Pol. J. Environ. Stud. Vol. 33, No. 5 (2024), 5003-5015
DOI: *10.15244/pjoes/178011* ONLINE PUBLICATION DATE: 2024-06-19

Review

A Review on the Challenges of Balancing Fisheries Resource Management in Indonesia's Inland Waters

Agus Djoko Utomo[1]*, Siti Nurul Aida[1], Yosmaniar[2], Khoirul Fatah[1], Mohammad Zaidan[3], Tuah Nanda Merlia Wulandari[1]

[1]Research Center for Conservation of Marine and Inland Water Resources, National Research and Innovation Agency, Cibinong 16911, Indonesia.
[2]Research Center for Marine and Land Bioindustry, National Research and Innovation Agency, Nort Lombok, 83352, Indonesia
[3]Research Center for Limnology and Water Resources, National Research and Innovation Agency, Cibinong 16911, Indonesia

Received: 14 August 2023
Accepted: 29 December 2023

Abstract

Inland waters have an important role in increasing fishermen's income, satisfying community nutritional needs, providing food security for the community, functioning as habitats for aquatic organisms, and maintaining environmental balance. The gap in fish resource management in Inland Water is that many problems in Inland Water have not been revealed and are not well documented. For this reason, it is necessary to collect references to review the problems and challenges of fish resource management in Inland Waters, as well as provide solutions so that Inland Water Fisheries can be sustainable. Inland water fisheries' problems in Indonesia are sedimentation, pollution, habitat destruction, lack of fishways, and overfishing. To reduce sedimentation, deforested land on the hillsides must be replanted. Green belts on the banks of reservoirs should not be used for agriculture and settlements, and must have a good master plan for land use, and sediment dredging should be carried out regularly. To tackle pollution from fish farming activities in inland waters, fish farming in reservoirs/lakes must not pollute the waters, and the amount must match the carrying capacity. To deal with pollution from industry, waste must be treated first before being discharged into water. Dams in rivers must be equipped with fishways so that fish can migrate. To overcome overexploitation, the number and types of large fishing gear, such as liftnets, filtering device, active seine, and active barrier, along with fishing using poisons, chemicals, or electricity, must be monitored and punished. Based on the findings in the review that explain the problem and how to overcome it, fish resource management has a chance of success if it is good in its management.

Keywords: fisheries resources, management, inland waters, sustainability

*e-mail: agussrgplg@yahoo.com

Introduction

Inland fisheries have an important role, satisfying the nutritional needs of the community, providing food security for communities, increasing the native income of the local government, serving as a habitat for aquatic organisms, and maintaining the balance of the environment [1, 2]. When compared to Southeast Asian countries, Indonesia has the widest inland waters [1, 3, 4].

Indonesia's Inland Waters (3.85 million ha) consist of rivers and floodplains (12 million ha), lakes (1.8 million) and reservoirs (0.05 million ha). Indonesia's inland waters are 65% on Kalimantan Island, 23 % on Sumatra Island, 7.8 % on Papua Island, 3.5% on Sulawesi Island, and 0.7 % on Java Island, Bali Island, and Nusa Tenggara Island [5, 6]. It has a high fish diversity, inhabited by more than 1000 fish species [7]. Even according to FAO, Indonesia's Inland Waters contain approximately 2000 fish species. It is estimated that there are still many species of fish that have not been recorded [8].

Inland waters have the characteristics of open access by their users. Inland waters users include agriculture, plantations, transportation, fisheries, industry, and others. The activities of users in inland waters have an impact on the quality and quantity of waters [9, 10]. Based on information on Indonesian fisheries statistics, there are indications of a decline in fish catch production in Indonesia's inland waters. Some fish species even became extinct due to damage to the aquatic environment and over-exploitation [2, 11, 12]. Building dams and reservoirs has an impact on disrupting the migration patterns of fish that could result in the extinction of some species of fish [13-16]. Reclamation of inland water land for oil palm plantations also often occurs, which results in a reduction in the area of inland fishery. Pollution of industrial waste and household waste into rivers also often occurs, which results in the death of fish [17].

The disadvantage to managing inland waters is that many problems in inland waters have not been revealed and are not well documented. A lot of information or references that are still spatial and separate have not been compiled properly. For this reason, it is necessary to collect references for review, so that the problems and challenges of fish resource management in Inland Waters can be studied to provide solutions. Based on the findings in the review, we can explain the problem of fish resources in inland waters and provide solutions to improve it. The hope in the future is that the health condition of fish resources will be better and more sustainable. Fish resource management has a chance of success if it is efficient in its management.

Fisheries resources in inland waters need to be managed properly so that they can be utilized sustainably, but the efforts that are being made to manage capture fisheries in Indonesia's inland waters are still lacking, what is done is generally only in the form of stocking fish in reservoirs and lakes [1, 18]. Studies in manuscripts are the result of reviews in various scientific information (journals, proceedings, books, and others). From the summary of scientific information related to fisheries in inland waters we will be able to provide recommendations for fisheries resources management in inland waters, which are based on scientific studies.

