Diversity of Introduced Species of Fishes in Penjalin Reservoir Central Java Indonesia

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Abstract. The decreased diversity of fish is partly due to the introduction of fish or foreign species into the waters. The impact of this entry is relatively vast, not only damaging the environment and genetic but also disturbing the indigenous species and spreading disease and parasites to the fish. This study aimed to analyze the fish diversity of introduced species and indigenous species captured in Penjalin Reservoir and the correlation between biodiversity and water quality. The method included a survey with five Stations of sampling. The present study caught 539 fish, consisted of seven families, ten breeds, and 11 species (six introduced and five indigenous). The diversity of introduced species was higher than that of the indigenous. The captured introduced fish were Oreochromis niloticus, Oreochromis sp, Oxyeletris marmorata, Clarias gariepinus, Cyprinus carpio, and Poecilia reticulata. The similarity index of fish diversity was almost equal across Stations. The O. marmorata species had the highest relative abundance and dominated Penjalin Reservoir. The diversity of introduced species was positively correlated with the parameters of depth, pH, and free CO2 in the center of the reservoir, while the Total Suspended Solid (TSS) of the indigenous species was in the inlet of the Garung river. The significance of the present research is to promote the conservation of fish resources and to maintain a balanced ecosystem, especially the existence of introduced species and indigenous species in the waters of Penjalin Reservoir.

1. Introduction
Indonesia is the home for the relatively high fish diversity, around 1300 species. Fish diversity in Indonesia is facing an imminent threat from human activities that potentially decrease fish diversity. The contributing factors to the depleting diversity of freshwater fish include changing habitat, overexploitation, foreign fish introduction, pollution, competition, and infiltration of pests and diseases into the fish[1][2][3].

Fish have been introduced to Indonesia since pre-1900. However, the previous fish introductions were mostly without a deep scientific probe and proven to have caused the loss or decline in the population of indigenous fish species, endemic, or disease carriers [4]. Fish introduction is an act of incorporating new fish species into a body of water where such species are non-existent, either on purpose (intentional introduction) or by chance (unintentional introduction). Fish are introduced to improve fishery production to meet protein demand for the community [5]. Unintentional introductions tend to impose negative impacts on the current ecosystem balance and biodiversity. The negative impacts include the potential harm or even extinction to the indigenous species of fish, especially the endemic fish inhabiting the waters[6].
The introduced species of fish can be found in many waters around the world, both ebbing and flowing waters. From 22 introduced fish species caught in Serbian waters, four comprise 51% population in the Serbian freshwaters [7]. In Greek, there are 28 types of introduced fish and 10 of them can grow well, such as Gambusia holbrooki, Cyprinus carpio, Oncorhynchus mykiss, Ctenopharyngodon idola, Hypophthalmichthys molitrix, and Carassius gibelio [8]. In the southern Everglades estuaries (south Florida), the population of introduced fish species has exceeded 50% of the entire caught fish [9].

There are eight introduced species of fish caught in Banjaran and Pelus rivers species in West Java [10], and 12 species in Batur Lake, dominated by Oreochromis genus [11].

Penjalin Reservoir is a means of irrigation, transportation, local tourism, and fishing ground. Penjalin Reservoir is the damming result of Penjalin river, Soka river, and Garung river. The reservoir is situated 365 meters above sea level, the surface is 125 ha wide and 12-m deep (normal), the embankment is 850-m long, and it contains 9.5million m3 water volume [12].

Fish diversity in Penjalin Reservoir considerably fluctuates with a declining population at a particular time. In 2011, there were 37 species of fish, including 17 indigenous and 20 introduced [13], but in 2013 were only six species combined, consisted of three indigenous and three introduced [14]. The fluctuated number and types of fish may be attributed to human activities, such as fishing and environmental modification that brought significant changes to the ecosystem. Furthermore, the changes also modify the abundance, productivity, and community structure like the changes in dominant species, size spectrum, and catching yield [15]. Introduced species in Penjalin Reservoir were intentional by the local Department of Fishery for consumption and livelihood of the neighboring community. In a span of 80 years, the existence of introduced species continues to decline, either the composition, dominance, or diversity. Accordingly, it needs an investigation into the composition and diversity of introduced species and its correlation with water quality parameters as the living media to obtain ecosystem balance. Penjalin Reservoir is a communal dam of several rivers with different land use that would exhibit a unique ecosystem in the waters, such as the abiotic factors (clarity, temperature, depth, TSS, TDS, free CO2, pH, and dissolved oxygen) correlate with fish diversity in the waters.

