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Morphological Variations in Endemic Fish Sailfin Silversides (*Telmatherina Prognatha)* in Matano Lake, South Sulawesi, Indonesia

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Abstract: *Telmatherina prognatha* is an endemic freshwater fish found in Matano Lake. This fish has different morphometric characters and colors between the male and female species. They are widely distributed in the lake in a small number of populations. This research aims at distinguishing the morphological differences of the fish based on their morphometric characters as an indication of the different populations inhabiting Matano Lake in Indonesia. The research was conducted from March to May 2018 in the lake on three sampling locations, namely Station1 (around Lawa River), Station 2 (Salonsa Beach), and Station 3 (around Petea River). The fish sampling was carried out using multifilament nets with 0.5 inches in size. The 21 morphometric character indicators were measured using a standardized method. This research confirms that a univariate analysis on the morphometric characters of both sexes of the fish in each research station does not differ significantly or may have originated from the same population. The more significant effects of the morphometric characters are TL (total length), SL (standard length), LBDF2 (length of the base of the second dorsal fin), DL2 (second dorsal fin base length), LBAL (length of the base of anal fin), AL (anal fin base length), PL (pectoral fin length), VL (ventral fin length), HH (head height), ED (eye diameter) for males fish, and TL, SL, CPL (caudal peduncle length), LBDF 1 (length of the base of the first dorsal fin), DL 1 (first dorsal fin length), LBDF 2, DL 2, VL, PL, HH, HL (head length), ED, LMPF (length of mouth to pectoral fin) for females. The similarity percentage of meristics traits for male fish is ≥97.56% and ≥85.33% for females.

Keywords: endemic fish, Matano Lake, Telmatherina prognatha.

印度尼西亞南蘇拉威西島馬塔諾湖特有魚類帆鰭銀邊(特爾瑪瑟琳娜普羅格納塔) 的形態變異

摘要：特爾瑪瑟琳娜普羅格納塔是一種在馬塔諾湖發現的地方性淡水魚。這種魚在雄性和雌性物種之間具有不同的形態特徵和顏色。它們廣泛分佈於湖中，少數種群。本研究旨在根據魚類的形態特徵來區分魚類的形態差異，作為棲息在印度尼西亞馬塔諾湖的不同種群的指示。該研究於 2018 年 3 月至 5 月在湖中的三個採樣位置進行，即站 1（拉瓦河周圍）、站 2（薩隆薩海灘）和站 3（皮特亞河周圍）。使用 0.5 英寸大小的複絲網進行魚取樣。使用標準化方法測量了 21 個形態特徵指標。這項研究證實，對每個研究站魚類兩性形態特徵的單變量分析沒有顯著差異，或者可能來自同一種群。形態特徵影響比較顯著的有 TL（總長度）、SL（標準長度）、LBDF2（第二背鰭基部長度）、深度学习 2（第二背鰭基部長度）、LBAL（第二背鰭基部長度）臀鰭）、铝（臀鰭基長）、PL（胸鰭長度）、VL（腹鰭長度）、高（頭

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高)、ED (眼徑)(雄魚) 和 TL、SL、CPL (尾柄) 長度), LBDF 1 (第一背鰭基部長度), DL 1 (第一背鰭長度), LBDF 2, 深度学习 2, VL, PL, 高, HL (頭部長度), ED, 低通滤波器(長度嘴到胸鰭) 對於雌性。雄魚的分生特徵相似度為· 97.56%，雌魚為· 85.33%。

关键词：特有魚類，馬塔諾湖, 特尔马瑟琳娜前体。

1. Introduction

Sixty eight endemic ichthyofaunas inhibit freshwaters of the Island of Sulawesi. Particula, South Sulawesi has five lakes inhabited by 40 species out of the total endemic ichthyofauna on the island [1]. The *Telmatherina (T.) prognatha* is one of the endemic fish species from the order Artheriniformes and family Telmatherinadae that inhabit the Matano Lake. This fish is widely distributed in the lake compared to other fish of the Telmatherina family, although in a relatively small amount [2].

