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ARTICLE

DIVERSITY AND COMMUNITY STRUCTURE OF FRESHWATER FISHES IN URBAN AQUATIC SYSTEMS OF MADIUN CITY, EAST JAVA, INDONESIA

[*Keanekaragaman dan Struktur Komunitas Ikan Air Tawar pada Sistem Perairan Perkotaan Kota Madiun, Jawa Timur, Indonesia*]

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ABSRACT

Indonesia prioritizes food security, stressing access to healthy and sustainable food sources. Fish play a crucial role as a renewable protein source and contribute to local economic growth. Madiun City, East Java, has rivers, irrigation canals, and ponds that offer potential for local fisheries. However, data on fish biodiversity are limited, despite effective management and conservation efforts. This study examines fish diversity in Madiun waters, identifying native and non-native species. Sampling took place at ten stations, with species identified morphologically. Ecological indices used included Simpson's Dominance (D), Shannon-Wiener Diversity (H'), Pielou's Evenness (E), Margalef's Richness (R), and Sorensen's Similarity (IS). A total of 1,031 individuals from 18 species were recorded, with Cypriniformes being the most common. Station 4 witnessed the rapid growth of the invasive *Pterygoplichthys pardalis*, which negatively impacted native species. Species richness ranged from 0.98 to 2.64, indicating low diversity. Stations 2 and 9 showed the highest similarity (94%) due to water connectivity. These results indicate initial ecological pressures on Madiun City's aquatic ecosystem and provide important baseline data for conservation, biodiversity management, and sustainable fisheries, which support increased local food security.

Keywords: Biodiversity, Fish, Native, Non-native, Madiun City

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ABSTRAK

Indonesia memprioritaskan ketahanan pangan, menekankan akses terhadap sumber pangan yang sehat dan berkelanjutan. Ikan memainkan peran penting sebagai sumber protein terbarukan dan berkontribusi pada pertumbuhan ekonomi lokal. Kota Madiun, Jawa Timur, memiliki sungai, kanal irigasi, dan kolam yang menawarkan potensi perikanan lokal. Namun, data mengenai keanekaragaman ikan masih terbatas, meskipun upaya pengelolaan dan konservasi telah dilakukan secara efektif. Studi ini meneliti keanekaragaman ikan di perairan Madiun, mengidentifikasi spesies endemik dan non-endemik. Pengambilan sampel dilakukan di sepuluh stasiun, dengan spesies yang diidentifikasi secara morfologis. Indeks ekologi yang digunakan meliputi Dominasi Simpson (D), Keanekaragaman Shannon-Wiener (H'), Keseragaman Pielou (E), Kekayaan Margalef (R), dan Kesamaan Sorensen (IS). Sebanyak 1.031 individu dari 18 spesies tercatat, dengan Ordo Cypriniformes sebagai yang paling umum ditemukan. Stasiun 4 terdapat pertumbuhan pesat yaitu spesies invasif Pterygoplichthys pardalis, yang berdampak negatif pada spesies endemik. Kekayaan spesies berkisar antara 0,98 hingga 2,64, menunjukkan keanekaragaman yang rendah. Stasiun 2 dan 9 menunjukkan kemiripan tertinggi (94%) karena konektivitas air. Hasil ini menunjukkan tekanan ekologis awal pada ekosistem perairan Kota Madiun dan memberikan data dasar penting untuk konservasi, pengelolaan keanekaragaman hayati, dan perikanan berkelanjutan, yang mendukung peningkatan ketahanan pangan lokal.

***Kata kunci**: Biodiversitas, Ikan, Endemik, Non-endemik, Kota Madiun*

INTRODUCTION

Food security is a top priority for the Indonesian government in its national development plans. This promise demonstrates that the government is still committed to ensuring that everyone has access to sufficient, affordable, and high-quality food (Kementerian Keuangan Republik Indonesia, 2025). Fish is an essential component of various types of food. Fish is a good source of animal protein and is also readily available, with significant economic potential (Bakhsh *et al*., 2024).

Madiun City, located in East Java Province, has promising aquatic resources supported by several rivers and irrigation channels. These waters contain a diverse array of fish species, including both native and non-native species (Prianto *et al*., 2017). Native fish are significant because they indicate the health of an ecosystem and are also an integral part of the local biodiversity. At the same time, non-native species are often important to the economy because they are used for food and aquaculture (De Heus, 2021; Razi & Patekkai, 2020; Samad *et al*., 2024).