This study aimed to analyze the diversity of introduced and indigenous fish species of fish caught in the Penjalin Reservoir and the correlation between fish diversity and water quality. The significance of the present research is to promote the conservation of fish resources and to maintain a balanced ecosystem, especially the existence of introduced and indigenous species in the waters of Penjalin Reservoir.

2. Materials and Methods

2.1. Sampling size and qualification habitat

The survey collected samples three times from five Stations with one-month intervals. The location of the research was in Penjalin Reservoir, Winduaji village, Brebes, Central Java. The study was undertaken from April through July 2017.

| Stations | Location | Coordinate |
|----------|----------|------------|
| I        | Inlet reservoir of Penjalin | (17°09’62,4” SL and 109°02’44,9” EL) |
| II       | Inlet reservoir of Garung river | (17°20’02,0” SL and 109°02’83,5” EL) |
| III      | Inlet reservoir of Soka river | (17°19’42,5” SL and 109°02’82,0” EL) |
| IV       | Reservoir center | (17°19’64,7” SL and 109°03’05,5” EL) |
| V        | Reservoir outlet | (17°19’65,5” SL and 109°03’22,8” EL) |
2.2. Sampling, prevation and identification of fishes

Fish sample was collected using fishnets (20x1.5x1 m and 40x1.5x1 m) with different mesh size from 0.2 cm, 1.5 cm, 2 cm, 2.5 cm to 3 cm. The fish sample was identified using a method in the book by [16], [17]. The water sample was collected using a Winkler bottle to measure the dissolved oxygen (DO), and one liter of water was collected in a bottle to measure the TSS, TDS, free CO2, and pH.

2.3. Analysis method

The data were subjected to descriptive analysis. The relative abundance of the species was measured by calculating the total individuals of fish species divided by the total species individual caught in each research Station.

\[ B = \frac{ni}{N} \times 100\% \]

\( B \): Relative abundance of the caught fish (%)
\( ni \): Total individuals of species i
\( N \): Total caught individuals of species

The data of Shannon-Wiener’s Diversity Index, Simpson’s Dominance Index, and the Index of Evenness (E) were analyzed using PAST 3 software. The correlation between water quality and diversity was subjected to PCA (Principal Component Analysis).

3. Result and Discussion

3.1. Composition and abundance of fish

We caught 539 fish in Penjalin Reservoir consisting of 7 families, 10 genus, and 11 species, including 6 introduced species (54%) and 5 indigenous species (46%). The introduced species included Oreochromis niloticus, Oreochromis sp, Oxyeletris marmorata, Clarias gariepinus, Cyprinus carpio, and Poecilia reticulata, while the indigenous species were Osteochillus vittatus, Barbonemus gonionotus, Rasbora agyrotaenia, Dermogenys pusilla, and Nemaceilus fasciatus (Table 2).

The types of fish caught in all Stations Stations were O. niloticus, Oreochromis sp, O. marmorata, D. pusilla, and N. Fasciatus. These fish can well-adapt to the environment and reproduce to continue the generation and permanently inhibit Penjalin Reservoir. Fish that are always found in all areas of Gajah Mungkur Reservoir is highly adaptable to environmental factors, such as DO, pH, and temperature, and able to compete for available natural food, and niche and quality of water that support the growth and sustainability of fish [18].

![Figure. 1. Research sites](image)
O. marmorata is the most caught introduced species in all Stations. Based on our conversation with the local fishermen, the O. marmorata fish, derived from The Center of Fish Breeding in East Java, was intentionally introduced to Penjalin Reservoir circa 2000. O. marmorata reproduced because the habitat in the waters was calm and without any current; therefore, it was dubbed the “fish reservoir” (personal communication). This type of fish is found in Limboto reservoir [19]; Gadjah Mungkur reservoir [20]; Kedung Ombo reservoir [21]; Cirata reservoir [22]; and in Malaysia’s Batang Kerang reservoir [23].

