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Diversity and ecological drivers of fish in Singkil Swamp Wildlife Reserve, Aceh, Indonesia

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Abstract. *Rohim N, Sulistiono, Yulianda F, Muhtadi A. 2024. Diversity and ecological drivers of fish in Singkil Swamp Wildlife Reserve, Aceh, Indonesia. Biodiversitas 25: 2849-2856.* Singkil Swamp Wildlife Reserve (SSWR) is a conservation area in Aceh Singkil District, Aceh, Indonesia, that has an important role in maintaining the sustainability of fisheries resources on the Singkil coast. This study analyzes fish biodiversity and ecological factors influencing fish distribution in SSWR waters. The data were collected at five stations (Station I and II in the watershed area while Station III, IV, and V in peat swamp area) every month from April to October 2021 (7 months), consisting of fish biodiversity and aquatic ecological characteristics. The data obtained were analyzed using an index of diversity, evenness, dominance, frequency of presence, and Canonical Correspondence Analysis (CCA). Fish biodiversity in the SSWR utilization area consists of 26 species, including 14 families and 19 genera. Station I (in the Alas-Singkil River) has a higher diversity value and is dominated by the white fish group compared to Stations II, III, IV, and V (in the Lae-Treup River), which the black fish group dominates. Based on ecological characteristics, the distribution of fish species in SSWR is divided into four groups. The first and second groups of fish were positively correlated with high pH and DO, while the third and fourth groups tended to have negative correlation values.

Keywords: Conservation, fisheries resources, peat waters ecology

INTRODUCTION

Singkil Swamp Wildlife Reserve (SSWR) is a peat swamp forest in Aceh Singkil District, Aceh Province, Indonesia (Harahap et al. 2020). Singkil Swamp is very important in determining the productivity of coastal fisheries in the western part of Aceh (Onrizal 2019). Since peat swamp forests are more susceptible to human disturbances than other forest ecosystems, their preservation and restoration are conservation priorities that must be addressed immediately (Sasidhran et al. 2016). The Director General of Natural Resources and Ecosystem Conservation established the SSWR Management Block on 16 January 2018 (SK.7/KSDAE/SET/KSA.0/1/2018) and divided it into 5 blocks, namely Protection Blocks (65,908.61 ha/80.51%), Utilization Blocks (4,666.44 ha/5.7%), Special Blocks (10,074.82 ha/12.32%), Rehabilitation Blocks (1,073.97 ha/1.38%), and Religious, Cultural and Historical Blocks (78.38 ha/0.1%), the five blocks are riparian forest, peat swamp and flowed by small rivers (Balai Konservasi Sumber Daya Alam 2018). The utilization block located in the southern part of the SSWR area is used by the local community for tourism and fishing purposes.

The biodiversity of peat swamp forest fish and Sumatran lowland forests is not well-informed. Hence, it is unsurprising that many new types of fish discoveries in science originated from Sumatran peat swamp forests (Muchlisin et al. 2015; Wibowo et al. 2015; Muhtadi et al. 2022). The diverse peat waters area of habitat type is home to various species of peat fish (Muchlisin et al. 2015; Wibowo et al. 2015; Clews et al. 2018; Santoso and Wahyudewantoro 2019). The SSWR water environment is also flood-swamp (Rohim et al. 2022); the swamp fish group, also known as blackfish, and the river fish group, often known as white fish, comprise the fish species found in the flood swamp habitat (Wibowo et al. 2015; Desrita et al. 2022). Fish from the blackfish group generally have additional breathing apparatus (labyrinth) to live in waters with low oxygen and acid (Lukas et al. 2021).

The white fish differ from the black ones, whose main habitats include rivers with better water conditions than swamps, white fish adaptability to the environment is not the same as blackfish, white fish cannot live with less dissolved oxygen (Akbar 2014). During the dry season, white fish live in the main river, tributaries, and the bottom of the river, then spread to the swamps for spawning during the rainy season. Meanwhile, the black fish live sedentarily and inhabit swamp waters to meet the entire life cycle (from spawning to development) (Desrita et al. 2022). The fish that are classified into the group of blackfish are swamp-dwelling fish with blackish-brown water conditions, so these fish are also dark brown (dark), in contrast to fish whose primary habitat in the river, such as pangas catfish (*Pangasius pangasius* Hamilton 1822), is bright white and is grouped into a white fish group (Lukas et al. 2021; Desrita et al. 2022). Therefore, fish have significant conservation significance due to their biological functions, such as controlling food webs as higher predators and consumers or driving nutrient cycles through excretory activity (Chua et al. 2019).

