CHAPTER 3

THREAT TO INLAND WATERS ENVIRONMENT AND FISHERIES

Inland water systems that include rivers, lakes, swamps, floodplains, small streams, ponds, and reservoirs, have a variety of biological, physical, and chemical characteristics. Inland waters are an ecosystem that easily becomes endangered and highly vulnerable to degradation. The aquatic organisms in inland waters are dependent on each other. While the consumption of fish is increasing with the increasing population of the world, the supply of wild-caught fish is put under pressure.

The inland waters of the Southeast Asian region are known for having one of the highest diversities and broadest geographical coverages in the world. Despite this natural endowment, there is a need to harmonize the use of land and aquatic habitats as they influence each other and vice versa. The inland water ecosystems are ecologically dynamic, although inland waters do not have artificial conceptual boundaries or ecosystem perspective. For example, in rivers with seasonally flooded areas, the water may be high during the rainy season, flooding or submerging the land, while in the dry season there may be no water and the rivers remain dry.

In everyday practice, inland waters are used as source of water supply and for water transportation. Moreover, man-made reservoirs are used to generate hydropower and dams are good source of fish. While fishing activities usually do not pay much primary attention to inland water resources, even if inland fisheries have always been dubbed as protein source provider for the rural people and one of the significant contributors to national economies, the inland fisheries subsector has been sustaining the livelihoods of peoples in rural communities.

The statistics data and records during the past 20 years have shown that fisheries production from inland waters had been substantially increasing, although at a slow annual average rate of increase of about 4% (Pongsri *et al*. 2015; SEAFDEC 2017). Nonetheless, the utilization of inland fishery resources needs to be monitored to ensure their sustainability and that the aquatic diversity is maintained.

Considering that inland waters, as an ecosystem could easily become endangered and are highly vulnerable, and where the aquatic organisms are dependent on each other, changes in the aquatic ecosystem would affect the organisms present in the waters. Moreover, nowadays, the consumption of fish is growing as the world's population expands. This has put the supply of wild-caught fish under pressure. In most cases, changes in the inland waters ecosystem are caused by natural or human factors. Thus, it is necessary to identify the various threats in the inland waters environment to address the multi-faceted problems over the inland waters.

Threat is the amount of damage from something done directly or indirectly. Therefore, the threats to inland waters, on its environment and fishery activities are significant and are likely to escalate as more water is used to meet human needs while the impacts of land-based activities further degrade the well-being of inland waters. Nevertheless, the main direct drivers of change in inland water environments could include habitat change, pollution, over-exploitation, introduction of invasive alien species, and climate change among others.

3.1 Natural Factors

In the upstream, river tends to flow fast because the slope of the land is steep, while, in lowland areas, the river tends to flow slowly because the slope of the land is more or less flat. The downstream areas become wider when a lot of rainfall is received, and the river will flood the flat areas that could extend into tens of kilometers. Increased intensity of agriculture and deforestation, and activities related to improving the runoffs with pesticide contamination could cause erosions and sedimentation of rivers. Several studies had been conducted to determine the relationship between vegetation and the hydrological cycle, the results of which showed that vegetation has direct influence on controlling erosion, water quality, and aquatic diversity present in the waters. The rising of water level related to changes in the precipitation, causes the soil to become warmer due to decreased water content. The increasing water temperature is one of the natural phenomena known as global climate change.

Deforestation

Forests with its vegetation cover can prevent the occurrence of shallow landslides (Bruijnzeel 1990). That is the same as saying that deforestation could enhance erosion, although the downstream areas cannot always be ascribed to the changing of upstream land use practices. Erosion contributes bulk of the sediments and the effects of erosion on the sediments would be felt in the downstream areas. In the region with high rainfall rates and unstable geological conditions, soil erosion would impact on the flow of sediments leading to accumulations of physical and chemical pollutants. Freshwater aquaculture and agricultural activities can add substantial nutrient loading to waters, increasing the nutrient contents of the surface and groundwater. On the other hand, application of pesticides in agricultural activities poses much danger to the water resources, since pesticide compounds are designed to be toxic and persistent, and could easily go with the flow of the water (**Figure 3.1**).

