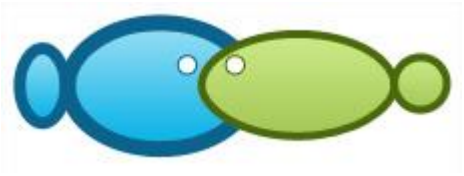

Size distribution, growth pattern and condition factor of common ponyfish, *Leiognathus equula*, in Takalar waters, South Sulawesi, Indonesia

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Abstract. The common ponyfish is a demersal fish that inhabits coastal waters, river estuaries, and fresh waters. It also lives in benthopelagic environments, where it resides in bottom waters until it reaches the surface. While this species is mostly found in the sea, some can be found in brackish water. Currently, there is a lack of information on the biological and reproductive aspects of this species in South Sulawesi waters. The objective of this study was to evaluate the size distribution, length-weight relationships, and condition factors of *Leiognathus equula* caught in the Takalar waters. Fish sampling was conducted from April to August 2023, resulting in 750 samples, 488 of which were females and 262 males. The research findings indicate that female fish have a greater mean total length and body weight than male fish. The growth pattern of common ponyfish females, males, and combined females and males exhibited negative allometric or hypoallometric, meaning that the increase in length was faster than the growth of body weight. The mean condition factor values for female fish, male fish, and combined female and male fish were 1.0047, 1.0037, and 1.0044, respectively.
Key Words: Leignathidae, length-weight relationships, hypoallometric, isometric, population.

Introduction. Fish in the Leiognathidae family, known as ponyfish, have very similar body morphology, making it difficult to distinguish between species. The number of new species and genera being described is increasing. According to Nelson et al (2016), Leiognathidae comprises nine genera, namely *Aurigequula, Equulites, Eubleekeria, Gazza, Karalla, Leiognathus, Nuchequula, Photolateralis,* and *Secutor*, and 48 species. The number of genera has increased due to the addition of *Photopectoralis*, and *Secutor* has been renamed *Deveximentum*. This brings the total number of genera to 10, with a total of 51 species (Froese & Pauly 2023). In Indonesian waters, there are 22 species of Leiognathidae, 16 of which can be found in Sulawesi waters (Woodland et al 2001). One of the common species found in Takalar waters, South Sulawesi, is the common ponyfish (*Leiognathus equula*). Fish species commonly caught in Takalar waters include Indian mackerel (*Rastrelliger kanagurta*), Indian scad (*Decapterus russelli*) and ponyfish (*Leiognathus* sp).

Ponyfish has a significant socio-economic importance for the community, due to their high economic value. This fish is widely utilized by Indonesians in processed form, as boiled fish and salted fish, so fishermen tend to exploit these fish species in large quantities. Ecologically, ponyfish is a plankton-eating fish that greatly affects the food chain in the ecosystem and it is also a prey for carnivorous fish, so it can be expected to affect the presence of carnivorous fish (Lisnawati 2004). If the population or condition of ponyfish decreases, it can indirectly cause the prey fish population to decrease and this will affect the aquatic ecosystem. Body length variability is a common measurement in fisheries science and population dynamics (Aura et al 2013). However, for fisheries management or conservation purposes, information on body weight is necessary for catch regulation and biomass estimation (Froese et al 2014; Shalloof & El-Far 2017). Fish

weight (W) can be predicted from body length (L) using the length-weight equation $W = aL^b$, where a and b are constants.

Length-weight relationships are commonly used in fisheries research to assess the growth patterns of fish stocks, to estimate condition factors and biomass, and to provide important data for the sustainable management of fish populations (Froese et al 2011; Silva et al 2020). The condition factor or ponderal index is a widely used parameter in fisheries biology. It is calculated based on the relationship between the length and weight of the fish to describe its 'condition' or level of fatness and well-being using numerical values (Hossain et al 2006). Information on the biological aspects of ponyfish, such as length-weight relationships and condition factors, is lacking in the Makassar Strait. Therefore, this study aimed to: 1) determine the length-weight relationships to predict fish growth patterns and 2) assess the habitat suitability for ponyfish growth, especially *L. equula*, by determining the condition factors.