General Description of Inland Water Fisheries, Problems in Indonesia

There are many problems in inland waters that impact fish resources; these include sedimentation, pollution, fish habitat destruction, and land use change. Sedimentation in inland waters has occurred in many places, in general due to overexploitation of the forest, as there are no riverside plants. The impact of sedimentation is the siltation of reservoirs, lakes, rivers to become shallow and the loss of "lubuk" (the deepest part of the river) and "lebung" (small lakes in floodplain area) [8, 9, 19].

Sedimentation

1) Main findings of the present study. An example of a case of sedimentation in "Gajah Mungkur Reservoir", Centre Java; The average depth in 1982 was 9 m and the average volume of the water was 630,000,000 m^3, in 2011 the depth decreased to 6.07 m and the average water volume decreased to 428,912,270 m^3, every year there is a reduction in the average water volume of 6,934,059 m^3 $year^{-1}$ and average depth reduction of 10.1 cm $year^{-1}$ [20]. Another reservoir with high sedimentation is the Kotopanjang Reservoir in Riau Province, which is 104 ton ha^{-1} $year^{-1}$, and average depth reduction of 52.6 cm $year^{-1}$. Sedimentation rate can be caused by landslides, due to the lack of vegetation on the banks of reservoirs [21]. The reason is that the land on the banks of reservoirs is often used for agriculture, so that the soil when it rains is easily eroded by water and sediment enters the reservoir [20]. Poor ecosystem management in Riau Province has resulted in the scarcity of several fish species, such as the Clown Featherback, Wallago, and Asian Arowana. In addition, the forest around the reservoir has suffered a lot of damage, resulting in soil erosion and sediment entering the reservoir. Reducing the volume and depth of water will result in a decrease in the carrying capacity of reservoirs for fisheries [22, 23].

Sedimentation also occurs in floodplain areas, which causes floodplain areas to be very dry, especially during the dry season. Sedimentation will close the "lebung" (swamp trough, small lakes in floodplain area), so that the floodplain area does not have "lebung". During the dry season, the "lebung" has an important role as a place for water reserves. If there is no "lebung", then during the dry season the floodplain area will experience drought. During the dry season, "lebungs" have an important role for fish places in floodplain areas. If there

are no "lebung" many fish die during the dry season because the waters in the floodplain are in drought. Some native fish species that will be in danger of disappearing if the floodplain becomes dry and there are no "lebung" include Gabus/Snake head (*Channa strata*), Sepat/Snakeskin gourami (*Trichogaster pectoralis*), Tembakang/Kissing gourami (*Helostoma temmenckii*), Betok/ Climbing perch (*Anabas testudineus*) [9, 24, 25].

Floodplain ecosystem has very large water fluctuations between the rainy and dry seasons, which is 3-4 m. During the rainy season, the water overflows and floods, while in the dry season floodplain land is dry. The peak of the rainy season is January to March, and the peak of the dry season is July to October (Fig. 1). Sedimentation also threatens the preservation of fish resources in rivers, rivers become shallow and "Lubuk" (river trough, the deepest part of the river) will be covered by sediment. "Lubuk" has an important role for the preservation of fish in rivers, especially large fish species tend to be in "lubuk" during the dry season. Some native fish species that will be in danger of disappearing if the floodplain becomes dry and there are no "Lubuk" include Patin Lubuk/Shark catfishes (*Pangasius djambal*), Tapa/Sheatfishes (*Wallago leerii*), Dalum/Goonch (*Bagarius yarelli*), Sengarat/ Sheatfishes (*Belodonticthys dinema*) [26, 27].

2) Comparison with other studies; Poor ecosystem management in Riau Province has resulted in the scarcity of several fish species such as the Clown Featherback, Wallago, and Asian Arowana [22]. Sedimentation that enters the river will cause siltation so that it can result in the loss of the "river hole" (the deepest part of the river). If a lot of damage will occur to vegetation around reservoirs/lakes due to soil erosion, the sediment will enter the reservoir/lake and result in silting [19]. Inland water management with an ecosystem function approach is very important. Land use change in land water will cause a decrease in water volume and depth, resulting in a decrease in the carrying capacity of reservoirs for fisheries [28, 22]. Reduced fish in reservoirs are often caused by sedimentation. The reservoir will become shallow and turbid, so the fish lack water and breathing is disturbed due to the large amount of sediment [29].

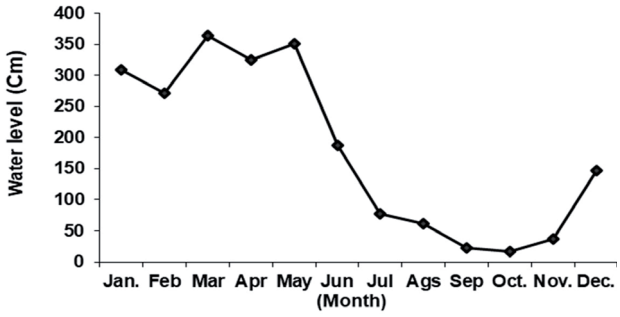

Fig. 1. Water Level Fluctuation in Floodplain, South Sumatera Indonesia.

