Economic performance and roles of local communities in the adoption of multi-species aquaculture

Tsutom Miyata
Japan International Research Center for Agricultural Science (JIRCAS), Tsukuba, Japan

Introduction

In a review of about 100 previous studies on multi-species aquaculture, it has been revealed that aquaculture increases profits, however, those profits were only realized in a few cases and places (Barrington *et al*. 2009). The success or failure of the practical use and adoption of a multi-species aquaculture technology depend on an economic rationality and utility (such as a value that cannot be converted into money) of stakeholders. In other words, it is important that the synergistic effect of implementing a multi-species aquaculture is clearly elicited in aquaculture management areas at a local or regional scale.

Many fields of research and aquaculture businesses were implemented but eventualy failed because they might have insufficient planning, discussions and understanding about the new multi-species aquaculture system. In order to increase the chances of success, a multi-species aquaculture venture will require to be fully analyzed, evaluated, and improved through a socioeconomic perspective. Only after such comprehensive planning can stakeholders of aquaculture research or business expect to potentially enjoy the benefits. Sometimes, if it is evaluated that there can be no synergistic benefits in a multi-species aquaculture, then the stakeholders can prevent a potentially wasteful spending of resources and investments.

External diseconomy (external expenses) and external economy

In general, excrement and residue of feed discharged from fish farms lead to environmental pollution (Naylor *et al*. 1998), and potentially damage other fisheries and aquaculture industries (**Figure 1**). Also, the eutrophication effect can enhance “green tide” like the over-growth of seaweeds such as *Ulva,* that can cover over a wide area of the shore or beach that can eventually decay and stink, causing discomfort to nearby residents. This becomes a form of “disutility.” If there is this adverse effect of aquaculture, then farmers have a social responsibility to reduce the discharged wates from their aquaculture activity. In addition, if the local government in this area defrays the cost to solve this problem, or if the citizens or a non-profit organization (NPO) pays money for it, then the cost becomes an “external expense”.

In order to improve the aquaculture environment, some farmers need to pay for reducing the environmental burden caused by the pollution, in terms of its own conscience and CSR (Corporate Social Responsibility) (**Figure 1**). For example, there are measures to build a feeding system that does not waste feed by automatically regulating the amount of feed based on the exact weight of the cultured fish in the fish cage (Aslesen, 2009).

Alternatively, there is a way to reduce environmental burden by imposing a kind of environmental tax (Naylor *et al*. 1998). In order to reduce environmental effects, some aquaculture farmers may implement measures to reduce the discharged wates and residue, while the local government carries out measures to improve the environment using the collected tax (**Figure 1**).

The added expense for the farmer may be offset by some other ways. One such option is the use of use “eco-labels” whereby premium selling prices can given to products that are produced sustainably and more environment-friendly. The challenge is to gain consumers’ understanding of the environmental conservation action by aquaculture farmers and to realize the added value of the farmed products (**Figure 1**). The aquaculture eco-labels in Japan include the international aquaculture eco-label ASC (Aquaculture Stewardship Council), AEL (Aquaculture Eco-Label) and SCSA (Seedlings Council for Sustainable Aquaculture). However, the Japanese consumers’ awareness of eco-labels are still low at the present (Asano, 2018), but should be encouraged some more.

Organic and inorganic wastes from aquaculture commonly perceived as an environmental problem. However, these substances are also beneficial nutrients to promote biomass growth of algae and phytoplankton.The productivity of non-feeding aquaculture and resources of small fish also increase due to the abundant biomass of phytoplankton around the farm. In this sense, aquaculture creates an “external economy”. In addition, if a farmer starts a non-feeding aquaculture venture with a seaweeds or bivalves, he will benefit from the nutrients emitted from the adjacent fed aquaculture farms. This reduces the burden to the environment and increases profit for the non-feeding aquaculture.

In a way, this is the main purpose and concept of IMTA (Integrated Multi-Trophic Aquaculture), whereby multiple species are used for optimal benefit.

