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Growth, Relationship of Length-Weight, and Condition Factor of Striped Eel Catfish (*Plotosus lineatus*) at the Grow-Out Stage in the Floating Net Cages

Asriyana Asriyana[1]*, Halili Halili[1], Abdul Muis Balubi[2] and Asnawati Asrari[3]

[1]Department of Aquatic Resources Management, Faculty of Fisheries and Marine Science, Halu Oleo University, Southeast Sulawesi, Indonesia
[2]Department of Aquaculture, Faculty of Fisheries and Marine Sciences, Halu Oleo University, Southeast Sulawesi, Indonesia
[3]Research Institute for Brackishwater Aquaculture and Fisheries Extension Maros South Sulawesi, Indonesia

***Corresponding Author**: asriyana@uho.ac.id

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ABSTRACT

Growth patern, relationships of length-weight, and condition factors are crucial information in fisheries management, aiding in biomass determination by converting length to weight and comparing species growth across seasons and locations. The purpose of this study was to examine growth, determine the relationship of length-weight, and assess condition factors for the striped eel catfish reared in floating net cage environments. The study spanned four months, from July to November 2023. A total of 450 juvenile stage fish were stocked in floating net cages, with stocking densities of 50 and 100ind./ 2m^3, raised in three separate rearing containers. At the end of the experiment, the fish exhibited total lengths and weights ranging from 94.00- 180.00mm and 5.40- 19.20g (50 individuals/2m^3), and 90.00- 170.00mm and 5.30- 31.70g (100 individuals/2m^3). Across all rearing conditions, the examination of the length-weight relationship revealed a negative allometric development tendency for the striped eel catfish. The equation model for the relationship of total length (TL) and weight (W) in the 50ind./ 2m^3 medium is W= 0.10 TL$^{1.86}$ (r=0.84; R^2=0.71), while in the 100ind./ 2m^3 medium, it is W= 0.01 TL$^{2.68}$ (r=0.94; R^2=0.89). Condition factors for the striped eel catfish raised at a density of 50ind./ 2m^3 indicate better conditions than those raised at a density of 100ind./ 2m^3. The study suggests that the striped eel catfish kept in a controlled environment at low density show superior conditions.

INTRODUCTION

The Plotosidae, commonly known as the eel-tail catfish, constitutes a fish family with ten genera encompassing 42 species **(Fricke *et al.*, 2025)**. These fish are found in diverse aquatic habitats, such as rivers, lakes, and coral reefs **(Froese & Pauly, 2024)**. One notable member of the Plotosidae family is *Plotosus lineatus*, known as 'Sembilang Karang' fish or sea catfish in Indonesia. This species shares characteristics with freshwater catfish but is distinguished by its eel-like tail and possesses three venomous spikes on its pelvic and dorsal fins **(Bentur *et al.*, 2017; Turan *et al.*, 2020)**. *P. lineatus* is unique as the only catfish found in coral reef waters and has a wide distribution from the Indo-Pacific, spanning the Red Sea and East Africa to Samoa. Its distribution spans from North to South Japan, South Korea, and the Ogasawara Islands, extending further south to Australia, Lord Howe Island, Palau, and Yap in Micronesia. Notably, it sometimes ventures into freshwater habitats in East Africa (Lake Malawi) and Madagascar. The species is also found in the Mediterranean region **(Asriyana *et al.*, 2020a; Froese & Pauly, 2024)**.

In the food chain, the striped eel catfish functions as an omnivorous organism, consuming benthic animals, algae, and detritus **(Clark *et al.*, 2011)**; fish, crustaceans, mollusks, brachiopods, and simultaneously, the striped eel catfish consume their own juveniles **(Ueng *et al.*, 2022)**. During its adult stage, it preys on a range of organisms, including crustaceans, mollusks, worms, and, on occasion, fish **(Golani *et al.*, 2021)**. In terms of food composition, the striped eel catfish is positioned at trophic level 3.57 **(Horinouchi & Sano, 2000)**.

The striped eel catfish holds potential for cultivation in a controlled environment, as highlighted in studies by **Asriyana *et al.* (2021, 2022, 2023)**. Renowned for its delectable taste and substantial nutritional content—rich in amino acids (MUFA and PUFA), carbohydrates, protein, and fat—this species plays a substantial role in the development of pharmaceutical products, dietary supplements, and antioxidant agents **(Suganthi *et al.*, 2015)**. Increasing the utilization of the striped eel catfish in aquaculture is crucial, as it presents an alternative protein source that can address local food needs.

