Biodiversity and morphometric characteristics of freshwater fishes in Aceh Tengah, Indonesia

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Abstract. Inventory of fish species is an essential basis for preserving and enriching recorded specimens in the world. Several studies reported a consistent increase in the number of fish collected during extensive exploration activities, showing that there were still hundreds of species yet to be discovered. Therefore, this study aimed to investigate the diversity of freshwater fish species in Aceh Tengah, Indonesia. An exploratory method was used and data were collected from rivers, lakes, reservoirs, and other open waters in the sampling locations. All samples were caught using fishing nets, gill nets, and fish traps. The sampling locations were spread across 10 villages in 6 sub-districts, and data collection was carried out from August to September 2023. The results showed the presence of 19 species belonging to 8 families, including Danionidae, Cyprinidae, Poeciliidae, Cichlidae, Clariidae, Channidae, Synbranchidae, and Loricariidae. Furthermore, Danionidae was the most dominant family (70.62%), and Loricariidae (0.44%) was the least dominant. The condition factor of the samples varied from 0.1 to 9.0. The results of this study can support the interests of fish conservation and become a database of fish types found in Aceh and Indonesia.
Key Words: Aceh Tengah, condition factor, diversity, freshwater, mapping.

Introduction. Indonesia is popularly known as a major fish biodiversity centers in the world and possesses the second-largest diversity after Brazil (Syafei 2017; Manullang & Khairul 2020). At present, approximately 4,782 fish species have been identified in the country, including 1,243 freshwater species (Ohee 2017). Furthermore, several studies showed that freshwater fish played an essential role as a source of protein, amino acids, docosahexaenoic acid (DHA), and other nutrients that meet human needs, specifically for people living in rural locations (FAO 2015; Samitra & Rozi 2018; Samad et al 2022).

Aceh Regency, specifically the middle location, has been reported to have great potential for fishery development but it remains underutilized. This location largely depends on traditional fishing systems, contributing to a relatively sluggish growth in fishing industry. Consequently, there is a pressing need to establish appropriate management aimed at increasing the production volume (BPS 2016; Putra et al 2021). The middle location of Aceh Regency has a land location of 45,000 hectares and provides habitats for different aquatic species, including wild fish. A previous study (Muchlisin & Azizah 2009) found 114 freshwater species in Aceh waters, with 26 being new samples. Aprilia et al (2023) also identified 11 species, while 1 remained unidentified. The results underscored the vast potential for discovering hundreds of additional fish in the location (Syafei 2017), and the number of fish species is increasing as exploration activities increase.

The genetic resources of freshwater species face severe threats due to various human activities. Destructive fishing practices using materials, tools, or methods that damage aquatic resources and the environment contribute significantly to the threats (Gamito et al 2015). Examples of the practices include the use of toxic materials and cyanide, explosives (Nurdin & Grydehøj 2014), electric shocks, and other environmentally unfriendly tools (Bailey & Sumaila 2015).

Over the years, a significant concern arises from the decline in public awareness about the potential of freshwater species, specifically those living in the wild. This decreased awareness can lead to reduced public attention towards these fish, potentially fostering their extinction. This shows that effective conservation and sustainable use of genetic resources must be undertaken to support sustainable food security for present and future generations. In this context, investigation of fish diversity is considered very important in efforts to maximize fisheries potential of each location. Therefore, this study aims to determine the diversity and abundance of fish species in Aceh Tengah. The results are expected to support the interests of conservation and become a database of fish types found in Aceh and Indonesia.

Material and Method

Study location. This study was conducted in Aceh Tengah Regency, where sampling locations were strategically allocated across 10 stations in 6 sub-zones, namely Silihnara, Kebayakan, Bebesan, Bies, Laut Tawar, and Bintang (Figure 1). Sampling occurred after location surveys and interviews with fishermen and local fisheries service agencies, and specimens were collected using gill nets, fishing poles, and traps. Furthermore, the selection of this location was based on the presence of a major river, incorporating geographical features, topography, distribution of typical wild fish species, temperature, organic matter content, and water speed line. Data were collected from July to August 2023, and fish sample identification was analyzed at the Laboratory of the Department of Aquaculture at Samudra University.

