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SPECIES COMBINATIONS; POLYCULTURE, INTEGRATED MULTI-TROPHIC AQUACULTURE, AND AQUAPONICS AS THE SUSTAINABLE AQUACULTURE PRACTICE

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Abstract

Sustainability refers to the ability of a society, an ecosystem, or an ongoing system to continue to function for generations to come without depleting its essential resources. Although the idea of sustainability is simple, its implementation is challenging in today's conditions due to economic reasons and various conflicts of interest. But implementing a sustainable system and setting standards is very important for future generations and the future of our world. Aquaculture is a sustainable strategic sector that contributes significantly to food security and promotes economic development. It provides employment and production in an environmentally compatible manner with the right technologies. For this reason, researchers and employees in the sector have given importance to sustainable fisheries research that they have been conducting on a global scale and with environmentalist approaches in recent years and have focused on innovative solutions. At the beginning of these innovative solutions are polyculture and integrated multitrophic aquaculture studies, which include species combinations. In addition, aquaponics systems, it has succeeded to be among the subjects that researchers and those working in the sector have worked on intensively in recent years. This study aims to provide information about polyculture integrated multitrophic aquaculture, aquaponics, and sustainable aquaculture studies.

Keywords: Sustainability, aquaculture, awareness, environmental approaches, polyculture, aquaponic

Introduction

The rapidly increasing world population, developing technology, and industrialization have brought climate change. Both climate change and the increase in the world population have reduced water resources, and therefore, the development of sustainable production techniques has become essential. Our world is rich in natural water resources, and aquaculture is among the best in meeting food needs (Chopin et al., 2001, 2003; FAO, 2018; Demir & Kizak, 2022). The United Nations Food and Agriculture Organization stated in its fisheries and aquaculture report in 2018 that total aquaculture production will increase by 28.1% in developed countries, 37.2% in developing countries, and 46.3% in underdeveloped countries in 2030 compared to 2016. Again, the same report showed that Aquaculture will reach 110 million tons in 2030 (FAO, 2018).

Studies on species combinations such as polyculture and integrated multi-trophic aquaculture, aquaponic have been among the subjects studied extensively in recent years (Yokoyama, 2013; Reid et al., 2020; Ondruška et al., 2022; Yamaner et al., 2022; Roy et al., 2022). Today, researchers and sector workers conduct polyculture and Integrated multi-trophic aquaculture, Aquaponic studies to obtain the benefits arising from the interaction of freshwater and saltwater creatures. It is possible to collect them under two main headings; the first can be considered polyculture and integrated multi-trophic aquaculture, and the second as aquaponics and its combinations.

Polyculture and Integrated multi-trophic aquaculture

Integrated aquaculture farming is the simultaneous or sequential cultivation of two or more species, of which at least one is aquatic (Little & Edwards, 2003). These aquacultural studies must be sustainable and compatible with the ecosystem. Previous studies have proven that integrated multitrophic aquaculture (IMTA) is a production technique that can solve marine pollution problems (Troell, 2014).

The IMTA system evaluates wastes from uneaten feed, feces, and metabolic excretion of one species to another. It is a technique that emerged based on the idea that it is an available input for the growth of species and also has a natural self-cleaning mechanism that is environmentally sustainable (Chopin et al., 2001).

There are several options available to reduce the nutrient load from aquaculture, including improving animal feed use and treating wastewater with biological filters. Most of the applications have been made about integrated multiple trophic aquaculture systems. Integrated multi-trophic aquaculture (IMTA), the integrated culture of forage species such as finfish, inorganic extractive species such as seaweed, and organic extractor species such as suspension and deposition feeders, has the potential to contribute to the sustainability of aquaculture (recent advances in IMTA breeding techniques have primarily, sewer outlets and aquaculture outlets). Environmental concerns about the rapid expansion of intensive aquaculture systems have also recently led to renewed interest in IMTA (FAO, 2006).

IMTA Combinations

Mussel farming is done in the form of raising on the seabed, raising on poles/piles, raising on ropes stretched horizontally to the sea surface with swimmers, raising on rafts. However, thanks to the developing opportunities, mussel farming can be done with integrated culture applications. In this system, crustacean aquatic organisms such as mussels, which filter the

water, are grown together in rope or raft culture systems placed at a distance of 20-50 m from the net cages. However, they are in the focus of studies for IMTA systems because they are fed by filtering the water.

Reid et al. (2010) investigated the absorption efficiency of blue mussel, *Mytilus edulis* and *M. trossulus* on the diet of Atlantic salmon particles (feed and faeces) and found that the technique of breeding these organisms in close proximity to salmon cages in IMTA systems would be a useful practice for removing solid waste. In addition, crustaceans are known to bioaccumulate human pathogens such as Vibrio species, hepatitis A virus, human sapovirus, and adenovirus. Several studies point to the potential for shellfish to serve as reservoirs for fish pathogens. Therefore, the integration of shellfish buret production into fish farms, as in IMTA, is thought to potentially change the infection dynamics for fish pathogens (Pietrak et al., 2012).

It seems reasonable to think that their production can be integrated into fish farming and has the potential to become a valuable crop for farmers (Mac Donald et al., 2011). Sea cucumber are valuable species that could be good candidates for IMTA systems that raise a species of fish where they can consume the residues of organic fish, bacteria, protozoa, microalgae, and dust from plants and animals. they are considered important surface precipitants in many coastal marine systems (Santos et al., 2017). Therefore, they may be good candidates for cultivation in IMTA systems (Yokoyama, 2013; Slater & Karton 2009). In another study, results showed that *C. frondosa* exhibits high sorption efficiency (>80%) when dealing with particulate material with high organic content (Nelson et al., 2012).

