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Editorial: Biology meets technology: Aquatic animals in novel and new aquaculture production systems

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Editorial on the Research Topic
Biology meets technology: Aquatic animals in novel and new aquaculture production systems

Aquaculture is not a new science. Humans have reared aquatic animals for over a millennium, and this has been documented by writings and archaeological evidence from ancient China, Egypt, and Rome. From backyard farming with unsophisticated technologies, aquaculture as we know it today, has developed on an unprecedented scale (Nash, 2011). It is now considered one of the fastest-growing food-producing sectors in the world and is often regarded as a key industry expected to supply the protein needs of the growing global population (FAO, 2020). This billion-dollar industry, characterised by a wide array of aquaculture commodities from different regions of the world, has greatly benefitted from technological innovations in recent years (Naylor et al., 2021; Lazado and Good, 2021). These innovations have allowed the diversification of aquaculture products, culture of species in new locations and novel technologies, optimisation of conditions in artificial environments and ramping of production through intensification.

Indeed, these technological innovations are impressive. Nevertheless, there is a concern shared by aquaculture stakeholders that while the industry is moving dramatically forward with the help of new technologies, the health and welfare of farmed aquatic species in these new environments and under different production technologies may not be prioritised as it should. These technologies must take into account the biological requirements of the cultured organisms. In addition, attention and concern for aquaculture is becoming an increasingly important issue for consumers, producers and regulators, and in many parts of the world, aquaculture is potentially at risk from the threats of climate change (Reverter et al., 2020). Therefore, studying how fish respond and thrive in new environments must be done in a holistic manner – particularly on the subjects of optimal productivity, lower environmental footprints and superior health and welfare.

The Research Topic "*Biology Meets Technology: Aquatic Animals in Novel and New Aquaculture Production Systems*" has gathered new information on the challenges and opportunities of farming aquatic animals using advanced farming protocols and in novel production environments.

Recirculating aquaculture system (RAS) is becoming more and more common in Atlantic salmon (*Salmo salar*) production (Stiller et al., 2020; Lazado and Good, 2021). RAS is considered a single production loop system because the fish tanks, filtration system and water treatment are all interconnected. Because of its distinct characteristics of limited water exchange and potential accumulation of metabolic by-products, maintaining optimal water quality is crucial (Lazado et al., 2021). One of the variables that is routinely monitored is nitrite (NO_2-N). Biofilters convert nitrogen by-products (ammonia → nitrite → nitrate) to less harmful nitrogen wastes. In the paper of Mortensen et al., they explored the consequences of fluctuating sub-lethal levels of nitrite on Atlantic salmon post-smolts in a commercial RAS facility. The authors presented a case study from a Faroese Atlantic salmon farm, that reared large post-smolts in freshwater RAS for 22 months before transfer to sea. They revealed that fluctuating levels of nitrite induced extracellular hyperkaliemia, a condition where the potassium level in the blood is higher than normal. The nitrite levels in the blood were at least 8 times higher than the ambient nitrite level, and positively corrected with the potassium level. The changes in biomass, feeding regimes, organic matter, and other environmental parameters influence biofilter performance, and thus, cause fluctuations in nitrite in RAS. The results from this study will be valuable in developing new protocols to reduce nitrite fluctuations. Conducting fish trials in experimental RAS is challenging and expensive. One common set-up in an experimental RAS facility is when one RAS (i.e., biofilter, water treatment units) is connected to several tanks, which is often a challenge during experimental conditions because the experimental units are not independent. An ideal set-up is a replicated RAS unit – where one tank is connected to a single RAS, thereby simulating a microcosm of a RAS environment (Pedersen et al., 2012). The single-tank RAS set-up has increased in demand recently, especially in studying pathogen dynamics in closed system. Mota et al. presented a new RAS facility that is designed to address key issues in Atlantic salmon RAS-based farming, including disinfection, pathogen breach and modern diets. Using 5 independent trials, the researchers evaluated the performance of the RAS facility and showed that the variation within tanks was larger than the variation between the tanks. Further, variations in water quality parameters controlled by sensors were relatively low. Nonetheless, the parameters depending on biofilter maturation level and performance showed a very high variation. To further aid future trials in this system, power analysis showed that 15 fish are required to be sampled per tank. This baseline information will be used to further develop the RAS facility and ensure that the system captures the conditions that are biologically sound and with high industrial relevance.

