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Population and distribution pattern of *Poropuntius tawarensis* in Lake Laut Tawar, Central Aceh Regency

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ABSTRACT

Poropuntius tawarensis is an endemic fish of Laut Tawar that is currently classified as Endangered according to the IUCN Red List. The decline in its population is caused by habitat degradation, overfishing, and the introduction of alien species that act as predators This study aims to analyze the diversity and distribution patterns the population of kawan fish (*Poropuntius tawarensis)* in Lake Laut Tawar, Central Aceh Regency. Fish samples were collected from four different locations and analyzed using the Shannon-Wiener and Morisita indices. The results indicate that the diversity level of kawan fish (*Poropuntius tawarensis)* is classified as a "Low level of diversity," with significant differences between sampling locations. All locations (Hakim Balai Bujang: 0.796845; Toweren: 0.301815; Kelitu: 0.753952; Kala Segi: 0.467728) show a low level of diversity, which is H' <1. Analysis using the Standardized Morisita Index indicates that the distribution pattern of kawan fish (*Poropuntius tawarensis)* in the four study locations tends to be clumped dispersion. This is evidenced by Morisita index values greater than 1 at all sites (Hakim Balai Bujang: 1.2834; Toweren: 1.0212; Kelitu: 1.0053; Kala Segi: 1.0134). These values suggest that the fish tend to concentrate in specific areas within each village rather than being evenly distributed.

Introduction

Lake Laut Tawar, located in Central Aceh Regency, is one of the vital freshwater habitats in the region. As a home to diverse aquatic ecosystems, the lake serves as a primary buffer for regional biodiversity, playing a crucial role in maintaining environmental balance (Amri *et al.*, 2023; Grantham *et al.*, 2019). Among the diversity of species present, kawan fish (*Poropuntius tawarensis)* stands out as one of the prominent endemic fish species that are highly important in the dynamics of the lake's ecosystem. (Mellisa *et al.*, 2022; Muthmainnah *et al.*, 2019). Its role in maintaining the ecological balance of the lake cannot be underestimated. However, amidst the beauty and biodiversity of Lake Freshwater, there are several looming issues.

One of the main problems faced is the overexploitation of fish. (Adhar *et al.*, 2021). Uncontrolled fishing practices and unsustainable harvesting activities have led to a decline in fish populations, including the kawan fish *(Poropuntius tawarensis)* species, which is the focus of our research.(Bănăduc *et al.*, 2022; Y. Li *et al.*, 2020). This condition raises concerns about the possibility of even greater ecological imbalance, threatening the sustainability of the lake and the life of fish within it. (Bănăduc *et al.*, 2022).

In addition to the problem of overexploitation of fish, another challenge faced is habitat degradation due to human activities. (Melo-Merino *et al.*, 2020). Water pollution, changes in land use around the lake, and unsustainable farming practices are some of the factors that have the potential to damage the lake ecosystem and fish habitats within it (Muchlisin, 2020; Purwanto *et al.*, 2022). Therefore, a deep understanding of the population dynamics and

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spatial distribution of kawan fish (*Poropuntius tawarensis)* is crucial in conservation efforts for the lake and environmental sustainability in the region(Yousefi *et al*., 2020).

In response to the existing knowledge gap, this research aims to conduct a detailed study on the complexity of population dynamics and spatial distribution patterns of kawan fish (*Poropuntius tawarensis)* in Laut Tawar Lake, Central Aceh Province. Considering various challenges in maintaining lake biodiversity, including factors such as overfishing and habitat degradation, a profound understanding of this endemic fish population becomes increasingly important (Gu *et al*., 2023; Zhang *et al*., 2023). The main objective of this research is to analyze the diversity, and distribution patterns the population of kawan fish (*Poropuntius tawarensis*) in Lake Laut Tawar, Central Aceh Regency.

