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Biodiversity of the ichthyofauna in the estuary area of Padang, West Sumatra, Indonesia

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Abstract. *Kamal E, Lubis AS, Mayzuri Z, Hertati R. 2025. Biodiversity of the ichthyofauna in the estuary area of Padang, West Sumatra, Indonesia. Biodiversitas 26: 2621-2630.* Estuaries are transitional ecosystems between marine and terrestrial environments, characterized by high biodiversity and a crucial role in maintaining aquatic ecosystems. This study aimed to identify the diversity, distribution patterns, and environmental influences on ichthyofauna in the estuaries of Padang, West Sumatra, Indonesia. Fish sampling was conducted in five estuarine sites from July to December 2024 using habitat-specific fishing gear, while water quality parameters, including temperature, salinity, pH, and dissolved oxygen, were measured in situ. Data analysis included species identification, Shannon-Wiener Diversity Index, Evenness Index, Simpson Dominance Index, and correlation and regression tests to evaluate the relationship between environmental factors and ichthyofauna biodiversity. Results indicate varying fish distribution across sites, with Teluk Buo exhibiting the highest diversity (H': 3.27), while the Batang Arau River Estuary showed species dominance and low diversity. The highest Evenness Index was recorded in the Batang Arau and Anai River Estuaries, where the highest Simpson Dominance Index was found in the Anai River and Batang Arau estuaries, primarily dominated by *Rasbora* sp. (28 individuals) and *Ambassis tetra* (21 individuals). Fish distribution was influenced by environmental factors such as food availability, habitat complexity, water quality, and interspecies interactions. More structurally complex habitats supported higher biodiversity, while disturbances like pollution, overfishing, and habitat degradation led to species dominance and reduced biodiversity.

Keywords: Biodiversity, estuaries, fish distribution, ichthyofauna

INTRODUCTION

Estuary areas are transitional ecosystems between marine and terrestrial environments, characterized by high biodiversity. This ecosystem is crucial for maintaining aquatic balance, serving as a spawning, nursery, and growth habitat for various aquatic species, including fish (Swadling et al. 2022; Nashima et al. 2023; Brink and Van Leeuwen 2024). Ichthyofaunal biodiversity in estuaries not only reflects local ecological conditions but also supports the economic and social well-being of communities reliant on fishery resources. This biodiversity is strongly influenced by environmental factors such as salinity, temperature, water quality, and nutrient inflow from rivers (Nascimento et al. 2021; Nana et al. 2023; Strydom et al. 2023). Moreover, the interaction between physical, chemical, and biological factors in estuaries creates a unique habitat that supports a diverse range of fish species. Estuaries are recognized as hotspots of tropical aquatic biodiversity but are highly vulnerable to environmental changes caused by both human activities and natural phenomena (Manna et al. 2012; Bradley et al. 2016).

Estuaries in West Sumatra, Indonesia, are important ecosystems that act as habitats for various fish species and are also spawning and rearing areas for marine biota. The main estuaries in this region have high biodiversity supported by river flows from upstream areas that carry important nutrients (Freeman et al. 2019; Laurino et al. 2021). This ecosystem also has high economic value for coastal communities that depend on the fisheries and aquaculture sectors. However, estuaries in West Sumatra face various environmental pressures due to human activities, such as urbanization, domestic and industrial waste pollution, and land conversion for infrastructure development and ponds (Kamal et al. 2024). Changes in environmental quality can disrupt the balance of the estuary ecosystem, reduce biodiversity, and impact the sustainability of fisheries resources (Firdaus et al. 2023).

Padang, located along the west coast of West Sumatra, has various estuaries that are habitats for various types of fish. This area also plays an important role as a fisheries center and economic source for coastal communities. However, the pressure of human activities such as urbanization, land conversion, domestic and industrial waste pollution, and exploitation of fishery resources has posed serious threats to biodiversity in the estuary area of Padang City (Yatno et al. 2019; Firdaus et al. 2023; Kamal et al. 2023). Research on the biodiversity of ichthyofauna in the estuary of Padang City is still limited, although this area has great potential as a conservation and sustainable

management area. Data on species composition, community structure, and fish distribution are needed to provide a more comprehensive ecological picture. This information is also important in supporting science-based coastal resource management policies (Abidin et al. 2022).

The presence of various fish species in estuaries also serves as an indicator of the health of aquatic ecosystems. Analysis of the structure of the ichthyofauna community can reveal the impact of human activities on the ecological balance in this area (Brink and van Leeuwen 2024; Koval 2024). In addition, data on the presence of endemic or endangered species can be the basis for designing more effective conservation strategies. By identifying the current state of biodiversity and the threats it faces, this study can serve as a reference for formulating sustainable environmental policies. This is very relevant considering the importance of estuarine ecosystems as a regional economic and ecological support (França and Cabral 2019; Laurino et al. 2021; Demchenko and Demchenko 2023).