Understanding growth, the relationship of length-weight, and condition factors are important factors in fisheries management studies and stock estimation **(Mimeche & Biche, 2015; Asriyana *et al.*, 2020a)**, while growth and survival rate factors is vital in the striped eel catfish domestication **(Asriyana *et al*., 2021)**. This information allows fisheries experts to convert length measurements to weight, evaluate the growth of species across different seasons and locations, and is valuable for analyzing fish biology. Additionally, the correlation between length and weight data can help identify fish growth patterns, whether isometric or allometric. Condition factor studies rely on body length analysis data and assume that fish heavier at a given length have better conditions **(Okomoda *et al.*, 2018; Asriyana *et al.*, 2020a)**.

Until now, there has been a lack of research on the aspects of growth, relationship of length and weight, and condition factors specifically for *P. lineatus* in a controlled environment. Existing research has been primarily focused on eel catfish in their natural habitats, as seen in studies by **Zare *et al.* (2013)**, **Ya *et al.* (2015)**, **Farooq *et al.* (2017)**, **Asriyana *et al.* (2020a)**, **Bayhan and Ergüden (2022)**, **Turan *et al.* (2022)**, **Ueng (2022),** and **Mehanna (2023)**. Consequently, this study represents an initial exploration into the growth dynamics, length and weight correlation, and condition factors of the *P. lineatus* under controlled conditions.

MATERIALS AND METHODS

1. Experimental design

The study was conducted at the Fisheries and Marine Sciences Faculty's experimental field site, the University of Halu Oleo in Indonesia, from July to November 2023. The four-month grow-out stage took place in the Floating Net Keramba, Tapulaga Village, Konawe Regency, which is an integral part of the field laboratory. The grow-out container within the floating net cage is a waring measuring $1x1x2m^3$, featuring a mesh size of 0.5cm.

The *P. lineatus* juveniles used in this investigation were gathered from the Southeast Sulawesi coast of Tanjung Tiram, Indonesia (Fig. 1). The fish were caught during low tide using a fishnet measuring 2.88 x 1.20cm in length and width, respectively. Fish net has a mesh size of approximately 0.5cm. After capture, all juveniles were transferred to a holding container for acclimatization before being introduced into the floating net cages.

After acclimatizing for a week, striped eel catfish were introduced into the grow-out containers. The juveniles used in the experiment were at the fry stage, with an average total length and weight of 74.40mm and 2.55g, respectively. The stocking density employed for the experiment was 50 and 100 individuals for each of the three grow-out containers, resulting in a total of 6 units (Fig. 2).

