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Research Article

Optimizing the Utilization of Genetic Resources of Indonesian Native Freshwater Fish

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ABSTRACT

Indonesia has a long story in the documentation of the richness of fish genetic resources. Identifying and documenting the diversity of fish species showing the country has around 1700 species. However, Fishbase records only 1258 species (10% contribution to the world) indicating around unrecorded 442 species (26%) in the site. Significant pressures on fish genetic resources and its habitat, small new species documentation/loss of existing species, a decreasing percentage of species at the global level, and un-optimal utilization seems to be essential issues. To deal with these issues, the re-inventory of Indonesia's freshwater fish genetic resources needs to be conducted with concern on unrecorded data in FishBase and threatened species. The government needs to increase awareness on establishing fisheries status through the implementation of the Ecosystem Approach to Fisheries Management (EAFM) for better fisheries management programs. Improvement of preservation and utilization programs for potential native fish species is also essential to provide alternatives species for aquaculture development and its conservation and the last is habitat rehabilitation through nature reserves empowers rules and strengthens regulation. To achieve action plan targets, cross-sectoral coordination is needed in which institutions involved in policy authority, scientific authority, and management authority must synchronize their programs and actions.

Key words: conservation, inland fisheries, fish biodiversity, native species

INTRODUCTION

Documentation of the richness of Indonesian fish genetic resources is 4,970 species, this number represents 15% of the rich diversity of fish in the world (Reid *et al*., 2013; Reis *et al*., 2016). Referring to FAO data (2003) there has been an increase of 300 fish species in Indonesia. However, the total number of fish species in the world increased by more than 11,000 species. This resulted in a reduction in the percentage of Indonesian fish genetic resources from 25% in 2003 to 15% in 2016. From the percentage above, some 1258 species are 10% of freshwater fish species in the world, 11,952 species (Reid *et al*., 2013; Froese and Pauly 2020). Moreover, Dudgeon (2000), estimated 1,700 species of Indonesian freshwater fish. Regarding the number of endemic species, it is about 19.5% of species belong to Indonesia (Widjaja *et al.*, 2014). Among the big Indonesian islands, Sulawesi is the highest endemic species about 76% of the total species on each island (Kottelat *et al*., 1993). The addition of relatively small new species documentation or loss of existing species, as well as a decrease in the percentage of species at the global level, seems to be a big question.

The development of molecular technology in the world is so rapid and has contributed greatly to increasing the number of new species identified as reported recently by Bachry *et al*. (2019). Systematic or evolutionary genetic studies that include taxonomy and phylogeny have a large impact on the documentation of genetic resources. The implementation of DNA barcoding for rapid and accurate taxonomic identification is also urgently needed for the improvement of fish diversity programs (Hubert, *et al*., 2015). It seems that this has not been widely applied in Indonesia, which still relies on the conventional identification of taxonomic-based species.

With a considerable amount of genetic resources, Indonesia has huge potential and challenges to utilize its biodiversity resources to meet human food needs in providing a source of protein, improving welfare, and contributing to national development (Rintelen *et al*., 2017). The Indonesian government has made a guidebook on the Indonesian Biodiversity Strategic Plan (IBSAP) to increase the contribution of genetic resources as assets or natural capital in national development (Bappenas 2003; 2015). In terms of fish genetic resources utilization, the Ministry of Marine Affairs and Fisheries of Indonesia has regulated the sustainable exploitation of fish resources in inland waters and domesticated native freshwater fish species for aquaculture and conservation (Kurniawan *et al*., 2021). However, the significant pressures on fish genetic resources and their habitat due to over-exploited, water pollution, land conversion, degradation, and climate change have treated freshwater ecosystems (Giam *et al*., 2012; Arthington *et al.*, 2016). Thus, it urgently needs proper strategic programs and planning to reduce fish biodiversity

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losses and to improve the utilization of freshwater genetic resources. This paper discusses state of art of freshwater fish genetic resources, action plans, and efforts to optimize the utilization of Indonesian native freshwater fish genetic resources.

