International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 20, No. 5, p. 109-119, 2022

INNSPUB

RESEARCH PAPER OPEN ACCESS

Morphometric and condition factor of tumid venus clam (*Gafrarium tumidum*, Roding 1798) in Lagonoy Gulf, Albay, Philippines

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Key words: Condition index, Morphometrics, Allometry, Bivalves.

http://dx.doi.org/10.12692/ijb/20.5.109-119 Article published on May 24, 2022

Abstract

This paper describes the length-weight relationship (LWR) and condition index (K) of the tumid venus clam *Gafrarium tumidum* collected off the coastal area along Lagonoy Gulf. Seven hundred individuals of *G. tumidum* were collected and subjected to various analyses. The results showed that the length and weight measures of the species have a strong relationship exist between them (R^2=0.80-0.83). The growth pattern base on the computed slope (b) values showed allometry in both cases. Specifically, length measures (Shell height, SH and Shell width, SW) show negative allometry indicating that *X* (SW) is increasing relatively faster than *Y* (SH); whereas, Total weight (TW) vs. SH and SW shows positive allometry indicating that *Y* (TW) is increasing faster than *X* (SH and SW). The *K* value ranges in different length groups were 1.07 to 1.18, whereas the *K* value ranges from 0.95 to 1.43 in different weight classes. Condition index shows significant variation per class in relation to length and weight measures ($P<0.05$). The average value of *K* was 0.97 (±0.22) indicating a slightly slender body condition. Therefore, such findings could provide basic information on the biology of the species and be an essential basis for the development of a management scheme for this vulnerable resource.

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Introduction

Bivalves are the main component of the benthic fauna of many marine and estuarine areas. Due to their high abundance (Gosling, 2003), they are important as a food source for other species, such as shorebirds, fishes, and crustaceans (Braber and De Groot 1973), as well as humans. Bivalve species can be found all around the globe in a variety of environments, from the poles to the tropics (Tebble, 1996). Over such a range, differences in environmental conditions such as water temperature, salinity, food availability and water current occur. These differences influence growth, survival and reproduction, and ultimately, they limit and determine the distribution of species.

Bivalve shell growth and shape are influenced by abiotic (exogenous/environmental) and biotic (endogenous/ physiological) factors. Different environmental factors are known to influence shell morphology and relative proportions of many bivalve species, such as latitude (Beukema and Meehan, 1985), depth (Claxton *et al.,* 1998), shore level (Franz, 1993), tidal level (Dame, 1972), currents (Fuiman *et al.,* 1999), water turbulence (Hinch and Bailey, 1988), wave exposure (Akester and Martel, 2000), type of bottom (Claxton *et al.,* 1998) and type of sediment (Newell and Hidu, 1982). Similarly, burrowing behavior, ability and efficiency also influence the relative growth of the bivalve species (Eagar, 1978; Seed, 1980).

Growth is a three-dimensional process with all dimensions changing over time. The allometric principles of animal morphology have long been recognized since the concept of allometry was first postulated by Huxley and Tessier (1936). Allometry is the study of the relationship between two measurable variables; whereas in this study, it is the relationship between length and weight measures, or in the most general sense, allometry is the study of size and its consequences (Mayrat, 1970) which can be used to calculate the condition indices. On the other hand, condition factors are used to measure various ecological and biological and important basis in assessing the proper condition of the organism.

Gafrarium tumidum, is a common species of bivalves that burrow shallowly in muddy sand near mangroves. It is a small, sturdy clam with a ribbed pattern that is sometimes seen on some of the Southern shores, usually occurring on sandy areas in calm lagoons near seagrasses and mangroves. Elsewhere, they are found on intertidal shores with coarse sand, 3 – 4 cm in diameter.