Climate Change

Climate change affects the inland waters and directly or indirectly on the biota. The significant expected impacts to inland waters include warming of the rivers, which in turn can affect the chemical and biological processes in the waters, reduce the amount of dissolved oxygen in deep waters, and affect the growth rates, reproduction, and distribution of organisms and aquatic species in the waters (Gitay *et al.* 2001). Climate change also affects the sea level to rise and salt water could intrude into floodplains and swamps (**Figure 3.2**). Plant species which could not tolerate increases in salinity or inundation could be eliminated, while salt-tolerant mangrove species could expand from nearby coastal habitats.

Figure 3.1 Agricultural activities (palm plantation, rice field and traditional plantation) and freshwater aquaculture could pose the danger to inland waters

Changes in the vegetation will affect both resident and migratory animals, especially if these cause major changes in the availability of staging, feeding, or breeding grounds for particular species (Boyd and Madsen 1997; Zockler and Lysenko 2000). Reduced rainfall and flooding across large areas will disturb the habitats that are episodically wet and fresh or drier and saline (Roshier *et al*. 2001).

Climate change also affects the wetland carbon sink because the potentials of absorbing more carbon into the carbon sink could be disrupted. The hydrology and vegetative community of a wetland could also change because of climate change, resulting in more extended and more frequent droughts altering the carbon balance in peatlands (Gitay *et al.* 2001).

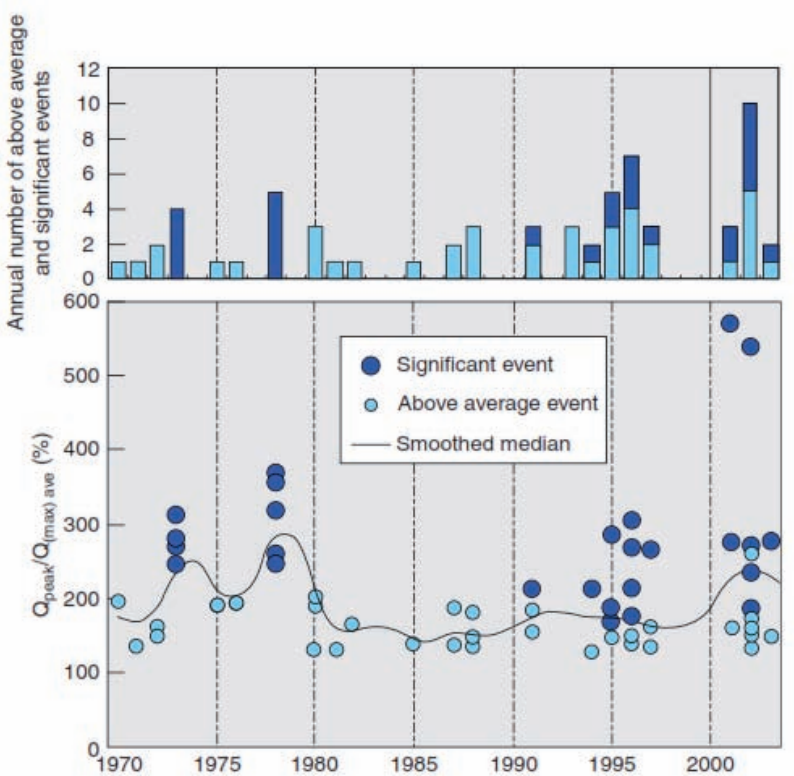

Figure 3.2 Regional incidence of "significant flood events" between 1970 and 2003, where a significant flood event is one with more than one standard deviation above the mean annual maximum flood peak (Adamson *et al*. 2009)

Recently, the impacts of climate change had been more pronounced, such as increasing incidences of floods and river erosions that affect the use and value of rivers for recreation, conservation, fisheries, water supply, and transportation (Ashmore and Church, 2001). Therefore, the extent of changes in inland waters as a consequence of climate change should not be addressed in isolation from the other drivers of change (Gitay *et al*. 2001; van Dam *et al*. 2002).

