Diversity and conservation status of fish in Batang Bungo River, Bungo Regency, Jambi Province, Indonesia

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Abstract. The Batang Bungo River is one of the largest rivers in Bungo Regency, Jambi Province, Indonesia, with diverse types of fish. The use of fish is a big concern because non-selective exploitation and anthropogenic waste significantly threaten fish diversity in the waters. This study assessed fish diversity and conservation status in the Batang Bungo River. Fish data collected from four observation stations were analyzed using the fish diversity index method, fish conservation status, nonmetric multidimensional scale analysis (nMDS), similarity test (ANOSIM), and Bray-Curtis cluster. A total of 784 fish from 13 families, 23 genera, and 26 species were caught in the Batang Bungo River. Cyprinidae is the family with the highest abundance (76.15%). Shannon diversity test results ranged from 2.85 to 3.45, while the uniformity index varied between 0.68 and 0.83. The dominance index ranges from 0.11 to 0.23. Based on the IUCN category, 84% of the 26 fish species are included in the least concern (LC) category. LC status indicates that most fish species have consumption and ornamental potential. Spatial analysis using nMDS shows differences in fish distribution. The ANOSIM showed a significant difference in fish catch between observation stations (global R = 0.6), with an R-value close to one, indicating considerable inequality. Further analysis using the Bray-Curtis method spatially produced two clusters with a similarity rate of 64%. The status of fish utilization is quite prominent in the Batang Bungo River, and the LC status is precious data for building a local community-based conservation management system.

Key Words: conservation areas, conservation status, fish diversity, fish habitats.

Introduction. Indonesia has sizeable aquatic potential with high fish diversity, both in species and genetic aspects (Gustiano et al 2021; Febrian et al 2022). Human pressure on fish species is increasing and has threatened the existence of populations, whereas each fish population has a vital role in the assessment of aquatic ecosystems (Arthington et al 2016; Liu et al 2018; Larentis et al 2022). Understanding the status of fish diversity and the wide spatial variation of species richness is a significant topic in biogeography and macroecology (He et al 2020; Keil & Chase 2019). Disruption of river aquatic ecosystems due to anthropogenic waste and interrupted fish migration has suppressed freshwater fish diversity (Arthington et al 2016; Reid et al 2019). Recent research has also reported that habitat fragmentation, anthropogenic waste, land use, and climate change have significant impacts on the sustainability of fish resources and diversity (Gustiano et al 2021; Miranda & Miqueleiz 2021; Laske et al 2022).

Fish diversity research is fundamental because it not only knows and understands the status of its population, but also plays a crucial role in efforts to protect resources and ecosystem (Doffou 2019; Maureaud et al 2019). Especially the understanding of fish composition, diversity, structure, and even genetic variation (Protasov et al 2019; Aguirre et al 2021; Petit-Marty et al 2022; Tracy et al 2022). Ennvironmental change such as wetland degradation, habitat fragmentation, water pollution and the overfishing had significant impacts on fish diversity (Aguirre et al 2021; Barbarossa et al 2021; Tracy et al 2022).

Therefore, understanding freshwater ecology is the main focus of freshwater fish conservation (Miranda et al 2022). Previously, many studies have been conducted to assess fish diversity, the condition of aquatic ecosystems, and design ecosystem management regulations (Protasov et al 2019; Alimpic et al 2022; Tracy et al 2022). So, more data must be implemented in natural and effective sustainable conservation activities (Guo et al 2018; Alimpic et al 2022). Understanding fish diversity is crucial for evaluating and assessing fish population (Guo et al 2018; Heilpern et al 2022) for the development of effective and sustainable freshwater fish conservation (Miranda & Miqueleiz 2021; Laske et al 2022).

On the other hand, as an open water ecosystem, the Batang Bungo River is also not spared from various threats of activities such as agricultural waste, gold and sand mining, and overfishing activities, all of which put pressure on the quality of water and diversity of species that inhabit these waters. Aquatic fish diversity is currently shaped by a range of ecological factors, including river flow dynamics, the impact of agricultural waste, siltation in rivers, and the availability and distribution of food within their habitat (Aryani et al 2019; Silva et al 2022). Moreover, the unauthorized extraction of gold and sand has significantly contributed to environmental pollution through the generation of waste materials (Fajri et al 2022). There is a growing dependence of local communities on natural fishing resources to meet their basic needs, which has resulted in the depletion of resources and ecological degradation. All human activities from various perspectives contribute to the continued degradation of habitats, which in turn leads to a decrease in the structure and diversity of fish communities (Amadi et al 2019), and can even decrease fish genetic variation (Mahboob et al 2019; Ray et al 2022).