MATERIALS AND METHODS

The manuscript was prepared based on the desk study. Data and information used in this review were collected from Indonesian statistics of marine and fisheries, Fishbase, Scimago journal, and country rank, and based on available publications regarding the past and recent information of Indonesian freshwater genetic resources development in the country. The data then were descriptively explored to synthesize the state of art in documenting freshwater fish biodiversity, alternative action plans, as well as strategies recommended for improvement of Indonesian fish biodiversity management.

RESULTS AND DISCUSSION

State of art of freshwater fish genetic resources

Many freshwater fishes are economically important species for aquaculture and fisheries. However, intensive exploitation and habitats destruction causing endangered species. In addition to the potential and challenges above, evolutionary systematic or genetic problems related to taxonomy and phylogeny are very urgent to understand the existing and extinct fish resources, and their current IUCN status and to implement CITES.

In the past, the focus of activities was concentrated on identifying and documenting the diversity of fish species in Indonesia. The fishes of Indo-Australian archipelago II, Malacopterygii, Myctophoidea, Ostariophysi: I. Siluroidea is the first book about the richness of fish genetic resources in Indonesia (Weber and de Beaufort, 1913). In 1953, a book was made about the local common name of Indonesian fish (Schuster and Djajadiredja, 1953). This book was very useful at that time to avoid naming the same fish as different names. Saanin (1968) made a book on taxonomy and the key to identifying fish in Indonesia. Freshwater fish from Papua were reported by Allen (1991) about 329 species and Ohee (2017) recorded around 400 species. The investigation conducted by Kottelat *et al*. (1993) found that 1,278 species are recorded from Western Indonesia and Sulawesi and the data then were updated to 1300 in 1996 (Kottelat and Whitten, 1996). Thus, there are around 1700 species in total.

At present, a re-inventory of Indonesia's freshwater fish genetic resources is being carried out concerning the validity of the correct scientific name and the position of the appropriate group (Haryono and Tjakrawidjaja 2004; Sudarto and Poyaud, 2005; Wowor and Ng, 2007; Rachmatika, 2010; Haryono, 2011; Jusmaldi, 2017; Renny, 2018; Gustiano, 2018a; 2018b; 2019a; 2019b; Herawati *et al*., 2019).

Many sectors involve in managing inland water with various roles and targets. According to Nasution (2013) is about 32% of 13.85 million ha has been utilized for fisheries. Regarding fish genetic resources from inland water, the species loss in West Java occurred in the Ciliwung River from 187 to 20 species, in the Cisadane River from 135 species to 39 species (Hadiaty, 2011), and in the Citarum river from 36 to 26 species (Kartamihardja, 2019).

In the Djuanda Reservoir, the diversity of freshwater fish also decreased from 31 to 18 species from 1968 to 2008 (Kartamihardja, 2008). The data Djuanda Reservoir is also followed by a change in the ratio between native and introduced fish from 23: 9 to 9:11. Wargasasmita (2002) reported that the status of genetic resources of freshwater fish in Sumatra, 14 native species and 7 of them are endemic in a threatening condition. Froese and Pauly (2020) reported 231 threatened species from Indonesia. Meanwhile, 19 introduced species are dominated by invasive species (Muchlisin, 2012). Haryono and Wahyudewantoro (2020) reported that 13 introduced species were in Galunggung areas.

Based on the production data of freshwater fish catches recorded at 487,621 tonnes representing 38 species of fish (Figure 1). If examined closely, the amount is likely not right because the grouping of species above is mostly based on groups not by species. For example, for the Clarias group containing more than ten species, as well as for Pangas catfish, snakehead, Asian redtail catfish, and sheat catfish. Whereas other fish groups have a smaller number of members.

