The potential and threats of nekton biodiversity in the Deli Watershed, North Sumatra Province

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Abstract. The Deli Watershed is an essential ecosystem in Medan, Binjai, Deli Serdang, and Karo (Mebidangro). This watershed is the main source of clean water for the city of Medan and its surroundings. However, the high utilization (e.g., land-use change) of the Deli Watershed area is likely to disrupt the aquatic habitat in the Deli Watershed ecosystem. In addition, issues of pollution and invasive species found in the Deli River certainly affect its biodiversity. This research aims to determine the species composition, spatial distribution, and economic potential of nekton biodiversity in the Deli Watershed ecosystem. This research was conducted in June-August 2023 throughout the Deli Watershed area, including the upstream, middle, downstream, and tributaries. Observation points were carried out spatially at 42 observation stations. The nekton was captured using fishing nets, fishing lines, hand/small nets, and traps. During observations in the Deli Watershed, 39 species of nekton were found, namely 35 species of fish, three species of shrimp, and one species of freshwater turtle. *Mystacoleucus marginatus* (Valenciennes,1842) and *Glyptothorax major* (Boulenger, 1894) were distributed from the middle to the upper reaches of the main river and its tributaries. At least 26 species (67%) are native fish, while 13 (33%) are non-native. Overall, the protection status of native nekton in the Deli Watershed falls into the Least Concern (LC) category for 22 species (85%); the remaining species are classified as Data Deficient (11%, 3 species) and Not Evaluated (4%, 1 species). Based on the potential and utilization of nekton in the Deli Watershed, it was found that 61% of these nekton species can be utilized or consumed directly, as much as 36% have the potential to be made into ornamental commodities, and only 3% are non-economic nekton. The threats to nekton biodiversity in the Deli Watershed are habitat destruction and water pollution. Habitat destruction in the Deli Watershed is caused by the pressure from settlements/urban areas, leading to the loss of riverbanks. Therefore, serious attention is required from the government, both the Medan City Government (middle-downstream) and Deli Serdang and Karo Regencies (middle-upstream), including the North Sumatra provincial government, to take serious steps to restore the river ecosystem and the Deli Watershed

Key Words: Deli, fish, nekton, river, North Sumatra.

Introduction. Every river is part of a network of rivers that forms a drainage basin (Stanford et al 2017). A watershed (a drainage basin) is a unit of land area drained by a river and all its tributaries. Watersheds are interconnected from upstream to downstream and between main rivers and their tributaries (Stanford et al 2017; Ha et al 2020). The characteristics of a watershed are heavily influenced by land topography and elevation (Stanford et al 2017; Muhtadi et al 2020, 2022, 2023b). Watersheds are natural environments bounded by ridges. Rainwater from this area flows into rivers that eventually flow into lakes or seas. Upstream water-contributing areas and downstream water-receiving areas are interconnected and impact the ecosystem units of the watershed (Stanford et al 2017; Ha et al 2020). Watersheds naturally collect, store, and convey water from rainfall to lakes or seas. Watersheds are crucial for maintaining the presence of water in the hydrological cycle (Stanford et al 2017; Dodds & Whiles 2019).

They play a significant role in preserving biodiversity, serving as habitats for various aquatic organisms (Desrita et al 2018, 2020; Muhtadi et al 2020, 2023). Additionally, watersheds support various social, economic, and cultural activities such as transportation, agriculture, and tourism (Rauf et al 2015; Muhtadi et al 2023b). Watersheds can also serve as energy sources through hydroelectric power generation and the development of micro hydro or mini hydro energy, which are renewable energy alternatives (Yankey et al 2023; Maulana et al 2024).

The Deli Watershed covers parts of Karo Regency, Deli Serdang, and Medan City. The Deli Watershed spans approximately 353.20 km^2 and has river sources in the Deli Serdang Regency (Sibolangit and Mount Sibayak) and Karo, flowing into Belawan (Medan). The Deli Watershed plays a crucial role in the hydrological cycle in the Medan area and its surroundings. The upper part of the Deli Watershed provides clean water for Medan and serves as a water catchment area. The Deli River, which divides Medan into two regions, east, and west, is vital for the flow from upstream to downstream to the Malacca Strait (Regional Regulation 2017; Hutapea 2018; Marselina et al 2024).

Currently, 45% of the upper part of the Deli Watershed is primarily utilized for plantations, 24.7% for agriculture, 11.45% for settlements, and only 11% for forested areas in the Sibolangit region (Verawaty et al 2018). Uncontrolled land use in the Deli Watershed area will inevitably impact riparian conditions and river ecosystems. It can lead to various ecosystem disturbances, including water management issues, floods, erosion, water pollution, and river habitat degradation.

Numerous reports have been issued regarding the condition of the Deli River, particularly concerning land use and the water balance of the river. These reports include changes in land use around the Deli Watershed (Verawaty et al 2018), assessments of water availability in the Deli Watershed (Hutapea 2018; Marselina et al 2024; Wardhana et al 2024), studies on erosion and floods in the Deli River (Hutapea, 2018; Siregar et al 2019; Agustin et al 2023), and the habitat condition and river pollution (Harpah et al 2021). However, no research has been conducted on the potential and biodiversity of nekton in the Deli Watershed. Studies of nekton biodiversity in rivers/watersheds are more often reported in other large watersheds in North Sumatra, such as Wampu Watershed (Desrita et al 2018), Batangtoru Watershed (Desrita et al 2020), Alas-Singkil Watershed (Muhtadi et al 2023b), and Barumun Watershed (Desrita et al 2022). Deli Watershed, although not as large as these Watersheds, has a vital role because of its strategic location in the capital city of North Sumatra province.

This study aims to determine the potential and threats of nekton biodiversity in the Deli Watershed from North Sumatra Province. This study is initial scientific data that reports the presence of fish and crustacean species in the Deli Watershed. Therefore, it is expected to be an initial reference in managing aquatic biodiversity in the Deli Watershed. This is because the Deli Watershed is strategically located in the development of Medan City and its surroundings. Therefore, this study needs to be conducted and reported globally to manage aquatic biodiversity in the Deli Watershed further.