There is still a shortage of knowledge regarding the fish biodiversity in SSWR. The taxonomic study of *Pandanus* (Marpaung et al. 2013), lower plant diversity (Onrizal 2019), vegetation analysis (Sugianto et al. 2021), and more recent research on the environmental features of SSWR Waters by Rohim et al. (2022) are among the studies that have been conducted at SSWR. The study of fish diversity and its relationship to the aquatic ecology at the study site has never been revealed, at the same time, this information is crucial as a basis for fisheries management. Departing from these problems, this study aims to analyze the biodiversity of fish and the ecological factors that influence fish distribution in SSWR waters. This research is important to carry out as a reference and basic information in developing conservation strategies, both at the species and habitat level to preserve aquatic resources in the SSWR conservation area.

MATERIALS AND METHODS

Study area

The research was carried out in the area of utilization of SSWR. Data collection was carried out at 5 stations, which include the Lae-Treup (Stations 3, 4, and 5) and Alas-Singkil Rivers (Stations 1 and 2), Singkil District (Aceh Province, Indonesia) (Figure 1). The method of determining observation stations was purposive sampling, that the sample is selected according to the specific research objectives (Bhardwaj 2019). The location of this research was determined based on the river type and where fishermen catch fish in the SSWR. The research was carried out from April to October 2021. For 7 months, field observations and data collection were carried out once a month in the middle of the month at all research stations. The data collected were primary data consisting of fish biodiversity and ecological characteristics (water physical and chemical parameters).

Data collection

Data collection was carried out every month by a team consisting of 3 people. The role of each team member was to handle fish catches, measure ecological parameters and fishermen who drive boats and catch fish. Fish sampling was conducted using fishing gears, such as fishing rods, gill nets (1, 2, and 3 inches), bamboo traps (*bubu*), and hand lift nets operated at each station. Bamboo traps and fishing rods were operated for 6-hour intervals, with installation at 06.00 AM and taken at noon (12.00 AM). Meanwhile, gill nets and hand lift nets were operated for 1 hour. Each type of fish caught was photographed, along with length-weight measurement and counting. Furthermore, the sample was stored in plastic, added with 10% formalin solution, and the time and location were labeled according to observations. Samples were then taken to the Laboratory for further identification. In Laboratories, 10% formalin solution was replaced with 70% alcohol so that the sample could last longer. The morphological identification and status of fish refer to Kottelat et al. (1993), White et al. (2013), Azmai et al. (2020), and Froese and Pauly (2024).

Data collection of the aquatic ecological characteristics consisted of in-situ and ex-situ data. Temperature, salinity, Dissolved oxygen, pH, current, transparency, depth, conductivity, and Total Dissolve Solid (TDS) are in-situ data measured directly in the field. At the same time, Total Suspended Solid (TSS), Nitrate, and Total phosphate are ex-situ data that would be measured in the Laboratory. Therefore, 500 mL of water samples were taken at each station to measure ex-situ water quality parameters. No preservative was added to the TSS samples. In contrast, for nitrate and total phosphate, water samples were taken of 1000 mL and given the preservative H_2SO_4 in all samples. The water was put into bottles and stored at 4ºC; the American Public Health Association (2017) follows aquatic physics and chemistry parameter measurements. Ex-situ water samples were analyzed at the Laboratory of the Environmental Health and Disease Control Engineering Center (BTKLPP) of Medan City.