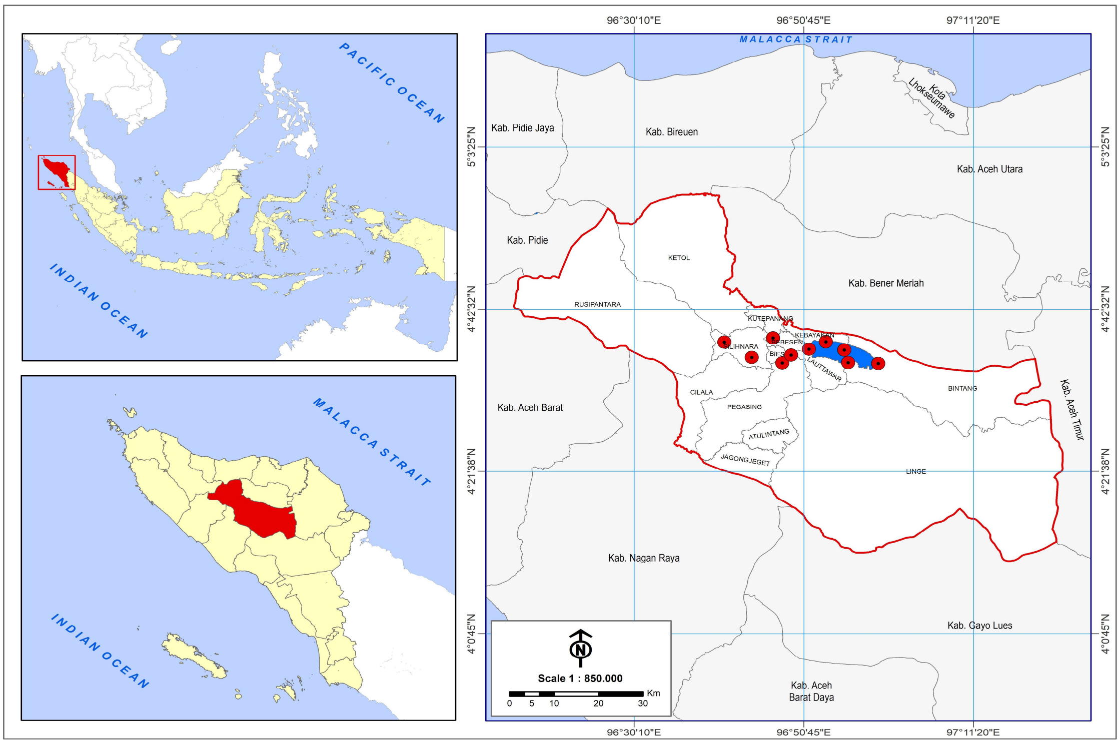

Figure 1. Map of study area.

Data collection. The exploration of typical fish in Aceh Tengah was conducted using the roaming method (Delariva & da Silva 2013). All species caught at the study location had family, scientific, local names, morphological, and meristical characteristics documented (de Lucena & Soares 2016). The morphological characteristics measured the total length (TL), standard length (SL), head length (HL), head height (HH), body height (BH), tail base height (TBH), eye diameter (ED), distance between eyes (DBE), body width (BW), length before dorsal fin (LBDF), length before ventral fin (LBVF), length before anal fin (LBAF), dorsal fin base length (DFBL), anal fin base length (AFBL), ventral fin base length

(VFBL), pectoral fin base length (PFBL), top tail fin length (TTFL), middle tail fin length (MTFL), and low tail fin length (LTFL). Whereas the meristical characteristics were done by counting the number of pectorals, ventrals, anal, caudal and dorsal fin rays. Subsequently, these species were identified in the laboratory (da Graça & Pavanelli 2008; Tencatt et al 2014; Roxo et al 2015), while the origin and location were determined based on Langeani et al (2007). The identification of endemic species followed methods outlined by Zawadzki et al (2004) and Gubiani et al (2006). The distribution model was generated using the coordinates of fish species found, which was recorded with GPS program (Viana et al 2013).

***Study parameters*.** The relative abundance of each fish type was determined by calculating the percentage using the formula (Aprilia et al 2023):

$$RA = \frac{ni}{N} \times 100$$

where: RA is the relative abundance, ni is the number of species I, and N is the total number of species.

Meanwhile, to access dominance, Simpson's dominance index (C) was applied with the formula:

$$C = \sum_{i=1}^{s} \left(\frac{ni}{N}\right)^2$$

where: C = Simpson's dominance index, ni is the number of species I, and N is the total number of species (Purwati et al 2021).

