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Genetic resources preservation and utilization of Indonesian native freshwater fish consumption

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ABSTRACT

As a megadiverse country, Indonesia should be able to take advantage of its biodiversity richness optimally for national purposes. This paper discussed current issues of freshwater fish genetic resources, regulations, and governance policies, as well as its preservation and utilization programs. The main global issues of extinction of genetic resources due to habitat degradation, over-exploitation, water pollution, invasive species, and climate change have also occurred in Indonesian waters. Indonesia has ratified international agreements relating to biological diversity, biosafety, access and benefit-sharing of genetic resources, Specific regulation on conservation of fish genetic resources has appeared in the conservation of its ecosystems, species, and populations. The Indonesian Ministry of National Development Planning (IMNDP) has drawn up a strategic action plan on biological resources management. At the central level, in addition to the Ministry of Environment and Forestry (MEF), the Ministry of Marine Affairs and Fisheries (MMAF) is determined as management authority, and the Indonesian Academy of Sciences (IAS) is appointed as scientific authority. Local government consisting of provincial and district/city governments can manage water areas be managed of water areas in their jurisdiction based on assessment and approval of MMAF. Aquatic habitat conservation of the freshwater ecosystem needs to be improved to support the domestication program and cultivation of endemic species to ensure the sustainability of fish population. From the study, it can be concluded that management and strategic planning of conservation need to be implemented properly through strengthening legislation, policy development, and its implementations to broader communities, improving synergic coordination among institutions and stakeholders, and training and education of conservation staffs in advanced technology for genetic preservation and utilization.

Key words : *Conservation, Fish genetic resources, Domestication, Freshwater*

Introduction

As a megadiverse country, Indonesia is rich in genetic freshwater fish resources. Its biodiversity represents up to 10% (1258/11952 species) of the total freshwater fish biodiversity of the planet (Fishbase, 2020; Reid *et al.*, 2013). The number of fish resources may increase as more advanced technologies are implemented in species identification such as taxonomic and phylogeny methods based DNA. Moreover, over 19.5% of that fish biodiversity is indigenous to Indonesia (Widjaja *et al.*, 2014). However, freshwater fish biodiversity management in Indonesia has become essential issues as most aquatic freshwater resources are over-exploited, pointed by an increasing number of threatened species. To cope with this problem, conservation programs can be conducted based on three target conservations, in-

cluding species, habitat, and ecoregion (Linke *et al*., 2011). Aquaculture is one of the advanced methods in species conservation to improve fish biodiversity population. For the success of the aquaculture program, a genetic improvement was mainly implemented in accelerating fish breeding and increasing fish production (Gustiano, 2018). The contribution of aquaculture to total fisheries production in Indonesia was around 57.14% (5.4 million tons) in 2018 and it is predicted that the trend will continue to grow considerably (CDI-MMAF, 2018)).

Although Indonesia is one of the fifth largest aquaculture producers in the world, the primary aquaculture production has been dominated by Nile tilapia *Oreochromis niloticus*, African catfish *Clarias batrachus*, Thai striped catfish *Pangasius hypophthalmus*, Carp *Cyprinus carpio*, and Giant gourami *Osphronemus goramy*. In fact, from these five most popular species, it is only giant gourami as a native species. Gustiano *et al.* (2015) reported that 30 freshwater species have been cultured by Indonesian farmers, while there are only 15 species implementing national best aquaculture practices. We are aware that it has not been an optimal result yet for the preservation and utilization of fish genetic resources. Thus, understanding of main issues impacting freshwater food fish, regulations, and governance policies, as well as its preservation and utilization programs, is essential for improving fish genetic resources management for future implementation.

Current issues

International frameworks in Conservation

Conservation refers to the preservation and utilization efforts of biodiversity. Habitat degradation, over-exploitation, water pollution, invasive species, and climate change are the main factors impacting freshwater biodiversity loss (Dudgeon, 2003). The economic value estimation of biodiversity loss is from 10 to 100 fold higher than conservation cost (Baggethun and López, 2010). To involve in genetic resource conservation, Indonesia has ratified the Convention on Biological Diversity (CBD), the Cartagena Protocol on biosafety to the convention on biological diversity, and the Nagoya Protocol on access and benefit-sharing of genetic resources to domestic regulations. These are critical elements for the country involved in global frameworks of sustainable development. Ensuring fair benefit-sharing is an essential effort when genetic resources were transferred to other countries through biopiracy and unsustainable utilizations. In the fisheries sector, since 2010, the government published regulations for a material transfer agreement to protect fish specimens analyzed and developed overseas. It is vital to raise awareness as the technological advance is likely implemented in biopiracy of material genetic transferred by digital sequence information. Thus, early anticipation of this issue needs to be conducted to protect the richness of genetic resources. For instance, the implementation of DNA barcoding is needed to increase the identification of indigenous fish (Jusmaldi *et al.*, 2017). This has been implemented in several economically important freshwater fish including snake head *Channa striata* (Gustiano *et al.*, 2019), Asian redtail catfish *Hemibragus nemurus* (Gustiano *et al*., 2018), striped catfish *Pangasius hypophthalmus* (Gustiano, 2009), and African catfish *Clarias bathracus*.