Pollution

1) Main findings of the present study; The problem fish farming reservoir for example Cirata Reservoir floating net cages reach 25000 plots, it is already more than six times it carrying capacity of only 4000 plots [30]. Another example, floating cages in "Kedung Ombo Reservoir" there are 3100 plots that have exceeded the carrying capacity of its waters which is 1050 plots only [31]. If a lot of organic matter from the floating net cage settles at the bottom of the reservoir, it will bring danger at some point. If at night it rains, the surface temperature is cooler and the specific gravity of the water is greater, the surface water will drop to the bottom and the bottom water will rise (*upwelling*), so that the organic matter at the bottom of the reservoir will be lifted upwards which causes the fish in the floating cage to die [32]. The two Reservoirs "Kedung Ombo" and Cirata, there are often many fish deaths on floating cages, especially in the beginning rainy season [31, 33].

Pollution also often occurs in river waters by industrial waste and household waste. For example: in the middle stream of Solo River between Solo city to Sragen city already heavily polluted by organic matter; and Sailfin Catfish (*Pterygoplichthys pardalis*) has dominated the river. The organic matter content in the waters will reduce the oxygen content causing low oxygen content in the waters. The oxygen content in Solo River is very low, especially during the dry season, which is between 0.65 mg L^{-1} to 3.4 mg L^{-1} (Tabel 1) [33]. During the dry season dissolved oxygen content is worse because the water volume is smaller, so that the concentration of pollutants in the water will be higher.

In the villages of Cemeng, Tenggak and Sragen Regency, the middle stream of Solo River has experienced serious pollution 3-4 times a month and many fish die. At the time of the incident, the water smelled bad and there was a mass death of fish (local term "Pladu"). In the Village of Bison, Karanganyar Regency, the oxygen content in Solo River is very low, 0.65 mg L^{-1} in dry season and 2,43 mg L^{-1} in rainy season (Table 1). In Bison Village, there is an alcohol factory that releases its waste into the Solo River, the alcohol waste can cause a decreasing oxygen content in Solo River, low levels of oxygen in the waters are the main cause of fishes death. In addition, organic matter pollution also causes a high increase in NH_3 and CO_2 content which are toxic gases for fish, as well as low water transparency which can cause respiratory problems for fish [34].

Sailfin Catfish is widely found in the middle stream of Solo River (City of Solo, Karanganyar, Sragen) because there is a polluted area, this fish is resistant to living in waters polluted with organic matter [35]. In polluted waters such as the Solo River, generally the abundance of phytoplankton is quite high. In the middle stream of the Solo River (Karanganyar districts) during the dry season phytoplankton abundance

Table 1. Water Quality in Solo River, Indonesia.

Parameters	Upstream	Middle stream			Lower stream	
	Sukoharjo	Solo	Karanganyar	Sragen	Ngawi	Bojonegoro
During the Rainy Season						
O_2 (mg L^{-1})	5.68	5	2.43	3.74	5.67	7.78
CO_2 (mg L^{-1})	0.06	0.5	2.64	2.5	0.8	0.52
NH_3 (mg L^{-1})	0.07	0.825	1.31	0.15	0.0	0.018
Transparency (Cm)	40	20	20	25	50	50
During the Dry Season						
O_2 (mg L^{-1})	6.75	3.44	0.65	0.98	4.5	5.63
NH_3	1,319	7,38	9,87	5,58	0,422	0,841
CO_2 (mg L^{-1})	0,05	8.8	10.56	7.7	5.5	5.26
Transparency (Cm)	45	20	10	40	50	50

Table.2. Phytoplankton in Solo River, Indonesia (Cells L^{-1}).

Phytoplankton	Station:					
	I	II	III	IV	V	VI
In Rainy Season						
1. Bacillariophyceae	60	38	142	100	72	66
2. Chlorophyceae	82	90	118	148	94	76
Total	142	128	260	248	166	142
In the Dry Season						
1.Bacilariophyceae	40	86	82	188	190	164
2.Chlorophyceae	158	208	986	356	240	580
3. Cyanophyceae	0	190	412	300	86	166
TOTAL	198	484	1480	844	516	910

Note: I = Sukoharjo districts; II = Solo city; III = Karanganyar districts; IV = Sragen districts; V = Ngawi districts; VI = Bojonegoro districts

is 1480 cells L^{-1} (Table 2). In the dry season Karanganyar Districts, the abundance of blue green algae (*Cyanophyceae*) reaches 412 cells L^{-1} (Table 2) [33].

2) Comparison with other studies; Pollution generally caused by industrial and domestic waste. Pollution of organic matter in reservoirs is often caused by fish farming in floating cages [29]. The number of inhabitants around rivers often causes increased pollution in the waters and can threaten aquatic organisms, especially fish [36]. The number of industries in the middle stream of Solo River also causes poor water quality [37]. Many industries/factories dispose of waste directly into waters without proper management, even the waste contains chemicals that can endanger the lives of aquatic organisms and humans [38, 18], even the Solo River has been polluted by Cd (Cadmium) and Cr (Chromium) [39].