In the research report of Fajri et al (2022), there were 18 species of fish caught in the Batang Bungo River, consisting of 11 species from the family Cyprinidae, 2 species from the Family Bagridae, 1 species from the Family Channidae, 1 species from the Family Siluridae, 1 species from the Family Pangasidae, 1 species from the Family Cobitidae, and 1 species from the Family Mastacembelidae. According to (Saez-Gomez & Prenda 2022), in recent years, various human activities have caused severe changes in fish distribution and diversity that threaten the conservation status of fish. The development of studies on fish diversity and the conservation status of fish has not reached an adequate level (Miranda et al 2022). Thus far, the assessment of fish diversity in the Batang Bungo River is still limited. Data information on fish diversity and conservation status is vital in supporting the development of conservation strategies to protect certain species (Aryani et al 2019; Miranda et al 2022). Therefore, this study aims to assess fish diversity and conservation status in the Batang Bungo River as a foundation for effective management and conservation strategies.

Material and Method

Study area. The research was conducted in the Batang Bungo River, one of the longest rivers in Bungo Regency, Jambi Province, Indonesia, measuring approximately 50 km long and 65 m wide (Fajri et al 2022). The study began with a survey, and sampling locations were selected using purposive sampling. The research was conducted from April to August 2023, to obtain assistance from local fishermen in accessing fishing grounds and deploying fishing gear. The study sites were located in the utilization conservation area and among the conservation areas in Bedaro village, Baru Pusat Jalo village, and Tebat village (Figure 1).

The first station was situated upstream, within the Bedaro conservation area, followed by the second station located between the Baru Pusat Jalo village conservation area and the Tebat conservation area. The third station was positioned between the Baru Pusat Jalo village conservation area and Tebat village, while the fourth station was downstream, within the Tebat village conservation area. Fish samples were collected using gillnet fishing gear (mesh sizes 1.5 inches and 2 inches) and stocking nets with the assistance of local fishermen, following the method described by Prchalova et al (2009). At each station, eight samples were collected. On-site, the fish were euthanized by inserting a nail or small knife between the eyes and gently moving it back and forth to quickly puncture the brain. After the fish died, each fish sample was labelled, counted, and immediately preserved in a 5% formalin solution for smaller specimens and a 10% formalin solution for larger specimens. The samples were transported in cold boxes (temperature 10°C) to the Ichthyology Laboratory at the Faculty of Fisheries, Muara Bungo University. After 15 days, the fish samples were washed under running water and transferred to a 70% alcohol solution for permanent storage.

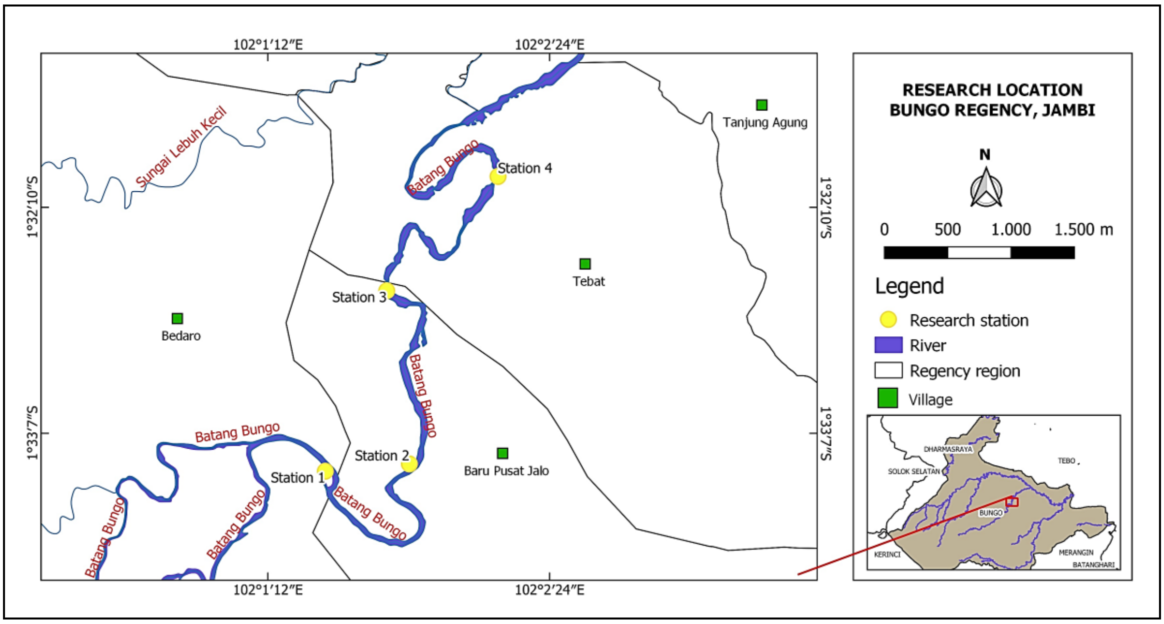

Figure 1. Map of fish sampling in Bungo District, Jambi Province, Indonesia.

Identification and conservation status of fish. Fish collected from four research stations were identified based on morphometric characters and meristic counts using Kottelat et al (1993) and Fishbase confirmed using Froese & Pauly (2023). Fish conservation status was determined using the IUCN Red List of Threatened Species (2023).

