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Length-weight relationship, condition factor dynamics, and feeding preference of *Clarias batrachus* (Linnaeus, 1758) from the rivers of Bataan, Luzon Island, Philippines

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ABSTRACT

There is a paucity of information on Philippine catfish (*Clarias batrachus*) thriving in fishery areas in Bataan, Luzon Island, and the Philippines. The study examined the length-weight relationship ($W = aL^b$), condition factor, and stomach content of *C. batrachus* collected from two major river systems in Bataan (Orani and Bagac Rivers), Philippines. A total of 60 fish specimens (12.4–25.5 cm) were collected using a 12-v electrofishing gear and fishing net. Although the specimens from Orani were significantly larger than those from Bagac, the latter exhibited an isometric growth rate ($b = 3$). Orani population displayed a negative allometric growth ($b < 3$). Female and male samples, regardless of site variability, showed a statistically isometric growth rate (b = 3). The condition factor of *C. batrachus* was K = 1.0, irrespective of site and sex variation, signifying that the populations are in good condition. Five food items were detected in Bagac, with the Gobiidae family emerging as the predominant prey items based on number (48.89%), frequency of occurrence (100%), and weight (72.83 %). Orani recorded three food items, primarily macroinvertebrates (Chironomidae), accounting for 75 %N, 86.67 %O, and a frequency of 91.19%. The Index of Preponderance and Index of Relative Importance recognized Gobiidae and Chironomidae as the two most important food items in Bagac and Orani, respectively. The baseline dataset generated from this study is hoped to provide insights into the current population status of this important fishery resource for improved riverine conservation management.

Keywords: Bagac, Growth coefficients, Index of preponderance, Orani, Prey items

Introduction

The *Clarias batrachus* (Linnaeus, 1758) populations are native to Southeast Asia and have been introduced worldwide for fish farming (Allen, 2011). This clariid species is an air-breathing and hardy fish that can thrive in areas where many other fish struggle to survive. It is mostly found in freshwater and brackish water rivers, lakes, ponds, streams, swamps, ditches, rice paddies, and reservoirs (Froese & Pauly, 2023; Allen, 2011). Successful aquaculture of this species provides socio-economic sustainability for rural communities (Debnath, 2011). Its economic importance stems from its attractiveness, taste, food conversion efficiency, ruggedness, and consumer popularity (Hossain et al., 2006; Debnath, 2011). This fish is also commonly referred to as Asian catfish and is considered an integral part of commercial fisheries, aquaculture, and home aquariums, particularly in Asia, where it is widely consumed. In the Philippines, the wild populations are now displaced (Paller, 2011) attributed to various factors such as drought periods, habitat destruction, and the uncontrolled introduction of a larger African catfish (*C. gariepinus*) that are known for fast growth and feral wild populations (Ahmad et al., 2012). In the Philippines, it is locally known as *hito* or *pantat* and supports communal and subsistence fisheries in the riverine fishery areas of Bataan, Philippines (Corpuz & Espaldon, 2023).

Despite the ecological and economic importance of *C. batrachus*, studies on fisheries biological tools, including length-weight relationships (LWR) and condition factors, have hitherto not been conducted at a local level to assess the ecological status of this important aquatic resource. Apart from LRW and condition factors, the gut analysis of the species provides important insight into feeding patterns and quantitative assessment of food habitats, which is also a key aspect of fisheries management (Hyslop, 1980). Moreover, the gut content analysis helps understand the food preference of fish species' natural history, nutritional requirements, trophic, material and energy dynamics, food webs, food chains, and material and energy transfers between and within ecosystems (Manko, 2016). It also reflects habitat separation in fish as the stomach content analysis can reveal the habitat where fish feed (Gümüş et al., 2002). Knowledge of morphometry, growth coefficients, food, and feeding is fundamental to understanding fish biology and trophic interactions between species in a fish community (Blaber, 2000; Corpuz et al., 2013; Corpuz, 2018). Similarly, these baseline datasets are yet known for *C. batrachus* populations thriving in Luzon Island, Philippines. Hence, the present study evaluated the LWR, condition factor, and feeding preference of *C. batrachus* populations based on the samples collected from Bataan's two separate river systems (Orani and Bagac).