In the Bakramat area there is an alcohol factory that dumps its waste into the Solo River, which has caused low oxygen in the Solo River, as well as high ammonia and carbon dioxide content. This often leads to the death of fish [34, 40]. If the water body has been polluted by organic matter then there will be a lot of "Sailfin Catfish", it is an indication that the waters are already polluted [41, 42]. Pollution causes waters to become potentially eutrophic, which can cause algae blooming and can grow blue green algae (*Cyanophyceae*) that are not liked by fish. Even some types of blue green algae such as *Mycrocystis* are toxic algae, and can be harmful to fish and humans [43].

Coastal communities in Bombana district, Southeast Sulawesi Province, Indonesia are affected by water consumption because they use tidal water and surface water is scarce. Complex waterways and littoral

problems inhibit sustainable development. Innovative water resource management, cross-sector collaboration, and the prioritization of marginalized individuals can enhance resilience, sustainability, and the future. Coastal habitats, biodiversity, and future water supplies can be preserved through pollution control, water conservation, and community involvement [44].

Pollution also occurs in other countries, namely in Soc Trang is a coastal delta province located in the southeast of the Mekong Delta. Surface water quality in the study area has been contaminated with organic matter, nutrients, microorganisms, salinity, and iron. During the dry season, the quality of water is worse than in the rainy season. The distribution of high-risk pollutants is concentrated in residential and coastal areas [45]. The study was conducted in the An Giang province, where rivers directly receive water from the Mekong River. The results show that the findings revealed that surface water quality in the study area was polluted by organic matter, total suspended solids, and coliform. This problem was observed worse in the rainy season. It was found that the density of planktonic communities in the dry season was greater than in the rainy season, which was associated with the seasonal enrichment of nutrients [46].

Habitat Damage to Spawning, Nursery and Feeding Ground for Fish

1) Main findings of the present study; Some types of fish-specific habitats in inland waters include swamp forests, which act as a place for feeding ground, spawning ground, and nursery ground [47]. The bottom of the river acts as a refuge for large fish, especially during the dry season, river stone acts as a spawning ground and shade for fry of Semah/Mahseer [48]. Some types of fish-specific habitats in inland waters include swamp forests because they act as feeding grounds, spawning grounds, and nursery grounds for fish [47]. "Lubuk" (the deepest part of the river) acts as a refuge for large fish especially during the dry season, river stones act as spawning grounds and nursery ground for Semah/Mahseer (*Tor. Douronensis*) [49].

Belida fish when spawning will stick eggs in swamp forest vegetation, besides that swamp vegetation also acts as a nursery ground for fry of Belida [47]. One of the important fish species in the upper rivers is the Semah/Mahseer (*Tor douronensis*), the fish lives in waters with strong currents, and many river rocks. Stones in the river have a role as a spawning ground, as a feeding ground because there are many periphytons and water insects in between the stones, as a nursery ground for Semah fish fry [48, 50]. The existence of stones in the river is often exploited for the needs of building houses, so it is threatened with extinction.

2) Comparison with other studies; Damage to specific habitats such as spawning grounds, feeding grounds, nursery grounds is a serious problem for the preservation of fish resources. The causes of damage to fish habitat are often caused by land reclamation, silting, pollution, logging, taking river stones in the river [51]. For example, the reclamation of a million hectares of land in central Kalimantan has led to a very serious decline in inland water fish populations, the loss of habitat important to fish. Several fish species that will be endangered if the swamp forest is damaged, including Belida/Giant featherback fish (*Chitala lopis*), Babat/ Finescale tigerfish (*Datniodes, spp*). That fish urgently needs swamp forests for spawning ground, feeding ground and nursery ground. Swamp forests have many aquatic insects as feed for these fish, besides that there are many periphytons as natural feed for young fish [52].

River Dam Construction

1) Main findings of the present study; Perjaya dam construction has facilitated a fishway for the movement of fish through the dam, but instead it is exploited by the local community - when the fish pass through the fishway, they are caught with various kinds of fishing gear (Fig. 2) [13]. This is due to the lack of awareness of the local community, or the lack of guidance by the government. Preferably, for the management of fish resources to succeed well, the management must involve the local community.

Some species of fish that are endangered when the river is dammed without a fishway such as "Catfish" (*Pangasius djambal*), Sidat/Eel (*Anguila spp*) and giant prawns (*Macrobrachium rosenbergii*) [9, 49]. Giant prawns when they are about to hatch eggs migrate downstream looking for brackish water, when they are adults, they migrate upstream looking for fresh water. Catfish (*Pangasius*) that mature during drought live in deep waters, while during the rainy season migrate against the current upstream, looking for colder waters for mating/spawning. Eel (*Anguila* spp) when adults are in freshwater rivers, when mating/spawning migrates to the deep sea. Based on the biological character of these fish, the smooth migration path for mating/spawning is very important for the preservation of fish resources [49, 50].