Data analysis. The diversity index (H') provides insight into the richness of species within a community, taking into account both the number of species and their respective abundance, measured by the count of individuals for each. The frequently employed diversity index is the Shannon-Wiener index (Krebs 1989):

$$H' = -\sum_{i=1}^{n}(p_i)(\log_2 p_i)$$

where: H' is the Shannon-Wiener diversity index, pi is the proportion of individual found in the i^{th} fish species with the total number of fish relative to the number of individual fish (pi = ni/N).

Uniformity describes how evenly distributed individual fish species are within a community. A more even distribution of individuals of each species within a region indicates a more balanced ecosystem, as there is no tendency for any particular fish species to dominate. The uniformity index (E) of fish can be calculated using the following equation (Odum 1971):

$$E = \frac{H'}{H'max}$$

where: E is the evenness index, H' is the Shannon-Wiener diversity index, H'max is the maximum value of H', calculated as ln(S), where S is the total number of species in the community.

To determine whether or not certain fish species dominate, we used the Simpson dominance index (D) with the following formula (Odum 1993):

$$D = \sum_{i=1}^{S}(pi)^2$$

where: D is Simpson's dominance index, s is the number of fish species, pi is the proportion of individuals of species-i to the total individuals in the community (pi = ni/N with ni being the number of individuals of species i and N being the total individuals of all species).

Fish distribution connectivity and similarity were assessed using nonmetric multidimensional scaling analysis (nMDS) to test the spatial distribution of fish communities. The stress value can assess the quality of the fish distribution configuration: lower values (< 0.25) indicate a better fit, while values > 0.25 suggest that the configuration model should not be used. Species composition similarity was evaluated using analysis of similarity (ANOSIM) with Bray-Curtis distances to examine differences in fish species composition between zones (observation stations). The global R-value indicates the degree of difference between groups: statistically significant values < 5% ($p < 0.05$) indicate a fundamental difference, while values < 1% ($p < 0.01$) indicate a genuine difference. If significant differences are detected, similarity percentage (SIMPER) analysis is used to identify critical species that differentiate between zones (distinguishing species) and to assess the similarity of zones (Clarke & Gorley 2001).

Results and Discussion

***Species composition*, *conservation status of the species*.** A total of 784 fish were caught and classified into 13 families, 23 genera, and 26 species. Of these, 76.15% were Cyprinidae, 8.04% were Danionidae, and 6.63% were Bagridae. These three families dominated the four observation sites, with Cyprinidae accounting for the largest proportion (10 species), the family Danionidae has one species, and the family Bagridae contributes three species. These species showed abundance and dominated with the highest proportion at the observation sites (Table 1).

The Cyprinidae species, particularly *Mystacoleucus marginatus* (22.32%) and *Barbonymus schwanefeldii* (10.97%), were the most abundant fish species caught at the site. *Rasbora sumatrana* (8.04%) from the Danionidae family and *Hemibagrus nemurus* (6.57%) from the Bagridae family were also relatively abundant. The least abundant fish species was *Homalopteroides nebulosus* (0.26%) from the Balitoridae family (Table 1). Previous studies have shown that Cyprinidae is the most dominant fish family in various waters (Hu et al 2019; Yagos et al 2022; Zare-Shahraki et al 2022).

A total of 26 species of fish were identified from four observation stations. This number is higher than the 19 fish species reported from the Sibugay River in Mindanao, Philippines (Yagos et al 2022), but lower than the 44 fish species reported from the upstream and downstream regions of the Koto Panjang Reservoir in Riau Province, Indonesia (Aryani et al 2019) and 37 fish species reported from the Iranian Mountain River Basin (Zare-Shahraki et al 2022). In addition, this number is slightly higher than the 24 fish species recorded in the Batang Hari River, Tebo Regency, Jambi Province, Indonesia (Aga Paramudita et al 2020). The diversity of fish species in a water area is strongly influenced by the water area itself, as well as by local knowledge that plays a vital role in fisheries conservation efforts, fish being a source of protein and food for the population. Therefore, knowledge is needed to maintain fish diversity and improve the management of freshwater ecosystems or certain water areas (Miqueleiz et al 2020; Miranda & Miqueleiz 2021).

The highest diversity of fish species in this aquatic environment is covered by the family Cyprinidae (Figure 2a, b). This is because habitat type is believed to affect fish diversity and species adaptation. In addition, this water area is lubuk (deeper waters) with mossy rocks and vegetation around it. In addition, dense vegetation on the banks of rivers provides shelter and the availability of food sources for fish species. In addition, the Cyprinidae family has many widespread species throughout its distribution area. However, knowledge of potential threats to this population is still limited (Zare-Shahraki et al 2022).