Of the 38 species, there are 29 species that have been utilized with a total production of 307,593 tons representing 7 dominant species eg. Asian redtailed catfish, "bilih" (Mystacoleucus padangensis), snakehead, sheat catfish, tinfoil barb, Pangas catfish, and dwarf gourami (Figure 1). Compare to the total freshwater fish production, the total catches were only 10% of the total freshwater fish production. Meanwhile, aquaculture production was 3.3 m tonnes, 90% of the total production. Five species have a great contribution to aquaculture production, Nile tilapia, African catfish, Pangas catfish, common carp, and giant gourami.

With the availability of abundant fish genetic resources, the low number of species and fish production indicates that the utilization of genetic resources is not optimal yet. At this time, the government is trying to inventory the existing genetic resources of fish, barcoding the genetic resources, develop potential fish species socially, economically and maintain the sustainability of fish genetic resources as assets of national development.

At present, the Convention on Biological Diversity (CBD), the Cartagena Protocol on biological safety for biodiversity conventions, and the Nagoya Protocol on access to and sharing of benefits from genetic resources have been ratified by domestic regulations. It was realized since 30 years ago that natural resources are the capital of future development that can be recovered if it is managed wisely and sustainably. For those purposes, Bappenas (2003, 2015) has published the Indonesian Biodiversity Strategic Plan guidebook. In the future, the action plan will focus on how to increase the contribution of genetic resources to sustainable development goals in terms of food security, human welfare, and national income.

Action plan for improvement of freshwater native fish genetic resources utilization

The first approach can be undertaken for optimizing a variety of fish genetic habitats to improve fisheries production both in the catchment and aquaculture sectors. This action plan is focused on dealing with main issues including re-inventory of Indonesia's freshwater fish

