Length-weight relationship and condition factor of the Celebes rainbowfish *Marosatherina ladigesi*, endemic to the Maros karst region, South Sulawesi, Indonesia

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Abstract. Locally called *beseng-beseng*, *Marosatherina ladigesi* (Ahl 1936) is a rainbowfish endemic to the Maros karst region in South Sulawesi, Indonesia. The colorful > ladigesi male has become popular within ornamental fish hobbyists worldwide. However there is a lack of published information on the basic biological parameters of this species. This research aimed to determine the length-weight relationship and condition factors of two wild *M. ladigesi* populations. Sampling was carried out in two studies. In the first study, samples were collected 12 times at fortnightly intervals from October 2013 to March 2014. The fish were caught using a rectangular net (3 x 1m), 0.5 cm mesh size, from Bantimurung River (N = 338) and Pattunuang River (N = 331), both in Maros District. The samples were examined in the Fisheries Biology Laboratory, Hasanuddin University. The fish collected from Bantimurung river comprised 69 males and 269 females, while those from Pattunuang River comprised 88 males and 243 females. In the second study, samples were collected 8 times from July to October 2020. The number of samples obtained from the Bantimurung River was 206 individuals, while in the Pattunuang River no fish samples were obtained. The growth pattern of both male and female *M. ladigesi* from both rivers was isometric. In both populations the female *M. ladigesi* tended to have a higher condition factor than male individuals. In the second study, the growth type of *M. ladigesi* was hypoallometric.
Key Words: endemic species, ornamental fish, biological parameters, isometric growth.

Introduction. In the field of ecology, endemism is a phenomenon where one or more species have distributions limited to a particular (restricted) geographical area. To be called endemic, a taxon must occur naturally in that particular area and nowhere else (Omar 2012). Endemism is extremely important in systematics and biogeography, as well as in conservation biology; areas with a high level of endemism and species biodiversity will generally be highly rated in terms of conservation priorities (Parenti 2011). Sulawesi Island has the highest level of freshwater fish endemism in Indonesia (Kottelat et al 1993). According to Hadiaty (2018), 68 endemic freshwater fish species have been described from Sulawesi.

The Maros karst region in South Sulawesi Province is spreaded over three Districts: Maros, Pangkajene and Kepulauan, and Barru. This area has a high level of endemism and is home to many unique species. Biospeleological experts have labelled this area as a biodiversity hot spot (Suhardjono & Ubaidillah 2012). The endemic ichthyofauna of the Maros karst area includes *Bostrychus microphthalmus*, *Dermogenys orientalis*, *Lagusia micracanthus*, *Nomorhamphus brembachi*, *Nomorhamphus liemi*, *Oryzias celebensis*, and *Marosatherina ladigesi* (Hadiaty 2012; Hadiaty 2018).

Marosatherina ladigesi (Ahl 1936), known locally as *beseng-beseng,* is a member of the Family Telmatherinidae, which includes the sailfin silversides and rainbowfishes. The Celebes rainbowfish was originally described as *Telmatherina ladigesi (*Ahl 1936), and Kottelat et al (1993) reported this fish from the Bantimurung River in the Maros karst region, in South Sulawesi. A phylogenetic analysis of the Telmatherinidae by Aarn et al (1998) found significant differences between this species and other members of the genus *Telmatherina*, warranting classification under a separate genus, named *Marosatherina* in recognition of the region from which the type species was first described. To date, *M. ladigesi* is not only the type species for the genus *Marosatherina* (Aarn et al 1998) but also the sole known species in this genus (Froese & Pauly 2018). Since this change in valid taxonomy, *M. ladigesi* has been found in several other rivers within the Maros karst region, i.e. Kassikebo, Ta'deang, Pattunuang, Leang-leang, Tampala, Manrepo, and Rumbia Rivers (Hadiaty 2007, 2012).