### Table 2. Composition species of fish caught in the Penjalin reservoir

| No | Family       | Species            | Stasions | Total |
|----|--------------|--------------------|----------|-------|
|    |              |                    | I       | II    | III  | IV  | V   |      |
| 1. | Cichlidae    | Oreochromis niloticus* | 16      | 10    | 5    | 3   | 5   | 39   |
| 2. |              | Parachromis managuensis* | 16      | 18    | 7    | 7   | 7   | 55   |
| 3. | Eleotridae   | Oxyeletris marmorata* | 77      | 36    | 34   | 40  | 32  | 219  |
| 4. | Chloridae    | Clarias gariepinus* | 0       | 0     | 7    | 0   | 11  |      |
| 5. | Cyprinidae   | Osteochillus vittatus | 2       | 2     | 2    | 6   | 0   | 12   |
| 6. |              | Barbonemus gonionotus | 1       | 2     | 0    | 0   | 3   |      |
| 7. |              | Cyprinus carpio* | 2       | 4     | 1    | 1   | 0   | 8    |
| 8. |              | Rashora agyrotania | 0       | 0     | 0    | 1   | 0   | 1    |
| 9. | Hemiramphidae| Dermogenys pusilla | 7       | 16    | 2    | 2   | 2   | 29   |
| 10.| Nemacheilidae| Nemaceilus fasciatus | 51      | 46    | 11   | 15  | 29  | 152  |
| 11.| Poecilidae   | Poecilia reticulata* | 0       | 0     | 5    | 0   | 5   | 10   |

|     |               |               | I       | II    | III  | IV  | V   | Total |
|-----|---------------|---------------|---------|-------|------|-----|-----|-------|
|     |               |               | 172     | 134   | 66   | 87  | 80  | 539   |

*= introduce species

The least caught fish was R. argyrotania found in Station IV (reservoir center). The fish belongs to small indigenous species and becomes the common food for the predator, thus depleting the population. Additionally, only a few Rasbora fish are caught in Koto Panjang Reservoir in Riau [24], Cirata reservoir [25] and Batur Lake in Bali [26]. The productivity of fish catch tends to fluctuate because the fish are seasonal, so the existence is dependent on the season that affects the composition and abundance of fish [27].

![Figure 2. The abundance of introduced species and indigenous species](image-url)
Based on the abundance, the introduced species was higher (342 fish or 63.4\%) than that of the indigenous species (197 or 36.5\%), and the introduced species dominate all sample collections across Stations (Figure 2).

The introduced fish species in the present study were more abundant than the indigenous because the former was more competitive for habitat and feed, so they could survive better in the water reservoir. A study in the inland waters of Western Australia reported that the entry of introduced fish undertook four stages of adaptation, namely introducing the fish for consumption, control to biological aspects, survival up to four decades, and compatibility for cultivation [28].

Introducing foreign species of fish, either intentionally or unintentionally could impose negative impacts on indigenous species as reflected from the declined population or extinction of indigenous species. When the introduced species outgrow the indigenous in competition for food and habitat, the population of indigenous species potentially declines. As a result, the introduced fish dominate the waters and the fish community becomes homogenous [1]. From 10 species of introduced species caught in the inland waters of Western Australia [28], six were caught in lake Ula, Mugla [29], ten in the waters of Banten, West Java [2] and 12 in Batur lake, Bali [12]. The fish were purposefully introduced to the waters as food to meet protein demand of the community and as ornamental fish.

The few catch of indigenous fish species during the study was due to the loss of food source because of the changing habitat or competition for food. Research in Cirata reservoir reported a declining population of indigenous species because of food competition and numerous predator fish [30]. The type of abundant indigenous species caught in Penjalin Reservoir is Nemaceilus fasciatus (152 individuals) that inhabited the current waters with a rocky bed. The maximum size of the fish is 10 cm [31]. An investigation by [32] revealed that Nemaceilus fasciatus were mostly found in the rocky habitat where alga grew in abundance to provide natural food and a hidden place to protect fish eggs and larvae from the predator.