Material and Method

Description of the study sites. The study was conducted over a period of five months, from April to August 2023. Fish samples were collected from the catch of fishermen who were fishing in Takalar waters, located about 2-3 miles from the coast of South Sulawesi. The locations where fish were sampled can be seen in Figure 1.

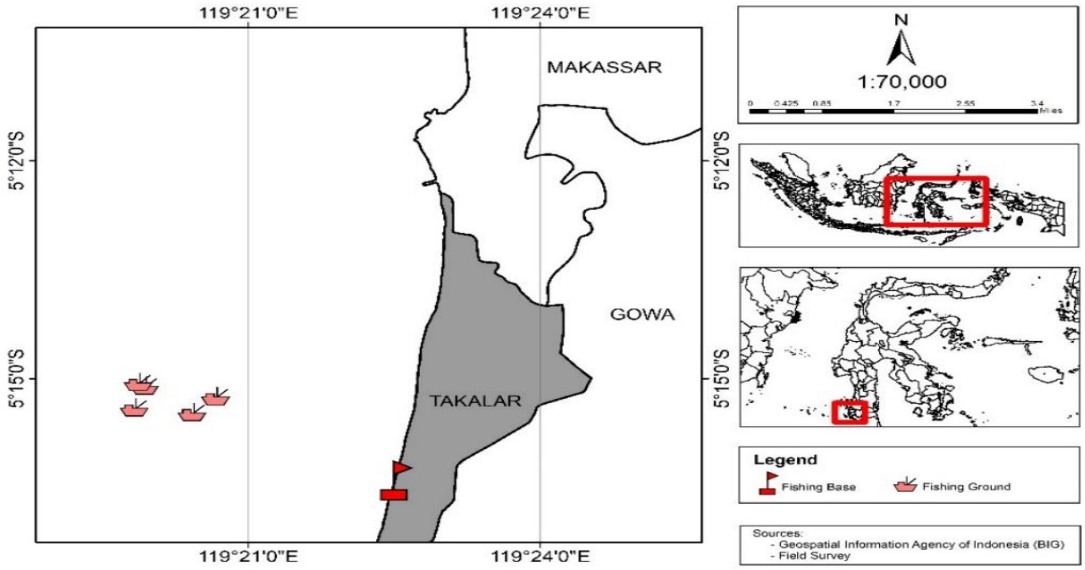

Figure 1. The location of *Leiognathus equula* at Takalar waters, South Sulawesi, Indonesia.

Sampling and sample handling. Ponyfish sampling was conducted monthly for five months. Each month, 150 fish samples were collected using net gear with a mesh size of 0.5 inches. Total body length was measured from the tip of the mouth to the tip of the tail using a digital caliper with an accuracy of 1 mm. Additionally, the fish samples were weighed for total body weight using an electric scale with an accuracy of 0.01 g. The fish sample's stomach was dissected, and its gonads were observed morphologically to determine its sex.

Data analysis. Length-weight relationships were analyzed by species, sex, and sampling period. The relationship between length and weight can be expressed by the formula $W = aL^b$, and then logarithmically converted into a straight line: $\log W = \log a + b \log L$ (where W = body weight in grams and L = total length in mm). The intercept (a) and regression coefficient (b) were calculated using the least mean squares method (Omar et al 2020). To determine if the value of b is equal to 3, a t-test was conducted at the 95% confidence level on the value of b obtained from the equation above (Zar 2014). The growth pattern of the fish can be determined based on the obtained regression coefficient