Like other rainbowfishes, *M. ladigesi* exhibits sexual dimorphism; the colorful and showy males are popular with the aquarium hobby, giving this species an economic value in the international freshwater ornamental fish trade. Demand from aquarium traders and hobbyists around the world has prompted fishermen to catch *M. ladigesi* to the point where populations have declined and the species is considered to be overfished. If this level of exploitation continues, it is feared that the ornamental fishery could threaten the survival of *M. ladigesi* in the wild. Together with habitat degradation, uncontrolled exploitation of this endemic species has already resulted in reduced reproductive capacity (Omar 2012). Listed as Vulnerable in the IUCN Red List of Endangered Species since 1996, the assessment of *M. ladigesi* was recently updated to reflect the change in taxonomy from the genus *Telmatherina* to the currently accepted genus *Marosatherina* (Kottelat 2018).

Research on *M. ladigesi* has covered several aspects of reproductive biology (Andriani 2000; Nasution et al 2006; Said & Mayasari 2007; Omar et al 2014; Kariyanti et al 2014; Kariyanti 2015; Jayadi et al 2016a; Jayadi et al 2018; Kariyanti et al 2019), bio-ecology and morphology (Andriani 2000), karyotype (Andriani 2000; Andriani et al 2004), habitat (Hadiaty 2007), and genetics (Jayadi et al 2015) as well as domestication (Said et al 2007; Jayadi et al 2016b; Kariyanti & Andi Lawi 2020), including the effect of live and artificial feed on growth (Triyanto & Said 2006). However there is still a lack of data on many aspects of the biology and ecology of this species, as evidenced by the paucity of data and information in both the IUCN Red List assessment (Kottelat 2018) and FishBase, the global database of fishes (Froese & Pauly 2018). In particular, there appear to be no published data on the growth pattern of this species in the wild. Therefore, the aim of the present research was the study of the length-weight relationship and condition factor of *M. ladigesi* populations in two rivers (Bantimurung and Pattunuang) within the endemic distribution of this species.

Material and Method

Period and location. The present research was conducted in two periods. The first study was conducted from October 2013 to March 2014, while the second study from July to October 2020. Samples of the endemic fish *M. ladigesi* were collected from the Bantimurung River and Pattunuang River in Maros District, South Sulawesi Province, Indonesia (Figure 1).

Sampling and sample handling. Samples were collected 12 times at fortnightly intervals in the first study, while in the second study collection was performed 8 times. The fish were captured using a rectangular multifilament net (4.7 x 1 m) with mesh size 0.3 cm. The net was set on the river bed by two fishermen, each holding one end of the net. The net was then swept to the left and the right and then lifted to the surface. The fish were carefully removed from the net, euthanized, and placed in a coolbox with ice blocks to preserve the fish cell structure during transport from the field to the laboratory.

The fish samples were analyzed at the Fish Biology Laboratory in the Fisheries Department, Faculty of Marine Science and Fisheries, Hasanuddin University, Makassar, Indonesia. The total length (TL) of each specimen was measured using calipers (0.1 mm precision). The specimens were then weighed using a digital balance (0.01 g precision). Each specimen was then dissected; the gonads were removed and observed to determine sexes.