Changes in environmental quality in the estuary of Padang City not only affect the local ecosystem but also have implications for the availability of fish resources, which are a source of livelihood for local communities. Previous studies have shown that environmental factors such as salinity and dissolved oxygen greatly determine the distribution of ichthyofauna in estuary areas (O'Mara et al. 2016; Freeman et al. 2019; Pessanha et al. 2021). However, in-depth and specific research on how these factors affect biodiversity in the Padang City estuary is still needed. Thus, the research conducted provides not only valuable scientific information but also contributes to biodiversity conservation efforts and sustainable fisheries management. Therefore, this study aimed to identify the biodiversity of ichthyofauna, analyze its distribution patterns, and evaluate the relationship with environmental parameters in estuarine areas.

MATERIALS AND METHODS

Study area

This research was conducted from July to December 2024. The location of this research is the estuary area in Padang City, West Sumatra, Indonesia, divided into five stations and repeated five times (Figure 1). Station I is the estuary area in Muara Anai, Station II is the estuary area in Pasir Jambak, Station III is the estuary area in Muara Kuranji, and Station IV is the estuary area in Muara Padang. Station V is the estuary area in Teluk Buo.

Data collection

The sampling method in this study was carried out using a survey and observation approach in the estuary area of Padang City, West Sumatra, Indonesia. Fish sampling was carried out at several stations selected based on habitat characteristics, including estuary waters, muddy areas, and areas with mangrove vegetation. The selection of stations was based on environmental variations that could affect the composition of ichthyofauna biodiversity. Sampling was carried out using various fishing gear that was adjusted to the type of habitat and the size of the targeted fish. The fishing gear used included gill nets to catch fish moving in the water column, bubu traps to catch fish that were more active at the bottom of the water and cast nets to catch small fish species in shallow areas. In addition, the electrofishing method was used selectively to obtain fish samples from areas with complex substrates, such as muddy and rocky waters.

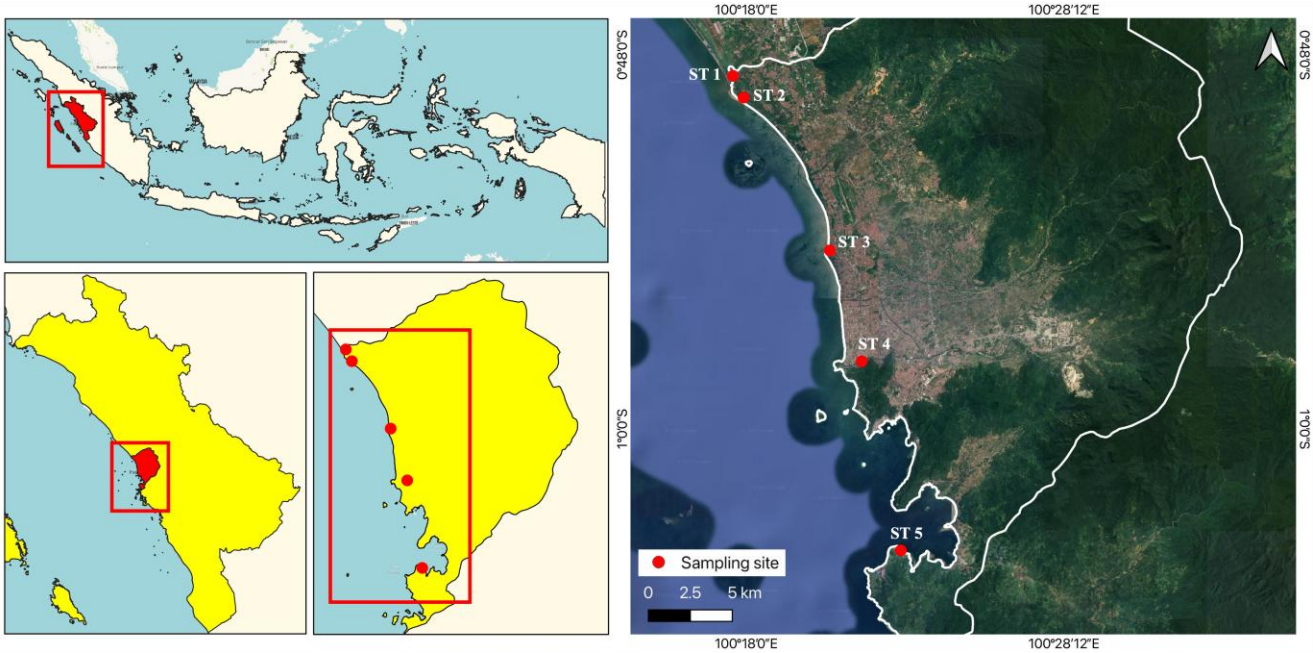

Figure 1. Location of the estuary area in Padang City, West Sumatra, Indonesia

Water quality data collection was conducted in situ at each ichthyofauna sampling station to understand the relationship between environmental parameters and biodiversity in the estuary area of Padang City. The physical and chemical parameters of water measured included temperature, salinity, pH, and Dissolved Oxygen (DO). Measurements were made using portable water quality tools such as to obtain accurate and real-time data. Water temperature and pH were measured using a digital pH meter EZ-9909 that was calibrated before use. Salinity was measured using a refractometer, Atago Master S/Mill M, to understand the effect of seawater on the estuary environment. Dissolved Oxygen (DO) was measured using a DO meter DO9100.