(b). There are three possible growth patterns that can be obtained: hypoallometric or negative allometric (b<3) which means the increase in body length is faster than the increase in body weight, isometric (b=3) which means the increase in body length is as fast as the increase in body weight, and hyperallometric or positive allometric (b>3) which means body length gain is slower than body weight gain (Omar et al 2020). To determine if there is a difference in the value of b between male and female fish, a t-test was conducted with a 95% confidence level (Fowler et al 1998). The condition factor or ponderal index of *L. equula* was analysed based on sex and sampling period, similar to the length-weight relationship. If the fish exhibits isometric growth, the Fulton condition factor formula ($K=10^5$ W/L^3) is used. Here, W represents the mean body weight of the fish in a given size class in grams, and L represents the mean total length of the fish in the same size class in mm. If the fish exhibits allometric growth (hypoallometric or hyperallometric), the relative condition factor formula can be used: Kn=W/W*, where W is the observed mass of an individual in grams, and W* is the theoretical weight of an individual of a given length. The theoretical weight is obtained from the linear regression of the length-weight relationship of the population sample (aL^b) in grams (Omar et al 2020). Lloret-Lloret et al (2022) stated that a Kn value greater than 1 indicates good individual fish condition, while a Kn value less than 1 indicates poor fish condition.

Results

Sample number and fish size. The number of common ponyfish studied during the study was 900 fish consisting of 570 female fish and 330 male fish. Table 1 shows the range and average total body length and weight of male and female fish at each sampling time. The body length and weight range of female fish was 77-115 mm (with the mean±se of 97.29±0.29 mm) and 13.00-31.43 g (with the mean±se of 19.00±0.14 g), respectively. The body length and weight range of male fish was 80-114 mm (with the mean±se of 94.70±0.36 mm) and 11.68-26.92 g (with the mean±se of 17.91±0.18 g), respectively (Table 1). Figure 2 shows the body length and weight distribution of male and female *Leiognathus equlaa.* The highest frequency of female and male *L. equula* was observed in the total length class interval of 95-99 mm and in the body weight class interval of 16.1-19.0 g.

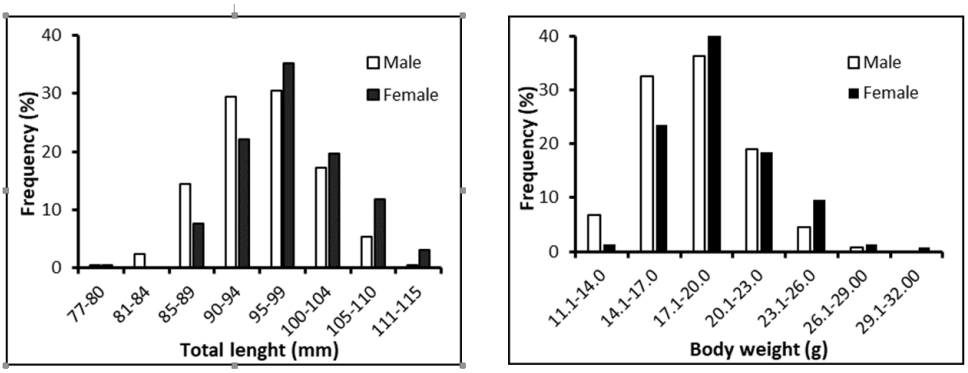

Figure 2. Frequency distribution of total length (mm) and body weight (g) of *Leiognathus equula* at Takalar waters, South Sulawesi, Indonesia.

Length-weight relationship. The relationship of total length (L) to body weight (W) of female and male *L. equula* had the equations $W=0.0045\ L^{1.8206}$ and $W=0.0008\ L^{2.1934}$, respectively (Table 1). The t-test analysis of b value indicates that both female and male fish exhibit hypoallometric growth type. Statistical analysis revealed no significant difference ($p>0.05$) between the regression coefficients of female and male fish. Therefore, it can be concluded that female and male *L. equula* are similar in terms of total length gain and body weight.