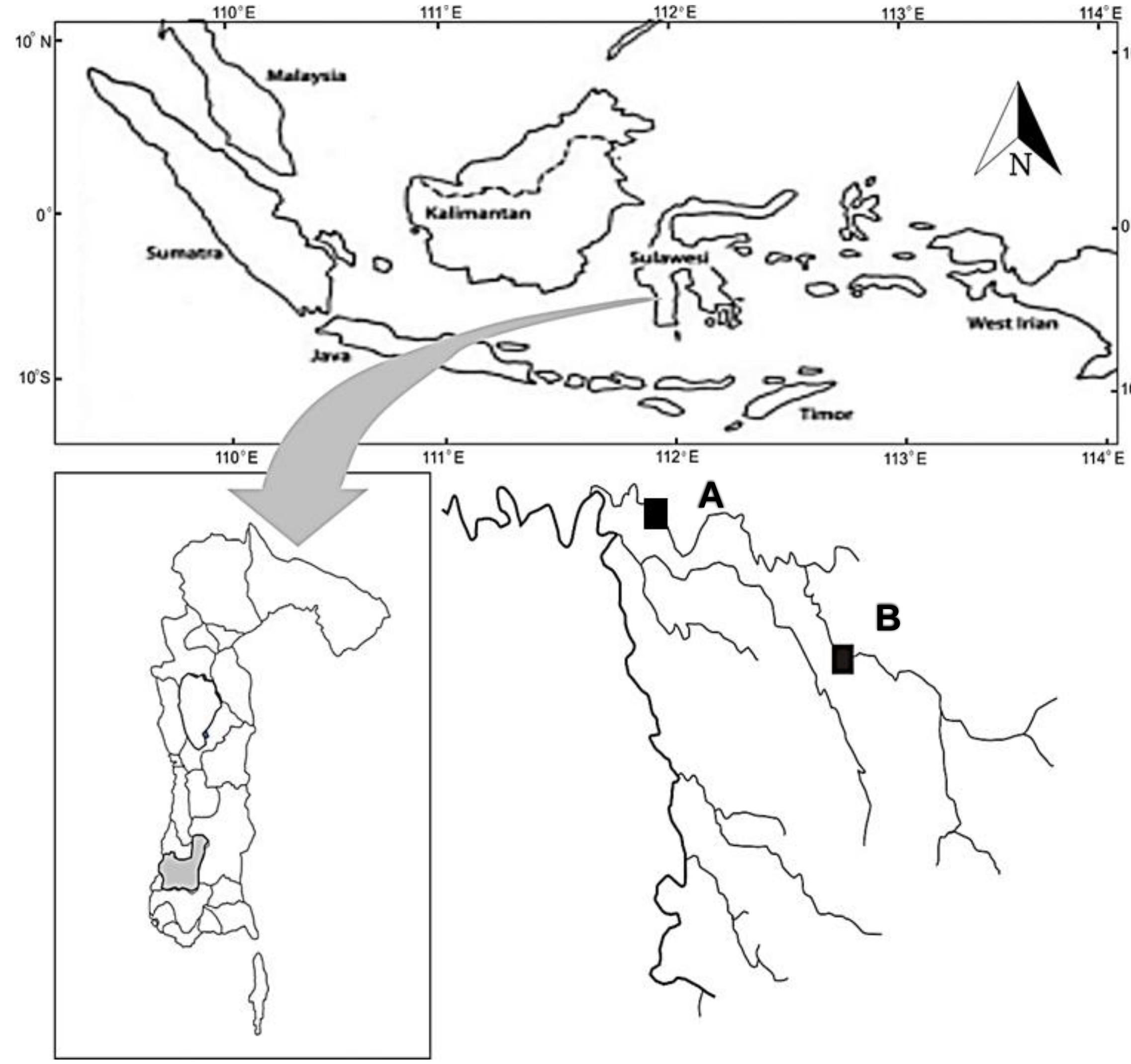

Figure 1. *Marosatherina ladigesi* sample collection sites on the Bantimurung River (A) and Pattunuang River (B), in Maros District, South Sulawesi Province, Indonesia.

Data analysis. The length-weight relationship was analyzed overall, by sexes, by site, and by sampling period. The parameters a and b in the length-weight relationship equation $W = a\ L^b$ were calculated as the intercept (a) and regression coefficient (b) using the least mean squares regression method on the log-transformed data using the linear equation $\log W = \log a + b \log L$ (W = body weight, in g; L = TL, in mm) (Le Cren 1951; Hamid et al 2015).

The growth pattern was determined based on the value of b as isometric ($b = 3$); hypoallometric or negative allometric ($b<3$); and hyperallometric or allometric positive ($b>3$) (Froese et al 2011). A t-test was used to determine whether the mean value of b was significantly different from 3 at the 95% confidence level (Hossain et al 2013). Differences in the mean values of the regression coefficient b by sex were also evaluated using a t-test with 95% confidence interval (Fowler et al 1998).