The shell is circular with a straight portion on one side. With thick 'ribs' made of up large squarish beads. Usually the color is plain white without any patterns, although there may be irregular blotches that seem to be discoloration or algae growth. *G. tumidum* is more 'swollen' or rounded with rougher ribs. Similar to *G. divaricatum*, it can be distinguished by the more pronounced nodules at the confluence of the posterior and central areas of the flank and distinguishable by its flatter posterior margin and more inflated valves (Abbott, 1991; Tan and Chou, 2000; Tan *et al.,* 2010) Despite the existence of many studies concerning several aspects of bivalve populations, information available on morphometric relationships as well as the condition index of this species is very scarce. Such information would allow for comparison between bivalve species from different geographical areas and could also be used both in fishery models and in improving fishing gear selectivity. The present study was, therefore, carried out to provide preliminary information on the biology and status of *Gafrarium tumidum* or locally known as “burugat” with emphasis on its length-weight relationship and condition index, which may serve as a basis necessary in fishery regulations, decision making and management purposes.

Materials and methods

Study site

The study was conducted in the coastal area of Barangay Pawa, Tabaco, City along with a mangrove site in Lagonoy Gulf, northwestern Philippines. The gulf is a semi-enclosed body of water lined by fringing coral reefs and seagrass-seaweed beds interspersed with mangroves (Soliman *et al.,* 2009). Fishing is a major source of livelihood for people along the gulf.

During the time of unfavorable weather conditions where fishing is not possible, the gleaning of molluscs is the alternative livelihood of fishers. *Gafrarium tumidum* locally known as “burugat” is one of the marine resources that provide income and food source for coastal people along Lagonoy gulf. Fig. 1 shows the map of the study site showing the sampling stations where *G. tumidum* was collected.