Materials and Methods

Study Areas

The specimens were collected in the daytime from the east and west coasts of Bataan, Philippines. The *C. batrachus* specimens for the east portion of Bataan were collected in Orani River, Tagumpay, Orani (14º48'46" N and 120°30'56" E). The fish specimens for the west coast were collected in the Bagac River (Silahis-Pag-asa, Bagac, 14º35'45" N and 120º23'47" E). Both river systems serve as a communal fishing area for the local stream communities. Apart from fishing, the area is often used as a water source for agricultural purposes.

A total of 60 *C. batrachus* individuals (30 specimens from Orani, Bataan, and 30 specimens from Bagac, Bataan) were collected using 12-v electrofishing gear and scoop net from August to November 2023. The fish specimens were immersed in a phenoxyethanol solution (1 ml 5 L^{-1}) to induce sleep and immediately preserved in an ice box to avoid the digestion of food items. The specimens were brought to the laboratory of Bataan Peninsula State University for further examination.

Fish Analyses

In the laboratory, the fish specimens were immersed in phenoxyethanol solution (0.2 ml L^{-1}) to sleep prior to length and weight determination. The total length (TL, measured from the snout to the tip of the caudal fin) was measured using a vernier calliper (0.01 cm). The wet weight of specimens was determined using a digital weighing scale (0.01 g).

Using a scalpel, the fish specimens were incised from the anus up to the throat to reveal the alimentary canal. The stomach was exenterated from the whole alimentary canal by separating the attached organs from it and cutting it from the cardiac area to the pyloric section. The incision was performed in the lesser curvature of the stomach. The stomach contents of each specimen were extracted and transferred in gridded Petri dishes with tissue paper (no fixation). The sorted food items were counted and identified to the lowest possible taxonomic level under a simple microscope. The wet weight of the prey item was determined to the nearest 0.01 g using an analytical balance. The volume of each prey taxa was measured by water displacement in a graduated cylinder.

