

food security (Taylor *et al.*, 2016). Aquaculture technologies had been developed not only to meet the demands of domestic and export-oriented markets but also as means of preserving the endemic fish for local communities. There are many fish culture techniques that could be promoted in inland water bodies, one such aquaculture system that is widely practiced in the region is cage culture where fishes are stocked and raised in cages in natural waters until marketable size. While it is already a challenge to make this aquaculture activity profitable, such system could also pose risk when the cultured species (which could be non-indigenous) escape into the natural habitats resulting in disruption of the ecological balance of the food chain, as well as changes in biodiversity and genetic diversity of the aquatic species. The rapid development of floating net cages with overfeeding has also caused a lot of leftover food to accumulate at the bottom of the water bodies (Makmur *et al.*, 2020). It is estimated that around 50–70 mt of feed are spread per day in water bodies where floating net cage culture systems are practiced. Besides, fish feces also accumulate at the bottom of the water bodies, where the organic materials are then broken down by microbes exposing a lot of oxygen, making the lake bottom run out of oxygen (anoxic) and resulting in the production of toxic sulfides.

Change in the weather also causes the hydrological conditions to be altered, and as the phenomenon lifts the inner layer of the lake bottom (overturn), the fish on the surface will die massively because of depleted oxygen and poisoning. Mass fish kills then repeatedly occur, causing enormous economic losses. Because of the presence of sulfur, the increasing number of leftover deposits and metabolism occurring at the bottom of the lake will cause a slight reversal of the water mass. As the weather changes again, repealing the water mass, it becomes toxic to fish, especially those in the floating net cages.

Nevertheless, inland aquaculture or freshwater aquaculture could still be promoted toward sustainability by taking into consideration environmental and social aspects. Environmental aspects comprise the important factors that should be considered while doing aquaculture. These factors could include the natural systems which consist of fish, ecosystem quality, and biophysical environment. Nonetheless, freshwater aquaculture should not in any way, impact the freshwater environment by the adoption of good aquaculture practices. Meanwhile, the social aspects include the human system that comprises the fishers, processors and the fishing community as a whole. It is necessary that inland aquaculture practices should benefit the stakeholders from the producers to the consumers by producing wholesome cultured fish. After identifying the elements of these two aspects, a fishery management system could be adopted, including the planning of the culture systems, management, and research. Factors that could possibly cause the decline of the condition of the inland fishery resources should

be avoided during freshwater aquaculture operations through the adoption of sustainable fisheries management strategies. Such freshwater aquaculture should therefore remain sustainable in order that it would be able to provide beneficial results to all stakeholders.

2.1.5 Conflicts on Use of Inland Water Resources among Various Sectors

In several countries, inland water resources are being tapped for food security, poverty alleviation, cultural services, and the preservation of biodiversity (Funge-Smith & Benneth, 2019). The future of inland fisheries is linked to the successful management of inland waters, such as rivers, swamps, lakes, and other wetlands (Funge-Smith & Benneth, 2019). In this regard, it has become necessary that inland fisheries management be considered as part of a larger environmental and socioeconomic scale that involves multistakeholder and sectors sharing and competing over the same water resources.

The inland fisheries sub-sector has been facing serious challenges between conserving fish biodiversity and fish production for food security. Management of inland fisheries through regulations and interventions can contribute to socioeconomic benefits, increase productivity, and preserve biodiversity. In developed countries, inland waters are used not only by the fisheries sector but also by other sectors that demand water (*e.g.* hydropower, agriculture, tourism, industry, or transportation), and thus, would require a lot of efforts to synergize between freshwater fisheries and other users that compete for the same inland waters through an ecosystem approach that involves cooperation among the stakeholders from all sectors to formulate the most appropriate comprehensive and inherent policies. Conflicts can arise because the users have differences in priorities, as a result, direct conflicts often exist between fisheries and other sectors because they use the same resource base, although many studies indicate that fisheries, agriculture, tourism, infrastructure, and other sectors would be able to co-exist in well-managed inland waters.

Water construction developments like dams and weirs for hydropower generation or agriculture, modification of environmental form and function, industrial and land-use practices including forestry and recreational use, can cause significant impacts on inland fisheries. Dams and weirs can block fish migration and environmental modification for some purposes can eliminate critical habitats, sedimentation, and water quality degradation. Dam construction has almost always created conflicts between energy supply and related economic interests, versus their social and environmental impacts (King *et al.*, 2007).

