FISH DIVERSITY AND HISTOLOGICAL CHARACTERISTICS OF FEMALE GONADS IN THE TRIPA PEAT SWAMP ECOSYSTEM, ACEH, INDONESIA

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Abstract: Fish reproductive condition is widely recognized as a sensitive biological indicator of ecosystem health because reproductive processes are strongly influenced by environmental conditions. This study aims to inventory fish species and analyze the reproductive condition of female fish through gonad and histology studies as indicators of the health of the Rawa Tripa ecosystem. Fish samples were collected at 6 location and then were identified to the species level. Reproductive analysis was performed on female fish by observing the level of gonadal maturity and histological preparations to observe the structure of the oocytes. In addition, water quality parameters such as temperature, pH, and dissolved oxygen were measured in situ to support ecological interpretation. The results of the study obtained 88 fish individuals consisting of 12 families and 23 species. The fish species with the most individuals found during the study were *Mystacoleucus marginatus*, *Osteochilus kappenii*, *Osteochilus hasseltii*, *Rasbora lateristriga*, with 10 individuals each. Only 5 of the 37 examined female individuals (13.5%) exhibited mature gonads, whereas the remaining 32 individuals (86.5%) were in earlier developmental stages. The histology of female fish gonads was obtained from five species, namely *Channa lucius*, *Oreochromis niloticus*, *Mystacoleucus marginatus*, *Osteochilus hasseltii*, and *Osteochilus kappenii*. The Tripa Peat Swamp exhibited acidic water conditions (pH 4–7), with temperatures of 25–30°C and dissolved oxygen concentrations of 3–7 mg/L, which may have contributed to the low number of species with mature female gonads, suggesting environmental constraint on reproductive development.
Keywords: Peat swamp ecosystem; Gonadal histology; Fish diversity; Rawa Tripa

Abstrak: Kondisi reproduksi ikan secara luas diakui sebagai indikator biologis yang sensitif terhadap kesehatan ekosistem karena proses reproduksi sangat dipengaruhi oleh kondisi lingkungan. Penelitian ini bertujuan untuk menginventarisasi jenis ikan serta menganalisis kondisi reproduksi ikan betina melalui kajian gonad dan histologi sebagai indikator kesehatan ekosistem Rawa Tripa. Pengambilan sampel ikan dilakukan pada 6 titik perairan rawa, kemudian diidentifikasi hingga tingkat spesies. Analisis reproduksi dilakukan pada ikan betina melalui pengamatan tingkat kematangan gonad dan preparat histologi untuk mengamati struktur oosit. Selain itu, parameter kualitas air seperti suhu, pH, dan oksigen terlarut diukur secara in situ untuk mendukung interpretasi ekologis. Hasil penelitian diperoleh sebanyak 88 individu ikan yang terdiri dari 12 famili dan 23 spesies. Spesies ikan dengan individu paling banyak yang ditemukan saat penelitian

adalah *Mystacoleucus marginatus*, *Osteochilus kappenii*, *Osteochilus hasseltii*, *Rasbora lateristriga*, yaitu masing-masing sebanyak 10 individu. Hanya 5 dari 37 individu betina yang diteliti (13,5%) yang menunjukkan gonad yang sudah matang, sedangkan 32 individu lainnya (86,5%) masih berada pada tahap perkembangan yang lebih awal. Histologis gonad betina ikan yang didapatkan berasal dari 5 spesies yaitu, *Channa lucius*, *Oreochromis niloticus*, *Mystacoleucus marginatus*, *Osteochilus hasseltii*, dan *Osteochilus kappenii*. Rawa Gambut Tripa menunjukkan kondisi air yang bersifat asam (pH 4–7), dengan suhu 25–30°C dan konsentrasi oksigen terlarut 3–7 mg/L, yang mungkin menjadi salah satu faktor penyebab rendahnya jumlah spesies dengan gonad betina yang matang, sehingga mengindikasikan adanya kendala lingkungan terhadap perkembangan reproduksi.
Kata kunci: Ekosistem gambut; Histologi gonad; Keragaman ikan; Rawa Tripa

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Introduction

Peat swamps are one of the wetland ecosystems that play a very important ecological role, both as carbon sinks, water regulators, and habitats for terrestrial aquatic biodiversity. In Indonesia, tropical peat swamp ecosystems are known as centers of freshwater fish diversity with high ecological and economic value (Batubara, 2025). The existence of this ecosystem plays an important role in supporting the stability of regional aquatic ecosystems and supporting the livelihoods of local communities.

Rawa Tripa peat swamp is one of the largest and most important peat swamp areas in Aceh Province, covering an area of approximately 61,803 ha (Iswahyudi, 2016). This area has deep peat characteristics, with a thickness ranging from 3 to 5 meters, so that ecologically it functions as a natural protected area. However, in recent decades, Rawa Tripa peat swamp has experienced intense anthropogenic pressure, mainly due to land conversion, deforestation, and hydrological degradation (Monalisa, 2014; Tata & Rahayu, 2015; Husna, 2023). Various studies show that ongoing deforestation in this area has led to a decline in aquatic habitat quality, changes in the physical and chemical characteristics of the water, and fragmentation of wetland habitats, which has had a direct impact on freshwater fish communities (Rizka, 2016; Widianto, 2012).