3.2 Anthropogenic Factor

An anthropogenic factor occurs when there is increase in human populations, which consequently affects the growing need for food resources, resulting in increases in the level of exploitation of the food sources including fish (Schindler 2001). The need for protein and food sources, especially from fish, encourages excessive exploitation activities to the extent of depleting the existing resources. Furthermore, the fulfillment of other requirements such as transportation, shelter, electricity or energy, and recreation, adds to the broad transition of the resource functions of land and waters. Construction of dams for irrigation and electricity generation, land reclamation for settlement and transportation, and reconstruction of natural recreation areas for tourism (**Figure 3.3**) are also part and parcel of the anthropogenic factors. As a result, the interests of development are more real-valued than the fisheries sector so that the well-being of the fishery resources tends to be overlooked.

Overfishing

Increase in the human population in an area induces an increase in the need for food sources, which could be met mainly from the availability of natural resources including fishery resources. Fulfillment of fish consumption needs has often been a point of discussions in many fora because the needs and demands are always increasing, but the existing resources tend to decrease and experience certain degradations. Inland fisheries are different from marine fisheries because in the former, the conditions of the land and environment significantly influence their existence. The increasing demand for fish has led to certain level of overexploitation of the fishery resources, and the need for fish is no longer selective in terms of consumption of particular fish species as other fishes not consumed before including by-catch are also being exploited (Welcomme *et al*. 2010). Using various types of fishing gear

is also practiced to obtain the desired amount of catch, with variety of fishing gear used to adapt to seasonal changes so that fish production remains high following the purpose of exploitation (Aroef *et al*. 2019).

In some areas, the smaller and shorter-lived species become the main component of the catch, because of the decreases in catch of the predatory species. The situation may look good for a while, however, smaller fish are often much less valuable, which could ultimately result in further recruitment failures. Furthermore, overfishing of larger fish in a population may eventually change the gene pool towards smaller-sized fish (Fenberg and Roy 2008; Van Wijk *et al*. 2013). This problem is generally overlooked and not addressed in many fisheries management plans.

Figure 3.3 Dams and hydroplants construction, water transportation, and establishment of tourism destinations could affect the well-being of inland water resources

Unfriendly Fishing Gears

Fishing that utilizes poisonous compounds and destructive gears, is harmful to the fishery resources and damages the water environment (**Figure 3.4**). Moreover, the unexpected behavior and quality of the catch could endanger the fishers and other persons such as the consumers. These fishing activities also tend to kill the essential aquatic organisms and reduce the sustainability and productivity of the fishery resources. Otherwise, regulations on the minimum mesh sizes must be heeded to minimize the mortality of undersized or juvenile fishes, although the mesh size regulations have not yet been reported to have significant impacts on the juveniles' survival to maturity. Another unfriendly fishing gear is the practice of disrupting the flow of water and catching the fish during their migration from upstream to downstream for spawning in the deep sea (**Figure 3.5**).

An important factor that looms the inland fisheries is the effective and efficient enforcement of legislations in each country (**see Chapter 4**). The globally large numbers of illegal fishing activities is caused by weak institutional and governance arrangements on illegal fishing and use of destructive fishing practices (Agnew *et al.* 2009). In most inland waters, the fisheries management of multi-species and multi-gear becomes particularly challenging.

Figure 3.4 Fishing with the use of electricity (above) and small mesh size of gillnet (below) could contribute to the degradation of the aquatic organisms in particular, and the fishery resources in general

Figure 3.5 "Waya Masapi", a fishing gear for anguillid eels in Poso Lake, Indonesia, cuts the flow of lake water threatening fish migration from upstream to downstream during their spawning in the oceans

Pollutant Matters

Pollutants and wastes contribute to the decreases in the environment's function in inland waters, especially with increasing human activities. Several lake and river systems can be particularly damaged by the increase of siltation and pollution coming from mine tailings and agricultural wastes. At present, the biggest issue in the world is plastic wastes irresponsibly thrown everywhere and finally coming down to the waters (**Figure 3.6**). This kind of wastes is difficult to decompose in nature because the materials used come from organic polymers that cannot be degraded quickly.