Telmatherina prognatha is endemic to the Matano Lake. It is a small fish with a maximum length of 4.7 – 8.4 cm [3]. It possesses a standard length of about 84 cm [4]. Each species in the family of fish exhibits differences in morphology and color. Some species in the fish group are characterized by their rounded second dorsal fin (*T. antoniae*, *T. prognatha*, and *T. celebensis*) or pointed fins (*T. sarasinorum*, *T. wahjui*, *T. opudi*, *T. abendanoni*, and *T. Obscura*) [5]. Local people refer to the fish as *Ikan Opudi*. It is included in the list of endangered species [6]. Based on the research [7], the catch of this species is lower (16.14%) than that of other Telmatherina species, such as *T. antoniae* (31.08%) and *T. sarasinorum* (19.28%). Currently, the existence of this fish in Matano Lake is threatened due to the presence of invasive fish species that compresses the indigenous fish. About 16 identified invasive fish species in the lake, such as flower horn fish, potentially endanger the indigenous population [8].

The Matano Lake is a deep water lake (the eighth lake in the world and the deepest in Southeast Asia) and has become one of the lakes in Indonesia, with its bottom at about 208 meters depth below the sea surface level (crypto depression). This lake covers an area of 164 km^2 with a maximum length and width of 28 km and 8 km, respectively [9]. The differences in height among lakes have formed barriers preventing organisms from moving upstream from downstream. This condition evokes a unique distribution pattern. The Matano Lake has fish communities simply with some endemic genus.

Furthermore, this lake is isolated from the surrounding areas where large anthropogenic stressors come from. This threat may lead to a decline in fish diversity. Variations in fish species are very important to preserve the existence of a certain species or population to be adaptable in the changing environments [10]. In addition, a morphometrical study is one of the methods that can be used to distinguish the differences in shapes, which can be an important factor in differentiating fish within homogeneous groups [11]. Several studies have been carried out on the lake, among them: Conservation of endemic fish *Telmatherina Celebensis* in Lake Towuti, South Celebes [12]; A comparative description of mating behavior in the endemic Telmatherinid fishes of Sulawesi's Malili Lakes [13]; Adaptive radiation and population genetics of the Telmatherinidae in Lake Matano [14]; Diversity and evolution of Telmatherinidae in the Malili Lakes System in Sulawesi [15]; Preliminary checklist of sailfin silversides (Teleostei: Telmatherinidae) in the Malili Lakes of Sulawesi (Indonesia), with a synopsis of systematics and threats [3]; Research on *Telmatherina prognatha* fish has never been done.

This research is intended to determine the morphological characters of *T. prognatha* fish based on the standards of morphometric characters to be used as an indication as to whether the fish originated from one or more populations in Matano Lake. The resulting information from this research is expected to become essential information in assessing the population, especially the *T. prognatha* fish in the lake.

2. Methods

2.1. Time and Location

The sampling of fish was conducted between March and May 2018 in three stations, namely Station 1 (Lawa River), Station 2 (Salonsa Beach), and Station 3 (Petea River). These stations were chosen considering the characteristic differences, namely inlets (Station 1) and lake outlets (Station 3,) as illustrated in Fig. 1.

2.2. Fish Sampling

Fish were sampled in the morning using a rectangular multifilament net 30 m long and 2 meters wide, with a 0.5-inch mesh size. This net was cast onto the water in 45^0-90^0 perpendicular to the coastline and pulled by two people on each station.