Urban freshwater ecosystems are often subject to significant anthropogenic pressures, including pollution, habitat modification, and hydrological alterations, yet they remain relatively understudied, particularly in secondary cities such as Madiun City. At present, however, there is still a lack of comprehensive data and information regarding the fish species inhabiting the waters of Madiun City. This lack of basic knowledge is a problem because accurate biodiversity data are necessary for managing fisheries resources, protecting the environment, and improving food security based on local potential (Hidayat *et al*., 2023; Nasution & Yanti, 2014).

Conducting an exploration and inventory of fish biodiversity in Madiun City is therefore a vital first step to understanding the current state of its aquatic resources. Moreover, distinguishing between native and non-native fish species can provide an important foundation for policy-making aimed at sustainable fisheries management, the protection of local species, and the optimization of fish resources to support both food security and the livelihoods of surrounding communities (Kementerian Kelautan dan Perikanan Republik Indonesia, 2019; Muchlisin *et al*., 2020).

In this context, the present study was carried out with the aim of documenting the fish biodiversity in Madiun City, while identifying native and non-native species inhabiting its waters.

MATERIALS AND METHODS

Location and Time of Research

This study employs a quantitative research approach with the main objective of examining fish biodiversity in Madiun City and distinguishing between native and non-native species, which was carried out from August to September 2025. Fish samples will be collected from ten selected stations (Figure 1), using purposive sampling techniques (Asari *et al*., 2023; Negara *et al*., 2025). Sampling was carried out at ten stations, with the exact coordinates of each location presented in Table 1.

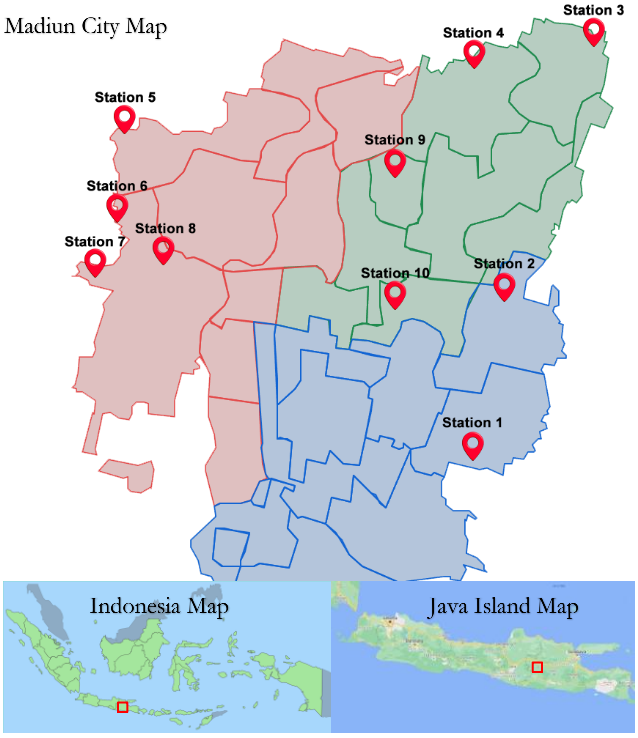

Figure 1. Map showing the location of observation stations (red dots) in Madiun City (*Peta yang menunjukkan lokasi stasiun pengamatan (titik merah) di Kota Madiun*).

Table 1. Position of ten stations in Madiun City (*Posisi sepuluh stasiun di Kota Madiun*).

Station Names (*Nama Stasiun*)	**Positions** (*Posisi*)
Station 1 (*Stasiun 1*)	S 7°38’46.9” and E 111°32’37.6”
Station 2 (*Stasiun 2*)	S 7°37’50.1” and E 111°32’46.0”
Station 3 (*Stasiun 3*)	S 7°36’16.4” and E 111°33’26.2”
Station 4 (*Stasiun 4*)	S 7°36’02.2” and E 111°32’33.3”
Station 5 (*Stasiun 5*)	S 7°36’19.6” and E 111°30’42.9”
Station 6 (*Stasiun 6*)	S 7°36’58.1” and E 111°30’21.9”
Station 7 (*Stasiun 7*)	S 7°37’21.1” and E 111°30’16.9”
Station 8 (*Stasiun 8*)	S 7°37’25.9” and E 111°30’45.6”
Station 9 (*Stasiun 9*)	S 7°36’54.8” and E 111°32’12.1”
Station 10 (*Stasiun 10*)	S 7°37’50.3” and E 111°32’13.2”

Data Collection and Sampling

Fish sampling in this study was performed using different types of fishing gear, selected to accommodate variations in fish size and species composition. Gill nets with mesh sizes of ¾ inch (50 m in length and 0,8 m in height) and 2,5 inches (50 m in length and 1 m in height) were used alongside simple fish traps that were baited prior to deployment using fish feed. At each sampling station, fish collection was repeated twice to reduce random variation and to better reflect local fish assemblages. During each sampling occasion, both gill net sizes were installed, and the duration and effort of fishing activities were kept consistent among stations.