Data analysis

The data obtained from this study were analyzed to understand the structure of the ichthyofauna community and the relationship between environmental parameters and biodiversity in the estuary area of Padang City. The analysis began with the identification of fish species based on morphological characters using taxonomic guidelines (Peristiwady and Fahmi 2015). The identification results were then used to compile a list of species, which includes the scientific name, family, and ecological category of each species.

The diversity of ichthyofauna communities was analyzed using the Shannon-Wiener Index (H'), which describes the level of species diversity in estuarine ecosystems. This index is calculated using the formula of Berger and Parker (1970):

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

Where, *pi* is the proportion of individuals of species ii to the total individuals found; a high *H'* value indicates a more stable and diverse ecosystem, while a low value indicates the dominance of a particular species or the presence of environmental pressure.

The Evenness Index (E) is calculated to determine the relative distribution of species in the community using the formula of Ulfah et al. (2019):

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

Where, S is the total number of species found, an E value close to 1 indicates that individuals are evenly distributed among species. In contrast, a value close to 0 indicates the dominance of a particular species.

Simpson Dominance Index (D) is also calculated to identify the most dominant species in the community. This index is calculated using the formula of Berger and Parker (1970):

$$D = \sum_{i=1}^{s} Pi2$$

A high D value indicates that a few species dominate the community, while a low value indicates a more even community.

To analyze the relationship between water quality and ichthyofauna biodiversity, Pearson correlation analysis or regression analysis was used to test the relationship between water physicochemical parameters (temperature, pH, salinity, and dissolved oxygen) with species diversity and abundance indices. All data analysis was performed using SPSS software version 26.0 and Python to ensure accurate results and deeper interpretation. Python was used for diversity analysis by calculating the Shannon-Wiener Index, Evenness Index, and Simpson Dominance Index. SPSS was used for statistical testing of the relationship between water quality and ichthyofauna biodiversity using regression analysis.

RESULTS AND DISCUSSION

Distribution of ichthyofauna

The stations studied included Anai River Mouth, Pasir Jambak, Batang Kuranji River Mouth, Batang Arau River Mouth, and Teluk Buo, with different species variations at each location. Figure 2 displays a heatmap showing the distribution of ichthyofauna species at 5 sampling stations in the estuary area of Padang City. The colors in the heatmap indicate the relative abundance of each species at various locations, with darker colors indicating higher numbers of individuals.

Figure 2 shows that the Anai River Mouth has a dominant *Rasbora* sp., with the highest number reaching 28 individuals. In addition, the *Ambassis tetra* species also has a high abundance (21 individuals). In contrast, other species, such as *Leiognathus equulus* and *Ambassis naula*, were found in lower numbers. This showed that this area is a suitable habitat for freshwater and estuarine fish species. In Pasir Jambak, the most abundant species is *Channa striata* with 14 individuals, followed by *A. tetra* with 10.5 individuals. Other species, such as *Toxotes jaculatrix* and *Hemibagrus nemurus*, were also found, although in smaller numbers. This showed that the fish community in this area is more diverse, with a relatively even distribution of species compared to other stations. Muara Kuranji River shows the dominance of the *L. equulus* species with 22 individuals. Unlike other stations, almost no other species were found at this location, except for *Eleutheronema tetradactylum*, which was found in small numbers. This may be due to environmental factors that are less supportive of species diversity, such as water quality or more extreme salinity levels. Meanwhile, Batang Arau River Mouth showed very low species diversity. The species found in significant numbers was *L. equulus* with 8.5 individuals, while other species were almost not found. This indicates that this area may have higher environmental pressure or habitat factors that are less suitable for most fish species.

Buo Bay showed a more varied species abundance compared to other stations. *Leiognathus equulus* had the highest abundance (19.5 individuals), followed by *C. striata* (13 individuals) and *H. nemurus* (10 individuals). In addition, several other species, such as *Mystus nigriceps* and *Eleutheronema hexapterus,* were also found in quite

significant numbers, indicating that this area has environmental conditions that are more supportive of fish biodiversity. This analysis indicates that there are differences in species abundance and distribution between stations, which are most likely influenced by environmental factors such as salinity and habitat structure. Areas with higher diversity, such as Teluk Buo and Pasir Jambak, may have more stable ecosystem conditions compared to Muara Batang Kuranji River and Muara Batang Arau River, which show the dominance of certain species with low diversity.

Diversity index in the estuary area of Padang

Figure 3 shows the Shannon-Wiener Diversity Index (H') values at five sampling stations in the estuary area of Padang City. This index reflects the diversity of fish species found at each research location. Station V has the highest diversity index value (H': 3.27), indicating that this location has a more diverse fish community than other stations. High diversity can indicate a more stable ecosystem with a more even species distribution. Stations II and I also have relatively high levels of diversity, with H' values of 2.77 and 2.59, respectively. This indicates that the fish communities in these two locations are quite diverse and are not dominated by one particular species. In contrast, Station III and Station IV have much lower diversity indices, of 1.35 and 1.31, respectively. This value indicates that the number of species found at this location is lower or their distribution is uneven, which may be caused by environmental pressure or other ecological factors. The low diversity values at Stations III and IV may be caused by less supportive environmental conditions, such as poorer water quality, pollution, or pressure from anthropogenic activities around the location. In contrast, Station V, which has the highest diversity index, may have better environmental conditions, such as more stable water quality, the presence of vegetation that supports fish habitat, or lower levels of disturbance compared to other locations.