Material and Method

Description of the study sites. This research was conducted in the Deli Watershed, North Sumatra Province. Sampling points covered 46 observation points (Figure 1), representing the main river and its tributaries, namely downstream (5 points), middle (16 points), upstream (10 points), and tributaries (15 points). The selection of observation location points is based on the representation of sub-DAS/tributaries, geographical representation (upstream, middle, downstream), and the condition/use of the surrounding land. Sampling was carried out from June to August 2023. The time of data collection is included in the dry season category. The selection of this time is related to the ease of sampling because if it is done during the rainy season, the Deli River is very prone to flooding so the observation results are less than optimal.

In the downstream of the Deli River is close to the Belawan estuary, which is an industrial and residential area. The condition of the waters is murky with a sandy substrate and many piles of garbage are found. In the middle part is also a residential

area of Medan City. The condition of the substrate is sandy and some gravel; in some locations, there are small piles of garbage. Upstream of the Deli River is a plantation area, except for upstream of the Sembahe River. The water substrate is rock and a little gravel (main river headwaters) (Leidonald et al 2025).

Necton data collection. The nekton was captured using fishing nets, fishing lines, hand/small nets, and traps. The nekton samples were photographed and preserved in a 10% formalin solution. These samples were labeled with the location/station, collection date, collector's name, and other necessary information. The books by Kottelat et al (1993) and Kottelat (2013) are cited when discussing fish sample identification. Identification of crustacean groups refers to Wowor et al (2004) and herpetofauna refers to Wowor (2010). We used the Global Invasive Species (ISSG 2024) and Dewantoro & Rachmatika (2016) for native and invasive fish categories. Refer to Kottelat et al.. (1993) and Kottelat (2013) for other classifications, such as migratory species and freshwater or brackish fish.

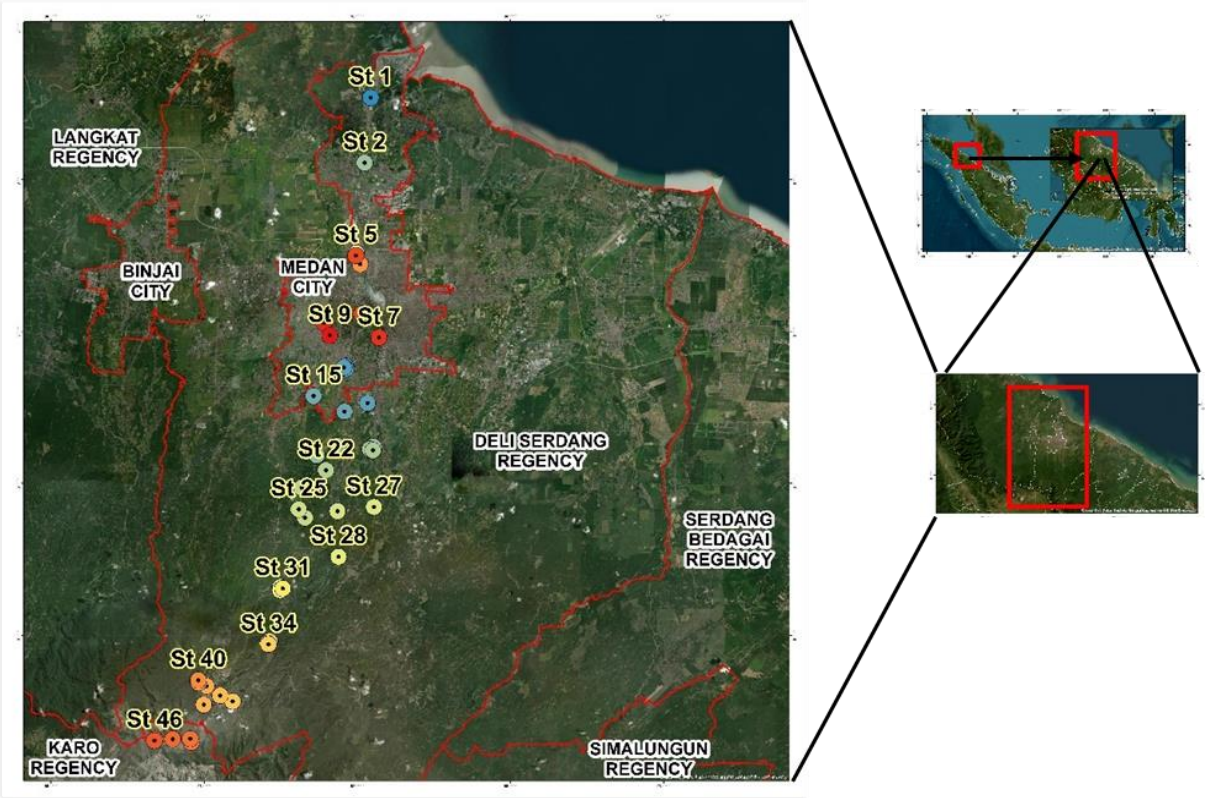

Figure 1. Sampling location of Deli Watershed, North Sumatra province, Indonesia.

Data analysis. Data analysis is related to the structure of fish communities, mainly related to 3 main attributes, namely: Shannon-Wiener function (H'), evenness (e), and dominance (C) (Odum & Barrett 2005; Krebs 2014). The diversity index (H') is used to get a mathematical representation of the organism's population. This index can make it easier to analyze information on the number of individuals of each species in a community. The evenness index (E) describes how big the ecosystem's balance is. Nekton diversity was calculated using the diversity index of Shannon & Wiener (1963) in Krebs (2014) with the following formula:

$$H' = - (\Sigma \, pi \, ln \, pi)$$

Explanation:
H '= species diversity index;
ni = Number of individuals of each species;
N = Number of all individuals;
Pi = Important Probability for each species = ni/N.

The equitability index (E) was calculated by following the equation (Krebs 2014):

$$E = H'/H` max$$

Explanation:
E = Shannon-Wienner uniformity index;
H = Species balance;
H`max = Maximum diversity index (ln S);
S = Total number of species.

The dominance index is calculated according to the Simpson index in Odum & Barret (2005).

$$C = \Sigma \left(\frac{ni}{N}\right)^2$$

Explanation:
C = Index of dominance;
ni = Number of individuals of each species;
N = Total individual community.