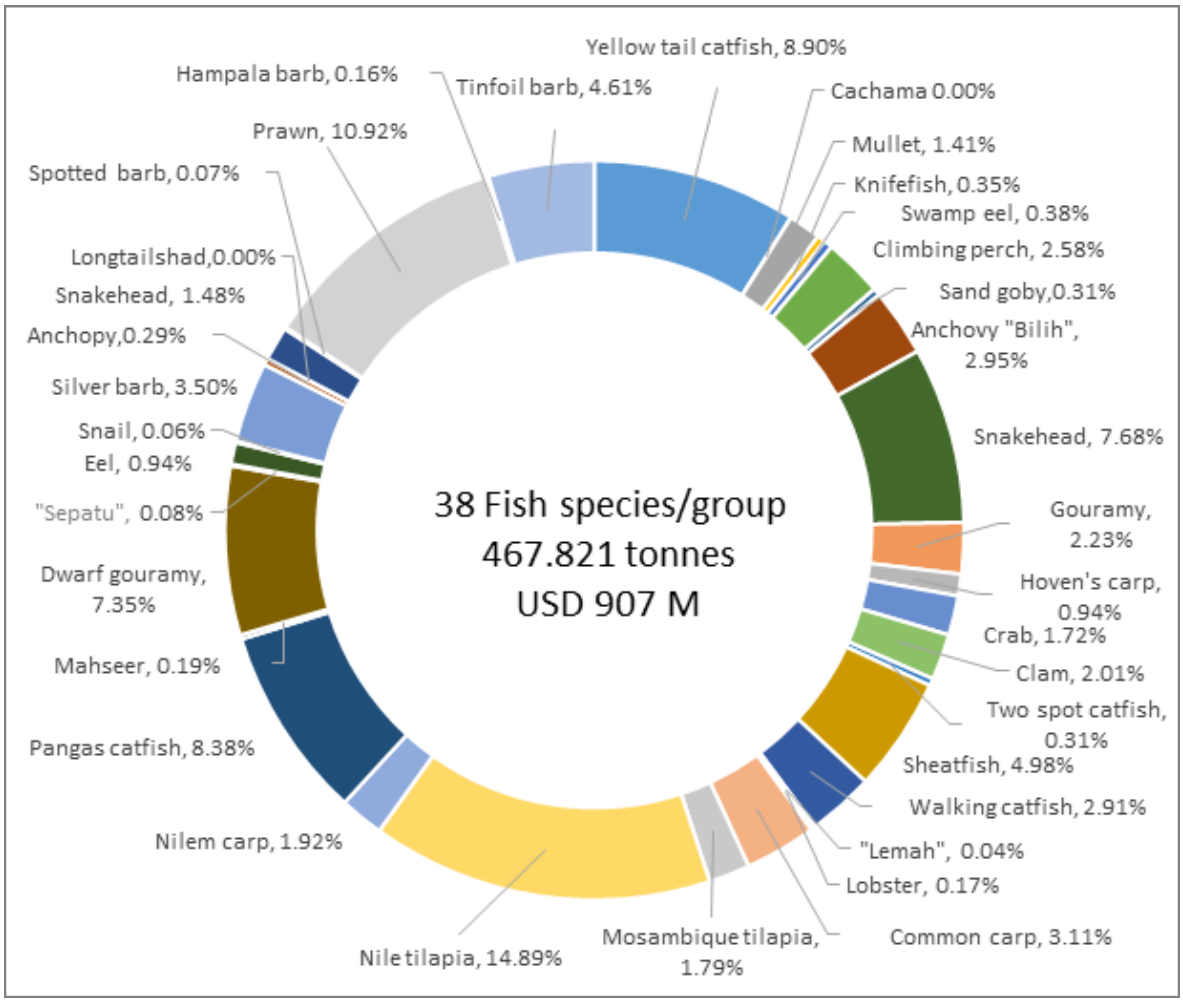

Figure 1. Total capture production of Indonesian freshwater fish in 2017 (Source of data was adapted from The Ministry of Marine Affairs and Fisheries (MMAF) Statistics 2018)

genetic resources, establishing of inland fisheries status, improvement of preservation and utilization programs, and habitat rehabilitation through nature reserves empowers rules and strengthens regulation.

Re-inventory of Indonesia's freshwater fish genetic resources

Information of freshwater fish genetic reported by Kottelat and Whitten (1996) as well as Gleick (2000) has been excellent references which presented Indonesia as the second-largest freshwater fish genetic resource in the globe with 1300 species. This information did not include freshwater fish reported in Papua with 400 species (Ohee, 2017). Thus, in total it would be estimated around 1700 fish species inhabited freshwater habitats in the country (Table 1). However, the present electronic database namely Fishbase records only 1258 species indicating that there are around unrecorded 442 species (26%). This information is likely an essential finding for the scientist involved in the re-inventory freshwater fish genetic research program to focus on the missing species recorded in FishBase in the future. Improvement of systematic reporting and proper documentation of conservation projects is essential for monitoring biodiversity loss and its current status to decrease pressures on species and their natural habitat (Anil *et al*. 2014).

As a case study, excellent improvement in the discovery of new freshwater fish species likely occurred in China and India around 58% and 32.89%, respectively, fish recorded in FishBase is higher than the previous database in two decades (Table 1). Xing *et al*. (2016) reported that freshwater fish in Chinese inland habitat is recorded around 1323 species in 2016, and then it significantly increases to 1601 fish species in 2020 which presents the second largest in the world based FishBase version. The primary fish species inhabiting the freshwater ecosystem of India are about 858 fish from a total of 1027 species (Gopi *et al*., 2017; Das, 2018). Significant improvements of fish genetic diversity in China and India likely correlate with aquatic sciences and conservation-related research output recorded in SCImago country rank which places China and India in 2019 as a second and fourth highest rank in research of these areas, respectively (Table 2). On the other hand, Indonesia was placed in 41 levels of aquatic sciences and conservation-related research output which the position in the list is below Thailand (37) and Malaysia (38). Indonesia fish scientists possibly discover new species of inland water in the country, but most papers likely published in local or national journals indicating that it has been not recorded in international publication. Thus, it is a good challenge for scientists, academics, and other stakeholders to increase awareness in the research and publication of freshwater fish genetic resources and published in international journals.