Evenness Index value of ichthyofauna in the estuary area of Padang

Figure 4 shows a graph of the Evenness Index (E) values of the ichthyofauna at five sampling stations in the Padang City estuary. The Evenness Index measures the extent to which individuals in a community are evenly distributed among the species present. Station III has the highest Evenness Index value of 0.4491, followed by Station IV with a value of 0.4369. This indicates that the distribution of individuals between species at these two locations is more even compared to the other stations. Stations I, II, and V have lower Evenness Index values of 0.3234, 0.2765, and 0.2977, respectively. These lower values indicate the dominance of certain species at these locations, so the distribution of individuals among species is even smaller. The low Evenness Index at Station II (0.2765) indicates that there are one or several species that dominate the population, while other species have many fewer individuals. Certain environmental factors or ecological pressures can cause this. On the other hand, the high Evenness Index at Stations III and IV indicates that the population at both locations is more ecologically stable, with a more balanced species distribution. This is often associated with environmental conditions more supportive of species diversity. Low Evenness Index values at some locations can indicate ecosystem disturbances, such as habitat changes, pollution, or resource exploitation that cause certain species to be more dominant than others. A high Evenness Index usually indicates a healthier and more well-functioning ecosystem because no species dominates excessively. Therefore, the E value can be used as an early indicator in assessing the quality of the aquatic environment.

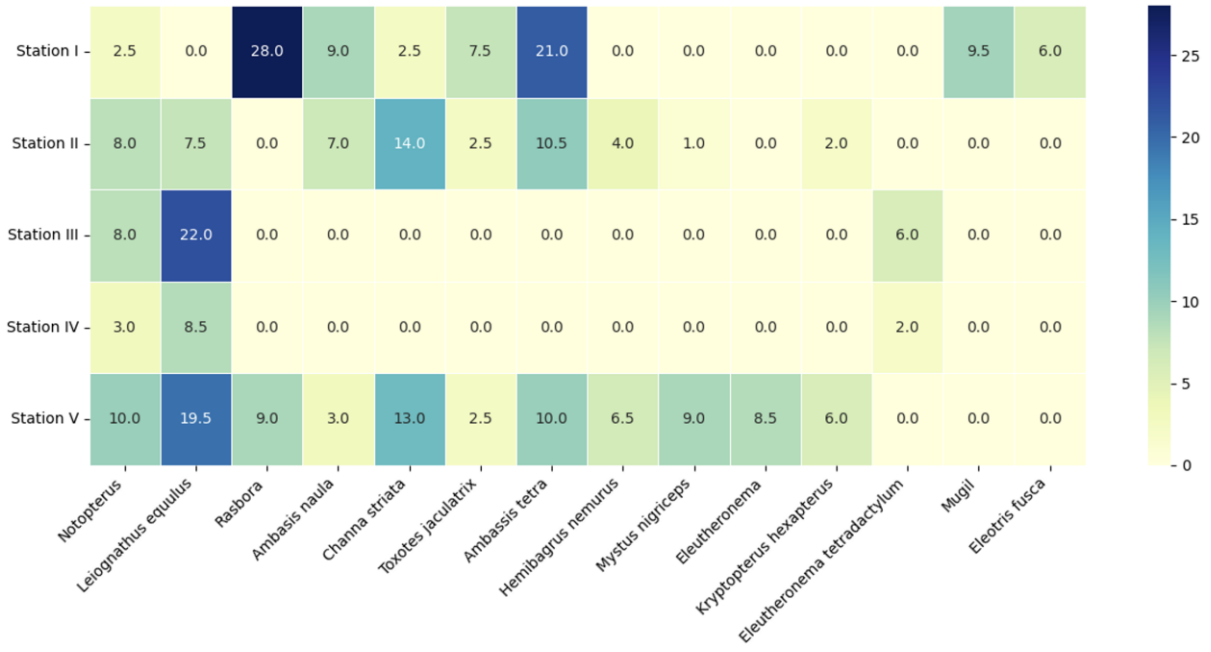

Figure 2. Distribution and abundance of ichthyofauna species in the estuary of Padang, West Sumatra, Indonesia

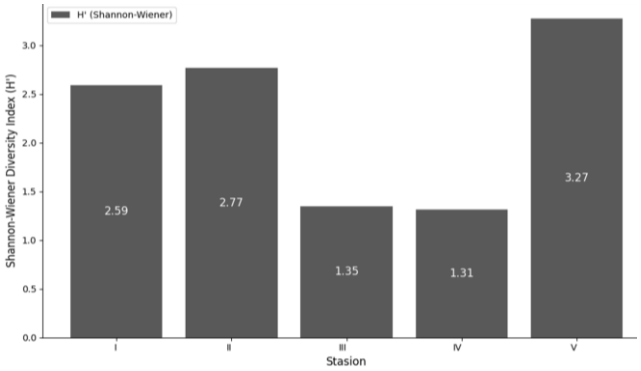

Figure 3. Shannon-Wiener Diversity Index (H') in the estuary area of Padang, West Sumatra, Indonesia