Dominance index values ranged from 0 to 1, with categories such as index = 1 showing very high species dominance, and index = 0 suggesting no dominance.

Furthermore, the condition factor, determined based on fish length and weight, was calculated using the formula:

$$K = \frac{Wt}{TL^3} \times 100$$

where: K is the condition factor, Wt is the final weight (g), and TL is the total length (cm) (Samad et al 2014).

Morphometric and meristic parameters were measured following the methods outlined by Fazillah et al (2022).

***Water quality parameters*.** The criteria for data collection in this study included water sources and fish habitats. Locations were selected based on accessibility to sampling points, considering time and cost effectiveness through the initial interpretation of the study location. Primary data on water quality parameters, such as temperature, dissolved oxygen (DO), pH, and brightness were directly collected on-site. Subsequently, the quality was analysed at the Laboratory of Agriculture Faculty of Universitas Samudra.

Results. The results showed that a total of 1,144 fishes were caught during the sampling period, which comprised 19 species from 8 families, with 1 species remaining unidentified (Figure 2). The identified families of freshwater fishes included Danionidae, Cyprinidae, Poecilidae, Cichlidae, Clariidae, Channidae, Synbranchidae, and Loricariidae. The dominant fish families were Danionidae, (70.63%), Cyprinidae (12.85%) and Poeciliidae (6.29%), while the least number of captured species was in Loricariidae (0.44%), as shown in Table 1.

Table 1

Relative abundance of fish family

No	*Fish family*	*RA (%)*
1	Danionidae	70.62
2	Cyprinidae	12.85
3	Poeciliidae	6.29
4	Cichlidae	4.90
5	Clariidae	2.36
6	Channidae	1.49
7	Synbranchidae	1.05
8	Loricariidae	0.44

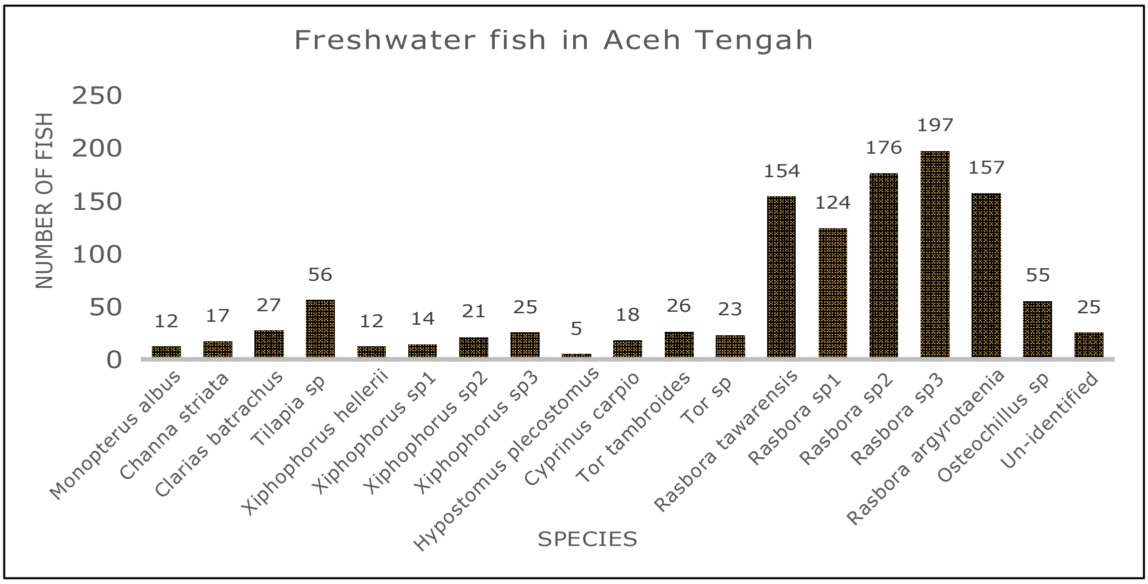

Figure 2. Number of freshwater fish during the sampling period.

Fish condition factor. Fish condition factor (K) described the body condition of fish, based on length and weight data. The condition factor values are crucial in determining the quality of fish meat, and the results are presented in Table 2.