Results

Species richness. A total of 39 nekton species were observed in the Deli Watershed, comprising 35 fish species, three shrimp species, and one freshwater turtle species (Table 1). The most frequently encountered fish in the Deli Watershed include *Mystacoleucus marginatus* (Valenciennes, 1842), *Hypostomus Plecostomus* (Linnaeus, 1758), and *Glyptothorax major* (Boulenger, 1894). The abundance of these three fish species amounted to 32.12%, with respective counts of 108 individuals (12.3%) for *M. marginatus*, 102 individuals (11.62%) for *H. plecostomus*, and 72 individuals (8.20%) for *G. major*. *M. marginatus* and *G. major* were distributed from the middle to the upper reaches of the main river and its tributaries. *M. marginatus* was located in habitats characterized by sandy or sandy gravel substrates. In the middle part of the Deli River, the substrate is primarily sand or sandy gravel. Meanwhile, *H. plecostomus* was mainly found from the downstream to the middle portion of the river. *H. plecostomus* prefers gravel habitats and waters that are polluted and cluttered with debris. In rocky substrates with swift currents, the Mahser species, *Neolissochilus sumatranus* (Weber & de Beaufort, 1916), and the Barb species, *Rasbora sumatrana* (Bleeker, 1852), were commonly observed, with abundances of 35 individuals (3.99%) and 34 individuals (3.87%), respectively. In addition to fish, three species of freshwater shrimp from the Atyopidae and Palamonidae families were found across upstream, middle, and downstream areas. A total of 80 individuals (9.11%) of Caridina shrimp were located in the main river and its tributaries. The freshwater turtle identified was *Amyda cartilaginea* (Boddaert 1770), which may have been released or escaped by locals into the river's vicinity due to its discovery in damaged habitats within residential areas (around Medan).

Fish from the Cyprinidae family are more commonly found than fish from other families. A total of 11 Cyprinidae species were found in the Deli Watershed (Figure 2). Cyprinidae is a freshwater fish family with the most species worldwide, except in areas like Australia, Madagascar, New Zealand, and South America (Kottelat et al 1993). Cyprinidae is the largest group of freshwater fish in Southeast Asia (Leroy et al 2019) and is also present in freshwater habitats in Sumatra (Chua et al 2019). Several research findings in several rivers in Sumatra show similar results, such as in the Alas-Singkil Watershed, where the Cyprinidae family is the largest population, followed by catfish groups (Bagridae, Clariidae, Pangasidae) (Muhtadi et al 2023b). In the Barumun Watershed, 13 out of 29 species found were Cyprinidae (Desrita et al 2022). In the Batangtoru Watershed, 19 out of 57 species belong to the Cyprinidae family (Desrita et al 2020). In the Wampu Watershed, 12 of 27 species were Cyprinidae (Desrita et al 2018).

The richness of nekton species in the Deli Watershed is more commonly found in the middle section compared to the downstream or upstream areas. In the middle section of the Deli River and Babura River, a total of 13 species were found. Meanwhile, there were eight species in the downstream section, and in the upstream section, there were 9

species. The higher number of fish species and populations in general found in the middle section is attributed to the better condition of the river compared to the downstream and the presence of various microhabitats compared to the upstream. Based on water quality observations, the middle section of the Deli River is still categorized as lightly polluted, and in specific locations, there are still natural water conditions (Leidonald et al 2025). The research results by Suryaningsih et al (2020) also found the diversity of fish in the middle of the river in the Serayu Watershed, Central Java.

The situation is quite concerning in the downstream section of the Deli River. Along the river segment that passes through Medan City, the riverbanks are almost surrounded by concrete, and rubbish is found throughout the river flow. Based on its habitat, the downstream section of the Deli River falls into the moderately polluted category. Meanwhile, in the upstream section, although the water quality status ranges from slightly polluted to good, the area is dominated by rocky and fast-flowing waters (Leidonald et al 2025). This environment supports fish species that prefer strong currents and can survive in such segments.

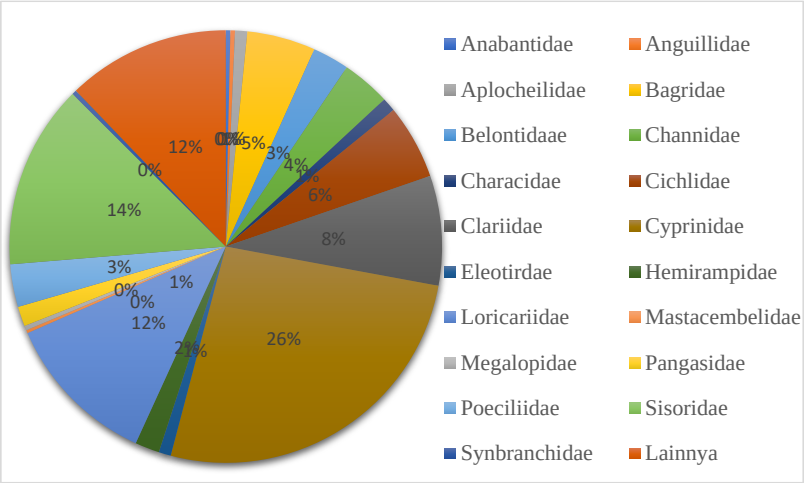

Figure 2. The composition of fish found in the Deli Watershed is based on families.

According to previous studies conducted by Desrita et al (2020) in the Batangtoru Watershed and Muhtadi et al (2023b) in the Alas-Singkil Watershed, the number of species and the population of nekton are significantly higher in the downstream areas compared to the middle and upstream areas. This is attributed to the presence of swamps in the Batangtoru and Alas-Singkil Watersheds, which create a more diverse range of microhabitats. In contrast, no swamps are found along the downstream section of the Deli River, which has been replaced by residential/urban areas. Freshwater aquatic diversity depends on the substrate types, which provide the prerequisite micro-conditions and can indicate stream habitat quality. Substrate coarseness and heterogeneity, representing substrate size and microhabitat diversity, may substantially influence stream fish assemblages (Amour et al 2011; Li et al 2016; Muhtadi et al 2023b; Muhtadi & Leidonald 2025). Variations in the richness and abundance of fish and freshwater biota are related to the height, depth, and width of the river (Hu et al 2019; Muhtadi et al 2023b; Muhtadi and Leidonald 2025).