To achieve this goal, we introduce reliable analysis methods, namely the Shannon-Wiener diversity index and the Morisita dispersion index. (Butturi-Gomes & Petrere, 2020; W.-P. Li *et al*., 2021). This method has proven effective in revealing the complex population structure and spatial distribution of species in different natural habitats. By employing this approach, we aim to uncover potential distribution patterns in various parts of the lake and identify the relationship between habitat characteristics and fish abundance.

Materials and Methods

Location and time of research

This research was conducted in the freshwater ecosystem of Laut Tawar Lake, Central Aceh District, with an area of 5,742 hectares divided into 4 sub-districts: Bintang, Laut Tawar, Kebayakan, and Bebesen. The study was conducted from January 5th to March 10th, 2024, starting with field data collection, data processing, and data presentation.

Based on interviews with local residents, the villages of Hakim Balai Bujang, Toweren, Rawe, Bewang, Kelitu, and Kala Segi are the places where the kawan fish *(Poropuntius tawarensis)* fish are most frequently caught by fishermen. After the researchers conducted initial observations in six villages, only four villages—Hakim Balai Bujang, Toweren, Kelitu, and Kala Segi—were selected as the study sites. This decision was made because the observations revealed that only in these four villages were the kawan fish *(Poropuntius tawarensis)* fish caught by fishermen. Hakim Balai Bujang village is located in the western part of the lake and has easy accessibility. The village is situated near densely populated areas, making it convenient for researchers to conduct observations and collect samples (Figure 1 and Figure 2).

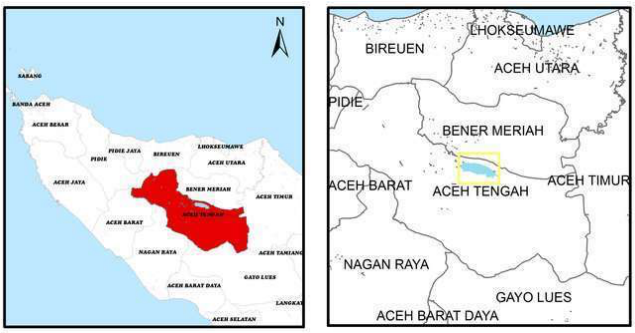

Figure 1. Maps showing the location (Yellow square) of Laut Tawar Lake, the site of this study

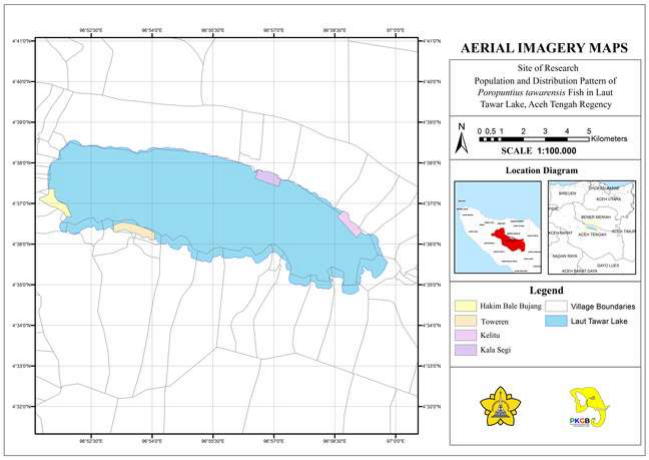

Figure 2. Site of Location Exploration

The village of Toweren is located in the southwestern part of the lake and boasts diverse freshwater habitats. The residents of this village are primarily engaged in paddy farming near the lake's edge, providing an opportunity for researchers to study the interaction between agricultural activities and the fish population.

Kelitu village is situated in the northeastern part of the lake and has a shoreline close to tourist attractions. With a high population of kawan fish *(Poropuntius tawarensis)* and significant tourism potential, researchers can investigate the impact of tourism on the fish population.

Kala Segi village, located in the eastern part of the lake, is still abundant with large trees, some of which are coffee plantations. This village maintains a natural and preserved habitat, allowing researchers to study the ecology of the kawan fish *(Poropuntius tawarensis)* in an environment undisturbed by human activities.