Table 1

Distribution, percentage of abundance (%), fish status (ornamental or consumption), and IUCN status of fish species in Batang Bungo River

Family	*Species*	*St. 1*	*St. 2*	*St. 3*	*St. 4*	*Potential / IUCN status*
		Pa (%), N = 187	*Pa (%), N = 179*	*Pa (%), N = 198*	*Pa (%), N = 220*	
Bagridae	*Hemibagrus nemurus*	1.60	5.59	6.57	2.27	C & Or / LC
	Mystus nigriceps	1.07	1.68	3.03	1.82	C & Or / LC
	Hemibagrus wyckii	0.00	0.56	2.02	0.45	C / LC
Balitoridae	*Homalopteroides nebulosus*	0.00	0.00	1.01	0.00	Or / LC
Butidae	*Oxyeleotris marmorata*	0.53	0.00	1.01	0.45	Or / LC
Channidae	*Channa gachua*	0.00	0.00	0.00	2.27	Or / LC
Cobitidae	*Acantopsis dialuzona*	1.07	1.68	0.00	0.00	Or / LC
Cyprinidae	*Barbichthys laevis*	0.53	0.56	0.00	0.00	C & Or / LC
	Barbonymus schwanefeldii	9.09	8.38	11.62	14.09	C & Or / LC
	Cyclocheilichthys apogon	18.18	5.03	6.57	10.45	C & Or / LC
	Cyclocheilichthys heteronema	8.56	0.00	0.00	4.09	C / LC
	Labiobarbus lineatus	13.37	21.79	11.62	23.18	C & Or / NE
	Mystacoleucus marginatus	12.30	41.34	20.71	16.82	C & Or / LC
	Osteochilus vittatus	14.44	2.79	11.62	5.45	C & Or / LC
	Osteochilus waandersii	3.74	2.79	1.52	0.00	C & Or / LC
	Thynnichthys thynnoides	2.67	1.12	0.00	0.00	C / LC
	Tor tambra	0.53	0.56	0.51	0.00	C & Or / DD
Danionidae	*Rasbora sumatrana*	0.00	0.00	14.65	15.45	C & Or / DD
Mastacembelidae	*Mastacembelus erythrotaenia*	0.53	0.56	0.00	0.91	C & Or / LC
Osphronemidae	*Osphronemus goramy*	0.00	1.68	0.51	0.00	C & Or / LC
	Trichopodus trichopterus	6.95	0.00	0.00	1.36	C & Or / LC
Pangasiidae	*Pangasius polyuranodon*	0.00	1.12	1.52	0.00	C / LC
Pristolepididae	*Pristolepis grootii*	4.28	0.00	0.51	0.00	C & Or / LC
Siluridae	*Kryptopterus cryptopterus*	0.00	0.00	3.54	0.00	C & Or / LC
	Silurichthys phaiosoma	0.00	1.68	1.52	0.91	Or / NT
Xenocyprididae	*Parachela oxygastroides*	0.53	1.12	0.00	0.00	C & Or / LC

Note: Pa = percentage of abundance; C = consumption fish; Or = ornamental fish; NE = not evaluated; DD = data deficient; NT = near threatened; LC = least concern.

Currently, most of the species in the Cyprinidae family are classified as species of least concern (LC) in the aquatic environment of the Batang Bungo River. Two species have data deficient (DD) status, one from Cyprinidae and one from Danionidae. In addition, one species has not evaluated (NE) status from the family Cyprinidae, and one species has near threatened (NT) status from the family Siluridae (Table 1 and Figure 2).