Table 1

Distribution of total length (mm), body weight (g), and length-weight relationship regression parameters of *Leiognathus equula* by sex and sampling period at Takalar waters, South Sulawesi, Indonesia

Sex	*Month*	*n*	*Total length (mm)*		*Body weight (g)*		*Length-weight regression parameters*			*Growth type*
			Range	*Mean±se*	*Range*	*Mean±se*	*a*	*b*	*R²*	
Female	April	125	85-115	96.85±0.53	14.36-24.90	18.04±0.17	0.1100	1.1144	0.3895	Hypoallometric
	May	116	86-106	95.66±0.38	14.10-21.81	17.54±0.16	0.0162	1.5318	0.4662	Hypoallometric
	June	106	85-115	100.82±0.66	14.09-31.43	21.11±0.31	0.0047	1.8204	0.6188	Hypoallometric
	July	105	77-112	97.70±0.68	13.00–28.32	20.17±0.31	0.0040	1.8612	0.7141	Hypoallometric
	August	36	85-104	92.50±0.82	13.16-24.03	13.16±0.49	0.0008	2.7072	0.7582	Hypoallometric
	Total	488	77-115	97.29±0.29	13.00-31.43	19.00±0.14	0.0045	1.8206	0.5955	Hypoallometric
Male	April	25	89-105	94.92±0.83	14.38-22.37	17.61±0.39	0.0039	1.8461	0.5152	Hypoallometric
	May	34	89-102	95.74±0.66	14.26-21.00	17.77±0.31	0.0096	1.6489	0.4120	Hypoallometric
	June	44	90-114	98.86±0.90	12.95–25.63	19.42±0.44	0.0017	2.0371	0.6513	Hypoallometric
	July	45	83-110	95.31±0.90	12.05–26.92	18.14±0.50	0.0006	2.2597	0.5775	Hypoallometric
	August	114	80-105	92.50±0.81	11.68-26.91	17.34±1.15	0.0002	2.5408	0.8537	Hypoallometric
	Total	262	80-114	94.70±0.36	11.68-26.92	17.91±0.18	0.0008	2.1934	0.7087	Hypoallometric

The data of female and male fish were combined, resulting in the regression equation $W=0.0024\ L^{1.9548}$ ($R^2=0.6442$). This equation also indicated a hypoallometric growth type, after the statistical analysis. Figure 3 shows a graph depicting the relationship between total length and body weight of female, male, and combined *L. equula*.