Table 1. Freshwater fish species richness of Indonesia compared to 10 countries with the most freshwater species richness in the world.

Countries		Number of fish species		Recorded New Species	Percentage
		Kottelat and Whitten (1996)	Fishbase (2020)		
1	Brazil	3000	3467	467	15.57%
2	Indonesia	*1700	1258	-442	-26.00%
3	Venezuela	1250	960	-290	-23.20%
4	China	1010	1601	591	58.51%
5	Congo	**962	1123	161	16.74%
6	Peru	855	902	47	5.50%
7	United States	790	963	173	21.90%
8	India	748	994	246	32.89%
9	Thailand	690	828	138	20.00%
10	Tanzania	800	841	41	5.13%
11	Malaysia	600	622	22	3.67%

*A total of 1700 fish species in Indonesia is a combination of total fish reported by Kottelat and Whitten (1996) in Western Indonesia and Sulawesi (1300 species) and Ohee (2017) reported in Papua (400 species) which is similar to Dudgeon (2000) prediction (1700 species). ** Gleick P. (2000). Recorded new species is predicted based on the subtraction of FishBase to the previous report.

Table 2. Aquatic Sciences and conservation-related research output of Indonesia compared with 10 top ranks of countries with freshwater species richness based on SCImago journal rank (SJR)

No	Countries	Aquatic Science		Conservation	
		Documents (1996-2019)	World's ranking	Documents (1996-2019)	World's ranking
1	United States	125655	1	3312	1
2	China	34584	2	1126	5
3	Brazil	15271	10	184	33
4	India	8968	15	546	11
5	Thailand	2564	37	21	65
6	Malaysia	2402	38	83	44
7	Indonesia	1862	41	43	50
8	Venezuela	963	52	38	54
9	Peru	588	62	40	53
10	Tanzania	444	67	15	72
11	Congo	51	140	1	134

Sort list of the countries follows the aquatic science documents published by The SCImago Journal Rank (SJR) 2020. The SJR indicator is designed to measure the scientific influence of scholarly journals based Scopus database

Establishing of inland fisheries status

The current status of inland fisheries in most Indonesian freshwater areas is categorized as unknown although commercial exploitation has been conducted for a long time. Food and Agriculture Organization (FAO) has recommended the implementation of the Ecosystem Approach to Fisheries Management (EAFM) to assess inland fisheries status. EAFM refers to the implementation of sustainable development principles for fisheries management considering ecological and human wellbeing through good governance (Staples *et al*., 2014). There are six domain indicators used for the implementation of EAFM including fish resources, habitat and ecosystem, fishing method, economic, social, and governance (Hutubessy and Mosse, 2015). Based on the multi-criteria analysis (MCA) approach, the flag model will be visualized to create flag status of fisheries such as red for poor, yellow for moderate, and green for good conditions. The implementation of EAFM mainly was reported in marine fisheries areas since 2012 pointed in the pilot project for sustainable fisheries development including Wakatobi, Aru sea, Arafuru sea, Sawu sea and South Sulawesi regions (Muawanah *et al*., 2018). Thus, the implementation of the EAFM approach in inland water areas needs to be immediately conducted to save freshwater fish from habitat loss and degradation, water pollution, intensive exploitation, and other potential threats to freshwater fishes. Freshwater fish production of inland water currently has not considered applying a sustainable approach before fisheries status of the habitat was well determined by the government. As the status of the fishery is unknown, exploitation of fish resources significantly threat the sustainability of fish genetic resources. Fluet-Chouinard *et al*. (2018) reported that there is an underestimation reporting of 64.8% in wild-caught freshwater fish production than

officially reported as compared with trade and household consumption in the low- and middle-income countries between 1997 and 2014. From this information, the government needs to increase awareness about the importance of fisheries assessment status determination for better fisheries management programs.