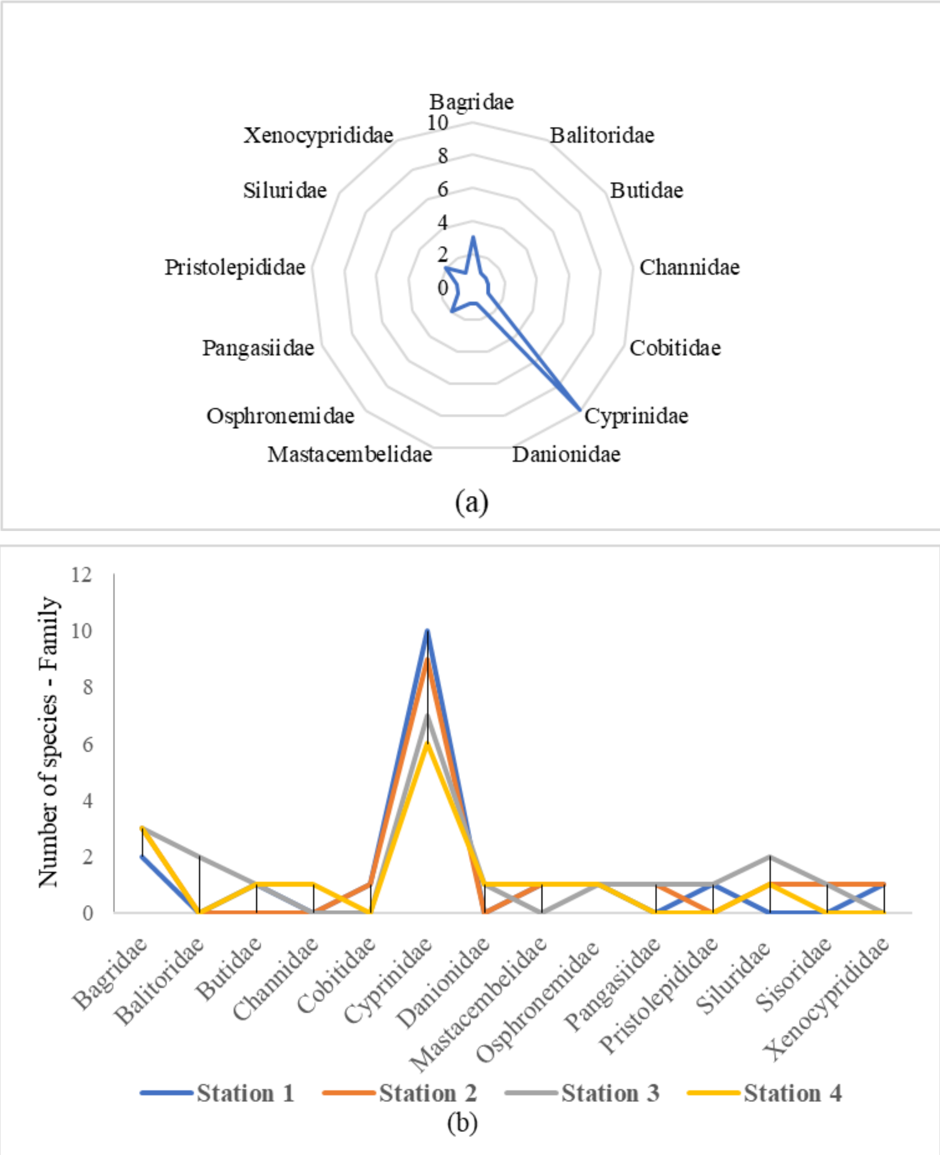

Figure 2. Distribution of fish species by family: (a) distribution of species within a station based on family, with the number of species represented by the distance from the center of the graph; (b) comparison between stations for each fish family.

The continued danger of overexploitation of diverse species in the aquatic environments persists, posing a risk to the dispersion pattern of these species. For example, LC species of the Cyprinidae family (such as *M. marginatus*, *B. schwanefeldii*, *C. apogon*, and *L. lineatus*) and Bagridae (such as *H. nemurus*) are among the most sought-after fish species in the Batang Bungo River due to their large populations. In addition, the ecological condition of waters is influenced by various anthropogenic activities such as agriculture and animal husbandry, and fisheries along the river also accelerate the impact of changes in the aquatic environment (Syafrialdi et al 2020b). Therefore, human intervention in every local aquatic environment in the Batang Bungo River is an essential factor affecting the sustainability and diversity of fish. Data on fish diversity in the Batang Bungo River is essential for describing the composition and distribution of fish species in the area and their conservation status. This is the basis for planned management and research efforts to protect these fish species from various threats in the Batang Bungo River.

Species diversity. The diversity index of fish species exhibited notable variation across four sampling stations, as indicated in Table 2. The analysis results at the four research stations showed that the value of H' was relatively high. The highest fish diversity was found at station 1 (H' = 3.45), while the lowest was at station 2 (H' = 2.82). These findings are in line with research reported by Myers et al (2021) and Pandion et al (2022), showing that the number of individual fish species and populations is positively correlated with fish diversity indices, in line with water physicochemical factors and suitable habitat conditions (Zare-Shahraki et al 2022). Habitat characteristics and the balance of male-to-female ratios in waters influence fish diversity (Syafrialdi et al 2020a, b).

The recorded fish diversity index (H' = 2.82) in station 2 shows a low level of diversity because there are two species of the Cyrinidae family, namely *M. marginatus* and *L. lineatus* which accounted for 41.34% and 21.79% of the total fish at station 2, respectively (Table 1). In addition, various activities, including sand and gold mining, also contribute to the decline in fish diversity in the river. This fact also aligns with research reported by Aryani et al (2019) and Fajri et al (2022). They said that destructive mining and fishing activities caused the decline in the value of fish diversity in the waters. In addition, local communities rely heavily on river catches to meet their needs, which include food needs and the acquisition of ornamental fish. As a result, the fish species that inhabit this river are the main targets of exploitation by local communities

The dominance of fish species at all four study stations ranged from 0.11 to 0.23. Dominance is relatively low, showing that fish distribution in these waters is relatively stable. A high evenness index value (0.83) at station 1 indicates that the ecosystem at that location is stable. The fish species distribute themselves evenly, and the individuals approach a more evenly distributed percentage of their presence.

Conversely, the low evenness index at station 2 (0.68) indicates the functional stability of the community. Certain species' high evenness and minimal dominance characterize a stable aquatic environment (Doffou et al 2019). Dissolved oxygen levels and water acidity (pH) have affected the distribution of fish and their communities (Hu et al 2019). Locally-based conservation approaches will have a lasting impact and can prevent more significant loss of fish diversity due to increased mining activities (Sonter et al 2018).