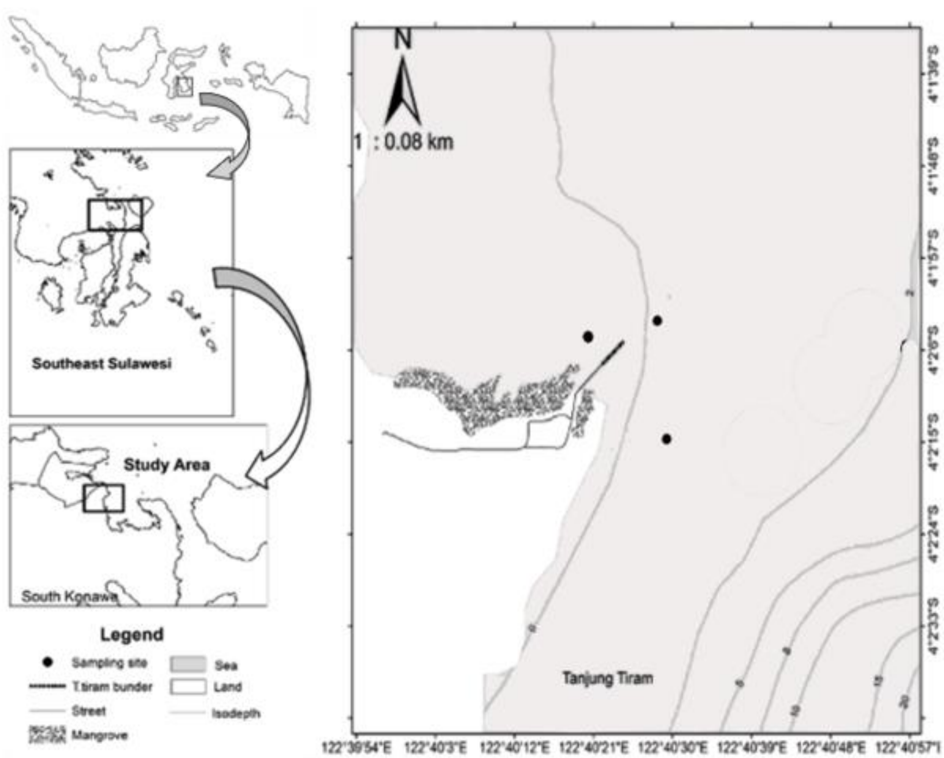

Fig. 1. A map showing the sample station and the Tanjung Tiram coast in Southeast Sulawesi, Indonesia **(**adapted from **Asriyana *et al.*, 2020b)**

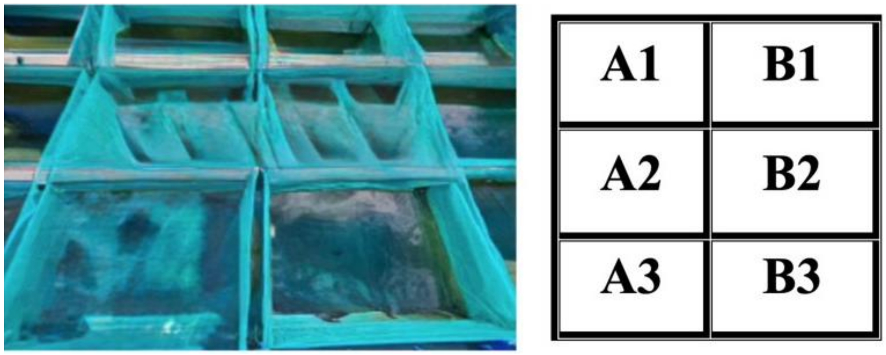

Fig. 2. The layout of the floating net cages used to raise striped eel catfish

During the period of raising, the juveniles were fed natural food consisting of *Litopenaeus vannamei* shrimp heads twice daily, in the morning and evening, at a rate of 5% of their total body weight **(Asriyana *et al.*, 2021)**. After the experiment was finished, measurements were taken of the fry's overall length and weight. Data collection involved randomly selecting fish from the population under cultivation. A digital scale with a precision of 0.01g was used to record the fry's weight, and a scale ruler was used to measure their overall length to 1mm. Gender-based separation of fish samples was not implemented, as distinguishing primary genital organs, namely genital papillae, is challenging during the fry stage, despite striped eel catfish being a dimorphic fish **(Asriyana & Halili, 2021)**.

2. Water quality

Temperature, pH, salinity, and dissolved oxygen were among the important water quality indicators that were tracked and recorded every two weeks in the rearing environment during the grow-out period. A Hg thermometer and a pH meter (Hanna model HI-98128) were used to measure the temperature and pH. A hand refractometer (Hanna model HI96822) was used to measure the salinity, and a DO meter (Lutron model DO-5510) was used to record the dissolved oxygen levels.

3. Calculations and statistical analysis

Le Cren's formula was used to determine the relationship of length-weight **(Asriyana *et al.*, 2020a)** : $W=aL^b$

Where, *W* is the weight of the fish in grams, L is the length of the fish in millimeters, and a and b are constants. A t-test was used to ascertain whether the value of b equals 3. The fish exhibits an allometric development pattern if $b \neq 3$, but an isometric growth pattern is suggested if $b = 3$.

The growth pattern obtained from the length-weight correlation was used to calculate the condition factor.

a. If the fish growth is isometric, then the formula used is: $K=(10^5 \times W)/L^3$
b. If growth is allometric, then the condition factor is determined by applying the formula: $K_n=W/(aL^b)$

Where, Kn is the relative ponderal index, K is the ponderal index, W is the weight of the fish in grams, L is the length of the fish in millimeters, and a and b are constants from the length-weight relationship. Using SPSS version 16.0, non-parametric statistics, especially the Kruskal-Wallis test, were performed with a significance threshold of 0.05 **(Sokal & Rohlf, 1995)** to ascertain whether there were variations in the water quality conditions in the rearing media.

RESULTS

1. Growth

P. lineatus can be successfully raised in a controlled environment. The acclimatization of seeds at the initial stocking stage has a positive impact, reducing stress and mitigating fish mortality post-stocking. In grow-out containers with varying stocking densities, eel catfish exhibit growth to an average length of 113.80±18.60mm and 113.20±14.90mm, with corresponding weights of 9.61±3.34g and 10.19±4.53g (Fig. 3).