Table 1

The richness of nekton species in the Deli Watershed

No.	*Family/Species*	*Indonesian name*	*Local name*	*Common name*	*locations*	*IUCN status* *
	Fish					
A	**Anabantidae**					
1	*Anabas testudineus* (Bloch, 1792)	Betok		Climbing perch	Channel/ditch	LC
B	**Anguillidae**					
2	*Anguilla bicolor* McClelland, 1844	Sidat	Dungdung	Indonesian Shortfin Eel	Main river (downstream to upstream)	LC
C	**Aplocheilidae**					
3	*Aplocheilus pancax (Hamilton, 1822)*	Kepala timah	Kepala tima	Blue pancax	Tributaries and swamps	LC
D	**Bagridae**					
4	*Hemibagrus nemurus* (Valenciennes, 1840)	Baung	Baung	Asian redtail catfish	Downstream – Middle Stream	LC
5	*Hemibagrus capitulum* (Popta, 1906)					LC
E	**Belontidaae**					
6	*Trichopodus trichopterus* (Pallas, 1770)	Sepat rawa	Capet	Three spot gourami	Channel/ditch	LC
F	**Channidae**					
7	*Channa striata* (Bloch, 1793)	Gabus	Gabus	Snakehead murrel	Channel/ditch, main river, and tributaries (downstream to upstream)	LC
G	**Characidae**					
8	*Colossoma macropomum* (Cuvier, 1816)			Cachama	Main river	-
H	**Cichlidae**					
9	*Oreochromis niloticus* (Linnaeus, 1758)	Nila	Nila	Nile tilapia	Tributaries	-
10	*Oreochromis mosambicus* (Peters, 1852)	Mujaer	mujaer	Mozambique tilapia		-
I	**Clariidae**					
11	*Clarias batrachus* (Linnaeus, 1758)	Lele kampung	Lele	Walking catfish	Tributaries	LC
12	*Clarias gariepinus* (Burchell, 1822)	Lele	Dumbo	Walking catfish	Tributaries	-
J	**Cyprinidae**					
13	*Barbodes binotatus* (Valenciennes,	Keperas	Pora-	Common barb or	Tributaries (upstream)	LC

No.	Family/Species	Indonesian name	Local name	Common name	locations	IUCN status *
	1842)		pora	spotted barb		
14	*Barbodes lateristriga (Valenciennes, 1842)*			T barb or spanner barb	Tributaries	LC
15	*Cyprinus carpio* (Linnaeus, 1758)	Mas	Mas	Common carp	Tributaries	-
16	*Cyclocheilichthys apogon* (Valenciennes, 1842)	Keperas	Sitengkal / Gar gar	Beardless barb	Upstream tributaries	LC
17	*Danio albolineatus* (Blyth, 1860)			Pearl Danio	Upstream tributaries	
18	*Hampala macrolepidota* Kuhl & Van Hasselt, 1823	Sebarau	Hampala /Kelubak	Hampala barb	Downstream-middle stream	LC
19	*Mystacoleucus marginatus* (Valenciennes, 1842)	Cencen	Cencen	Burmese rainbow barb	Main river (middle stream)	LC
20	*Neolissochilus sumatranus (*Weber & de Beaufort, 1916)	Jurung	Jurung	Mahser	Middle stream-upstream (main river)	LC
21	*Osteochilus hasseltii* (Valenciennes, 1842)	Nilem	Lampam	-	Middle stream-upstream (Tributaries)	DD
22	*Osteochilus vittatus* (Valenciennes, 1842)	Nilem	Paitan	Barb	Middle stream-upstream (Tributaries)	LC
23	*Rasbora sumatrana* (Bleeker, 1852)	Sulum	Sulum		Middle stream-upstream (Tributaries)	*DD*
K	**Eleotirdae**					-
24	*Oxyeleotris marmorata* (Bleeker, 1852)	Betutu	Seluntok	Marble goby	Middle stream (main river)	LC
L	**Hemirampidae**					
25	*Dermogenys pussilus* Kuhl & van Hasselt, 1823			Wrestling halfbeak	Middle stream (main river)	NE
M	**Loricariidae**					
26	*Hypostomus plecostomus* (Linnaeus, 1758)	Ikan sapu-sapu			Downstream-middle stream	-
N	**Mastacembelidae**					
27	*Macrognathus aculeatus* (Bloch, 1786)	Tilan	Mirik	Lesser spiny eel	Middle stream (Tributaries)	LC
O	**Megalopidae**					
28	*Megalops cyprinoides* (Broussonet, 1782)			Indo Pacific tarpon	Down stream	DD
P	**Pangasidae**					
29	*Pangasionodon*				Middle stream (main river)	-

No.	Family/Species	Indonesian name	Local name	Common name	locations	IUCN status *
	Hypophthalmus (Sauvage, 1878)					
30	*Pangasius djambal* Bleeker, 1846				Middle stream (main river)	-
Q	**Poeciliidae**					
31	*Gambusia affinis* (Baird & Girard, 1853)			The western Mosquitofish	Upstream (tributaries)	-
32	*Poecilia reticulata* Peters, 1859			The guppy	Upstream (tributaries)	-
R	**Sisoridae**					
33	*Glyptothorax major* (Boulenger, 1894)				Upstream (tributaries)	LC
34	*Glyptothorax platypogonides* (Bleeker, 1855)				Upstream (tributaries)	LC
S	**Synbranchidae**					
35	*Monopterus albus* (Zuiew, 1793)	Belut	Bolut	Swamp Eel.	Tributaries (middle stream)	LC
	Shrimp					
36	*Cherax quadricarinatus* (Von Martens, 1868)	Lobster			Middle stream-upstream (main river)	-
37	*Macrobrachium rosenbergii* (De Man, 1879)	Udang			Middle stream-upstream (main river)	LC
38	*Caridina gracilirostris* (De Man, 1892)	Udang			Middle stream-upstream	LC
	Turtle					
39	*Amyda cartilaginea* (Boddaert, 1770)	Kura-kura			Middle stream (main river)	-

IUCN (2024) Abbreviations: LC, Least Concern; NE, Not Evaluated; VU, Vulnerable; DD, Data Deficient; NT, Near Threatened; EN, Endangered.