The condition factor was analyzed by sexes. For fish populations with an isometric growth pattern, the condition factor (Pl) can be determined using the equation $K = 10^5\ W / L^3$ (Barnham & Baxter 1998) where W = mean body weight (in g) of the fish in a given size class and L = mean total length (in mm) of the fish in the same size class. For fish populations with an allometric growth (hypoallometric or hyperallometric), the relative condition factor (K_n) was used with the equation $K_n = W / W^*$ (Le Cren 1951) where W = the observed mass (in g) of an individual and W* = predicted mass, which is obtained from the linear regression of the weight-length relationship of the respective population sample (aL^b).

Results

Sample number and fish size. During the first research a total of 338 *M. ladigesi* were collected from Bantimurung River, comprised of 69 males and 269 females, while a total of 331 *M. ladigesi* were collected from Pattunuang River, and comprised of 88 males and 243 females. The total number of *M. ladigesi* in the second study collected from Bantimurung River was 206 individuals, without differentiating between male and female fish. On the other hand, in Pattunuang River there were no fish in the four months of sampling (Table 1).

Table 1

Total length and body weight of *Marosatherina ladigesi* specimens collected during first and second study by sexes and site

Site: River	*Sexes*	*Total length (mm)*			*Body weight (g)*		
		Range	*Mean*	*SE*	*Range*	*Mean*	*SE*
First study (October 2013 – March 2014)							
Bantimurung	Male	34-65	48.71	1.06	0.30-3.11	1.29	0.09
Bantimurung	Female	20-70	42.74	1.19	0.06-3.06	0.94	0.08
Pattunuang	Male	30-60	48.19	0.77	0.19-2.19	1.15	0.05
Pattunuang	Female	20-55	35.33	1.10	0.05-1.74	0.54	0.05
Second study (July – October 2020)							
Bantimurung	Unknown	19-69	44.80	0.63	0.06-2.42	0.89	0.09

Length-weight relationship. Based on the t-tests performed on the values of *b* obtained (through linear regression of log-transformed data), the growth pattern of *M. ladigesi* collected during the first study from both Bantimurung River and Pattunuang River was isometric (p>0.05). Isometric growth indicates that all body parts grow at approximately the same rate, and thus that body proportions do not vary significantly over the size range studied. There was no significant difference in the value of *b* for male and female specimens from either the Bantimurung River or the Pattunuang River (p>0.05), so that the length-weight data on males and females could be analyzed together. The length-weight curves for male and female *M. ladigesi* by site and for all specimens combined, together with the regression equations obtained, are shown in Figure 2. In contrast, the growth type of *M. ladigesi* during the second study from Bantimurung River was hypoallometric. The curve of the length-weight relationship of *M. ladigesi* and its correlation coefficient can be seen in Figure 3.

In addition to the lack of significant difference in the *b* values by site or by sexes, the high correlation coefficient (r) values in Figure 2 and Figure 3 (0.8553 to 0.9642) show a very strong correlation between growth in length and increase in weight for both male and female *M. ladigesi* individuals, in the Bantimurung River and the Pattunuang River.

