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Biodiversity of Fish Inhabit Aquatic Ecosystem in Senepis Peat Forest, Riau, Indonesia

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ABSTRACT

The Senepis Peat Forest in Riau, Indonesia, represents a unique and sensitive aquatic ecosystem that supports a diverse range of freshwater biodiversity. This study aims to assess the structure and abundance of aquatic organisms, particularly focusing on the biodiversity of fish and supporting biotic components such as phytoplankton, zooplankton, and benthos across four monitoring stations (P1, P2, P3, and P4). Phytoplankton abundance showed the highest mean at Station P1 (57,405.56 ind/m³), indicating high primary productivity, but also displayed considerable variability (SD: 206,330.71), likely due to environmental fluctuations. Zooplankton abundance positively correlated with phytoplankton, particularly at P1, suggesting a close trophic relationship between primary producers and primary consumers. In contrast, benthic organisms exhibited the highest abundance at P2 (mean: 58.34 ind/m²; max: 319 ind/m²), implying a habitat-specific adaptation possibly related to substrate type and oxygen levels. The diversity and distribution patterns of fish and aquatic biota in Senepis reflect the complex interplay of biotic and abiotic factors shaping community structures in peatland aquatic systems. The findings emphasize the ecological importance of Senepis as a habitat for aquatic biodiversity and highlight the need for continuous environmental monitoring and integrated conservation strategies.

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1. Introduction

Peat swamp ecosystems represent a unique tropical wetland system characterized by distinct hydrological and ecological properties. These ecosystems feature waterlogged, acidic soils formed through millennia of organic matter accumulation, creating specialized habitats that support flora and fauna adapted to low-oxygen conditions, limited light penetration, and soft substrates (Page et al., 2011; Harrison et al., 2020). Indonesia possesses the world's second-largest tropical peat swamp forests after Brazil, with Riau Province containing some of Sumatra's most extensive peatland areas, including ecologically significant landscapes like Kerumutan, the Kampar Peninsula, and Senepis that harbor rich biodiversity, particularly among fish communities (Murdiyarso et al., 2019; TFCA Sumatera, 2023).

However, Riau's peat swamp ecosystems face severe threats from land conversion for oil palm plantations, infrastructure projects, and recurring forest fires, which degrade aquatic habitats and endanger endemic species, including specialized peat-dwelling fishes with both economic and ecological value (Richards et al., 2020; Suwondo et al., 2023). Despite this pressure, scientific understanding of fish diversity in Senepis remains limited compared to better-studied areas like Kerumutan and Kampar River, where previous research such as Fahmi et al. (2015) documented 27 freshwater fish species in the Bukit Batu Biosphere Reserve, highlighting the need for expanded biodiversity surveys across Riau's peat swamps.

This study examines fish community structure through ecological indices (diversity, abundance, and dominance) to assess ecosystem health and species interactions while investigating relationships between fish assemblages and environmental conditions (Odum & Barrett, 2005; Magurran, 2021). The research carries important implications for developing sustainable conservation strategies and ecosystem-based management approaches in eastern Sumatra's coastal regions, aligning with blue economy principles that balance ecological preservation with responsible resource use (UNEP, 2022). By documenting Senepis' ichthyofauna and analyzing community dynamics, the study aims to establish a scientific foundation for integrating biodiversity conservation with sustainable coastal development in peat swamp ecosystems.

2. Methods

This study employed a survey method, involving direct field observations, in-situ measurements, and sample collection at the research site. Fish species identification and abundance analysis were subsequently conducted in the laboratory.The approach combined field surveys with quantitative ecological analysis to examine fish community structure in the Senepis peat swamp. Standard sampling protocols were followed to ensure data consistency, including systematic recording of environmental parameters alongside biological sampling. Laboratory work focused on taxonomic classification and ecological index calculations (diversity, dominance, and abundance) to characterize the aquatic community composition.

This methodology aligns with established practices for wetland biodiversity assessment, enabling comprehensive evaluation of both species distribution and habitat conditions in the peat swamp ecosystem.