The introduced fish with relatively high abundance in this area are *O. marmorata* (40.63\%), and *Oreochromis* spp (17.44\%), while indigenous species with relatively high abundance is *N. fasciatus* and the lowest is *R. agyrotaenia* (0.19\%) (Figure 3).

![Figure 3. The relative abundance of fish species in Penjalin reservoir](image)

The relative abundance of *O. marmorata* in this study was lower than that caught in the Panglima Jenderal Soedirman Reservoir, namely 63.16\% [33]. *O. Marmorata* belongs to an introduced species that is thriving in Penjalin Reservoir because the fish can survive in a water puddle habitat. Since the fish can adapt to the environment, they reproduce to preserve the offspring [34]. Also, *O. marmorata* lives in freshwaters like rivers, lakes, reservoirs, and swamp, prefers shallow water with a muddy bed, slow current, and hiding place, and likes to stay around the water plants on the water surface for protection [21]. The distribution area of *O.marmorata* includes Singapore, Thailand, Fiji Islands, and...
The relative abundance of Oreochromis spp is attributed to their competitiveness for food and habitat and the water quality that could increase the population. According to [35] Oreochromis exhibits fast reproduction and growth rates, enabling it to utilize food sources like the plant, detritus, or animals. The species is regarded as a green movement and easily adapt to the environment.

N. fasciatus is the indigenous species with the highest relative abundance (28.20%). This fish lives in the inlet of Penjalin river and the shallow Garung river. Also, N. fasciatus survives the low oxygen level and high murkiness, and reproduces well to multiply the offspring. A study by [36] in Banjaran river, Banyumas, Central Java reports that N. faciatus has a fecundity of 2.285–5.916 granules and body length of 67-70 mm, so the chance to reproduce is high, thus increasing the population.

Furthermore, [31] on Nemacheilidae familia caught in Tons river, India is 16% lower than the present study in Penjalin Reservoir. According to [20], fish with a high relative abundance have a large distribution, while those with low abundance have a narrow distribution because their adaptability to the environment is not high.

### 3.2. Biological Index

#### Table 3. Diversity Index (H), Simson (D) and Evenness (E) of introduced species and indigenous species.

| Parameter       | STATIONS | STATIONS |
|-----------------|----------|----------|
|                 | I        | II       | III      | IV       | V        | I        | II       | III      | IV       | V        |
| Taxa_S          | 4        | 4        | 5        | 6        | 4        | 4        | 4        | 3        | 4        | 2        |
| Individuals     | 111      | 68       | 51       | 63       | 49       | 61       | 66       | 15       | 24       | 31       |
| Shannon_H       | 0.8845   | 1.137    | 1.047    | 1.189    | 1.022    | 0.5776   | 0.8071   | 0.7648   | 0.9798   | 0.2392   |
| Simpson_1-D     | 0.4769   | 0.6246   | 0.5206   | 0.5634   | 0.5323   | 0.2865   | 0.4536   | 0.4267   | 0.5382   | 0.1207   |
| Evenness_e^H/S  | 0.6054   | 0.7794   | 0.57     | 0.547    | 0.6947   | 0.4454   | 0.5603   | 0.7162   | 0.666    | 0.6351   |

Fish diversity of introduced and indigenous species in Penjalin Reservoir is greatly varied in each Station. The diversity of introduced species is higher (0.8845-1.189) than that of indigenous species (0.2392-0.9798) (Table 3) because the total species and individuals of introduced fish (342 individuals, six species) outnumber those of indigenous fish (197 individuals, five species). The diversity index of introduced and indigenous species of fish is relatively low. According to [37], the diversity index is categorized into three: low diversity (H’ ≤ 1.5), moderate diversity (1.5< H’≤3.5), and high diversity (H’>3.5). Stations IV in the reservoir center has higher diversity than all other Stations because the size of Penjalin Reservoir is medium (125ha), so many fish gather in the central habitat and adapt to the environment. Moreover, fishing activity is scarce because the area mostly functions for rowboat transportation. [38] stated that human activity in the fish habitat affected fish diversity. Every fish species to live and reproduce must adapt to the environmental condition of their habitat. Low diversity in Station 1 and IV is attributed to some types of fish that cannot adapt to the available feed and predator dominance.