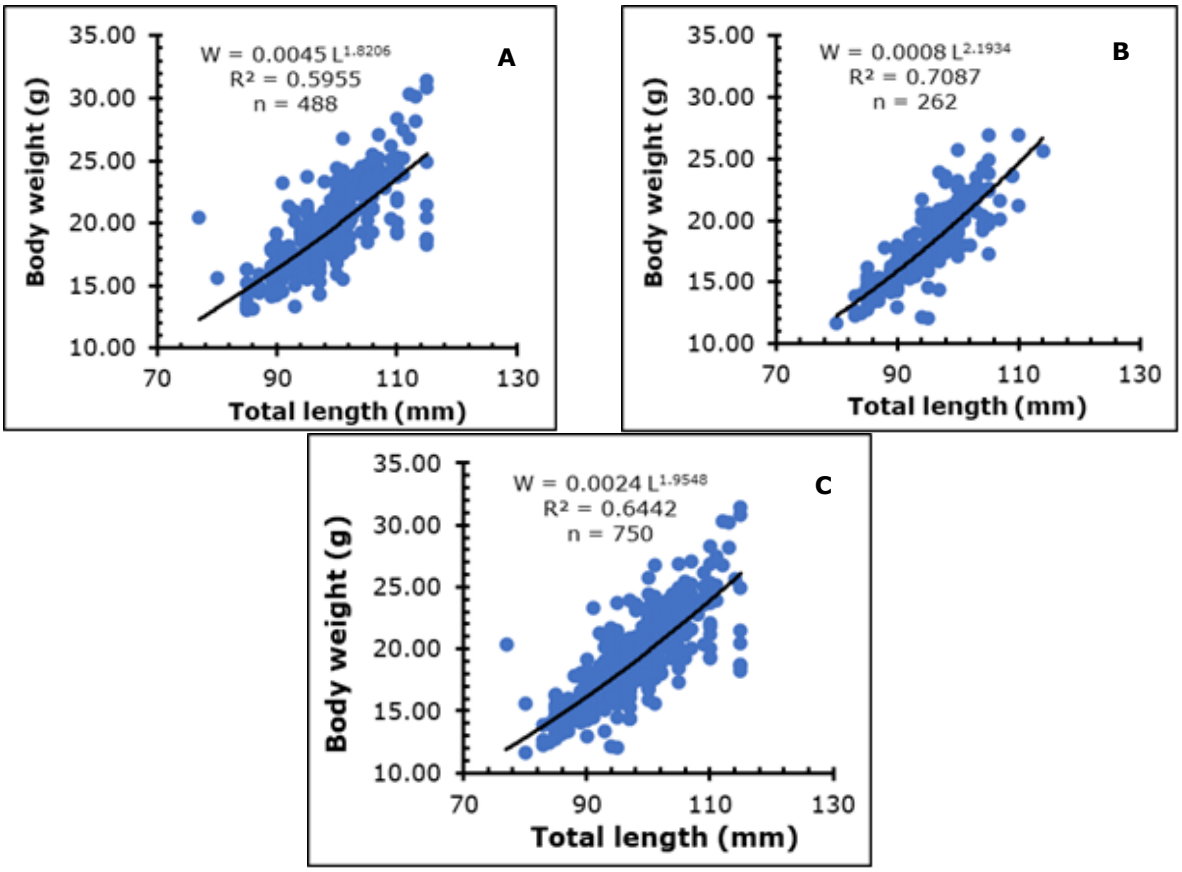

Figure 3. Total length-body weight curves and equations of *Leiognathus equula* at Takalar waters. A. female fish; B. male fish; C. combined female and male fish.

Condition factor. The range and average condition factor values of *L. equula* caught in Takalar waters, based on the sampling time, for both females and males, are listed in Table 2. Overall, the combined condition factor values of female and male fish ranged from 0.6715-1.7157, with a mean of 1.0044±0.0035.

Table 2

Distribution of range and mean condition factor of *Leiognathus equula* by sex and sampling period at Takalar waters, South Sulawesi, Indonesia

Sex	*Month*	*n*	*Range*	*Mean±se*
Female	April	125	0.7976-1.2569	1.0034±0.0074
	May	116	0.8040-1.1574	1.0025±0.0066
	June	106	0.7910-1.3391	1.0046±0.0094
	July	105	0.8310-1.5891	1.0038±0.0090
	August	36	0.7827-1.2867	1.0287±0.0134
	Total	488	0.7137-1.6586	1.0047±0.0045
Male	April	25	0.8275-1.1321	1.0029±0.0154
	May	34	0.7938-1.1522	1.0030±0.0135
	June	44	0.8136-1.2907	1.0040±0.0139
	July	45	0.6777-1.2897	1.0071±0.0174
	August	114	0.8316-1.1707	1.0020±0.0815
	Total	262	0.6742-1.2874	1.0037±0.0053