Figure 3.6 Plastic wastes in inland waters take much longer time to decompose

The expansion of plantation and agricultural areas that use toxic active ingredients in massive quantities is dangerous and the wastes that directly flow to the rivers could not be controlled. Meanwhile, the development and expansion of coal mining ventures and the production of crude oil and gas in many Southeast Asian countries, such as Indonesia, Thailand, and Viet Nam have been intensified. It is well established that pollution from sources such as mining and agriculture have had devastating impacts on the biota of inland waters. Threats of water quality degradation are usually most severe in areas where water is scarce due to the reduced capacity for waste dilution. Meybeck (2003) provides an overview of water pollution problems in inland waters from industrialized countries, and the emerging problems from agriculture run-offs that are increasing everywhere in developing countries. Urban and industrial pollution sources are also increasing faster than the related wastewater treatments, while nutrient enrichment resulting from the use of high protein feeds to spur the growth of cultivated fish is also on the rise. Also, air pollution coming from factories and vehicles increases carbon emissions, and contribute to the amount

of CO_2 discharged to the air. Consequently, this condition affects the fish that consumes the phytoplankton and zooplankton, and other microorganisms that have been polluted (Tanaka *et al*. 2015).

Land-use Changing

Projects on agro-industry, wood and paper production, mining, chemical and power plants, tourism, and infrastructure development, could have various effects on the inland waters environment (**Figure 3.7**).

Figure 3.7 Mining activities (sand, gold, and logging) affect the inland waters environment

As mentioned above, pollutions caused by agriculture, plantation, and mining activities are already discussed above. Generation of electricity from hydropower dams has increased enormously in recent years. Consequently, large hydropower projects will cause flooding of vast land areas, and projects on the development of dams threaten the rich

biodiversity and ecosystems by constraining the adjustments of the range of warm temperatures of the waters. Furthermore, dams also interfere with fish migrations by stopping them from reaching their habitats for spawning and as a consequence, also harm the livelihoods of local people from the inundation of agricultural and residential lands (Kano *et al*. 2016).

3.3 Biological Factors

The introduction of some alien invasive species has contributed to species extinction in some freshwater systems (Tockner and Stanford, 2002). The problems caused by introduction of invasive species had posed a big global concern (Mooney and Hobbs 2000). Fish introducing activities done over the last 150 years in tropical Asia (carps and tilapias, for instance) are usually conducted to enhance fish production and recreational fisheries or to control pests such as mosquitoes and aquatic weeds (Revenga and Kura 2003).

Nonetheless, the spread of exotic species in inland waters has been increasing with the development of aquaculture as mentioned by FAO (1999). Many fish species have been spread beyond their native ranges, often as an important component of aquaculture. This species have overgrown and reached maximum population densities within a period of few months, and then later, the species flourished and became serious problems (Williamson 1996; Manchester and Bullock, 2000). Not only fish species, but also plants spread quickly to rivers and lakes, clogging the waterways and infrastructures, reducing the penetration of light and occurrence of oxygen in freshwater systems, and causing changes in the water chemistry and species assemblages. Water hyacinth is an example of a widespread of alien water plant species that causes considerable economic and ecological damages in inland water systems around the world (Gopal 1987) including in many Southeast Asian countries (**Figure 3.8**).

Figure 3.8 Plants like water hyacinth can spread quickly clogging the inland water systems

The existence of water hyacinths and other aquatic plants has been a major concern in Rawapening Lake, Indonesia, becoming a serious problem for more than 50 years (Kenneth 1980; Hidayati 2018). Nutrient input from water catchment area and fish feed residues are suspected to lead to eutrophication, a condition that induces uncontrolled growth of aquatic plants. In dry season, aquatic plants cover almost 70% of the lake area. This problem should be handled properly due to the wide range of lake functions such as utilization of the water resources, fish farming, operationalization of power plants, flood control, irrigation, and many other important uses and activities (Hidayati 2018).

The impacts of introduced species on the native fish and ecosystems have not been well documented, although Fernando (1991) reported that in some cases introduced fish were not found to have caused severe damage to indigenous species. In recent decades, tilapia species have been established and become a substantial contributor to inland fisheries to fulfill human needs for fish consumption, indicating a significant shift in the composition and structure of biological communities in those systems.