Changes in environmental conditions in peat swamp ecosystems, particularly water level fluctuations, increased acidity, and decreased dissolved oxygen levels, can affect fish community structure and important physiological processes, including reproduction (Cowan, 2024). The success of fish reproduction is largely determined by environmental conditions that support gonadal development, oogenesis, and vitellogenesis (Servili, 2020). In degraded habitat conditions, fish tend to allocate energy for survival rather than reproduction, as reflected in the low

proportion of individuals with mature gonads (Schreck et al, 2001). Therefore, studies of fish reproductive biology, particularly through a gonadal histology approach, are important indicators for assessing fish population responses to environmental pressures. Microscopic examination (histology) of the gonads is far more accurate and objective in determining the reproductive status of fish than macroscopic examination (Sauger et al, 2026). Macroscopic methods rely solely on visual observations—such as size, color, and shape—and are therefore subjective and prone to misinterpretation (Flores et al, 2019).

Although Rawa Tripa swamp is known as an area with high freshwater fish diversity (Muchlisin et al, 2015), scientific information on fish community structure and reproductive conditions is still very limited. Little information is available regarding the reproductive status of fish populations and how environmental conditions may influence reproductive development. To date, studies combining fish diversity inventory with female gonadal histology analysis as an indicator of reproductive readiness in the Rawa Tripa peat swamp ecosystem are still rarely reported. This study aims to inventory freshwater fish species and describe the histological condition of female fish gonads in the Rawa Tripa peat swamp area, Pulo Kruet Village, Nagan Raya Regency. The results of this study are expected to provide an initial overview of the status of fish diversity and reproductive potential in peat swamp ecosystems experiencing environmental pressure, as well as to serve as a scientific basis for efforts to manage and conserve fish resources in a sustainable manner in the Rawa Tripa area.

Methods

This study was conducted from September 2024 to May 2025. Fish sampling was carried out in the Tripa Peat Swamp area, Pulo Kruet Village, Darul Makmur District, Nagan Raya Regency, Aceh. Histological analysis of fish gonads was conducted at the Animal Structure and Development Laboratory, Faculty of Mathematics and Natural Sciences, Syiah Kuala University. Sampling was carried out at six locations that were purposively selected based on the presence of permanent water pools during the dry season. The research location map is presented in **Figure 1**.

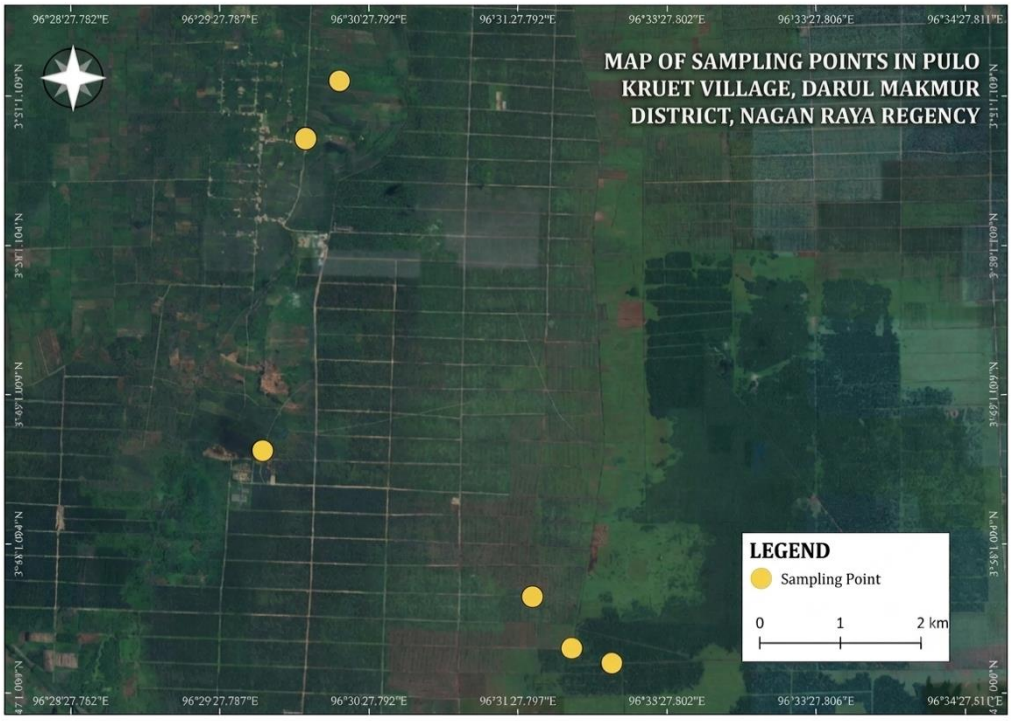


Figure 1. Research location map.

Fish Sampling

Fish sampling was conducted using an exploratory survey method with purposive sampling techniques, considering the condition of peat swamp waters that undergo water shrinkage due to the dry season. The fishing gear used included gill nets, fishing rods, and fish traps, which were selected to minimize selectivity in terms of fish size and species. The fish specimens were collected and their total body length was measured using a tape measure with an accuracy of 0.1 cm. The species, number, and location of each individual found were recorded. Fish species were identified based on morphological characteristics using identification keys and relevant taxonomic literature.

Gonad Collection and Identification

The fish obtained were dissected to determine their sex and gonad condition. Of the 23 fish species recorded during the study, females individuals were identified in 10 species, comprising a total of 37 individuals. Body length and gonad size were recorded before the gonads were further processed. The maturity level of female gonads was identified based on observations of the anatomical structure and histological characteristics of the gonads.