The research utilized a variety of materials to effectively conduct fieldwork and data collection in Laut Tawar Lake. These materials included gill nets, digital cameras, boats, buckets, and writing utensils.

Gill nets played a crucial role in capturing samples of kawan fish (*Poropuntius tawarensis*), the focal species of the study. These nets were strategically deployed in the lake's waters to collect representative samples for further analysis.

Digital cameras were employed for visual documentation throughout the research process. They were utilized to capture images of fish habitats, sampling locations, and various stages of the research activities, aiding in detailed documentation and analysis. Boats served as essential transportation and operational platforms, enabling researchers to navigate the waters of Lake Freshwater efficiently. They facilitated the deployment and retrieval of gill nets, ensuring comprehensive coverage of sampling areas.

Buckets were utilized to contain captured fish specimens for subsequent measurement and observation. This allowed researchers to conduct detailed examinations and collect pertinent data on the captured individuals. Writing utensils were indispensable tools for recording vital information during fieldwork. Researchers utilized them to document observation data, measurement results, and other crucial details, ensuring accurate and comprehensive record-keeping throughout the research process.

Data analysis

The approach adopted in this research is quantitative in nature. Quantitative research is a systematic, planned, and structured approach that heavily relies on numerical data, from data collection to interpretation and analysis, often accompanied by figures, tables, and graphs. Statistical analysis is employed to analyze the data and draw conclusions (Ahyar *et al.*, 2020). The type of research conducted is basic research, which involves the pursuit of knowledge for the sake of understanding the outcomes of an activity out of curiosity.

The data obtained are described quantitatively. Community indices are calculated based on the formulas presented in the Shannon-Wiener diversity index and the Morisita dispersion index. (Butturi-Gomes & Petrere, 2020; W.-P. Li *et al.*, 2021)

The diversity index of the Kawan fish *(Poropuntius tawarensis)* fish can be analyzed using the Shannon-Wiener equation. (Larekeng *et al.*, 2022; W.-P. Li *et al.*, 2021; Shannon, 1948; Sun & Ren, 2021):

$$H' = -\sum pi \ln pi$$

Where:

H' = The diversity index of the Poropuntius tawarensis fish
Pi = The proportion of each species in the sample

Diversity index criteria (Dharmawan *et al.*, 2022; Feranchuk *et al.*, 2018) :

- H' <1: Low level of diversity
- H' 1–3: Moderate level of diversity
- H' >3: High level of diversity.

The distribution pattern is determined using the Morisita dispersion indeks (Abd El-Aal *et al.*, 2020; Arismaya Metananda *et al.*, 2015; Larekeng *et al.*, 2022).

$$Id = \frac{N\sum X^2 - \sum X}{(\sum X)^2 - \sum X}$$

Where:
Id = Morisita dispersion index
N = Total number of plots
X = Number of species in one plot

Kiteria distribution pattern (D'Amato *et al.*, 2023):

- Id < 1: Uniform dispersion
- Id = 1 : Random dispersion
- Id > 1 : Clumped dispersion

$$\text{Uniformity indeks} = M_u = \frac{X^2_{0,975-n+\sum X_i}}{(\sum X_i)-1}$$

$$\text{Clustering indeks} = M_c = \frac{X^2_{0,025-n+\sum X_i}}{(\sum X_i)-1}$$

$X^2 0.975^{-n}$ = The value from the table with df (n-1) which has 97.5% area to the right of the curve
$X^2 0.025^{-n}$ = The value from the table with df (n-1) which has 2.5% area to the right of the curve
$\sum Xi$ = The sum of organisms in square i (i=1,.....n)
n = The number of squares

Based on the results of the Mc or Mu index above, the standard Morisita index (Ip) is calculated based on one of the following four equations (Adnan *et al.*, 2021; de Freitas Alves & de Santana, 2022):