Decreasing trends of freshwater fish resources

Freshwater habitat is one of the most vulnerable ecosystems that directly compete with human use (Grafton *et al*., 2012). Globally, the trend of freshwater biodiversity decreased significantly by 83% from 1970 to 2014 (Reid *et al*., 2019). The increasing trend of fish biodiversity loss also occurred in most Indonesian freshwaters. Diversity loss of native freshwater species of Ciliwung and Cisadane rivers in West Java province between 1890 and 2010 reach to 92,5% from 187 species to 20 species and 75,6% from 135 species to 39 species, respectively (Hadiaty, 2011). Investigation of fish biodiversity loss in the Djuanda reservoir over 40 years from 1968 to 2007 showed that the number of fish decreased from 31 to 18 species, and the ratio between native to exotic fish changed dramatically from 23:9 to 9:11 (Kartamihardja, 2008). Besides, there were 14 native freshwater species in Sumatera island categorized as threatened species and 7 species of them are endemic to the island (Wargasasmita, 2002). In addition, Muchlisin (2012) identified more than 19 exotic species introduced to Indonesian freshwater. Most of fish are invasive and impact on decreasing native species in natural habitats. The decreasing indigenous fish population can be observed in Indonesian mahseer *Tor soro* (Gustiano *et al.*, 2013), Mahseer Tambra *Tor tambroides*, Feather back *Notopterus* spp., Striped catfish *Pangasius nasutus*,

Mad barb *Leptobarbus hoeveni*, the Marble goby *Oxyeleotris marmorata* and *Dinema catfish Belodontichthys dinema* (Utomo *et al.*, 2008).

The complexity of freshwater resources management

Indonesian inland water area covers around 13.85 million ha, and it has been utilized only 32% for the fisheries sector (Nasution, 2013). Management of inland waters, especially river commonly, is more complicated than marine areas as most river management has multi-sectoral characters involved in many institutions with different roles and targets. The Ministry of Environment and Forestry (MEF) involves in watershed river management, the Ministry of Public Works and Housing operates water resources management and reservoir infrastructure development, the Ministry of Agriculture needs rivers for agricultural irrigation sources, the local government manages the river for fishing and recreation, and there are public companies utilize water resources for electricity and drinking water. Although the Ministry of Marine Affairs and Fisheries (MMAF) has the authority to conserve inland water ecosystems, there is currently no institution conducting primarily rules to protect specific watersheds. However, the MMAF still has continuously conducted research and development in fish conservation, habitat protection and restoration (in-situ conservation) as well as the domestication of endemic species (ex-situ conservation) of inland waters.

Government Efforts for Preservation and Utilization

Regulations for fish genetic resources conservation

Supporting the conservation of fish genetic resources, since 2007, the Indonesian government has issued Government Regulation No.60/2007 concerning fish resources conservation. The regulation includes the conservation of fish resources based on ecosystems, fish species, and genetic. There are four different levels of water conservation based ecosystems, namely national water park, tourism water park, water sanctuary, and fishery sanctuary. Conservation based species is conducted by publishing the national red list of threatened species published by MEF since 1999. Until 2018, there are 21 threatened species protected by the laws and 16 species are freshwater fish namely Maninjau lizard loach (*Homoloptera gymnogaster*), Javanese feather back (*Notopterus notopterus*), Asian arowana (*Scleropages formosus* and *Scleropages jardinii*), Sentani stingray (*Pritis* spp), Wader goa (*Puntius microps*), Balashark (*Balantiocheilos melanopterus*), Batak fish (*Neolissochilus thienemanni*), Pasa fish (*Schismatorhynchus heterorhynchus*), Marbled whipray (*Himantura oxyrhyncha*), Giant freshwater stingray (*Himantura polylepis*), White-edge freshwater whipray (*Himantura signifier*), Indonesian featherback (*Chitala borneensis*), Giant featherback (*Chitala lopis* and *Chitala hypselonotus*), and Longtail shad (*Tenualosa macruca*).