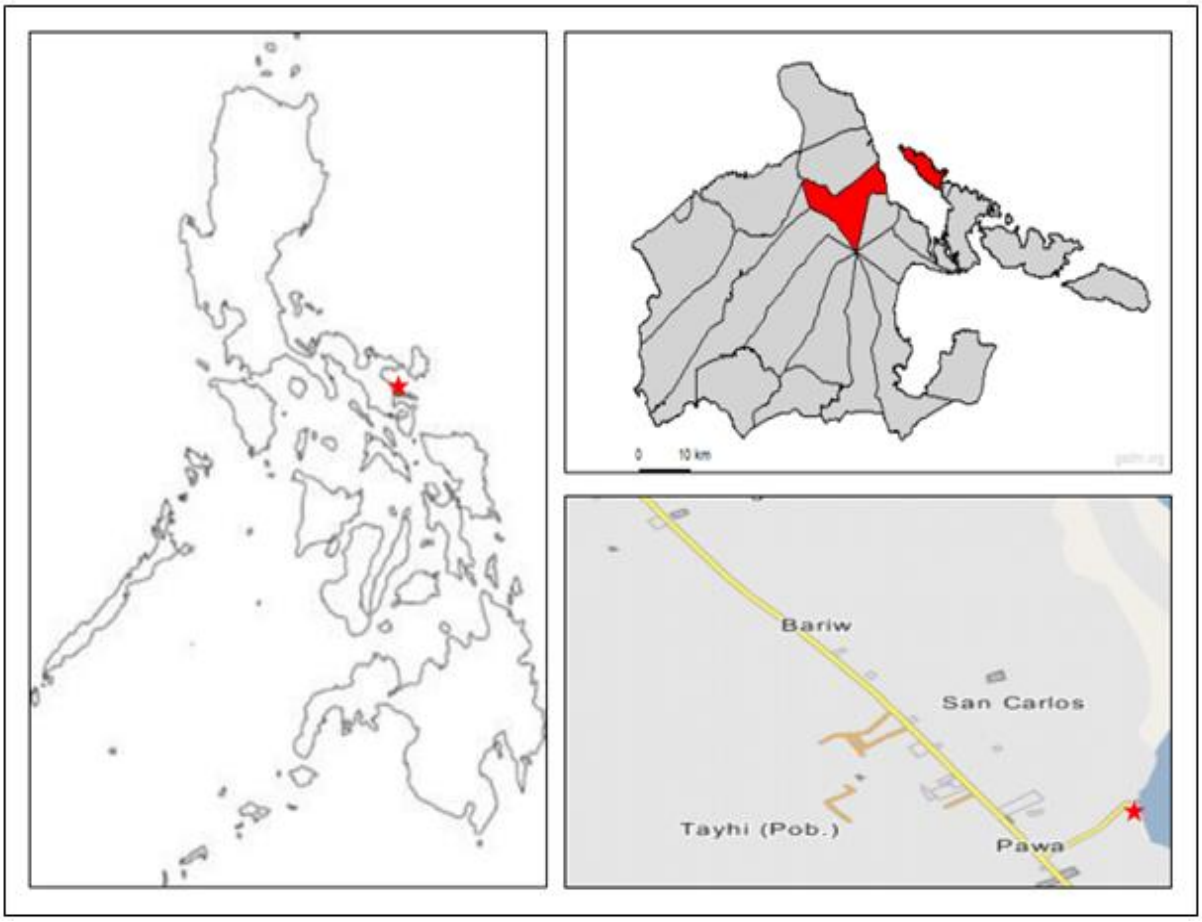

Fig. 1. Sampling site of the Venus shell *G. tumidum* locally known as “burugat” off Pawa coast, Tabaco City.

Data collection

Collection of Venus shell (*G. tumidum*), locally known as “burugat” (Fig. 2), was done using an improvised tool for gleaning at the mangrove area of Pawa, Tabaco City, along Lagonoy Gulf, during low tide.

Seven hundred (700) individuals of *G. tumidum* were collected throughout the study period. After collecting, they were thoroughly washed using clean seawater for measurement and further examination.

Morphometric relationships

Morphometric measurements, namely shell length (SL, maximum distance along the anterior-posterior axis), and shell width (SWD, maximum distance along the 2 valves-lateral axes) were obtained to the nearest 0.1 mm using a vernier caliper correct to ±0.01 cm. Total wet weight (TW) was taken using a top-loading balance with an accuracy of ±0.01g.

The relationship between weight and length of *G. tumidum* was described using power function $W = aL^b$, this equation can be expressed in its linearized form;

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

where W = total weigh (g), L = length (mm), a = intercept and b = slope.

On the other hand, linear regression analysis was used to establish the relationship between the shell length to shell width as expressed by the equation Y=a+bX, where: y = dependent variable, a = intercept, b = slope, and X = independent variable.

The growth pattern of the test variables were determined using the values of slope (b). When the growth is isometric (b = 3), test variables proceeds in the same dimension. When $b \neq 3$, growth is allometric indicating that the test variables proceeds in a different dimension. In order to confirm if the values of b obtained in the linear regressions were significantly different from the isometric value (b=3), a t-test with a confidence level of ±95% was applied as expressed by the equation:

$$t = \frac{\text{s.d. (logL)} * (b3) * \sqrt{n-2}}{\text{s.d. (logW)} * \sqrt{1-r2}}$$

The comparison between the obtained value of the t-test and the tabled critical value of the t-test allowed the determination of the statistical differences of the b value and its inclusion in the isometric and allometric ranges.

Condition factor

The condition factor which indicates the changes in food reserves and therefore an indicator of the general condition of *G. tumidum* collected from Tayhi coast was calculated. Condition factor (K) for *G. tumidum* was determined according to Le Cren 1951 equation with the formula;

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

Where, W = weight (g)
L = length (cm)
a = intercept
b = slope

Data analysis

The study applied a quantitative research design; Descriptive statistics such as mean and standard deviation (±SD) were computed. The degree of functional relationships between the variables was assessed from the coefficient of determination (R^2) obtained from a suitable regression analysis model using Microsoft excel 2010. Statistical analysis was at a 5% level of significance. Results were presented as mean ± standard deviation unless otherwise defined.