Fish traps were deployed at each sampling station for approximately eight hours and inspected at two-hour intervals to record captured fish and to ensure that the traps remained in proper condition throughout the sampling period. Sampling was conducted during both diurnal and nocturnal periods, typically from 08:00 to 16:00 and 18:00 to 02:00, in order to capture fish species with different activity patterns. This approach was intended to minimize temporal bias in species detectability, as some fish are more active during the day while others exhibit nocturnal behavior. The application of gill nets with different mesh sizes made it possible to collect fish across a wide range of body sizes. In contrast, the use of baited traps proved useful for capturing species that were less likely to be entangled in gill nets. The combination of these fishing methods provided a broader overview of the fish assemblage present at each station.

All collected specimens were subsequently examined at the Bioentrepreneurship Laboratory, Muhammadiyah University of Madiun. Species identification was based on morphological observations, emphasizing external features such as overall body form, coloration, fin configuration, scale patterns, and meristic counts. Taxonomic identification primarily referred to the keys presented in *Freshwater Fishes of Western Indonesia and Sulawesi* (Kottelat *et al*., 1993). To minimize misidentification, the observed characters were cross-checked with descriptions and illustrations from recent peer-reviewed studies on freshwater fish diversity in Indonesian river systems (Haqqi *et al*., 2024; Negara *et al*., 2025; Zamzami *et al*., 2023).

Data Analysis

The collected data were subsequently examined through biodiversity analysis, employing several ecological indices, including The Simpson Dominance Index (D), The Shannon-Wiener Species Diversity Index (H'), The Pielou Evenness Index (E), The Margalef Richness Index (R), and The Sorensen Similarity Index (IS) (Begon *et al*., 1996; Latuconsina *et al*., 2022; Margalef, 1958; Negara *et al*., 2025; Odum, 1993; Pielou, 1966). These indices were used to evaluate species diversity, dominance patterns, distribution evenness, and similarity among sampling stations. All calculations and data processing were performed using Microsoft Excel 2019, while statistical analyses were conducted using IBM SPSS Statistics version 27.0.1. The use of these indices allows for a comprehensive quantitative assessment of fish community structure and biodiversity patterns across the study area.

a. The Simpson Dominance Index (D)

The Simpson Dominance Index is used to describe the level of dominance of a species in a community (Latuconsina *et al*., 2022; Odum, 1993).

$$D = \sum_{i=1}^{s} (ni/N)^2$$

Description:
D = Simpson Dominance Index
ni = number of individuals of i-type/species
N = number of individuals of all type/species
S = number of fish species.

b. The Shannon-Wiener Species Diversity Index (H')

The Shannon-Wiener Species Diversity Index describes the level of species diversity by considering the number of species and the proportion of individuals of each species (Negara *et al*., 2025; Odum, 1993).

$$\mathrm{H}' = -\sum_{i=1}^{s} \mathrm{Pi}\ ln\mathrm{Pi}$$

Description:
H' = Shanon-Wiener Species Diversity Index
Pi = *ni/N* (proportion of the entire community made up of i-species)
N = total number of individual fish
ni = number of individuals of i-type/species

S = number of fish type/species
ln = natural log.

c. The Pielou Evenness Index (E)
The Pielou Evenness Index is used to assess the evenness of individuals between species in a community (Pielou, 1966; Smith & Wilson, 1996).

$$E = \frac{H'}{ln\ (S)}$$

Description:
E = Pielou Species Evenness Index
H' = Shannon-Wiener Species Diversity Index
S = Number of fish type/species. Index values range from 0-1
ln = natural log.

d. The Margalef Richness Index (R)
The Margalef Richness Index describes species richness based on the number of species found compared to the total number of individuals (Gamito, 2010; Kunakh *et al*., 2023; Margalef, 1958).

$$R = \frac{S-1}{ln(N)}$$

Description:
R = Margalef Species Richness Index
S = number of type/species
In = natural log
N = total number of individuals

e. The Sorensen Similarity Index (IS)
The Sorensen Similarity Index is used to measure the level of similarity in species composition between two locations or communities (Erlangga *et al*., 2023; Negara *et al*., 2025; Odum, 1993).

$$IS = \frac{2C}{A+B} x100\%$$

Description:
IS = The Sorensen Species Similarity Index
A = number of type/species in area 1
B = number of type/species in area 2
C = same number of type/species in both areas.