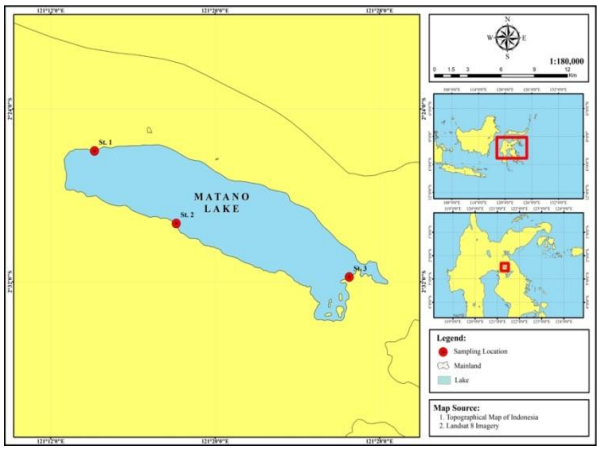

Fig. 1 Research site in Matano Lake of South Sulawesi, Indonesia

2.3. Samples Identification

The caught fish were then sorted and separated by species. The sampled fish for morphometric identifications were preserved using 10% formalin and then washed with fresh, clean water. Those fish were immersed in a container with 70% ethanol. After 24 hours, the ethanol was replaced with fresh ethanol for laboratory measurement. The measurement was conducted on the preserved fish based on morphometrical characters by using a caliper with 0.5 mm accuracy. This measurement followed a standard method referring to [4], [12], and [14]. The measured characters consisted of 21 morphometric characters as described in Table 1 and Fig. 2 below.

Table 1 Morphometric characters of *T. prognatha*

Morphometrical characters	
Total length (TL)	Anal fin length (AL)
Standard length (SL)	Pectoral fin length (PL)
Fork length (FL)	Ventral fin length (VL)
Body height (BH)	Head height (HH)
Caudal peduncle height (CPH)	Head length (HL)
Caudal peduncle length (CPL)	Mouth length (ML)
Length of base of first dorsal fin (LBDF 1)	Eye diameter (ED)
First dorsal fin length (DL 1)	Length of mouth to the first dorsal fin (LMDF 1)
Length of base of second dorsal fin (LBDF 2)	Length from mouth to pectoral fin (LMPF)
Second dorsal fin length (DL 2)	Length from mouth to anal fin (LMCF)
Length of anal fin base (LBAL)	

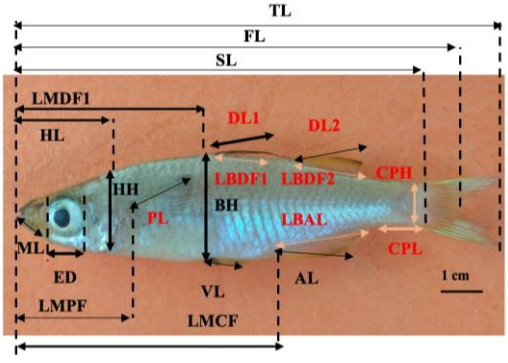

Fig. 2 Morphometric characters of *Telmatherina prognatha* caught in Matano Lake of Indonesia

2.4. Data Analysis

In determining whether there are any population classifications of *T. prognatha* fish among research stations, two analyses were performed, namely univariate analysis using ANCOVA and multivariate analysis using Principal Component Analysis (PCA), on the 21 standard morphometric characters of the fish. The results of the PCA analysis were then clarified through a cluster analysis by using a percent similarity coefficient. The data above were processed using the software XLSTAT and MVSP Version 3.1.

3. Research Results

The total number of *Telmatherina prognatha* fish observed in this research amounted to 182 individuals composed of 102 males and 80 females. Those fish were unequally distributed in each station, namely Station 1 (Lawa River), Station 2 (Salonsa Beach), and Station 3 (Petea River), totaling 64, 89, and 29 individuals, respectively.

The caught male and female *T. prognatha* had differences in morphology and color. The morphological characteristics of the fish are described in succession as follows. The first dorsal fin of the male was longer than the female's, while the second dorsal fin of the male was more rounded than the female. Males were brighter than females (Fig. 3).

Fig. 3 The caught fish of *T. prognatha* fish, male (a), and female (b) in Matano Lake

The sizes of the male and female *T. prognatha* varied in each station. The body lengths between male and female of the fish in Stations 1, 2, and 3 were in the range of 41.40 – 57.94 mm and 40.42 – 66.05 mm; 40.50 – 60.17 mm and 32.93 – 59.11 mm; and 42.99 – 59.56 mm and 39.00 – 61.96 mm, respectively.