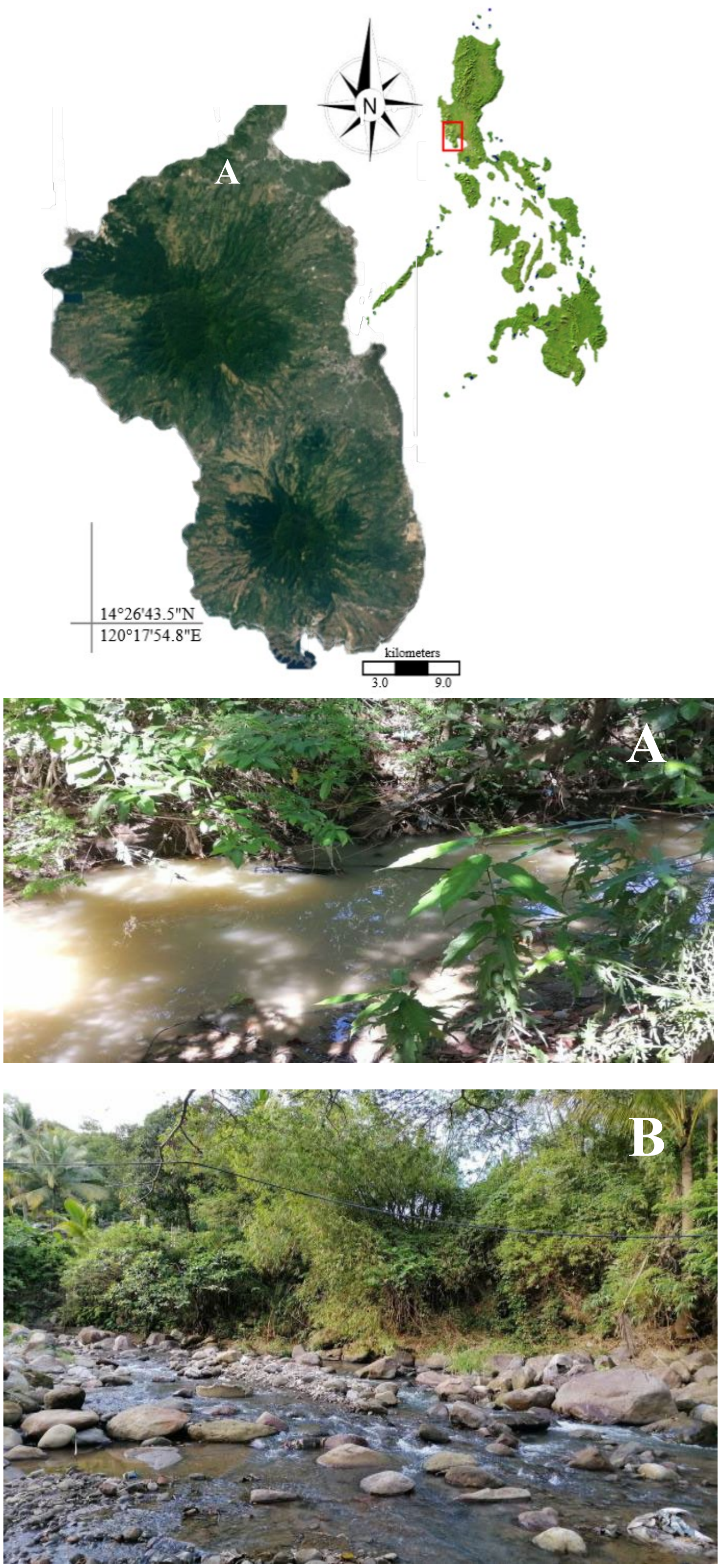

Figure 1. Map of Bataan, Philippines, showing the collection sites. (A) Tagumpay in Orani and (B) Parang in Bagac

Data Analyses

The equation expressed the allometric LWR:

$$W = a\ TL^{\ b}$$

Where W = is the weight (g) of an individual fish; TL = is the total length (cm) of fish individuals; *a* is the intercept, and *b* is the slope. The transformation of fish length and weight as Log w = log *a* + *b* x log (TL) was used to compute the *a* and *b* (Froese, 2006). The fish body condition factor was calculated using the equation by Fulton (1902).

$$K = W/LWR$$

K = condition factor, W = weight (g) of fish, and LWR = Length-weight relationship.

The growth rate pattern of the fish (allometric or isometric) as expressed in the value of *b* (slope) was tested for theoretical value for isometry when *b* was significantly equal to 3; growth was regarded as isometric if $b < 3$ is negative allometric, and $b > 3$ is positive allometric (Santos et al., 2020) (*t-test*, $P < 0.05$).

The relative measures of stomach content were evaluated quantitatively using three methods of occurrence (O%), defined as the number of stomach samples in which prey occurs expressed as a percentage of all stomachs; numeric percentage (N%) was defined as the number of individual in each prey categories recorded for all stomachs with the total expressed as a percentage of the total individuals in all prey categories and wet weight percentage (W%) defined as the wet weight of each prey recorded for all stomachs, with the total expressed as a percentage of a total wet weight of all prey categories (Hyslop, 1980). The partial fullness index was computed to compare the variation of the food found in the stomach among sampling sites. Two indices of dietary importance were also calculated to evaluate the prey importance through the equations:

- Index of Preponderance (IOP) (Natarajan and Jhingran 1962); IOP = %V.%F÷∑%V.%F*100;
- Index of Relative Importance (IRI) (Pinkas et al., 1971): IRI = %F (%N + %V); %IRI = (IRI/ΣIRI) *100.

The correlation between the prey item biomass and TL of *C. batrachus* was predicted using the transformed $\log_{10}$ (x+1), and the relationship was determined by a non-linear regression function: f = axb, where a = coefficient, x = TL, and *b* = slope.

Results and Discussion

Total Length and Weight

The mean and SD of the total length and weight of *C. batrachus* specimens are summarized in Table 1. The TL variation between *C. batrachus* populations was significant (t = 3.62; P < 0.01), with Orani (22.15 ±2.98 cm) having longer TL than Bagac (19.25 ±3.20 cm). The length of female samples in Orani (23.36 ±2.29 cm) was significantly larger than the male (20.56 ±2.29 cm). While in Bagac, the length of the female (19.56 ±3.11 cm) was slightly longer than the male (18.64 ± 3.46 cm). Inter-sexual variation in TL was not significant (t = 1.66; P < 0.05), albeit the site-sex factor was found to be statistically different (F = 7.2; P < 0.01).

The weight of specimens from Orani (82.65 ±30.81 g) was significantly heavier than in Bagac (52.06 ±24.79 cm) (t = 4.24; P < 0.01). The weight of female specimens in Orani (92.41 ±35.15 g) was heavier than the male specimens (69.89 ±19.66 g). While the weight of female specimens in Bagac (53.01 ±24.16 g) was slightly heavier than the male (48.82 ±28.51 g), sexual differentiation was not significant (P > 0.05).