The nekton found in the Deli Watershed is lower than in other North Sumatra and Indonesia Watersheds. Desrita et al (2020) found 68 nekton species in the Batangtoru Watershed (North Sumatra). In the Wampu Watershed (North Sumatra), 50 species of nektons (42 fish species) were found (Desrita et al 2018; Putri et al 2017). In the Barumun Watershed, 39 nekton species were identified (Desrita et al 2022). In the Alas-Singkil Watershed, 109 nekton species were discovered (Muhtadi et al 2023b). Dekar et al (2018) found 44 fish species in the Aceh River, while Irhami et al (2018) identified 32 species in the Meureubo River, West Aceh, and Hidayat et al (2023), reported as many as 21 species and nine families in the Merbau River, Leuser Ecosystem. Muslim et al (2024) found 49 species and 19 families were recorded in the Kelekar River, South Sumatra, Indonesia. Purnama and Yolanda (2016) recorded 35 species and seven families of fish in the Kumu River (Riau). In the Batanghari Watershed (Jambi), it was reported that as many as 36 species, 30 genera, and 16 families (Marnis et al 2024), and in the Muara Bulian District Watershed, there were 51 species, 32 genera, and 18 families of fish (Apriliawati et al 2024).

However, when comparing the richness of nekton species in the Deli River Basin to that in other rivers on Java, it reveals a higher diversity of species. Suryaningsih et al. (2020) reported only eight species of fish in the Klawing River Basin (Central Java). In the Serayu River Basin, the largest watershed in Central Java, only 21 species of freshwater fish were recorded. The Ciliwung River (Jabotabek area, metropolitan) revealed just 11 species of fish (Effendi et al 2022). In the Cikawung River, Cianjur, West Java, the count is still lower, with only 32 fish species identified (Partasasmita et al. 2015). The Citarum River Basin (West Java) also shows a maximum of 32 fish species present (Kartamihardja 2019).

Species categories and protection status. Despite the many damaged and threatened river habitats in the Deli Watershed, many native fish species remain. At least 26 species (68%) are native fish, while 13 species (32%) are non-native (Figure 3). The redtail catfish (*H. nemurus* and *H. capitulum*) are native species that are now rarely found but remain popular fishing targets around Medan City. The cencen fish are still relatively abundant in the middle sections of the river. Eels are also still found in the Deli River, particularly in the upstream areas where the aquatic habitat remains natural and well-preserved. This aligns with the findings of Muhtadi et al (2023), who reported that eels are still found in the Belawan estuary.

However, urban pressures and plantation activities around the Deli Watershed threaten these fish, compounded by the proliferation of non-native species in the Deli River. Suckermouth catfish are dominant in the downstream sections up to the urban areas due to their ability to survive in polluted and damaged habitats. Other fish, such as Cachama and catfish, are suspected to have escaped into the river from community ponds located in the upstream areas. Additionally, activities by specific individuals who release goldfish or tilapia into the river as part of a "bad luck cleansing" ritual have introduced more non-native species into the river.

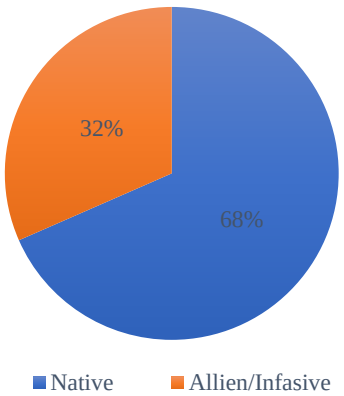

Figure 3. The proportion of native fish species and alien fish species in the Deli Watershed.

Overall, the protection status of native nekton in the Deli Watershed falls into the Least Concern (LC) category for 22 species (85%) (Figure 5); the remaining species are classified as Data Deficient (11%, three species) and Not Evaluated (4%, one species) (IUCN 2024). According to Indonesia's regulations, none of the aquatic animals in the Deli Watershed are listed as protected species (MEF 2018; MMAF 2021). However, due to the increasingly critical condition of their habitats, this issue warrants attention from the local government, particularly the North Sumatra provincial government. The populations of animals living in the Deli Watershed, especially the redtail catfish, are declining. Locally, in Bengkurung Village, Sibolangit District, Karo Regency, there is an agreement among the local community, particularly local tourism managers, to prohibit fishing with any gear other than hooks. This measure aims to maintain the fish population in the area.

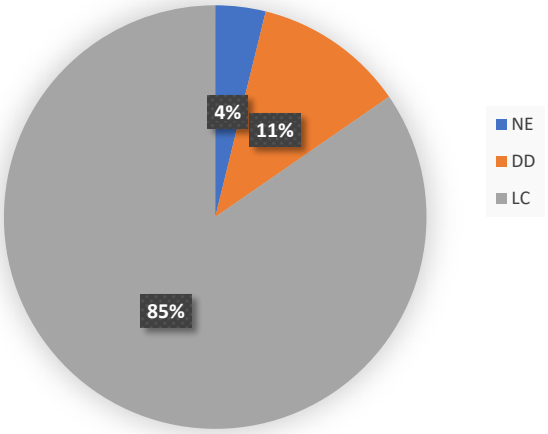

Figure 4. The IUCN status of native nekton biodiversity in the Deli Watershed.

Diversity index. The highest Diversity Index (H') of nekton in the Deli Watershed is found in the middle stream segment in the Babura sub-watershed, while the lowest is in the upstream Simai-mai sub-watershed (Table 2). Consistent with the findings of higher species richness and abundance in the middle section, the nekton diversity is also highest in the middle part of the Deli Watershed, particularly in the Babura, Bekala, and Deli sub-Watersheds. Generally, high species richness, abundance, and absence of dominant species indicate high species diversity. This pattern, observed by Desrita et al (2019, 2020, 2022) in the Wampu, Batangtoru, and Barumun Watersheds and by Muhtadi et al (2023b) in the Alas-Singkil Watershed, shows that high species richness and population yield a high diversity index.

However, the highest diversity index is found in the downstream segments in the Wampu, Batangtoru, Barumun, and Alas-Singkil Watersheds. In contrast, it is found in the middle segment of the Deli Watershed. This discrepancy is due to the lower species richness and abundance in the downstream part of the Deli Watershed, caused by limited habitat diversity, which contrasts sharply with the Wampu, Batangtoru, Barumun, and Alas-Singkil Watersheds. Swamps and numerous tributaries in the Wampu, Batangtoru, Barumun, and Alas-Singkil Watersheds allow for a greater variety of nekton habitats than the Deli Watershed.

