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Ecological Role of Siombak Lake as a Nursery and Feeding Ground for Aquatic Species in the Belawan Estuary, Indonesia

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Abstract: Tidal lake is a coastal lake whose water condition is influenced by the dynamics of tides. This lake serves as a habitat for a diverse array of aquatic biota, including freshwater, brackish, and marine species. This study aims to describe the distribution of larvae, juveniles, crustacea, and adult fish in the context of the coastal lake's role as a nursery and feeding ground. The study was conducted from September 2018 to August 2019, at Lake Siombak, a coastal lake located in the Belawan River estuary along the northern coast of Medan City, Indonesia. Data were collected at high and low tides during the full moon. Larva and juvenile fish? sampling used larval nets with a mesh size of 300 µm and a diameter of 60 cm, while adult fish were caught with gill nets with a mesh size of 1 inch and a dimension of 10 × 2 m. Crustaceans were captured with traps. The research found nine families consisting of six fish families, two crustacean family, and one cnidarian family. The abundance of larvae and juveniles found was 17 to 1797 individuals per 100 m^{-3}. At the high tides, the composition of Ulmaridae (jellyfish: *Aurelia aurita*) that was caught reached 57.7%. While at low tides, there were more Penaeid families in the Mysis phase, reaching 78.6%. The abundance of Mysis (Penaeid) and jellyfish indicates that the lake serves as a nursery ground for post larvae crustaceans and jellyfish. The presence of adult fish migrating from the sea and Belawan River indicates that the lake functions as a feeding ground in the Belawan estuary. Therefore, Lake Siombak still plays a crucial role as a nursery and feeding ground for fish, crustaceans, and jellyfish originating from the Belawan River estuary and its surrounding areas. Preserving the sustainability of this lake is crucial to ensuring the continued productivity of fisheries in the Belawan River estuary.

Keywords: Belawan, coastal lake, estuarine, juvenile, larvae, nursery and feeding ground

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1. Introduction

An estuary is a coastal area where freshwater from rivers or streams meets and mixes with saltwater from the ocean. These regions are often characterized by unique ecosystems, with a variety of plants, animals, and microorganisms that thrive in the brackish (partly salty) water. Estuaries serve as important habitats for many species, acting as nurseries for fish and other marine life. They also provide crucial ecosystem services such as water filtration, flood control, and habitat for

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wildlife (Nybakken and Bertness, 2005; Odum and Barrett, 2005; Wolanski and Elliott, 2016; Hopkinson *et al.*, 2019). The estuarine ecosystem is very important for coastal fishery activities. It is well known that estuaries and other coastal ecosystems (mangroves, seagrasses, and coral reefs) are essential ecosystems in supporting coastal fisheries' productivity and production (Haimovici and Cardoso, 2017; Rangkuti *et al.*, 2017; Berkström *et al.*, 2020; Cheminée *et al.*, 2021; Scapin *et al.*, 2021). The main role of estuarine areas is spawning, nursery, and feeding ground for various fresh and marine organisms (Igulu *et al.*, 2014; Dutta *et al.*, 2017; Gómez-Ponce *et al.*, 2018; Pelage *et al.*, 2021). The estuarine region plays an important role in the survival of many fish species in the larval and juvenile phases. Typically, larvae and juveniles grow and develop in safe areas where abundant natural food is available, commonly referred to as nursery grounds (da Silva *et al.*, 2023; Mocuba *et al.*, 2023; Azrieli *et al.*, 2024; Elston and Murray, 2024).

The extent to which the estuary ecosystem supports coastal fishing operations has sparked a lot of curiosity among experts. Numerous studies on fisheries have been conducted in river mouths or estuaries (Nybakken and Bertness, 2005; Rangkuti *et al.*, 2017). The distribution of larvae, juveniles, fish, and adult crustaceans with regard to coastal lakes as spawning, nursery, and feeding grounds is one of the few remaining features of Indonesia's coastal lakes, or tidal lakes. Since fish larvae are one of the most significant stages of fish life, research on one of their ecological characteristics is crucial as a foundational study for the estuary region's fisheries (Berkström *et al.*, 2020; da Silva *et al.*, 2023; Mocuba *et al.*, 2023; Azrieli *et al.*, 2024; Campbell *et al.*, 2024; Elston and Murray, 2024), including coastal lakes/ coastal lagoon (Ocaña-Luna and Sánchez-Ramírez, 2016; Jaxion-Harm and Speight, 2017; Baptista *et al.*, 2020).

Some tidal lakes in the world include: Lagoa dos Patos and Lagoa de Araruama, Brazil, Lake St. Lucia, South Africa, Coorong, Australia, Lake Songkla, Thailand, Laguna de Terminos, Mexico, and Lake Pontchartrain, USA, Mississippi Sound, USA, and Wadden Zee, Netherlands-Denmark. Tropical tidal lakes themselves are found in Lake Chilika, India; Laguna Nokue, Benin; Laguna Teluk Belukar (Nias-Indonesia), Lake Anak Laut (Singkil-Indonesia), and Lake Siombak in Medan City, North Sumatra Province (Muhtadi and Leidonald, 2025). A coastal lake in poor condition is Chilika Lake in India, where water pollution hurts fish quantity and quality, which in turn has an impact on household incomes. However, this lake still has the highest mega biodiversity for tropical coastal lakes in the world (Mengo *et al.*, 2025). Coastal lakes in Indonesia with fairly good conditions are Anak Lau Lakes (Leidonald *et al.*, 2024). Anak Laut Lakes have higher biodiversity (Muhtadi *et al.*, 2023d; 2025) than Siombak Lake (Muhtadi *et al.*, 2020c; 2022; 2023a) and Teluk Belukar Lake (Hasudungan *et al.*, 2008).