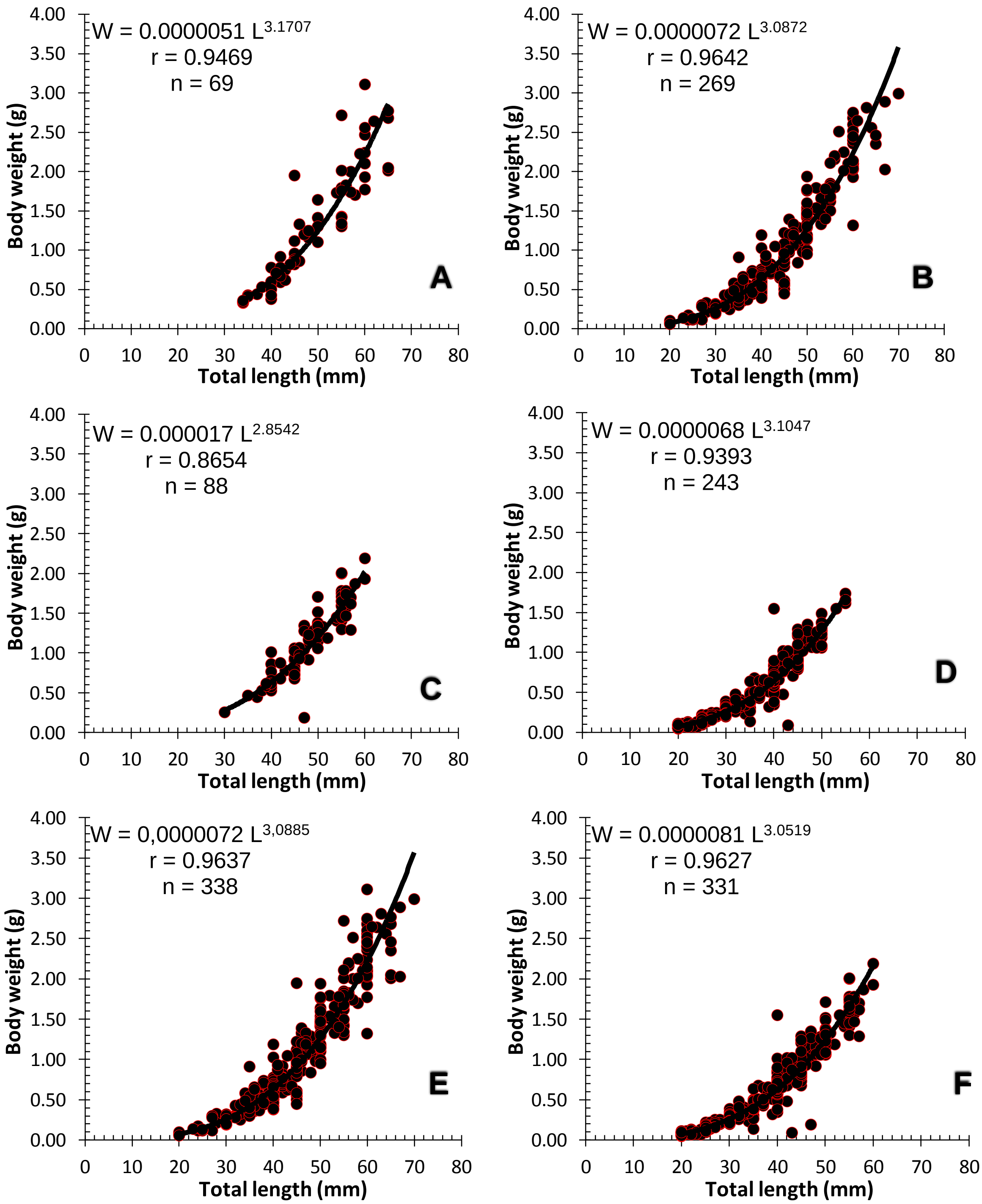

Figure 2. Length-weight curves and equations for *Marosatherina ladigesi* in the first study. A- Males from Bantimurung River; B - Females from Bantimurung River; C - Males from Pattunuang River; D - Females from Pattunuang River; E - All specimens (male + female) from Bantimurung River; F - All specimens (male + female) from Pattunuang River.

