Population structure and gonadal maturity stage of endemic and alien fish dominant species in Lake Matano, South Sulawesi

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Abstract. Lake Matano, one of the lakes in the Malili Lake complex, is located in East Luwu District, South Sulawesi Province. Lake Matano is an ancient lake that is very deep with high biota and endemicity, including fish. The dominant endemic fish found on Lake Matano is Telmatherina antoniae. At present, dominant alien fish which is Louhan fish is also found at this site. This paper aims to convey the latest information regarding population structure of the dominant endemic and alien fish in Lake Matano, namely relative abundance distribution, size structure (length and weight), growth patterns and gonadal maturity stages. Sampling was carried out in May and August 2016 at five stations. Fish were caught using gill nets with seven mesh sizes and installed for at least two hours. The relative abundance of fish at each station is determined based on the average of catch per unit effort, namely the number of fish caught per hour of gillnet installation (ind/hour), with growth pattern determined based on the length weight relationship, and the stage of gonadal maturity determined morphologically. Telmatherina antoniae and Louhan were found at all stations with the highest relative abundance in MT4 (Petea) and MT2 (Nuha), respectively. The length of T. antoniae ranged from 64 to 105 mm (82.24 ± 0.61 mm) and weight from 2.3 to 11 grams (5.62 ± 0.14 mm). The length of Louhan ranged from 51 to 185 mm (96.42 ± 3.36 mm) and weight from 2.5 to 102.6 grams (21.66 ± 2.36 grams). In May and August, both T. antoniae and Louhan were found with gonadal maturity stage I to IV.

1. Introduction
Lake Matano, located in the Soroako area (south Sulawesi), is an ancient lake which is a tectonic lake, as a part of the Lake Malili complex (Matano, Mahalona, Towuti, Lantoa, and Masapi). Lake Matano is located in the upper stream, Lake Mahalona in the middle stream and Lake Towuti in the lower stream. Lake Matano has an area of 164 km², with oligotrophic trophic status, water visibility up to 20-23 meters, and a depth of 596 m. Lake Matano is utilized by the surrounding community as a recreation area, cage culture for fish, a source of hydroelectric power, source of water for domestic needs, and furthermore for nickel mining activity around Lake Matano area.

Indonesia has 7,000-8,500 species of fish, and 3,000 of them are freshwater fish, most of which are ornamental fish. There are 14 species of fish endemic to Lake Matano [1]. Lake Matano has endemic biota such as Opudi fish (Telmatherina sp.) which consists of nine species and currently extending to 10 species [2]. Moreover, butini (Glossogobius matanensis) is other endemic fish whose presence is
scarce due to anthropogenic activities and the presence of alien species such as the Louhan fish. In addition to fish species, there are also types of endemic shrimp, crabs and mollusks in this lake.

Fish diversity in Indonesia currently faces threats from various human activities that can cause a decline in the fish diversity. Of the 87 species of Indonesian fish that are threatened with extinction, 66 species (75%) are known as freshwater fish [3]. Most (68%) of these endangered freshwater fish are endemic fish [15]. According to [4], destruction of freshwater fish stock is mostly as a consequence of habitat damage (35%), introduction of alien species (30%), over exploitation (4%), pollution and global warming. As an example, some activities around Lake Towuti have the potential to damage the water environment such as: 1) legal and illegal deforestation; 2) industrial sawmill yielding waste of saw-mill; 3) industrial nickel mining yielding waste; and 4) intensive fishing [5]. It is estimated that alien fish species entered Lake Matano would threaten the existence of endemic fish (Telmatherina spp.) which inhabits Lake Matano.

This paper aims to convey the latest information regarding population structure of the dominant endemic and alien fish species in Lake Matano, namely relative abundance distribution, size structure (length and weight), growth patterns and Gonadal Maturity Stages (GMS).

2. Research Methodology

2.1. Study Site

This research was conducted at Lake Matano, East Luwu Regency, South Sulawesi in May and August 2016 which represented the rainy and dry season. Fish were caught at five representative observation stations in littoral zones of Lake Matano (figure 1). Descriptions of the sampling stations are presented in table 1.