RESULTS

Based on observations conducted at ten sampling stations across the aquatic systems of Madiun City, a total of 1,031 individual fish were recorded (Table 2). These individuals were classified into 8 orders, 10 families, and 18 species (Table 3).

Table 2. Number of fish species at each station (*Jumlah spesies ikan di setiap stasiun*).

Species (*Spesies*)	**Station** (*Stasiun*)									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Pterygoplichthys pardalis	25	13	10	156	5	8	11	10	30	47
Clarias batrachus	-	-	-	-	-	-	-	1	-	-
Oxyeleotris marmorata	-	-	-	-	-	-	1	-	-	-
Channa striata	-	-	1	-	-	-	3	-	-	2
Mystus nigriceps	-	-	-	-	-	-	-	3	-	-
Mystus singaringan	-	47	10	-	8	7	8	10	20	5

Species (*Spesies*)	Station (*Stasiun*)									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Osteochilus vittatus	-	-	5	19	2	5	4	8	-	-
Labiobarbus leptocheilus	-	-	-	3	-	-	-	-	-	-
Barbonymus balleroides	-	-	-	2	-	2	7	14	-	-
Barbonymus gonionotus	-	4	-	-	4	-	-	12	-	-
Mystacoleucus marginatus	-	-	-	-	-	-	5	3	-	-
Barbodes binotatus	5	8	4	-	5	-	4	3	2	-
Rasbora argyrotaenia	5	31	-	16	12	-	10	10	10	10
Dermogenys pusilla	11	6	10	3	8	6	9	7	4	9
Gambusia affinis	13	9	8	6	9	7	9	12	15	13
Anabas testudineus	-	5	3	-	2	10	-	-	29	5
Trichopodus trichopterus	-	24	5	16	-	11	7	-	32	45
Glypothorax platypogon	-	-	-	-	-	-	-	1	-	-

Table 3. Abundance of each fish species (*Kelimpahan setiap spesies ikan*).

Order (*Ordo*)	**Family** (*Famili*)	**Species** (*Spesies*)	**Total Individuals** (*Total Individu*)
Anabantiformes	Anabantidae	*Anabas testudineus*	54
Anabantiformes	Channidae	*Channa striata*	6
Beloniformes	Zenarchopteridae	*Dermogenys pusilla*	60
Cypriniformes	Cyprinidae	*Barbodes binotatus*	31
Cypriniformes	Cyprinidae	*Barbonymus balleroides*	25
Cypriniformes	Cyprinidae	*Barbonymus gonionotus*	20
Cypriniformes	Cyprinidae	*Labiobarbus leptocheilus*	3
Cypriniformes	Cyprinidae	*Mystacoleucus marginatus*	8
Cypriniformes	Cyprinidae	*Osteochilus vittatus*	43
Cypriniformes	Cyprinidae	*Rasbora argyrotaenia*	104
Cyprinodontiformes	Poeciliidae	*Gambusia affinis*	101
Gobiiformes	Butidae	*Oxyeleotris marmorata*	1
Perciformes	Osphronemidae	*Trichopodus trichopterus*	140
Siluriformes	Bagridae	*Mystus nigriceps*	3
Siluriformes	Bagridae	*Mystus singaringan*	115
Siluriformes	Clariidae	*Clarias batrachus*	1
Siluriformes	Sisoridae	*Glypothorax platypogon*	1
Siluriformes	Loricariidae	*Pterygoplichthys pardalis*	315
Total			**1.031**

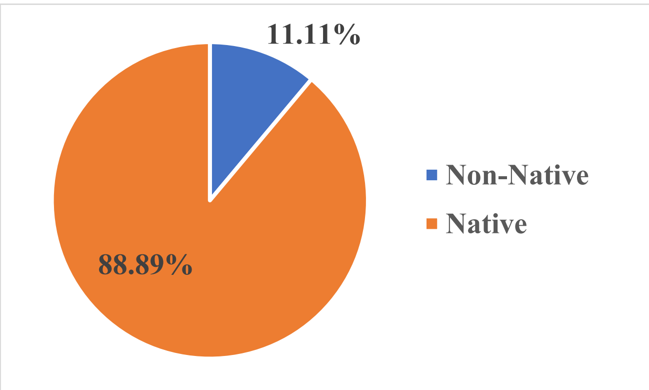

Figure 2. Proportion of native and non-native fish in Madiun City (*Proporsi ikan endemik dan non-endemik di Kota Madiun*).