Improvement of preservation and utilization programs for potential native fish species for aquaculture and conservation

Assessment for the species selection of aquaculture development was determined mainly based on commercial value and practical feasibility for cultures such as market demand, tolerance to crowding, feeding habits and nutritional requirements, resistance to environmental variations, disease resistance, and captive breeding (Mustafa and Shapawi, 2015). Many fish were introduced from other countries to meet the requirements of the national target aquaculture production. As the result, introduced fish species have presented excellent performances and dominated national aquaculture production such as Nile tilapia *Oreochromis niloticus*, African catfish *Clarias batrachus*, Thai striped catfish *Pangasiusianodon hypotalmus*, and Carp *Cyprinus carpio.* Recently, assessment for potential fish species not only aimed for aquaculture but also for conservation purposes. Thus it needs to consider the development of freshwater native species in the preservation and utilization of existing diversity for various purposes, e.g. food security, industry, and export targets. Enhanced natural reproduction and accelerated production of endangered species through domestication for restocking and production programs (Kurniawan *et al*., 2021). Products released from domestication are expected to increase production with a guarantee of quantity, quality, and timeliness. For the utilization of genetic resources to support food, industry, and export security studies have been carried out through the search for potential candidates for the above purpose. Selected candidates will be collected, characterized, evaluated for their performance, and eligible for breeding through the domestication process.

Currently, there are six species, Silver barb (*Barbonymus gonionotus*), bonylip (*Osteochilus vittatus*), giant gouramy (*Osphronemus gouramy*), kissing gouramy (*Helostoma temmenckii*)**,** and snakehead (*Channa striata*) that have been cultivated by the fish farmers forming the farm conservation (MMAF, 2015; Gustiano *et al*., 2021). While the domesticated fish that have been released by the government are 16 species. One of them is red tail catfish, *Hemibagrus nemurus*, reported by Kusmini *et al* (2019). At an advanced level, if the cultivation technology is optimally used in an optimal production process, then quality improvement will be carried out through selective breeding e.g. outbreeding of tinfoil barb, *Barbonymus schwanenfeldii* (Kusmini *et al*., 2020). The last approach is the promotion of fish domestication result for the development of native species in aquaculture sector and conservation of genetic resources of freshwater native fish.

Habitat rehabilitation through nature reserves empowers rules and strengthens regulation

The loss of fish biodiversity in inland water previously mentioned is related to habitat loss and degradation. Habitat rehabilitation should be carefully assessed to identify positive and negative implications on the sustainability of ecology, economy, and tradition of the impacted people. Thus, as the regulation for habitat restoration was published it would be accepted well by stakeholders. Hannah *et al*., (2019) designed a model of freshwater protected areas (FPAs) as a comprehensive system used in providing water, energy, and fish production that are not only giving benefits for all fishermen and its community but also protecting habitat degradation. To ensure rehabilitation targets are achieved, sufficient monitoring needs to be continuously conducted in the rehabilitation areas before, during, and after the programs to enable an adaptive management approach to future planning and implementation of the programs. Based on Hammer *et al*. (2009), the rehabilitation programs of inland water areas can be implemented to deal with habitat loss and degradation including fish passage at artificial barriers, environmental water provisions for increasing the diversity of habitat types, strategic revegetation for improving riverbank vegetation cover, providing a buffer from terrestrial impacts (catchment areas)for a flow energy balance, instream works for improving habitat availability, the stock exclusion for minimizing trampling of sensitive habitat and improving water quality, and refuge areas for habitat protection and restoration measures. To achieve targets of habitat rehabilitation programs, it needs an excellent synergic to improve nature reserves empowers rules and strengthened regulation among institutions and stakeholders who are responsible for managing river, lakes, and other wetlands areas by improving national policy, scientific approach, and its implementation to optimize the effectiveness of existing regulations.