![Sampling stations in Lake Matano (MT.1-MT.5).](image-url)
Table 1. Descriptions of the sampling stations.

| No. | Sampling Stations | Description                                                                                                                                                                                                 | Figure of station |
|-----|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| 1   | MT1 Lawa River    | Lawa River is an inlet of Lake Matano, while around the sampling location there is still a forest, the substrate is gravel to a depth of 2 meters and at depths of 5 and 10 meters dominated by sand, the disturbance from anthropogenic activities (residential settlements) is very minimal. | ![Image](image1) |
| 2   | MT2 Nuha          | Location is close to Nuha Village, there are fishing villages, boat docks, boat crossings from Nuha Village to Sorowako. Around the village there is still natural vegetation cover (forest), the type of substrate is small gravel to a depth of 2 meters and at depths of 5 and 10 meters is sand. | ![Image](image2) |
| 3   | MT3 Petea         | Outlet of lake Matano is Petea station, a more open area, there is a former forest clearing to be converted into a plantation area. Formerly a former area of nickel tailings waste disposal, the substrate from a depth of 0 to 2 meters is mud and fine sand and at a depth of 5-10 meters is sand. There are swamps. | ![Image](image3) |
| 4   | MT4               | There are cage aquaculture, in front of flats, no natural vegetation, near PT Vale, land clearing for pepper plantations, the substrate from a depth of 0 to 2 meters is gravel and sand and at a depth of 5-10 meters is sand. | ![Image](image4) |
| 5   | MT5 Butterfly beach/ Bubble beach | There are Butterfly group around this area, also known as Bubble beach, gas bubbles which are suspected to be H2S are found in the waters, the riparian zone around the location is still dominated by native vegetation, the substrate at depth of 0-2 meters is dominated by gravel and at depth of 5 and 10 meters is sand. | ![Image](image5) |
2.2. Type of Research
The research method used is descriptive quantitative approach. The research station was determined based on different habitat types representing the waters of Lake Matano.

2.3. Research Focus
This paper aims to convey the latest information regarding population structure of the dominant endemic and alien fishes in Lake Matano, in the form of relative abundance distribution, size structure (length and weight), growth patterns and the gonadal maturity stages (GMS).

2.4. Techniques of Data Collection and Data Analysis
Fish samples were caught using experimental gill nets consisting of seven different mesh sizes, namely: ¾, 1, 1½, 2, 2½, 3, and 3½ inches with lengths of 25 m each and 1.8 m high, so that the total length of one unit is 175 m. The net were equipped with buoys at the top and ballasts at the bottom. Thenet was installed at each station from the direction of the beach towards the free water in the upper water column [6] for two hours during the day between 08.00-12.00 pm (figure 2). The number of catch at each observation station was recorded and separated by sex. Then the total length and total wet weight were measured.

Figure 2. Position of fish sampling using Gill net on Lake Matano.

Total length is the length of the fish measured from the anterior tip of the longest jaw to the most posterior part of the caudal fin. The total length can be measured to the nearest unit below it [7] or to the nearest unit [8]. The total length was measured to the nearest unit below it. The weight of the fish measured was the total wet weight. Total wet weight is the total weight of the fish's body tissue and the water contained in it. Total wet weight measurements were carried out in the field [9]. A measuring board (accuracy of 1 mm) was used to measure length and the digital scales of ACIS BC 500 series (accuracy of 0.1 g) to measure the weight of fish. Another tool used was a surgical device to determine the Gonadal Maturity Stage (GMS). Furthermore, the GMS was determined morphologically by following Cassie's classification [10] and [11]. For identification purpose, some of the fish samples were preserved in 4% formaldehyde solution and then immersed in 70% alcohol solution. Fish were identified using references from [12], [13], [14], and [15] at the laboratory.

Data were analysed descriptively and analytically. The relative abundance of fish at each observation station is seen based on the average value of CPUE (individual/hour), namely the number of fish caught per hour per the length of installation of gillnet. Length, weight, and GMS of fish were analysed using descriptive statistics. Fish growth patterns were determined using a lengthweight relationship equation, \( W = aL^b \) [16]. If \( b = 3 \), then the growth pattern is isometric (length increase is proportional to weight gain). If \( b \neq 3 \) then the growth pattern is allometric (length increase is not proportional to weight gain). If \( b > 3 \), then the growth pattern is a positive allometric where weight gain is more dominant than the increase in length, whereas if \( b < 3 \), then the growth pattern is negative
allometric where length is more dominant than weight gain [17]. To test the null hypothesis that $\beta = \beta_0$ can be calculated $t$. If the value of $t > t (\alpha / 2, n-2)$ then the null hypothesis is rejected and if $t < t (\alpha / 2, n-2)$ the null hypothesis fails to be rejected [18] in this case $\beta_0 = 3$. Some of physical and chemical water quality parameters (temperature, pH, and dissolved oxygen/DO) was measured directly using Horiba U-51 Water Quality Checker / WQC Horiba U-51. This measurement was carried out together with the gill net installation.