Fish domination in Penjalin Reservoir is medium around 0.4769 - 0.6246 (introduced species) and around 0.1207- 0.5382 (indigenous species) (Table 3). The category is based on a dominance index between 0 and 1; index 1 is very high domination while 0 is no domination. The waters in Penjalin Reservoir in the inlet of Garung river, Soka river, and the center part had a high dominance index because the total fish caught was fewer and mostly O.marmorata. O.marmorata fish has been intentionally introduced in 2000 and well-adapted to the environment in Penjalin Reservoir. Similarly, the population of Cyprinus carpio and Carrasius auratus was introduced for 20 years and dominated the waters of Ula Reservoir, Turkey [29]. In addition, O.marmorata exhibit an optimum potential of
reproduction, so they are viable for cultivation. A study by Fatah & Aji, [21] reported that O. Marmorata are spawning progressively with a fecundity of 6.414-56.302 granules, egg diameter of 0.2 – 0.67 mm, Gonado Somatic Index (GSI) of 0.03%-0.65% (male) and 0.11% - 5.57% (female). The dominating O.marmorata in Penjalin Reservoir poses an extinction threat to the indigenous species because the competition for food and habitat has turned the community structure in the waters into homogenous.

The fish community in the waters of Penjalin Reservoir has a low to moderate level of evenness index, i.e., 0.547-0.7794 (introduced species) and 0.4454-0.7162 (indigenous species) (Table 3). Stations II and III shared a relatively high index of evenness, but overall, the index is almost equal and relatively low in all Stations. This condition of low evenness demonstrates the uneven distribution of individuals among species; therefore, the community balance is low. It is indicated by the high dominance index in the Station in which the more even the distribution of individuals among species, the higher the ecosystem balance. It is attributed to some factors, including the unfavorable environmental condition and fishing season that result in the domination of particular species, and the complex habitat structure that allows spatial and temporal distribution of fish.

3.3. The correlation between fish diversity and water quality

Fish diversity is partly affected by environmental factors, namely water quality. The correlation between water quality and the diversity of introduced and indigenous species in Penjalin Reservoir has formed components 1 and 2 (Figure 4).

![Figure 4. Biplot fish diversity and water quality](image-url)
toxicity. The deepest part of the reservoir is 14.25m, but the sun can penetrate the waters, allowing the photosynthesis process and phytoplankton as the natural food for fish. The pH value of a body of water reflects the acidic or base level of the water. In Station IV, the average pH was almost normal, i.e., 6.75 (near 7), so it supported the life, especially the introduced fish. An optimum pH for fishing activity is 6.5-8. The high pH (base) provides less optimum support for the fish because it is associated with the toxic ammonia in the water [39]. The average free CO2 was the best (4.68 mg/l) because it is under 12 mg/l, allowing the fish to adapt to the habitat in the reservoir center. An excessive amount of free CO2 would decrease oxygen intake and render active breathing in fish and, therefore, decreasing the appetite of the fish [40]. The clarity, TDS, and DO in Station V (outlet) negatively contributed to the diversity of introduced and indigenous fish. It showed that the fish diversity in Station V was not affected by the high clarity, TDS, and DO but remained optimum for the standard life quality of the fish. The outlet areas are the exit flow of the reservoir and the current is strong, so many fish are there, especially those who prefer the strong current. According to [20], fish caught in the outlet of the Gajah Mungkur reservoir are more diverse because the strong current may affect both biotic and abiotic factors of the waters.

4. Conclusion

1. Fish diversity of introduced species is higher than that of indigenous species but remains in moderate index across Stations.
2. O. marmorata species have the highest relative abundance and they dominate the fish population in Penjalin Reservoir.
3. Fish diversity of introduced species is positively correlated with the physical factors, namely the depth and chemical elements (pH and free CO2) in the center part of the reservoir, while the indigenous species is positively correlated with the Total Suspended Solid (TSS) in the inlet of Garung river.

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