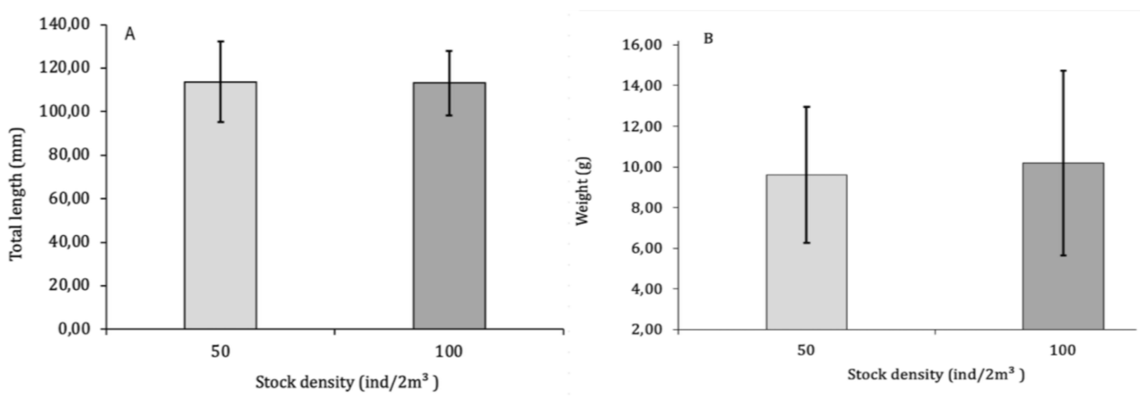

Fig. 3. Striped eel catfish reared in floating net cages showing: (A) Average total length, and (B) Total weight (B)

2. Length-weight relationship

P. lineatus's weight and length have a very strong correlation, as evidenced by the high values of the correlation coefficient (r) and coefficient of determination (R^2), both exceeding 80 and 70%, respectively, as presented in Table (1). The t-test results for testing the b value revealed a significant difference from the value 3, regardless of whether the fish were raised with a stocking density of 50 or 100ind/ 2m³. The growth pattern is identified as negative allometric ($b < 3$), signifying that the increase in length outpaces the increase in fish weight (Fig. 4). The detailed formula model for the relationship of total length (TL) and total weight (W) of the eel catfish in the two rearing media is provided in Table (1).

Table 1. Growth, relationship of length-weight, and condition factors of *P. lineatus* during the rearing period in floating net cages

Parameters		Unit	Stock density (ind/2 m^3)	
			50	100
Growth in length	Range	mm	94.00-180.00	90.00-170.00
	Mean	mm	113.80±18.60	113.20±14.90
Growth in weight	Range	g	5.40-19.20	5.30-31.70
	Mean	g	9.61±3.34	10.19±4.53
LWr	Formula		$W = 0.10\ TL^{1.86}$	$W = 0.01\ TL^{2.68}$
	Intercept (a)		0.10	0.01
	Determination coeff. (R^2)		0.71	0.89
	Correlation coeff. (r)		0.84	0.94
Condition factor	Range		0.78-1.54	0.67-1.25
	Mean		1.01±0.16	1.01±0.13

3. Condition factors

Throughout the rearing period, striped eel catfish exhibited diverse condition factor values, as detailed in Table (1). Fish stocked at lower densities demonstrated superior condition factors compared to those stocked at higher densities.

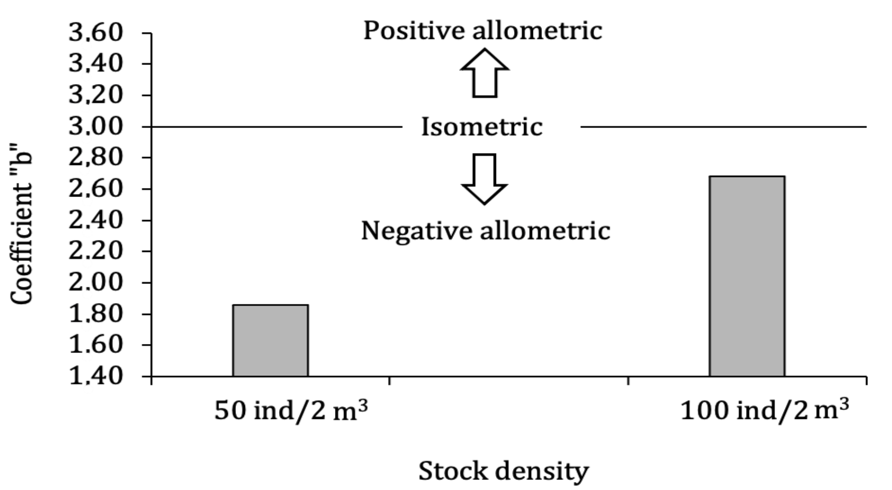

Fig. 4. The regression coefficient of length-weight relationship (b) of *P. lineatus* on rearing in floating net cages

