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Length Weight Relationship, Condition Factor, and Feeding Habits of the Red Shrimp *Parhippolyte uveae* in the Anchialine Waters of Tanjung Sanjangan, Central Sulawesi

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ABSTRACT

Parhippolyte uveae is an anchialine shrimp species recorded in the coastal waters of Tanjung Sanjangan, Central Sulawesi. This study aims to determine the length–weight relationship, condition factor, and feeding habits of *P. uveae* to improve understanding of its growth pattern and ecological characteristics. A total of 300 individuals (139 males; 161 females) were collected using purposive sampling. Total length and body weight were measured to estimate the length–weight relationship (LWR), while stomach contents were examined microscopically to determine dietary composition. The shrimp measured 2.81– 4.89cm in length and 0.27– 1.82g in weight. The combined LWR was described by $W= 0.0263L^{2.65}$ ($R^2= 0.76$), indicating negative allometric growth ($b< 3$). The condition factor ranged from 0.40 to 1.97, classifying individuals as slender to moderately plump. Stomach content analysis revealed an omnivorous diet, dominated by phytoplankton (*Skeletonema*, *Ceratium*, *Rhizosolenia*) and zooplankton (*Temora*, *Balanus* larvae, *Bivalvia* fragments). These biological parameters demonstrate that *P. uveae* is well adapted to the semi-enclosed, nutrient-limited anchialine ecosystem. The findings provide baseline information essential for ecological monitoring and sustainable management of anchialine shrimp populations in Central Sulawesi.

INTRODUCTION

Anchialine ecosystems are unique semi-enclosed coastal water bodies characterized by subterranean hydrological connections, limited nutrient input, and distinct biological assemblages **(Camacho-Cruz *et al.*, 2024)**. These systems support specialized crustacean communities, including species of the family Barbouriidae, which are known for their ecological adaptation to low-nutrient, variable environmental conditions. One of the species associated with such habitats is *Parhippolyte uveae*, a small red shrimp widely distributed across the Indo-Pacific, including Aldabra, Halmahera, Kakaban Island, the

Philippines, Fiji, and the Hawaiian Islands **(Malay *et al.*, 2021)**. In Indonesia, populations of *P. uveae* have been documented in several isolated anchialine systems such as Kakaban, Maratua, Halmahera, Sombano Lake, Buton Island, and multiple islands in West Papua **(Findra *et al.*, 2024)**.

In the coastal waters of Tanjung Sanjangan, Central Sulawesi, *P. uveae* has recently been recorded and morphologically confirmed by a researcher from the Zoology Division of the Indonesian Institute of Sciences (LIPI) **(Sari & Arisuryanti, 2020; Sari *et al.*, 2023)**. Previous research in this area has focused primarily on habitat description and genetic diversity **(Sari & Arisuryanti, 2020; Sari *et al.*, 2023; Serdiati *et al.*, 2025)**, but biological information about the species remains limited. Despite its broad geographic range, detailed studies on key biological parameters, including length–weight relationship (LWR), condition factor (K), and feeding habits are scarce for *P. uveae*, particularly for populations inhabiting anchialine waters in Central Sulawesi.

The LWR is a fundamental tool in fisheries biology, providing insights into growth patterns, energy allocation, and population structure **(Fang *et al.*, 2022; Li *et al.*, 2023; Rodríguez-García *et al.*, 2023)**. Variations in the allometric coefficient (b) can reflect environmental quality, reproductive cycle, and feeding success **(Nguyen *et al.*, 2022)**. Similarly, the condition factor (K) serves as an indicator of physiological well-being and habitat suitability **(Faruque & Das, 2024; Usman *et al.*, 2024)**. Feeding analysis provides complementary information on trophic ecology and resource use, especially in ecosystems with naturally low nutrient availability such as anchialine systems.

A clear understanding of these biological parameters is essential not only for evaluating the health and ecological role of *P. uveae* populations but also for supporting conservation and management of anchialine habitats, which are often sensitive to environmental disturbances. However, no comprehensive assessment of growth pattern, condition, and diet has yet been conducted for *P. uveae* in Tanjung Sanjangan.