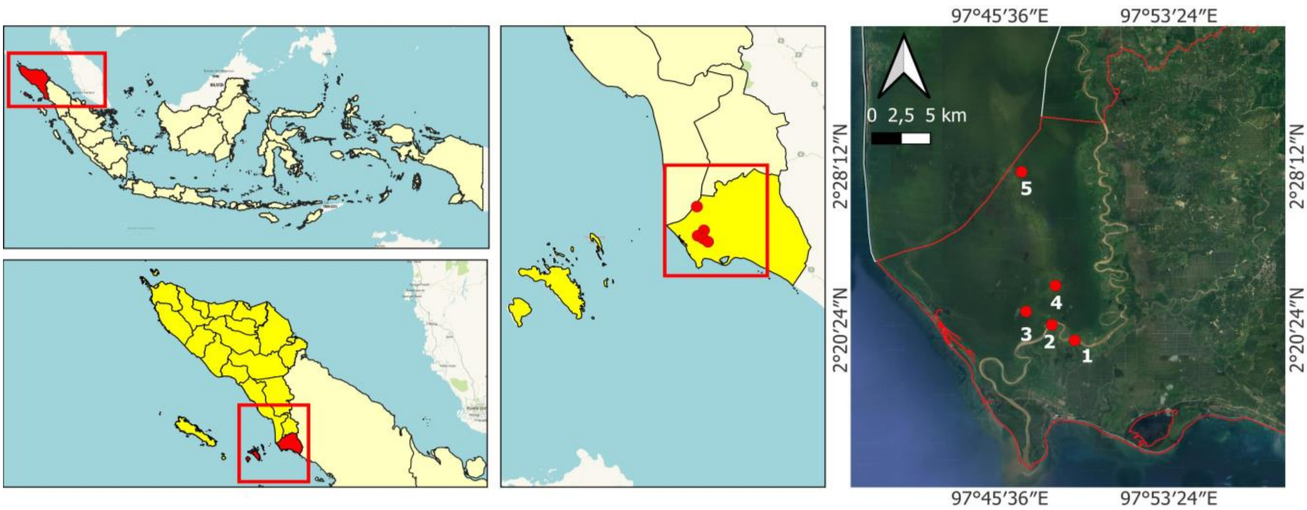

Figure 1. Sampling site in Singkil Swamp Wildlife Reserve, Aceh Singkil, Aceh, Indonesia

Data analysis

The fish community at each of the research stations in SSWR was determined through the Shannon diversity index analysis (H'), Evenness index (E), and Simpson dominance index (D) using Microsoft Excel 365 software. The Shannon diversity index (H') is the most commonly used. According to Shannon and Wiener (1949), the following formula was used to determine the diversity index:

$$H' = -\sum_{i=1}^{n} \left(\frac{ni}{N}\right) ln \left(\frac{ni}{N}\right)$$

Where:
H' : Diversity index
ni : Number of individuals of each type
N : Number of individuals of all kinds

Determining the balance of communities used the evenness index, the similarity of individuals between species in a community. The evenness index formula (E), according to Krebs (2014), is as follows:

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

Where:
E : Evenness index
H' : Diversity index
S : Number of species

The Dominance index (D) was used to determine how a group of biota dominates another group. Considerable dominance would lead to unstable and depressed communities (Odum and Barret 2005). In determining whether or not there was a dominating species, the dominance index from Simpson (1949) was used:

$$1 - D = 1 - \sum_{i=1}^{n} \left(\frac{n_i}{N}\right)^2$$

Where:
D : Simpson dominance index
n_i : Number of individuals in the 'each' species
N : Total number of individuals

Relative Abundance (RA) was expressed in the number of one group of organisms in a community. Relative abundance was calculated through the formula put forward by Krebs (2014) that was:

RA = ni/N x 100

Where:
RA : Relative abundance (%)
n_i : Number of individuals in the 'each' species
N : Total number of individuals

Presence Frequency (PF) is a value that states the number of species present in a predetermined research station. FK could be calculated using the following formula (Krebs 2014):

$$PF = \frac{\text{Number of stations occupied by a species}}{\text{Total number of stations}} x\ 100$$

Where:
PF 0-25% : Hardly ever-present
PF 25-50% : Seldom present
PF 50-75% : Sometimes present
PF 75-100% : Generally present

Canonical Correspondence Analysis (CCA) analysis was used to determine the relationship between the presence of fish species and the aquatic environment in the SSWR. Canonical correlation analysis is a family of multivariate statistical methods for analyzing paired sets of variables (Uurtio et al. 2017). CCA analysis uses PAST (Palaeontological Statistics) 4.03 software.

