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Ecosystem approach to sustainable aquaculture

Introduction

During the last few decades, world aquaculture production has increased from 7% of global fisheries to over 40% as per FAO estimates. A key factor is the feed conversion ratio (kilos of feed required for a 1kg increase in weight). Whilst typical intensive poultry and swine production systems have feed conversion ratios of between 1:1.5 and 1:3, certain species of fish can be as low as 1:1. The efficiency of feed conversion into protein is twice as high for commercial aquaculture as land-based protein production systems. While there are a number of ways aquaculture benefits the environment, there also are several concerns regarding its use that are important to understand.

1. The farming of marine fish, crustaceans and even bivalves produces waste in the form of faecal matter and unused feed. These largely nitrogen-based wastes can cause oxygen depletion in coastal environments and a net loss of marine productivity in certain coastal areas. Chemicals such as antibiotics and water treatment agents are commonly used in the aquaculture industry, and aquaculture systems need to be closed, or wastewater treated prior to discharge.
2. Aquaculture operations can spread parasites and disease into the wild. Farmed fish also are exposed to disease through the use of unprocessed fish used as a food source, as opposed to safer processed fish pellets.
3. Aquaculture is one of the largest causes for the occurrence of foreign species introduced into new areas, which creates invasive species under the right conditions. Additionally, escaped farm fish are able to breed with the wild stock which can dilute the natural gene pool and threaten the long-term survival and evolution of wild species.
4. Because farmed fish need a food source, other wild species are at risk for being overfished for the manufacture of fish food. Because most farmed fish are carnivorous, they are fed either whole fish or pellets made from fish. Species such as sardines and anchovies are threatened because of the need to create food for farmed species.

The Genesis of EAA

Over a decade ago, the ecosystem approach to aquaculture (EAA) emerged from discussions between the FAO and international aquaculture experts on how to move aquaculture development towards greater sustainability. The rapid growth of the aquaculture sector worldwide, and the interaction of aquaculture activities with other economic sectors and natural resources users, requires a responsible and integrated approach to aquaculture development, as expressed in Article 9 of the CCRF. In response to the explicit request of its member countries in 2006 to improve the management and enhance the socio-economic impacts of aquaculture, FAO initiated the development of an ecosystem approach to aquaculture production.

An EAA is a strategy for the integration of the activity within the wider ecosystem such that it promotes sustainable development, equity, and resilience of interlinked social-ecological systems. The EAA is guided by three strategic principles:

1. Aquaculture development and management should take account of the full range of ecosystem functions and services and should not threaten the sustained delivery of these to society.
2. Aquaculture should improve human well-being and equity for all relevant stakeholders.
3. Aquaculture should be developed in the context of other sectors, policies and goals, as appropriate.

The EAA builds on these principles to provide a planning and management framework for effectively integrating the aquaculture sector into local planning. The approach provides clear mechanisms for producers and government authorities to engage with one another for the effective and sustainable management of aquaculture operations and requires them to simultaneously embrace the environmental, socio-economic and governance objectives of the sector.

EAA in India

India is the second largest aquaculture producer nation in the world. However, the concept of EAA has not been fully integrated into its policies and management systems. A recent draft National Mariculture Policy (NMP) indicates the need to align the development of mariculture in the country with EAA concepts. Very often the uncontrolled boom of aquaculture practices in the country has resulted in ecological catastrophes, like the black tiger shrimp farming failure due to viral disease outbreaks and the issues of carrying capacity and protozoan diseases in the fledging mussel farming sector. It is very evident that scientific management practices with due consideration to the environmental carrying capacity could have helped prevent such catastrophes.

Carrying Capacity – a key factor

Carrying capacity (CC) is an important concept in EAA. Earlier, while estimating the CC, only the resource which was farmed was taken into consideration and accordingly CC was defined as the maximum standing stock that may be kept within a particular ecosystem to maximise production without negatively affecting growth rate. Later considering the negative impacts aquaculture can have on the ecosystem services, CC was redefined and now CC can be defined as "the amount of change that a process or variable may suffer within a particular ecosystem, without driving the structure and function of the ecosystem beyond certain acceptable limits".