Therefore, this study aims to analyze (1) the length–weight relationship, (2) the condition factor, and (3) the feeding habits of *Parhippolyte uveae* inhabiting the anchialine coastal waters of Tanjung Sanjangan, Central Sulawesi. The findings are expected to provide baseline biological information and contribute to a better understanding of the ecological adaptation and population status of this species within anchialine environments.

MATERIALS AND METHODS

Study area

The research was conducted in the coastal waters of Tanjung Sanjangan, located in Salumbia Village, Dondo District, Tolitoli Regency, Central Sulawesi Province, Indonesia. This area is characterized by mangrove-dominated coastal ecosystems with

minimal anthropogenic disturbance, providing suitable habitat conditions for *Parhippolyte uveae*.

Sampling and equipment

Shrimp were collected using a purposive sampling strategy, targeting microhabitats where *P. uveae* was previously observed. Specimens were captured manually using a cone-shaped nylon hand net. Sex determination was conducted by observing morphological characteristics of the endopod of the first pleopod under a stereomicroscope. Total length (±0.01 mm) was measured with a digital caliper, and wet weight (±0.01 g) with a digital balance.

Data collection

A total of 300 shrimp individuals were collected, consisting of both males and females. Each specimen's total length (from the tip of the rostrum to the end of the telson) and total body weight were recorded. These measurements were used to determine the length-weight relationship and condition factor of the species.

To analyze feeding habits, the stomach contents were removed by carefully dissecting the digestive tract using fine scissors. The stomach contents were placed in a petri dish and examined under a compound microscope for identification of food items. Phytoplankton were identified using *Phytoplankton Identification Manual* **(NIO, 2004)**, while zooplankton were identified following published method **(Masithah & Islamy, 2023)**.

Data analysis

Length-weight relationship

The LWR was estimated using log-transformed least-squares regression:

$$\log W = \log a + b\log L$$

Normality of residuals was tested using the Shapiro–Wilk test, while homogeneity of variance was examined using Levene's test. A t-test was applied to evaluate whether the allometric coefficient differed significantly from isometry (b = 3) at α = 0.05:

$$t = \frac{b - 3}{SE_b}$$

Condition factor (K)

The condition factor was calculated following **Ricker (1975)**, with the appropriate formula depending on the growth pattern:

- For isometric growth ($b = 3$):

$$K = 10^5 \times \frac{W}{L^3}$$

- For allometric growth ($b \neq 3$):

$$K = \frac{W}{aL^b}$$

Where:

- K = condition factor
- W = body weight (g)
- L = total length (cm)
- b = allometric exponent obtained from the length–weight relationship

The condition factor reflects the physiological well-being or relative "plumpness" of individuals and is commonly used as an indicator of habitat quality, environmental stress, and energy reserves.

Feeding habits

Food composition was analyzed based on the percentage occurrence of each food item and the index of preponderance (IP) to determine the dominant diet components **(Natarajan & Jhingran, 1961)**:

$$IP = \frac{(V_i \times O_i)}{\sum(V_i \times O_i)} \times 100$$

Where:

- V_i = volume percentage of food item *i*
- O_i = frequency of occurrence of food item *i*

Food items were categorized as:

- Main food: IP > 15%
- Supplementary food: 5% < IP ≤ 15%
- Additional food: IP ≤ 5%

Stomach contents were quantified using both frequency of occurrence (FO%) and volume percentage (V%), and combined to obtain the index of preponderance (IP).

RESULTS

Length–weight relationship

A total of 300 *Parhippolyte uveae* individuals were analyzed, consisting of 139 males and 161 females. Total length ranged from 2.81– 4.89cm and body weight fluctuated between 0.27 & 1.82g (Table 1).

Table 1. Length and weight range of *Parhippolyte uveae* collected from Tanjung Sanjangan, Central Sulawesi

Sex	n	Length Range (cm)	Mean ± SD (cm)	Weight Range (g)	Mean ± SD (g)	LWR Equation	b Value	Growth Type
Combined	300	2.81–4.89	3.85 ± 0.62	0.27–1.82	1.04 ± 0.45	$W = 0.0263L^{2.65}$	2.65	Negative allometric
Male	139	2.81–3.97	3.34 ± 0.42	0.27–1.28	0.78 ± 0.31	$W = 0.021L^{2.85}$	2.85	Negative allometric
Female	161	3.74–4.89	4.32 ± 0.37	0.62–1.82	1.26 ± 0.39	$W = 0.025L^{2.67}$	2.67	Negative allometric

Note: $b < 3$ indicates negative allometric growth, where the increase in length is faster than the increase in weight.