Preparation of Gonad Histological Specimens

The preparation of gonadal specimens followed Mujimin (2016). The female gonads that had been removed were cut to a maximum size of ±1 cm^3 and fixed in a 10% Neutral Buffered Formalin (NBF) solution for ±48 hours at room temperature. The samples were then processed through stages of graded

dehydration using alcohol, clearing with xylene, and embedding in paraffin. The resulting paraffin blocks were cut using a microtome with a slice thickness of 4–5 µm, then attached to a glass slide. The preparations were stained using the Hematoxylin–Eosin (H&E) method. Histological observations were conducted qualitatively to identify the developmental stages of oocytes present in each ovarian sample. Oocyte stages, including perinuclear oocyte, cortical alveolar oocyte, vitellogenic oocyte, and maturation oocyte, were identified based on their morphological characteristics following Smith (2012). Observations were performed on five randomly selected microscopic fields per slide at 400× magnification using light microscope (Primo Star 415500-0059-000, Germany). No quantitative measurements or percentage calculations of oocyte stages were conducted; the analysis focused on describing the presence and developmental composition of oocytes within each ovary.

Physical and chemical factors Assesment

The assessment of the physical and chemical characteristics of the water was conducted at each site of fish sampling. The parameters measured included water temperature, pH, and dissolved oxygen (DO) levels. Water temperature was measured using a thermometer, pH was measured using litmus paper, and DO was measured using a DO meter. The values obtained were recorded and subsequently employed to describe the aquatic environmental conditions during the study.

Data Analysis

Data on fish diversity, abundance, and female gonad condition were analyzed descriptively and presented in tables and figures. This approach was used to summarize species composition, distribution of individuals, reproductive condition of female fish, and environmental characteristics of the Rawa Tripa Peat Swamp. Fish community structure was evaluated using species richness (S), relative abundance (RA), Shannon-Wiener diversity index (H'), and Simpson's dominance index (D). Relative abundance was calculated as the percentage contribution of each species to the total number of individuals recorded. The Shannon-Wiener diversity index was calculated using:

$$H' = -\sum pi \ln pi \quad \text{..... (1)}$$

where *pi* is the proportion of individuals belonging to species *i*.

Simpson's dominance index was calculated as:

$$D = \sum pi^2 \quad \text{.....(2)}$$

where higher values indicate greater dominance by one or a few species.

Results and Discussion

Fish Species and Composition in Tripa Swamp, Pulo Kruet Village

A total of 23 fish species belonging to 12 families and 4 orders were recorded in the Tripa Peat Swamp. The fish community exhibited a species richness (S) of

23 species (**Table 1**). The Shannon-Wiener diversity index (H') was 2.77, indicating moderate diversity, while the Simpson domination index (D) was 0.07, suggesting low dominance within the assemblage (**Suplementary file**). Our research found that the Persiformes order was the most widely distributed, with 7 families consisting of 12 species. Meanwhile, the least common order was Anguliformes, with only 1 family and 1 species found. According to Rukmana et al. (2014), the Perciformes order has a high adaptability and can adapt to freshwater, brackish water, and even seawater. During the study, several fish species were found with only one individual. This pattern may be associated with multiple factors, including naturally low abundance, habitat specialization, seasonal movements, sampling limitations, or changes in habitat availability during the dry season. According to Zainuri (2019), fish have behavioral patterns that depend on their environmental conditions. Some fish species can survive because of their specialized organs, while others will move to areas with more extensive wetlands to survive.

Table 1. Species and numbers of fish found and their conservation status

Ordo/Family	Spesies	Local names	Indonesian names	IUCN Status	Number of Individuals
Persiformes					
Channidae	*Channa striata* (Bloch, 1793)	Bacei	Gabus	LC	1
	Channa lucius (Cuvier, 1831)	Bujok	Bujuk/kiung	LC	6
	Channa cyanospilos (Bleeker, 1853)	Jampak	Bujuk	DD	1
Chandidae	*Ambassis kopsii* (Bleeker, 1858)	Putihan	Putihan	NE	3
Eleotrididae	*Butis amboinensis* (Bleeker, 1853)	Turak	Gabus pasir	LC	1
	Butis sp. (Bleeker, 1853)	Turak	Mabai	LC	1
Gobiidae	*Glossogobius giuris* (Hamilton, 1822)	Turak	Goby putih	LC	1
Belontiidae	*Trichogaster pectoralis* (Regan, 1910)	Sepat	Sepat siam	LC	5
	Trichogaster trichopterus (Pallas, 1770)	Sepat	Sepat rawa	LC	5
	Betta anabatoides (Bleeker, 1851)	Laga blang	Cupang sawah	LC	1
Cichlidae	*Oreochromis niloticus* (Linnaeus, 1758)	Nila	Nila	LC	1