Lake Siombak is a coastal lake located in the estuarine region of the Belawan River, close to Medan City in North Sumatra Province. This lake is distinguished by its unique characteristics and is one of Indonesia's tidal lakes. Lake Siombak is an open lake whose waters are affected by tides from the sea (Belawan-Malacca Strait). This lake has an area of 29 ha. Like other coastal lakes, Lake Siombak is one of the shallow lakes. The average lake depth ranges from 2.96 - 5.26 m when it rains and 2.96 - 4.90 m when it is dry. This lake is a type of tidal lake. Tidal characteristics in Lake Siombak are semi-diurnal, which means that there are two high tides and two low tides, with the height relatively the same. Tidal measurement results in Lake Siombak showed that the highest water level elevation (HAT) is 2.66 m during rain and 2.23 m during the dry season. The lowest water level (LAT) is -0.43 m during rain and -0.04 m during the dry season. Tidal elevation differences that are relatively high (> 2 m) indicate that the lake waters are very dynamic (Muhtadi *et al.*, 2020a). Some parts of the lake are bordered by mangrove forests with varying densities, ranging from sparse to moderate (Leidonald *et al.*, 2019a; Muhtadi *et al.*, 2020b). A range of freshwater, brackish, and marine species, including fish, shrimp, crabs, and shellfish, inhabit the lake (Yulianda *et al.*, 2020; Muhtadi *et al.*, 2022; Muhtadi *et al.*, 2023a). These environmental conditions likely make Lake Siombak an important nursery for various larvae, juveniles,

and small fish, as well as a feeding area for adult fish. Thus, this study aims to gather insights into the presence and distribution of larvae and juveniles in this lake, focusing on its role as a nursery and feeding ground for fish and other organisms. Such information is crucial for effectively managing fisheries resources in the Belawan River estuary.

2. Materials and Method

2.1. Study Area

This research was carried out in Lake Siombak, Medan City, North Sumatra Province, Indonesia. (Figure 1), from September 2018 to August 2019. There are 11 observation points consisting of 8 points in the lake (St 1 to St 8) and 3 points in the river (St 9 to St 11). Point 8 is the inlet and outlet of the lake. The fish ponds around (north, St 4 - St 6) enter the lake through St 5. The selection of St 9, St 10, and St 11 is based on the consideration of the existence of a small river, called 'paluh', as the closest comparison to the lake, which still contributes, especially to the water quality of the lake. The detailed conditions of the observation points are presented in Table 1. The sampling was conducted during both high and low tides, specifically every month at the peak of the full moon.