Atlantic salmon aquaculture is traditionally characterised by two phases of production – starts on land in fresh water, and the next phase at sea. Sea cage culture of salmon is prompted by two main challenges, sea lice and escapees, and both entail significant economic and environmental consequences (Nilsen et al., 2017). The closed containment systems (CCS) are characterised by a physical barrier that ensures that fish do not have direct contact with the outside environment. Floating semi-closed containment systems (S-CCS) have been proven to be effective against lice and escapees. Several prototypes have been developed in recent years. In Norway alone, 28 CCS concepts are available to date, and several are in the pipeline. In our paper (Lazado et al.), we presented FishGLOBE V5, a novel 3500 m^3 S-CCS where water is pumped in through pipes from approximately 14 m deep, a level where sea lice do generally not thrive. Water quality in FishGLOBE V5 supports the biological requirements of salmon. In addition, allowing the fish to stay in the system before sea cage transfer could reduce mortality. Growth was not hampered in FishGLOBE V5. Interestingly, the growth (expressed as specific growth rate, SGR) during the months in FishGLOBE V5 was better than in the RAS system prior to and open net cage after the S-CCS stay. However, the prevalence of eye, fin, and skin lesions and induction of stress in FishGLOBE V5 should be considered in the risk assessment regarding its use. The data from this paper support the further development of FishGLOBE V5 as a viable technology for salmon production at sea.

In traditional sea cages, salmon are exposed to several microbial agents, many of which are opportunistic pathogens resulting in complex gill health issues (Herrero et al., 2018). Farmers are then prompted to use therapeutic interventions to address these challenges. Though the use of antimicrobials and chemical therapeutics has been reduced to a reasonable extent, there are cases where these are the only available options. Slinger et al. demonstrated that relevant antimicrobial agents affect the branchial microbiota of Atlantic salmon. Bath treatment with either chemotherapeutants (chloramine-t and hydrogen peroxide) and antibiotics (oxytetracycline and florfenicol) resulted in the reduction of cultivable bacteria in the gills as well as a decrease in bacterial richness and abundance. The study provided insight into how these common treatments could result in branchial dysbiosis, potentially impacting microbial gill diseases and fish health in general.

Fish health and welfare are determinants of productivity in aquaculture, and of increasingly important concern to consumers and legislators. Parameters that reveal the state of the fish in aquaculture systems in real-time, termed outcome-based indicators of welfare, are critical to support optimum health and welfare. In support of this need, technologies that can monitor these parameters in real-time have received attention in the last years (Endo and Wu, 2019). One of the advantages of real-time monitoring is the early detection of health and welfare issues that allow producers to initiate an early response, thus avoiding further serious consequences. In recent years, most of the technologies for the health and welfare monitoring of farmed fish have used sensitive sensors and machine learning algorithms. The metabolic rate could be used as a proxy of the energetic expenditure related to daily activities and husbandry changes in fish. In the paper of Alfonso et al., a telemetry sensor (i.e., acoustic transmitter) tagged to a European sea bass (*Dicentrarchus labrax*) was used to monitor oxygen consumption rate (MO_2). Implantation of accelerometer tags did not change fish swimming performance or cause a particular stress response. Acceleration values recorded by the tag were correlated with MO_2, therefore bringing us a step further on real-time monitoring of energetic costs to environmental variations and/or aquaculture practices of an individual fish. In addition to supporting fish health and welfare, sensors and other real-time approaches to monitor fish condition could be valuable tools to enhance consumer confidence and provide the evidence required to meet fish welfare certification schemes.

Overall, the contributions gathered in this Research Topic provide a snapshot of the current knowledge on the novel and new aquaculture production systems in aquaculture and their effects on the farmed animals. Aquaculture technologies are rapidly developing and expanding. These innovations must not only be focused on technological breakthroughs but also ensure that they support the biological requirements of the farmed organisms. Indeed, technological innovations should develop in conjunction with biological advances, securing sustainable aquaculture production today and beyond.

Author contributions

CL wrote the first draft of the editorial. CL, ÅE, and RF revised the paper. 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.

Publisher's note

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