- If Id ≥ Mc > 1: Ip = 0,5 + 0,5 ((Id-Mc)/(n-Mc))
- If Mc > Id ≥ 0: Ip = 0,5 ((Id-1)/(Mc-1))
- If 1 > Id > Mu: Ip = -0,5 ((Id-1)/(Mu-1))
- If 1 > Mu > Id: Ip = -0,5 + 0,5 ((Id-Mu)/Mu)

The standardized Morisita index (Ip) ranges from -1 to 1. If Ip = 0, then the distribution pattern is random. If Ip < 0, then the distribution pattern is uniform, and if Ip > 0, then the distribution pattern is clumped. (Arismaya Metananda *et al.*, 2015; Quinteros-Gómez *et al.*, 2023; Utari *et al.*, 2023). Sampling was conducted using gill nets with a mesh size of 3/4 inch, a length of 100 meters, and a width of 0.5 meters (1 hasta). Each station had three transect plots, with one net installed on each transect. The nets were set along the predetermined Belt Transect path, which was drawn perpendicular to the shoreline with a length ranging from 10 to 20 meters and a width of 5 meters. The nets were set up at 6:00 PM and retrieved the next day at 6:00 AM. Sampling was performed at three different points in each site, namely site 1 in Hakim Balai Bujang village, site 2 in Toweren village, site 3 in Kelitu village, and site 4 in Kala Segi village. After fish samples were collected using randomly thrown nets. The obtained fish samples were counted, and the number of individuals was recorded in an observation table. Subsequently, the collected data were analyzed and documented.

Results

The data obtained consists of three hundred and ninety-seven individuals. This data was collected from four different locations. At each location, three sampling sites were designated. The results obtained vary at each sampling site. Each sampling site shows different results based on the distance from the lake edge to the sampling area. The sampling results data can be seen in Figure 3.

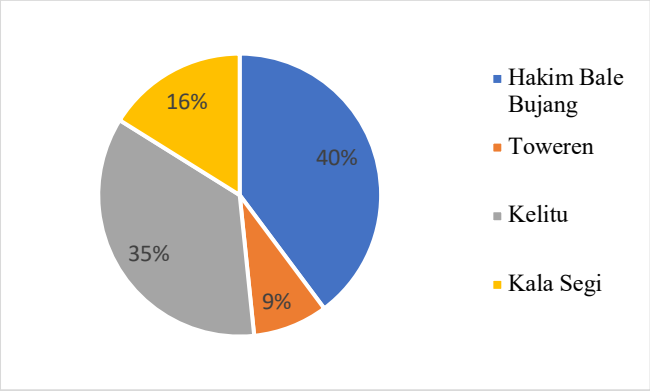

Figure 3. Grafik Samples Obtained

Based on the graph above, the total number of kawan fish (*Poropuntius tawarensis)* obtained is 397 individuals. Specifically, there were 158 individuals from Hakim Balai Bujang, 34 from Toweren, 141 from Kelitu, and 64 from Kala Segi. This results in a percentage distribution of 40% from Hakim Balai Bujang, 9% from Toweren, 35% from Kelitu, and 16% from Kala Segi. The village with the highest fish population is Hakim Balai Bujang, while the village with the lowest fish population is Toweren.

Analyzing the data diversity using Excel allows for quick and accurate calculations, especially for the Shannon-Wiener equation. Excel also speeds up the process of determining distribution patterns through Data Distribution Pattern analysis. The results of this analysis can then be utilized in Geographic Information System (GIS) applications such as ArcGIS. The use of ArcGIS helps in visualizing data distribution in a more detailed and clear manner, enriching understanding of the observed distribution patterns.

Discussion

Population

Analysis of diversity was conducted on 4 sites. Based on the use of Shannon-Wiener, the results obtained for the diversity level of *Poropuntius tawarensis* fish can be seen in Table 1.

The diversity level of *Poropuntius tawarensis* found in this study is classified as low level of diversity (Dharmawan *et al.*, 2022). However, based statistic test obtained significant differences are observed among different sampling locations. The results indicate that the highest diversity index is recorded in the waters of Hakim Balai Bujang village, while the lowest index is found in Toweren. Sampling locations in Hakim Bale Bujang, Toweren, Kelitu, and Kala Segi villages all show diversity index values falling into the category of low level of diversity (Dharmawan *et al.*, 2022).