Table 2

The fish diversity and evenness indices among the sites in the Batang Bungo River

Station	*∑ species*	*∑ individual*	*Shannon-Wiener diversity index (H')*	*Evenness index (E)*	*Simpson's index of diversity (D)*
Station 1	18	187	3.45	0.83	0.11
Station 2	18	179	2.82	0.68	0.23
Station 3	18	198	3.44	0.82	0.12
Station 4	15	220	3.13	0.80	0.14

Potential benefits and conservation status of fish. The distribution and potential utilization of fish species and the conservation status of species in the Batang Bungo River are presented in Table 1. Stations 1, 2 and 3 have 18 fish species each, while station 4 has 15 species (Table 1). The highest number of fish individuals (220) was found at station 4, while the lowest number of individuals (179) was at station 2. Overall, the fish in the Batang Bungo River are native species to Indonesia. These test results may indicate the natural state of the Batang Bungo River’s waters. The assessment has identified the status and potential proportion of fish species collected from the Batang Bungo River.

On average, the Cyprinidae family is the most significant contributor of species for both consumption and ornamental purposes (refer to Table 1 and Figure 3a). Sixty-six percent (17 species) of these fish are utilized for both consumption and ornamental purposes, while 15% (four species) exclusively serve as consumption fish, and 19% (five species) are only used as ornamental fish. These results highlight variations compared to the study reported by Dey et al (2015). The number of ornamental fish species was reported to be higher than that of consumption fish species. However, the total number of individual fish for consumption was higher than that of ornamental fish. Recently, Saez-Gomez & Prenda (2022) and Sarker et al (2022) reported that fish species intended for consumption outnumber ornamental fish species. Alternatively, even when compared, ornamental fish species exhibit a greater diversity than consumption fish species. Most fish species in the Cyprinidae family are either carnivorous or omnivorous, which leads to complex interactions within aquatic ecosystems (Maureaud et al 2019). Furthermore, the dominance of carnivorous and omnivorous feeding behaviors among Cyprinidae species further contributes to intricate ecological interactions in fish diversity (Maureaud et al 2019).

Thus, differences in fish diversity are influenced by population connectivity and distribution. However, the response to increasing fish diversity also depends on the fragmentation of anthropogenic environments, which disrupts population distribution and affects the presence of various fish species in aquatic ecosystems (Brauer & Beheregaray 2020). Consequently, the proportion of fish species inhabiting a given body of water is influenced by the availability of natural food sources, which serves as a reference for the sustainable utilization of these fish in the future.

The distribution and conservation status of various fish species in the Batang Bungo River are presented in Table 1 and Figure 3b. Based on the International Union for Conservation of Nature (IUCN) classification (2023), the 26 fish species identified in the Batang Bungo River fall into four categories: Least Concern (LC), Not Evaluated (NE), Data Deficient (DD), and Near Threatened (NT). Among these species, 84% (22 species) are classified as Least Concern (LC). Data Deficient (DD) species account for 8% (2 species), while both Not Evaluated (NE) and Near Threatened (NT) categories each represent 4% (1 species per category) (Figure 3b).

Most fish species classified under the Least Concern (LC) status have the potential to be utilized as both consumption and ornamental fish. This category includes 10 species from the Cyprinidae family, which predominantly consists of omnivorous and pelagic fish (Hu et al 2019). The Least Concern (LC) fish species found in the Batang Bungo River are detailed in Table 1. These findings are consistent with studies conducted in the Southern Guadalquivir River, Spain (Saez-Gomez & Prenda 2022), as well as in the Djim and Mpem Rivers of central Cameroon (Njom et al 2022), and similar results have been reported from the Brahmaputra and Chindwin Rivers in northeastern India (Vishwanath 2017). However, the Batang Bungo River faces threats from various anthropogenic activities, including gold mining, sand mining, agriculture, and plantations, which pose significant risks to fish diversity. Fish species with low tolerance to environmental disturbances, such as those caused by mining activities, are particularly vulnerable to extinction (Doffou et al 2019). The ongoing decline of freshwater fish species, many of which are becoming increasingly difficult to find, raises concerns about potential extinctions occurring unnoticed.

Over the past few decades, human activities have disrupted fish distribution and threatened the conservation status of various fish species (Brauer & Beheregaray 2020; Saez-Gomez & Prenda 2022). Therefore, maintaining the ecosystem is crucial by implementing regulations on fishing practices and establishing protected areas to support fish diversity in this river. Regular assessments of fish diversity and freshwater conditions are essential for effective conservation efforts.

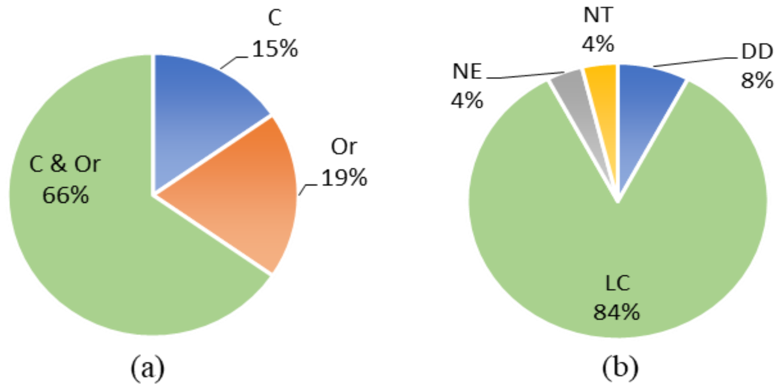

Figure 3. (a) The potential utilization and (b) conservation status (%) of sampled threatened fish species (IUCN Red List criteria, Version 2022-2). Note: C = consumption fish, Or = ornamental fish, NE = not evaluated, DD = data deficient, NT = near threatened, LC = least concern.

