Sustainable use and conservation of inland water ecosystem in Indonesia: Challenge for fisheries management in lake and river ecosystem

G S Haryani*

Research Center for Limnology, Indonesian Institute of Sciences

*Corresponding author: gadis@limnologi.lipi.go.id

Abstract. The paper aims to provide sustainable use and conservation insight into tropical aquatic resources with a special emphasis on inland water ecosystems in Indonesia, such as lakes and rivers. The talk focuses on certain use of resources in these ecosystems by humans. The inland water ecosystem should be properly managed to protect and maintain its biodiversity and sustainability through wise use of the aquatic resources with several ecological approaches. The richness in inland water resources does not lead Indonesia to freedom from water crises, and social and environmental problems. Degraded inland water ecosystem with much reduced carrying capacities, trapping people in conflicts of ecosystem use. The challenge of simplifying the adoption of conservation and sustainable use approaches to promote the implementation of practices in Indonesia remains.

1. Introduction

The inland water area is the cornerstone of human life in meeting its needs in the present and the future because the inland water ecosystem provides productive natural resources both as a source of raw water for drinking and daily needs, sources of animal protein, minerals and energy, transportation media, and tourist areas. Healthy and well-managed inland water resources contribute to continuing nutritional and economic needs and human life [1].

According to the United Nations, water use has grown at more than twice the rate of population increased in the last century. By 2025, an estimated 1.8 billion people will live in areas plagued by water scarcity, with two-thirds of the world's population living in water-stressed regions as a result of use, growth, and climate change. The challenge we now face as we head into the future is how to effectively conserve, manage, and distribute the water we have [2].

As the global population grows (increasing agricultural, industrial and domestic demands for water), and water demand increases, water stress and the risk of water scarcity is now a common concern. This is even more applicable for particular regions with lower water resources and/or larger population pressures [3].

Thousands of species are highly dependent on freshwater habitats, including fish, amphibians, butterflies, insects and insects, and thousands of mollusk species. Some bird species also depend on terrestrial aquatic habitats. The small surface area covered by freshwater makes it a habitat for some invertebrate & vertebrate species. Thus, it makes sense if we have to provide adequate allocations of terrestrial waters to maintain biodiversity. Besides, diversity and ecosystem health will provide direct and indirect benefits for the economy, food, tourism, storage reserves, and water purification. An
assessment of the annual ecosystem services provided by inland waters needs to be done, including supply functions for millions of people who depend heavily on terrestrial ecosystem services.

Ecosystems make water available to the organisms that live in it. However, ecosystems can also be seen as water users, which are needed to meet their needs for water in certain quantities, quality, and flow of circulation. Ecosystems also provide services that support the lives of millions of people and provide the basis for development.

On the other hand, inland water ecosystems in addition to being a very productive area as an economic source, but also increasingly experiencing great pressure due to human activity. There is strong competition for the availability of freshwater and inland water resources, specifically to maintain the existence of biodiversity that must deal with the need to produce food, power generation, for industrial use, and maintain the carbon content of ecosystems. Groundwater meets a small portion of freshwater needs, but the pressure on surface water is very large.

Ironically, human water needs usually fail to recognize the water requirements required by ecosystems. This is the fundamental reason why there is a decline in the quality of terrestrial waters and the loss of biodiversity contained therein. The lack of awareness of the need for water for these ecosystems has an impact on the high costs that must be borne by the community, which in turn requires greater investment, among others, for flood control, storage, and purification of water.

Half the world's wetlands have been drained, filled, planted, or paved, and fewer than 70 of the world's 177 longest rivers (620 miles and longer) remain free-flowing, unimpeded by dams or other barriers. Only 21 rivers longer than 620 miles retain a direct connection with the sea. Animals such as crayfish, fish, and mussels that depend on freshwater habitats are disappearing faster than marine species and tropical forest species. People are also affected by the loss of freshwater; more than 1 billion people lack access to clean drinking water and 2 billion lack adequate sanitation. This lack of freshwater is one of the most urgent environmental and development issues of the 21st century [4].