Fig. 2. Fishing on a fishway in Komering River South Sumatera.

2) Comparison with other studies; River dams will turn flowing waters into stagnant waters, resulting in a reduction in migratory fish populations [53, 54]. Most river dams in Indonesia haven't fish ways; only Perjaya dam in Komering River South of Sumatra, and Poso dam in the middle of Sulawesi have fishways [55]. No natural resource management works well without involving local communities. Local communities have the potential to be used as government partners in natural resource management (Co-management). Management of migratory fish in the fishway must also involve local communities [56, 57]. Eel fish (Anguila) is a fish species that migrates far when adults are in freshwater rivers, when spawning migrate to the deep sea, then the fry will return to the river [58], for that fishway on river dams is very necessary for the preservation of Eel fish.

Fishing Activities

1) Main findings of the present study; Some fishing gear that is not selective to the size of fish are hampang (*Barrier with traps chamber*), selambau (*Fyke net*), mangumpe (*Seine with fish aggregating device*), and beje (*Seine with pond traps*). These fishing gear endanger the sustainability of fishery resources, especially for large fish species, such as Baung/Asian redtail catfish (*Hemibagrus nemurus*) and haruan /Snake head (*Channa strata*), others. These fishing gear can catch fish that are young and have not had time to reproduce [59, 60].

One of the fishing gears that can catch fish in large quantities is a Tuguk (*filtering device*). The operational method of the tuguk fishing gear (*filtering device*) is to be installed transversely cross the across the river (Fig. 3). Principle the operation of tuguk fishing gear is to block fish migration and the mesh size in the bag is very small, which is 0.75 cm, so that the fishing gear can endanger the preservation of fish resources [24]. Fish species that are threatened with sustainability due to tuguk fishing gear are migratory fish species, including giant prawns (*Macrobrachium*), Patin/Pangas Catfish (*Pangasius*), Lais/Blue sheatfish (*Kryptopterus*) and others. In addition, tuguk often endangers traffic in rivers. For this reason, it is necessary to arrange tuguk fishing gear in the river so as not to cut the river completely.

Ngesar (*active seine with traps chamber*) is also a fishing gear that can catch fish in large quantities, operated on the river. The principle of catching with "ngesar" is to dribble/sweep the fish with seine to enter the trap chamber, after which the fish is taken by a scoop net. Fishing by dribbling/sweeping such fish is repeated up to 2-3 times and done during the dry season [61]. It is necessary to regulate fishing in large quantities by dribbling/sweeping fish during the dry season in river waters, to maintain the preservation of fish in the river. Likewise, "Ngesek" (active barrier with traps chamber) is a fishing gear that can catch large amounts of fish (Fig. 3).

In reservoir/lake waters, gillnets are often operated at river inlets that enter reservoirs, with the aim of blocking the migration of fish that will carry out mating/spawning at the inlet. Some types of fish during the rainy season migrate to the inlet to spawn, for example Patin/ Striped catfish (*Pangasianodon hypophthalmus*) in the "Gajah Mungkur" Reservoir [62]. Fishing activities in Inlet Reservoirs/Lakes must be arranged so that no fishing gear closes/crosses the migration of fish for mating/spawning. Fishing gear with stroom and poison is also still commonly found in inland waters, although this method has been banned by the government; This is due to the difficulty of surveillance in remote areas; besides that, there is also

Fig. 3. Some of the large fishing gear in floodplain Sumatra and Kalimantan, Indonesia.

a lack of awareness by the community. For this reason, co-management-based natural resource management is needed [62].

2) Comparison with other studies; Different types of fishing gear have been operated in Indonesia's inland waters, especially in floodplains; these include small fishing gears, e.g. Pancing (hook and line), Jala (*cast net*), Bubu (*pot traps*), others; as well as large fishing gear that captures large quantities of fish, e.g. Hampang (*barrier with trap chamber)*, Tuguk (*filtering device*), Kilung (*Fyke net*), Ngesar (active seine), others. The big fishing gear " Ngesek" (*active barrier with traps chamber*) is operated in swamps during the dry season, when swamps experience drought so that fish are easily caught. The principle of catching fish by " Ngesek" (*active barrier with trap chamber*) is to dribble/sweep fish with bamboo barrier to enter the fish chamber [60]. Stocking Patin/striped catfish (*Pangasianodon hypophthalmus*) in Gajah Mungkur Reservoir has been successful. However, many gillnet fishing gear is operated at the reservoir inlet, while the inlet is where Patin/Striped catfish to spawn [57]. During the rainy season, the fish migrate to the inlet of the reservoir to spawn. For this reason, local people's awareness is needed not to catch fish that migrate to the reservoir inlet [63].

