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Best Management Practises (BMPs): A Sustainable Step for Future Global Food Security

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Abstract

Aquaculture is the practise of raising fish or shellfish primarily for human consumption. It includes constant engagement with the environment because it is done in ponds, cages, or open water bodies. If it is done so in a way that is both socially and environmentally appropriate, aquaculture can be a sustainable activity. The term "sustainable aquaculture" is related to an aquaculture production system that is considerate of the local human and social environment, utilises renewable resources to the greatest extent possible, provides animals with living conditions that are as close as possible to those of their native habitat, and uses recycled materials. The Best Management Practises (BMPs) can be used to achieve sustainability. BMPs include things like following the law, being socially responsible, choosing appropriate sites for farms, building them well, and using the best practises for farm management throughout the process, everything from pond layout to harvesting and after harvesting management measures. Adopting BMPs would result in increased output, productivity, and profitability as well as obligations to the environment and society.

Keywords: Aquaculture, BMPs, Disease, Feed, Fish, Sustainability

Introduction

One of the food production industries with the fastest growth rate worldwide is aquaculture. Globally, aquaculture has grown, increased, and diversified over the years. One of the world's fastest expanding food production industries is aquaculture (Bostock *et al.*, 2010). It began as a long-standing customary practise and has now grown into a large science and a prosperous enterprise. A range of chemical and biological treatments are employed to cure and mitigate epidemics, manage turbidity and water chemistry, and tackle the enormous rise in aquaculture output over the prior couple generations. The Best Management Practises (BMPs) are meant to act as a guide for aquaculture enterprises, whether they are starting out or growing. BMPs heavily rely on site location, health monitoring, water quality management, wastewater management, yield management, disinfection and sanitising, monitoring of feed intake behaviour, pathogen tolerance, and pharmacological management of that specific system. Modern aquaculture is constantly spreading throughout the area, which calls for attention to both environmental and economic sustainability, which are tangentially related to the best management practises of that aquaculture system.

Species Selection

A balance between biological understanding and the regional economic requirements generally goes into selecting the right species for a specific aquaculture system. These features, which support management in culture systems with relatively large population densities, include low feeding costs, ease of propagation, resistance to infection, rapid growth, and high survival (Webber and Riordan, 1976). It should be simple to sell the cultured species locally or to the intended consumers (Webber and Riordan, 1976). It is a remarkable chance to improve survival through biological selection since resistance to certain pathogens usually demonstrates moderate to exceptional heterogeneous in aquaculture-farm variety (Odegard *et al.*, 2011).

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Fish that reach a larger size in a shorter amount of time are good candidates for culture. The farmed species should be able to adapt to the farm's specific climatic circumstances and have the ability to withstand significant changes in the water's physico-chemical properties, such as oxygen content, salinity, and temperature. It is ideal for the farmed fish to be resilient enough to fend against parasites and common diseases. The proposed fish species should be capable of living together freely and without harming one another. Consumers favour fish species that provide more palatable meat per unit of food ingested (Webber and Riordan, 1976).

Transportation and Handling

Fish from the aquaculture plant must be transported. To lessen fish distress and transport high mortality, appropriate transporting tanks, water quality, and stocking ratios ought to be implemented. The size and layout of the shipping tank may establish on every variety of species and unique physiological period while being transported. Based on tank volume, type species, age group, quality of water, and exterior environmental parameters, carrying densities should be modified. The stocking densities can be raised by mechanical aeration and extra oxygen. In order to allow waste to be expelled, fish usually kept apart from intake of feedstuffs for a few days prior to transportation. Conditionings probably lessen fish stress and assist in maintaining the quality of the water in the transport tanks. During transport, high CO_2 concentrations may pose a bigger risk than high ammonia levels. Increased CO_2 levels in the holding tank can lessen the gradient of concentration between the water and blood where diffusion happens through the gills (Harmon, 2009). High blood CO_2 levels, acidosis, and possibly narcosis and mortality could occur as a result of excessive CO_2 levels (Wedemeyer, 1997). However, handling fish in nets during transit operations is essentially a requirement (Harmon, 2009). When nets are required, it is best to utilise less abrasive nets. Avoid using nets manufactured of polypropylene or polyethylene since they are typically rigid and can lead to scale damage (Yeager *et al*., 1990).