Fish distribution connectivity and similarity between observation stations. The nMDS analysis of fish distribution in the Batang Bungo River revealed significant differences among observation stations. Variations in resource utilization within conservation areas produced distinct spatial groupings at each station (Figure 4a). These groupings were shaped by differing levels of human activity, particularly at station 2, which experiences the most substantial impact from anthropogenic activities such as sand mining, gold mining, agriculture, and animal husbandry. Water pollution has emerged as a major threat, negatively affecting fish diversity and conservation efforts in aquatic environments (Ogidi & Akpan 2022). Previous studies have also indicated that the dominance of fish assemblages in a body of water is determined by species capable of efficiently utilizing available energy sources. This is strongly influenced by abiotic factors (Maureaud et al 2019), changes in land use (Aryani et al 2019), and the distribution and productivity of biotic communities in aquatic ecosystems (Liu et al 2018).

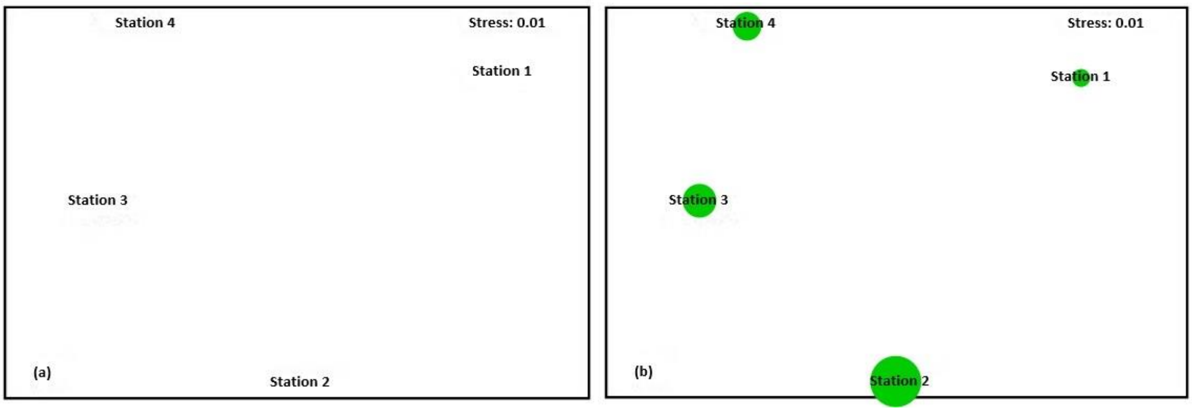

Figure 4. Nonmetric multidimensional scaling (nMDS) configuration for (a) the utilization zones of the Batang Bungo River, and (b) the connectivity distribution of *Mystacoleucus marginatus* across these zones.

The distribution pattern and configuration, as indicated by the consistent high abundance of certain fish species, will be visualized accordingly (Engman et al 2019). Proximity or overlap in the plots suggests the presence of similar community groupings, whereas distant and distinct plot structures indicate different community compositions (Hu et al 2019; Kundu et al 2019). The configuration pattern, supported by an excellent stress value of 0.01, further validates the results of the nMDS analysis. This outcome highlights the utility of the emerging pattern in assessing the accuracy and reliability of the plotted values.

Based on the nMDS pattern, the habitat distribution of fish species with high abundance, such as *M. marginatus*, can be observed (Figure 4b). Spatially, *M. marginatus* exhibits extensive distribution connectivity across utilization zones and prohibition areas within the Batang Bungo River, indicating that this water body serves as its primary habitat. This species prefers flowing waters with high levels of dissolved oxygen. The overall ecological relationships among species demonstrate that fish diversity and assemblage composition are influenced by the sampling methods used to collect data (Deacon et al 2017). The findings of this study clearly show that utilization zones - before, between, and after conservation areas - provide valuable insights into fish diversity, species composition, and variations across research stations.

The ANOSIM statistical test results for the observation station categories, which were divided into three types (utilization zone before the conservation area, utilization zone between the conservation area, and utilization zone after the conservation area), indicated a significant difference in catch composition among observation stations (Global R = 0.6; significance level = 33.3%). This finding is further supported by similarity analysis, which assessed species composition across stations using the Bray-Curtis method. The analysis spatially identified two distinct clusters with a similarity level of 64% (Figure 5). The first cluster comprises station 3 and station 4, exhibiting a similarity of 71%. These stations are located within the utilization zone between the prohibition area and the utilization zone after the prohibition area. The second cluster consists of station 1 and station 2, with a similarity level of 66%. These stations are situated in the utilization zone before the prohibition area and the utilization zone between the prohibition area.