In an integrated multi-trophic aquaculture study, high survival rate was obtained in sea cucumber by feeding only fish with sea bream-sea cucumber *H. forskali* combination (Santos et al., 2015). However, most studies have focused on land-based systems, and to date only a few have explored the possibilities of open water IMTA farming. Over the past fifteen years, the integration of seaweeds with marine fish farming has been studied and studied in Canada, Japan, Chile, New Zealand, Scotland and the USA. The integration of mussels and oysters as biofilters in aquaculture has also been studied in a number of countries, including Australia, USA, Canada, France, Chile, Spain. Recent reviews of IMTA research include a focus on seaweeds, bivalves, crustaceans, and integrated cultures from a coastal zone management perspective.

In aquatic ecosystems, it is of great importance to produce according to certain criteria and techniques, which are important for the protection of the environment and the maintenance of sustainable cultivation. Some integrated agricultural environmental systems by creating natural fishery products are very important in terms of the protection of ecosystems as well as the economic development of our country. Studies on this subject have also shed light on future ecological and sustainable fisheries research.

Aquaponic Combinations

In summary, these aquaculture techniques are based on raising the same or different species of "terrestrial and aquatic" living things together, which have the potential to benefit each other in a freshwater (or less salty) environment. The technical focus of research in recent years is aquaponic aquaculture. Hydroponic means agriculture with water without using soil. In this production technique, production is made with some additions to the water that make up the nutrients of the plants. Aquaponic production also differs from hydroponics at this point as soilless agriculture. Aquaponics production; fish etc. It is based on the principle of terrestrial

plant production with the waste water of living things. The substances that emerge as a result of the metabolic activities of the fish form the nutrients of the plants, and there is no need to add an extra nutrient. In this way, the environmental impact of production-related wastes is minimized. In this regard; Aquaponics is an innovative, environmentally friendly and sustainable agricultural production system created by the integration of hydroponic system and aquaculture, which is made by using recirculated water in regions where access to water is difficult and on unfavorable rough lands, allowing soilless agricultural production as well as fish farming (Love et al., 2015; Shete et al., 2016). The main purpose of aquaponic systems is the effort to produce minimum water consumption and maximum amounts of plants and fish with recirculated aquaculture systems (Rakocy, 2012).

Aquaponic systems, in which plants and aquatic products are cultivated jointly, have become a new agricultural production area today and have managed to attract attention all over the world in agricultural production, since they are also suitable for vertical farming (Khandaker & Kotzen, 2018). Another factor that makes aquaponic systems important is the increase in salinity due to irrigation water formed in soil agriculture. As stated in the FAO (2015) reports, Turkey; Along with Afghanistan, Egypt, Kazakhstan, Iraq, Turkmenistan, Mexico and Syria, agricultural lands are among the most affected countries due to the increase in soil salinity (Squires & Glenn, 2011). Nile tilapia (*Oreochromis niloticus*) (Effendi et al., 2015); red tilapia (*Oreochromis* sp.) (Rafiee & Saad, 2006); rainbow trout (*Onchorynchus mykiss*) (Alcarraz et al., 2018); There are scaly carp, mirror carp and koi (*Cyprinus carpio*) (Shete et al., 2016) species. Aquaponic systems are important systems in sustainable agricultural and animal production, as they are closed circuit, suitable for intensive production, suitable for vertical farming in urban areas, and environmentally friendly production with minimum waste (Rakocy et al., 2012).

Conclusion

To meet future needs (and recognizing that land-based sources of fish and other foods are also part of the solution), we ask whether the sustainable production of food from the sea has an important role in future supply (Costello et al., 2020)**.** Rapid population growth leads to urban expansion and wildlife extinction. Wildlife species will disappear at the same rate as this destruction. However, some scientists and conservationists are aware of the threat, albeit very few, and are working to protect wildlife habitats. But their efforts are limited to terrestrial habitats. In reality, when aquatic ecosystems also need protection. Because sustainable life will be realized through sustainable aquatic research. Overexploitation is known to be one of the biggest causes of endangered aquatic life forms. When you add environmental pollution, global warming and climate changes to the list, the extent of the threat to aquatic life forms (fish, aquatic plants and plankton, etc.) is very frightening. In this case, it is inevitable that aquatic ecosystem researches in terms of sustainable aquaculture production and biodiversity will be among the firsts to be conducted today (Troell et al., 2014). "The aquatic ecosystem should be considered with all aspects of production better selected places should comply with standard production techniques and be checked regularly. These production areas are in mind as an ecosystem, newly added to the environment, and by well calculating their farming ecosystem effects, by entering this new ecosystem, they are neutral systems needs to be developed.

With the system in which sustainable production methods will be developed, cage farming will be integrated and it can provide benefits for the growing ecosystem by increasing productivity and competitiveness. Because the project planned to create artificial life forms with benthic habitat systems can be provided to reduce the load on the sediment. In this case, the existing

crustacean-fish, seaweed-fish, sponge fish integrated system integration can be continued. Aquatic production and some agricultural activities are applied against a mixed method to express the execution of the term "integrated aquatic farming", especially feed costs for savings. In this method, intensive fish culture plant monoculture, in addition to the fish breeding unit, contains nutrients that will clean other components of the environment to weave natural foods. Such studies are important to do, especially when considering sediment. In the field of natural ecosystems such as fish, mussels, lobsters, shrimps and the sea, net as cage farming may be important in future studies such as cucumber, which has economic value in the development of aquatic life. The water is one of the indispensable natural resources. Increasing sensitivity in the protection of water resources is also reflected in the environmental policies of governments. The issue of protecting water resources, which is of strategic importance for the environment, health, nutrition and energy economies, is on the agenda more than ever in our country and in the world.

Ethical approval

The author declares that no ethical approval needed for this review study.

Data availability statement

The authors declare that data are available from authors upon reasonable request.

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