RESULTS AND DISCUSSION

Diversity and conservation status of fish

The total number of fish obtained during the research was 442 fish, representing 14 families, 19 genera and 26 species (Table 1). Two groups of fish were identified in SSWR: the river and the swamp fish groups. Two types of fish are found in flood swamp ecosystems: black and white (Utomo 2016). The black fish in SSWR were comprised of striped snakehead (*Channa striata* Bloch 1793), forest snakehead (*Channa lucius* Cuvier 1831), climbing perch (*Anabas testudineus* Bloch 1792), snakeskin gourami (*Trichopodus pectoralis* Regan 1910), brilliant rasbora (*Rasbora einthovenii* Bleeker 1851), Philippine catfish (*Clarias batrachus* Linnaeus 1758), microspilus catfish (*Clarias microspilus* Ng and Hadiaty 2011), punctifer catfish (*Mystus punctifer* Ng, Wirjoatmodjo and Hadiaty 2001), bonylip barb (*Osteochilus vittatus* Valenciennes 1842) and breviristus catfish (*Ompok brevirictus* Ng and Hadiaty 2009). The fish species of white fish group include: selais (*Kryptopterus lais* Bleeker 1851), caveatus catfish (*Hemibagrus caveatus* Ng, Wirjoatmodjo and Hadiaty 2001), bunguranensis rabora (*Rasbora bunguranensis* Brittan 1951), two spot catfish (*Mystus nigriceps* Valenciennes 1840), pearl catfish (*Mystus castaneus* Ng 2002), greenback mullet (*Planiliza subviridis* Valenciennes 1836), tank goby (*Glossogobius giuris* Hamilton 1822), amazon sailfin catfish (*Pterygoplichthys pardalis* Castelnau 1855), vermiculated sailfin catfish (*Pterygoplichthys disjunctivus* Weber 1991), nile tilapia (*Oreochromis niloticus* Linnaeus 1758), Indonesian shortfin eel (*Anguilla bicolor* McClelland 1844), bumble bee catfish (*Leiocassis micropogon* Bleeker 1852), scalloped perchlet (*Ammbassis nalua* Hamilton 1822), Asian swamp eel (*Monopterus albus* Zuiew 1793), jeruk barb (*Osteochilus jeruk* Hadiaty and Siebert 1998), and beardless barb (*Cyclocheilichthys apogon* Valenciennes 1842).

The conservation status of 26 fish species indicated that *A. bicolor*, *M. punctifer*, *H. caveatus*, *C. microspilus*, and *O. brevirictus* is threatened in nature. In addition to conservation status, *M. punctifer*, *H. caveatus*, *R. bunguranensis*, and *O. jeruk* must be considered because they are endemic fish from Sumatra (Lembaga Ilmu Pengetahuan Indonesia 2020).

Index of diversity, evenness, and dominance

The fish community structure balance and fish species richness in aquatic ecosystems could be seen through the index of diversity, evenness, and dominance (Odum and Barret 2005). The diversity index is a value that can indicate the balance of diversity in a division of the number of individuals of each type (Desrita et al. 2018; 2020; 2022). The results of the diversity, evenness, and dominance index analysis are presented in Table 2.

Table 1. Fish biodiversity in Singkil Swamp Wildlife Reserve, Aceh Singkil, Aceh, Indonesia