4. Water quality

The water quality conditions of the rearing environment during the seed-rearing phase are summarized in Table (2). All measured parameters across the floating net cages were relatively homogeneus [$P > 0.05$ ($\alpha = 5\%$, db= n-1)].

Table 2. Water quality parameters in the grow-out media for striped eel catfish

Parameter	Unit	Stock density A (50 ind./2m^3)	Stock density B (100 ind./2m^3)
Temperature	(°C)	29.83±0.42	30.11±0.14
Salinity	(‰)	33.13±0.23	33.23±0.54
pH	-	7.95±0.16	7.93±0.11
Dissolved Oxygen	(mg/L)	5.99±0.59	5.63±0.37
[$p > 0.05$ ($\alpha = 5\%$, db = n-1)]			

DISCUSSION

The striped eel catfish, identified as a coral demersal fish, proves adaptable to a controlled environment **(Asriyana *et al.*, 2021)**. The outcomes of a four-month cultivation period yielded varying average final weights, as depicted in Fig. (2). Despite relatively consistent water quality conditions (Table 2), the striped eel catfish demonstrates effective adaptation to the rearing environment. The four water quality parameters measured showed little variation compared to the environmental conditions of the striped eel catfish in their wild habitat or rearing environments, as noted in earlier studies **(Kolbadinezhad *et al.*, 2018; Asriyana & Halili, 2021; Asriyana *et al.*, 2022; Asriyana *et al.*, 2023)**.

The average total length of the eel catfish population during the four months of rearing did not indicate that they had reached the adult stage. Various studies in the eel catfish's native environment indicate that this species attains adult size at varying lengths. In Indian and Korean waters, maturity of *P. lineatus* occurs when the length is 159mm and >150mm **(Vijayakumaran, 1997; Heo *et al.*, 2007)**, while in the waters of Kolono Bay, Indonesia, maturity of this type is relatively slower, measuring 198.3mm **(Asriyana & Halili, 2021)**. The slow growth of the eel catfish in Indonesian waters can be observed from the low growth coefficient value of only K=0.27 per year, whereas in Indian waters, it is relatively faster at K=1.37. The difference in size when reaching maturity is caused by differences in growth rate, aquatic environmental conditions that support fish growth, food availability, and the influence of fishing activities **(Hunter *et al.*, 2015; Goldberg *et al.*, 2019; Sande *et al.*, 2019; Asriyana & Halili, 2021; Goodrich & Clark, 2023)**. The mean overall length and mass of fish raised with stocking densities of 50 and 100ind/ 2m^3 were relatively uniform. This indicates that stocking density treatment did not affect the total length and weight of the eel catfish after four months of rearing.

In the present research, it was observed that eel catfish, whether raised with a density of 50 or 100ind/ 2m^3, exhibited the same growth pattern, namely negative allometric (b< 3). This indicates that the eel catfish's length development outgrew its weight growth. The relationship of length-weight also demonstrates a high correlation **(**r≥ 0.80**)**. The strong correlation between length and weight is presumed to result from favorable conditions in the rearing media, including food availability and water quality, which support the concurrent growth of eel catfish.

The negative allometric growth pattern suggests that the fish grew at different rates in various parts of the body, a phenomenon also reported for several other reef fish **(Asriyana *et al.*, 2020a)**. Additionally, the eel catfish in the rearing media remained in the juvenile stage, where most of the metabolic resources were allocated to somatic growth. During the juvenile stage, growth primarily focuses on body length and somatic weight. Body length growth tended to be faster than body weight growth in this phase. Fish in the juvenile stage undergo a significant increase in body length along with the growth of their organs and body tissues. While weight growth occurred during this phase, it did not progress as rapidly as body length growth. This prioritization of body length growth is essential to allow the fish to attain a larger size before entering the maturity stage.