Results

Size structure of G. tumidum

A total of 700 individuals of *G. tumidum* with sizes ranging from 14.52 mm to 32.00 mm were collected from the mangrove swamps of Brgy. Pawa, Tabaco City along Lagonoy Gulf.

Table 1. Morphometric relationship parameters of *G. tumidum*.

Morphometric relationship	N	a	b	R2	Remarks	Growth pattern
SH vs SWD	700	1.10	0.89	0.83	Significant	Negative Allometry
TW vs SWD	700	0.01	3.40	0.81	Significant	Positive Allometry
TW vs SH	700	0.01	3.60	0.80	Significant	Positive Allometry

The mean SH was 22.7mm (±2.7). Class size of 23.68-25.96 mm was observed to be the most dominant size recorded on *G. tumidum*. Referring to the reported size at first maturity by Jagadis *et al.*, 2007 using the same species which was 22.3 mm, 40.7% are immature while 59.3% are considered as mature individuals (Fig. 3).

Morphometric relationship of G. tumidum

Shell height and shell width relationships: Shell height of *G. tumidum* ranges from a minimum of 14.52 mm to a maximum of 32 mm whereas shell width ranges from 16.60 mm to 36.42 mm.

The mean shell height was 22.7 ± 2.7, while the mean shell width was 25.9 ± 3.2. Length measures of *G. tumidum* (SH and SW) show a significant relationship (P=5.7E-267). Regression analysis between SH and SW revealed a strong relationship exists between them (R^2 = 0.82) (Fig. 4).

Fig. 2. *Gafrarium tumidum.*

Length (sh and sw) and weight (tw) relationships: Regression between length and weight measures of *G. tumidum* were established to determine the relationship between the test variables. Results revealed that length (SH and SW) and weight (TW) measures show significant relationships *(P = 1.1E-247; 6.9E-247)*. Values of R^2 from regression analysis show that length measures (SH and SW) are highly correlated to weight with the R^2 value of 0.80 (Fig. 5) and 0.81 (Fig. 6), respectively.