3. Results and discussion

3.1. Environment

In general, the entire range of water quality in research stations still meet the requirements for fisheries activities according to the quality standards of the Ministry of Environment [19] as shown in table 2. The water quality standard tolerance threshold for fluctuating temperature parameters does not exceed 3°C, pH 6-9 and minimum dissolved oxygen (DO) 3 mg/L. The surface water temperature of Lake Matano during the study ranged from 26.9 to 29.08 °C.

Acidity and alkalinity of a lake is measured with a pH value, on a scale of 1-14. pH is defined as the negative log of hydrogen ion concentration. The concentration of hydrogen ions controls the chemical condition of the nutrients and carbon dioxide in the waters. Carbon dioxide in the waters is used by plants for photosynthesis [15]. In general, lake pH ranges from 6-9, Lake Matano has a neutral pH to close to bases. Carbon dioxide is free to maintain the equilibrium of $\text{HCO}_3^-$ in solution and is called $\text{CO}_2$ balance. Based on observations (the water pH of Lake Matano ranges from 8.39 - 8.87), it can be predicted that the equilibrium of the reaction is in the form of carbonate.

Distribution of dissolved oxygen (DO) in water is very important in the metabolic processes of organisms. Solubility of some inorganic nutrients is affected by DO. Changes in nutrient distribution will affect the speed of growth of microorganisms. The dissolved oxygen value in Lake Matano ranged from 5.5 - 7.67 mg/L.

| No. | Stations                  | Temperature (°C) | pH       | DO (mg/L)   |
|-----|--------------------------|------------------|----------|-------------|
| 1   | MT1(Lawa River)          | 27.5-28.5        | 8.39-8.65| 5.50-7.73   |
| 2   | MT2(Nuha)                | 26.9-28.8        | 8.75-8.87| 7.26-7.63   |
| 3   | MT3 (Petea)              | 27.9-28.3        | 8.74-8.79| 7.29-7.46   |
| 4   | MT4 (Front of flats)     | 28.7-29.08       | 8.47-8.64| 7.29-7.54   |
| 5   | MT5 (Butterfly beach)    | 28.3-28.9        | 8.39-8.70| 6.12-7.67   |

3.2. Catch composition

The dominant endemic fish species found in May and August was *Telmatherina antoniae* by 57% and 32%, while the dominant alien fish species was Louhan, by 27% and 42% (figure 3). Species of *Telmatherina* sp. belongs to the Telmatherininidae family, which is an endemic tribe in Sulawesi waters, estuary waters and mangrove swamps in Papua New Guinea [15]. Furthermore [15] explained that the Telmatherininidae family such as *Telmatherina antoniae* (figure 4a) had two dorsal fins where the first dorsal fin had simple spines and generally had a colour difference between males and females. Louhan fish found in Lake Matano is thought to be the result of artificial cross hybrid of *Amphilotopus citrinellus* and *Cichlasoma trimaculatum* (figure 4b). The percentage of Louhan has increased even to become the dominant type as a whole. Furthermore, both *Telmatherina antoniae* and Louhan will be analysed in this paper.
3.3. Dominant Fish Population Structure

3.3.1. Relative abundance distribution.

The distribution of relative abundance of *T. antoniae* at each sampling location can be seen in table 3 and figure 5.

**Table 3.** Catch per unit effort of *Telmatherina antoniae* in each location.

| Stations               | May  | August | Average |
|------------------------|------|--------|---------|
| MT 1 (Lawa River)      | 5    | 10.5   | 7.75    |
| MT 2 (Nuha)            | 6.5  | 1      | 3.75    |
| MT 3 (Petea)           | 64   | 5.5    | 34.75   |
| MT 4 (Front of flats)  | 19   | 0.5    | 9.75    |
| MT 5 (Butterfly beach) | 1    | 2.5    | 1.75    |
Telmatherina antoniae found in all sampling stations with a relative abundance score in MT3 (Petea) is very high compared to other stations. [21] also reported that T. antoniae was found in nine observation sites on Lake Matano with abundance in Petea is low. The habitat of Telmatherina fish has diverse substrates. As reported by [22] that T. antoniae spawned on habitats with substrate sand/mud, cobblestone to rocks, and aquatic plants. Telmatherina antoniae spawn at a depth of less than 1 m to more than 10 m. All types of Telmatherina fish are substrate spawner which are types of fish that lay and spawn their eggs on the substrate.