Ordo/Family	Spesies	Local names	Indonesian names	IUCN Status	Number of Individuals
Anabantidae	*Anabas testudineus* (Bloch, 1792)	Krup	Betok	LC	5
Cypriniformes					
Cyprinadae	*Mystacoleucus marginatus* (Valenciennes, 1842)	Serukan ue	Genggehek	LC	10
	Osteochilus kappenii (Bleeker, 1856)	Serukan mirah mata	Kapar	LC	10
	Osteochilus hasseltii (Valenciennes, 1842)	Serukan ijo	Nilem	LC	10
	Leptobarbus hosii (Regan, 1906)	Suwi kerabu	Piam/Tomopong	LC	1
	Rasbora lateristriga (Valenciennes, 1842)	Bilieh	Seluang kuning	NT	10
	Trigonopoma pauciperforatum (Weber & de Beaufort, 1916)	Bilieh	Rasbora garis merah	LC	5
Anguiliformes					
Anguilidae	*Anguilla bicolor* (McClelland, 1844)	Ileih	Belut	NT	1
Siluriformes					
Clariidae	*Clarias batrachus* (Linnaeus, 1758)	Limbek	Lele hutan	LC	1
Bagridae	*Mystus olyroides* (Roberts, 1989)	Suwik	Baung akar	NT	4
	Mystus bimaculatus (Volz, 1904)	Suwik	Baung tikus	NT	1
Loricariidae	*Hypostomus plecostomus* (Linnaeus, 1758)	Sapu-sapu	Sapu-sapu	LC	4
Total individuals					88

Cyprinidae represented the most species-rich family (6 species) and contributed the highest proportion of individuals recorded during the survey (52% or 46/88 of total individuals) (Table 1). The dominance of Cyprinidae in peat swamp ecosystems has been widely reported in various tropical freshwater bodies, particularly in swamp and lowland river systems with high hydrological fluctuations (Batubara, 2025; Razi, 2023; Muchlisin, 2015; Santoso & Wahyudewantoro, 2019). The high dominance of this family indicates good

ecological adaptation to dynamic environmental conditions, including changes in water depth, food availability, and water quality variations. Cyprinidae species found in high numbers in this study, such as *M. marginatus*, *O. kappenii*, *O. hasseltii*, and *R. lateristriga*, generally have a fusiform body shape that supports high mobility and flexible living strategies. These morphological and behavioral adaptations allow Cyprinidae fish to utilize various microhabitats, including river channels, swamp pools, and shallow waters with dense vegetation. In addition, several members of Cyprinidae are known to tolerate the conditions of peat swamp ecosystems with low dissolved oxygen and acidic pH (Filice, 2020; Johansen, 2023; Srineetha, 2013).

The presence of fish species known to tolerate acidic and low-oxygen environments represents a notable feature of the fish assemblage in the Rawa Tripa peat swamp. Species belonging to the families Channidae (*C. striata*, *C. lucius*, and *C. cyanospilos*), Belontiidae (*Trichogaster* spp. and *B. anabatoides*), and Anabantidae (*A. testudineus*) were recorded at location 1, 2, and 3, where relatively acidic conditions and lower dissolved oxygen concentration were observed (Table 3). These species have been reported to possess physiological adaptations that enable them to persist in waters characterized by low pH and limited dissolved oxygen levels. The presence of accessory respiratory structures, such as labyrinth organ, allows some species to utilize atmospheric oxygen and may enhance their ability to survive under such environmental conditions. The relatively frequent occurrence of these taxa in the study area may be associated with their tolerance to environmental conditions commonly found in peat swamp ecosystems. In addition, the acidic water conditions and the reduced water levels observed during the study period may have influenced the composition of the fish community. Although the present study was not designed to test mechanisms of environmental selection directly, the observed assemblage patterns is consistent with previous studies reporting that peat swamp fish communities often include species capable of tolerating acidic and oxygen-low environments (Azis, 2022; Batubara, 2025; Muclisin, 2015; Thorntorn, 2018).

In addition to patterns of dominance and environmental tolerance, the inventory results also indicate the presence of several fish species with Near Threatened (NT) and Data Deficient (DD) conservation status. The species *R. lateristriga*, *A. bicolor*, *M. olyroides*, and *M. bimaculatus* are listed as NT, indicating that these species are potentially at risk of population decline if environmental pressures continue. The presence of Anguilla bicolor in the Rawa Tripa has important ecological value, given that this species is catadromous and highly dependent on habitat connectivity between freshwater and marine environments (Kautsari, 2023; Triyanto, 2019). Degradation of peat swamp habitats and disruption of hydrological connectivity may hinder its reproductive migration and negatively affect population sustainability. Similarly, *M. olyroides* and *M. Bimaculatus*, which are closely associated with riverine and floodplain habitats, are

vulnerable to habitat alteration and declining water quality. Meanwhile, the species *C. cyanospilos*, which is listed as Data Deficient (DD), indicates that there is still a lack of information regarding the distribution, population, and ecology of this species. The presence of DD species in the Rawa Tripa area underscores the importance of further research to fill the gaps in scientific data, particularly regarding the population dynamics, bioecology, and habitat requirements of these species. Without adequate information, conservation and management efforts for DD species become difficult to implement effectively.

Description of Female Fish Gonads

A of total of 88 fish individuals representing 23 fish species were collected during the study. Female fish were recorded from 10 species, comprising 37 indiviuals in total (**Table 2**). Gonadal examination revealed that only five individuals (13.5% of all females) from the species *C. lucius*, *O. niloticus*, *M. marginatus*, *O. hasseltii*, and *O. kappenii* possessed mature ovaries. The remaining 32 females (86.5%) were in earlier stages of ovarian development. The observed sex composition varied among species, with some species represented predominantly by females and others by males. Apparent sex-biased distributions may result from sampling effects, differences in habitat use, behavioral characteristics, seasonal variation, or natural population structure rather than reflecting true population-level sex ratios.