Sex-specific relationships

Male and female shrimp showed the following LWR equations:

- **Males:**

$$W = 0.021L^{2.85}$$

- **Females:**

$$W = 0.025L^{2.67}$$

Both sexes exhibited $b < 3$, indicating negative allometric growth (Fig. 2). Summary parameters are presented in Table (1).

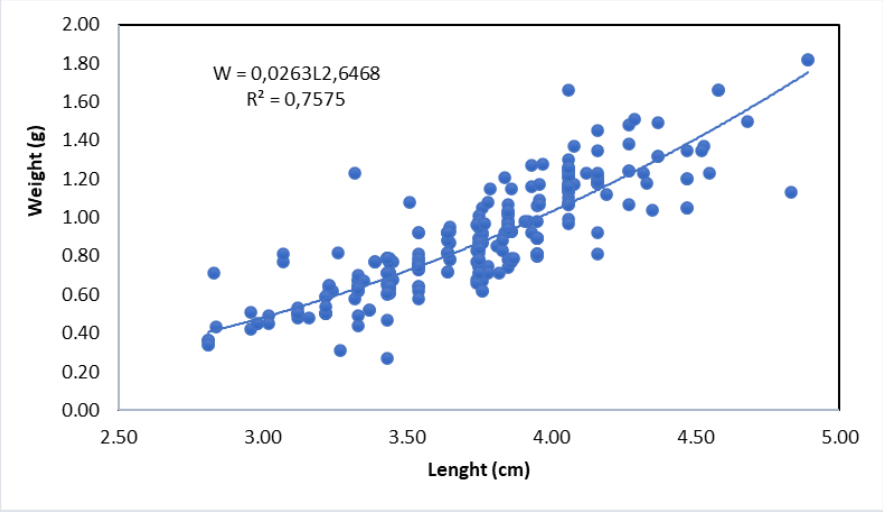

Fig. 1. Relationship between length and weight of red shrimp by gender combined

When analyzed separately by sex, males showed a relationship of $W = 0.021L^{2.85}$ and females exhibited that of $W = 0.025L^{2.67}$ (Fig. 2). Both male and female shrimp exhibited *b* values less than 3, confirming negative allometric growth in both sexes. This result is consistent with findings from previous studies on other shrimp species, such as *Penaeus indicus*, *Metapenaeus conjunctus*, and *Metapenaeus ensis*, which also demonstrated negative allometric patterns **(Razek *et al.*, 2022; Hassan *et al.*, 2024; Mohale *et al.*, 2024)**.

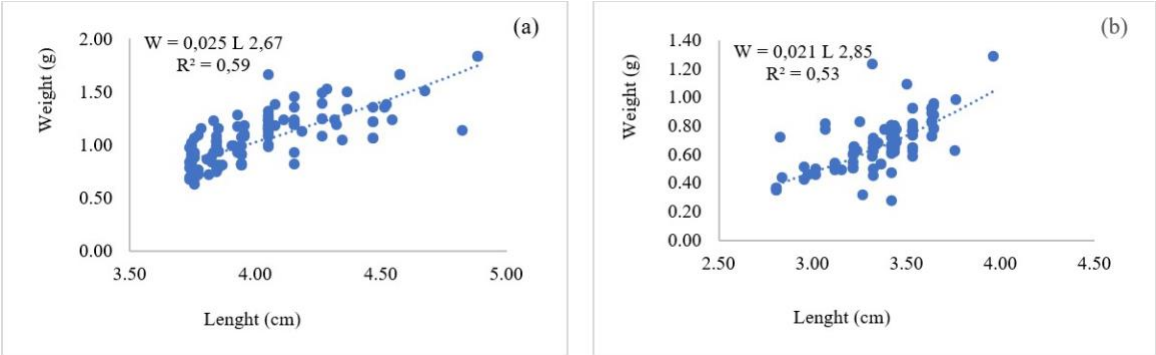

Fig. 2. Relationship between length and weight of red shrimp (a) Female; and (b) Male

Condition factor

Condition factor values (K) for the combined sample ranged from 0.40–1.97, with a mean of 1.02 ± 0.35 (Table 2). Male values ranged from 0.38–1.92 (mean 0.96 ± 0.31) and female values from 0.67–1.58 (mean 1.11 ± 0.28).