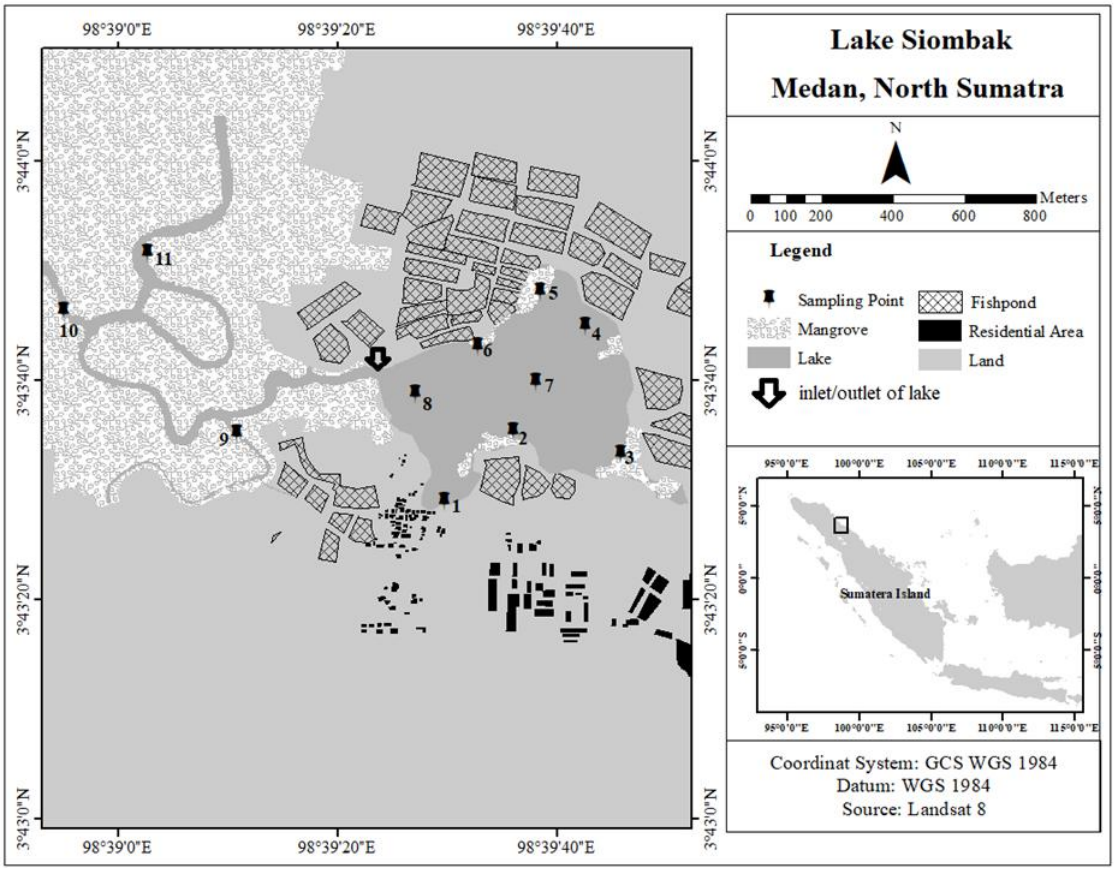


Figure 1. Map of the study area showing 11 observation points

2.2. Sampling of environmental conditions

Water physicochemical parameters, including temperature, salinity, dissolved oxygen, pH, water currents, and water depth, were directly measured in the field during sampling. Temperature and dissolved oxygen were measured by a DO meter (Pen DO meter Lutron), salinity was measured by a refractometer (Atago refragtometer), pH was measured by a pH meter (Atago pH meter), and current velocity was measured by a current meter.

2.3. Sampling of larvae and juveniles

Larvae and juvenile samplings were conducted using larval nets with a mesh size of 300 µm and a diameter of 60 cm. The nets were mounted and secured to the back of a

motorboat, positioned 10 m away from the boat at a depth of approximately 0.5 m. The net was then towed horizontally at a boat speed of 1.5 knots for 10 minutes. Afterward, the boat was stopped, and the net was retrieved to collect the samples. The samples collected from the study site were then sorted to separate the larvae, juveniles, eggs, and other materials, such as debris, that might have been captured during sampling. Once sorting was complete, the samples were placed in sample bottles and preserved in a 10% formalin solution. After 24 hours, this was replaced with 70-80% ethanol. Finally, the larvae and juvenile samples were observed and identified in the laboratory Aquatic Environment Laboratory, University of North Sumatra to the most likely taxon. Identification was performed using a microscope equipped with a camera and an ocular micrometer Hirox HRX-01 Digital Microscope to measure the body length of juveniles. Morphological characteristics were examined for larvae identification, which was conducted at the family level using the Leis & Carson-Ewart method (Leis & Carson-Ewart 2004).

Table 1. Characteristics of the observation sites in the Siombak Lake ecosystem

Loca-tions	Mangrove density (tree/ha)	Mangrove conditions	Additional information
St 1	150	Low density	Lake
St 2	250	Low density	Lake
St 3	1,533	high density	Lake
St 4	300	Low density	Lake
St 5	1,200	Medium density	Lake
St 6	150	Low density	Lake
St 7	-	-	Middle of the lake
St 8	150	Low density	Inlet and outlet of lake
St 9	2,500	High density	River
St 10	1,400	Medium density	River
St 11	2300	high density	River

2.4. Adult fish and crustacean sampling

Adult fish were captured using gill nets with a mesh size of 1 inch and dimensions of 10 × 2 meters, while shrimp and crabs were trapped in 1 × 0.5-meter traps placed on the lake bed. Additionally, adult fish, shrimp, and crabs were counted and then dissected for food (gut) analysis and gonad maturity assessment.

2.5. Data Analysis

Calculation of larva and juvenile abundance was done using the modified formula of APHA (2017), as follows:

$$N_i = \frac{C_i}{V} \times 1000$$

where,

Ni = abundance of to-i larvae and juveniles (fish/1000 m^3)

Ci = number of i-th juveniles counted

V = volume of filtered water (Vtsr = $l \times t \times v$), with, l is the width of the mouth opening of the larval net, t is larval net withdrawal time (minutes), and v is the pull/tow speed (m/min).

3. Result and Discussion

3.1. Habitat Characteristics

Spatially and temporally, temperature and pH are the most stable water quality parameters in the waters of Lake Siombak during high and low tides. The temperature ranged from 28.4 to 31.5°C (St. dev <1) and the pH ranged from 6.9 to 7.5 (St. dev <0.5) (Table 1-2). In general, the temperature in the tropics is quite stable with low fluctuations. However, at the dry season (Mar-Apr) peak, it shows higher temperatures than other months. In this case, it is suitable for jellyfish conditions, which were found abundantly in March and April.

The pH in brackish waters is relatively stable between 7 to 8.5, and the change (fluctuation) of pH is also relatively small (Odum & Barrett 2005). This finding indicates that coastal lake waters are buffers. Temperature and pH are stable water quality parameters in tropical waters (Sim & Tai 2018). It is the same as in the Akulum Lake, India (Sajinkumar *et al.*, 2017), Chilika Lake, India (Barik *et al.*, 2017), Coastal Bolgoda Lake, Sri Lanka (Ratnayake *et al.*, 2018), and Anak Laut Lake, Singkil, Indonesia (Leidomald *et al.*, 2024) showed stable pH and temperature values throughout the year. However, it is different from Itapu tropical coastal lagoon (Brazil) with more varied temperature and pH values (Raposo *et al.*, 2018). Certainly, the pH and temperature values are more varied than those in coastal lakes in sub-tropical regions (Elshemy *et al.*, 2016; Jamila *et al.*, 2016).