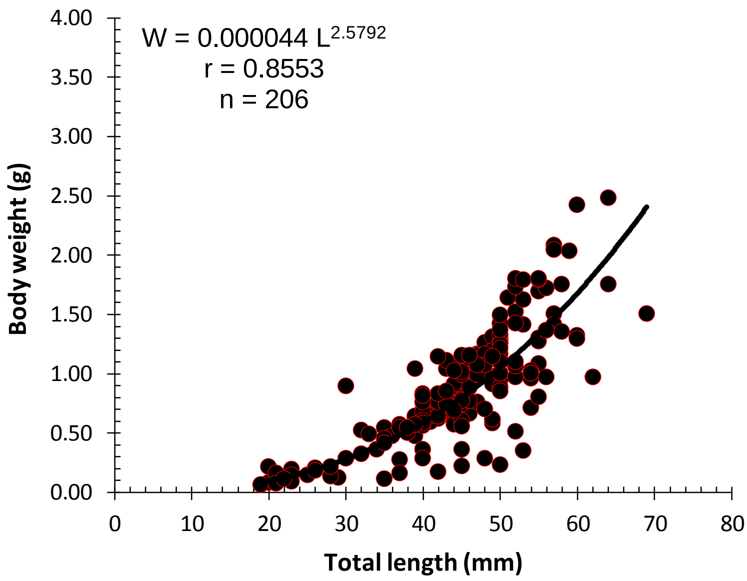

Figure 3. Length-weight curve and equation for *Marosatherina ladigesi* from Bantimurung River in the second study.

Condition factor. The range and mean values obtained for *M. ladigesi* during this study are shown in Table 2.

Table 2

Condition factor of *Marosatherina ladigesi* from the two study sites during first and second study

Site: River	*Sexes*	*n*	*Range*	*Mean*	*SE*
		First study (October 2013 – March 2014)			
Bantimurung	Male	69	0.5938-2.1399	1.0107	0.0270
Bantimurung	Female	269	0.4938-2.1224	1.0192	0.0127
Bantimurung	Male + Female	338	0.4938-2.1399	1.0174	0.0115
Pattunuang	Male	88	0.1830-1.5781	0.9850	0.0180
Pattunuang	Female	243	0.1132-2.4219	1.0044	0.0140
Pattunuang	Male + Female	331	0.1132-2.4219	0.9993	0.0113
		Second study (July – October 2020)			
Bantimurung	Unknown	206	0.2192-3.1671	1.0587	0.0231

Discussion

Size distribution. Nasution et al (2006) reported that body lengths of *M. ladigesi* caught in several rivers in the Maros karst region ranged from 35.8 to 43.3 mm with a body weight of 0.46-2.90 g. Hadiaty (2007) reported that the total length of the fish found ranged from 15.9 to 58.0 mm. The body length and body weight of the fish were also reported by Said et al (2007). They found fish lengths in Bantimurung River ranged from 37-55 mm and body weights from 0.61 to 2.89 g, while in Pattunuang River 44-52 mm and 0.95-1.72 g. The latest data on *M. ladigesi* was presented by Jayadi et al (2016a) who found body lengths ranging from 36.4-56.4 mm and body weights of 1.04-2.40 g. The size range of both male and female specimens collected during the first and second studies (Table 1) was relatively large compared to samples reported from several other studies on *M. ladigesi* within the Maros karst region. On average, male *M. ladigesi* were larger (both longer and heavier) than females in both Bantimurung River and Pattunuang River.

Length-weight relationship. The body weight of fishes varies exponentially with body length. This is reflected in the form of the length-weight equation $W = aL^b$. The exponent *b* can be used to determine the growth pattern. In fish with an isometric growth pattern ($b \approx 3$), weight increases in proportion with length. A hypoallometric or negative allometric growth pattern ($b<3$) means that length increase proportionately faster than weight; conversely, a hyperallometric or positive allometric growth pattern ($b>3$) means that weight increase proportionately faster than length (Froese et al 2011).

Furthermore, Froese et al (2011) consider the length-weight relationship to be extremely important for fisheries management. The equation describing the relationship can be used to convert length data into biomass data, to determine the condition factor, and to compare fish growth between fisheries management areas, as well as in studies on reproduction food habits.

There are no previous studies on the growth pattern of this fish in its native habitat, the Maros karst region. Therefore, the data obtained are compared with data on other, related, endemic species from Sulawesi. The species include *Adrianichthys oophorus*, *Glossogobius matanensis*, *Paratherina striata*, *Telmatherina antoniae*, *Telmatherina celebensis*, *Telmatherina prognatha*, and *Oryzias matanensis*. In general, these endemic fishes also tend to have isometric and hypoallometric growth patterns (Table 3).