Figure 5. Relative abundance distribution of T. antoniae and Louhan in Lake Matano.

As previously stated, Louhan fish is a very dominant alien fish in Lake Matano and its population continues to increase. The distribution of relative abundance of Louhan fish in Lake Matano can be seen in table 4 and figure 5.

| Station            | May  | August | Average |
|--------------------|------|--------|---------|
| MT 1 (Lawa River)  | 6.5  | 6.5    | 6.5     |
| MT 2 (Nuha)        | 29   | 4      | 16.5    |
| MT 3 (Petea)       | 0.5  | 3.5    | 2       |
| MT 4 (Front of flats) | 2    | 2.5    | 2.25    |
| MT 5 (Butterfly beach) | 8.5  | 10.5   | 9.5     |

Louhan are found in all sampling stations with the highest relative abundance at MT2 (Nuha) stations followed by MT5 (Butterfly Beach/Bubble beach) and in other stations with relatively low abundance. As reported by [23] that Louhan fish occupy a wider habitat from the edge of the lake to a depth of more than 13 m and adult fish generally prefer habitat with rocky substrate.
3.3.2. Size Distribution

- Telmatherina antoniae

Based on figure 6 it is known that the length of female *T. antoniae* ranged from 69-105 mm with the highest frequency in the class interval 79 to 83 mm. Whereas male fish were found with a length range of 64 to 102 mm with the highest frequency in the class interval of 79 to 83 mm. The size of both female and male fish was relatively smaller than previously reported by [24] in [21], namely 64 to 106 and 64 to 120 mm, respectively female and male fish. Spatially, there is a tendency that fish length at MT4 and MT5 stations was greater than in other locations. The weight ranged from 3.2 to 11 gram for female and 2.3 to 11 gram for male (figure 7).

**Figure 6.** Total length distribution of *T. antoniae* in Lake Matano.

**Figure 7.** Wet weight size distribution of *T. antoniae* in Lake Matano.

- Louhan

The length and weight of analysed Louhan male fish varied more than female fish, as shown in figure 8 and 9. Based on these figures, it was found that the length and weight of male fish were in the class 59-187 mm and 8.75-96.95 grams. The size of female fish is also smaller than male fish, namely the length in the class interval 59-171 mm and the weight of 8.75-84.35 grams. The Louhan fish analysed were smaller than the Louhan fish size reported by [25] which was around 250 mm. This is not much different from the information posted on the website www.fishbase.org which reports that the maximum size of *Amphilopus citrinellus* fish is 244 mm SL and *Chlicosoma trimaculatum* 365 mm SL.

**Figure 8.** Total length of Louhan fish in Lake Matano.

**Figure 9.** Wet weight of Louhan fish in Lake Matano.
3.3.3. Length-weight relationship.

Length-weight relationship models of male, female and overall *T. antoniae* are \( W = 6 \times 10^{-6}L^{3.12} \), \( W = 5 \times 10^{-5}L^{2.63} \) and \( W = 1 \times 10^{-5}L^{2.95} \) (figure 10). The exponent value of \( b \) for length and weight in individual male is 3.12 and female is 2.63. T-test \((\alpha=0.05)\) results on the regression coefficient value \((b)\) shows the value of \( b < 3 \) for female and \( b=3 \) for male and all fish. This value indicates that the growth pattern of female is allometric, both male and overall *T. antoniae* is isometric. This means that the growth of *T. antoniae* weight is balanced with length growth. [26] states that the length weight relationship will slightly deviate from the cubic law \((b \neq 3)\) because the environment and fish’s condition often changes. Biologically the value of \( b \) relates to the condition of the fish, while the condition of the fish depends on the food, age, sex and maturity of the gonads [10].