Table 2. Condition factor (K) of *Parhippolyte uveae* from Tanjung Sanjangan, Central Sulawesi

Sex	N	K Range	Mean ± SD	Body Condition Category
Combined	300	0.40–1.97	1.02 ± 0.35	Slender–moderately plump
Male	139	0.38–1.92	0.96 ± 0.31	Slender
Female	161	0.67–1.58	1.11 ± 0.28	Moderately plump

Note: According to **Effendie (2002)**, $K < 1$ indicates a slender body; K between 1-3 indicates moderate condition; and $K > 3$ represents a plump or robust body form.

These results suggest that *P. uveae* populations in Tanjung Sanjangan are generally within the slender category. Variations in K may be influenced by environmental factors such as food availability, reproductive status, and dissolved oxygen concentration. The relatively low K values recorded may also be related to the natural habitat conditions of *P. uveae*, which inhabits minimally disturbed mangrove and anchialine systems with fluctuating water parameters.

Feeding habits

Stomach content analysis showed that *P. uveae* consumed both phytoplankton and zooplankton. Food items were identified to the lowest possible taxonomic level and quantified using frequency of occurrence (FO%), volume percentage (V%), and index of preponderance (IP%).

Six categories of food items were identified (Table 3 & Fig. 3). Phytoplankton taxa *Skeletonema* sp., *Ceratium* sp., and *Rhizosolenia* sp. were the dominant components with IP > 15%, classifying them as main food items. Zooplankton groups (*Temora* sp., *Balanus* larvae, and *Bivalvia* fragments) were classified as supplementary foods.

Table 3. Food composition and index of preponderance (IP) of *Parhippolyte uveae*

Food Item	Occurrence (%)	Volume (%)	IP (%)	Feeding Category
Ceratium sp.	20.32	21.10	20.0	Main food
Skeletonema sp.	22.86	23.40	23.0	Main food
Rhizosolenia sp.	17.78	18.20	18.0	Main food
Temora sp.	17.78	17.50	18.0	Supplementary
Balanus larvae	10.79	10.50	11.0	Supplementary
Bivalvia fragments	10.48	9.80	10.0	Supplementary

Note:

- Food items were classified according to the Index of Preponderance **(Natarajan & Jhingran, 1961)**:
  - Main food: IP > 15%
  - Supplementary food: 5% < IP ≤ 15%
  - Additional food: IP ≤ 5%
- Results indicate that *Parhippolyte uveae* is an omnivorous species, with phytoplankton (particularly *Skeletonema* and *Ceratium*) as dominant dietary components.

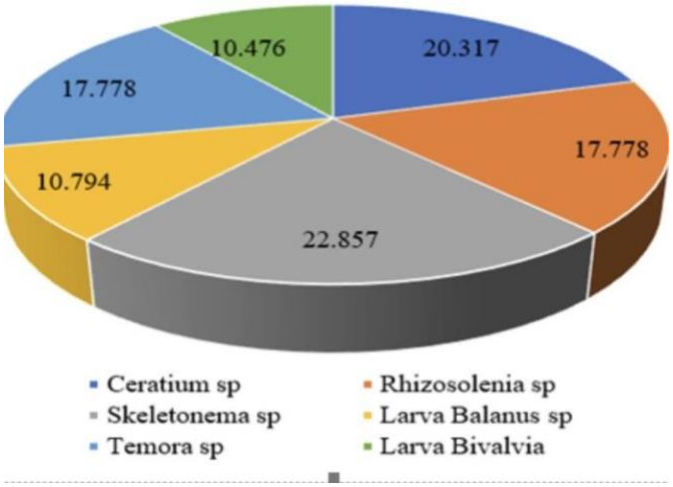

Fig. 3. Preponderance index

Based on the Index of Preponderance (IP), phytoplankton species such as *Ceratium* sp., *Skeletonema* sp., and *Rhizosolenia* sp. were classified as main food items, while *Temora* sp., *Balanus* sp., and *Bivalvia* served as supplementary food.