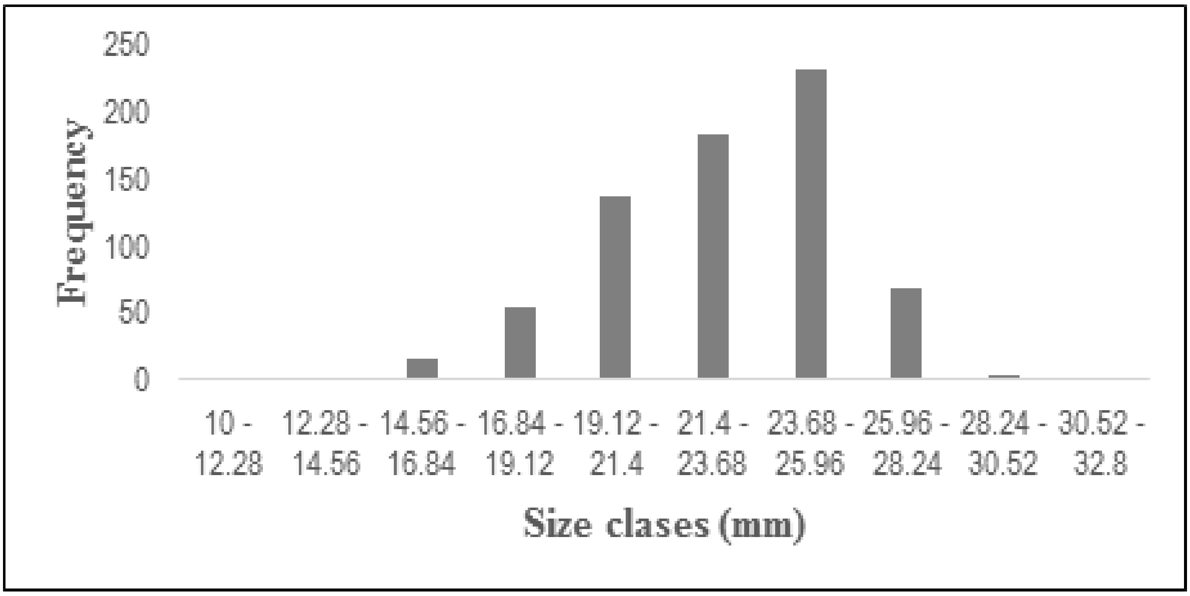

Fig. 3. Length-frequency distribution of *G. tumidum* collected off Pawa coast (N=700).

Table 1 shows the morphometric relationship parameters of *G. tumidum*. It was revealed that length (Shell height (SH) and Shell width (SW)) and weight (Total weight (TW)) measures has significant relationships ($P<0.05$). Values of slope (b) shows negative allometry ($b<3$) for SH and SWD; whereas TW vs SH and SWD shows positive allometry in both cases ($b>3$). All the computed b values show significant differences from 3.

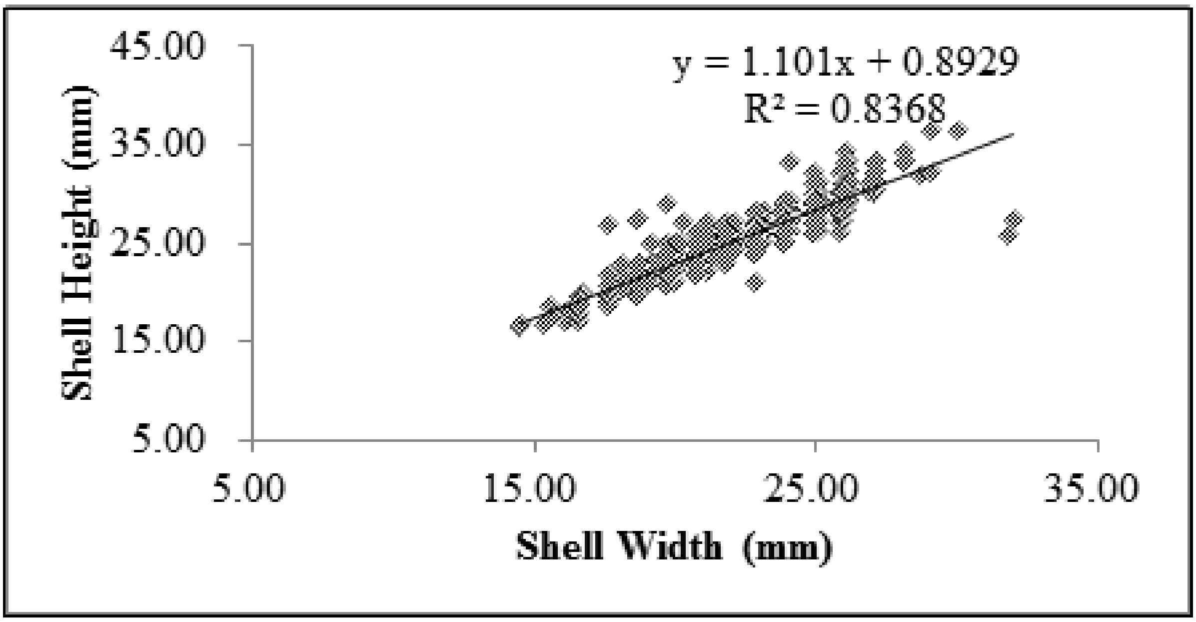

Fig. 4. SH and SW relationship of *G. tumidum* (N = 700).