Modern approaches to fisheries management are needed and have proved successful in promoting close integration between the fisheries and irrigation sectors. There is a

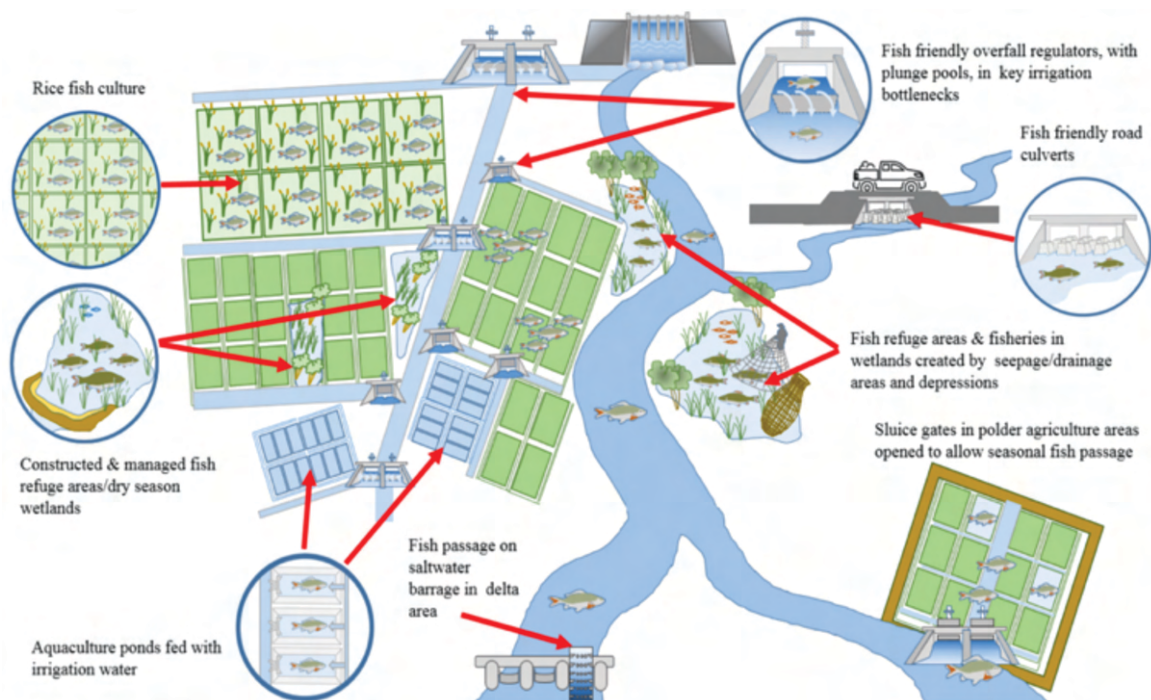


Figure 66. Fisheries, aquaculture, and irrigation integration (Gregory *et al.*, 2018)

tendency to integrate the management of natural resources in Southeast Asian countries but this would need deeper involvement of communities in the planning and co-management of natural resources. These trends offer opportunities for the various natural resources departments and sectors to work together. In order to achieve such a goal, the integration process proposed would require the collaboration of irrigation, agriculture, and fisheries sectors (Figure 66) (Gregory *et al.*, 2018).

Fisheries stakeholders, therefore, need to interact and make alliances with the multi-stakeholder environment to minimize aquatic ecosystem damage and to promote conservation activities. Welcomme *et al.* (2010) suggested five main actions that could usually address the challenges for inland fisheries managers and stakeholders relative to the environment. These actions could aim for the establishment of policies relevant to: 1) creation of reserves or refuge areas; 2) pollution prevention and control; 3) maintaining environmental flows; 4) freedom of passage for fish; and 5) rehabilitation of degraded habitats.

Moreover, the fact that several rivers and lake basins lie within the territories of more than one country, and fish often migrate from one country to another for breeding, feeding, or refuge, any human activities in one country, *e.g.* pollution control, water obstruction, and damming, can also affect those of the other countries. Common approaches should therefore be adopted for their management using the ecosystems (river or lake basin) approach. Many international mechanisms for such collaboration exist in the form of river and lake basin commissions, but these usually address developmental issues such as water supply, power

generation or navigation, and rarely consider the fisheries aspects (Welcomme *et al.*, 2010)

Establishment of regulations and management of inland fishery resources

General policies are necessary for regulating and managing the inland waters properly. The establishment of regulations is very crucial, which should be raised as a priority action because inland waters produce significant economic commodities. Without proper management, the inland water resources would be gradually depleted. A better understanding of the significance of sustainable resources of inland waters could influence the direction of general policies, particularly in maintaining the relationship between fisheries and with other sectors such as agriculture, tourism, infrastructure development, and transportation.