Conservation based fish genetic was carried out by the implementation of procedures regarding the limited utilization of fish genetic resources relied on quotas, license, distribution, monitoring, and evaluation. The government also supported the International Union for Conservation of Nature (IUCN) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in the protection of vulnerable endemic freshwater fish.

The regulation for the prevention of invasive species distribution was also published to protect native species. There are 145 invasive species that have not been allowed introduced to the country. Similarly, the government also regulated the new aquaculture species, which will be introduced to Indonesia. The new species must be registered, approved, and regularly monitored and evaluated by MMAF. Fish restocking program was also regulated to improve native species populations in natural habitats.

The Governance of fish conservation

The Indonesian Ministry of National Development Planning (IMNDP) has figured out a strategic action plan on biological resources management. In the aquatic conservation field, the implementation is carried out by MMAF and MEF that performed as management authorities, while the Indonesian Academic of Sciences (IAS) is appointed as scientific authority (Figure 1). MMAF operates through the Directorate General of Marine Spaces Management, which is responsible for administration, legislation, law enforcement, and license. This was supported by the Agency for Marine and Fisheries Research and Human Resources, the Directorate General of Aquaculture, and the Directorate General of Capture Fisheries involved in the utilization of fish resources for national fisheries production. MMAF

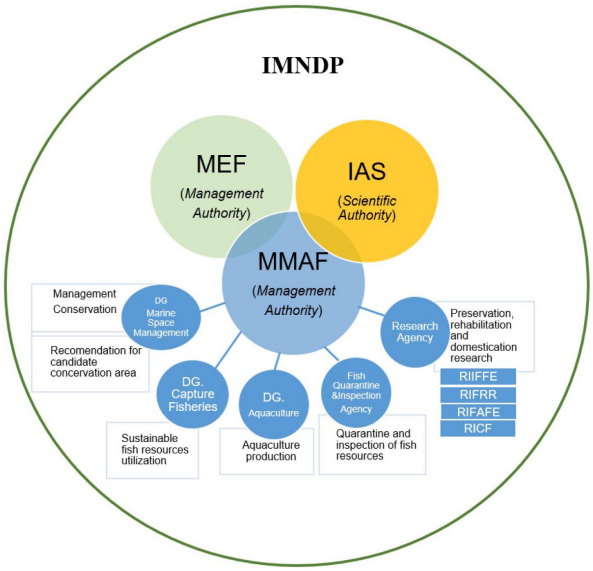
also investigates live fish and fishery product distribution for both export and import through the Fish Quarantine and Inspection Agency. IAS as the scientific authority, is responsible for providing scientific information recommended to the management authority regarding the exploration of fish genetic richness. Scientific recommendations for exploring fish genetic resources can also involve universities.

Local government, including provincial, district, and the city can manage conservation areas under their authorities after MMAF conducted assessment and approval processes. The provincial government is responsible for managing water areas for 12 miles measured from the coastline towards offshore or archipelagic waters and areas within the regency or city authority. Meanwhile, regency or city government is responsible for managing 1/3 area of provincial authority, including brackishwater and freshwater within their jurisdictions.

Preservation and Utilization Programs

Aquatic habitat conservation (*in-situ* conservation)

Aquatic habitat conservation, one of the in-situ conservation programs, refers to a range of actions to protect the threatened animal population in its natural habitat and ensure ecosystem sustainability (FAO, 2013). There are 131 water conservation areas covered 15.76 million ha over the country distributed in various government levels, including MEF with 32 areas, MMAF with 10 areas, and the remaining under local governments about 89 areas (Dermawan, 2014). However, most of the conservation areas are marine and coastal ecosystems, while inland waters such as lake and river ecosystems have been protected less than 10%.



Note: DG=Directorate General, RIIFFE=Research Institute for Inland Fisheries and Fisheries Extension, RIFRR = Research Institute for Fish Resources Rehabilitation, RIFAFE=Research Institute for Freshwater Aquaculture and Fisheries Extension, RICF=Research Institute for Capture Fisheries

Fig. 1. Conservation governance for fish resource management in Indonesia waters.

Implementation of conservation programs for freshwater ecosystems can vary in different regions. In Sumatera island, fisheries sanctuaries were established for a long time and regulated local-based tradition. Most area commonly has not been supported by legal instruments as a fundamental requirement of conservation. However, some local governments have started to implement formal procedures to determine conservation candidates in some areas (Amri *et al.*, 2017). Research in Sundaland waters including Sumatra, Borneo, Java, and Bali shows that the best conservation program for lake and reservoir ecosystems is habitat rehabilitation, while rivers, wetlands, and estuaries ecosystems are fishery sanctuary (Prianto *et al.*, 2015). Adrianto (2015) suggested that the integration of fish resource management and the socio-economic welfare of the community is an essential strategy for the success of the fisheries conservation programs in Indonesia. A successful program for freshwater conservation-based economic approach has been reported by Riepe *et al.* (2019) in four European countries including Norway, Sweden, Germany, and France. The program improved native fish population, water quality for domestic purpose, accessibility of the river, and electricity resource that provide excellent benefits on the community.