Decline in Fish Populations

The implication of sedimentation, pollution, habitat destruction, and overfishing is a decline in fish populations. Overfishing has been observed in many places, for example in the Kapuas River, Barito, Musi, Bengawan Solo. As a result, there has been a decline in fish populations and some fish species are endangered [41, 48, 61]. In Indonesia's inland waters, there are 10 important freshwater fish species that are now rarely found and there are 12 species of fish that are now populations are greatly declining (Table 3). The decrease in fish potential is caused by

Table 3. The present status of important freshwater fish species that need attention in Indonesia's inland waters.

No	Local /Common Name	Scientific Name
Rarely found		
1	Tangkleso/ Asian bonytongue	*Scleropages formosus*
2	Kapas-kapas/ Minnows	*Rochteichthys micropeltis*
3	Ikan Elang/ Finescale tigerfish	*Datniodes quadrifsciatus*
4	Timah-timah/ sheatfish	*Phalacronotus apogon*
5	Mok-mok/ sheatfish	*Ceratoglanis scleronema*
6	Sengarat/ Tabirin	*Belodonticthys dinema*
7	Temparang/ Long pectoral-fin minnow	*Macrochirichthys macrochirus*
8	Puntung Hanyut/ Bala shark	*Balantiocheilos melanopterus*
9	Lumajang/ Carps	*Cyclocheilichthys enoplos*
10	Dalum/ Goonch	*Bagarius yarelli*
Extremely decreasing		
1	Patin/ Shark catfishes	Pangasius spp
2	Tapa/ Borneon petomonni	*Wallago leerii*
3	Belida/Giant featherback fish	*Chitala lopis*
4	Semah/ Mahseer	*Tor douronensis*
5	Betutu/ Marble goby	*Oxyeleotris marmorata*
6	Sidat/ Eel	*Anguilla spp*
7	Tebengalan/ Minnows	*Puntioplites bulu*
8	Jelawat/ Mad barb	*Leptobarbus hoeveni*
9	Tilan/ Zig-zag eel	*Mastocembelus armatus*
10	Botia/ Clown loach	*Botia macracanthus*
11	Kalui/ Giant gourami	*Osphronemus goramy*
12	Toman/ Giant snakehead	*Channa mricroleptes*

the increase in fishing efforts, and also fishermen still use dangerous fishing gear such as stroom (electrical fishing) and poison. Likewise, environmental damage and pollution are the causes of the decline in fish populations [8, 12].

Future Strategies: Efforts to Solve Problems in Inland Fisheries

Efforts to Tackle Sedimentation

1) Main findings of the present study; Sedimentation in inland waters is generally caused by land erosion around the waters that enter the waters. For this reason, it is necessary to reforest critical lands, especially on barren hills and on the edge of water bodies. Land use in green belts in reservoirs/lakes for agriculture also causes sedimentation; therefore, it is necessary that green belts on the banks of reservoirs/lakes should not be for agriculture and settlements, must have a good master plan for land use, and sediment dredging should be carried out regularly. To reduce sediment coming from the river, it is necessary to install sediment traps at the reservoir inlet, so that sediment does not enter the reservoir. Check dams made at the inlet of "Gajah Mungkur reservoir" can function as sediment traps that can reduce sedimentation by 3.11x 106 m3 yea^{r-1} [20].

2) Comparison with other studies; To reduce silting, sediment dredging is required on the bottom of the water regularly every year using dredges or excavators. For reservoirs/lakes that have a lot of mud at the bottom, it is necessary to pump the sediment removed from the reservoir/lake [64, 65].

Efforts to Tackle Pollution

1) Main findings of the present study; Fish farming in floating cages often releases organic waste and pollutes the waters, causing eutrophication. Therefore, in the development of fish farming in lakes/reservoirs should calculate the amount of feed given must be in accordance with the needs of fish and should not be excessive, the phosphorus content in the feed should not be more than 1%, and the number of fish cultivated must be in accordance with the carrying capacity. Water pollution can also come from industry, to deal with pollution from industry, waste before being discharged into water must be treated first [31, 33].

2) Comparison with other studies; If water bodies in inland waters (reservoirs, lakes, rivers) have been exposed to serious pollution, then some alternatives that should be taken to rehabilitate them are [66, 67].

a) Fertilizer Control

The source of occurrence of the cause of pollution should be reduced, even if it may have to be stopped for a while [68]. Stopping the source of pollution can improve the quality of the waters, as was done by stopping the operation of the existing soda plant around Lake Onondaga, New York. As long as the soda plant is still operating the total content of phosphorus, chlorophyll, TSS in the Lake is 1 mg/l, 50 μg L^{-1}, and 22 g m^{-2}, respectively. After the Soda Plant was closed, four years later the total content of phosphorus, chlorophyll, and TSS dropped to 0.25 mg L^{-1}, 10 μg L^{-1}, and 3g m^{-2} respectively [69].