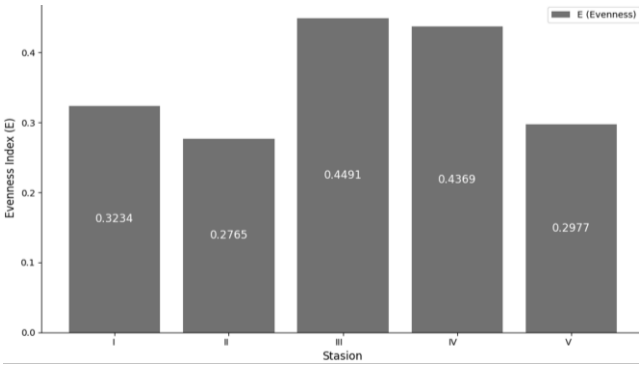

Figure 4. Evenness Index (E) of ichthyofauna in the estuary area of Padang, West Sumatra, Indonesia

Simpson Dominance Index in the estuary area of Padang

Figure 5 shows the Simpson Dominance Index (D) values at five sampling stations in a body of water. This index measures the level of species dominance in a community, where higher values indicate the presence of dominant species that dominate the ecosystem. Station IV has the highest Simpson Dominance Index value of 0.4678, followed by Station III with a value of 0.4506. This indicates that these two locations are dominated by one or more particular species, which most likely have a much larger population than other species. In contrast, Station V showed the lowest Simpson Dominance Index value, 0.1145. This value indicates that the species distribution of species at the location is more even, with no species that dominate significantly. This is often associated with more stable ecosystem conditions and high biodiversity. It is frequently linked to environmental factors that support species diversity. Low Evenness Index values in certain locations may indicate ecosystem disturbances, such as habitat changes, pollution, or resource exploitation, which lead to the dominance of specific species over others.

Stations I and II have relatively low Simpson Dominance Index values, at 0.2029 and 0.1949, respectively. This value shows that although there are several dominant species, their distribution is not too unequal compared to Stations III and IV. The high Simpson Dominance Index values at Stations III and IV can be caused by various factors, such as environmental conditions that are favorable for certain species or the presence of ecological pressures that cause only a few species to survive. This can reflect an imbalance in the ecosystem due to factors such as pollution, habitat change, or resource exploitation. Conversely, the low Simpson Dominance Index value at Station V can indicate that the ecosystem there is healthier and supports species diversity. This condition is usually found in habitats that are still natural or have lower levels of disturbance. When compared to the Evenness Index in the previous figure, it can be seen that stations with high Simpson Dominance Index values (Stations III and IV) have lower Evenness Indexes. This strengthens the indication that the dominance of certain species causes inequality in the distribution of individuals between species.

The relationship between water quality and the diversity of ichthyofauna in estuaries

The results obtained from analyzing the relationship between the diversity index and water quality parameters show a varied pattern of relationships (Figure 6). In general, the relatively low R^2 values in all graphs indicate that the water quality factors analyzed have a weak influence on the diversity index. However, several trends can be observed from each parameter analyzed.

The relationship between temperature and the diversity index demonstrates a positive correlation, represented by the regression equation $y = 0.3694x - 8.6077$ and an R^2 value of 0.1125. This shows that although there is a tendency for the diversity index to increase with increasing temperature, its influence is still relatively weak. The low R^2 value indicates that temperature is not the only factor that determines the level of species diversity in the waters studied. In analyzing the relationship between salinity and the diversity index, a negative correlation was obtained with the regression equation $y = -0.0276x + 2.7918$ and R^2: 0.151. The higher R^2 value compared to other parameters indicates that salinity has a slightly greater contribution to determining the variation of the diversity index. This trend indicates that the higher the salinity, the diversity index tends to decrease, which may be due to the limited tolerance of species to changes in salinity.

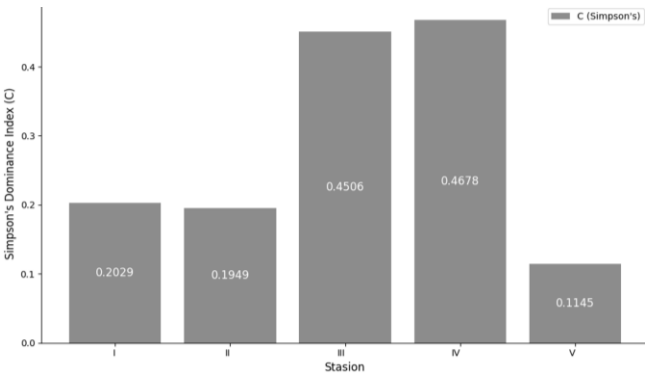

Figure 5. Simpson Dominance Index (D) of ichthyofauna in the estuary area of Padang, West Sumatra, Indonesia

The pH parameter shows a very weak relationship with the diversity index, as seen from the regression equation y = 0.1444x + 1.2786 and R^2: 0.0026. The R^2 value approaching zero indicates that pH has almost no effect on the variation of the diversity index in the waters analyzed. This indicates that the pH variation at the research site remains within the range tolerable for most fish species. Analysis of the relationship between Dissolved Oxygen (DO) and the diversity index shows a negative correlation with the regression equation y = −0.1286x + 3.5213, and the R^2 value: 0.0761 R^2: 0.076. Although it shows a negative relationship, the low R^2 value indicates that dissolved oxygen is not the main factor in determining the diversity index. However, this trend may indicate the presence of species that are more dominant in lower oxygen conditions or the presence of other more influential factors. Overall, the results of the analysis indicate that there are no water quality factors that dominantly affect the diversity index in this study. The low R^2 value for all parameters indicates that a combination of various other environmental factors, such as food availability, predation, and interactions between species in the ecosystem, influences variations in species diversity.