Research Location

This study was conducted from June to December 2017 in the Senepis peat swamp area, Rokan Hilir Regency, Riau Province. This region represents a critical ecosystem along Sumatra's western coastal zone, characterized by unique aquatic features that support diverse aquatic organisms.

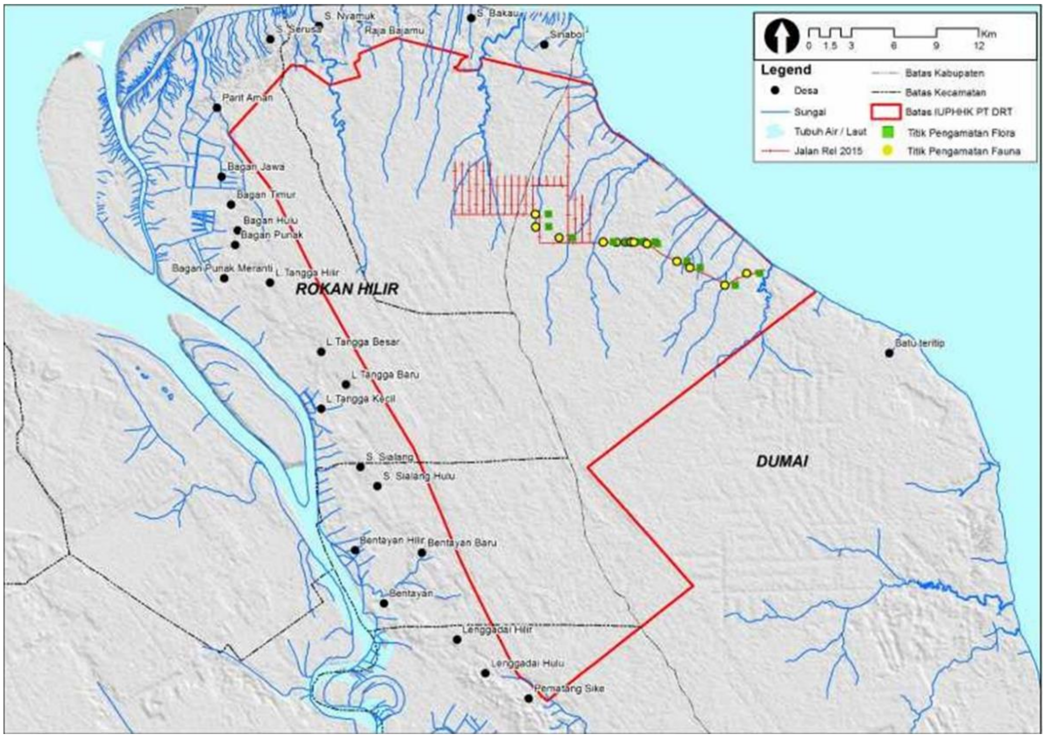

Fig 1. Research Location Map – Senepis, Rokan Hilir Regency, Riau Province

The data collection in this study primarily focused on primary data as the main source, supplemented by secondary data obtained through reviews of previous research findings that had been proven valid, reliable, and relevant. Based on the study's focus, the collected data was classified into three main components: (1) the fish component, (2) the plankton and benthos component, and (3) the oceanographic component. Each component had its own specific approach in terms of data collection and analysis, which are explained in detail in the following sections.

Table 1. Types of data, data collection methods, and equipment used

No	Component	Parameter	Method	Equipment Used
1	Fish	Species, population, distribution, protected species	In-situ measurement, Capture, Observation, Identification, Interview	Boat, nets, questionnaires, writing tools, clipboard, camera, GPS, fish identification books, Government Regulation No. 7/1999, CITES list, IUCN Red List
2	Plankton & Benthos	Species, population, diversity, dominance index,	In-situ measurement, Observation, Identification, Laboratory analysis	Boat, Ekman grab, sediment sieve, bucket, sample bags, formalin/lugol, marker, questionnaires, writing tools, clipboard, camera, GPS, plankton & benthos identification guides, CITES

		distribution		list, IUCN Red List, formalin, lugol
3	Oceanography (Physical)	Water clarity	In-situ measurement	Secchi disk, GPS
4		Water temperature	Pengukuran insitu	Thermometer, GPS
5	Oceanography (Chemical)	Dissolved Oxygen (DO)	In-situ measurement	DO meter, GPS
6	Oseanografi Kimia	Derajat Keasaman (pH)	Pengukuran insitu	pH Meter, GPS
7	Oseanografi Kimia	Salinitas Perairan	Pengukuran insitu	Refraktometer, GPS