Equipment Safeguarding

While some of the equipment used in RAS is highly specialised, expensive, and complex, all aquaculture systems require equipment that is dependable and economical in order to function. To prevent future breakdowns, even the best equipment will need routine maintenance. In order to avoid downtime and lower fish stress and mortality, it is important to have a suitably skilled workforce, a recurring upkeep schedule, follow described operating manuals, and stock replacement components. It is necessary to develop and document appropriate maintenance schedules.

Fish Escapement Control

For environmental and financial reasons, it should be a top concern to prevent fish and diseases they carry from exiting a facility. In order to stop of flow of infected eggs, fry, fingerlings as well as pathogens from cultured ponds and other aquaculture systems, these anticipation techniques must be used. The prevention of escapement is particularly important for shore-based facilities that discharge into state waterways. Aquaculture altered genetic strains and non-native or alien strain must not escape. Escapees may have an adverse impact on entire ecosystems. Defectors have the potential to cause genetic changes in the native population, compete for scarce resources like feeding intake habitation, reproduce unchecked by means of wild carnivores, and spread infection. The design and the standard operating procedure must be included a confinement plan. Both the regular evaluation and urgent implementation should be part of the strategy. A functional sterility is mainly achieved through the use of multiple advance technology, such as stopping transmission of pathogens *via* screening of pathogens by means of use of filtration, UV light, and chemical treatments as by chlorine, sodium, potassium permanganate, *etc*. Though because of their shrouded cone, cage systems present a special problem.

Fish Health Management

Fish health management is one of the most important factors in aquaculture which describes management practices to prevent fish disease. The most important element affecting aquaculture is unquestionably disease. In aquaculture systems, disease development typically follows a disruption of the regular environment in which the animals are being raised (Palíková *et al.*, 2015). Animals may experience stress due to unfavourable circumstances, such as overcrowding, temperature changes, insufficient dissolved oxygen, excessive handling, physical abuse, poor meals, or poisonous chemicals (Palíková *et al.*, 2015; Wedemeyer, 1997). The result can be fatal if the degree of stress surpasses one's capacity for adjustment. The speed at which bodily defences function and antibody production occurs may be impacted by less severe stimuli. As a result, stress is considered to be a significant risk factor for fish and shellfish infections. Stress in fish is typically connected to operating, shipping, handling methods, environmental quality, and stocking density. Instead of starting with therapy, effective fish health management starts with prevention of disease. Fish illness may be avoided by managing water quality, diet, and hygiene. Opportunistic disease epidemics cannot be stopped without this base. Potential diseases including bacteria, fungus, and parasites are continually bathing the fish. Many of the infections that harm fish and shellfish are facultative types that are common in aquatic environments (Palíková *et al.*, 2015). In the wild, a large proportion of animals that appear healthy and normal are really harbouring potential infections that have no overt symptoms of disease or clinical signs. The complicated interaction between the host, the infection, and the environment leads to disease (Bondad-Reantaso *et al.*, 2005; Snieszko, 1974). Utilizing sterilisation technologies (such as ozonation and ultraviolet sterilisers) does not completely purge the surroundings of possible microbes. These possible pathogens can spread disease when there is a poor water quality, inadequate nourishment, or immune system suppression, which is typically linked to stressful situations. However, there is little to no chance of either treatment or eradication once a virus or disease agent is introduced and becomes entrenched in the natural environment (Bondad-Reantaso *et al*., 2005).