As for the fisheries sector, the practice of managing the fishery resources in inland waters had been carried out for a long time by the local people. Such practice includes habitat conservation which is actually not something new for local people had ever since practiced conserving and protecting the fish habitats, either temporarily or permanently, and had been doing this for hundreds of years. Habitat conservation could refer to an area of public waters with a certain portion that is protected also known as reserve or refuge, as a habitat for fish to live and complete their life cycle. Currently, the existing habitat conservation has various forms, management rules, and regulations. This is because most of the management strategies had been developed by local people having different customs and cultures. In some areas, traditional fishing communities usually have

their own forms of fisheries management, one of which is designating an area in inland waters as a protected area to be free from any form of fishing activities. Protection and/or prohibition of any fishing activities in such an area could be carried out continuously or temporarily. Nevertheless, in inland fisheries management, determining the areas for fishery reserves could be difficult to realize, because there are already a good number of protected areas in inland waters that have so far been managed by local communities.

In order to manage the reserved areas or refuges in a sustainable manner, it is necessary to have an institution consisting of the elements of human resources as the manager of the habitat conservation, as well as plans and rules for managing such habitats being conserved and/or protected. Moreover, in order to succeed in habitat conservation, the human resources for its management should come from the local government and representatives from the local fishing communities. The habitat conservation group should have an organizational structure consisting of a chairman, secretary, and members.

2.2 Challenges and Future Direction

The importance of inland capture fisheries to food security, as well as improved livelihoods and socioeconomic well-being of the Southeast Asian countries, is well recognized. The inland fisheries sector also contributes to recreational services, biodiversity conservation, and ecotourism. Nevertheless, the sector has been facing challenges brought about by competition of several sub-sectors that may result in deterioration (including disconnectivity) of the resources and habitats, as well as conflicts in the utilization of inland aquatic resources, that may continue to threaten the sustainability of inland capture fisheries. It is therefore necessary that inland fisheries should be properly and sustainably managed by the AMSs for the food security of their peoples, especially those in the rural areas. Inland fisheries also make substantial contributions towards achieving several SDGs, particularly SDG 1: No Poverty, SDG 2: Zero Hunger, SDG 12: Sustainable Consumption and Production; and SDG 15: Life on Land. To enhance the sustainable contribution of the inland fishery resources to the socioeconomic well-being of peoples in the region, the following aspects should be considered by the AMSs and relevant institutions and organizations:

Developing new methods of data collection, analysis, and dissemination

- The AMSs and relevant organizations/institutions should consider examining new methodologies for data collection and analysis appropriate for the small-scale and multispecies characteristics of inland capture fisheries, especially coming up with data that could substantiate the socioeconomic value and the important contribution of inland capture fisheries to food security

and livelihoods of people, for dissemination to planners and policymakers, not only for the fisheries but also other relevant sectors. This is considering that improvement of conventional catch/landing data collection is not always possible as it requires a large number of enumerators and high cost due to the dispersed characteristics of inland capture fisheries activities.

- The AMSs and relevant organizations/institutions should continue to pursue the development of novel and innovative methodologies, using appropriate indicators and local/indigenous knowledge, for conducting research studies on the status of inland fishery resources, taking into consideration the specificity of inland capture fisheries. Strengthening international cooperation should be explored when undertaking research studies on inland aquatic species and habitats that are transboundary, considering that one country alone could not come up with complete information on the species or habitat.
- Relevant institutions/agencies should consider developing an application-based system for mobile phones, *e.g.* in an android system, to support efficient and effective data collection from inland capture fisheries. The application should also allow offline data inputting when the internet connection is unreliable or unstable or unavailable, in order that the data could be uploaded into the database once the internet connection is restored or available.

Sustaining inland aquatic habitat conservation and restoration

- The AMSs and relevant organizations and institutions should enhance the promotion of appropriate habitat conservation and restoration measures, *e.g.* establishing fish refuge areas, as a habitat for fish to live and complete their life cycle, or deep pools; as well as appropriate management, *e.g.* by habitat conservation groups comprising members of local governments and representatives from local fishing communities, and so on. Identification of fish refuge areas could be based on the best scientific evidence including local indigenous knowledge on inland fisheries habitats in association with economically important aquatic species.
- The AMSs should consider formulating technical policies for prevention, control, and rehabilitation of habitats and their environment; investigating the carrying capacity of waters for fishery activities, including restocking, introduction, and control of alien species; and pursuing culture-based fisheries, species/genetic conservation, and conservation-based capture fisheries, with a view to supporting the sustainability of the utilization and preservation of the fishery resources and their environment