Anthropogenic pressure can also mean that progressively less freshwater is available for the benefit of the ecosystem or to maintain its biodiversity. For the acquisition of more balanced inland water management, it is very important to understand the pattern of human use of freshwater and development activities that pose dangers and threats to freshwater and terrestrial waters over the past few decades.

Climate change is adding pressure to the functions of freshwater ecosystems, which will further threaten the ecological services provided and their biodiversity content, increasing water scarcity in higher frequencies and extreme flooding which will also be more frequent. As such, this will have a direct impact on biodiversity, change the range and range of distribution of various species, and affect the various habitats and recesses of other species [5].

Hundreds or even thousands of hectares of wetlands in Indonesia have been lost during the past 20th Century. Many freshwater habitats are now experiencing increased vulnerability and threatened to disappear. The lost freshwater species are much faster than other species. There are several reasons why this happens. One of the main things is the vulnerability of species that depend on a small area of habitat that is under pressure by the increasing human need for freshwater. The biggest threats generally come from pollution from agricultural and industrial activities, the use of freshwater, and several dams. Damage and reduced carrying capacity that occurs is not infrequently irreversible and recovery requires a large cost and a long time [6].

The balance between human water use and watershed health and ecological integrity is one of the prosperous well-being that has come up against the human recognition that the ecosystem services provided by healthy watersheds are collapsing from human overuse and abuse [7].

2. Inland water ecosystem in Indonesia
Indonesia is the fifth largest country in the world with freshwater resources (3,221 billion m$^3$/year), blessed with an extraordinary number of multi origin (tectonic, volcano-tectonic, oxbow, and enclosed) lakes [8].
Based on data from the Department of Regional Infrastructure Settlement in 2003, Indonesia has around 5,590 major rivers and around 65,017 tributaries, with the total length of the main rivers reaching 94,573 km, and the area of the river basin reaching 1,512,466 km². Along with increasing population growth, the potential of aquatic resources, the mainland is under pressure due to the activities of the inhabitants on the mainland as well as its utilization pay less attention to aspects of conservation. Damage to resources due to the exploitation that is not environmentally friendly is partly driven by growth pressures and poverty of the population whose livelihoods tend to pay less attention to environmental sustainability. For examples, cases of over-exploitation, pollution from agriculture and domestic, the use of toxic chemicals, and the use of electrical fishing.

Many inland water ecosystems in Indonesia should be managed seriously to meet the needs of the people and the environment for their services. In entering the 21st century, there exist increasingly complex problems of the lakes and rivers whereby the function is decreasing over time due to both increasing utilization of the resources of the ecosystem and in line with population growth [9]. The overall lake and river ecosystem in the catchment area, water bodies, and the riparian are heavily affected by human activities. The inland water ecosystem suffers from heavy pollution, siltation, ecosystem deterioration, and fish killed. Sewage, sludge, garbage, and even toxic pollutants are all dumped into the inland water ecosystem. These have resulted in a decline in the carrying capacity of the ecosystem to support the productivity of water. The water crisis is not only from water scarcity but also from a lack of access to affordable clean water. Table 1 shows the ecosystem condition of 15 priority lakes Ecosystem in Indonesia.