The results of the ANCOVA analysis in three stations for 21 characters indicated significant and insignificant differences between the male and female species. In Station 1, there were nine characters observed with no significant differences ($p>0.05$) and twelve characters observed with significant differences ($p<0.05$). Furthermore, the female's BH, CPH, CPL, LBDF1, PL, VL, HH, ML, ED, LMDF1, and LMPF were longer than the male's (Table 2).

Table 2 Results of a relationship analysis among morphometric characters of *T. prognatha* in Matano Lake

Morphometric characters	Station I (p<0.05)/(p>0.05))	Station II ((p<0.05)/(p>0.05))	Station III ((p<0.05)/(p>0.05))
TL	0.626*	0.300*	0.722*
SL	0.695	0.390*	0.608*
FL	0.398*	0.066**	0.392*
BH	0.045**	0.932*	0.477*
CPH	0.088**	0.088**	0.492*
CPL	0.088**	0.073**	0.328*
LBDF 1	0.042**	0.623*	0.899*
DL1	0.059**	0.000**	0.012**
LBDF2	0.211*	0.419*	0.550*
DL2	0.191*	0.060**	0.218*
LBAL	0.175*	0.775*	0.864*
AL	0.108*	0.405*	0.827*
PL	0.096**	0.771*	0.822*
VL	0.062**	0.568*	0.050**
HH	0.003**	0.062**	0.245*
HL	0.193*	0.120*	0.157*
ML	0.000**	0.000**	0.235*
ED	0.003**	0.126*	0.129*
LMDF1	0.003**	0.050**	0.932*
LMPF	0.014**	0.045**	0.195*
LMCG	0.421*	0.046**	0.108*

(*) no significant difference; (**) significant difference

In Station 2, there were eleven and ten characters with no significant (p>0.05) and significant differences (p<0.05), respectively. These ten characters are described as follows. The male's FL was higher than the female's, the male's CPH was longer than the female's, the female's CPL was longer than the male's, the male's DL1 male was longer than the female's, the male's DL2 was longer than the female's, the male's HH was longer than the female's, the female's HL was longer than the male's, the male's LMDF1 was longer than the female's, the male's LMPF was longer than the female's, the male's LMCF was longer than the female's (Table 2). In Station 3, there were nineteen and two characters with no significant differences (p>0.05) and significant differences (p<0.05), respectively. The two characters signify that the male's DL1 was longer than the female's, and the male's VL was longer than the female's (Table 2).

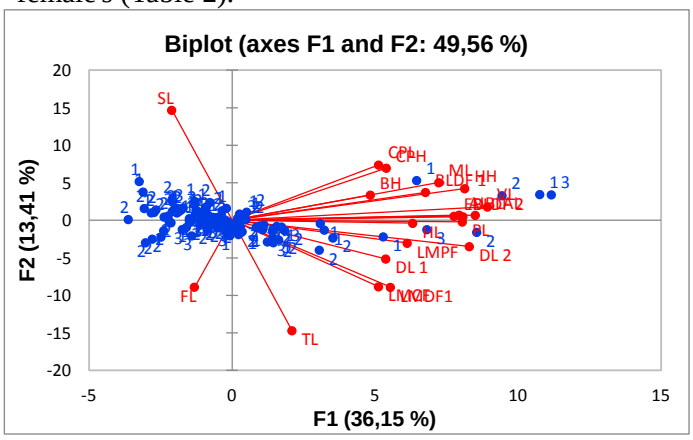

Fig. 4 The PCA Results on Morphometric Characters of *T. prognatha* male in Matano Lake

The PCA results for 21 morphometrical characters of *T. prognatha* male exhibited that the two axes (F1 and F2) with their quality information quality were 36.15% and 13.41%. Two axes can explain the morphometrical characters analysis and research stations at 49.56%. The biplot diagram in Fig. 4 pointed out that most characters were correlated with the F1, and TL and SL were correlated with F2. The morphometric characters that distinguished *T. prognatha* male were TL, SL, LBDF2, DL2, LBAL, AL, PL, VL, HH, and ED.