DISCUSSION

Length-weight relationship

The present study shows that *Parhippolyte uveae* in the anchialine waters of Tanjung Sanjangan exhibits a negative allometric growth pattern ($b < 3$), indicating that increases in body length occur more rapidly than increases in weight. Such growth patterns are commonly documented in crustaceans inhabiting nutrient-limited or fluctuating environments, where energy allocation favors somatic elongation rather than biomass accumulation **(Hartnoll, 2001; Zhou *et al.*, 2019)**. In anchialine ecosystems that characterized by restricted water exchange, moderate primary productivity, and spatial variability in food availability organisms often adopt growth strategies that optimize mobility and resource acquisition under constrained energetic conditions.

The combined b-value (2.65) aligns with those reported for other tropical shrimps exhibiting negative allometry, such as *Penaeus indicus*, *Metapenaeus conjunctus*, and *Metapenaeus ensis*, which typically show b-values between 2.27 and 2.88 in estuarine and lagoon environments. Although no previous LWR studies exist specifically for *P. uveae*, negative allometry has been reported for other anchialine crustaceans, including *Procaris hawaiana* and *Metabetaeus lohena*, whose elongated body form is interpreted as an adaptation to crevice habitats and low-nutrient water columns **(Hartnoll, 2001; Zhou *et al.*, 2019)**.

Differences in b-values between males and females (2.85 vs. 2.67) may be related to sex-specific physiological needs. Females often allocate energy to gonadal development, which may increase weight relative to length during certain reproductive phases, whereas males may invest more in structural growth or mobility. Such sex-related differences in allometric patterns have also been described in penaeids and alpheid shrimps **(Chak *et al.*, 2015; Ocasio-Torres *et al.*, 2015)**.

The coefficient of determination ($R^2 = 0.76$) demonstrates a strong relationship between length and weight, indicating reliable predictive power. Such strong LWR relationships are essential in stock assessment, particularly for species in non-exploited or data-poor environments, as they allow estimation of biomass from length-frequency data alone **(Gillespie, 2021; Zhang *et al.*, 2021; Taylor *et al.*, 2025)**. Overall, the negative allometric pattern observed in *P. uveae* suggests ecological adaptation to a semi-enclosed anchialine system with fluctuating food availability and moderate productivity. These growth characteristics are consistent with the species' morphological and ecological traits and may serve as indicators of environmental condition in future monitoring programs.

Condition factor

The condition factor (K) values recorded in the study, ranging from 0.40 to 1.97, suggest that the individuals vary from slender to moderately plump. While K values below 1 often signal depleted energy reserves, the values here are consistent with those typically found in shrimp species inhabiting oligotrophic anchialine systems **(Mejía-Ortíz *et al.,* 2022)**. These moderately low values are therefore more likely a reflection of the natural trophic limitation inherent to the subterranean estuary environment, rather than an indicator of poor health in the *P. uveae* population **(Brankovits *et al.,* 2017)**. The structural development and restricted nutrient flow in these unique cave habitats, which have evolved since the last ice age, naturally limit plankton density compared to open coastal waters **(Van Hengstum *et al.,* 2019)**.

Several environmental and physiological factors likely interact to influence the observed K values. First, the dissolved oxygen (DO) levels recorded (2.7– 2.9mg/ L) fall within a suboptimal range for most decapods, a condition known to negatively affect metabolic efficiency and growth **(Zeng *et al.,* 2024)**. Second, a notable variation in K was found between the sexes, with females showing a higher mean K (1.11) than males (0.96). This difference is consistent with findings in other crustaceans where the higher K in females reflects greater reproductive investment **(Ogunola *et al.,* 2018)**. Maturing females must accumulate substantial lipid and protein reserves to support oocyte development, which increases their overall weight relative to their length.

Given that the condition factor is highly sensitive to both environmental and physiological variation, the values reported here serve as crucial baseline information for future comparative research on *P. uveae*. Long-term monitoring efforts are essential to fully understand the population's ecology. Such studies could determine the extent to which factors like seasonal shifts in food availability, the timing of reproductive cycles, or hydrological fluctuations drive temporal variation in the condition of the population, providing a more complete picture of their adaptive success in this resource-limited environment.