Table 2. Data on the sex and life stage of fish found in the Tripa Peat Swamp, Pulo Kruet Village

Spesies	Number of individuals	Sex ratio (Males:Females)	Female fish gonad stages
Channa striata	1	1:0	-
Channa lucius	6	4: 2	1 Mature; 1 Juvenile
Channa cyanospilos	1	1:0	-
Ambassis kopsii	3	2:1	Juvenile
Butis amboinensis	1	1:0	-
Butis sp.	1	1:0	-
Glossogobius giuris	1	1:0	.
Trichogaster pectoralis	5	1:4	Juvenile
Trichogaster trichopterus	5	2:3	Juvenile
Betta anabatoides	1	1:0	-
Oreochromis niloticus	1	0:1	Mature
Anabas testudineus	5	5:0	-
Mystacoleucus marginatus	10	6:4	1 Mature; 3 Juvenile
Osteochilus kappenii	10	3:7	1 Mature; 6 Juvenile
Osteochilus hasseltii	10	4:6	1 Mature; 5 Juvenile
Leptobarbus hosii	1	1:0	-
Rasbora lateristriga	10	4:6	Juvenile
Trigonopoma pauciperforatum	5	2:3	Juvenile
Anguilla bicolor	1	1:0	-
Clarias batrachus	1	1:0	-
Mystus olyroides	4	4:0	-
Mystus bimaculatus	1	1:0	-
Hypostomus plecostomus	4	4:0	-

Histological analysis of female gonads revealed that five fish species exhibited a mature gonadal condition. The histological structure of the ovaries in these five species generally exhibited the presence of mature oocytes, characterized by their substantial size and cytoplasm filled with yellow egg globules (**Figure 2**). In addition, other stages of oocyte development were observed, including perinuclear oocytes, cortical alveolar oocytes, and/or vitellogenic oocytes. The presence of an ovarian cavity was also noted. The combination of these oocyte stages indicates that the female gonads are in an advanced stage of development and are ready for spawning and fertilization. In the species *O. hasseltii* and *O. kappenii*, the presence of a greater variety of oocyte development stages indicates that the spawning period is not yet complete and does not occur simultaneously.

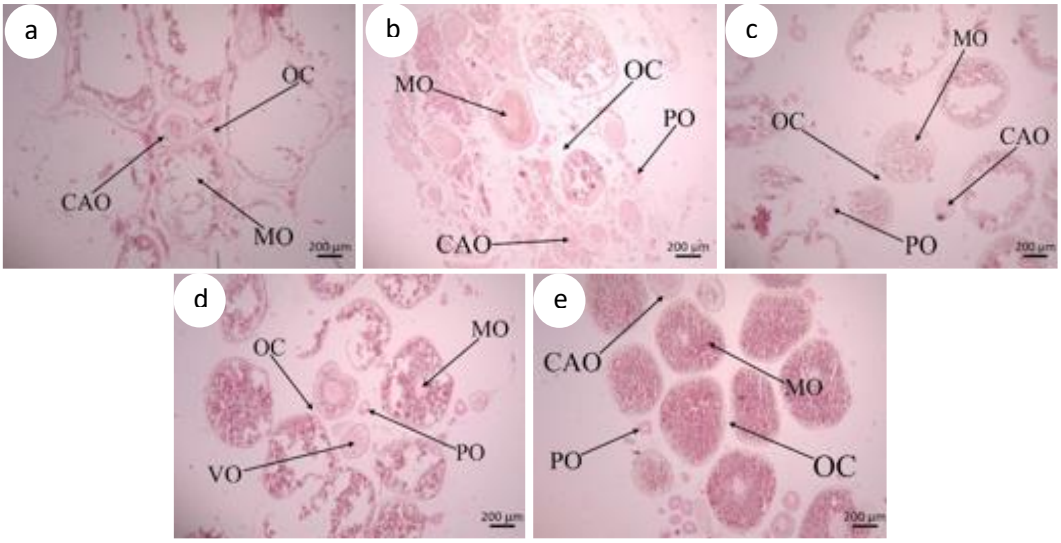


Figure 2. Female Gonad Histology, a). *Channa lucius*, b). *Oreochromis niloticus*, c). *Mystacoleucus marginatus*, d). *Osteochilus hasseltii*, and e). *Osteochilus kappenii*. Description: MO = Maturation Oocyte; PO = Perinuclear Oocyte; CAO = Cortical Alveolar Oocyte; OC = Ovary Cavity.

Analysis of female gonads and their histological structure provides important information about the reproductive status of fish and the ecological conditions of the habitat in which they live. In this study, only a small proportion of fish species showed mature female gonads, while most individuals were in the juvenile life stages. This pattern indicates that the reproductive process of fish in the Tripa Peat Swamp did not occur optimally during the observation period. Mature oocytes (late vitellogenic to hydration stages) were detected in only a few species, including some taxa commonly associated with peat swamp habitats and known for their tolerance to acidic and oxygen-limited conditions. In contrast, most female specimens are still at earlier stage of gonadal development. These pattern suggests that reproductive maturity was limited among sampled females at the time collection.

However, studies conducted in peat swamp ecosystems and lowland rivers in Indonesia, including those in Central Kalimantan and South Sumatra, have reported that many female fish are found in immature gonadal stages, particularly during the dry season, when water levels decline and the available aquatic habitats become more limited (Herliwati & Rahman, 2013; Sudarmo, 2025). The low proportion of mature female gonads observed in this study coincided with environmental conditions characterized by acidic water (pH 4–7) and dissolved oxygen concentrations ranging from 3–7 mg/L in the Rawa Tripa peat swamp. Environmental factors such as water acidity, oxygen availability, and hydrological variation have been reported to influence fish reproductive processes through the hypothalamic–pituitary–gonadal (HPG) axis and may affect gonadal development under unfavorable conditions (Canosa & Bertucci, 2023; Saha et al., 2022; Zhao et al., 2023).

