expression of genes related to circadian rhythm, lipid metabolism, and immunity in mackerel tuna liver is influenced by diurnal cycles and environmental light conditions, undergoing significant expression fluctuations.

In contribution 12, Yu and colleagues conducted a comparative analysis of the growth dynamics and nutrient profiles of large yellow croakers cultivated within two distinct environments: a novel offshore aquaculture vessel and a conventional nearshore cage system. Their investigation revealed that the offshore aquaculture ship offers a protective haven against environmental adversities, such as typhoons and harmful algal blooms, commonly known as red tides. Remarkably, the large yellow croakers acclimatized to the ship-based farming system in a relatively short time frame, with no significant stress incidents reported throughout the cultivation period. The data gathered from this study indicate a superior growth rate and nutritional quality in the croakers bred on the offshore ship compared to those raised in traditional cages. This study substantially contributes to our comprehension of the offshore ship-based aquaculture paradigm for cultivating large yellow croakers.

In contribution 13, Zhou and colleagues delved into the effects exerted by salinity stress on the antioxidative responses in yellowfin tuna, *Thunnus albacares*. The findings from this research suggest that juvenile yellowfin tuna demonstrate alterations in their antioxidant capabilities when subjected to low-salinity environments. Conversely, evidence points to the robust resilience of these juveniles to saline conditions of 29 parts per thousand (‰), indicating a strong adaptive capacity. Nonetheless, it is important to note that excessive stress could potentially deplete the organism's energy reserves, thereby diminishing its overall resistance to environmental stressors.

In contribution 14, Guo and colleagues delved into the pathology of *Cryptocaryon irritans*, its impact on the immune enzyme activities, and the regulation of the NEMO gene within the Golden pompano (*Trachinotus ovatus*). The team discovered a marked elevation in the mRNA expression levels of the *T. ovatus* NF-kappa-B essential modulator (ToNEMO) following *C. irritans* exposure, with significant increases noted across multiple organs including the gills, skin, liver, spleen, and head kidney. These findings imply a potential role for ToNEMO in the fish's immune defense mechanisms, providing valuable insights into the biological reactions triggered by the parasitic infection.

In contribution 15, Zhou and colleagues explored how curcumin intake influences non-specific immune functions and the antioxidative capacity of *Seriola dumerili* when subjected to ammonia-induced stress, as well as during the subsequent recovery period. The experimental design included three distinct feed formulations, with curcumin concentrations set at 0, 75, and 150 mg/kg. The findings of this investigation reveal that incorporating curcumin into the diet can bolster the non-specific immune mechanisms and antioxidative potential in juvenile *S. dumerili*, thereby augmenting their resilience against the detrimental effects of elevated ammonia levels.

Contribution 16 conducted by Qian et al. explored the impact of varying water flow rates on the development and physiological health of the coral trout (*Plectropomus leopardus*) within a recirculating aquaculture system (RAS). Their research concluded that elevated water velocities disrupt the physiological balance and impair the digestive processes in the intestinal tract of the coral trout, leading to a compromised growth rate. This suggests that coral trout exhibit a heightened sensitivity to increased water flow. Practical applications in RAS operations should, therefore, maintain water flow rates at or below 1 bl/s to ensure optimal conditions for the health and growth of this species.

In contribution 17, Wang et al. delved into the impact of artificial reefs on the survival and behavioral patterns of juvenile sea cucumbers (*Apostichopus japonicus*) post air exposure and during disease proliferation at a temperature of 25 °C. The study illuminated that artificial reefs may serve as a sanctuary, mitigating direct interaction among healthy and diseased individuals, thereby potentially curtailing the spread of illness. Building on this foundation, our current study unveils an economically viable strategy to enhance the viability of young sea cucumbers within hatchery environments, particularly under elevated thermal conditions.

In contribution 18 conducted by Li and colleagues, the presence of a gene akin to the Forkhead Box O (FOXO), referred to as EsFOXO-like, was discerned within the crustacean species *Eriocheir sinensis*. The study probed into how this gene influences the 20-hydroxyecdysone (20E) signaling cascade. The team's experiments uncovered that, upon administering a combination of AS1842856 and Rapamycin to the subjects, there was a marked depletion in 20E levels and a down-regulation of the E. sinensis molt-inhibiting hormone (EsMIH) expression when contrasted with the use of AS1842856 with DMSO. In tandem, an upsurge was noted in the expression of *Eriocheir sinensis* ecdysone receptor (Es-EcR) and Retinoid X Receptor (EsRXR). These observations collectively infer that the EsFOXO-like gene modulates the 20E pathway via the mTOR signaling route, thereby enriching our comprehension of the molting mechanics in crustacean species.

In contribution 19, Cui et al. explored the genetic makeup and diversity across five distinct groups of yellowtail kingfish (*Seriola aureovittata*). They found minimal genetic variance, as indicated by low Fst values, between the yellowtail kingfish populations of China and Japan, coupled with high levels of gene flow (Nm). These findings imply a frequent genetic interchange between these collections, which points to a shared population structure. On the other hand, the Australian yellowtail kingfish showed significant genetic divergence from both the Chinese and Japanese groups, hinting at disparate evolutionary lineages and distinct population identities. The insights gleaned from this research are poised to enhance the genetic breeding programs for the Chinese yellowtail kingfish and foster the preservation and responsible management of its genetic resources.

This Special Issue delves into the forefront of aquaculture technology, placing innovative biotechnological approaches for identifying gene sequences that bolster resistance against bacterial infections and environmental challenges in the spotlight. It encompasses advancements in nutritional strategies designed to enhance the immune response and resilience of aquatic organisms. Included within this issue are insightful investigations into the thermal stress impacts on the immune systems of marine fish, along with explorations into the strategic use of light spectrum adjustments to accelerate algal proliferation. Additionally, the issue explores the benefits of employing integrated multi-trophic aquaculture systems for boosting production efficiency. This compilation of cutting-edge research not only sheds light on the technological strides in cultivating marine fish, shrimp, sea cucumbers, sea urchins, and algae, but also sets the stage for translating these breakthroughs to a broader spectrum of species within the aquaculture industry.

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