Table 1 Diversity Index of *Poropuntius tawarensis* Fish

Site	Village	H'	Category
1	Hakim Bale Bujang	0.796845	low level of diversity
2	Toweren	0.301815	low level of diversity
3	Kelitu	0.753952	low level of diversity
4	Kala Segi	0.467728	low level of diversity

This finding provides important insights into the distribution and diversity of the *Poropuntius tawarensis* population along Lake Laut Tawar. Environmental factors such as habitat conditions, water quality, and anthropogenic pressures may contribute to differences in population diversity at various locations.

Based on interviews with local residents, it was revealed that the decline in fish numbers is caused by chemical pesticide pollution originating from agricultural practices around the lake. Coastal farmers use chemical pesticides to control pests on their crops, which then flow into the lake waters. As a result of this pollution, there are physical and chemical changes in the fish habitat (Abd El-Aal *et al.*, 2020; Rad *et al.*, 2022). In addition, several fish breeding grounds have been covered with fish traps along the lake's coastline. Furthermore, the coverage of the lake's coastline by *Eichornia crassipes*, a type of aquatic plant, is also a problem. This plant can deplete excessive oxygen in the water, leading to a decline in water quality that negatively impacts fish populations. When this plant covers the water surface extensively, the excessive photosynthesis process by *Eichornia crassipes* can deplete the available oxygen in the water, especially at night when the plant is not undergoing photosynthesis (Masese, FO.; Raburu, P.O.; Kwena, 2012). As a result, this can lead to a decrease in dissolved oxygen levels in the water, which can have a negative impact on aquatic life, including fish populations.

The results of the diversity analysis of Poropuntius, indicating low levels of diversity, provide important insights into the population status and habitat of this species in Lake Laut Tawar. These findings are consistent with previous literature indicating a decrease in species diversity in several freshwater ecosystems affected by human activities. This discussion highlights the need for more proactive conservation measures to protect and restore habitats and maintain the sustainability of Poropuntius populations in their natural environment. Additionally, further research is needed to gain a deeper understanding of the factors influencing the diversity of this species, as well as to design more effective conservation strategies to address the ecological challenges faced by this species in the future.

Distribution Pattern

Based on the results of the Morisita dispersion index (Id) analysis, the data analysis of distribution patterns can be seen in Figure 4.

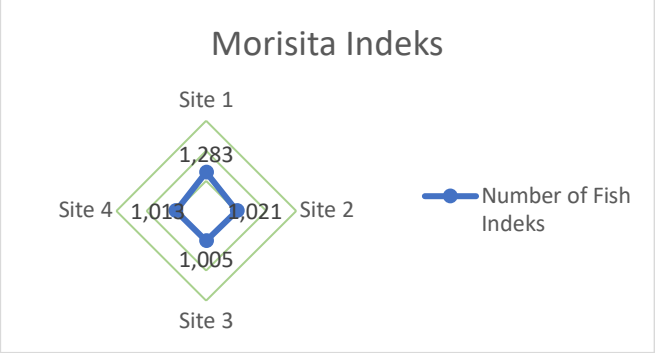

Figure 4. Morisita indeks of *Poropuntius* tawarensis

Figure 4 shows that the values of Id for the four observation locations (site 1, 2, 3, and 4) are 1.283, 1.021, 1.005, and 1.013 respectively. By using dispersion categories, it can be concluded that the dispersion patterns in Hakim Balai Bujang, Toweren, Kelitu, and Kala Segi villages fall into the category of clumped dispersion (Jaman *et al.*, 2023). Visualizing data distribution in more detail and clarity using the Geographic Information System (GIS) application ArcGIS. The areas of the Morisita index levels can be seen in Figure 5.