Discussion

Environmental factors and water quality significantly influence the distribution of ichthyofauna species in a body of water. These factors determine how species are distributed and whether they can survive in an ecosystem (de Freitas et al. 2018; Pini et al. 2021; Lu et al. 2023). Heterogeneous habitats with a variety of substrates and the availability of shelter generally support higher species diversity than more homogeneous or environmentally disturbed habitats. One of the main factors that influences the distribution of fish species is the water quality (Kamal et al. 2023). Species that have a generalist diet tend to have a wider distribution than specialist species that depend on a particular type of food (Li et al. 2021; Chetry et al. 2024). Differences in the type of bottom substrate of the water also play a role in determining fish distribution. Some species prefer rocky, sandy, or muddy substrates depending on their foraging strategy. Physicochemical parameters of water, such as temperature, salinity, dissolved oxygen, and pH, have a major influence on the distribution of fish species. Euryhaline species tend to have a wider distribution due to their tolerance to salinity fluctuations, while stenohaline species can only survive in a narrower range of environmental conditions (Rodrigues et al. 2018; Camiolo et al. 2021; Asha et al. 2023).

Changes in water quality due to anthropogenic activities, such as pollution or excessive sedimentation, can cause changes in fish distribution because some species are more sensitive to changes in environmental conditions. Biological interactions such as competition and predation also play an important role in determining the distribution of fish species (Sacher et al. 2019; Wahab et al. 2022; Qin et al. 2025). Species with highly competitive abilities will be more dominant in habitats with limited resources, while species with lower survival abilities tend to be pushed into less competitive habitats. The presence of predators can also change fish distribution patterns, where prey species tend to avoid areas with high predation risks (Gesto 2019; et al. 2020; Adamczuk 2022).