Ecologically, low levels of female gonadal maturity have serious implications for fish population sustainability. If stressful environmental conditions persist over the long term, spawning success and larval recruitment will decline, which could ultimately lead to a gradual decline in fish populations. This situation has the potential to strengthen the dominance of fish species that are tolerant to extreme environments, while species that have narrow tolerance to changes in water quality will be increasingly eliminated from the community.

The Relationship Between Water Quality and Fish Reproduction Conditions in the Rawa Tripa

The physical and chemical factors of the water in the Rawa Tripa swamp area, Pulo Kruet Village, Darul Makmur Subdistrict, at the time of the study, showed variations at six different locations. The selection of these locations for the collection of environmental data was informed by an exploratory method employing a purposive approach, given the significant depletion of water resources during the dry season. The selected locations comprised water bodies, specifically the Tripa Swamp area, its channels, and tributaries. The study measured three physical and chemical factors of water: temperature, pH, and DO (dissolved oxygen). These three factors are abiotic elements that exert a direct and substantial influence on the life of aquatic organisms, such as fish. The physical-chemical factors of the water at the time of the study (Table 3) demonstrate that the environmental conditions in the Rawa Tripa swamp were as follows: the temperature ranged from 25 to 30°C, with an average of 26.67 ± 1.86°C; the pH ranged from 4 to 7, with an average of 5.5 ± 1.38; and the DO ranged from 3 to 7 mg/L, with an average of 5 ± 1.89 mg/L.

Table 3. Physical and chemical characteristics of Rawa Tripa Swamp water

Sampling Location	Temperature (°C)	pH	DO (mg/L)
Location 1	25	4	3
Location 2	30	4	3
Location 3	27	5	4
Location 4	25	6	6
Location 5	27	7	7
Location 6	26	7	7
Mean ($\bar{x}$ ± sd)	26.67±1.86	5.5±1.38	5±1.89

Water quality is a major environmental factor that directly controls the physiological processes of fish, including growth, metabolism, and reproduction. In peat swamp ecosystems such as Rawa Tripa, water characteristics are generally marked by high water level fluctuations, acidic pH, and relatively low dissolved oxygen levels. These conditions require special physiological adaptations from the fish that live in them, but at the same time, can limit reproductive success, especially in environmental conditions that are under pressure due to habitat degradation.

The observed temperature range (25–30°C) is generally suitable for tropical freshwater fishes and is unlikely to have imposed substantial thermal stress during the sampling period. Temperature plays an important role in regulating the metabolic rate and enzymatic activity involved in the processes of oogenesis and vitellogenesis. At the optimal temperature range, fish gonad development can proceed normally, while temperatures that are too low or too high can inhibit oocyte maturation and reduce egg quality (Bhat, 2025). Several studies have shown that changes in water temperature can affect spawning time and gonadal maturation synchronization in tropical fish, especially in shallow water ecosystems such as swamps and floodplains (Rahman, 2024). Nevertheless, differences in gonadal maturity among species observed in this study may also be related to species-specific reproductive cycles and seasonal spawning patterns, which were not directly evaluated because sampling was conducted during a single season.

In addition to temperature, pH is an important factor that affects fish reproduction (Bhat, 2025). The pH value of the water in the Rawa Tripa in this study ranged from 4 to 7, with an average of acidic. Acidic water conditions are known to affect the ion balance in fish bodies, disrupt hormonal functions, and impact gonadal development (Santos, 2020). At low pH, fish metabolic energy tends to be diverted to maintain physiological homeostasis, thereby reducing the allocation of energy for reproductive processes (Li et al, 2023). This may explain the low number of fish species found to have mature female gonads at the study site. However, some species, such as *Channa* spp. and labyrinth fish, are still able to survive and reproduce in acidic water conditions, indicating physiological adaptation to extreme environments. Water pH was measured using litmus paper as a rapid field assessment tool. Although this method provides a general estimate of water acidity, its precision is lower than that of a calibrated digital pH meter.

Therefore, the pH values reported in this study should be interpreted as approximate indicators of environmental conditions. Future studies are recommended to employ digital pH meters to improve measurement accuracy and facilitate more robust ecological analyses.

Dissolved oxygen (DO) levels in Rawa Tripa during the study ranged from 3–7 mg/L, with the lowest values found at several points that experienced water shrinkage due to the dry season. Dissolved oxygen is a major limiting factor in fish reproduction because it directly affects cellular respiration and energy production. DO concentrations below 5 mg/L can have a negative impact on growth and reproduction (Bhat, 2025). Low DO conditions can cause physiological stress, suppress gonadotropin activity, and inhibit oocyte development to maturity (Bhat, 2025). The low number of fish with mature female gonads in this study is thought to be related to the relatively low DO conditions at most observation points. Several fish species that were still found in low DO conditions generally have special adaptations, such as the ability to take oxygen directly from the air, making them more tolerant to hypoxic environments.