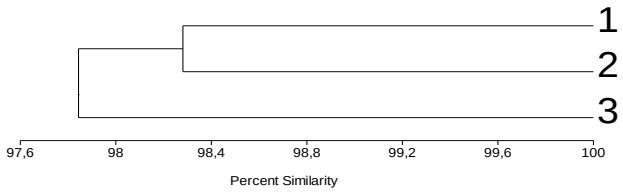

Fig. 5 The population grouping of *T. prognatha* males based on research stations in Matano Lake (1= Lawa River, 2= Salonsa Beach, 3= Petea River)

The results of character grouping in Fig. 5 were supported by the Percent Similarity Method. This grouping indicates that Stations 1 and 2 belonged in the same group, while Station 3 belonged in another distinct group. The similarity values of the three stations are 98.28% (Stations 1 and 2), 97.56% (Stations 1 and 3), and 98.12% (Stations 2 and 3), as presented in the following Fig. 6.

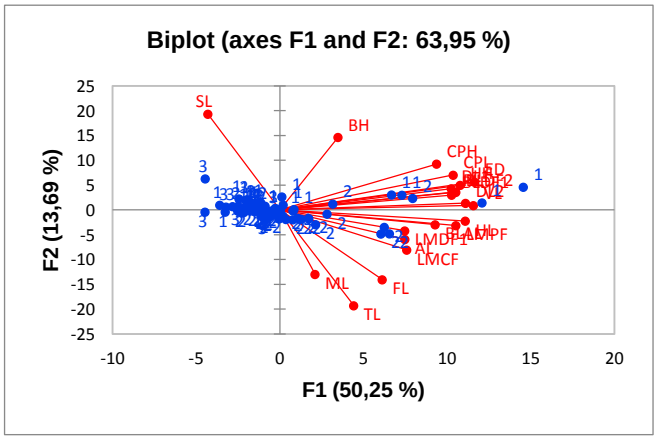

Fig. 6 The PCA results of morphometrical characters of *T. prognatha* female in Matano Lake

The results of PCA for 21 morphometric characters of *T. prognatha* female denote similarity with the male, where a majority of the characters are correlated with F1 (50.25%) (Fig. 5). The influential characters for the *T. prognatha* fish are TL, SL, CPL, LBDF1, DL 1, LBDF 2, DL 2, PL, VL, HH, HL, ED, and LMPF. The grouping results for the female *T. prognatha* fish exhibit that the similarity between group 1 (Stations 1 and 2) was 89.88%, and group 2 (Stations 1 and 2, and Stations 2 and 3) was 94.04% and 85.33% (Fig. 7).

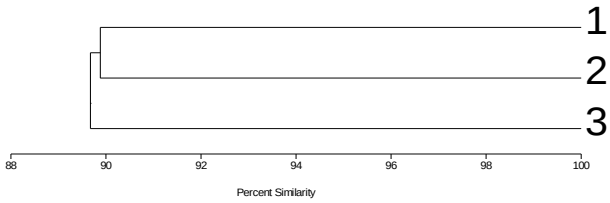

Fig. 7 Population grouping of female *T. prognatha* based on research stations in Matano Lake (1= Lawa River, 2= Salonsa Beach, 3= Petea River)

4. Discussion

The results of this research on the morphometrical characterization of *T. prognatha* fish support the assumption that the fish in the three research stations belong to a single group of the population, even though the distance between stations is quite far. The results of this research are in line with the propositions of [12] that the *T. celebensis* fish living in Towuti Lake is categorized into one group of the population, even though their territory is quite wide. The fishes from different population groups will possess differences in morphological characters, as proposed by [16], that habitat fragmentation leads to differentiation in morphological characters, resulting in an isolated population.