Site Selection

The choice of a location is one of the most crucial factors in aquaculture since it establishes the framework for not only the financial gain but also the sustainability, good name, and longevity of both the individual farm and the sector as a whole. Site choice affects practically every element of aquaculture, including productivity and economic performance (Llorente and Luna, 2013), environmental effect (Wu, 1995), social acceptability (Katranidis *et al*., 2003), and even the site may have an impact on human health (Jang *et al.*, 2006). Both technical and non-technical considerations, such as socioeconomic, political, and legal elements, climate-related features, and significant environmental problems, will need to be taken into account while selecting a location. According to the needs of the culture systems, a specific location would be chosen. Several more diverse factors need to be taken into consideration, including topography and ground elevation, soil, water supply, dynamical, physical, chemical, and biological properties of water, and land-vegetation. The choice of a location and the success of a project are heavily influenced by non-technical factors, including the attractiveness of the fish produced marketing resources, and labour availability.

Feed & Feeding Behaviour

Several more diverse factors need to be taken into consideration, including topography and ground elevation, soil, water supply, dynamical, physical, chemical, and biological properties of water, and land-vegetation. The choice of a location and the success of a project are heavily influenced by non-technical factors, including the attractiveness of the fish produced marketing resources, and labour availability (Glencross *et al*., 2007). Maximizing growth, preserving a strong immune system, reducing feed waste, and minimising adverse effects on water quality all depend on feeding fish with high-quality feed that has the appropriate amount and nutritional content (protein, vitamins, and minerals) for the size of fish being cultured. To prevent feed waste and get knowledge about fish health, it is important to observe fish feeding habits and appropriate feeding rates. Modern aquaculture diets are frequently created using criteria for digestible nutrients and energy (Cho and Kaushik, 1990). Furthermore, intense cultivation methods with poorly managed feed consumption and waste output have a negative impact on the environment (Graslund and Bengtsson, 2001). Variations in the environmental and biological parameters from the optimum range introduce stress to the animals under culture, which has a direct bearing on their growth performance, reproduction and flesh quality (Maule and Shreck, 1990; Shreck *et al.*, 2001). To maintain the feed quality and safety, feeds should always come from reliable feed providers and be consumed within roughly three months after receipt. On-site, feed should be maintained cool, dry, and clean, ideally in a structure or enclosure that can also be kept free of rats and other pests. The feed should be removed from the area right away and properly disposed of, if moisture, mildew or rancidity are found. When feed from the feed manufacturer is received, it should be rejected right away if it is damp or shows signs of mould.

Biosecurity

Fish are protected from pathogens of any kind-viral, bacterial, fungal, and parasitic-through biosecurity. A biosecurity plan is a collection of policies and practises that control or stop the spread of pathogen-causing organisms (CT Department of Agriculture, 2013). Excluding undesirable plants, fish species, invertebrates, and chemical contaminants from an aquaculture facility can help to maintain biosecurity. All employees (workers and management), all guests, and all equipment are subject to biosecurity. For each site, a biosecurity strategy should be developed. In the plan, there should be provisions for the importation and quarantine of disease-free, healthy stock, testing of the water supply, a plan for sanitising tools and equipment, the exclusion or sanitization of off-site tools and vehicles, the exclusion or sanitization of visitors, adequate feed storage to prevent pest and fungal growth that could result in the formation of mycotoxin, and the exclusion of animals, pests, and livestock from the facility (CT Department of Agriculture, 2013).