Table 4. Species Diversity (H'), Dominance (D), Evenness (E), and Richness (R) Indices across sampling stations (*Indeks Keanekaragaman Spesies (H'), Dominasi (D), Keseragaman (E), dan Kekayaan Spesies (R) di seluruh stasiun pengamatan sampel*).

Analysis (*Analisis*)	**Station** (*Stasiun*)									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
H'	1,4286	1,8763	2,0495	1,0942	2,0568	1,8577	2,3349	2,3539	1,8496	1,6341
D	0,2772	0,1914	0,1403	0,5173	0,1412	0,1648	0,1061	0,1048	0,1741	0,2508
E	0,8876	0,8539	0,9328	0,5262	0,9361	0,9547	0,9396	0,9177	0,8895	0,7858
R	0,9810	1,6031	1,9874	1,2967	1,9963	1,5337	2,5805	2,6413	1,4125	1,4249

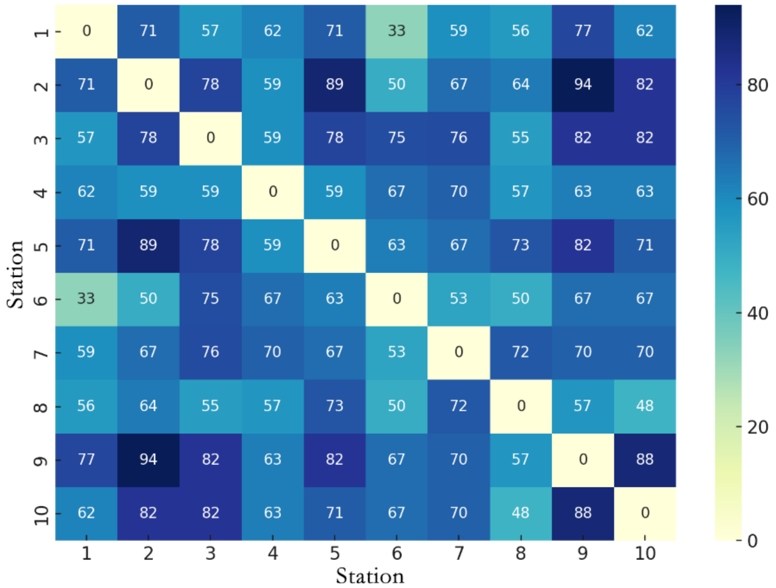

Figure 3. Heat Map of fish species similarity index in Madiun City (*Heat Map indeks kesamaan spesies ikan di Kota Madiun*).

DISCUSSION

Overview of Sampling Station

Sustainable management of fisheries resources depends on a clear understanding of fish community structure and diversity within aquatic ecosystems (Abdullah *et al*., 2025; Charles, 2023). Information on species diversity, evenness, richness, and similarity provides an important foundation for evaluating ecosystem stability and identifying potential environmental pressures (Li *et al*., 2022). Fish diversity is widely recognized as an ecological indicator that reflects both ecosystem balance and overall water quality (Iyiola *et al*., 2024; Muktitama *et al*., 2025). In this study, field observations were carried out at ten sampling stations selected using a purposive sampling approach.

Fish Community Structure

There was considerable variation in how fish were distributed across the sampling stations. Station 4 had the most fish, with 221, and Station 1 had the fewest, with only 59. Several factors, including human activity and the complexity of the habitat, contribute to these differences. Human activities, such as disposing of trash and overusing resources, have been linked to declines in both the number of people and the variety of species (Pratomo *et al*., 2024).

The most prevalent order was Cypriniformes, encompassing 234 individuals across seven species: *Barbodes binotatus*, *Barbonymus balleroides*, *Barbonymus gonionotus*, *Labiobarbus leptocheilus*, *Mystacoleucus marginatus*, *Osteochilus vittatus*, and *Rasbora argyrotaenia*. The prevalence of this order signifies that members of the family Cyprinidae exhibit a significant adaptive capacity to diverse environmental conditions within freshwater ecosystems (Vagenas *et al*., 2022; Wang *et al*., 2024).