Challenges, Constraints, and Strategies

Challenges

So far, activities related to the management of fish genetic resources involve many sectors. Therefore cross-sectoral coordination is needed in which institutions involved in policy authority, scientific authority, and management authority must synchronize their programs and actions. In practice, institutions for managing fish genetic resources will intersect with those who manage watersheds and forest areas, users of water bodies such as agriculture, drinking water, and public transportation, as well as the development interests of the area concerned. How to align interests and reduce friction among stakeholders is a major challenge in managing genetic resources supporting sustainable development. Ideally, policy institutions must have a national strategy that can be translated by implementing institutions in terms of scientific, technical, and regional ownership. While from the opposite direction, the area owner together with the implementing agency provides consideration material that is included in the preparation of the national strategy. Two-way communication through the mediation of the implementing agency will provide good national development planning related to fish genetic resources.

At the global level, access and distribution of benefits from genetic resources must be regulated when these materials are transferred to other countries. It is important to increase awareness of the availability of advanced technology to be applied in biopiracy using digital sequence information or de-materials genetic

resources. Therefore, Indonesian fish barcoding activities should be one of the priorities as carried out by Fahmi *et al*. (2020).

Related to global climate change, it must also be anticipated and be a concern for the preservation and utilization of existing fish genetic resources (Gustiano *et al*., 2020; Prakoso *et al*., 2020). From a technical aspect, it is necessary to apply and integrate advanced technology that is more effective and efficient in the preservation of fish genetic resources in Indonesia as mentioned by Lestari *et al*. (2020).

Constrains

Conflict of interest is a major problem impacting the management and utilization of fish genetic resources. Where the short-term economic target orientation is very dominant. To maintain sustainability, it must be emphasized that development orientation must be placed within a long-term development framework. Therefore, all programs and actions of various implementing institutions and regional stakeholders must always be in the national context with a global perspective.

Strategies

Integrated management of fish resources and the socio-economic welfare of the community is a strategic choice to support the success of programs related to the preservation and utilization of freshwater fish genetic resources in Indonesia. The success of the program with an economic approach in the management of freshwater fish genetic resources is expected to maintain native fish populations through suitable habitats, and healthy water quality for household needs, river accessibility, and other uses that provide exceptional benefits to the community.

CONCLUSION AND RECOMMENDATION

Conclusion

Regarding the genetic resources of freshwater species in Indonesia, the documentation has not been well recorded in an adequate database at the global level. Along with re-inventorying existing species, it is necessary to immediately understand the status of inland fisheries from various aspects, for example, ecology, economics, etc. Based on databases and an understanding of status, action plans can be reproduced from national priorities and scientific perspectives. Synchronization and synergy of plans related to fish genetic resources must be monitored at the national level to minimize conflicts of interest among stakeholders. The community approach using socio-economic welfare needs to be considered as an option in participatory programs to achieve this goal. Such a large resource has not been optimally utilized and maintained. In the future, fish genetic resource assets will become one of the national development that can be renewed if managed properly.

Recommendations

Efforts to optimize the use of genetic resources of native freshwater fish in Indonesia are a comprehensive understanding of the existing species richness and challenges, the status of fisheries management, and the design of action plans for further management programs. Here we provide recommendations:

1) Collaborative research at the national and global level for re-inventory species richness needs to be expanded in inland areas especially the areas with lack information or no record of fish richness to acquire accurate information for improving database and to support better conservation management plans and fisheries utilization

2) Implementation of EAFM approach in determining inland fisheries status is urgently conducted to decrease species and habitat loss, external pressures, and difficulties in the establishment of a monitoring system with appropriate indicators after fisheries status published is an essential factor.

3)Determining conservation priority for threatened species and habitat loss essentially within inland fisheries areas

4) Creating synergies among national development policy, fishing activities, and ecosystem approach for sustainability of livelihood and food security among neighboring provinces or regency especially for watershed/ rivers areas

5) More efficient and advanced technology in preservation as applied in other sectors needs to be done e.g. farm conservation, selective breeding, cryopreservation, gen bank collection, etc. The position of farmer and breeder rights must be standardized to share benefits at the practitioner level is regulated by the World Intellectual Property Organization (WIPO).

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