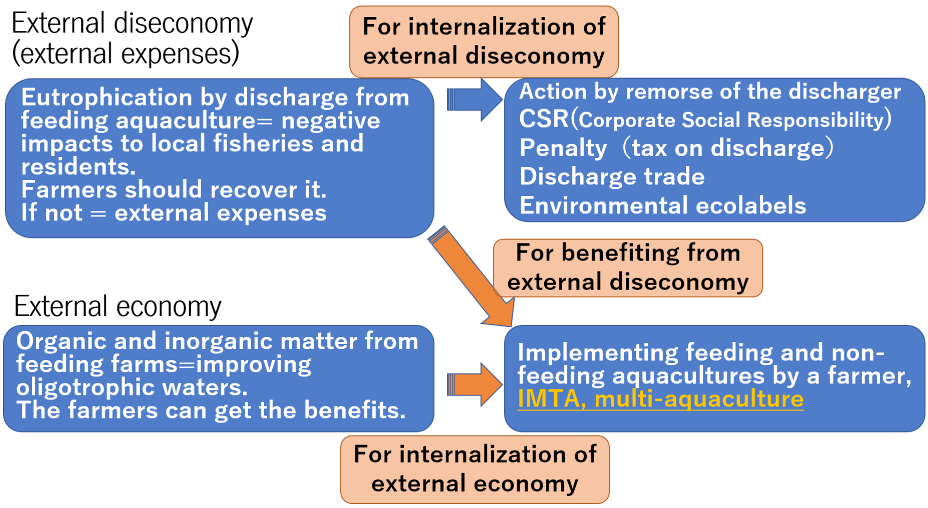

Figure 1. External diseconomy and economy in a feeding aquaculture scenario

Business analysis complexity for multi-species aquaculture

Business analysis of aquaculture of a single species may be relatively easy. It can be calculated from the total income and expenditures of the aquaculture management body. However, in the case of multi-species aquaculture, the business analysis is required for each species, which can becomes considerably difficult and tricky to calculate because it is necessary to “properly” determine cost rates of each cost item relevant to each aquaculture species.

Some indirect labor costs, salesperson salary, clerk salary, welfare expenses, and indirect material expense tend to be overlooked when a planner or researcher estimates the expenses in a multi-species aquaculture. In order to adopt the new multi-species technology, it is essential to estimate appropriate expenses such that an overestimate expense is allowed, but an underestimate expense is not allowed.

Another risk for farmers is that prices of farmed fish, bivalve and algae can fluctuate. Prices are influenced by quantities and prices of domestic products and importation of each species, national income, quantities and prices of substitute species, as well as the prices of common goods like chicken and pork (Ariji, 2013). To reduce this risk, multi-species aquaculture can be an advantage from the point of view of “risk hedging”, because one species may be vulnerable low price, but chances are that the other cultiured species are not. Of course, the risk of mortality and other losses can also be alleviated in a multi-species aquaculture.

Furthermore, farmers tend to experiment through trial and error while adopting and improving a new aquaculture technology. This oftentimes lead to very low initial productivity and many wasteful costs. This is a risk in the multi-species aquaculture venture where many aspects are uncertain. If the initial low profitability is prolonged, the loss due to the initial costs will be difficult to defray, and the period to cover all losses will be extended. Eventually, the management body of the multi-species aquaculture is become exhausted, and the farmer will conclude it to be an unacceptable aquaculture technology. Such a negative notion can then spread throughout the region. Therefore, researchers should work up a new technology to a high degree of confidence even at the research stage. In order to achieve this, the researcher should collaborate with aquaculture farmers and conduct more practical research activities.

Multi-species aquaculture as a whole

As mentioned above, feeding aquaculture has a negative impact on the surrounding environment of the farms, which is difficult to contain in open aquaculture facilities. It also affects the surrounding aquaculture grounds and sometimes, the local community.

In the actual aquaculture areas, there are multiple types of aquaculture operations interacting and affecting each other. This seems comparable to large-scale multi-species aquaculture (Watanabe, 2016). Multi-species aquaculture and IMTA are often discussed in terms of profitability and rationality of an individual aquaculture operation. It is quite un-realistic to ignore the benefits and rationalities of other operations within the whole aquaculture area, as in the case of mariculture. In other words, it is necessary to implement modifications that optimize a combination of different types of aquaculture, with the proper placement of aquaculture facilities, and maximize total benefit of all farmers and stakefolders in the aquaculture area and local communities.