Low diversity is generally found in the upstream section due to the low species richness. As previously noted, the upstream waters are characterized by fast currents. Thus, the fish species found are those capable of adapting to such conditions, namely the Mahser and Hampala barb groups. This is related to the fact that there are fewer microhabitats in the upstream section compared to the middle or downstream segments. Muhtadi et al (2023) found that the speed of the river flow is one of the limiting factors for the distribution of nekton populations in river ecosystems.

Compared to the diversity of nekton in other watersheds in Indonesia, the fish diversity in the Deli Watershed is relatively low. Desrita et al (2018) reported high fish diversity in the Wampu Watershed, with an index range of 1.83-2.90. The nekton diversity index in the Batangtoru Watershed ranges from 1.99 to 2.33. In the Barumun

Watershed, the nekton diversity index ranges from 2.05 to 2.20 (Desrita et al 2022). The nekton diversity index in the Alas-Singkil Watershed ranges from 2.01 to 4.39 (Muhtadi et al 2023b).

The highest evenness values in the Deli Watershed are found in the middle stream, while the lowest is in the upstream and middle streams of the Sei Sikambing sub-watershed. The nekton dominance index in the Deli Watershed is relatively low in the middle stream segment, with values less than 0.5, but is high in the upstream and middle stream of the Sei Sikambing sub-watershed. The upstream segment is dominated by Poeciliidae, an alien species that lives in groups in the tributaries of the upper reaches. Additionally, *D. albolineatus* is found in the main upstream river of Sembahe. Meanwhile, the Sei Sikambing sub-watershed is dominated by suckermouth catfish, which thrive in dirty and polluted waters. A dominance index value approaching 1 indicates a community dominated by a particular species, while an index value approaching 0 suggests no species dominance (Odum & Barret 2005).

Table 2

The nekton community structure in the Deli Watershed

Sub basin	*River segment*	*Community structure*		
		H'	*E*	*C*
Deli Watershed	Down stream	1.75	0.87	0.22
	Middle stream	1.66	0.93	0.22
Sei Sekambing	Middle stream	1.09	0.65	0.52
Babura	Middle stream	1.97	0.90	0.17
	Upstream	0.95	0.91	0.42
Bekala	Middle stream	1.51	0.88	0.27
	Upstream	1.64	0.89	0.24
Petane	Upstream Petane	0.94	0.63	0.50
	Ustream Sembahe	0.86	0.93	0.47
Simai Mai	Middle stream	1.65	0.85	0.20
	Upstream	0.53	0.76	0.65

The potential and threats of aquatic biodiversity in the Deli Watershed. Based on the potential and utilization of nekton in the Deli Watershed, it was found that 61% of these nekton species can be utilized or consumed directly, as much as 36% have the potential to be made into ornamental commodities, and only 3% are non-economic nekton (Figure 5). Redtail catfish (*H. nemurus* and *H. capitulum*) are native fish commodities (main prey) caught by anglers in the Deli River. Burmese rainbow barbs have the most potential as fish commodities because their population and distribution are still more than other native fish (Muchlisin et al 2009). In addition, the presence of *R. sumatrana*, *P. latesteriga*, and *D. albinolineatus*, which have beautiful patterns, is very potential to be developed for ornamental fish.

The threats to nekton biodiversity in the Deli Watershed are habitat destruction and water pollution. Habitat destruction in the Deli Watershed is caused by the pressure from settlements/urban areas, leading to the loss of riverbanks. The increase in settlements and population, especially around Medan City, results in high waste disposal into the Deli River. This causes the banks of the Deli River to be filled with rubbish, particularly plastic waste. Sand mining activities also cause habitat destruction in the Deli Watershed at several points in the middle part of the Deli River and Babura River. These mining activities also result in high turbidity in the Deli Watershed. Community activities along the Deli Watershed that open up plantations cause the river water to be polluted. The Deli River Watershed is generally classified as lightly to moderately polluted. Good river conditions are only found in the upper stream of the Sembahe River around the Sibolangit Forest. Another threat to the biodiversity of the Deli Watershed is the increasing population of invasive species, particularly the suckermouth catfish. The suckermouth catfish is dominant, especially in the downstream and middle segments around Medan City. This is caused by the damaged and polluted river conditions, allowing the suckermouth catfish to adapt well to the deteriorated and polluted water conditions (Elfidasari et al 2020; Rana et al 2023; Haqqi et al 2024).

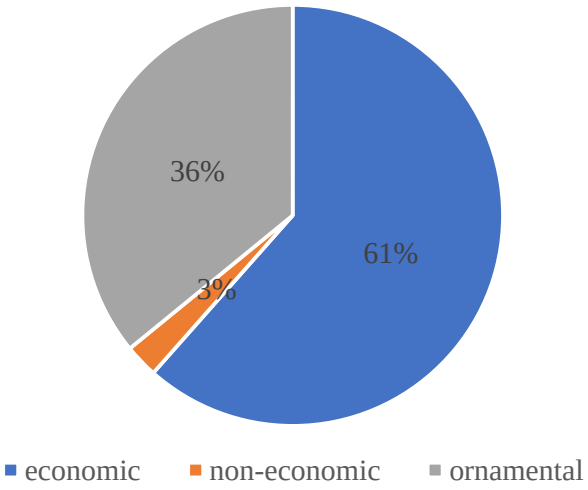

Figure 5. The economic and non-economic commodities of nekton in the Deli Watershed.

Conclusions. This study investigated the distribution, potential, and distribution of nekton in the Deli Watershed, a watershed highly threatened by human activities, both land use changes in the upper part and river boundary pressures in the middle to lower parts. We conclude that although this watershed is highly threatened by human activities, the existence of native fish, such as *M. marginatus* (Valenciennes, 1842), *Hemibagrus* spp., *Glyptothorax* spp., and even the existence of eels shows that this watershed can and needs to be "saved." Therefore, serious attention is required from the government, both the Medan City Government (middle-downstream) and Deli Serdang and Karo Regencies (middle-upstream), including the North Sumatra provincial government, to take serious steps to restore the river ecosystem and the Deli Watershed. This not only saves the existence of the river as a source of clean water in Medan City but also as a habitat for aquatic organisms as an effort and step in saving the aquatic biodiversity of the Deli River.