DO values are relatively stable in the waters of Lake Siombak, but at a low range, which is below 4 mg/L. This finding is very different from other coastal lakes with a stable DO value at a value higher than 5 mg/L (Jamila *et al.*, 2016; Barik *et al.*, 2017; Raposo *et al.*, 2018; Ratnayake *et al.*, 2018; Leidonald *et al.*, 2024). This condition is caused by the high organic matter in Lake Siombak compared to other coastal lakes, especially the BOD and COD (Muhtadi *et al.*, 2023b).

Salinity in the lake is quite varied, especially temporally. The salinity value is lower in the rainy season (Sep-Jan and May), ranging from 4 to 8 ‰. While in the dry season (Feb-Aug, except May), the value of salinity is more, which ranges between 6 to 14 ‰. The salinity value is relatively high (> 10 ‰) in March-April, causing jellyfish very abundant in that month. While in the rainy season with low salinity, no jellyfish are found. Spatially, the salinity on the surface of Lake Siombak is almost evenly distributed throughout the lake. This situation indicates that the tidal effect is quite large, affecting the salinity distribution in Lake Siombak. However, the distribution of surface temperatures differs spatially based on the time of measurement. However, vertically, the distribution of temperature and salinity is different between the surface and the lake floor. The temperature on the surface is higher than that on the floor, while the salinity value on the surface is lower than that on the floor (Leidonald *et al.*, 2019b ; Muhtadi *et al.*, 2020a; Muhtadi *et al.*, 2024).

The presence of several larvae and juveniles from the sea entering Lake Siombak is inseparable from the role of Lake Siombak, which provides food in the form of plankton. Other research results by Muhtadi *et al.*, (2020c) show that Lake Siombak is very abundant in phytoplankton and zooplankton larval and juvenile food. This finding is inseparable from the high availability of nutrients in the waters of Lake Siombak. The high nutrients come from rivers and mangrove litter found on the edge of Lake Siombak, and the density of mangroves on the edge of Lake Siombak varies from sparse to dense. The location of the mangrove that is still good (tight) is in the southeast (station 3), while in the north (station 5), it is moderate. The remaining mangroves on the edge of Lake Siombak grow "inline" on the lake's edge. In the forest, "Nipa palm in the Lake Siombak ecosystem can be said to be still good with very dense densities (more than 2000 trees/ha) (Muhtadi *et al.*, 2020b). The existence of mangrove vegetation can also be a protection for fish larvae and juveniles. Andolina *et al.*, (2020), found that aquatic plants in the coastal lagoon could support Sparus aurata larvae's growth in the lake.

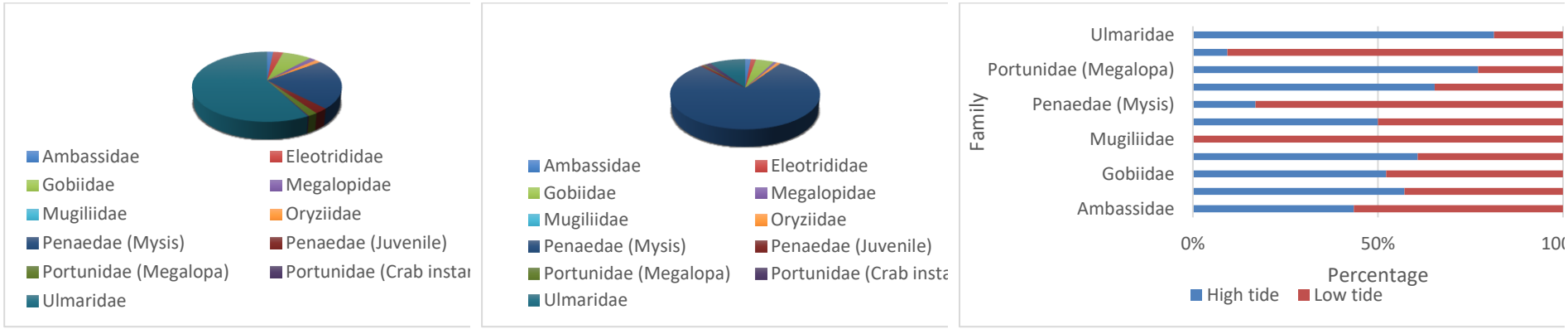
3.2. Composition of larvae and juvenile

Based on the results of larvae and juvenile fish and crustacean research in Lake Siombak, families consisted of 6 families of fish, two families of crustaceans, and one family of Cnidaria. At the time of tides, the composition of Ulmaridae (Jellyfish: *Aurelia aurita*) that was caught reached 57.7%. While at low tides, there were more Penaeids families in the Mysis phase, reaching 78.6%. The number of fish families was mostly found there, in which the crustacean and Cnidaria were dominant during low tides. This condition proves that the estuary area, including tidal lakes, is a nursery ground for crustaceans and jellyfish (Gómez-Ponce *et al.*, 2018; Puspasari & Aisyah, 2018; Fernández-Alías *et al.*, 2020). In general, referring to Figure 2c, it can be seen that crustacean larvae (instar crabs and Mysis) are most commonly found at low tides, whereas in the juvenile phase, including their megalopa, are most commonly found at high tides. Meanwhile, jellyfish larvae are most commonly found at high tides, in which these larvae are carried away when the tides enter Lake Siombak.