Length-Weight Relationship and Condition Factor

The summarized dataset of LWR and the condition factor of *C. batrachus* is presented in Table 2. The observed growth coefficient of Bagac (b = 3.11, SE = 0.284) was isometric despite a slight deviation from b = 3.0. On the other hand, a negative allometric growth rate was observed in Orani populations (b = 2.55, SE = 0.200). Male and female populations exhibited isometric growth coefficients (male b = 2.963, SE = 0.285; female b = 2.9458, SE = 0.202). For Bagac, the male and female growth coefficients were isometric (male b = 3.40; female b = 3.04), while in Orani, male and female had negative allometric (male b = 2.45; female b = 2.73). Scatter plots of the relationship between the length and weight of specimens are illustrated in Figures 3 and 4.

Table 1. Descriptive statistics of *Clarias batrachus* in Orani and Bagac, Bataan, Philippines

Collection Sites	Sex	*n*	Total Length (cm)			Body Weight (g)		
			Min	Max	Mean ± SD	Min	Max	Mean ± SD
Orani	F	17	18.43	28.79	23.36 ±2.92[a]	51.05	163.49	92.41 ±34.59[a]
	M	13	15.76	23.27	20.56 ±2.29[a]	30.79	92.21	69.89 ±19.66[ab]
Bagac	F	20	14.14	23.27	19.56 ±3.11[b]	19.21	91.74	53.01 ±24.16[b]
	M	10	13.73	23.27	18.64 ±3.41[b]	19.24	100.72	48.82 ±28.51[b]

Similar letters indicate no statistical difference in each row at a 5% confidence level. a > b.

Table 2. The LWR parameters and condition factor of *C. batrachus* in Orani and Bagac, Bataan, Philippines

Collection Sites	Sexes	*n*	Growth coefficients			Condition Factor	
			a	*b*	r^2		
Orani	Female	17	0.02	2.73	0.83	0.99	1.01
	Male	13	0.04	2.45	0.85	1.04	
Bagac	Female	20	0.01	3.04	0.81	1.01	1.01
	Male	10	0.01	3.40	0.93	1.01	

The overall computed condition factor value showed no significant deviation from K = 1.0 (Table 2), signifying that the two populations are well-being. Moreover, regardless of sex, the K scores of specimens from the two sites were not significantly different (F = 0.002; $P > 0.05$). The result of the present study is similar to the results obtained by Rosli and Isa (2012), wherein the growth of *Plicofollis argyropleuron* from the Northern Part of Peninsular Malaysia was also observed to be isometric. A similar result was also reported by Fafioye and Ayodele (2018), where *Coptodon zillii*, *Brycinus nurse,* and *Oreochromis niloticus* from Oyan Lake, Nigeria, were observed to have negative allometric growth coefficients. Similarly, the condition factor (K) recorded in the above-stated fishes was greater than one (>1). Several factors have been noted to influence the LWR in fishes, including season, habitat, gonad maturity, sex, diet and stomach fullness, health, and preservation techniques, which can contribute to the different b values of the same species from various areas (Perez & Ignacio, 2019).

The LWR is usually used to determine the stock assessment, population dynamics, growth pattern, general health, habitat conditions, life history, fish condition, and morphological characteristics (Falsone et al., 2022; Jisr et al., 2018; Santos et al., 2020). A recent study revealed that the male and female *C. batrachus* in Orani had negative allometric ($b < 3$). Negative allometric occurs when the fish's body length increases faster than the fish's body weight, meaning these fish become lighter with increasing size (Mazumder et al., 2016). At the same time, the population from Bagac revealed that the male and female *C. batrachus* had isometric growth ($b = 3$), where the weight and length of the organism increased at the same rate.