Several previous studies have indicated that striped eel catfish do not consistently exhibit a negative allometric growth pattern (Table 3). The growth pattern is determined by the constant b value derived from the relationship of length-weight, where a higher b value suggests relatively productive water environmental conditions **(Olopade *et al*., 2018)**. The b value may fluctuate within a fish population, influenced by various factors as reported by previous researchers. These factors include the reproductive period **(Ouannes-Ghorbel & Bradai, 2002)**, sexual dimorphism **(Artigues *et al.*, 2003)**, parasite pressure **(Neff & Cargnelli, 2004)**, seasonal changes, and adequate food **(Gupta & Gupta, 2006; Olopade *et al.*, 2018)**, habitat, season, feeding rate, and fish health **(Zhu *et al.*, 2008)**, optimal temperature, as well as environmental parameters, food availability, ontogenetic development in fish, gonad development, and spawning period **(Asriyana *et al.*, 2020a; 2020b)**.

In contrast to fish in the adult stage, fluctuations in the b constant value in juvenile-stage fish are thought to be more influenced by food availability and environmental parameter conditions. Juvenile-stage fish are reported to be more susceptible to changes in environmental parameters and food availability compared to adult stages. Fish in the juvenile stage possess an immune system that is not fully developed, making them more susceptible to water quality fluctuations such as changes in pH, temperature, dissolved oxygen levels, and other water qualities. Poor water quality can impact the health and growth of young fish more rapidly than in adults with better tolerance **(Fatma & Ahmed, 2020; Jiang *et al.*, 2021; Abd El-Hack *et al.*, 2022; Dayrit *et al.*, 2023)**.

Juvenile fish require proper nutrition for optimal growth, often needing feed that is richer in nutrients and more frequent feeding than adults. Feeding disruptions can have a major impact on the growth and health of juvenile fish **(Zhixin *et al.*, 2018; Xiao *et al.*, 2022)**. The digestive systems of young fish are still developing, making them more susceptible to changes in feed or poor feed quality, which can cause digestive and nutrient absorption problems impacting their growth **(Infante *et al.*, 2008; Hamre *et al.*, 2013;**

Carmen *et al.*, 2024). Additionally, juvenile fish tend to be more susceptible to drastic environmental changes, such as extreme shifts in environmental parameters **(Volkoff & Rønnestad, 2020)**.

Table 3. Growth pattern of catfish *P. lineatus* in several locations

Sex	b value	r^2	Location	Reference
Male Female	Positive allometry (3.35) Positive allometry (3.43)	0.99 0.99	North Andhra Pradesh Coast	**Vijayakumaran (1997)**
Mixed	Negative allometry (2.76)	0.87	Estuary, Malaysia	**Ya *et al.* (2015)**
Mixed	Positive allometry (3.74)	0.98	Arabian Sea coast of Pakistan	**Farooq *et al.* (2017)**
Male Female	Positive allometry (3.29) Negative allometry (2.85)	0.84 0.93	Tanjung Tiram, Indonesia	**Jumiati *et al.* (2017)**
Male Female	Positive allometry (3.23) Positive allometry (3.13)	0.98 0.99	Kolono Bay, Indonesia	**Asriyana *et al.* (2020a)**
Male Female	Positive allometry (3.29) Isometric (3.09)		Taiwan's southwest coast	**Ueng *et al.* (2022)**
Mixed	Negative allometry (2.68)	0.78	Palawan, Philippines	**Froese & Pauly (2024)**
Mixed	Negative allometry (2.95)	0.97	Malatapay, Philippines	**Froese & Pauly (2024)**
Mixed	Negative allometry (1.86 and 2.68)	0.84 0.94	Tapulaga, Indonesia	**This research (2025)**

At the end of the rearing period, the striped eel catfish exhibited diverse condition factor values (Table 1). Considering the range of condition factors, it is clear that *P. lineatus* reared at a stocking density of 50ind./ 2m³ exhibited superior condition compared to those reared at a density of 100ind./ 2m³. This difference is related to the absence of competition in feed utilization and space for fish movement at lower stocking densities, allowing for more efficient feed utilization and resulting in faster growth in both length and weight. In contrast, higher stocking densities can have adverse effects on growth, stress, and immune responses, as reported by **Long *et al.* (2019)** in the case of Chinese sturgeon (*Acipenser sinensis*).

CONCLUSION

The striped eel catfish can thrive in controlled environmental conditions, exhibiting favorable condition factor values (K > 1). During rearing efforts, the eel catfish demonstrated enhanced growth when raised in media with a stocking density of approximately 50ind./ 2m³ compared to 100ind./ 2m³.

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