The purpose of water circulation is to rotate water, especially those in the lower layers (*hypholimnion*) can be lifted upwards to get oxygen supply. Aeration can add oxygen in waters so that organic pollutants can oxidize faster. Waterwheels for water circulation are placed in several locations and prioritized in the *hypholimnion* layer [70].

b) Cleaning of dirt at the bottom of the water

Done by sucking up water that is based on the waters, the purpose of the call at the bottom of the water (*hypholimnion zone*) are: 1). Removes organic matter (feed residues that settle to the bottom) and gases (H_2S, CO_2 and others), that are present at the bottom of reservoir/lake. 2). Reducing the water present in the base layer, which is poor in oxygen; so that the upper layer (epilimnion), which is rich in oxygen will descend to the bottom of the waters [71].

c) Dilution

Reservoirs/lakes/rivers that are already in hypertrophic condition (very high fertility) can be overcome by dilution, namely flowing river water into the polluted reservoirs/lakes/rivers. For example, Lake Moses in Columbia which is already in a very high fertility condition with a total phosphorus content of 152 μg /l, chlorophyll 71 μg /l, brightness 1 meter after being drained of water from the river the phosphorus content decreases to 18 μg L^{-1} and chlorophyll to 11 μg L^{-1}, brightness rises to 2.1 meters [72].

Efforts to Overcome Habitat Damage

1) Main findings of the present study; Damage to specific habitats such as spawning grounds, feeding grounds, nursery grounds is a serious problem for the preservation of fish resources. Some fish species such as Belida/Giant featherback (*Chitala lopis*), Babat/ Finescale tigerfish (*Datniodes, spp*), others are in dire need of swamp forests for spawning ground, feeding ground and nursery ground. Thus, it is necessary to preserve the vegetation of swamp forests and replant in swampy areas where swamp vegetation is already damaged [27]. Important types of swamp forest vegetation are: Putat (*Barringtonia acutangula*), mentangis (*Ixora mentangis*), menyawai (*Elaeocarpus submonoceras*), melayak (*Croton californicus*). The tree is not high (2-6 m) when the water is large (flooded) the tree will sink to the leaves, so it is a good fish habitat. If the swamp vegetation has been damaged, then to restore the fish population, of course, it is necessary to plant the swamp vegetation [47].

Semah/Mahseer (*Tor douronensis*) lives in waters with a strong current, and a lot of river rocks. River

stone has a role as a spawning ground, feeding ground and nursery ground. For the preservation of Semah/ Mahseer, it is necessary to preserve river stones so that they are not overexploited which results in the destruction of fish habitat in the upper reaches of the river [27].

2) Comparison with other studies; Vegetation in swamp forests plays a role for fish, namely for nursery ground, feeding ground and spawning ground. For this reason, it is necessary to preserve the swamp forest ecosystem, if there is damage to the ecosystem, it is necessary to replant [73]. The tributary that enters the reservoir is an important ecosystem for fisheries, because it is a spawning ground for fish from reservoirs. Vegetation on the banks of the river is a feeding ground, nursery ground and spawning ground for several species of freshwater fish (Striped catfish, Minnows, barb). Likewise, river rocks also have a role as a seedbed, feeding ground and spawning ground, especially for Semah fish (Tor douronensis). River holes also have a role for the residence of large fish, especially during drought [54].

Efforts to Overcome River Dam Problems

1) Main findings of the present study; The construction of the dam will lead to the cutting of the fish migration path, especially in the case of highly migratory fish species such as Patin/Shark catfish (*Pangasius djambal*), and giant prawns (*Machrobrachium rosenbergii*) [49]. The main purpose of fish migration is for spawning; the dam construction will interfere with fish passage, causing the life cycle of fish to be disrupted; If this happens, migratory fish could become extinct. Unfortunately, only two dams in Indonesia have a fishway installed (Komering River Dam in South Sumatra and Poso in Central Sulawesi). Actions to overcome the migration problem, dams in rivers must be equipped with fish ways so that fish can migrate.

The Fish Way in Komering River is very important for the migration of fish passing through the dam, but due to lack of understanding by the community, so fish way was instead used as a fishing location (Fig. 3) [13].

2) Comparison with other studies; The construction of dams will interfere with the migration of fish. An example of a fish that migrates long distances for spawning from the river to the sea is the Eel (Anguilla), a river dam causing the life cycle of the fish to be interrupted. So that dams that do not have a fishway, will cause some species of fish that migrate far will be extinct [74, 75]. Preferably, for fish resource management to succeed well, management must involve local communities [76].

Efforts to Overcome Overfishing

1) Main findings of the present study; Tuguk (*Filtering device*) is a fishing gear that is not environmentally friendly because the operation of the "tuguk" fishing gear will be installed transversely across the river. The principle of operation of tuguk fishing gear is to block the migration of fish that will spawn/mate, so that the fishing gear can thwart mating/spawning that endangers the preservation of fish resources. Thus, it is necessary to arrange a "tuguk" operated on the river, so it does not cross/cut the river completely, perhaps it should only close less than half the width of the river, so that there are still fish that escape from the "Tuguk" [8].

Ngesar (active seine with traps chamber) is a fishing gear on the river that can catch fish in large quantities, operated very intensively during dry season. To reduce the pressure of fishing in the river, it is necessary to make rules to establish protected parts of rivers, especially those with a "lubuk" (the deep part of the river). Ngesek (active barrier with traps chamber) is a fishing gear on the swamp/floodplain area that can catch fish in large quantities, operated very intensively during the dry season. To reduce the pressure of fishing in the swamp/floodplain during dry season, it is necessary to make rules to establish protected parts of swamp/floodplain, especially those with a "lebung" (small lake in the swamp/floodplain) [77].