On the other hand, there were only a few species from the Gobiiformes (*Oxyeleotris marmorata*) and Siluriformes (families Clariidae and Sisoridae) orders. *Oxyeleotris marmorata* exhibits slow growth, nocturnal activity, and solitary, territorial behavior (Lim *et al*., 2020; Yusoff *et al*., 2023). *Oxyeleotris marmorata* is a native freshwater fish species widely distributed across Southeast Asia, including Indonesia, Malaysia, and Thailand. In Indonesia, this species has been reported from various regions, including Sumatra, Kalimantan, and Java, and is commonly found in slow-moving or stagnant waters with soft substrates. It is also known for its high economic value due to its desirable flesh and market demand (Kottelat *et al*., 1993; Muchlisin & Azizah, 2009; Saanin, 1984). This species also needs calm, clear waters with muddy or soft sandy bottoms. It is also very valuable because its soft flesh is highly sought after by people in the area. As a result, habitat degradation from sedimentation, human activities, and overfishing can significantly lower the number of animals living there (Damayanti *et al*., 2024; Khowhit *et al*., 2024; Lestari *et al*., 2019; Widiansyah *et al*., 2025; Zhao *et al*., 2017).

Clarias batrachus is a native freshwater fish of Indonesia, including Java Island, that can live in very harsh aquatic conditions, such as low dissolved oxygen and high turbidity. This species is one of the most adaptable members of the Clariidae family. It can live in many different types of freshwater habitats, such as rivers, swamps, and even man-made ponds (Lee & Sulaiman, 2015; Ng & Kottelat, 2008). People in the area also really like it as a food fish. *Clarias batrachus* is often overexploited because it is very important to the economy and can live in many different environments. This could threaten the long-term survival of its natural populations (Januardy *et al*., 2023; Sahoo *et al*., 2010; Tamam *et al*., 2021).

Glyptothorax platypogon is a freshwater fish species found in Sumatra, Kalimantan, Malay, and Java. It usually lives in rivers that flow quickly and have rocky or gravel bottoms (Kottelat *et al*., 1993; Maizul *et al*., 2023). This species possesses a thoracic adhesive apparatus that enables it to adhere to rocks in strong currents, which facilitates its survival in rivers with high flow rates (Maizul, 2021; Maizul *et al*., 2023). *Glyptothorax platypogon* is usually found in clear, well-oxygenated rivers with hard bottoms and good water quality (Maizul *et al*., 2023; Nuryanto *et al*., 2015). The study area's low number of this species is probably because it needs a very specific type of habitat and is very sensitive to changes in the environment. Anthropogenic activities, including sedimentation, water extraction for irrigation, and the development of river infrastructure, can diminish current velocity and obscure rocky substrates critical for survival (Maizul, 2021; Maizul *et al*., 2023; Nuryanto *et al*., 2015). Additionally, its benthic habitat and propensity to conceal itself among rocks render it challenging to identify through standard sampling techniques (Nuryanto *et al*., 2015).

After that, verification was conducted to determine if each recorded species was native or not. The prevalence of non-native fish signifies a possible risk to the diversity of indigenous species (Prianto *et al*., 2017). Figure 2 shows the percentage of fish species that are native and those that are not.

Out of the 18 fish species found in Madiun City, 16 (88,89%) were native and 2 (11,11%) were not. This ratio indicates that native fish species still comprise the majority of the aquatic ecosystems in Madiun City. Native species are crucial for maintaining ecosystem balance and serve as effective indicators of aquatic environment health (Fitri *et al*., 2024; Herawati *et al*., 2020). The three non-native species found were *Pterygoplichthys pardalis* and *Gambusia affinis*.

Pterygoplichthys pardalis, commonly known as the suckermouth catfish, is a non-native species with an exceptionally high survival ability, thriving not only in polluted waters but also in low-oxygen conditions. It eats both plants and animals, which means it can consume a wide range of materials, including organic debris, algae, and detritus (Burhanuddin *et al*., 2023; Mangkuasih & Rohmawati, 2021).

The plague minnow, also known as *Gambusia affinis*, originates from the eastern and southeastern parts of North America (Mischke *et al*., 2013; Pyke, 2005, 2008). The word “Gambusia” comes from Latin and means “nothing” or “frustration”. This is because people initially thought the species was unimportant and not very useful to the environment or the economy (Pyke, 2005). However, its introduction in the early 20th century as a biological agent for controlling mosquito larvae changed its status from unimportant to well-known as a species that is both beneficial and harmful (Jourdan *et al*., 2021; Kulman & Tamïr, 2022; Syarif *et al*., 2025).