The condition factor of a fish reflects physical and biological circumstances and fluctuations, such as feeding conditions and parasitic infections (Datta et al., 2013). It is an important tool that provides information on fish inter-population variation in growth patterns and condition factors (De Leon et al., 2017; Santos et al., 2020). The K values for *C. batrachus* in Orani and Bagac observed in the study are similar to the observation by Abobi (2015). This study also provides evidence of good overall health and welfare of *C. batrachus.*

Prey Composition and Food Analysis Indices

Sixty stomachs were examined in two sampling sites, and no empty stomach was recorded. In Bagac, five food categories were identified in the stomach: fish, gastropods, insects, plant materials, and crustaceans. Large prey items, particularly *Glossogobius giuris*, a common species of goby found in the river of Bagac, dominated the diet, comprising 48.89% by number (%N) and 100% by frequency of occurrence (%O). This was followed by crustaceans with 26.67 %N and 60 %O, plant materials with 11.11 %N and 33.33 %O, insects with 8.89 %N and 26.67 %O, and the least amount in the diet was gastropods with 4.44 %N and 6.67 %O. On the other hand, only three categories were identified in Orani comprising insects with 75 %N and 86.67 %O, gastropods with 16.67 %N and 33.33 %O, and plant materials with 8.33 %N and 13.33 %O.

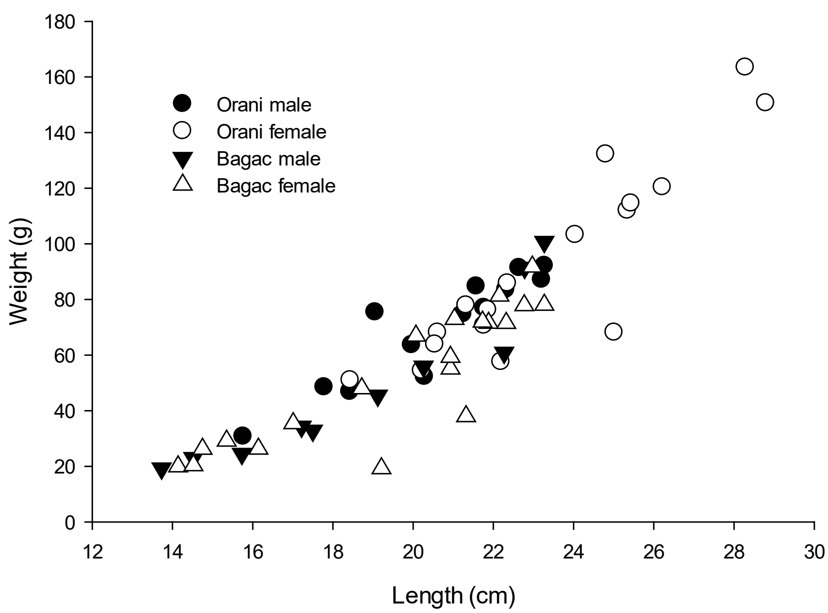

Figure 3. Scatter diagram plot of male and female *Clarias batrachus* length-weight relationship from Orani and Bagac, Bataan, Philippines.