Table 2. Temporally water quality in Lake Siombak

Para-meters	Condi-tions	Month											
		Sep	Oct	Nov	Dec	Jan	Feb	Marc	Apr	May	June	July	Aug
Salinity	HT	7±2.64	4±1.77	6±1.38	6±1.27	8±2.46	8±2.09	14±1.92	12±1.45	7±2.61	8±2.61	8±2.18	10±2.26
($^0/_{00}$)	LT	6±2.63	7±1.88	6±1.58	6±1.57	10±2.49	8±3.18	13±2.16	11±1.92	8±3.79	6±1.94	6±2.78	10±2.65
Tempe-	HT	30.2±0.52	30.9±0.70	28.9±0.24	29.8±0.34	30.0±0.38	30.0±0.24	31.1±0.60	31.3±0.51	30.4±0.39	28.4±0.54	30.5±0.41	31.2±0.42
Rature (^{0}C)	LT	30.3±1.37	31.5±1.09	28.8±0.71	29.2±0.34	30.3±0.73	29.5±0.99	30.7±0.42	30.8±0.39	29.7±0.76	28.7±0.70	30.1±0.61	30.7±0.45
pH	HT	7.4±0.21	7.0±0.15	7.1±0.06	7.4±0.31	7.3±0.15	7.3±0.20	7.3±0.15	7.3±0.19	7.2±0.10	7.4±0.17	7.2±0.21	7.1±0.15
	LT	7.2±0.33	6.9±0.16	7.1±0.21	7.2±0.10	7.4±0.27	7.2±0.12	7.1±0.07	7.3±0.16	7.2±0.14	7.4±0.11	7.0±0.09	7.0±0.07
DO	HT	4.8±1.34	4.9±1.27	2.0±0.63	3.2±0.94	4.1±0.60	2.6±0.78	2.8±1.05	3.4±0.83	3.4±1.29	2.6±1.03	2.0±1.09	1.9±0.52
(mg L^{-1})	LT	5.1±2.62	4.1±2.02	1.9±1.09	2.1±0.79	4.8±1.19	2.6±0.97	1.9±0.62	1.5±0.73	1.7±0.46	2.6±0.80	1.3±0.57	1.0±0.71
Current*	HT	0.24±0.05	0.19±0.06	0.45±0.12	0.75±0.11	0.72±0.11	0.48±0.09	0.38±0.13	0.44±0.12	0.38±0.13	0.22±0.10	0.16±0.03	0.17±0.04
(m/s)	LT	0.43±0.08	0.24±0.06	0.34±0.11	0.23±0.10	0.37±0.10	0.53±0.12	0.48±0.24	0.51±0.25	0.48±0.24	0.19±0.03	0.33±0.19	0.15±0.23

HT = high tide; LT = low tide; * measured currents at part of inlet and outlet (station 8)



a. High tide b. Low tide c. Dominant Families

Figure 2. Larva and juvenile composition found in Lake Siombak during (a) High tide, (b) Low tide, (c) percentage Families dominancy

The richness of larvae in Lake Siombak is still higher compared to larvae in Lake Anak Laut, where 10 genera were found. This may be due to the research conducted in Lake Siombak for longer (one year) compared to Lake Anak Laut, which was only 1 month (Muhtadi *et al.*, 2024). Larvae research is mostly done at river mouths. In general, the larvae found in the river's mouth are very abundant in the species' composition (their family). Sixteen Families in Campi Bay (West Nusa Tenggara) (Nastiti *et al.*, 2016), 24 larval species in East Plawangan of Segara Anakan (Cilacap) (Nuryanto *et al.*, 2017), and 13 families in Timbulsoko Village, Demak (Nugroho *et al.*, 2019). However, only seven families were in the Musi River estuary (Prianto *et al.*, 2013), including only six families were in the Jakarta Bay and surrounding areas (Puspasari & Aisyah, 2018). Meanwhile, in tidal lakes or other coastal lakes abroad, data showed that the composition of larvae in Lake Siombak was lower. There are 40 species, 37 genera, and 19 fish families found in the Tamiahua lagoon, Veracruz (México) (Ocaña-Luna & Sánchez-Ramírez, 2016), but not much different from those found in Oyster Bed Lagoon (Honduras) with nine families (Jaxion-Harm & Speight, 2017).

3.3. Spatial and temporal distribution of larvae and juvenile

Spatially, the abundance of larvae and juveniles was highest at station 1, which reached 1797 individual 100m-3 at low tides, and at station 9, which reached 354 individual 100m-3. Meanwhile, the lowest abundance at station 2 is only 17 individual 100m-3 at low tide, and at station 10, which is only individual 100m-3 at high tide. spatially, at high tide larval and juvenile abundance were higher in the northern part (Figure 3), whereas at low tide abundance and juvenile were higher in the southwest (Figure 4). Penaeidae and Ulmaridae are always found at every station during high and low tides. Penaedae, especially shrimp in the Mysis phase, were found to be quite large in Lake Siombak. Mysis abundance ranges from 2-78 individual 100m-3 at high tides and 3-1733 individual 100m-3. Crustaceans, including Penaeid, are marine organisms that make estuaries care areas. After spawning in the middle of the sea, they will be carried by currents into estuaries (Gómez-Ponce *et al.*, 2018). Meanwhile, jellyfish (*A. aurita: Ulmaridae*) are abundant in Lake Siombak. The abundance of jellyfish in Lake Siombak ranges from 2-340 individual 100m-3 at high tides and 1-50 individual 100m-3 at low tides. The abundance of jellyfish in Lake Siombak is higher than in other estuaries.