Non-native species, particularly invasive ones such as *Pterygoplichthys pardalis* and *Gambusia affinis*, pose significant ecological threats to native fish communities by competing for space, food, and habitat resources (Kulman & Tamïr, 2022; Ramadhanu *et al*., 2024; Syarif *et al*., 2025). Therefore, conservation of native fish species must be prioritized through habitat management and regulation of non-native species to maintain ecological balance of freshwater ecosystems in Madiun City.

The Shannon-Wiener diversity index (H') across the ten observation stations exhibited noticeable variation (Table 4). Stations 7 and 8 recorded the highest values (H' = 2.33 and 2.35), indicating that these sites support relatively stable and diverse fish communities, with an even distribution of individuals among species. Such conditions are typically found in aquatic habitats that remain relatively natural, possess complex structural features, and experience minimal anthropogenic pressure (Roux & Clinton, 2023). In contrast, Station 4 showed the lowest H' value (1.09), reflecting a decline in community stability due to the dominance of the invasive species *Pterygoplichthys pardalis*. This species is known for its exceptional adaptability to extreme environmental conditions, high reproductive capacity, and strong competitive ability against native fishes (Soria-Barreto *et al*., 2024). The fast growth of *Pterygoplichthys pardalis* at Station 4 has probably made it harder for native species to find food and space because there are more of them fighting for these things (Sarkar *et al*., 2023; Seshagiri *et al*., 2021). Similar patterns have been reported in several Indonesian freshwater systems, where *Pterygoplichthys pardalis* has established invasive populations and contributed to the decline of native fish communities, particularly in urban or human-impacted waters (Haqqi *et al*., 2024; Patoka *et al*., 2020). From a risk assessment perspective, the high dominance of this species at Station 4 is likely influenced by environmental degradation, low habitat heterogeneity, and reduced ecological resistance from native species. These conditions increase ecosystem vulnerability to biological invasion and may lead to long-term biodiversity loss if not properly managed. Consequently, despite the relatively high number of individuals recorded, the community structure at Station 4 is heavily skewed toward a single species, resulting in lower diversity values. Overall, however, the H' values across all stations still fall within the moderate diversity category, suggesting that the aquatic ecosystems of Madiun City retain a certain level of ecological resilience.

The analysis of Simpson's dominance index (D) revealed that the values fluctuated between 0.10 and 0.52, indicating that the degree of species dominance differed among stations (Table 4). Higher D values usually mean that one or a few species are more dominant, while lower values mean that no one species is more dominant (Magurran, 2004). Station 4 had the highest dominance (D = 0.5173), indicating that one species, *Pterygoplichthys pardalis*, an invasive fish known for its ability to dominate aquatic communities in tropical environments, was particularly dominant (Soria-Barreto *et al*., 2024). Because this species grows so quickly, there are fewer of the other species, primarily native fish, as they compete for space and food (Sarkar *et al*., 2023). This finding is consistent with the low Shannon-Wiener diversity index (H' = 1.09) observed at the same station. This supports the idea that species dominance and community diversity are related oppositely. Stations 8 (D = 0.1048) and 7 (D = 0.1061), on the other hand, had the lowest dominance values. This means that the fish community structure is more balanced and no one species has too much power. These conditions are typically found in habitats characterized by high environmental quality, diverse habitat types, and minimal human activity, facilitating coexistence among numerous species in relative harmony (Roux & Clinton, 2023).

The analysis of species evenness index (E) showed values ranging from 0.5262 to 0.9547 (Table 4). An E value of 0 means that one or a few species dominate the community, while an E value of 1 means that the species are evenly spread out (Pielou, 1966). Station 4 had the lowest evenness (E = 0.5262), which means that the species were not very similar to each other. This situation is caused by the rapid growth of *Pterygoplichthys pardalis*, an invasive fish species that can thrive in many different types of water and often outcompetes other fish in the area (Lardizabal *et al*., 2020; Mahesvaran *et al*., 2025). The dominance of this species disrupts the ecosystem's balance because native fish lack sufficient space to live and food to eat, resulting in significantly fewer of them compared to the invasive species. Station 6 had the highest evenness value (E = 0.9547), followed by Station 5 (E = 0.9361) and Station 7 (E = 0.9396). This suggests that individuals are spread out fairly evenly among species. This pattern suggests that the environment is more stable, enabling different types of fish to coexist in optimal proportions (Sihombing *et al*., 2017). A high level of evenness means that no single species is more common than any other. This shows that the fish community is more ecologically balanced and healthy.