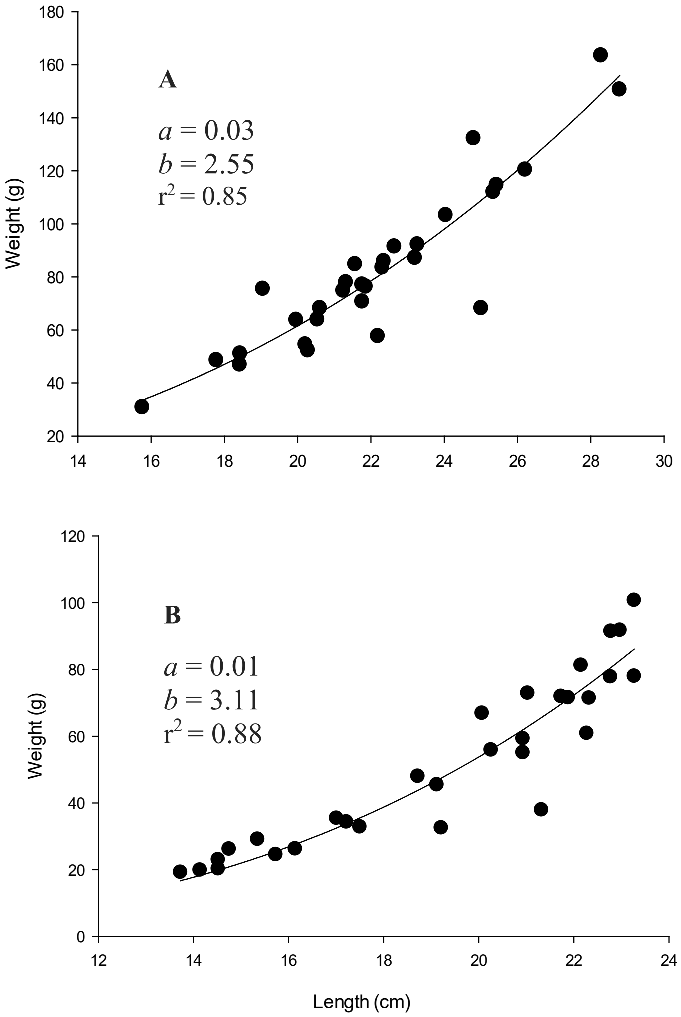

Figure 4. Scatter diagram plot of the length-weight relationship of *Clarias batrachus* in (A) Orani and (B) Bagac, Bataan, Philippines

The ranking of prey items based on IRI and IOP is presented in Table 3. The most important food item in Bagac, which comprised 76.61 %IRI and 83.13 %IOP, was fish prey item. While in Orani, insects were recognized as the most relevant food items comprising 94.26 %IRI; in terms of %IOP, it appeared with 94.26%.

Diet Variation

The relationship between number, volume, and occurrence displayed a degree of diet variation among the *C. batrachus* specimens (Table 5). In Bagac, fish was recognized as the major prey item by number and exhibited the highest occurrence and volume rate in the gut content. In Orani, insects were determined as the major prey item by number and exhibited the highest volume and occurrence rate.

A fish-based diet was the dominant prey item of Bagac populations (48.89 %PFI), but no fish consumption was recorded in Orani. The proportion of crustacean prey items was 26.67 %PFI, and there was no crustacean intake in Orani. On the other hand, insects were recorded as the major prey in Orani samples (75 %PFI); on the contrary, they ranked second to the least (8.89 %PFI) on the other site. Plant materials (11.11 %PFI) and gastropods (4.44 %PFI) were also recorded in Bagac. The Orani specimens also consumed gastropods (8.33 %PFI) and plant materials (16.67 %PFI). There was no significant relationship between the TL (cm) of the fish and prey item weight (g), as the amount of food consumed by the fish was not dependent on its length (r^2 = 0.33, b = 10.24) (Figure 6).

Table 3. Index of Preponderance (IOP) and Index of Relative Importance (IRI) of *C. batrachus* populations from Bagac and Orani

Prey items	IOP	Rank	IRI	Rank
Bagac				
fish	83.13	1	76.61	1
crustaceans	15.61	2	18.68	2
insects	0.57	5	1.81	4
gastropods	0.07	4	0.22	5
plant materials	0.63	3	2.68	3
Orani				
fish	0	0	0	0
crustaceans	0	0	0	0
insects	97.41	1	94.26	1
gastropods	0.69	3	1.09	3
plant materials	1.91	2	4.65	2

The feeding habit of *C. batrachus*, a carnivorous fish species, reveals a high preference for preying crustaceans, insects, and teleost fishes. A similar observation was reported by Sakhare and Chalak (2014), wherein *C. batrachus* populations in India preferred small fishes and insect larvae as the primary food items. The small fish prey items found in Bagac specimens signified the importance of small fishes in the river to sustain native catfish protein source requirements. The present findings agreed with the observation of Ramesh and Kiran (2016) and several authors in South Africa that indicated that the *C. gariepinus* did not rely only on offshore fishes and benthic invertebrates at high lake levels. However, they readily switched their feeding to littoral fishes and invertebrates when these became abundant (Wakil et al., 2014). On the other hand, nourishment for the growth of Orani samples is highly dependent on insects. This change in feeding habits might be attributed to the absence of other fish species in the Orani River caused by anthropogenic activity such as the illegal use of chemical compounds (e.g. sodium) for fishing, including other environmental perturbations (Romero et al., 2016: Flores et al., 2015).