Table 3

Regression coefficients and growth patterns of some fishes endemic to Sulawesi

Species	*Sexes*	*n*	*Regression parameters*			*Growth type*	*Source*
			a	*b*	*r*		
Telmatherina celebensis	Male	141	0.0093	3.1124	0.8958	Isometric	Furkon (2003)
	Female	132	0.0036	3.1556	0.9602	Isometric	
Telmatherina celebensis	Male	812	0.00078	3.0729	0.9000	Isometric	Nasution (2007)
	Female	713	0.00005	3.0476	0.9487	Isometric	
Paratherina striata	Male	168	0.5209	2.9740	0.9251	Isometric	Wardani (2007)
	Female	235	0.6615	3.1024	0.9566	Isometric	
Glossogobius matanensis	Male	1401	0.0089	2.98	0.92	Hypoallometric	Mamangkey (2010)
	Female	794	0.0851	2.30	0.88	Hypoallometric	
Telmatherina antoniae	Male	1437	0.00008	3.210	0.979	Hyperallometric	Tantu (2012)
	Female	1270	0.0003	2.915	0.958	Hyperallometric	
Adrianichthys oophorus	Male	169	0.000006	3.074	0.9701	Isometric	Gundo et al (2014)
	Female	566	0.000008	3.011	0.9487	Isometric	
	Pooled	735	0.000006	3.089	0.9607	Isometric	
Lagusia micracanthus	Male	307	0.00002	2.9489	0.9430	Isometric	Nur (2015)
	Female	292	0.00001	3.0600	0.9284	Isometric	
	Pooled	599	0.00002	3.0041	0.9376	Isometric	
Telmatherina prognatha	Male	483	0.0004	2.5995	0.8544	Hypoallometric	Chadijah et al (2019)
	Female	370	0.0006	2.4875	0.8660	Hypoallometric	
Oryzias matanensis	Male	410	0.0014	2.0367	0.8695	Hypoallometric	Rinandha et al (2020)
	Female	470	0.00072	2.2444	0.8523	Hypoallometric	

The regression coefficients can vary both temporally and spatially, as they are affected by many internal and external factors. These include sexes, gonad development, spawning seasons, gut fullness, health condition, habitat type and condition, the food available (quantity, quality, and size), seasonal effect, as well as capture and preservation techniques (Le Cren 1951; Wootton 1998; Ahmed et al 2011; Alavi-Yeganeh et al 2011; Froese et al 2011; Ahmed et al 2012; Hossain et al 2012; Alam et al 2013; Hamid et al 2015; Jafari et al 2016; Ahamed et al 2017; Ahmed et al 2017; Azevedo et al 2017; Shalloof & El-Far 2017; Olopade et al 2018; Mitu et al 2019; Hanif et al 2020). The value of *b* can vary not only between species, but also between stocks of the same species (Amin et al 2005). Kharat et al (2008) and Asadi et al (2017) both report variations in *b* depending on the number and size range of fish observed, while Patimar et al (2009) consider that variations in *b* can occur in response to changes in habitat. Harrison (2001), Acosta et al (2004), and Hamid et al (2015) consider that life-stage can affect the length-weight relationship. None of these factors appear to have had a significant influence on the results of this study.

Condition factor. Knowing the length-weight relationship for a fish species or population enables the condition factor to be estimated. The condition factor can be used to evaluate and compare the plumpness of an individual fish or group of fishes with the average value for the population or species. The condition factor can be influenced by both biotic and abiotic environmental factors so that it can be used as an index representative of the status of the aquatic ecosystem in which the fish are living. The condition factor can also be useful in monitoring fishing intensity, ontogenetic population structure, and growth rates (Ahmed et al 2011).