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References

Agustin U., Siregar M. A. P. P., 2023 Frequency analysis of Deli River flood distribution plan using the gumbel probability distribution method. Sinkron: Jurnal dan Penelitian Teknik Informatika 8(3):474-1485.

Amour B. A., Bosclair D., Dray S., Legender P., 2011 Relationships between species feeding traits and environmental conditions in fish communities: a three-matrix approach. Ecological Applications 21(2):363-377.

Apriliawati, Sukmono T., Nugraha A., 2024 Biodiversity of Ichthyofauna In Mainland Waters of Muara Bulian District Jambi Province and Its New Record. The 5th International Conference on Life Sciences and Biotechnology (ICOLIB 2023), BIO Web Conference 101:03006.

Chua K. W. J., Tan H. H., Yeo D. C. J., 2019 Loss of endemic fish species drives impacts on functional richness, redundancy and vulnerability in freshwater ecoregions of Sundaland. Biological Conservation 234:72-81.

Dekar M., Sarong M. A., Batubara A. S., Muchlisin Z. A., 2018 Ichthyofauna of Aceh River, Aceh Province, Indonesia. Institute of Physics (IOP) Conference Series: Earth and Environmental Science 216:012024.

Desrita, Muhtadi A, Leidonald R, Sibagariang R. D., Nurfadillah, 2020 Biodiversity of nekton in Batangtoru River and its tributaries in North Sumatra, Indonesia. Biodiversitas 21:2344-2352.
Desrita, Muhtadi A., Tamba I. S., Ariyanti J., Sibagariang R. D., 2018 Community structure of nekton in the upstream of Wampu Watershed, North Sumatra, Indonesia. Biodiversitas 19(4):1366-1374.
Desrita, Rambey R., Muhtadi A., Onrizal, Manurung V. R., Hasibuan J. S., Tamba I. S., 2022 Biodiversity of nekton in the Barumun Watershed, Labuhanbatu District, Indonesia. Biodiversitas 23:2426-2432.
Dewantoro G. W., Rachmatika I., 2016 [Foreign Introduced and Invasive Fish Species in Indonesia]. LIPI Press, Jakarta. Pp. 192. [in Indonesian]
Dodds W. K., Whiles M. R., 2019 Freshwater ecology: Concepts and environmental applications of limnology: Third Edition. Academic Press. Pp. 998.
Effendi H., Aprilia M., Permatasari P. A., Amalo L. F., 2022 Aquatic eDNA for monitoring fish biodiversity in Ciliwung River, Indonesia. AACL Bioflux 15(6):3311-3318.
Elfidasari D., Wijayanti F., Muthmainah H. F., 2020 Short Communication: The effect of water quality on the population density of Pterygoplichthys pardalis in the Ciliwung River, Jakarta, Indonesia. Biodiversitas 21(9):4100-4106.
Ha D. T. T., Kim S. -H., Bae D. -H., 2020 Impacts of upstream structures on downstream discharge in the transboundary Imjin Watershed, Korean Peninsula. Applied Sciences 10:3333.
Haqqi M. R. A., Sholichah D. M., Armando M. F., Sani M. F., Aprianto M. K., Dewangga A., Yap C. K., Dadiono M. S., Setyawan A. D., 2024 Species diversity and the spreadof invasive fish in the Upper Begawan Solo River, Central Java, Indonesia. Biodiversitas 25(10):4000-4010.
Harpah N., Ageng P., Addauwiyah R., Rizki A., Perdana Z., Suryati I., Leonardo R., Husin A., Faisal M., 2021. Microplastic pollution in Deli River Medan. Institute of Physics (IOP) Conference Series: Earth and Environmental Science 802:012019.
Hidayat M., Maulizar S., Batubara A. S., Kautsari N., Latuconsina H., Nur F. M., Zulfahmi I., 2023 Ichthyofauna of Merbau River, Leuser Ecosystem Area, Indonesia:species composition, diversity, biometric condition, potency, and conservation status. The European Zoological Journal 90(2):747–761.
Hu M., Wang C., Liu Y., Jia S., 2019 Fish species composition, distribution and community structure in the lower reaches of Ganjiang River, Jiangxi, China. Scientific Reports 9:10100.
Huang J., Huang L., Yuanin M., Naicheng W., 2019 Correlation of fish assemblages with habitat and environmental variables in a headwater stream section of Lijiang River, China. Sustainability 11:1135.
Hutapea H., 2018 The damage of Deli River Watershed causing flood, Medan, Indonesia. Global Journal of Agricultural Research 6(1):10-20.
Irhami S., Fithri A., Batubara A. S., Muchlisin Z. A., 2018 Fish fauna of Meureubo River, Aceh Barat District, Indonesia. Institute of Physics (IOP) Conference Series: Earth and Environmental Science 216:012023.
ISSG (Invasive Species Specialist Group), 2024 Global invasive species database.
IUCN (The International Union for Conservation of Nature), 2024 The IUCN red list of threatened species. Version 2023-1.
Kartamihardja E. S. 2019. Degradation of Native Fish Diversity in the Citarum River, West Java. Warta Iktiologi 3(2):1-8.
Kottelat M., 2013 The fishes of the Inland Waters of Southeast Asia: a catalogue and core bibliography of the fishes known to occur in freshwaters, mangroves and estuaries. Raffles Bull. Zool. 27:1-663.
Kottelat M., Whitten A. J., Kartikasari S. N., Wirjoatmodjo S., 1993 Freshwater Fishes of Western Indonesia and Sulawesi, first ed. Periplus Editions, Jakarta. Pp. 221.
Krebs C. J., 2014 Ecological Methodology, third ed. Harper Collins Publisher, New York. Pp. 654.
Leidonald R., Muhtadi M., Ashshiddiq M. A., Siahaan V. S. P., Manurung B. U., 2025 Water quality assessment in the Deli Watershed, North Sumatra Province,