Family	Genus	Species	Stations					Numbers	Presence frequency (PF) (%)	Relative Abundance (RA) (%)	IUCN Red List
			I	II	III	IV	V				
Ambassidae	*Ammbassis*	*A. nalua*	2	3	-	-	-	5	40	1.13	LC
Anabantidae	*Anabas*	*A. testudineus*	2	1	1	1	2	7	100	1.58	LC
Anguillidae	*Anguilla*	*A. bicolor*	2	-	-	1	1	4	60	0.90	NT
Bagridae	*Mystus*	*M. punctifer*	-	1	4	4	2	11	80	2.49	VU
		M. castaneus	-	2	-	-	-	2	20	0.45	LC
		M. nigriceps	8	10	-	-	-	18	40	4.07	LC
	Hemibagrus	*H. caveatus*	8	4	1	6	4	23	100	5.20	NT
	Leiocassis	*L. micropogon*	2	-	-	-	-	2	20	0.45	LC
Channidae	*Channa*	*C. lucius*	-	6	10	9	19	44	80	9.95	LC
		C. striata	3	2	2	5	1	13	100	2.94	LC
Cichlidae	*Oreochromis*	*O. niloticus*	2	-	-	-	-	2	20	0.45	LC
Claridae	*Clarias*	*C. batrachus*	-	1	2	9	22	34	80	7.69	LC
		C. microspilus	-	-	1	1	7	9	60	2.04	
Cyprinidae	*Cyclocheilichthys*	*C. apogon*	1	1	1	-	-	3	60	0.68	LC
	Osteochilus	*O. jeruk*	3	-	-	-	-	3	20	0.68	LC
		O. vittatus	-	12	8	6	-	26	60	5.88	LC
	Rasbora	*R. einthovenii*	-	-	59	65	74	198	60	44.80	LC
		R. bunguranensis	2	-	-	-	-	2	20	0.45	DD
Gobiidae	*Glossogobius*	*G. giuris*	3	-	-	-	-	3	20	0.68	LC
Loricariidae	*Pterygoplichtys*	*P. pardalis*	1	-	-	-	-	1	20	0.23	NE
		P. disjunctivus	2	-	-	-	-	2	20	0.45	NE
Mugilidae	*Planiliza*	*P. subviridis*	8	-	-	-	-	8	20	1.81	NE
Osphronemidae	*Trichopodus*	*T. pectoralis*	3	-	1	2	-	6	60	1.36	LC
Siluridae	*Kryptopterus*	*K. lais*	1	2	-	-	-	3	40	0.68	LC
	Ompok	*O. brevirictus*	-	2	2	-	1	5	60	1.13	EN
Synbranchidae	*Monopterus*	*M. albus*	6	-	1	1	-	8	60	1.81	LC
Total			**59**	**47**	**93**	**110**	**133**	**442**	-	-	-

Note: DD: Data Deficient, EN: Endangered, LC: Least Concern, NE: Not Evaluated, NT: Near Threatened, VU: Vulnerable

The value of the fish diversity index in the SSWR based on the five observation stations ranges from 0 to 2.01, with an average of 0.97-1.47 (Table 2). The highest diversity was obtained at Station I (June) while the lowest was at Station II (October), where only one fish species was caught. Diversity has the greatest value if all individuals comprise different genera or species, while diversity has the smallest value if all individuals comprise one genus or species (Odum and Barret 2005). Fish diversity in SSWR tended to be higher than the diversity value in Barumun River Swamp Ecosystem (North Sumatra), with H' reaching 1.65-1.98 (Khairul 2020) and Selangor Peat Swamp (Malaysia) with H' reaching 1.42-1.75 (Ahmad and Samat 2015), and swamp forest Kinabalu (Malaysia) with H' reaching 0.0-1.9 (Soo et al. 2022). However, fish diversity in SSWS is still low compared to the Tripa Peat Swamp Forest (Aceh), with H' reaching 1.23-2.71 (Muchlisin et al. 2015), Kelekar Floodplain Ogan Ilir District (Indonesia) reaching 2.18-2.39 (Muslim and Syaifudin 2022), the Ratargul Swamp Forest (RSF) of Bangladesh with a diversity index value (H') reaching 2.77-2.98 (Kunda et al. 2022).

Moreover, the diversity of fish in Station I was higher than in Stations II, III, IV, and V. This result is because Station I is on the Alas Singkil River, which has different water characteristics from the other four stations located in the Lae-Treup River flow located in the SSWR forest. The DO and pH parameters at Station I tend to be higher than at other stations so that they support the presence of more fish species, this can be seen in Table 2 and Figure 2. In Table 2, it can be seen that the diversity value is higher than other stations, and in Figure 2, it can be seen that the direction and position of the pH and DO lines with Station I are in the same direction and closer than the other stations. According to Sule et al. (2018), Thornton et al. (2018), and Lukas et al. (2021), the number of fish collected in peat waters was less (less diverse) than in freshwater due to low pH conditions resulting in the survival of only high adaptable fish. The difference in value DO at different stations produces different fish distribution patterns; some fish are able to survive at low DO values , and some require optimal DO, namely 5 mg/L or higher (Subayu et al. 2024).