![Figure 10. Length-weight relationship of *T. antoniae* in Lake Matano.](image)

The length weight relationship model of the male, female, and overall Louhan are \( W = 2 \times 10^{-5}L^{3.02} \), \( W = 9 \times 10^{-6}L^{1.15} \), and \( W = 1 \times 10^{-5}L^{3.08} \) (figure 11). T-test results show that \( b \) value of female is higher than 3 and \( b \) value for male and overall of Louhan is equal to 3. This value indicates that the growth pattern of female is allometric, male and overall Louhan fish is isometric which means that fish weight growth proportionally with its length.
3.3.4. The gonadal maturity stage (GMS) of the dominant fish

- *Telmatherina antoniae*

According to [27] that the testicular and ovarian organs in most teleostei fish are a pair of organs located in the body cavity. But in some types of fish, testicular and ovarian pairs develop only one organ. Bonti-bonti fish have one reproductive organ that developed. The same thing according to [24] found in opudi fish (*T. antoniae*) originating from Lake Matano, [28] in rainbow selebensis (*T. celebensis*) from Lake Towuti, and [29] reported on fish beseng-beseng (*T. ladigesi*) from several rivers in Maros, South Sulawesi. These fish are classified as sexual dimorphism, which means that the fish has properties that can be used to distinguish male and female fish.

Gonadal maturity stage (GMS) is a certain stage of gonadal development before and after the fish spawns. The development of gonads is part of the reproductive process of fish. The occurrence of gonadal development as a result of the vitellogenesis process which is the process of deposition of egg yolk on each egg cell. Before spawning occurs, most of the fish's metabolic products are used for gonad development purposes.

Gonadal development of *T. antoniae* is classified into five stages, namely GMS I (undevolved), II (early development), III (developing), IV (mature), and V (post spawning) both in male and female fish that refer in [30], [31], [32] and [33] with modifications (figures 12 and 13). The GMS of *T. antoniae* fish in May and August was I - IV, but male *T. antoniae* in August at MT4 and MT5 stations was not found. In August more male and female *T. antoniae* were found at the GMS IV. This shows that *T. antoniae* fish are more likely to spawn, especially at MT1 station so that they can recruit (figures 12 and 13).
\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure12.png}
\caption{Gonadal maturity stage of \textit{T. antoniae} (a) female and (b) male in May at Lake Matano.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure13.png}
\caption{Gonadal maturity stage of \textit{T. antoniae} (a) female and (b) male in August at Lake Matano.}
\end{figure}

- Louhan

During May and August 2016, GMS of Louhan ranged from I to IV (figures 14 and 15) at all stations, except at MT3 and MT4 stations female fish was not found on May. This allows Louhan fish to reproduce quickly. Louhan fish also eat eggs of endemic fish that are attached to the substrate [23], so that it is estimated that the recruitment of endemic fish will not be achieved. Some of these facts indicate the potential threat of Louhan fish to the Lake Matano ecosystem. However, dominant endemic fish such as opudi (\textit{T. antoniae}) with gonad maturity stage (GMS) I-IV was also found in almost all stations. Therefore it is expected that \textit{T. antoniae} fish can reproduce and recruitment will be achieved, so that the population could be sustainable.
4. Conclusion

*Telmatherina antoniae* was relatively more abundant in Petea and near Flats, while Louhan was abundant in Nuha and Bubble beach. Female of *T. antoniae* was relatively bigger than male. Length of *T. antoniae* ranged from 69 to 105 mm for female and 64 to 102 mm for male, furthermore the weight ranged from 3.2 to 11 gram for female and 2.3 to 11 gram for male. On the other hand, female of Louhan was relatively smaller than male. Length of female Louhan ranged from 51 to 172 mm and male from 53 to 185 mm. Weight of Louhan ranged from 2.5 to 90.2 gram and 2.5 to 102.6 for female and male, respectively. The growth pattern of overall *T. antoniae* was isometric as well as Louhan.
Both *T. antoniae* and Louhan were found in GMS I to IV with a greater proportion of mature gonads in August.

Alien fish species that tend to be invasive, such as Louhan, must be controlled through mass capture either using a net of at least 2 inches (gonad mature Louhan and opudi fish not caught), fishing rods, or rifles that could be done by the community through government or private programs. So that Louhan fish can be controlled quickly. Moreover, compensate the Louhan catch with some incentive also could be an alternate.

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**Acknowledgments**

This study was a part of research project titled “Adaptasi dan Mitigasi Perubahan Iklim pada Perairan Darat. Studi Kasus: Ekosistem Perairan Danau dan Situ” (Adaptation and Mitigation of Climate Change in Inland Waters. Case Study: Lake Ecosystem) funded by Unggulan LIPI programme. We thank to all team members who helped this research.