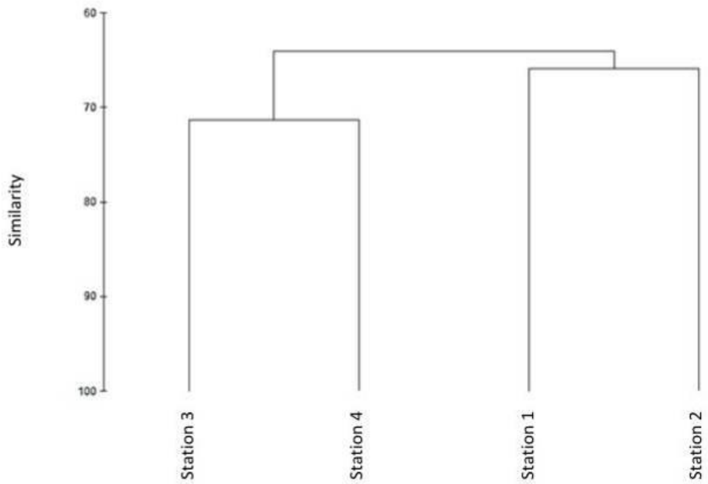

Figure 5. Dendrogram of similarity among observation stations.

The R-value indicates a low level of similarity in fish species composition across observation zone categories. In simpler terms, different fish species dominate each observation station. These variations suggest differences in fishing pressure and the impact of non-selective fishing practices. Overfishing and non-selective fishing methods can lead to habitat degradation and the destruction of fish breeding grounds (Jewel et al 2018). The differences and similarities in fish species composition are also influenced by environmental factors such as water depth, substrate type, and habitat size (Samoilys et al 2022). The results of the ANOSIM statistical test were further supported by the Similarity of Percentage (SIMPER) test, which quantified the degree of variation among the observation zone categories. The analysis revealed a 61.50% similarity in fish species composition across stations, with key species contributing to this similarity, including *M. marginatus* (33.67%), *L. lineatus* (18.89%), *B. schwanefeldii* (13.63%), *H. nemurus* (9.08%), and *C. apogon* (8.18%). The level of dissimilarity between observation station categories varied across zones. Between the utilization zone before the conservation area and the utilization zone among conservation areas, the dissimilarity level was 45.71%. The primary species contributing to this differentiation were *M. marginatus* (20.48%), *C.*

apogon (13.55%), *C. heteronema* (9.36%), *R. sumatrana* (8.01%), and *O. vittatus* (7.91%). Between the utilization zone before the conservation area and the utilization zone after the conservation area, the dissimilarity level was 40.21%. The main species distinguishing these zones included *R. sumatrana* (19.22%), *L. lineatus* (12.20%), *O. vittatus* (11.17%), *C. apogon* (9.61%), and *T. trichopterus* (6.95%). Lastly, the dissimilarity level between the utilization zone among conservation areas and the utilization zone after the conservation area was 33.35%. Key species contributing to this differentiation were *M. marginatus* (21.30%), *R. sumatrana* (12.19%), *L. lineatus* (9.72%), *C. apogon* (6.98%), and *O. vittatus* (6.61%).

Fish utilization in the conservation areas is predominantly characterized by the presence of *M. marginatus*, except in the area before conservation and the utilization zone before the conservation area, where *R. sumatrana* is the dominant species. These variations in fish abundance are influenced by inter-zone interactions and the distinct ecological characteristics of each species. Consequently, pressures from various anthropogenic activities in the aquatic environment remain key factors shaping fish diversity both upstream and downstream (Watson et al 2021). The findings further indicate that stations with lower levels of human activity exhibit relatively higher fish diversity. Additionally, *M. marginatus* is frequently captured using stocking nets or gillnets and holds economic significance as a commercially valuable fish, making it a primary target for local fishermen. Therefore, the development of effective fisheries management strategies is crucial for conserving fish diversity (Jewel et al 2018) and enhancing aquatic conservation efforts (Kundu et al 2020). Furthermore, data on fish diversity serve as a critical foundation for future bioecological studies of this aquatic ecosystem.

Conclusions. Research on fish diversity at four stations in the Batang Bungo River revealed that the diversity index ranged from 2.82 to 3.45. Station 1 exhibited the highest diversity index, with the most significant contribution from species within the family Cyprinidae. The study found that 84% of the recorded fish species were classified as Least Concern in conservation status, 66% were categorized as commercially valuable food fish, and a substantial proportion were identified as ornamental fish. This research provides critical and pioneering data on fish diversity in the Batang Bungo River, serving as a foundational reference for future conservation efforts. Information on fish diversity and conservation status is essential for managing fishing activity zones and promoting the regulation of fishing gear in riverine ecosystems. Effective conservation strategies should involve local communities and government stakeholders to ensure the sustainable utilization of fish resources.

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