Temporally, larval and juvenile abundance reaches its peak in the dry season (Feb-August) compared to the rainy season (Sep-Jan) (Figure 5). Jellyfish larvae are only found in the dry season, in which salinity and temperature are higher than those in the rainy season. The peak population of jellyfish larvae is at the peak of the dry season in March, reaching 1548 individual 100m-3 at high tides and 121 individual 100m-3 at low tides. The abundance of A. aurita is influenced by temperature. While jellyfish are more commonly found when temperatures and salinity are high (summer), and during the rainy season, A. aurita was not found (Rahmah & Zakaria 2017; Puspasari & Aisyah 2018; Fernández-Alías *et al.*, 2020). Jellyfish are light-sensitive animals; in sunny weather conditions, the jellyfish will swim horizontally near the surface of the water, and when the weather is cloudy, the jellyfish will swim vertically to the depths away from the surface (Hamner *et al.*, 1994; Suzuki *et al.*, 2019).

Research results in Batu Kalang Beach Tarusan, Pesisir Selatan District, West Sumatra, found that in March, the jellyfish larvae were in the ephyra phase. This month is considered to represent the beginning of the A. aurita season. In May, obtained the medusa phase jellyfish (adult jellyfish) (Rahmah & Zakaria, 2017). In this case, at Lake Siombak the following month after the peak of the dry larvae of jellyfish that will mature into the sea, jellyfish are organisms that prefer salty waters (Puspasari & Aisyah, 2018; Fernández-Alías *et al.*, 2020b). Therefore, (Puspasari & Aisyah, 2018; Fernández-Alías *et al.*, 2020) explain that A. aurita often lives in brackish waters whose salinity is low ± 6 ‰ (larvae) and in open-air ± 30 ‰ (adults).