A new type of IMTA

In many developing countires like the Philippines, most fishing families were considered to be in the poverty group as defined by the government. Moreover, the resource level of the main target species for fisheries is usually low because of overfishing. In order to improve the deteriorating resources, it is necessary to implement some fisheries management strategy in these areas, and enforce fishing regulations to control catch efforts. However, our survey results showed that the implementation of the regulation with catch restriction leads to a strong backlash from fishers in poverty, so it is very difficult to implement such a policy (Miyata *et al*. 2017). Therefore, some alternative income sources to make up for the decrease in catches due to regulations is required. This is where I recommend the Integrated Multi Trophic Aquaculture for Marine Protected Area or IMTAMPA to these villages (**Figure 2**). The concept is to set up oyster farming facilities using bamboo poles in and/or around a nursery area of fish and shellfish. The potential profit from oyster harvests may compensate for the loss of catch from the fishing grounds (nursery area). Furthermore, fishers can still catch fish and shellfish spilling over from the facilities when the fishery resource have recovered.

In addition, some support from the government or NGOs may supplement the resources through stock enhancement of other species like shrimps and sea cucumbers. Local universities and resaerch institutions can also support the implementation by sharing facilities and research resources. Through a collaborative partnership of the local government, NGO and/or NPO, and universities, IMTAMPA can be a good prospect towards providng incentives to local fishers in sustainably managing their resources while benefiting from multiple harvests from various species from the same area.

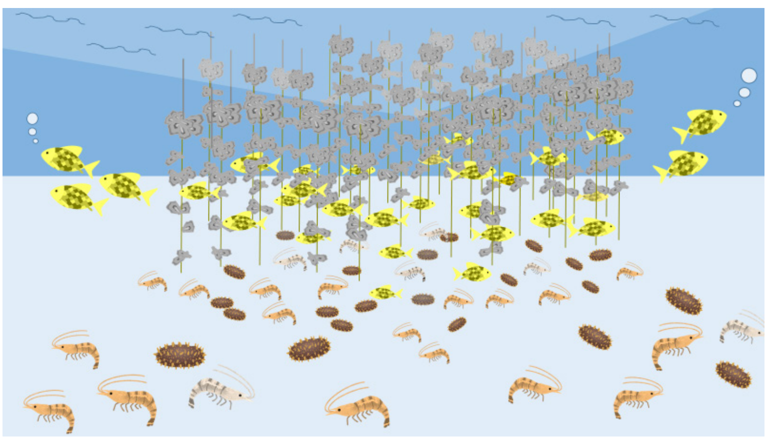

Figure 2. IMTAMPA Integrated Multi Trophic Aquaculture for Marine Protected Area), (Miyata *et al*. 2017)

Conclusion

Currently, the income level of many aquaculture farmers is low because of high costs of feeds and materials, so they try to avoid taking risks associated with multi-species aquaculture. However, the benefits clearly contributed to the success of a few cases of aquaculture management bodies (Barrington *et al.*, 2009).

In order to adopt this new technology widely, it needs good research results of not only the biological aspect but should also include profit analysis in order to convince farmers of "the benefits that clearly contribute to their management efforts". In addition, it will be necessary to seek support of local governments in providing subsidies to extend the technology. In other words, the officers need to also understand the usefulness of the multi-species aquaculture technology.

It will be difficult for a farmer to have a complete understanding of the whole mariculture system, especially from an economic point of view where there are external diseconomy and external economy, as discussed above. Hence, it is significant to have a bird's eye view of the all the interacting aquaculture systems in an aquaculture area or community. The concept of IMTAMPA was also born from such viewpoint.

Among the remaining IMTA research issues are the practical research for sustainable community-based fishing and aquaculture such as IMTAMPA. However, it is clear that more research is needed to clarify various aspects of the system like the flow of organic and inorganic substances discharged from feeding aquaculture ground to non-feeding aquaculture ground. These researches also need to be conducted through interdisciplinary approaches that involves both natural and social sciences.

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