Drugs and Chemicals

Because of the possible effects that chemicals may have on aquatic ecosystems downstream, the use of chemicals in aquaculture farms has sparked environmental concerns (Rico *et al.*, 2012). The environmental fate and impacts of the chemicals used in aquaculture are currently poorly understood. The Asian aquaculture market has been plagued by a numerous aquatic animal health issues, nevertheless, as the aquaculture procedures have become more advanced (Rico *et al.*, 2012). Aquaculture operations have suffered significant financial losses as a result of the spread of parasite pests, bacterial, fungal, and viral illnesses. One of the main obstacles to the growth and expansion of Asia's aquaculture industry is now these issues (Bondad-Reantaso *et al*., 2005). As a result, aquaculture producers have relied on a wide range of artificial and natural chemical and biological therapies to stop and treat disease outbreaks, improve the health of the cultured species, and increase the environmental conditions of the aquaculture production systems (Rico *et al.*, 2012). These include prescription medications, cleaning agents, pesticides, fertilisers, and chemicals for treating water and soil (Graslund and Bengtsson, 2001). A sizeable portion of the chemicals and biological products used in these aquaculture production systems may eventually be released into the surrounding aquatic ecosystems, endangering their natural composition and ability to function naturally as well as fostering the emergence of resistant strains of bacteria and parasites (Boyd and Massaut, 1999; Burridge *et al*., 2010; Graslund and Bengtsson, 2001; Rico *et al.*, 2012).

A key worry is the lack of understanding of disease diagnosis and the mechanisms of action of these chemicals, particularly among smallholders (Faruk *et al*., 2005; Holmstrom *et al*., 2003; Pathak *et al*., 2000; Rico *et al.*, 2012). This sometimes results from inadequate or unclear information on chemical labels (such as those that exclude the active ingredient's name or the recommended dosage), which several farmers have reported having trouble interpreting (Faruk *et al*., 2005; Graslund *et al*., 2003; Rico *et al.*, 2012).

Structure Design

In Recirculating Aquaculture System

It uses the least amount of water and doesn't require as much waste water output to circulate, clean up, and remove waste. For RAS design, the goal is to completely reuse all waste water and stop discharging it. Regular waste water outflow and water replenishment are needed to maintain the water's chemistry and prevent waste from building up. Larger stocking densities are possible in recirculating aquaculture systems due to the ability to modify water chemistry parameters levels. A biological filter can be used to handle fish excretions, ammonia can be reduced and converted to less dangerous forms, and solid waste can be removed using filters and settling tanks. All of these methods above mentioned can enhance water quality. Aquaculture is already realistic in areas that were not previously thought of because of the enclosed component, minimal water demand, and low wastewater reuse. The intricacy, focused knowledge, and enlarged expenditure required to develop as well as to drive RAS might outweigh its recompense. Cultivation tanks, flow pumps, suspension of solid filters, settling the storage tank, and biosensors are all contained in the design phase. Particularly, mechanisms for oxygen flow, CO_2 disposal, protein sequencing, disinfection *etc*. are additional mechanical systems. Infection control largely relies on sanitation measures like ultraviolet light, ozone, *etc*. Recirculating systems can use well water, groundwater, city water, or seawater as their supply water. At early stage groundwater and seawater should be examined for impurities and treated as necessary. Prior to use in the system, municipal water may need to be sanitized (CT Department of Agriculture, 2013). Municipal water is chlorinated and fluoridated. A municipal water source might come at an extra cost. Microorganisms, pollutants, and agricultural and human waste may be present in seawater. Seawater should be treated to remove and sanitise any potential pollutants. A biosecurity plan should take into account the use of ultraviolet disinfection to treat incoming water for biological diseases. Permits will be necessary to minimise operational interference caused by the strict administration and acquit piping and the excavation required to lay the pipes when using saline composed water. It is forbidden to discharge salt water into freshwater areas. Recirculating aquaculture systems (RASs) are farm aquaculture facilities whereby wastewater is reused *via* technical and physiological purification in an effort to decline water usages and the transfer of nutrients into the surroundings (Martins *et al*., 2010). RASs have benefits in terms of decreased water use, enhanced opportunities for improved sewerage options, and nutrient availability (Piedrahita, 2003; Verdegem *et al*., 2006).