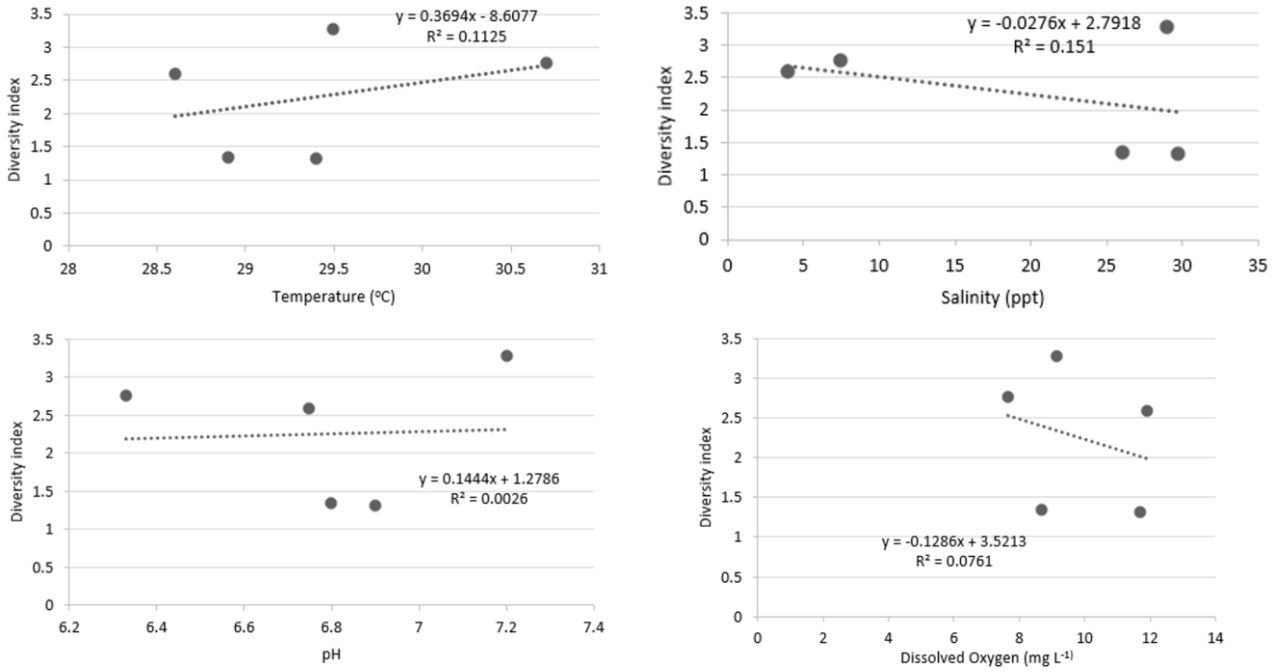

Figure 6. Relationship between diversity index and water quality parameters

Anthropogenic disturbances such as fishing activities, coastal development, and land-use changes also affect the distribution of ichthyofauna (Liu et al. 2021). Overexploitation of certain species can cause drastic population declines, which ultimately affect the balance of the ecosystem. Habitat changes due to reclamation or deforestation of mangroves can also reduce the presence of fish that depend on coastal ecosystems as spawning or rearing areas (Hunt et al. 2020; Geng et al. 2023; Kamal et al. 2024). Seasons and hydrodynamic factors such as currents and tides can also affect the distribution of fish species, especially in coastal and estuarine ecosystems. Some fish species have seasonal migration patterns that depend on changes in temperature or salinity, while others follow currents in search of areas richer in food (Guallar and Flos 2016; Olivia et al. 2025). These migration patterns are often related to the life cycle of fish, such as spawning or juvenile growth. Fish distribution can also be an indicator of the condition of aquatic ecosystems. The presence of species that are intolerant of pollution can be a sign that a habitat has good environmental quality, while the dominance of species that are more tolerant of polluted water conditions can indicate high ecological pressure (Aguzzi et al. 2013; Peterson and Grubbs 2023).

The Shannon-Wiener Diversity Index (H') reflects the level of species diversity in an aquatic ecosystem, which is influenced by environmental factors, ecosystem stability, and ecological pressures that occur. High index values indicate a more stable and diverse community, while low index values may indicate the dominance of certain species due to environmental conditions that are less supportive of other species (Zhang et al. 2018; van Roon 2020). One of the main factors that influences diversity is habitat availability and resources. Environments with complex and diverse habitat structures, such as coral reef ecosystems, mangrove forests, or seagrass beds, tend to have higher H' values because they can support various species with different ecological needs (Hafezi et al. 2021; Kamal et al. 2024). Conversely, environments that experience degradation or habitat homogenization can cause a decrease in diversity due to reduced shelter for various species. In addition to habitat factors, water quality parameters such as temperature, dissolved oxygen levels, pH, and salinity also play an important role in determining species diversity (Zhang et al. 2018; Sloey et al. 2024).

Extreme changes in these parameters can cause stress for aquatic organisms, which ultimately leads to decreased diversity. Species unable to adapt to environmental changes will experience a population decline or even disappear from the ecosystem, ultimately reducing the H' index value. Ecological pressures such as competition and predation also play a role in determining the level of diversity (Chang et al. 2019; Costa et al. 2024). In a balanced environmental condition, interactions between species can maintain community stability with an even distribution of species. However, if there is a dominant species that is too strong in resource competition or high predation pressure on certain species, there will be an imbalance in community composition, which can reduce overall diversity (Song et al. 2022; Zhao et al. 2023).

Anthropogenic impacts, such as excessive fishing activities, pollution, and changes in land use in coastal areas, can also cause a decrease in the Shannon-Wiener Index value (Liu et al. 2021). Overexploitation of certain species can cause an imbalance in aquatic communities. At the same time, pollution from domestic and industrial waste can disrupt the survival of species that are sensitive to changes in water quality. Consequently, species that are more tolerant of polluted environmental conditions become more dominant, leading to a reduction in overall diversity (Chang et al. 2019; Dimarchopoulou et al. 2023). Seasonality and natural environmental variability can also cause fluctuations in the diversity index. Some aquatic ecosystems experience significant changes in their community structure due to seasonal factors such as increasing temperatures or changes in current patterns that affect the availability of nutrients and the abundance of plankton as the main food source (Guallar and Flos 2016; Olivia et al. 2025). This seasonal variation can cause temporal differences in the H' value, which reflects the natural dynamics of an ecosystem. Diversity indices can also be an indicator of ecosystem health. Healthy ecosystems generally have high H' values because they support species diversity and ecological balance. Conversely, ecosystems that experience high environmental stress, such as eutrophication or excessive sedimentation, tend to have lower H' values due to decreased abundance and the number of species that can survive in the environment (Hadlich et al. 2018).

The Evenness Index (E) reflects the relative distribution of individuals among species in an aquatic community. The higher the E value, the more even the distribution of individuals among species, indicating a more balanced community (Fernandes et al. 2018). Conversely, a low E value indicates the dominance of a particular species, which can be caused by certain environmental factors or ecological pressures (Lehikoinen et al. 2019; Liang et al. 2024). One of the main factors affecting species evenness is the availability of resources, such as food, shelter, and habitat space. If resources are evenly distributed and accessible to various species, then the distribution of individuals among species is likely to be more even. However, suppose there is high competition or the presence of limited resources that only benefit certain species. In that case, the distribution of individuals becomes uneven, leading to a decrease in the E value (Vignaud et al. 2023).