Indonesia. Journal of Natural Resources and Environmental Management 15(2):324-334.
Leroy B., Dias M. S., Giraud E., Hugueny B., Jézéquel C., Leprieur F., Oberdorff T., Tedesco P. A., 2019 Global biogeographical regions of freshwater fish species. Journal of Biogeoraphy 46:2407-2419.
Li X., Li Y. R., Zhu R., Wang L. Z., Yan Y. Z., 2016 Influences of local habitat, tributary position, and dam characteristics on fish assemblages within impoundments of low-head dams in the tributaries of the Qingyi River, China. Zoological Research 37(2):67-74.
Marnis H., Syahputra K., Darmawan J., Febrianti D., Tahapari E., Larashati S., Iswanto B., Primanita E. P. H., Syaifudin M., Subangkit A. T., 2024 DNA barcoding of fish diversity from Batanghari River, Jambi, Indonesia. Fisheries and Aquatic Sciences 27(2):87-99.
Marselina M., Hanie M. Z., Nurhayati S. A., 2024 Understanding and mitigating water resource decline in the Deli Watershed: A comprehensive analysis. H_2Open Journal 7(1):1–22.
Maulana A. P., Indrayani, Arifin F., 2024 Preliminary design of micro hydro power plant in Enim river, Plakat village. International Journal of Science and Research Archive 11(2):939–945.
MEF (Minister of Environment and Forestry), 2018. Minister of Environment and Forestry Regulation of the Republic of Indonesia No. P.20/Menlhk/Setjen/Kum.1/6/2018 Concerning Protected Plant and Animal Species. Pp. 24.
MMAF (Minister of Marine Affairs and Fisheries), 2021 Minister of marine affairs and fisheries regulation no. 1 of 2021 Concerning Protected Fish Species. Pp. 64.
Muchlisin Z. A., Siti-Azizah M. N., 2009 Diversity and distribution of freshwaters fish in Aceh waters Northern Sumatera Indonesia. International Journal of Zoology and Research 5 (2):62-79.
Muhtadi A., Aldiano R., Khairunnisa, Leidonald R., 2022 Morphometric characteristics of the Alas-Singkil drainage basins. Institute of Physics (IOP) Conference Series: Earth and Environmental Science 977:012090.
Muhtadi A., Leidonald R., 2025 [Limnology: Theory, concept, and model of Inland water management]. IPB Press. Pp. 155. [in Indonesian]
Muhtadi A., Leidonald R., Desrita, 2020 Habitat characteristics and water quality status in the Batangtoru Watershed, North Sumatra Province, Indonesia. Institute of Physics (IOP) Conference Series: Earth and Environmental Science 454:012092.
Muhtadi A., Leidonald R., Fauzia A. D., 2023b Habitat characteristics and biodiversity of nekton in the Alas-Singkil Watershed, Northern Sumatra, Indonesia. Biodiversitas 24(7):3673-3689.
Muhtadi A., Yulianda F., Boer M., Krisanti M., Desrita. 2023a Ichthyofauna diversity and its distribution in a low-saline lake of Indonesia. HAYATI Journal of Biosciences 30(3):421-431.
Muslim M., Irawan R., Karolina A., Fahleny R., Haitami M. A., Isawpatita D, 2024 Conservation and population status of freshwater fishes from Kelekar River, South Sumatra, Indonesia. International Journal of Current Science Research and Review 7(2):1247-1255.
Odum E. P., Barrett G. W., 2005 Fundamental of ecology, (fifth ed). Brooks/Cole Publishing Co, California. Pp. 624.
Partasasmita R., Nuari T., Erawan T. S., Iskandar J., 2015 The diversity of fish species and the disturbances in the Cikawung river, Cianjur, West Java, Indonesia. Nusantara Bioscience 7:171-176.
Purnama A. A., Yolanda R., 2016 Diversity of freshwater fish (Pisces) in Kumu River, Rokan Hulu District, Riau Province, Indonesia. AACL Bioflux 9(4):785-789.
Putri D., Sitorus H., Muhtadi A., 2017 Fish diversity at mangrove ecosystem of Jaring Halus Villlage in Langkat Regency, North Sumatera. Depik 6(2):145-152.
Rana M. M., Mahmud .S, Siam K. S., Chowdhury H. A., Das S. R., Islam M., Sultana M., Shafiullah Habib A. H. M., Naser E. S., Mustafa T., Saif S., Momin M., Naser M. N., 2023 Invasive suckermouth catfishes (Siluriformes: Loricariidae) In Bangladesh

wetlands: present status and challenges. Bangladesh Journal of Zoology 51(3):371-396.
Rauf A., Rahmawaty., Hidayat Y., Slamet B., 2015 [Watershed management: An integrated management plan for the Batang Gadis Watershed, North Sumatra]. 1st edition. Conservation International Indonesia, Jakarta, Indonesia. Pp. 208. [in Indonesian]
Regional Regulation No. 2, 2017, on the spatial planning plan of North Sumatra Province for the Years 2017-2037. North Sumatra Provincial Gazette Year 2017 Number 22.
Siregar P. Z., Tarigan A. P. M., Irsan M., Irwandi H., 2019 GIS-based flood mitigation of Deli River. IOP Conf. Series: Materials Science and Engineering 505:012125.
Stanford J. A., Alexander L. C., Whited D. C., 2017 Riverscape: in methods in stream ecology: 3rd Edition Volume 1: Ecosystem Structure. Ed., Hauer, F., Lamberti, G. Academic Press. Pp. 3-19.
Suryaningsih S., Bhagawati D., Sukmaningrum S., Sugiharto, Puspitasari I. G. A. A. R., 2020 Freshwater fish diversity in three tributary streams in Serayu Basin, Central Java, Indonesia. Biodiversitas 21(12):5811-5817.
Verawaty I., Widiatmaka, Firmansyah I., 2023 Modeling of land use and cover changes (LUCC) in Deli Serdang Regency, North Sumatra Province. Journal of Natural Resources and Environmental Management 13(2):237–251.
Wardhana A., Samsuri, Aththorick T. A., 2024 Analysis of flood inundation vulnerability to the Deli Watershed of North Sumatra using remote sensing and GIS techniques. Journal of Environmental and Development Studies 5(1):9-19
Wowor D., Cai Y., Ng P. K. L., 2004 Crustacea: Decapoda, Caridea. In: Yule C. M., Sen Y. H., editor. Freshwater invertebrata of the Malaysian region. Akademi Sains Malaysia, Kuala Lumpur. Pp. 337-357.
Yankey B. E., Gyamfi C., Arthur E., Dekongmen B. W., Asantewaa-Tannor P., Tawiah J. K., Mends L. G., 2023 Small hydropower development potential in the Densu Watershed, Ghana. Journal of Hydrology: Regional Studies 45:101304.

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