Overall, the combination of acidic water conditions and low dissolved oxygen levels in the Rawa Tripa has the potential to limit fish reproduction, especially during the dry season when the availability of aquatic habitats is increasingly limited. The histological finding of mature female gonads in only five fish species indicates that only certain species with high physiological tolerance are able to continue their reproductive cycle under these environmental conditions. This shows that water quality not only affects the presence and distribution of fish, but also determines the potential for fish population regeneration in peat swamp ecosystems.

This study has several limitations. First, the number of fish collected was relatively low, and several species were represented by only one or a few specimens, limiting robust species-specific analyses of sex ratio and reproductive condition. Second, sampling was conducted during a single survey period, providing only a temporal snapshot of fish assemblage structure and reproductive status, while seasonal variation in hydrological conditions and reproductive cycles was not assessed. Third, only 37 female individuals from 10 species were available for gonadal examination, and mature gonads were observed in only five individuals, restricting broader inferences about population-level reproductive patterns. Fourth, environmental characterization was limited to temperature, pH, and dissolved oxygen, whereas other potentially influential variables, including nutrient concentrations, water depth, habitat structure, and food availability, were not evaluated. In addition, pH measurements were obtained using litmus paper, which provides lower precision than a calibrated digital pH meter. Future studies incorporating larger sample sizes, repeated seasonal sampling, quantitative reproductive metrics, and more comprehensive environmental assessments are needed to better understand fish reproductive ecology in the Tripa Peat Swamp ecosystem.

Conclusion

This study recorded 23 fish species belonging to 12 families and 4 orders in the Rawa Tripa Peat Swamp. Cyprinidae was the most species-rich family (six species) and contributed the highest proportion of individuals recorded. Several species known to tolerance to acidic and low-oxygen environments were also documented, reflecting the characteristic fish assemblage of tropical peat swamp ecosystems. Histological examination of female gonads showed that mature oocytes were observed only in five species, whereas most female specimens were at earlier stages of gonadal development.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. This study utilized artificial intelligence tools solely to assist in improving language clarity and manuscript organization. The use of AI did not influence the research design, data analysis, interpretation of results, or scientific conclusions.

Author Contribution

W.S contributed in supervision of research ideas and conceptualization. M.A contributed in project administration, investigation, and original draft preparation. C.N.D., and A.F. contributed supervision of data processing, methodology, and data validation. H.I.K contributed in investigation and manuscript review and editing.

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References

Affandi, R., Kamal, M. M., & Haryani, G. S. (2019). Fungsi rawa pesisir sebagai habitat sidat tropis Anguilla spp. Di estuari sungai Cimandiri, Sukabumi Jawa Barat. *Jurnal Ilmu dan Teknologi Kelautan Tropis*, *11*(2), 475-492.

Batubara, A. S., Zulfahmi, I., Nur, F. M., Maulizar, S., Maghfiriadi, F., Nafis, B., & Mutia, R. (2025). Ichthyofauna in the peat swamp waters of East Kalimantan, Indonesia. *The European Zoological Journal*, *92*(1), 507-517.

Bhat, I. A., Rather, M. A., Ahmad, I., Ahmad, I., Mir, I. N., & Hussna. (2025). Impact of shifting abiotic factors in aquaculture on fish breeding and

reproduction: a review. *Blue Biotechnology*, *2*(1), 3.

Canosa, L. F., & Bertucci, J. I. (2023). The effect of environmental stressors on growth in fish and its endocrine control. *Frontiers in endocrinology*, *14*, 1109461.

Cowan, Z. L., Green, L., Clark, T. D., Blewett, T. A., De Bonville, J., Gagnon, T., & Binning, S. A. (2024). Global change and premature hatching of aquatic embryos. *Global Change Biology*, *30*(9), e17488.

Dos Santos, J. A., Soares, C. M., & Bialetzki, A. (2020). Effects of pH on the incubation and early development of fish species with different reproductive strategies. *Aquatic Toxicology*, *219*, 105382.

Filice, M., Mazza, R., Leo, S., Gattuso, A., Cerra, M. C., & Imbrogno, S. (2020). The hypoxia tolerance of the goldfish (*Carassius auratus*) heart: the NOS/NO system and beyond. *Antioxidants*, *9*(6), 555.

Flores, A., Wiff, R., Ganias, K., & Marshall, C. T. (2019). Accuracy of gonadosomatic index in maturity classification and estimation of maturity ogive. *Fisheries Research*, *210*, 50-62.

Hasani, Q. (2022). Strategi dan Taktik Reproduksi Ikan, Hubungannya dengan Kondisi Lingkungan. *AQUACOASTMARINE: Journal of Aquatic and Fisheries Sciences*, *1*(2), 97-101.

Herliwati, H., & Rahman, M. (2013). Tingkat kematangan gonad dan fekunditas ikan di kolam rawa Danau Bangkau pada musim kemarau [Gonadal development stage and fecundity of fishes in swamp pond of Danau Bangkau at dry season]. *Jurnal Iktiologi Indonesia*, *13*(1), 85-90.

Husna, A. Y., Anhar, A., & Sugianto, S. (2023). Estimasi Laju Deforestasi Kawasan Ekosistem Gambut Rawa Tripa Dengan Pendekatan Data Penginderaan Jauh. *Jurnal Ilmiah Mahasiswa Pertanian*, *8*(1), 620-635.

Iswahyudi, I. (2016). Konflik Lahan di Hutan Gambut Rawa Tripa Provinsi Aceh. *Jurnal Penelitian Agrosamudra*, *3*(2), 38-46.