Table 2

Data on condition factors of fish species in Aceh Tengah

No	*Family*	*Scientific name*	*W (g)*	*L (cm)*	*K*
1	Synbranchidae	*Monopterus albus*	87.9	44	0.10
2	Channidae	*Channa striata*	20	11.7	1.25
3	Clariidae	*Clarias batrachus*	95	10	9.50
4	Cichlidae	*Tilapia* sp.	5.4	6.3	2.16
5	Poeciliidae	*Xiphophorus hellerii*	2.2	7.1	0.61
6		*Xiphophorus* sp. 1	2.1	5.5	1.26
7		*Xiphophorus* sp. 2	4.3	6.8	1.37
8		*Xiphophorus* sp. 3	1.9	5.3	1.28
9	Loricariidae	*Hypostomus plecostomus*	13.1	11.5	0.86
10	Cyprinidae	*Cyprinus carpio*	44.8	29	0.18
11		*Tor tambroides*	44.8	15.5	1.20
12		*Tor* sp.	18.6	15.5	0.50
13		*Osteochillus* sp.	55.1	16	1.35
14		Un-identified	28.1	13	1.28
15	Danionidae	*Rasbora argyrotaenia*	7	8.4	1.18
16		*Rasbora tawarensis*	1.9	6.1	0.84
17		*Rasbora* sp. 1	1.1	5.2	0.78
18		*Rasbora* sp. 2	12.8	11.3	0.89
19		*Rasbora* sp. 3	1.3	4.3	1.64

Site location. Sampling was conducted in freshwater locations distributed across 6 sub-zones. Fishing targets were dispersed among 10 stations, including lake locations, Peusangan River, Takengon River, irrigation canals, and other public waters. Furthermore, the distribution covered the districts of Silihnara (2 stations), Bebesan (1 station), Pegasing (2 stations), Kebayakan (2 stations), Laut Tawar (2 stations), and Bintang (1 station), as indicated in Table 3.

Table 3

Sampling sites

No	*Coordinate points*	*Rivers-Districts*	*Scientific name*	*No. ind.*
1	4°38'20.4"N 96°41'07.4"E	Terang Engon, Silih Nara, Central Aceh Regency, Aceh	*Monopterus albus*	9
			Channa striata	17
			Clarias batrachus	27
			Tilapia sp.	11
2	4°36'19.5"N 96°44'26.0"E	Paya Beke, Silih Nara, Central Aceh Regency, Aceh	*Monopterus albus*	3
			Xiphophorus hellerii	7
			Xiphophorus sp. 1	5
			Tilapia sp.	12
			Cyprinus carpio	5
3	4°35'36.4"N 96°48'09.8"E	Simpang Kelaping, Pegasing, Central Aceh Regency, Aceh	*Xiphophorus* sp. 2	21
			Hypostomus plecostomus	3
			Cyprinus carpio	7
			Tilapia sp.	15
			Rasbora tawarensis	23
			Rasbora sp. 1	24
4	4°36'37.3"N 96°49'13.0"E	Kayu Kul, Pegasing, Central Aceh Regency, Aceh	*Tilapia* sp.	4
			Rasbora sp. 2	13
			Rasbora sp. 3	31
			Rasbora argyrotaenia	32
			Xiphophorus hellerii	5
			Xiphophorus sp. 1	9
5	4°38'50.0"N 96°47'01.7"E	Atu Gajah Reje Guru, Bebesen, Central Aceh Regency, Aceh	*Tilapia* sp.	6
			Rasbora sp. 2	34
			Rasbora sp. 3	25
			Rasbora argyrotaenia	19
			Cyprinus carpio	6
			Tor tambroides	26
6	4°37'23.3"N 96°51'26.7"E	Belangmersah dua, Takengon Timur, Central Aceh Regency, Aceh	*Rasbora argyrotaenia*	22
			Osteochillus sp.	12
			Un-identified	25
			Xiphophorus sp. 3	25
			Tilapia sp.	8
			Hypostomus plecostomus	2
7	4°35'40.6"N 96°56'07.1"E	Bamil Nosar, Bintang, Central Aceh Regency, Aceh	*Rasbora tawarensis*	54
			Rasbora sp. 1	26
			Rasbora sp. 2	25
			Rasbora sp. 3	65
			Rasbora argyrotaenia	15
			Osteochillus sp.	22
8	4°35'35.3"N 96°59'47.6"E	Kala Bintang, Bintang, Central Aceh Regency, Aceh	*Tor* sp.	14
			Rasbora tawarensis	19
			Rasbora sp. 1	30
			Rasbora sp. 2	32
			Rasbora sp. 3	34
			Rasbora argyrotaenia	27
			Osteochillus sp.	21
9	4°37'10.8"N 96°55'49.6"E	Danau, Central Aceh Regency, Aceh	*Tor* sp.	9
			Rasbora tawarensis	26
			Rasbora sp. 1	32
			Rasbora sp. 2	27
			Rasbora sp. 3	18
			Rasbora argyrotaenia	14
10	4°38'20.7"N 96°53'27.7"E	Mendale, Kebayakan, Central Aceh Regency, Aceh	*Rasbora tawarensis*	32
			Rasbora sp. 1	12
			Rasbora sp. 2	45
			Rasbora sp. 3	24
			Rasbora argyrotaenia	28