Based on the analysis of the species richness index (R), which ranged from 0.9810 to 2.6413, the overall level of fish species richness in the aquatic ecosystems of Madiun City can be categorized as low to moderate (Table 4). According to the criteria by (Krebs, 1999), values of $R < 2.5$ indicate low richness, $2.5 > R > 4$ indicate moderate richness, and $R > 4$ indicate high richness. Accordingly, most sampling stations exhibited low richness, except for Station 7 (R = 2.5805) and Station 8 (R = 2.6413), which fall within the moderate category. The higher richness values observed at Stations 7 and 8 suggest that these sites possess more complex habitats and better environmental quality compared to others. The presence of diverse habitat structures, such as moderate water flow, mixed sand and gravel substrates, and dense riparian vegetation provides a variety of ecological niches that support fish species with different habitat preferences (Suryaningsih *et al*., 2020). Conversely, stations such as Station 1 (R = 0.9810) and Station 4 (R = 1.2967) exhibited low species richness. This is likely due to habitat loss, sedimentation, and human activities such as littering and overfishing. Additionally, the population explosion of certain species like *Pterygoplichthys pardalis* in several locations may have suppressed the abundance of native species, thereby reducing overall community richness (Haqqi *et al*., 2024). Most stations have low R values, which means that the aquatic ecosystems in Madiun City are under ecological stress. This is probably because the water quality is getting worse, the habitats are becoming less connected, and the new species are competing with each other. These kinds of patterns with low richness are common in rivers that run through cities. Human activities and habitat loss are bad for aquatic biodiversity (Paujiah *et al*., 2019).

Figure 3 illustrates the level of fish species similarity across sampling stations in Madiun City. Dark blue shows high similarity index values, which means that the fish communities at those stations are very similar. Light green shows low values, which means that the fish communities at those stations are very different. According to (Odum, 1993), the criteria for the Species Similarity Index are as follows: 1-30% indicates low similarity, 31-60% moderate, 61-91% high, and values above 91% are categorized as very high (Erlangga *et al*., 2023). The highest similarity value was recorded between Stations 2 and 9, with an IS of 94%, falling within the very high category. These two stations share dominant species including *Rasbora argyrotaenia*, *Gambusia affinis*, *Mystus singaringan*, and *Labiobarbus leptocheilus*. Field observations confirm that both stations are located along the same river flow, suggesting that the similarity of fish communities is primarily influenced by the connectivity of the habitats and the consistency of environmental factors (Latuconsina *et al*., 2022). Aquatic connectivity facilitates the exchange and dispersal of individuals among sites, particularly for eurytopic species that can tolerate a wide range of physical and chemical conditions. This corroborates the overarching ecological trend that locations within the same river system typically display elevated similarity indices (Anggraini *et al*., 2019). Even though Stations 2 and 5 have a high similarity index of 89%, they are not connected by the same waterway. This phenomenon can be attributed to similar habitat structures and environmental characteristics shared between the two stations. Species that are found in many places and can live in different environments, like *Pterygoplichthys pardalis*, *Gambusia affinis*, and *Rasbora argyrotaenia*, help make this pattern by making similarity values higher even in habitats that are not connected (Jourdan *et al*., 2021; Parawangsa *et al*., 2022; Patoka *et al*., 2020; Rosadi *et al*., 2014).

CONCLUSION

This study shows that the aquatic ecosystems in Madiun City have a low to moderate number of different fish species, which suggests that there are different levels of ecological stress at the different sampling sites. The dominance of the invasive species *Pterygoplichthys pardalis* at certain stations, particularly Station 4, has resulted in low evenness and high dominance values, reflecting ecological imbalance and reduced stability of native fish communities. Stations 7 and 8, on the other hand, had moderate richness and higher diversity indices. This is probably because they have more complex habitats and better environmental quality. The Species Similarity Index analysis showed that stations in the same river flow, like Stations 2 and 9, were very similar because the water flow connects them and helps species spread. However, the similarities between unconnected stations, like Stations 2 and 5, were mostly due to the fact that species like *Pterygoplichthys pardalis*, *Gambusia affinis*, and *Rasbora argyrotaenia* are found in many places and can live in many different environments. Overall, Madiun City's waters are still mostly home to native species. However, the presence of non-native and invasive species is becoming a bigger threat to the biodiversity of native species. This shows how important it is to manage habitats sustainably, control pollution, and regulate introduced species to keep the ecosystem in balance and support food security based on biodiversity.

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AUTHOR CONTRIBUTIONS

SPPSN: Creating research concept, collecting research data, drafting article, revising final manuscripts; MHAB: Collecting research data, verifying research data; LDP: Creating research concepts, drafting articles, revising manuscripts.

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