2) Comparison with other studies; Lift-net is a non-selective fishing gear in East Java and Central Java, and the number continues to increase in almost all reservoirs; For this reason, the number of fishing gear must be limited. So, regulations are needed to limit fishing activities in reservoirs/lakes, especially during the spawning season, namely in the rainy season (November-January), it is even necessary to introduce a closed season or protected areas at the inlet of reservoirs/lakes. Management of fishing in inland waters must involve local communities as users [56, 57].

Efforts to Overcome Decline in Fish Populations

1) Main findings of the present study Aside from regulating fishing, conservation and rehabilitation as well as stocking must be carried out continuously. Restocking fish from hatcheries (aquaculture-based fisheries, or CBF) is one approach to increasing the yield of capture fisheries; CBF should be implemented in Indonesia using local species [13]. Natural or man-made lakes are good bodies of water for restocking because reservoirs/lakes have clear boundaries that make it easier to manage [26]. In the stocking of fish should be convinced in advance that there is a compatibility between the fish and its aquatic environment, there is a spawning habitat, there is enough natural food available, there are fishing rules, if necessary a conservation area is created [59, 27]

2) Comparison with other studies; To restore fish populations, it is necessary to restock native fish, obtained from hatcheries. Reservoirs need to be stocked with fish because these waters are artificial waters, if not stocked fish then the fish population will not be much.

In stocking fish must be adjusted between the species of fish to be stocked and the aquatic environment, and the number of fish stocked must be in accordance with the carrying capacity of the waters [4, 6].

The Strengths on Management Success Chances

Although the management of fishery resources in inland waters has many problems and limitations that have been mentioned in the previous chapter, but if managed well, the sustainability of inland fisheries resources has a chance of success because:

1. The boundaries of water bodies (lakes/reservoirs/rivers) are clear, allowing them to be easily managed and controlled.
2. In general, local fishermen have formed groups, so it will be easier to foster and cooperate with the government (co-management).
3. Reservoirs/lakes have a complete habitat: a). The Inlet, usually as a habitat for spawning fish., b). The Bays and banks of reservoirs / lakes, usually many aquatic plants become seedbeds and feeding grounds for fish larvae / fry., c). The deep part (river hole/trough), as a place for big fish.
4. Stocking activities in reservoirs/lakes have a great chance of success because the ecosystem is closed, the boundaries of the waters are clear, the volume of water is available throughout the year, natural foods such as plankton and periphyton are available, the community around the reservoir/lake can be involved in its management.
5. Fishermen organizations that have been formed can help to manage and supervise.

Conclusions and Recommendations

Conclusions

The main problems and solutions of fishery resource management in inland waters are (1). Sedimentation: it is necessary to reforest critical lands. (2). Pollution: it is necessary to implement fertilizer control, cleaning of dirt at the bottom of the water, dilution. (3). Habitat destruction; it is needed to protect the area of spawning ground, feeding ground and nursery ground. (4). River dam problems: for this reason, dams in rivers must be equipped with fish ways so that fish can migrate; (5). Overfishing: for this reason, the number of big fishing gear must be limited (Filtering device, active seine with traps chamber, active barrier with traps chamber). (6). All such problems lead to a decrease in the fish population. For this reason, fish stocking must be done continuously. Hope in the future if fisheries in inland waters are managed properly, then the sustainability of inland fisheries resources has a chance of success because: The boundaries of water bodies (lakes/reservoirs/rivers) are clear, allowing them to be easily managed and controlled; Inland waters have a complete ecosystem that can support an increase in fish populations, fish stocking into inland waters has a good chance of success; Fishermen organizations that have been formed can help to manage and supervise.

Recommendations

Future Strategy so that fishery resources in inland waters can be better, and sustainable:

a) Reforestation of crucial land on slopes is necessary to prevent sedimentation. The reservoir/green belt's boundary should be free of settlements and agriculture, there must be good planning for land use, and sediment should be dredged regularly.

b) To tackle pollution from fish farming activities in inland waters, Fish farming in reservoirs/lakes must not pollute the waters, and the amount must match the carrying capacity. To deal with pollution from industry, waste before being discharged into water must be treated first.

c) To overcome overexploitation, the number and types of big fishing gear such as *liftnets, filtering device, active seine, active barrier* must be reduced, and the mesh size must not exceed 2 cm. Fishing using poisons, chemicals, electricity must be monitored and punished.

d) Dams in rivers must be equipped with fish ways so that fish can migrate.

Acknowledgments

The author would like to thank: Research Institute for Inland Fisheries and Fisheries Extension Palembang as the funder in this research; research team colleagues, also the fishers as enumerators who collaborated in collecting research data.

Conflicts of interest

Authors declare no conflict of interest.

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