Data Collection

Data collection related to fish species, populations, protected species, and their distribution in each sampling plot will be carried out using a combination of methods, including the use of boats and nets, interviews with local fishermen, and direct field observations. The identification process of fish species, including those categorized as protected, will refer to fish identification guides as well as regulations stated in Government Regulation (PP) No. 7 of 1999, the CITES List, and the IUCN Red List.

Meanwhile, the collection of plankton and benthos data includes information on species, population, diversity index, uniformity index, dominance index, and their distribution at each sampling point. A plankton net will be used for plankton collection, while an Ekman Grab sampler will be used for benthos. The samples obtained will be processed using sieves, buckets, sample plastics, and Lugol's solution for plankton and formalin for benthos. The identification of plankton and benthic organisms will be based on identification guides and references from PP No. 7 of 1999, CITES, and the IUCN.

Table 2. Tools and Materials Used

No.	Nama	Fungsi
1	Ekman Grab	To collect benthic organism samples from the bottom of the water body.
2	Plankton Net	To collect plankton samples from the water column.
3	GPS Garmin	To determine the geographic coordinates of sampling points.
4	DO Meter	To measure dissolved oxygen levels and water temperature directly.
5	Refraktometer	To assess the salinity or salt concentration in water.
6	Secchi Disk	To measure water clarity or transparency.
7	Camera DSLR Canon	To document field activities in the form of photos and videos.
8	pH Meter	To determine the acidity or alkalinity level of the water.
9	Thermometer	To manually measure water temperature.
10	Additional Equipment	Ropes, markers, buckets, sediment sieves, sample plastics, sample bottles, cool boxes, formalin, and Lugol's solution for sampling, preservation, and transportation.

Measurement of Environmental Characteristics

Oceanographic data collection includes parameters of water quality such as brightness level, temperature, dissolved oxygen (DO), pH, and salinity. These parameters will be measured directly using instruments such as the Secchi disk (for brightness), thermometer (for temperature), DO meter (for dissolved oxygen), pH meter (for acidity), refractometer (for salinity), and GPS to accurately determine the geographical coordinates of the research locations.

Analysis of Plankton and Benthos Density

Density refers to the number of individuals of a species in a given unit of area or volume. It is calculated using the formula from Brower et al. (1989):

$$Di = Ni / A$$

Description:
Di = Density of species i (individuals/m^2)
Ni = Number of individuals of species i
A = Total sampling area

Species Diversity Index

Species diversity reflects the variation and complexity within a community and indicates ecological stability. Diversity is calculated using the Shannon-Wiener Index (H') with the formula:

$$H' = -\sum (pi \times \ln pi)$$

Description:

H'	= Diversity index
pi	= Proportion of individuals of species i to the total individuals (pi = ni / N)
ni	= Number of individuals of species *i*
N	= Total number of individuals of all species

Interpretation of H' values (Krebs, 1989):

$H' < 1$	= Low diversity, unstable community, high pollution indication
$1 < H' < 3$	= Moderate diversity, relatively stable community
$H' > 3$	= High diversity, stable community, relatively clean environment

Species Evenness Index

Evenness describes the relative abundance distribution among species. It is calculated using the formula:

$$E = H' / \ln S$$

Keterangan:

E	= Evenness index
H'	= Diversity index
S	= Total number of species (taxa)

Kriteria nilai E:

$E < 0,4$	= Low evenness
$0,4 < E < 0,6$	= Moderate evenness
$E > 0,6$	= High evenness

Analysis of Oceanographic Parameters

Oceanographic data will be processed using microsoft excel and analyzed descriptively, then compiled into a database. The parameters analyzed include:

1. Water Brightness
   Used to estimate light penetration depth, which affects photosynthesis of aquatic organisms.
2. Dissolved Oxygen (DO)
   Indicates the amount of oxygen available for aquatic respiration and reflects water quality.
3. pH (Acidity Level)
   Determines water's acidity or alkalinity, essential for the survival of aquatic life.
4. Water Temperature
   Influences metabolism, distribution of organisms, and biochemical processes in aquatic environments.
5. Salinity
   Describes the salt content in water, affecting the osmoregulation of aquatic biota.