Table 1. Ecosystem Condition/Status of the 15 Priority Lakes Ecosystem in Indonesia [10]

| No. | Name of Lake          | Terrestrial of Water Catchment Area | Lake Riparian Zone | Trophic Status |
|-----|-----------------------|------------------------------------|--------------------|---------------|
| 1.  | Toba                  | Threatened                         | Threatened         | Eutrophic     |
| 2.  | Singkarak             | Damage                             | Damaged            | Eutrophic     |
| 3.  | Maninjau              | Threatened                         | Threatened         | Hypereutrophic|
| 4.  | Kerinci               | Threatened                         | Threatened         | Eutrophic     |
| 5.  | Rawa Danau            | Threatened                         | Threatened         | Eutrophic     |
| 6.  | Rawapening            | Threatened                         | Threatened         | Hypereutrophic|
| 7.  | Batur                 | Threatened                         | Threatened         | Eutrophic     |
| 8.  | Tempe                 | Damaged                            | Damaged            | Hypereutrophic|
| 9.  | Matano                | Threatened                         | Threatened         | Oligotrophic  |
| 10. | Poso                  | Threatened                         | Threatened         | Oligotrophic  |
| 11. | Tondano               | Threatened                         | Damaged            | Eutrophic     |
| 12. | Limboto               | Threatened                         | Damaged            | Eutrophic     |
| 13. | Mahakam (Semayang, Melintang, Jempang) | Threatened | Threatened | Eutrophic |
Inland water in Indonesia is a global heritage that must be restored and protected to enhance their life-supporting ecosystem services. Therefore, conservation and sustainable use require a wise and adequate scientific foundation, including the likely interdisciplinary adaptation and mitigation efforts and the active societal role in maintaining the inland water conservation in Indonesia as well. Hence, reformed management of the inland water in Indonesia is inescapable to comply with the sustainable use of different end-users like clean and drinking water supply, transportation, fishery and agriculture, industrial use, waste disposal, energy generation, natural habitat for fauna and flora, climate regulator, and cultural activities. How the effort of conservation and sustainable use in inland water has been attempted in several inland water ecosystems is presented below.

3. Efforts for the sustainable use and conservation of inland water ecosystems in Indonesia

The sustainable use of natural resources for the welfare of the community requires management efforts aimed at protecting, conserving, and utilizing natural resources and their habitats, especially in inland waters [11]. Indonesian inland waters have considerable potential for fishery resources both as land for capture fisheries and aquaculture businesses (in the form of consumption fish and ornamental fish) high biodiversity and germplasm sources.

Citarum River is the longest (297 km) and largest river in the region of West Java Province, flows from its upstream origins at Mount Wayang in Bandung District to the south of the city of Bandung towards the north where it discharges into the Java Sea in Muara Gembong, Bekasi Regency. The Cisanti spring, located on Mount Wayang in Tarumajaya Village-Kertasari Subdistrict-Bandung District, is one of the water sources feeding the upstream reaches of the Citarum River. The Citarum River holds a vital role in the livelihood of 27.5 million people in both West Java and the Jakarta province. 80% of the drinking water of Jakarta citizens came from the river that runs through 12 districts in West Java. In 2018, The President of the Republic of Indonesia launched a seven-year program to clean up the Citarum River. The fish community in the Citarum River has changed due to various anthropogenic activities along this river. To restore fish communities, we must protect river segments or small streams that show a relatively healthy ecological function [12]. A traditional conservation system (local name ‘lubuk larangan’) as a form of local wisdom of the people in the Sumatra region which is still running and quite effective in maintaining the condition of existing fish resources. Prohibition area is a section / part of a river that is protected by natural conditions and the environment so that a good habitat condition is created for the fish community. “Lubuk Larangan” is a form of ecosystem conservation that supports existing fish resources. This system should be used as a reference in building a fish habitat conservation system in the Citarum River [13].

The number of fish species in Indonesia reached 4,782 native fish species, which are scattered in various territorial waters. Of these, freshwater fish has 1,248 species, marine fish with 3,534 species, 130 endemic fish, 120 species introduced, endangered 150 species, and invasive 13 species. Conservation of fish resources and their environment in inland waters is an important part of fisheries’ sustainability and economic sustainability of fishing communities.