The evenness of fish types in Stations I to V in the sequence was 1±0.17, 0.81±0.36, 0.73±0.17, 0.71±0.12 and 0.86±0.5, respectively (Table 2). The more evenly distributed individuals between species, the greater the degree of community balance (Odum and Barret 2005). The high value of evenness was directly proportional to the value of diversity. The dominance of fish in SSWR at Stations I to V were 0.3±0.12, 0.46±0.27, 0.48±0.15, 0.48±0.19 and 0.47±0.21, respectively. The value of dominance was inversely proportional to diversity and evenness. A lower dominance rating suggests that there isn't a dominant fish population in the body of water.

Table 2. Index of diversity, evenness, and dominance at each station

Index	Stasiun				
	I	II	III	IV	V
Diversity (H')	0.67-2.01 (1.47±0.47)	0-1.77 (0.97±0.59)	0.53-1.44 (0.97±0.31)	0.32-1.68 (1.02±0.42)	0.82-1.37 (1±0.17)
Evenness (E)	0.82-1.3 (1±0.17)	0-1 (0.81±0.36)	0.48-0.94 (0.73±0.17)	0.46-0.79 (0.71±0.12)	0.41-1.91 (0.86±0.5)
Dominance (C)	0.14-0.52 (0.3±0.12)	0.22-1 (0.46±0.27)	0.33-0.73 (0.48±0.15)	0.27-0.82 (0.48±0.19)	0.26-0.85 (0.47±0.21)

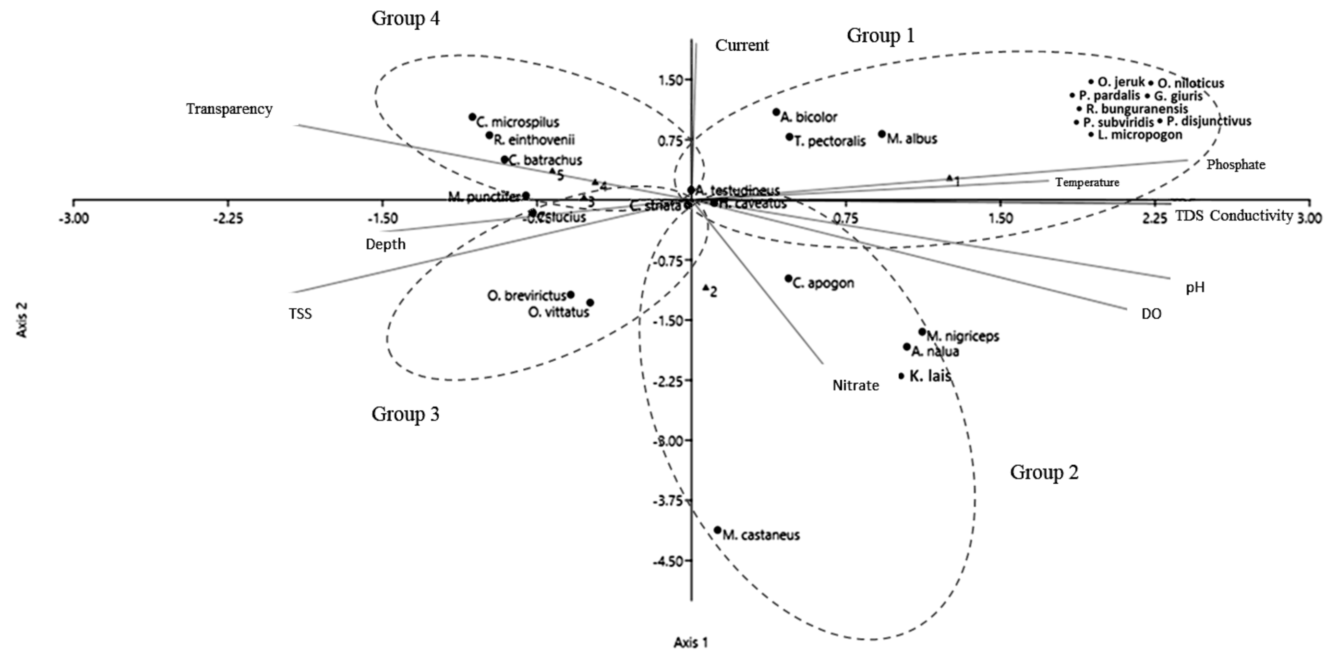

Figure 2. Coordination of CCA biplots the relationship between the distribution of fish species and the aquatic environment