3. Results and Discussion

Descriptive statistical data on zooplankton abundance at four observation stations. Zooplankton are microscopic drifting organisms that play a crucial role as primary consumers in the aquatic food web (Steinberg & Landry, 2017). The data show significant variation between stations:

- Station P1 recorded the highest zooplankton abundance with an average of 26,094.64 individuals/m³ and a maximum value of 378,362 individuals/m³. The high standard deviation (69,736.365) indicates large fluctuations in abundance at this station. The high zooplankton abundance is likely due to the rich nutrient availability and favorable environmental conditions for phytoplankton growth, the primary food source for zooplankton.
- Station P2 had an average abundance of 2,468.65 individuals/m³ with a maximum value of 35,791 individuals/m³. The standard deviation of 6,916.72 shows lower variability compared to P1, but still significant.
- Stations P3 and P4 showed lower abundances, averaging 3,526.55 and 2,115.95 individuals/m³, with maximum values of 51,130 and 30,678 individuals/m³, respectively. The lower standard deviations at these two stations (9,768.57 and 6,189.64) indicate a more uniform abundance distribution compared to P1 (Table 3).

Tabel 3. Zooplankton

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
P1 ZOOPLANKTON	29	0	378362	26094,64	69736,365
P2 ZOOPLANKTON	29	,00	35791,00	2468,6521	6916,71783
P3 ZOOPLANKTON	29	0	51130	3526,55	9768,573
P4 ZOOPLANKTON	29	0	30678	2115,95	6189,643
Valid N (listwise)	29				

Phytoplankton are microscopic primary producers capable of photosynthesis and form the base of the aquatic food web (Cloern et al., 2020). The analysis shows: Station P1 has the highest average phytoplankton abundance (57,405.56 individuals/m³), with a maximum value reaching 1,262,911 individuals/m³. The very high standard deviation (206,330.71) indicates significant fluctuations in abundance, possibly due to seasonal variation or environmental factors such as nutrient availability, light intensity, and temperature.

Station P2 shows an average abundance of 39,277.62 individuals/m³ with a maximum value of 864,097 individuals/m³. The high standard deviation (137,420.86) also indicates considerable variability. Station P3 records a much lower average abundance (6,740.24 individuals/m³) with a maximum value of 148,277 individuals/m³ and a standard deviation of 22,859.88. Station P4 has an average abundance of 32,770.18 individuals/m³, a maximum value of 720,933 individuals/m³, and a standard deviation of 120,347.20 (Table 4).

Benthos are organisms that live on the bottom of aquatic environments and play an important role in decomposition processes and nutrient cycling (Snelgrove et al., 2018). The analysis shows that Station P2 has the highest benthic abundance with an average of 58.34 individuals/m² and a maximum value reaching 319 individuals/m². The high standard deviation (122.18) indicates large variability in benthic abundance at this station.

Tabel 4. Fitoplankton

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
P1 FITOPLANKTON	44	0	1262911	57405,56	206330,707
P2 FITOPLANKTON	44	0	864097	39277,62	137420,856
P3 FITOPLANKTON	44	0	148277	6740,24	22859,875
P4 FITOPLANKTON	44	0	720933	32770,18	120347,197
Valid N (listwise)	44				

Station P1 recorded an average abundance of 10.95 individuals/m² with a maximum value of 58 individuals/m² and a standard deviation of 19.32. Stations P3 and P4 showed identical abundance values with an average of 5.45 individuals/m², a maximum value of 29 individuals/m², and a standard deviation of 11.65. This similarity suggests that both stations may share similar habitat characteristics or may indicate errors in data collection or reporting (Table 5).