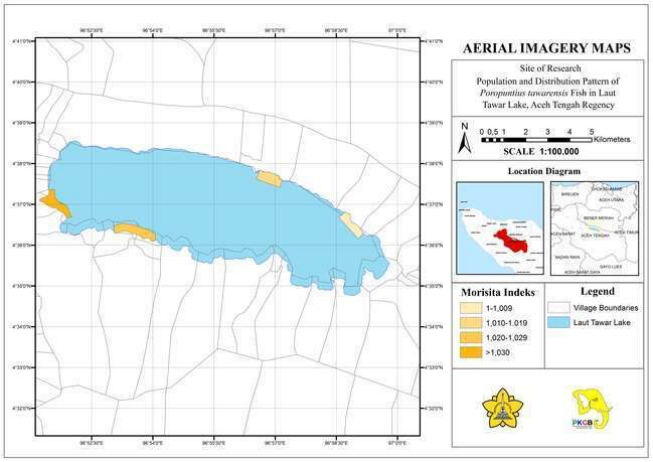

Figure 5. Map Distribution Pattern at 4 site on Laut Tawar Lake

Based on Figure 5, specifically, the observation locations tend to exhibit a tendency to have tight or concentrated clusters, meaning that observation points tend to cluster in certain areas around the observation locations. The mentioned observation locations, namely Hakim Balai Bujang (site 1), Toweren (site 2), Kelitu (site 3), and Kala Segi (site 4), all show similar dispersion patterns, with observation points tending to cluster in limited areas. The brighter the color of the site area, the closer it is to Random dispersion. The darker the site area, the higher the Clumped dispersion of fish. Next, we conducted a Standard Morisita index (Ip) to examine significant differences in community structure or species diversity between different conditions. The

results of the Standard Morisita index test can be seen in Table 2.

Table 2 Standardized Morisita indeks

Site	Mu	Mc	Id-1	Mc-1	Ip	Category
1	10.06	9.18	0.2834	8.18	0.0173	Clumped dispersion
2	14.05	9.86	0.0212	8.86	0.0012	Clumped dispersion
3	10.19	9.20	0.0053	8.20	0.0003	Clumped dispersion
4	11.64	9.45	0.0134	8.452	0.0008	Clumped dispersion

Where :
Id : Morisita indeks of dispersion
Mu : Morisida indeks for uniform distribution pattern
Mc : Morisida indeks for clustered distribution pattern
Ip : Standardized morisita indeks

Based on Table 2, displaying the differences in Standard Morisita index (Ip) values between observation locations, indicates variation in the distribution patterns of observation points in the observed area. The Ip calculation is based on the category Mc > Id ≥ 0. Therefore, all sites use the formula Ip = 0.5 ((Id-1)/(Mc-1)). Locations with higher Ip values (site 1) indicate stronger concentration or clustering, indicating lower diversity levels. Meanwhile, Ip values approaching zero at other locations (sites 2, 3, and 4) depict more uniform and homogeneous distribution patterns, where observation points are evenly scattered around the observation area.

The results of the Ip analysis provide a clear picture of the distribution pattern structure at each observation location. Hakim Balai Bujang (site 1), Toweren (site 2), Kelitu (site 3), and Kala Segi (site 4). This information can be highly valuable in the context of environmental management, spatial planning, and conservation efforts, enabling the identification of areas that require special attention for habitat restoration or protection, as well as the development of sustainable management strategies.

Conclusion

The population of kawan fish (*Poropuntius tawarensis)* in Lake Laut Tawar and finds variation in diversity levels across different research sites. According to the analysis, the diversity level in the waters of the villages of Hakim Balai Bujang, Toweren, Kelitu, and Kala Segi is categorized as 'low level of diversity'. This indicates that the variation of this fish species at these locations is limited.

Distribution pattern analysis shows that kawan fish (*Poropuntius tawarensis)* tends to concentrate in specific areas, with the distribution pattern categorized as 'clumped dispersion'. This suggests that this fish species is not evenly distributed throughout the lake but is more frequently found in groups at specific locations.

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