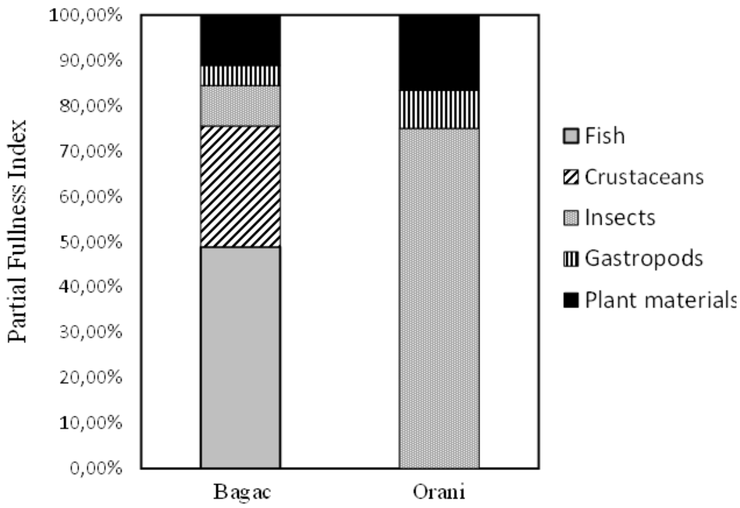

Figure 5. A stack bar representation of the main diet composition of *Clarias batrachus* is expressed as a distribution of the Partial Fullness Index among sampling sites

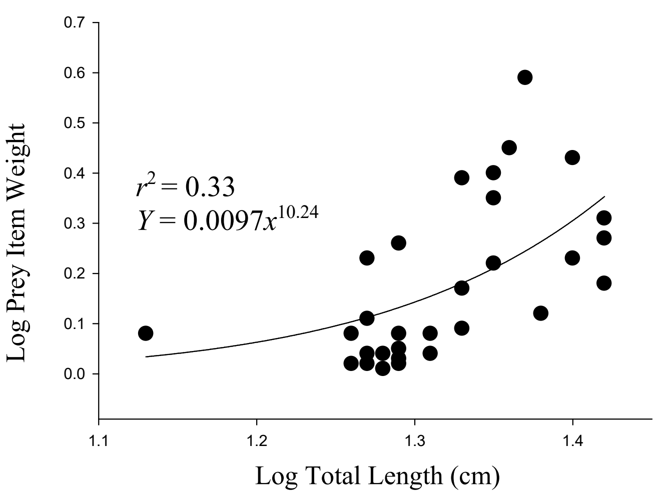

Figure 6. Relationship of prey item biomass with the total length of *Clarias batrachus*

The present study revealed that the amount of prey items ingested by *C. batrachus* is not size-dependent. It is highly evident that *C. batrachus* is a voracious feeder that consumes a large amount of food regardless of its size, as shown in Figure 6. This contradicts the study of Admassu et al. (2015), who stated that the proportion of insects and zooplankton decreased with the increase in fish size, while fish prey increased with the increase in Lake Babogaya.

Although the study is limited to a few individuals, to the best of our knowledge, it provided vital datasets of the population profile of *C. batrachus*, which can serve as a baseline reference for future investigation. There is a need to reduce fishing pressure (Romero et al., 2016) and other aquaculture activities (Flores et al., 2015) impacting the ecological integrity of the river ecosystems, which may eventually affect the *C. batrachus* and other native fish populations. This study hoped to enlighten the local community on the status and growth condition of *C. batrachus*. It could serve as a basis for the conservation management program for the two studied rivers.

Conclusion

Despite being larger in length and weight, the growth coefficient of Orani populations had negative allometry compared to the isometric growth rate of those from Bagac. However, the good condition factor of the two populations is similar, attributed to their biological capacity to adapt to varying habitat conditions. Both populations were in good condition, albeit their growth coefficients were dissimilar, indicating morphological plasticity to adjust to external environmental pressures.

Further investigations on potential factors (diet, physico-chemical, and anthropogenic disturbances) affecting LWR and condition factors are necessary. Increasing sample size and inclusion of other populations from other river systems can improve the robustness of LWR and condition factor data. Further investigation is also suggested to assess the influence of sexes and seasonality on the feeding pattern dynamics of *C. batrachus.* An additional study can also be done to understand further the dietary aspects and feeding habits of *C. batrachus*. Given the importance of stomach content analysis, future investigation should also be extended to other fish species, especially indigenous ones, to provide scientific information for their management.

Compliance with Ethical Standards

Conflict of interest: The author(s) declare no actual, potential, or perceived conflict of interest for this article.

Ethics committee approval: The Animal Care and Use Committee of Peninsulares Ethics Review Board of the Bataan Peninsula State University (REDO.PROJ.OC026) approved protocols for animal experiments.

Data availability: Data will be made available on request.

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Disclosure: -

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