Feeding habits

The stomach content analysis confirms that *P. uveae* is an omnivorous species, consuming both phytoplankton and zooplankton. The predominance of diatom taxa (*Skeletonema*, *Rhizosolenia*) and dinoflagellates (*Ceratium*) suggests reliance on suspended particulate matter typically found in calm, sunlit anchialine pools **(Masithah & Islamy, 2023)**. Zooplankton such as *Temora* sp. and *Balanus* larvae, along with *Bivalvia* fragments, indicate opportunistic feeding on motile microfauna and detrital material.

Omnivory is a common strategy among anchialine crustaceans, allowing them to maintain energy balance under fluctuating resource availability. Similar dietary patterns

have been described for penaeids and caridean shrimps in lagoonal or semi-enclosed habitats, where phytoplankton and detritus form major energy sources **(Karnan *et al.*, 2020; Masoud *et al.*, 2021; Walton *et al.*, 2022)**. The ability of *P. uveae* to utilize both plant-based and animal-based food likely contributes to its persistence in the nutrient-limited ecosystem of Tanjung Sanjangan.

The presence of copepods and barnacle larvae in the diet suggests that *P. uveae* occupies an intermediate trophic position, linking planktonic producers to higher-level consumers. This trophic role is ecologically important in anchialine pools, where food webs are often short and energy transfer pathways are simple but highly sensitive to disturbance. Because feeding patterns often shift with season, life stage, and environmental conditions, future studies incorporating temporal sampling would help clarify how feeding ecology responds to changes in hydrology and productivity within the anchialine system.

Ecological implications

The combined findings negative allometric growth, moderate condition factor, and omnivorous feeding indicate that *P. uveae* is well adapted to the semi-enclosed, low-nutrient anchialine environment of Tanjung Sanjangan. These biological traits support survival under conditions of restricted water exchange, variable oxygen levels, and moderate planktonic productivity. The species' trophic flexibility and tolerance to fluctuating environmental parameters may contribute to maintaining population stability despite ecological limitations.

Given the restricted and often isolated nature of anchialine systems, species inhabiting these environments may be vulnerable to habitat alteration, pollution, or hydrological changes. The biological parameters established in this study therefore provide an important baseline for long-term ecological monitoring and future conservation planning.

CONCLUSION

This study provides the first comprehensive assessment of the length–weight relationship, condition factor, and feeding habits of *Parhippolyte uveae* inhabiting the anchialine waters of Tanjung Sanjangan, Central Sulawesi. The species demonstrated a negative allometric growth pattern ($b = 2.65$), indicating that body length increases more rapidly than body weight. This growth characteristic is typical of crustaceans living in nutrient-limited or fluctuating environments and suggests that *P. uveae* allocates proportionally more energy toward somatic elongation than biomass accumulation. The condition factor values (0.40–1.97) show that individuals range from slender to moderately plump, reflecting a population that is physiologically stable but influenced by environmental constraints such as limited food supply, moderate productivity, and

suboptimal dissolved oxygen levels. Slightly higher K values in females indicate greater energy reserves likely associated with reproductive development. Analysis of stomach contents revealed that *P. uveae* is omnivorous, consuming both phytoplankton (e.g., *Skeletonema*, *Ceratium*, *Rhizosolenia*) and zooplankton (e.g., *Temora*, *Balanus* larvae, *Bivalvia* fragments). This trophic flexibility represents an adaptive strategy for survival in semi-enclosed anchialine systems where food availability can fluctuate spatially and temporally. Overall, the biological characteristics observed in *P. uveae* negative allometry, moderate condition factor, and omnivorous feeding reflect the species' ecological adaptation to the low-nutrient, hydrologically restricted conditions typical of anchialine environments. These findings contribute important baseline information for understanding the population biology of *P. uveae* and support efforts to monitor and conserve anchialine habitats in Central Sulawesi. Future research should include seasonal sampling, reproductive cycle analysis, and environmental parameter monitoring to clarify how temporal variation in ecological conditions influences growth, physiology, and feeding dynamics. Such investigations will enhance understanding of the resilience and vulnerability of anchialine shrimp populations and inform conservation management of these unique coastal ecosystems.

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