Johansen, A., Thiede, B., Anonsen, J. H., & Nilsson, G. E. (2023). Surviving without oxygen involves major tissue specific changes in the proteome of crucian carp (*Carassius carassius*). *PeerJ*, *11*, e14890.

Kautsari, N., Latuconsina, H., & Zulfahmi, I. (2023). Preliminary Study of Eels (Anguilla) in Sumbawa Island According to the Knowledge of Local Communities: Distributions, Pattern of Fishing, and Utilizations. *Scientific Journal of Fisheries & Marine/Jurnal Ilmiah Perikanan dan Kelautan*, *15*(1).

Monalisa, M. (2014). Peluang dan Tantangan Gerakan Penyelamatan Rawa Tripa Berbasis Komunitas di Provinsi Aceh. *Jurnal Agrisep*, *15*(1), 25-30.

Muchlisin, Z.A., Akyun, Q., Rizka, S., Fadli, N., Sugianto, S., Halim, A., Siti-Azizah, M.N. (2015). Ichthyofauna of Tripa Peat Swamp Forest, Aceh province, Indonesia, OJS/PKP, 11(2), 121-129.

Mujimin, M. (2016). Histologi Berbagai Jenis/Tingkatan Gonad Ikan Kerapu Sunu

(*Plectropomus leopardus*). Buletin Teknik Litkayasa Akuakultur, 7(2), 101-103.

Rahman, A. (2024). Influence of Water Temperature on Fish Reproduction in Bangladesh. *International Journal of Natural Sciences*, 4(2), 62-72.

Razi, N. M., Nasir, M., Khalidin, K., Savira, D., Najmi, I., Mahfud, M., ... & Muchlisin, Z. A. (2023). The diversity, distribution, biomass, and conservation status of ichthyofauna of the Singkil peat swamp in Aceh Province, Indonesia. *Biodiversitas Journal of Biological Diversity*, *24*(12).

Rizka, S., Muchlisin, Z. A., Akyun, Q., Fadli, N., Dewiyanti, I., & Halim, A. (2016). *Komunitas makrozoobentos di perairan estuaria rawa gambut Tripa Provinsi Aceh* (Doctoral dissertation, Syiah Kuala University).

Rukmana, R. M., Trijoko, T., & Pratiwi, R. (2014). Keragaman ikan anggota ordo perciformes di Sungai Sukamade Taman Nasional Meru Betiri. Biomedika, 7(2), 46-52.

Saha, N., Koner, D., & Sharma, R. (2022). Environmental hypoxia: A threat to the gonadal development and reproduction in bony fishes. *Aquaculture and Fisheries*, *7*(5), 572-582.

Santoso, E., & Wahyudewantoro, G. (2019). Biodiversitas Spesies Ikan Perairan Gambut Air-Kumai Kabupaten Kotawaringin Barat Kalimantan Tengah. *Jurnal Ikhtiologi Indonesia*, *9*(2), 315-335.

Sauger, C., Quinquis, J., Kellner, K., Berthelin, C., Lepoittevin, M., Elie, N., & Dubroca, L. (2026). Comparing Macroscopic and Quantitative Histological Methods to Determine Sexual Maturity in the Female European Plaice, Pleuronectes platessa Linnaeus, 1758. *Animals*, *16*(3), 519.

Schreck, C. B., Contreras-Sanchez, W., & Fitzpatrick, M. S. (2001). Effects of stress on fish reproduction, gamete quality, and progeny. In *Reproductive biotechnology in finfish aquaculture* (pp. 3-24). Elsevier.

Servili, A., Canario, A. V., Mouchel, O., & Muñoz-Cueto, J. A. (2020). Climate change impacts on fish reproduction are mediated at multiple levels of the brain-pituitary-gonad axis. *General and comparative endocrinology*, *291*, 113439.

Srineetha, U., Reddy, M. V., & Bhaskar, M. (2014). Effect of Environmental acidic pH on Oxygen Consumption in Different stages of Fish, Cyprinus carpio (L). *Journal Environmental Science Toxicology and Food Technology*, 17-21.

Sudarmo, A. P., Dwirastina, M., & Ditya, Y. C. (2025). Environmental conditions and actual distribution of fish resources in the Lower Musi River South Sumatra, Indonesia. *Fisheries and Aquatic Sciences*, *28*(4), 261-274.

Tata, H. L., & Rahayu, S. (2015). Hutan Rawa Tripa Sebagai Habitat Orangutan Sumatera: Ancaman dan Peluang. *World Agroforestry Centre (ICRAF)*.

Thornton, S. A., Page, S. E., Upton, C., & Harrison, M. E. (2018). Peatland fish of Sebangau, Borneo: diversity, monitoring and conservation.

Wahyudewantoro, G. (2010). Kajian potensi ikan di lahan gambut Tasik Betung, Riau. *Bionatura*, *12*(2), 218473.

Widyanto, U. (2012). Tripa Peat Swamp Aceh's Burning Shame. Majalah Tempo. Available: https://www.academia.edu/download/38478077/Tempo-MBM_Rawa-Tripa_English-July2012.pdf [Accessed: 22 Jan 2025].

Zainuri, M. (2019). Rekayasa dan Tingkah Laku Ikan. UTMPRESS. Madura.

Zhao, C., Yan, J., Zhang, Y., Zhang, G., Wang, T., Zhang, K., & Yin, S. (2023). Effect of long-term hypoxia on the reproductive systems of female and male yellow catfish (Pelteobagrus fulvidraco). *Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology*, *267*, 110864.