The mussel farming in Kerala, particularly in the main production area, Padanna Backwaters is recently confronted with several problems. With rapid growth in farming the availability of mussel seeds became limiting and farmers sourced seeds from distant locations resulting in poor seed quality at the time of seeding. The supply-demand gap pushed the farmers to compromise on the seed quality. This resulted in tended mussel farmed stocks which were susceptible to stress. The environmental degradation in the farmed area of Padanna due to excessive number of farms per unit area and reduced flushing of water in certain pockets was further burdened by the extremely high ambient air and water temperatures in 2015-16. The prevailing environmental anomaly resulted in higher than normal salinity and high temperature, which compounded the environmental stress on the farmed mussels. This resulted in a crisis in February 2016, leading to stunted growth, high mortality and prevalence of the protozoan parasite, *Perkinsusolseni*. The Central Marine Fisheries Research Institute (CMFRI) provided 21 recommendations to tackle the problems. These recommendations are complementary to the global guidelines for Best Aquaculture Practices for mussels. This requires the collaborative effort from the farmers, local administration and the fisheries department in line with EAA principles.

Integrated Multi-trophic Aquaculture Systems (IMTA)

Though majority of aquaculture production originate from extensive and semi-intensive farming systems, the recent increase in intensive farming of marine carnivorous fed-species is associated with environmental concerns. Integrating waste generating (fed) and cleaning (extractive) organisms in aquaculture is a way to achieve sustainability. In a balanced integrated system, aquaculture effluents can be converted into commercial crops while restoring water quality. IMTA is the practice which combines, in the appropriate proportions, the cultivation of fed aquaculture species (e.g. finfish/shrimp) with organic extractive aquaculture species (e.g. shellfish/herbivorous fish) and inorganic extractive aquaculture species (e.g. seaweed) to create balanced systems for environmental sustainability (biomitigation) economic stability (product diversification and risk reduction) and social acceptability.

In a conceptual open-water integrated culture system, filter-feeding bivalves are cultured adjacent to meshed fish cages, reducing nutrient loadings by filtering and assimilating particulate wastes (fish feed and faeces) as well as any phytoplankton production stimulated by introduced dissolved nutrient wastes. Waste nutrients, rather than being lost to the local environment, as in traditional monoculture, are removed upon harvest of the cultured bivalves. With an enhanced food supply within a fish farm, there is also potential for enhancing bivalve growth and production beyond that normally expected in local waters. Therefore, integrated culture has the potential to increase the efficiency and productivity of a fish farm while reducing waste loadings and environmental impacts.

In an integrated oyster-fish culture system, oysters played an important role in carbon fixation by removal of phytoplankton and organic matter through filter feeding. This was evident by the lower values of total organic carbon and total carbon in sediment. Oysters in the IMTA system behaved as bentho-pelagic couplers in nutrient cycling of phosphorous, releasing it as phosphate to the water column thereby increasing its level in the water column. Increased growth of fish and oysters were obtained from the oyster-fish integrated cultures than compared to fish monoculture due to the improved water quality caused by oysters.

Ecological Modelling in Aquaculture

Trophic modelling modules like ECOPATH have been used to model energy flows in contained aquaculture systems. This helps to identify problems in the system and energy wastage. An ECOPATH model has been constructed to optimise stocking densities in extensive shrimp and crab system, modified extensive system and polyculture of shrimp, fish and mussels in Kerala. This model indicated that the stocking rate of shrimps in the modified extensive system could be reduced by 50% to achieve better yields. The model also indicated that mussels could be effectively used for controlling eutrophication caused by aquaculture feeds.

Prospects

The application of EAA concepts in aquaculture would definitely pave the way for more sustainable aquaculture practices. What is needed is more location-specific and condition-specific research work to demonstrate EAA principles.

References

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