In Pond Aquaculture

One of the earliest techniques for producing fish is aquaculture in earthen ponds. Innate ponds, artificial ponds dug out of level ground, and dammed creeks that were filled space are all examples of pond kinds. In CT, a technique similar to the manmade earthen pond type is used to produce fish for stocking and baitfish. Depending on the business's size and the size of the fish being raised, ponds can be anywhere from three to eight feet deep and up to more than an acre in area. The type of fish, where they are in their life cycle, and if land and water are available all affect the size of the pond. Before building a pond, every site needs to be thoroughly assessed. Considerations for the top-soil category, rainwater runoff patterns, geographic features, water resources and exonerate alternatives are all crucial. For the construction of ponds, expert design blueprints are available. For proper operation and drainage, the banks and bottom must be kept at the right slope. Drainage dams (pond outlet structure) need to be built and placed correctly. The monk's positioning and the slope of the pond's bottom should allow the pond to drain completely.

In Marine Aquaculture

The majority of marine aquaculture produced has been shellfish. In saltwater finfish aquaculture is carried out using land-based systems that include inlet pipelines that suck sea waters into them. Future maritime environments may employ cage systems to confine and develop native fish species. Finfish farming in the oceanic atmosphere assessed similarly to other fisheries culture due to the prospective to obstruct navigates as well as affects water chemistry. The proposed location and system design will be examined by numerous local, state, and federal entities.

In Flow through Systems

Aquaculture relies on a lot of high-quality water flowing continually through the system in large quantities. Very little water is conditioned or filtered. In addition to the source water's quality, each utilised aquifer, the pond or lake, should have its volume and replenishment rate to be carefully monitored. Coastal flow through systems uses marine water as their resource should cleanse the entering water to get rid of pollutants and parasites. Water permission could be required based on the type and amount of source water being used (CT Department of Agriculture, 2013). For their placement, the shoreline-based inlet and outlet pipework will need permits, and they might also need corresponding marking vessels. When building the system, a strategy for treating the effluent that effectively flees from solid waste and waste feed should be developed (ammonia). The effluent can be treated using artificial wetlands and settling ponds. One benefit of a flow through system is that, with very few exceptions, the water quality will remain within ideal levels. The length of the system should be taken into account throughout the design phase because the water quality may decline near the system's terminus. Monitoring of dissolved oxygen is necessary, particularly at the system's conclusion where it may fall below ideal levels. Oxygen can be used up quickly in situations with high stocking densities. For each type of fish, the amount of water in the tanks or ponds, and the rate of flow through those tanks or ponds, stocking densities should be monitored and adhere to industry standards (CT Department of Agriculture, 2013). Ammonia levels may rise to a point where they stress fish, slow growth, and spread sickness. Parameters relating to water quality should be checked and recorded every day.

Conclusion

Making a business plan is the initial way in starting a triumphant aquaculture enterprise. Research must be conducted to look at elements like the product, species, pricing, and demand in order to develop a strong business plan. A market analysis establishes the local demand for various species and items as well as the going rate. A fish species that can be easily farmed, legally imported, and for which a dependable system design can be built should be picked after doing market research. The Best Management Practises (BMPs) are intended to offer directions for aquaculture ventures that are beginning, continuing, or growing. The recommendations in this document are meant to help fish farmers produce high-quality fish while preventing or limiting environmental consequences.

References

Bondad-Reantaso, M.G., Subasinghe, R.P., Arthur, J.R., Ogawa, K., Chinabut, S., Adlard, R., Shariff, M., 2005. Disease and health management in Asian aquaculture. *Veterinary Parasitology* 132(3-4), 249-272. DOI: https://doi.org/10.1016/j.vetpar.2005.07.005.

Bostock, J., McAndrew, B., Richards, R., Jauncey, K., Telfer, T., Lorenzen, K., Little, D., Ross, L., Handisyde, N., Gatward, I. Corner, R., 2010. Aquaculture: Global Status and Trends. *Philosophical Transactions of the Royal Society B: Biological Sciences* 365(1554), 2897-2912. DOI: https://doi.org/10.1098/rstb.2010.0170.

Boyd, C.E., Massaut, L., 1999. Risks associated with the use of chemicals in pond aquaculture. *Aquaculture Engineering* 20(2), 113-132. DOI: https://doi.org/10.1016/S0144-8609(99)00010-2.