The fish diversity index in SSWR tended to be lower when compared to the diversity index in other types of waters such as rivers and estuaries. Several studies of diversity indexes on rivers were obtained H'=2.06-2.09, E=0.63-0.83, D=0.17-0.18 (Barumun Watershed) (Desrita et al. 2022), H=2.4-3.0, E=0.77-0.80, D=0.2-0.4 (Batangtoru River and its tributaries) (Desrita et al. 2020). Higher diversity indexes were obtained in estuary waters, such as the study by Sulistiono et al. (2022) in Banten Bay (H'=2.18-3.76, E=0.63-0.78, D=0.07-0.23) and Siombak coastal Lake (H' reached 3.24) (Muhtadi et al. 2023).

Aquatic ecological characteristic

The water physico-chemical parameters measured during the study in SSWR ranged as follows: Temperature (25-31.1°C), transparency (12.5-145 cm), depth (0.8-5 m), current (0.06-0.456 m/s), salinity (0 ppt), pH (3.8-6.5), DO (1-4 mg/L), TDS (13-65 mg/L), TSS (4-236 mg/L), conductivity (26-130 S/m), nitrate (0.5-25.7 mg/L), and total phosphate (0.01-2.14 mg/L).

The pH value of SSWR, which ranged from 3.8 to 6.5, indicates that SSWR waters are acidic. The peatland waters are characterized by their acidic quality due to microbial activity in peatlands' breakdown of organic matter; the pH value lowers as CO_2 concentration rises (Sule et al. 2018; Thacker and Karthick 2022). In addition to acidic pH, the brown-to-black watercolor in SSWR is also a feature of peat waters. Peat is formed from organic plant material with a low pH and turns peat water from brown to pitch-black. Dissolved oxygen in SSWR Waters, which ranges from 1 to 4 mg/L, is relatively low compared to the tolerance range for dissolved oxygen in fish, which ranges from 3 to 5 mg/L (Ali et al. 2022).

Fish distribution based on ecological characteristic

The relationship between fish species and ecological characteristics was presented through Canonical Correspondence Analysis (CCA) (Figure 2). CCA produced biplot coordination that described the relationship between research stations and water physicochemical parameters and the relationship between species and the water physicochemical parameters. Biplot coordination between stations and aquatic environment parameters indicated that Stations III, IV, and V have positive values on Axis 1 and clusters on the left. In contrast, Stations I and II have positive values on Axis 2 (Figure 2). The CCA eigenvalues of the two main axes are 0.56 (Axis 1) and 0.26 (Axis 2), respectively, with a percentage of 60.6% and 28.23% or 88.83% of the total variance (Table 3).

Table 3. Canonical Correspondence Analysis (CCA) eigenvalues

Axis	Eigenvalue	%
1	0.56658	60.6
2	0.26392	28.23
3	0.073912	7.906
4	0.030459	3.258

Based on Table 1, the highest number of catches was found at Station V (133 individuals), followed by Station IV (110 individuals), Station III (93 individuals), Station II (47 individuals), and Station I (59 individuals). The *R. einthovenii* and *C. lucius* were the largest catches, with 198 and 44 individuals, respectively, while the least obtained fish was *P. pardalis*, with as many as one individual. The type of fish that had the greatest relative abundance value was *R. einthovenii*, of 44.80% spread on Stations III, IV, and V. Meanwhile, the type of fish that had the smallest relative abundance value was *P. pardalis* of 0.23%, which only found in Station I.

The Presence Frequency (PF) is related to the distribution area of fish. The greater the PF value of a species, the area of its spread, and the wider the spreading area. The frequency of presence value of fish species in SSWR showed three fish with a 100% PF percentage, namely *A. testudineus*, *H. caveatus*, and *C. striata*, which had a widespread area. Meanwhile, the fish that had a percentage of PF 20% or only obtained at one station, namely *M. castaneus* at Station II, *L. micropogon*, *O. niloticus*, *O. jeruk*, *R. bunguranensis*, *G. giuris*, *P. disjunctivus*, *P. pardalis*, and *P. subviridis* at the Station I.