Discussion

Fish size. The study recorded the total length distribution and body weights of female and male *L. equula*. Female fish had a total length ranging from 77-123 mm and body weights of 13.00-33.63 g, while male fish had a total length ranging from 80-119 mm and body weights of 11.68-28.78 g (Table 1). As shown in Figure 1, female fish were larger in both length and body weight than male fish. It is worth noting that Pratiwi (2011) found the opposite to be true in the same species in Jakarta Bay, where male fish were larger than female fish. The body length of *L. equula* caught in Takalar waters is shorter compared to those caught in other Indonesian waters. Novitriana (2004) reported that female *L. equula* in Mayangan, Subang, West Java, ranged from 50-208 mm and males ranged from 45-195 mm. Similarly, Ramadhani (2016) found female fish in the waters of Sunda Strait, West Java, with a total length ranging from 78-237 mm and males ranging from 84-191 mm. In Palabuhanratu, Sitindaon (2023) found that the total length of female *L. equula* ranged from 74 to 190 mm and male fish ranged from 70 to 191 mm. Woodland et al (2001) reported that the maximum length of this species is 240 mm, with most caught fish measuring 180 mm. Based on this data, it appears that *L. equula* caught in Takalar waters have a smaller body size than the same species caught in other waters. The body length of *L. equula* caught in Takalar waters is not only smaller, but their body weight is also inferior. Simanjuntak (2010) reported that fish caught in Subang had body weights ranging from 16 to 169 g, while those caught in Labuan weighed between 26 and 97 g, and those caught in Palabuhanratu weighed between 32 and 145 g. Female *L. equula* caught in Sunda Strait weighed between 11 and 188 g, while males weighed between 11 and 113 g (Shidqi 2016). Permatasari et al (2022) obtained fish with a body weight range of 6.0-75.1 g in the waters of Kendal, Central Java. Differences in body size among ponyfish are believed to be due to variations in the geographical location of the fishing area and the fishing gear utilized, particularly the mesh size of the net. In Takalar waters, ponyfish fishing is conducted relatively close to the coast using fishing gear with a mesh size of 0.5 inches. Furthermore, the high exploitation rate of fishing in Takalar waters results in the capture of smaller fish.

Length-weight relationship. In fisheries management, it is necessary to have information on the length and weight of an organism (Omar 2013). The analysis of the length-weight relationship of female and male *L. equula*, based on both the sampling time and overall data, revealed a negative allometric or hypoallometric growth type ($b<3$), indicating that length growth is faster than weight gain. Similarly, the combined female and male fish exhibited a hypoallometric growth type. Similar findings were obtained in *L. equula* caught in Palabuhanratu, Jakarta Bay, and in Sunda Strait. Several other researchers have reported that the common ponyfish exhibits a positive allometric or hyperallometric growth type ($b>3$), with slower length growth compared to weight gain. For example, Novitriana (2004) reported this in Subang, and Aditriawan & Runtuboy (2017) reported it in Pabean Bay. Generally, ponyfish from various waters in Indonesia exhibit hypoallometric growth patterns, as shown in Table 3. During the study in Takalar waters, the regression coefficient values of female and male fish ranged from 1.1144 to 2.7072 and 1.6489 to 2.5408, respectively. The observed male *L. equula* obtained had higher regression coefficient values than the female fish, indicating that male fish have a better growth than female fish. According to Karna et al (2020), the regression coefficient value should be in the range of 2.5 to 3.5.

The regression coefficient values for fish can vary depending on internal and external factors, both spatially and temporally. Table 3 displays differences in regression coefficient values among species and populations of the same ponyfish species.

Table 3

Length-weight relationship coefficients for some Leiognathidae species from several regions in Indonesia