Anthropogenic activities such as overexploitation, water pollution, and habitat changes can reduce the evenness of fish communities. Selective fishing of certain species can lead to dominance by smaller or less economically valuable species. In addition, pollution that increases excess organic matter content can support the proliferation of certain species more tolerant of eutrophic conditions, thereby reducing the overall community balance (Liu et al. 2021). Ecological interactions such as predation and competition also play a role in determining species evenness. If there is a dominant predator that preys on a few species, then the population of that species will decline, causing an uneven distribution (Liu et al. 2021; Koval 2024; Qin et al. 2025). On the other hand, if the

aquatic community has balanced competitive dynamics, where no single species dominates significantly, then the species evenness will be higher (Zhao et al. 2023). Seasonality and natural environmental variations can also affect the Evenness Index. In certain seasons, some species may experience significant population increases due to reproductive factors or abundant food availability. Conversely, in other seasons, species more adapted to less favorable environmental conditions may dominate the community, causing fluctuations in E values over time. A low Evenness Index can indicate ecological stress or environmental disturbances that cause uneven species distribution (Nascimento et al. 2021; Lu et al. 2023; Olivia et al. 2025).

Simpson Dominance Index (D) reflects the level of dominance of a particular species in an aquatic community. A high value indicates that the community is dominated by one or a few species with a very large number of individuals compared to other species (O'Brien et al. 2018). Conversely, a low value indicates that the community is more diverse, with a more balanced distribution of individuals among the various species. This level of dominance is often influenced by environmental factors, ecological pressures, and human activities that change the structure of aquatic communities. Seasonal fluctuations also play a role in the level of species dominance in a body of water (Lehikoinen et al. 2019; Hunt et al. 2020; Costa et al. 2024). Some species may thrive in certain seasons due to more favorable environmental conditions. Conversely, in other seasons, species that adapt better to less favorable conditions will dominate the community. This variation illustrates that species dominance is not a static condition; rather, it can fluctuate based on environmental factors and ecological pressures that develop over time (Abidin et al. 2022; Asha et al. 2023). A high Simpson Dominance Index in an ecosystem can indicate an ecological imbalance that needs attention in efforts to manage aquatic resources. Sustainable management, such as habitat conservation, controlling invasive species, and regulating the use of fisheries resources, is essential to maintain community balance and prevent the dominance of certain species that can disrupt ecosystem stability. Regular monitoring of the Simpson Dominance Index can be one step in assessing the health of aquatic ecosystems and identifying potential disturbances that need to be addressed immediately (O'Brien et al. 2018).

The relationship between diversity indices and water quality parameters in this study showed a low correlation, as indicated by the low coefficient of determination (R^2) value (Figure 6). This indicates that water quality parameters such as temperature, salinity, pH, and dissolved oxygen are not dominant factors that determine variations in species diversity in the studied ecosystem. In other words, although water quality still plays a role in supporting the life of aquatic organisms, variations in diversity indices are likely to be more influenced by other factors that were not directly measured in this study (Bielmyer-Fraser et al. 2018; Freeman et al. 2019). One factor that may play a greater role is habitat structure. More complex habitats, such as the presence of aquatic vegetation, diverse substrates, and protection from strong currents, often provide space for more species to coexist. Heterogeneous habitats allow for more ecological niches, which support higher species diversity. Suppose the habitat structure at the study site varies. In that case, variations in species diversity are more likely to be controlled by the physical aspects of the habitat than by the water quality itself. In addition, the availability of resources such as food and space can also be the main factors controlling species diversity (Li et al. 2021; Adamczuk 2022; Chetry et al. 2024).

Even if water quality parameters are within the range that supports life, without sufficient resources, some species may experience stress in competing for survival. This factor becomes more relevant in ecosystems experiencing stress from interspecific competition, where species with higher adaptability will dominate the community, reducing overall diversity (O'Mara et al. 2016; Chang et al. 2019; Freeman et al. 2019). Anthropogenic pressures are also potentially influential factors in the observed diversity patterns. Human activities such as overfishing, changes in land use around waters, and pollution can cause changes in fish community structure directly or indirectly. In ecosystems that experience disturbances due to human activities, species diversity often no longer reflects natural water quality conditions but is influenced by external pressures that change species abundance and composition (Liu et al. 2021; Demchenko and Demchenko 2023).

Temporal and spatial scale factors in data collection may also cause a low relationship between diversity indices and water quality parameters. Variations in species diversity often occur over a longer period, while water quality measurements in this study may only represent conditions at the time of sampling (Geng et al. 2023; Strydom et al. 2023). Short-term changes in temperature, salinity, or dissolved oxygen may not be sufficient to explain species diversity patterns that have formed over a longer period. Thus, although water quality remains an environmental factor supporting aquatic life, in the context of this study, the results suggest that additional factors such as habitat structure, resource availability, and anthropogenic pressures are more likely to play a role in determining fish community dynamics (Pessanha et al. 2021; Firdaus et al. 2023; Nana et al. 2023).

The findings of this study revealed that the ichthyofauna diversity in the estuary waters of Padang City showed spatial variability, but environmental parameters did not have a close relationship with it. Buo Bay recorded the highest species richness, possibly due to its relatively stable environmental conditions and complex habitat structure. In contrast, Muara Batang Arau River showed a lower diversity index. It was dominated by a few tolerant species, indicating increased ecological stress possibly caused by urban runoff, pollution, and anthropogenic activities. These results underline the need for integrated estuary management and habitat conservation strategies to ensure the sustainability of fisheries resources and preserve the ecological functions of coastal ecosystems in West Sumatra.

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