Burridge, L., Weis J.S., Cabello F., Pizarro J., Bostick K., 2010. Chemical use in salmon aquaculture: a review of current practices and possible environmental effects. *Aquaculture* 306, 7-23. DOI: https://doi.org/10.1016/j.aquaculture.2010.05.020.

Cho, C.Y., Kaushik, S.J., 1990. Nutritional energetics in fish: energy and protein utilization in rainbow trout (*Salmo gairdneri*). In: *Aspects of Food Production, Consumption and Energy Values*, Volume 61, (Ed.) Bourne, G.H. World Review of Nutrition and Dietetics, Basel, Karger. pp. 132-172. DOI: https://doi.org/10.1159/000417529.

CT Department of Agriculture, 2013. *Best Management Practices for Finfish Aquaculture in Connecticut*. Connecticut Department of Agriculture. Bureau of Aquaculture, 190 Rogers Avenue, Milford, CT 06460, USA. Available at: https://portal.ct.gov/-/media/DOAG/Aquaculture/Aquaculture-permitting-and-guidance/Best-Management-Practices-for-Finfish-Aquaculture-in-CT.pdf. Accessed on: 21st November, 2022.

Faruk, M.A.R., Sultana, N., Kabir, M.B., 2005. Use of chemicals in aquaculture activities in Mymensingh area, Bangladesh. *Bangladesh Journal of Fisheries* 29, 1-10.

Glencross, B.D., Booth, M., Allan, G.L., 2007. A feed is only as good as its ingredients - a review of ingredient evaluation strategies for aquaculture feeds. *Aquaculture Nutrition* 13(1), 17-34. DOI: https://doi.org/10.1111/j.1365-2095.2007.00450.x.

Graslund, S., Bengtsson, B.E., 2001. Chemicals and biological products used in south-east Asian shrimp farming, and their potential impact on the environment - A review. *Science of the Total Environment* 280, 93-131. DOI: https://doi.org/10.1016/S0048-9697(01)00818-X.

Graslund, S., Holmstrom, K., Wahlstrom, A., 2003. A field survey of chemicals and biological products used in shrimp farming. *Marine Pollution Bulletin* 46, 81-90. DOI: https://doi.org/10.1016/S0025-326X(02)00320-X.

Harmon, T.S., 2009. Methods for reducing stressors and maintaining water quality associated with live fish transport in tanks: a review of the basics. *Reviews in Aquaculture* 1(1), 58-66. DOI: https://doi.org/10.1111/j.1753-5131.2008.01003.x.

Holmstrom, K., Graslund, S., Wahlstrom, A., Poungshompoo, S., Bengtsson, B.E., Kautsky, N., 2003. Antibiotic use in shrimp farming and implications for environmental impacts and human health. *International Journal of Food Science and Technology* 38, 255-266.

Jang, C.S., Liu, C.W., Lin, K.H., Huang, F.M., Wang, S.W., 2006. Spatial analysis of potential carcinogenic risks associated with ingesting Arsenic in aquacultural tilapia (*Oreochromis mossambicus*) in Blackfoot Disease hyperendemic areas. *Environmental Science & Technology* 40(5), 1707-1713.

Katranidis, S., Nitsi, E., Vakrou, A., 2003. Social acceptability of aquaculture development in coastal areas: the case of two Greek islands. *Coastal Management* 31(1), 37-53. DOI: https://doi.org/10.1080/08920750390168291.

Llorente, I., Luna, L., 2013. The competitive advantages arising from different environmental conditions in Seabream, *Sparus aurata*, production in the Mediterranean Sea. *Journal of the World Aquaculture Society* 44(5), 611-627. DOI: https://doi.org/10.1111/jwas.12069.

Martins, C.I.M., Eding, E.H., Verreth, J.A.J., 2010. The effect of recirculating aquaculture systems on the concentrations of heavy metals in culture water and tissues of Nile tilapia *Oreochromis niloticus*. *Food Chemistry* 126, 1001-1005. DOI: https://doi.org/10.1016/j.foodchem.2010.11.108.