Figure 2 revealed the SSWR waters compared to other types of waters, resulting in the presence of fish having a very close correlation with pH and DO, which was low and highly transparent. Thornton et al. (2018) found that the average monthly river fish catch was negatively correlated with the monthly average river depth, increased river acidity, and reduced fish catch after fires reduced fish populations in Peatland fish of Sebangau, Borneo. Fish communities in The Nee Soon Swamp Forest (Singapore) are positively correlated with depth, stream order, and canopy cover and are negatively correlated with distance to a connected reservoir, mean velocity, and silt substrate (Ho et al. 2018).

Four groups of fish species were formed based on the presence of fish species with water physical-chemical parameters. The Alas-Singkil River region was represented by the first group (*A. bicolor, T. pectoralis, M. albus, P. pardalis, P. subviridis, L. micropogon, O. niloticus, O. jeruk, R. bunguranensis, G. giuris, P. disjunctivus, P. pardalis, T. pectoralis,* and *M. albus*) with positive values on Axis 1 and 2. These species were associated with temperature, total phosphate, TDS, and high conductivity. The second group, which included *A. nalua, M. nigriceps, H. caveatus, C. apogon, K. lais,* and *M. castaneus*, exhibited positive values on Axis 1 and negative values on Axis 2. This fish is linked to elevated DO, pH, and nitrate levels. Axis 1 and 2 showed negative values for the third group (*C. lucius, C. striata, O. breviristus,* and *O. vittatus*). The TSS parameters and depth showed a strong association with the third group. The fourth group consisted of *A. testudineus, M. punctifer, C. batrachus, R. einthovenii,* and *C. microspilus*; this group was associated with high transparency. The first and second groups of fish were positively correlated with high pH and DO in contrast to the third and fourth groups of fish that tended to have negative correlation values. This difference indicated the characteristics of the black fish group (the third and fourth fish groups) except for *T. pectoralis*, which belongs to the first group. In this study, the low dissolved oxygen concentration in swamps allowed species to live since they have the labyrinth organ from the family Anabatidae, Anguilidae, Channidae, Claridae, and Siluridae. The labyrinth-like respiratory organ helped them to directly get oxygen from the air instead of respiration in the water using their gills. Especially for species *R. einthovenii* is a common genus of rasbora in peat and swamps (Azmai et al. 2020).

Management strategies oriented towards resource sustainability must be implemented in the SSWR. Moreover, currently there are no specific regulations regarding the use of fisheries resources in the SSWR and the threat of fishing using electric fishing gear. Some of the efforts that must be made to preserve and protect fish in the SSWR are the use of environmentally friendly fishing gear and the prohibition of damaging environments, restrictions on the quantity and time/season of catching fish, catchment endangered fish prohibitions, fish protection mapping areas, and identified invasive species like *P. pardalis* and *P. disjunctivus*. Therefore, further studies covering a wider area and a longer sampling period should be conducted to get comprehensive fish community data as the basis for fishery management.

In conclusion, fish biodiversity in the Singkil Swamp Wildlife Reserve (SSWR) utilization area comprises 26 species from 14 families and 19 genera. Bagridae, Claridae, Channidae, and Cyprinidae are the common fish groups with the most species and individuals. The high diversity and evenness index of Station I fish shows that the diversity and stability of the Alas-Singkil River are higher than those of the other four stations in the Lae-Treup River flow. Furthermore, the water physical-chemical parameters in SSWR divide the presence of fish into four groups. The first group (*A. bicolor*, *T. pectoralis*, *M. albus*, *P. pardalis*, *P. subviridis*, *L. micropogon*, *O. niloticus*, *O. jeruk R. bunguranensis*, *G. giuris*, *P. disjunctivus*, *P. pardalis*, *T. pectoralis* and *M. albus*) is associated with temperature, total phosphate, TDS and high conductivity. The second group (*A. nalua*, *M. nigriceps*, *H. caveatus*, *C. apogon*, *K. lais*, and *M. castaneus*) is associated with high pH, DO and nitrates. The third group (*C. lucius*, *C. striata*, *O. brevirictus*, and *O. vittatus*) closely correlates with TSS parameters and depth. The fourth group with *A. testudineus*, *M. punctifer*, *C. batrachus*, *R. einthovenii*, and *C. microspilus* is associated with high transparency. The first and second groups of fish were positively correlated with high pH and DO compared to the third and fourth groups, which tended to have negative correlation values, different fish have specific requirements for dissolved oxygen and pH levels.

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