Species	*Region*	*Sex*	*n*	*a*	*b*	*R²*	*Growth pattern*	*References*
Eubleekeria splendens	Labuan, Banten	F	208	0.00003	2.902	0.9604	Isometric	Sjafei & Saadah (2001)
		M	539	0.00002	2.981	0.9409	Isometric	
	Sunda Strait, Banten	F	230	0.00003	2.9852	0.6246	Isometric	Fadillah (2015)
		M	316	0.00002	3.0162	0.577	Isometric	
	Banten	F	121	0.014	3.081	0.81	Hypoallometric	Prihatiningsih et al (2014)
		M	62	0.022	2.879	0.81	Hypoallometric	
	Jakarta Bay	C	405	0.212	2.76	0.97	Hypoallometric	Triharyuni et al (2017)
	Sunda Strait, Banten	F	184	0.0002	2.4825	0.9134	Hypoallometric	Ramadhan (2019)
		M	285	0.0041	1.909	0.8047	Hypoallometric	
		C	469	0.0015	2.1038	0.8476	Hypoallometric	
	Sunda Strait, Banten	F	184	0.0001	2.65	0.7392	Hypoallometric	Septyowati (2019)
		M	284	0.000065	2.7317	0.9122	Hypoallometric	
Gazza achlamys	Jakarta Bay	C	398	0.209	2.936	0.88	Hypoallometric	Triharyuni et al (2017)
Gazza minuta	Pabean Bay, West Java	C	190	0.1270	2.388	0.8743	Hypoallometric	Hasan (2021)
Leiognathus equula	Mayangan, West Java	F	362	0.000005	3.2404	0.9734	Hyperallometric	Novitriana (2004)
		M	528	0.000009	3.1174	0.9548	Hyperallometric	
	Palabuhanratu, West Java	C	850	0.0001	2.8321	0.9095	Hypoallometric	Hazrina (2010)
	Blanakan, West Java	C	264	0.00001	3.0888	0.98	Hypoallometric	Simanjuntak (2010)
	Labuan, Banten	C	108	0.00001	3.1171	0.98	Hypoallometric	
	Palabuhanratu, West Java	C	280	0.00006	2.7433	0.88	Hypoallometric	
	Jakarta Bay	F	131	0.00007	2.694	0.907	Hypoallometric	Pratiwi (2011)
		M	243	0.00003	2.882	0.936	Hypoallometric	
		C	411	0.00004	2.836	0.917	Hypoallometric	
	Banten	F	1021	0.0021	2.0628	0.77	Hypoallometric	Permatachani et al (2016)
		M	874	0.0008	2.2405	0.79	Hypoallometric	
	Sunda Strait, Banten	F	434	0.00007	2.7021	0.96	Hypoallometric	Ramadhani (2016)
		M	501	0.0787	2.6837	0.96	Hypoallometric	
	Sunda Strait, Banten	F	437	0.1036	2.6304	0.9203	Hypoallometric	Shidqi (2016)
		M	502	0.0842	2.6695	0.9627	Hypoallometric	
	Pabean Bay, West Java	C	154	0.000007	3.1983	0.9469	Hyperallometric	Aditriawan & Runtuboy

Species	*Region*	*Sex*	*n*	*a*	*b*	*R²*	*Growth pattern*	*References*
								(2017)
	Jakarta Bay	C	2332	0.237	2.848	0.88	Hypoallometric	Triharyuni et al (2017)
	Semarang Bay, Central Java	C		0.00002	3.05	0.7786	Isometric	Solichin et al (2021)
	Palabuhanratu, West Java	F	210	0.0007	2.2673		Hypoallometric	Haerunnisa (2023)
		M	109	0.0002	2.523		Hypoallometric	
		C	319	0.0003	2.4486		Hypoallometric	
	Palabuhanratu, West Java	F	218	0.0001	2.5947	0.8561	Hypoallometric	Sitindaon 2023
		M	241	0.00003	2.909	0.9132	Hypoallometric	
Leiognathus fasciatus	Jakarta Bay	C	306	0.184	3.081	0.99	Hyperallometric	Triharyuni et al (2017)
Leiognathus ruconius	Jakarta Bay	C	55	0.265	2.571	0.99	Hypoallometric	Triharyuni et al (2017)
Nuchequula gerreoides	Jakarta Bay	C	117	0.157	3.222	0.99	Hyperallometric	Triharyuni et al (2017)

F = female, M = male, C = combined sexes (male and female).