Water quality parameters. In this study, water quality parameters examined included temperature, DO, pH, and brightness, as presented in Table 4.

Table 4

Water quality parameters

Variable	*Value*
Temperature (°C)	15.5-22.6
DO (mg L^{-1})	4.5-6.5
Brightness (m)	1.5-3.0
pH	5.5-8.3

Upon observing these parameters, it was determined that water quality was sufficient to support fish life in the natural environment. Temperature values ranging from 15.5 to 22.6°C, pH 5.5 to 8.3, and DO concentrations between 4.5 and 6.5 mg L^{-1} were deemed suitable for fish habitat. Water quality conditions were consistent with the values reported by Aprilia et al (2023).

Meristic characteristics and morphometric measurements. Meristic characteristics represented traits in fish taxonomy, and this included countable features, including elements such as spines on the fins. Data on meristic characteristics are presented in Table 5.

Table 5

Data on meristic characteristics

No	*Scientific name*	*Number of fin rays*									
		Pectoral fin rays		*Ventral fin rays*		*Anal fin rays*		*Caudal fin rays*		*Dorsal fin rays*	
		Hard	*Soft*	*Hard*	*Soft*	*Hard*	*Soft*	*Hard*	*Soft*	*Hard*	*Soft*
1	*Monopterus albus*	0	0	0	0	0	0	0	0	0	0
2	*Channa striata*	0	15	0	7	0	9	0	17	0	10
3	*Cyprinus carpio*	0	14	0	10	0	7	0	20	0	21
4	*Tilapia* sp.	0	6	0	7	0	11	0	18	16	14
5	*Xiphophorus hellerii*	0	5	0	3	0	3	0	20	0	11
6	*Xiphophorus* sp. 1	0	3	0	4	0	4	0	16	0	11
7	*Xiphophorus* sp. 2	0	4	0	8	0	5	0	20	0	14
8	*Xiphophorus* sp. 3	0	3	0	4	0	6	0	20	0	12
9	*Hypostomus plecostomus*	1	5	1	5	1	4	2	12	1	12
10	*Tor tambroides*	0	10	0	9	0	7	0	18	0	11
11	*Tor* sp.	0	14	0	4	0	6	0	20	0	9
12	*Clarias batrachus*	1	6	0	6	0	32	0	17	0	41
13	*Rasbora tawarensis*	0	5	0	5	0	6	0	14	0	8
14	*Rasbora* sp. 1	0	11	0	8	0	10	0	16	0	5
15	*Rasbora* sp. 2	0	7	0	6	0	8	0	20	0	7
16	*Rasbora* sp. 3	0	6	0	3	0	5	0	16	0	5
17	*Rasbora argyrotaenia*	0	8	0	6	0	6	0	16	0	9
18	*Osteochillus* sp.	0	14	0	9	0	7	0	20	0	17
19	Un-identified	6	8	10	11	3	5	0	24	9	15

This study used 21 indicators (Table 6) to measure morphological characteristics in specimens, which included body weight, total length, standard length, snout or lip length, and dorsal fin length and tail peduncle height. The results showed that *M. albus* exhibited the heaviest body performance (95.0 g) and the longest total length (44 cm).