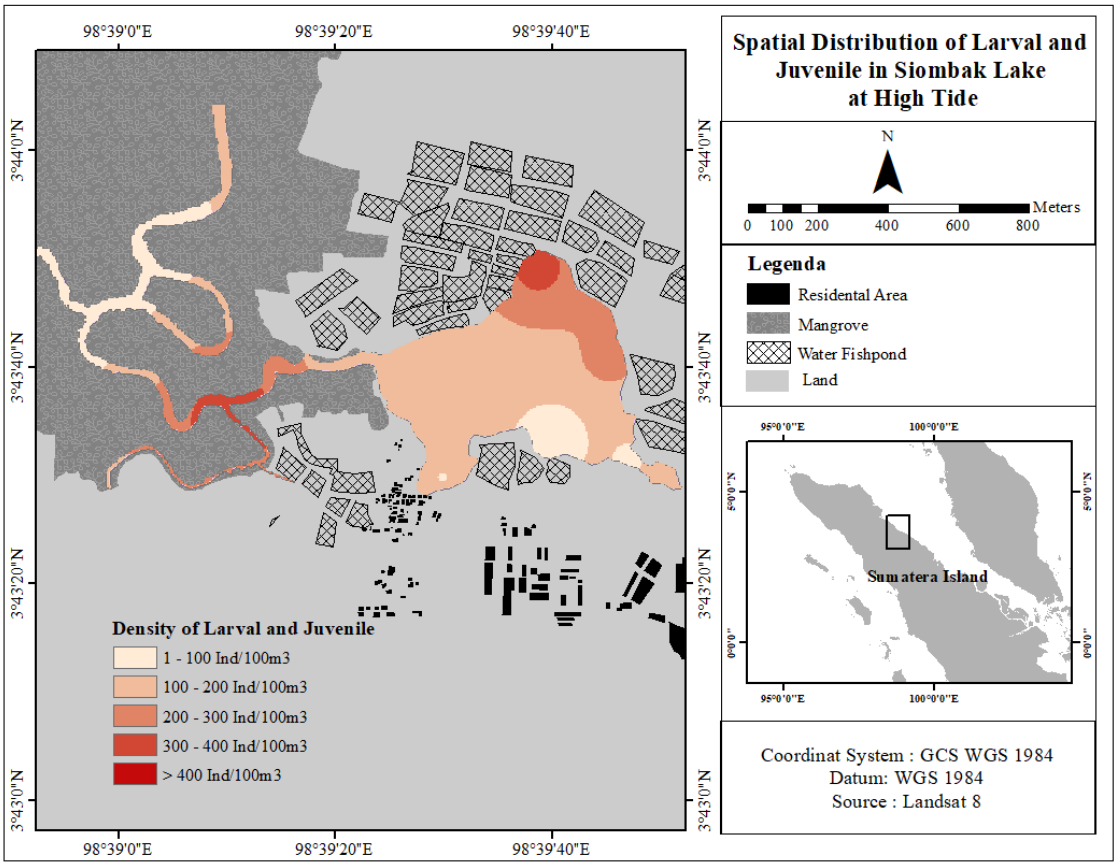


Figure 3. Larva and juvenile spatial distribution in Lake Siombak at high tide

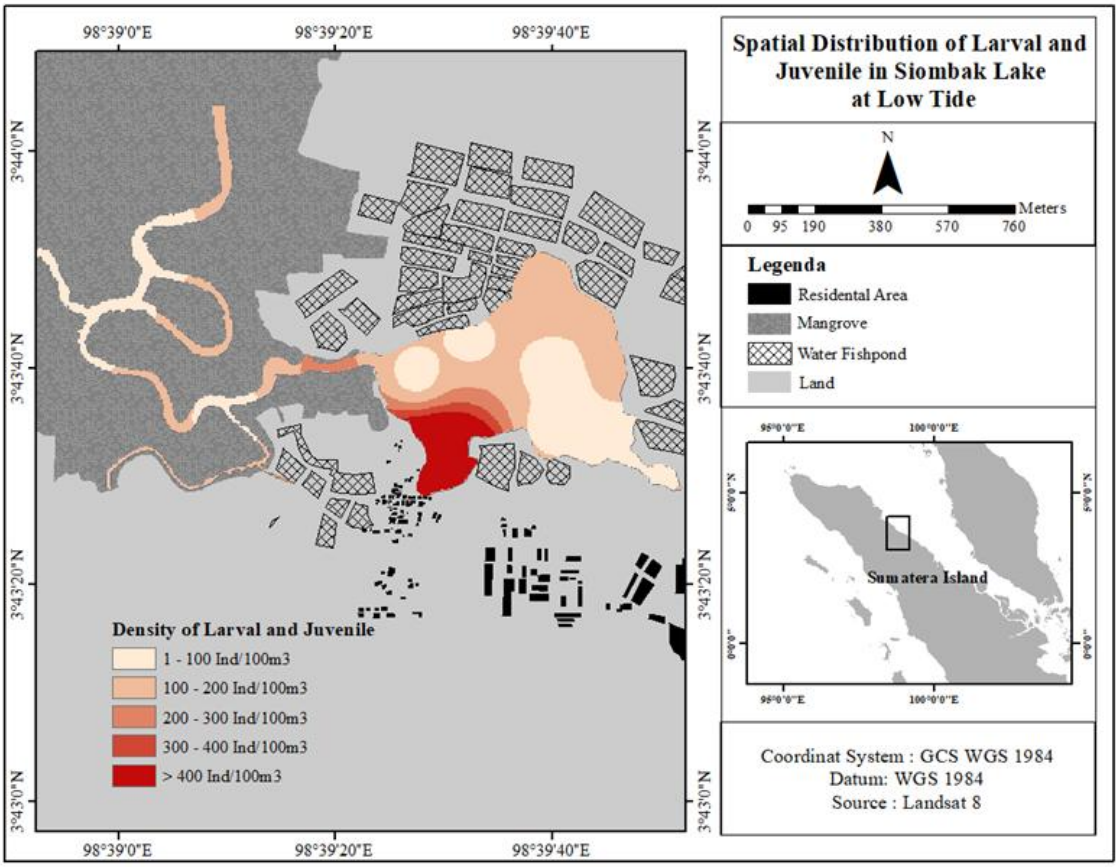


Figure 4. Larva and juvenile spatial distribution in Lake Siombak at low tide

Meanwhile, crustacean larvae (Portunidae and Penaeid) are also more common during the dry season than in the rainy season. Portunidae spawns in the deep sea, where larvae migrate to estuary areas with lower salinity levels to continue their life stage to become mysis and juveniles. This finding was reported by (Kembaren and Suprapto, 2011), that penaeid shrimp larvae tend to move towards the river mouth before metamorphosing to the mysis stages and juveniles. Larvae and mysis need brackish waters and a mangrove environment as a protection area. Mysis and juvenile penaeid shrimp are commonly found in river-mouth environments (Ruas *et al.*, 2019) and tend to like waters with mangrove forests (Jaxion-Harm & Speight, 2017).

Larvae and juveniles found in general are larvae and juveniles originating from marine and originating from the estuary itself (Berkström *et al.*, 2020; Cheminée *et al.*, 2021; Tournois *et al.*, 2017; Mocuba *et al.*, 2023; Elston & Murray 2024). In this study, only the fish larvae of Gobiid and Oryziidae were the larvae originating from Siombak lake. Other larvae are marine species that spawn in estuaries and the sea, then larvae and juveniles are carried by tidal currents into the lake (Berkström *et al.*, 2020). Several fish larvae and juveniles, and crustaceans in Lake Siombak indicate that the lake is a nursery and feeding ground. This is shown by the abundance of mysis crustaceans (Penaeid) throughout the year in Lake Siombak. This condition is compounded by the abundance of jellyfish larvae in the dry season, where jellyfish are very abundant in March-April. This fact is inseparable from the tidal lake in which food is abundant for larvae. The results of previous studies recorded at least 66 genera of plankton, consisting of 54 genera of phytoplankton and 12 genera of zooplankton. Furthermore, plankton in Lake Siombak is very abundant. At the time of plankton abundance, it reached 18.61 million cells m-3 consisting of 15.09 million cells m-3 phytoplankton (81.11%) and 3.51 61 million cells m-3 (18.89%) zooplankton. At low tides, plankton abundance reached 18.20 million cells m-3, consisting of 12.48 million cells m-3 (76.91%) phytoplankton and 3.74 million cells m-3 (23.09%) zooplankton (Muhtadi *et al.*, 2020c).