Fish domestication program (Ex-situ conservation)

Ex-situ conservation refers to the maintenance and cultivation of live animal populations outside its natural habitat (FAO, 2013). Ex-situ conservation includes domestication and cultivation programs of wild species. Domestication is a range of actions conducted by humans to adapting wild animals to gradually live and breed outside natural habitat under controlled conditions (Saraiva *et al.*, 2018). This mainly involves adjusting fish to the new environmental conditions, giving respond to artificial feed, capable of growing and sexually mature for producing traits. Domesticated fish can also express

Table 1. The progress of domestication and cultivation of Indonesian native freshwater fish consumption officially domesticated and released by MMAF

		
Pangas catfish *Pangasius djambal* Released 2000	Indonesian Mahseer *Tor Soro* Released 2011	Climbing Perch *Anabas testudineus* Released 2014
		
Snakehead *Channa striata* Released 2015	Kelabau fish *Osteochilus melanopleurus* Released 2016	Giant Gourami *Osphronemus gourami* Released 2018
		
Kissing gourami *Helostoma temminckii* Released 2018	Silver barb *Barbonymus gonionotus* Domesticated process	Asian Redtail catfish *Hemibagrus nemurus* Domesticated process
		
Mad barb *Leptobarbus hoevenii* Domesticated process	Snakeskin gourami *Trichopodus pectoralis* Domesticated process	Javanese barb *Barbonymus balleroides* Domesticated process
		
Tinfoil barb *Barbonymus schwanefeldii* Domesticated process	Bonylip barb *Osteochilus vittatus* Domesticated process	Giant freshwater prawn *Macrobrachium rosenbergii* Released 2001
		
	Freshwater crayfish Cherax *albertisii* Released 2001	

additional attributes desired by fish farmers, such as excellent growth (Lorenzen *et al.,* 2012). Thus, the breeders need to understand biological and genetic performance, disease, and socio-economic aspects of the domesticated species (Fabrice, 2018). Consideration of selected fish species for domestication can be conducted through focus group discussions (Gustiano, 2007; Sukadi *et al.*, 2007). This program is vital for the development of aquaculture based native species integrated with tradition and local wisdom to support food security and poverty alleviation in a rural community (Gustiano and Sugama, 2005). Fish farmers have domesticated a small number of native freshwater fish consumption such as Silver barb (*Barbonymus gonionotus*), bonylip (*Osteochilus vittatus*), giant gouramy (*Osphronemus gouramy*), and kissing gouramy (*Helostoma temminckii*) (MMAF, 2015), but the productivity is still low performance. On the other hand, the MMAF has succeeded in releasing and promoting domesticated native fish species for aquaculture development (Table 1).

Conclusion and Recommendations

Indonesia still has performed a luxury fish genetic resources that need to be maintained and utilized for economic welfare and national development, but it also faces significant pressures on fish genetic resources and its habitat. Thus,management and strategic planning of conservation need to be properly implemented to improve its utilization and to reduce losses of fish biodiversity as valued assets of the country. Here we provide recommendations to cope with the issues:

1. Preservation of fish genetic resources trough aquaculture development based freshwater fish endemic needs strategic policies for its implementation. The government must strengthen legislation and policy development with publishing Genetic Resources Act based international framework formally ratified as the primary regulation. Although Indonesia has ratified international agreements on genetic resource biodiversity conservations,the derived legislations implemented are sectoral based institutions that have various roles and targets.
2. Synergic coordination among institutions and stakeholders who are responsible for managing genetic resources and habitat preservation and utilization need to be improved from national policy, scientific approach, and its implementation to optimize the effectiveness of existing regulations.
3. The importance of preservation of genetic resources also should be promoted to the local communities to involve and to get benefits from its utilization.
4. Training and education in advanced technology for genetic preservation and biopiracy investigation need to be conducted to improve the capability and competency of technical and managerial staff.
5. The success domestication of freshwater fish endemic (ex-situ conservation) needs to be supported by the preservation of endemic and threatened fish species in the inland water habitat (in-situ conservation).
6. The breeding process and restocking of endemic fish species in the natural habitat should be monitored to ensure the sustainability of the species.

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