Table 6

Data on morphometric measurements

No	Species	*Morphometric characters (cm)*																				
		W (gr)	*TL*	*SL*	*HL*	*HH*	*BH*	*TBH*	*ED*	*DBE*	*BW*	*LBDF*	*LBVF*	*LBAF*	*DFBL 1*	*DFBL 2*	*AFBL*	*VFBL*	*PFBL*	*TTFL*	*MTFL*	*LTFL*
1	*Monopterus albus*	87.9	44	43	3	2	2.4	0	0.2	0.7	1.7	0	0	0	0	0	0	0	0	0	0	0
2	*Channa striata*	20	11.7	10.2	5	3	3.3	2	1.6	1.6	1.5	6	6	16	12.5	0	8	2	3	2	3.2	2
3	*Cyprinus carpio*	44.8	29	27	8	6.5	10	4.5	1.5	1	5	14	12	21	5	0	3.5	4	4.3	5	3	5
4	*Tilapia* sp.	5.4	6.3	5	2.2	1.9	2.5	0.6	0.5	0.7	1.5	2.2	2.3	4	3.3	0	1.3	1.2	1.5	1.3	1.1	1.3
5	*Xiphophorus hellerii*	2.2	7.1	4.4	0.8	0.9	1.5	0.9	0.3	0.3	0.8	2.3	2.1	3.4	1.5	0	1	0.9	0.8	1.3	1.3	3
6	*Xiphophorus* sp. 1	2.1	5.5	4.3	0.7	0.8	1.4	0.8	0.3	0.3	0.8	2.3	2.5	3.1	1.7	0	0.7	0.8	0.7	1.1	1.1	1.1
7	*Xiphophorus* sp. 2	4.3	6.8	5.3	1	1.1	1.5	1.1	0.5	0.4	0.8	2.8	3.2	4.4	1.9	0	1.2	0.6	0.9	1.7	1	1.7
8	*Xiphophorus* sp. 3	1.9	5.3	4.4	0.8	0.8	1.3	0.7	0.3	0.3	0.5	2.2	2.3	3.4	1.5	0	0.9	0.5	0.5	1.2	1.2	1.2
9	*Hypostomus plecostomus*	13.1	11.5	8.5	1.8	1	1.9	1	0.5	0.4	1.2	3.4	2.3	5.7	3.5	0	1.5	1.9	2.4	3.1	1.2	3.6
10	*Tor tambroides*	44.8	15.5	12.5	2.8	2.5	3.7	2	0.9	1.2	1.5	6.5	6.2	11.5	2	0	1.3	2.9	2.9	3.5	1.4	3.5
11	*Tor* sp.	18.6	15.5	12.4	3	2.7	4.1	1.9	0.8	1.2	2	6.5	6.5	11	3.8	0	2	1.8	2.5	2.9	1.3	2.9
12	*Clarias batrachus*	95	10	9.2	1.8	1	2	1.2	0.5	1.1	1	3.3	4.4	4.7	6.4	0	4.4	1	1	1	2	1
13	*Rasbora tawarensis*	1.9	6.1	4.9	1.2	1.3	1.9	0.6	0.3	0.3	0.5	2.5	2.3	4	1	0.7	0.7	0.8	1.8	0.9	1.8	1.9
14	*Rasbora* sp. 1	5.2	4.1	3.4	0.6	1.1	0.4	0.3	0.3	0.4	2.1	2.9	3.3	0.9	0	0.8	0.8	0.8	1.2	0.9	1.2	
15	*Rasbora* sp. 2	12.8	11.3	9.4	1.7	1.5	2.5	1	0.5	0.6	1	5	4.8	7.5	1.9	0	1.9	1.5	1.5	2.5	1	2.5
16	*Rasbora* sp. 3	1.3	4.3	3.5	0.6	0.5	1	0.4	0.2	0.3	0.4	2.3	1.6	2.9	0.7	0	0.5	0.3	0.6	0.7	0.7	0.7
17	*Rasbora argyrotaenia*	7	8.4	6.8	1.9	2	2.9	0.8	0.5	0.7	1.2	3.5	3.5	6	1.7	0	1	1.1	1.2	1.9	1.3	1.9
18	*Osteochillus* sp.	55.1	16	12.3	2.8	2.5	5	1.7	0.7	1.3	2.5	6.2	6.8	12.2	5.5	0	2.5	2.8	2.4	3.8	1.4	3.8
19	Un-identified	28.1	13	10	3	2	3.2	1.2	0.4	0.4	2.2	3	5.5	8.5	4	0	2	1.5	2	2.3	1.5	2.3

Note: TL = total length; SL = standard length; HL = head length; HH = head height; BH = body height; TBH = tail base height; ED = eye diameter; DBE = distance between eyes; BW = body width; LBDF = length before dorsal fin; LBVF = length before ventral fin; LBAF = length before anal fin; DFBL = dorsal fin base length; AFBL = anal fin base length; VFBL = ventral fin base length; PFBL = pectoral fin base length; TTFL = top tail fin length; MTFL = middle tail fin length; LTFL = low tail fin length.