Efforts to conserve fish resources and their environment in inland waters include:
• Control of un-environmentally friendly fishing.

| No. | Name of Lake | Terrestrial of Water Catchment Area | Lake Riparian Zone | Trophic Status |
|-----|--------------|------------------------------------|-------------------|---------------|
| 14. | Sentarum     | Threatened                         | Threatened        | Eutrophic     |
| 15. | Sentani      | Threatened                         | Threatened        | Eutrophic     |
• Control of invasive fish against native fish populations and the development of invasive fish
• Conservation and improvement of habitat (sanctuary) and restocking of native species in their habitat
• Development of conservation through traditional approaches (local wisdom)
• Implementation of Collaborative Management (Co-management)

In Lake Sentarum, West Kalimantan, the use of fishing gear in the form of waring has the potential to have an impact on the decline in the consumption and ornamental fish populations, which could eventually lead to extinction. This is due to the types of fish that do not get the opportunity to mature and breed due to intensive fishing using waring fishing gear [14].

Floating fish ponds are becoming common practice in raising fishes, not only on river banks but especially in lakes and reservoirs. The development of these aquaculture facilities has reached an alarming level as a consequence of the feeding practices employed that have caused serious increases in pollution levels. These consequences become obvious during the dry season with increasing incidences of dead and diseased fishes due to the upwelling of hypolimnetic water with low dissolved oxygen levels.

The main cause of trophic status change is floating fish cage waste, not from river influent loads. Certain areas of Lake Toba that have experienced eutrophication are generally tourist areas. Based on the results of a study from the Limnology Research Center-LIPI, to recover the trophic status of Lake Maninjau to mesotrophic, it is necessary to reduce the number of floating fish cage in eight (8) villages to 6,701 plots and reduce nutrient load originating from Catchment Area by 20% [15]. Eutrophication of waters in some floating fish cage areas of Lake Toba can be controlled up to oligotrophic status by reducing the number of floating fish cage plots/segments. In 2016 the number of plots was 10,424 plots and the company's floating fish cage plots were 992 plots. From the optimization results to achieve oligotrophic, the maximum number of plots is 1,925 community plots and 730 company plots. The maximum number of plots per segment from each area can be used as a reference in the formulation of policies related to the management of Lake Toba based on the carrying capacity of ecosystems [16].

Lake Tempe in South Sulawesi suffered a significant reduction in lake storage capacity that occurred due to sedimentation at rates of between 600,000 m$^3$ year$^{-1}$ (1980) and 675,000 m$^3$ year$^{-1}$ (2003). Conduct of an ecohydrological engineering study for the restoration of the aquatic ecosystem in Lake Limboto. Ecohydrological engineering will potentially be applied to 562 ha in the eastern and northern parts of the lake to improve the water retention of up to 10 million m$^3$ (15%), reduce flood risks in the downstream areas, and increase fishery productivity by up to 300 tons year$^{-1}$ [17]. Accelerated refinement and better understanding of the key processes of the critical cases of Indonesian inland waters, both in terms of hydrological and ecological aspects, are of utmost importance to secure their resilience and enhance their ecosystem services for the society, including the habitat functions which support biodiversity and productivity of the inland waters [18].

The fishery sanctuary will function as a body of water where the fish community in it can carry out their life cycle and can supply the seeds and prospective brood fish to the surrounding fishing grounds. The fish sanctuary will be able to restore the carrying capacity of the surrounding water bodies, to provide optimal and sustainable benefits for the benefit of fishermen and the surrounding community. With the recovery of fish populations in the waters around fishery reserves, the potential of fish resources can be sustainable and can function optimally as expected.

An area of water must have core parts (core zone) as a center for conservation activities, parts for economic fishing activities (sustainable fishing zones), and parts that function to reduce the impact of fishing activities on the core (utilization/ buffer zones). In this connection, efforts to sustainably utilize fish resources and their environment in inland waters are important and strategic step.