Overall, in both the Bantimurung River and the Pattunuang River in the first study, females tended to have a slightly higher condition factor than males. Furthermore, for both males and females, the condition factor of fish from the Bantimurung River tended to be higher than that of fish from the Pattunuang River. The analysis of variance (ANOVA) and Student's t-test showed that in the Bantimurung River, the difference between the condition factor of male and female *M. ladigesi* was not significant ($p>0.05$). Conversely, in the Pattunuang River, there was a significant difference between the condition factor of male and female *M. ladigesi* ($p<0.05$). There was no significant difference in condition factor ($p>0.05$) between males from Bantimurung River and males from Pattunuang River; between females from Bantimurung River and females from Pattunuang River, or between the combined (male + female) samples from the Bantimurung River and the Pattunuang River. The condition factor in the second study in Bantimurung River shows a value that is relatively greater than the value of the condition factor in the first study

Barnham & Baxter (1998) consider that fish with a condition factor (K) of 1.00 are generally in poor condition, with a long and thin body, while fish in good condition should have a condition factor around 1.40. Values of $K>1$ can be considered indicative of environmental conditions favorable for fish growth, while values of $K<1$ indicate poor environmental conditions (Ahmed et al 2017; Singh & Serajuddin 2017). Based on these criteria, the higher mean condition factor of *M. ladigesi* from Bantimurung River indicates that conditions may be more favorable than in the Pattunuang River.

As for the length-weight relationship, there are no previous studies on the condition factor of *M. ladigesi* from the Maros karst region. Table 4 provides information on the condition factor of some other fishes endemic to Sulawesi. Based on the data in Tables 2 and 4, the condition factor values for *M. ladigesi* in this study are similar to those found for other Sulawesi endemic fishes. Similar to the results of this study, Manangkalangi (2009) also found that in the rainbowfish *Melanotaenia arfakensis* the condition factor of females tends to be higher than that of males.

Table 4

Condition factor values reported for some fishes endemic to Sulawesi

Species	*Sexes*	*Sample size*	*Range*	*Source*
Telmatherina antoniae	Male	556	0.85-1.19	Sumassetiyadi (2003)
	Female	228	0.90-1.20	
Telmatherina celebensis	Male	812	0.93-1.21	Nasution (2007)
	Female	713	1.09-1.26	
Paratherina striata	Male	168	0.41-2.50	Wardani (2007)
	Female	235	0.48-2.08	
Telmatherina antoniae	Male	1437	0.944-1.117	Tantu (2012)
	Female	1270	0.0820-1.481	
Adrianichthys oophorus	Male	169	0.76-2.47	Gundo et al (2014)
	Female	566	1.04-2.12	
Lagusia micracanthus	Male	307	1.2710-4.0294	Nur (2015)
	Female	292	1.1264-3.5095	
Oryzias matanensis	Male	156	0.61-1.58	Rinandha et al (2020)
	Female	200	0.62-1.83	

As Baby et al (2011) pointed out, spatial and temporal variations in the condition factor of both male and female fishes can be linked to biotic and abiotic environmental conditions. Furthermore, the sex and abundance of organisms present in a given aquatic environment can affect the condition factor (Zargar et al 2012; Awasthi et al 2015; Ahmed et al 2017). The condition factor is also related to the availability of food and gonad weight (Le Cren 1951; Asadi et al 2017). According to Hossain et al (2013), the condition factor tends to remain fairly constant during the pre-spawning period, falls during spawning, and is lowest for a period just after spawning. Other factors which can result in fluctuations of fish condition factor include the size class or life-stage of the fish (Encina & Granado-Lorencio 1997; Asadi et al 2017), stress (Neff & Cargnelli 2004; Ahmed et al 2017), and other water quality parameters (Khallaf et al 2003; Olopade et al 2018). None of these factors were apparent during this study.

Conclusions. In the first study, an isometric growth pattern was observed in both male and female *M. ladigesi* individuals from the Bantimurung River and the Pattunuang River, indicating weight gain is proportional to the increase in length. In contrast, a hypoallometric growth type was found in *M. ladigesi* in Bantimurung River in the second study. Hypoallometric or allometric negative growth pattern ($b<3$) means that length increase proportionately faster than weight. On average, the condition factor of the second study tended to be higher than that of the first study in the Bantimurung River. The mean condition factor of *M. ladigesi* from Bantimurung River was higher than that of fish from the Pattunuang River.

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