Character differentiation may occur due to the different water bodies inhabited, such as flowing water (Station 1), an inlet of Matano Lake, and calming waters (Stations 2 and 3). The above can be observed from some characters that are significantly higher in findings from Station I than in other stations. The research [17] expressed that the character differentiations found in *T. ladigesi* fish in two rivers were presumed based on differences in the flowing water habitat. Another result has also been proposed by [18], expressing the differences in morphometric characters observed in Milky Fish (*Cyclocheilichthys lineatus*) in Diatas and Batang Gumanti Lakes were due to the age group differences of the captured fishes. The research [16] for Desert Chub Fish (*Gila eremica*) in several rivers in Mexico exhibited that the occurring character differences observed were caused by the isolation of fish species. In addition, differences in geographical conditions, habitat fragmentations, and ancestors may have also contributed to the changing morphometric characters of fish [19].

The results of the current research present that the morphometric characters in general between males and females of *T. prognatha* fish, in general, do not exhibit any significant differences in each research station. The sampled population in this research does not exhibit any population differences despite the different stations. Two stations (Stations 1 and 2) displayed a higher similarity than the other station that is surmised due to the closer distance between the inlets of Matano Lake and Salonsa Beach tends to be closer than to the lake's outlet. A similar result has been discovered by [20], expressing that *T. celebensis* fishes in Tuwoti Lake are a single population group, even though the geographical condition in the lake can give birth to sub-species. The emergence of sub-species usually happens in an isolated habitat [16, 21, and 22] reported that isolation by distance and different environmental conditions, such as variability of food items, growth pattern, and abiotic characteristics, are responsible for population differentiation. The above does not apply to *T. prognatha* fish in Matano Lake because the fish are distributed throughout the entire lake, and there are no barriers to migration.

A striking difference between male and female of *T. prognatha* fish found in the three stations can be observed in two characters, namely the first dorsal fin (DL1) and the second dorsal fin (DL2) lengths. These morphological characters can be used in distinguishing the sex of the fish, male or female, in addition to color. Apart from these characters, other characters do not present any significant differences caused by the habitat of the fish in an isolated lake, which prevents the fish from moving out of its natural habitat. The research [23] similarly stated that specific environmental conditions of the studied area might underline the morphological differentiation among the research stations. This condition is unlike other endemic fish species that inhibit largely different habitats. The contrasting condition is illustrated by Neretva chub fish (*Squalius syallize*) living in lakes and rivers, where huge character variations were observed [24]. Furthermore, *Devario aequipinnatus* fish exhibits different morphological characters in five sampling locations along the Kalakkad Mudanthurai Tiger Reserve's rivers [25], and *Sillago javanico* fish have wide variations among the samples that were collected from six locations in Japan [26]. In addition, variations in morphometrical characters can also be influenced by the number of specimens observed, varying from small to larger sizes.

T. *prognatha* fish is an endangered endemic species categorized by IUCN as vulnerable species. In addition, seven other species of Telmatherina inhabit Matano Lake, such as *T. abendanoni, T. Obscura, T. opudi, T. sarasinorum. T. antoniae, T. wahjui*, and *T. albolabiosus*. However, only some species support the bio-ecological aspects of other Telmatherina fish in the lake. Further research is required to record detailed information regarding the endemic fishes in Indonesia, particularly in Matano Lake, South Sulawesi.

5. Conclusion

This study results showed that the morphometric characters between male and female opudi fish (*T. prognatha*) did not significantly differ at each research station. The population groups formed in this study did not show population differences even though they were at different stations.

The analysis findings on the 21 morphometric characters of male and female *T. prognatha* fish in Matano Lake indicate that the fish population originated from a single group of population. The more influential characters for the male fish were TL, SL, LBDF2, DL2, LBAL, AL, PL, VL, HH, and ED, while the more dominant characters for the female of the fish were TL, SL, CPL, LBDF 1, DL 1, LBDF 1, LBDF 2, DL 2, VL, PL, HH, HL, ED, and LMPF. The similarity percentages between males and females are ≥97.56% and ≥85.33%, respectively.

In the future, this study will be more comprehensive if compared with the validation results using a molecular approach.

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