Actually, introduction of alien species can increase the production and value of inland ecosystems, but they can also have profound and severe impacts on the ecosystem (Bartley 2006). Another risk from fish

aquaculture is in the event when some fish escape from fish farms to the waters. The escaped fish usually grow up rapidly, about twice that of the native fish species' growth, resulting in the native species either getting extinct or inhabiting only in small populations (Kolding *et al.* 2008).

3.4 Other Factors

Various activities done by other sectors in inland waters would often create competition on the utilization of the inland water resources. Many development projects proposed for enhancing the economy and quality of life for people living in low-income countries, could lessen or lose the high productivity potentials and aquatic ecosystem services of the inland waters. For establishing the basis of proper management, data and information on these aspects would be necessary to come up with a complete report.

Conflict of Interests

The need for water to support fish and fisheries can conflict with the needs of other sectors, in particular, agriculture, in both water quality and flow requirements for sustaining the aquatic habitats. Decisions on water management frequently do not take into account the impact on fish and fisheries, and on the rural livelihoods of the populations that depend on them. In part, this is because inland fisheries are significantly undervalued in the water management plans at local, national, and basin-wide levels. In the local scene, specific provisions governing access to rice field fisheries have been introduced by local wisdom (Figure 3.9), where two separate regimes of access are recognized depending on whether the area where the rice fields are located is flooded or not.

Figure 3.9 Local wisdom in floodplain areas, indicating areas where fishing is not allowed (right) and deep pools for fish culture during the dry season (left)

Under the general regulation, any person wishing to fish in a rice field is required to seek permission from the field owner or the holder of land use right over that field. In the event of a flood, any person may fish in submerged rice fields without permission from the field owner, but if the water level covers only the deep pool, only the owner can catch the fish.

Insufficient Data and Information

Data and information are the basis for proper management, and thus, should be properly monitored and collected. It is common in tropical watersheds that fish landings could go completely unreported and the amount of catch is oftentimes estimated from unreliable information sources. This clearly contributes to the severely incorrect production data from inland capture fisheries. In many cases, the amount of catch reported is only an underestimation because the contributions of many fisheries on smaller tributaries and water bodies are generally overlooked (Coates 2002).

A problem on data collection is that the statistical system is very much production oriented. There appears to be limited information collected on the participation of stakeholders in fisheries including

those involved in catching, processing, and marketing (Welcomme 2011). The majority of inland fisheries activities is not licensed, operated at a semi-commercial or subsistence level, and widely dispersed along the numerous waterbodies (FAO 2010). There are often no centralized landing ports or major markets where data can be easily collected, and a large part of the catch is bartered locally or consumed domestically by the fishers' households. Moreover, the catch size and composition, gears used, and numbers of fishers vary significantly during the different seasons. These forms of challenges make the data collection not only time-consuming but also costly.

Furthermore, the amount of landings is often recorded for some indicative fisheries, but is subsequently extrapolated up to the national level, with large errors occurring especially when the numbers of gears, fishers, and households involved are unreliable (FAO 2010), making the overall quality of the data weak (Ernst and Young 2011).

Alternative approaches to data collection are needed to improve the situation. These could include the conduct of traditional catch and effort surveys, as well as efforts in addressing the issues, such as through population census, consumption studies, market surveys, and habitat classification.

3.5 Challenges

There are two broad challenges in fisheries production; *i.e*. sustained and increased production. In supporting the present level of fisheries production, it is necessary to maintain or restore the aquatic environment, including its diversity, and improve management of capture fisheries and other ecosystem services through the provision of target-directed environmental flows. To increase the present stages of fisheries production, wider adoption of methods for enhancing and intensifying production could be promoted.

Figure 3.10 Building partnerships between Government and fishers/ Fishers' Groups to address the concerns on the sustainable utilization of the inland water resources

The methods could include proper adoption of stocking densities and good aquaculture practices, as well as appropriate management adequate enough for suitable habitats and arrangements. Both challenges can be surmounted by building partnerships between fisheries and other interested groups concerned with water management and to be facilitated by the Government (**Figure 3.10**). Those engaged especially in water management for agriculture and fisheries, should strengthen their collaboration in searching for more efficient ways of obtaining the overall benefits of water uses that would raise food security and reduce poverty.