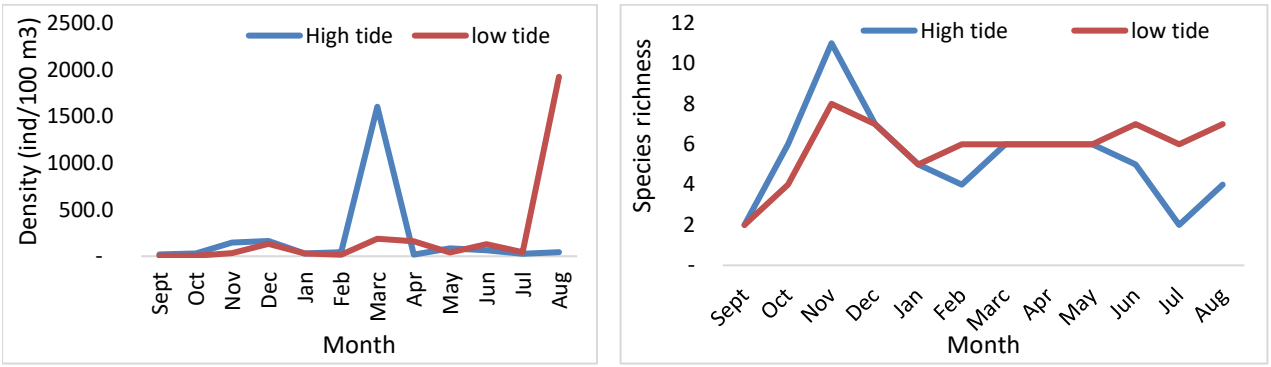


Figure 5. Temporal distribution of larva and juvenile in Lake Siombak

Lake Siombak habitat in the transition area between the fresh and marine ecosystems is possible to visit by both fresh and estuary fish and crustaceans. Based on the previous results study in Lake Siombak, which found that 81.48% of fish and crustaceans found in Siombak Lake are not organisms that settled in the lake. Fish and crustaceans that enter the lake are organisms from the sea (marine organisms) and rivers (new organisms) to the feeding ground (Muhtadi *et al.*, 2022; Muhtadi *et al.*, 2023a). In the rainy season, the fish that enter the lake to feed are freshwater fish, such as snakehead fish, catfish, eels, and Snakeskin gourami. However, during this season, mangrove crabs are also found, namely at stations 1, 3, and 6. Meanwhile, in the dry season, the fish that enter are sea fish, such as gudgeon, snapper, and scat. however, fish such as Indo-Pacific tarpon, marine catfish, and mangrove shrimp are always found in Lake Siombak both in the rainy season and in the dry season (see Table 3).

The main food, based on the analysis of the fish and crustaceans in Lake Siombak, shows that zooplankton is a type of food often eaten

by fish and crustaceans by 44.63%, then phytoplankton by 31.07% (Figure 6). Cladocera, Chlorophyceae, and Copepod are the main types of food eaten by fish and crustaceans caught in Lake Siombak, each by 30.51%, 17.80%, and 12.15%. Based on the fish's stomach and crustaceans' analysis, at least 14 fish and crustaceans in Lake Siombak can eat food groups, not including litter and detritus used by mollusks, shellfish, and shrimp.

Table 3. Aquatic organisms that feeding ground in Lake Siombak

Rainy Season	Dry Season	Each Season
Trichopodus pectoralis	*Ambassis buruensis*	*Mystus gulio*
Trichopodus trichopterus	*Anguilla bicolor*	*Megalops cyprinoides*
Channa striata	*Butis gymnopomus*	*Penaeus merguiensis*
Clarias bathracus	*Ophiocara porocephala*	*Parapenaeopsis coromandelica*
Monopterus albus	*Chanos chanos*	
Scylla olivacea	*Acentrogobius viridipunctatus*	
Scylla serrata	*Brachygobius xanthozonus*	
	Zenarchopterus buffonis	
	Lutjanus johnii	
	Valamugil engeli	
	Scatophagus argus	

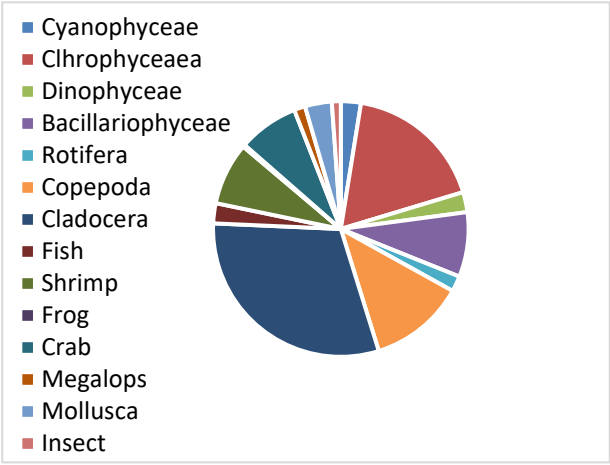


Figure 6. The percentage of the frequency of food groups that are eaten by fish and crustaceans in Lake Siombak.

4. Conclusion

From the results of this study, it can be concluded that Lake Siombak, as part of the Belawan River estuary, has an important role as a nursery area and feeding ground for fish, crustaceans, and even jellyfish found around the Belawan River estuary and its surroundings. There are at least nine families consisting of 6 fish families, 2 crustacean families, and 1 Cnidaria family that come to Lake Siombak. In addition, there are at least 22 species of adult fish that make Lake Siombak a feeding ground, which of course, "alternately" visit the lake according to the changing seasons. Therefore, it is important to maintain the sustainability of this lake to support the sustainability of fisheries productivity in the Belawan River estuary and its surroundings.

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Conflict of interest

This manuscript has no identified and possible conflicts of interest among authors

Data availability statement

All data included and used in the study is open and contains no confidential and ethically private information.

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AM contributed to designing the topic and research methods, data collection and analysis, and wrote the manuscript. **AP** contributed to data collection and analysis, wrote the manuscript. **RM** contributed to data analysis and wrote the manuscript.

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