In Lake Toba, it is proposed zoning for the development of endemic fish species, in 11 main areas for the conservation of endemic fish Mystacoleucus padangensis (local name: bilih). Determination of the conservation area must be followed by fishing regulations, namely fishing should not be carried out in rivers and their entrances entering the lake, gillnet and charting equipment used must have a net
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and water and the natural resources contained therein are controlled by the State and are used to the
greatest extent possible for the welfare of the people. These provisions are then constitutional and at
the same time the direction for regulating various matters relating to inland water resources. Law

concerning the Environment no.32 of 2009 concerning Conservation of Living Natural Resources and

Ecosystems, including regulating the carrying capacity of the environment. Fisheries Law No.31/2004,

concerning Fisheries amended no. 45/2009 has mandated conservation as an effort to protect, preserve,

and utilize fish resources and the environment. Fisheries management in the territory of the Republic

of Indonesia is carried out to achieve optimal and sustainable benefits and to ensure the preservation of

fish resources.

Inland water management is also strengthened by the Minister of Marine Affairs and Fisheries

Regulation concerning the Republic of Indonesia Fisheries Management Area for Inland Waters

(Ministry Regulation no.9/2020 concerning WPPNRI PD). The Republic of Indonesia Fisheries

Management Area in Inland Water (WPPNRI PD) regulates the management area for fishing, fish

cultivation, conservation, research, and fisheries development. Given the extent of Indonesia's inland

waters (54 million ha), the inland water area is divided into 14 regions. WPPNRI will become an

umbrella in the management of inland water that regulates the use of inland fisheries, through spatial

planning, preparation of fisheries management plans, conservation, fish culture, research, and
development of fisheries by responsible fisheries utilization in Indonesia.

At the local level, there are various Regional Regulations, for example, the Regulations of the

Regents of Agam Regency which regulate the utilization of aquaculture in Lake Maninjau using a

maximum of 6,000 floating net cages. Various regions in Indonesia has local wisdom and specifically

regarding the management or conservation of water resources. In certain areas such as Jambi province

and Riau province, there is a form of fisheries conservation which is well managed by community
groups through local customary and village rules [22].

- Implementation of Collaborative management (co-management)

The concept of joint management (co-management) provides an understanding as a partnership

arrangement using the ability of interests of local and community stakeholders, supplemented by the

ability of the government as a facilitator in providing all legal instruments and other supports that can
be accepted and applied by the main actors in management (local community and their families).

Rawapening is the lake area that has several functions, including fisheries, irrigation, power plant, and
tourism. The multiple functions produce positive and negative effects. The excessive use of

Rawapening affects the polarisation of interests, leading to environmental degradation [20]. The
centralized management model by reducing the role of community resource users makes management

of Rawapening inefficient. This has resulted in conflicts of interest in resource use and fisheries

resource crisis. The unbalanced distribution between the role of government and the role of the

community that utilizes resources in the background to the importance of a co-management approach

to improving resource management systems by integrating the recognition of rights and partnerships

of all stakeholders [21]. The involvement of local institutions in establishing management tools to

ensure more participatory management principles to manage sustainable economic activity in

Rawapening area comprehensively, it is needed paradigm shift from the polarization of interests to

collaboration [20]. The basic principle of collaborative management is mutually reinforcing, mutually

beneficial, and mutually beneficial to the parties, as well as providing a greater synergy effect in

anticipating various threats and disturbances to the preservation of natural resources.

- Law & Regulation

Various laws and regulations relating to the use and protection of natural resources, including

terrestrial ecosystems, are already quite numerous in Indonesia.

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terrestrial ecosystems, are already quite numerous in Indonesia.
4. Conclusion
Based on the description above, it is feasible to obtain maximum benefits from land-water ecosystem services in a sustainable manner. The implementation of the program of 15 priority lake and river ecosystem set up by The Ministry of Environment and Forestry, also the Team work of the Save Indonesian Lake Ecosystem, should be maintained and monitored frequently. Scientific recommendation such as Policy Brief also should be implemented by the local government or stakeholder to reach the sustainable use of inland water ecosystem in Indonesia.

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