The growth patterns of female and male fish in Takalar waters differ due to sex-related differences. The coefficient value is influenced not only by sex, but also by factors such as gonad development, spawning season, food availability, the number and size range of fish studied, habitat changes, life-stage, and preservation techniques (Hamid et al 2015; Jafari et al 2016; Ahmed et al 2017; Asadi et al 2017; Azevedo et al 2017; Shalloof & El-Far 2017; Nazir & Khan 2017; Blasinaa et al 2018; Olopade et al 2018; Mitu et al 2019; Hanif et al 2020; Omar et al 2020). Nazir & Khan (2017) advised against using young or old fish samples in length-weight regression calculations. Some of the factors mentioned above were not observed during sampling in Takalar waters. During the study, the coefficient of determination (R^2) values obtained in female fish ranged from 0.3895 to 0.7582, which were lower than those in male fish ranging from 0.4120 to 0.8537. These values are relatively lower than the results of other studies on *L. equula* in Indonesian waters, except those caught in Banten waters (Permatachani et al 2016) and in Semarang Bay (Solichin et al 2021) (Table 3). A high coefficient of determination indicates good predictive power and small data dispersion. According to Hanif et al (2020), ideal fish growth has an R^2 coefficient value ranging between 0.9 and 1.0.

Condition factor. The condition factor is a quantitative index that indicates the health of fish. It is a morphometric index that evaluates the physiological status of a specimen based on the principle that individuals with a certain length and greater weight are in better condition than others (Froese 2006; Awasthi et al 2015; Falaye et al 2015; Azevedo et al 2017). The condition factor indicates the physical condition of the fish in terms of reproduction and survival (Aditriawan & Runtuboy 2017). The calculation of the condition factor value in this paper is based on the previously obtained length-weight relationship. Table 2 shows that the average condition factor at each sampling time is greater than 1. This suggests that *L. equula* living in Takalar waters are in good condition. According to Lloret-Lloret et al (2022), a Kn value greater than 1 indicates good condition for individual fish, while a Kn value less than 1 indicates poor condition. According to Awasthi et al (2015) and Falaye et al (2015), a fish with a condition factor greater than 1 is considered to be in better condition than a fish with a condition factor less than 1 in the same waters. However, Parawansa et al (2020) note that there may be considerable variation in condition factor values among members of the same population due to differences in body length, even when sampled at the same time. Table 4 displays the condition factor values of other ponyfish from Indonesian waters.

Table 4

Condition factor of some Leiognathidae species from several regions in Indonesia

Species	*Region*	*Sex*	*Condition factor*	*References*
Eubleekeria splendens	Labuan, Banten	F	0.589-2.285	Saadah (2000)
		M	0.447-2.752	
	Banten	F	1.214-2.043	Prihatiningsih et al (2014)
		M	1.483-1.937	
	Sunda Strait	F	1.33-1.81	Ramadhan (2019)
		M	0.98-1.81	
Leiognathus equula	Mayangan, West Java	F	0.5976-1.5670	Novitriana (2004)
		M	0.6214-2.5041	
	Blanakan, West Java	F	0.84-1.36	Simanjuntak (2010)
		M	0.78-1.13	
	Labuan, Banten	F	0.90-1.13	
		M	0.83-1.43	
	Palabuhanratu, West Java	F	0.77-1.21	
		M	0.90-1.21	
	Jakarta Bay	F	0.8710-1.0232	Pratiwi (2011)
		M	0.8279-1.0124	
	Pabean Bay, West Java	C	0.67-1.42	Aditriawan & Runtuboy (2017)

F = female, M = male, C = combined sexes (male and female).

The results indicate that the condition factor value of *L. equula* caught in Takalar waters is similar to those found in other studies. The condition factor of fish is influenced by various factors, such as sex, season, environmental conditions, stress, gonad development, food availability, feeding activity, age, and water quality parameters (Zargar et al 2012; Awasthi et al 2015; Falaye et al 2015; Olopade et al 2018; Situmorang et al 2021). Sarkar et al (2013) reported that seasonal differences throughout the year can also affect the value of the condition factor.

Conclusions. Female *L. equula* had greater mean total length and body weight than males. Both female and male fish have hypoallometric or negative allometric growth patterns (b<3), indicating that the total length growth is faster than body weight growth. The mean condition factor value of female fish is greater when compared to male fish.

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Conflict of interest. The authors declare no conflict of interest.

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