The analysis reveals different distribution and abundance patterns between zooplankton, phytoplankton, and benthos at the four observation stations. This variation reflects the complexity of aquatic ecosystems and the interactions between biotic and abiotic components. A positive correlation between phytoplankton and zooplankton abundance at Station P1 suggests a strong trophic relationship between primary producers and primary consumers (Calbet & Landry, 2020). The high abundance of phytoplankton provides an abundant food source for zooplankton, thereby supporting rapid population growth.

The low benthic abundance at stations with high plankton abundance (P1) may be due to differences in habitat characteristics or environmental factors such as depth, substrate, and oxygen content (De Meester et al., 2019). Conversely, Station P2, which has the highest benthic abundance, indicates benthic organisms' adaptation to specific environmental conditions at that station. High variability in abundance across all biotic components (as shown by large standard deviations) suggests complex temporal dynamics, which may be influenced by seasonal fluctuations, environmental changes, or biotic interactions (Cael et al., 2021).

Tabel 5. Bentos

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
P1 BENTOS	11	0	58	10,95	19,319
P2 BENTOS	11	0	319	58,34	122,177
P3 BENTOS	11	0	29	5,45	11,648
P4 BENTOS	11	0	29	5,45	11,648
Valid N (listwise)	11				

Based on the analysis results, the following suggestions and recommendations are proposed:

1. Regular Monitoring
   Conduct continuous monitoring of plankton and benthic abundance to understand temporal dynamics and responses to environmental changes.
2. Environmental Factor Analysis
   Supplement organism abundance data with measurements of physicochemical water parameters (temperature, salinity, pH, DO, nutrients) to identify factors affecting the distribution and abundance of aquatic organisms.
3. Advanced Taxonomic Studies
   Perform species-level identification to understand community structure and biodiversity at each station.
4. Ecosystem Status Evaluation
   Use plankton and benthos abundance data as bioindicators to assess the health status of the aquatic ecosystem.
5. Sustainable Management
   Develop water resource management strategies based on an understanding of aquatic community structure and function.
6. Advanced Statistical Analysis
   Apply multivariate statistical analysis to identify complex patterns and relationships among various biotic and abiotic components.

This study provides valuable information on the structure of plankton and benthic communities across four observation stations. Variations in organism abundance and distribution reflect the complexity of aquatic ecosystems and the importance of a holistic approach in understanding ecosystem dynamics. This knowledge can serve as a foundation for conservation efforts and sustainable management of aquatic resources.

4. Conclusion

The results of the analysis showed varying distribution and abundance patterns between zooplankton, phytoplankton, and benthos at four observation stations. Station P1 showed the highest abundance of zooplankton (average 26,094.64 individuals/m^3) and phytoplankton (average 57,405.56 individuals/m^3), but had a relatively low benthos abundance (average 10.95 individuals/m^2). This indicates a close trophic relationship between phytoplankton as primary producers and zooplankton as primary consumers, where the high abundance of phytoplankton provides abundant food sources for the growth of zooplankton populations. In contrast, Station P2 had the highest benthos abundance (average 58.34 individuals/m^2) with a fairly high phytoplankton abundance (average 39,277.62 individuals/m^3) but a lower zooplankton abundance (average

2,468.65 individuals/m³). Station P3 showed the lowest abundance of phytoplankton (average 6,740.24 individuals/m³) and had moderate zooplankton abundance (average 3,526.55 individuals/m³) and low benthos abundance (average 5.45 individuals/m²). Station P4 had the lowest zooplankton abundance (average 2,115.95 individuals/m³) with fairly high phytoplankton abundance (average 32,770.18 individuals/m³) and benthos abundance similar to P3. The high standard deviation at all stations indicated large fluctuations in abundance, which may be caused by seasonal variations or the influence of environmental factors such as nutrients, light intensity, temperature, depth, substrate, and oxygen content. These variations reflect the complexity of the aquatic ecosystem and the interactions between biotic and abiotic components. For sustainable management, regular monitoring, analysis of environmental factors, further taxonomic studies, evaluation of ecosystem status using bioindicators, development of aquatic resource management strategies, and multivariate statistical analysis are required to better understand the complex patterns and relationships in aquatic ecosystems.

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