Maule, A.G., Shreck, C.B., 1990. Changes in number of leucocytes in immune organs of juvenile Coho Salmon after acute stress of contisol treatment. *Journal of Aquaculture Animal Health* 2, 298-304.

Odegard, J., Baranski, M., Gjerde, B., Gjedrem, T., 2011. Methodology for genetic evaluation of disease resistance in aquaculture species: challenges and future prospects. *Aquaculture Research* 42, 103-114. DOI: https://doi.org/10.1111/j.1365-2109.2010.02669.x.

Palíková, M., Navrátil, S., Navrátil, L., Mareš, J., 2015. Preventive and prophylactic measures in intensive salmonid fish breeding - a review. *Acta Univ. Agric. Silvic. Mendelianae Brun.* 63(4), 1409-1416. DOI: https://doi.org/10.11118/actaun201563041409.

Pathak, S.C., Ghosh, S.K., Palanisamy, K., 2000. The use of chemicals in aquaculture in India. In: *Proceedings of the Meeting on the Use of Chemicals in Aquaculture in Asia*. (Eds.) Arthur, J.R., Lavilla-Pitogo, C.R., Subasinghe, R.P. Southeast Asian Fisheries Development Centre, Tigbauan. pp. 87-112.

Piedrahita, R.H., 2003. Reducing the potential environmental impact of tank aquaculture effluents through intensification and recirculation. *Aquaculture* 226, 35-44. DOI: https://doi.org/10.1016/S0044-8486(03)00465-4.

Rico, A., Satapornvanit, K., Haque, M.M., Min, J., Nguyen, P.T., Telfer, T.C., van den Brink, P.J., 2012. Use of chemicals and biological products in Asian aquaculture and their potential environmental risks: a critical review. *Reviews in Aquaculture* 4(2), 75-93. DOI: https://doi.org/10.1111/j.1753-5131.2012.01062.x.

Shreck, C.B., Wilfreds, C., Fitzpatrick, M.S., 2001. Effect of stress on fish reproduction, gamete quality and progeny. *Aquaculture* 197, 3-24. DOI: https://doi.org/10.1016/B978-0-444-50913-0.50005-9.

Snieszko, S.F., 1974. The effects of environmental stress on outbreaks of infectious diseases of fishes. *Journal of Fish Biology* 6(2), 197-208. DOI: https://doi.org/10.1111/j.1095-8649.1974.tb04537.x.

Verdegem, M.C.J., Bosma, R.H., Verreth, J.A.J., 2006. Reducing water use for animal production through aquaculture. *International Journal of Water Resources Development* 22, 101-113. DOI: https://doi.org/10.1080/07900620500405544.

Webber, H.H., Riordan, P.F., 1976. Criteria for candidate species for aquaculture. *Aquaculture* 7(2), 107-123. DOI: https://doi.org/10.1016/0044-8486(76)90001-6.

Wedemeyer, G.A., 1997. Effects of rearing conditions on the health and physiological quality of fish in intensive culture. In: *Fish Stress and Health in Aquaculture*. (Eds.) Iwama, G.W., Pickering, A.D., Sumpter, J.P., Schreck, C.B. Cambridge University Press, New York. pp. 35-72.

Wu, R.S.S., 1995. The environmental impact of marine fish culture: towards a sustainable future. *Marine Pollution Bulletin* 31, 4-12. DOI: https://doi.org/10.1016/0025-326X(95)00100-2.

Yeager, D.M., Van Tassel, J.E., Wooley, C.M., 1990. Collection, transportation, and handling of striped bass brood stock. In: *Culture and Propagation of Striped Bass and its Hybrids*. (Eds.) Harrell, R.M., Kerby, J.H., Monton, R.V. American Fisheries Society, Bethesda, MD. pp. 39-42.