Discussion. The diversity of fish species comprised the entire scope of ecological adaptation and described the evolution of species in certain environments. Therefore, it was understandable that fish diversity varied from one location to another (Syafei 2017). This was in line with this study. Consequently, species caught in Silihnara Sub-district (river location) differed from those collected in Bintang and Danau Sub-districts (lake location). This suggested that the environment could impact fish living habitat. Febriani et al (2019) showed that the size of the river flow and position in the watershed had a significant influence on the composition of fish species. Several studies showed that human activities could also affect diversity (Sirait et al 2018). Every type of fish that could live and reproduce effectively needed to adapt to environmental conditions.

In this study, Danionidae family exhibited a high abundance of species, and the prevalence was attributed to the favorable condition of the aquatic habitat and the water quality that was conducive to the living environment. Cyprinidae family comprised *Cyprinus carpio*, *Tor tambroides*, *Tor* sp. and *Osteochillus* sp., and was distributed across 7 stations. According to Hossain et al (2017), fish thrived in fresh water, including shallow waterways, ponds, and lakes, showcasing adaptability and rapid reproductive capabilities. Furthermore, Hossain et al (2009) reported that the highest abundance values generally stem from the effective use of available resources, enabling robust adaptation. Communities with low species diversity were influenced by a low uniformity index and the dominance of a single species. The richness, abundance, and structure of fish communities in rivers were contingent upon habitat conditions, water volume, the presence of predators, and competition for food (Rahman et al 2012).

Samitra & Rozi (2018) and Sukomono et al (2013) conducted an initial exploration of freshwater samples in Kelingi river Lubuklinggau and Harapan river rainforest Jambi respectively. However, ongoing study was essential to periodically enhance the understanding diversity of freshwater fish in Kelingi River and the ecosystem restoration in the rainforest and assess the health of the aquatic life in specific ecosystems. In this study, an unidentified species was discovered and classified as part of Cyprinidae family. Therefore, it was imperative to continue fauna exploration studies for the conservation of species and the prevention of extinction.

Fish condition factor, expressing the plumpness based on length and weight data, played a crucial role in assessing the quality of meat (Aprilia et al 2023). According to Table 2, the condition factor in Aceh Tengah ranged from 0.10 to 9.50 during the experiment period. Furthermore, *Clarias batrachus* exhibited the highest condition factor at 9.50, boasting a length of 10 cm and a weight of 95 g. Samad et al (2023) stated that fish achieving a condition factor value of 3 or higher showed a well-fed, fat body.

In estimating fisheries potential, understanding the relationship between the length and weight of species becomes crucial (Fazillah et al 2022). This information provides valuable insights into the composition of organisms in nature, gonad maturity, mortality, life cycle, growth, and reproduction. Tsoumani et al (2006) previously noted that fishes possess measurable or countable body parts, including scales and fin rays. However, four species in our study, namely *Hypostomus plecostomus*, *Clarias batrachus*, *Tilapia* sp. and un-identified species exhibited hard fin rays, as shown in Table 5.

Fish growth process comprises various factors, including water quality conditions, feed availability, and the presence of other fish sharing the same resources (Samad et al 2020). In this study, pH values from each location were observed, achieving optimum water quality in the range of 5.5 to 8.3. Based on the obtained pH values, waters were deemed suitable to support the life of organisms (Aprilia et al 2023). The recorded temperature DO values for each location ranged from 15.5 to 22.6°C and 4.5 to 6.5 mg L^{-1}, respectively. This temperature range was found to be optimal for living organisms in Aceh Tengah (Tamara et al 2022).

Conclusions. This study collected a total of 1,144 fishes during the sampling period, which comprised 19 species belonging to 8 families, including Danionidae, Cyprinidae, Poeciliidae, Cichlidae, Clariidae, Channidae, Synbranchidae, and Loricariidae. Danionidae was the most dominant family, accounting for 70.63%, while Loricariidae family constituted the least at 0.44%. An unidentified species was observed during the study, emphasizing the need for further investigation. Moreover, this study documented varied distribution among stations and suggested that habitat (river or lake) could influence the types of fish.

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