Condition factor of G. tumidum

The *K* value ranges from different length group were 1.23-1.46 (1.07 ± 0.11), 1.46-1.68 (1.03 ± 0.17), 1.68-1.91 (1.07 ± 0.17), 1.91-2.14 (1.07 ± 0.22), 2.14-2.37 (1.02 ± 0.20), 2.37-2.60 (1.05 ± 0.21), 2.60-2.82 (1.18 ± 0.23), 2.82-3.05 (0.94 ± 0.49), 3.05-3.28 (0.27 ± 0.11) whereas the *K* value ranges from different weight group were 0.00-2.63 (0.95 ± 0.14), 2.63-5.26 (0.97 ± 0.17), 5.26-7.88 (0.98 ± 0.19), 7.88-10.51 (1.06 ± 0.20), 10.51-13.14 (1.10 ± 0.19), 13.14-15.77 (1.24 ± 0.17), 15.77-18.40 (1.36 ± 0.22), 18.40-21.02 (1.43 ± 0.23), 21.02-23.65 (1.38 ± 0.31), 23.65-26.28 (1.35 ± 0.24). Small variation was observed in the *K* as the animal increases its length (Fig. 7).

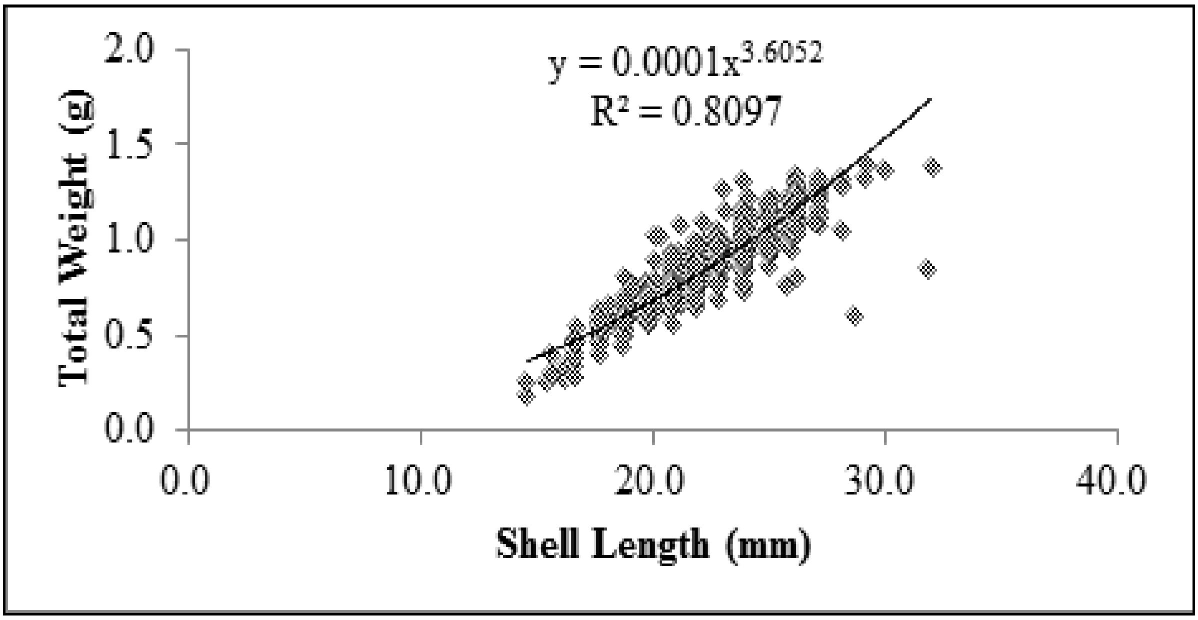

Fig. 5. TW and SH relationship of *G. tumidum* (N = 700).

Similar findings were observed in weight, indicating that condition index of *G. tumidum* increases proportional to the increasing weight (Fig. 8). ANOVA test result revealed significant differences in condition index of *G. tumidum* in different shell height and weight classes ($P<0.05$). Adult *G.*

tumidum has significantly higher mean *K* value than juvenile. The average value of *K* was 0.97 (±0.22) indicating a slightly slender body condition. The present condition of the species under study reflects the fluctuation of physiological and biological factors in the environment.

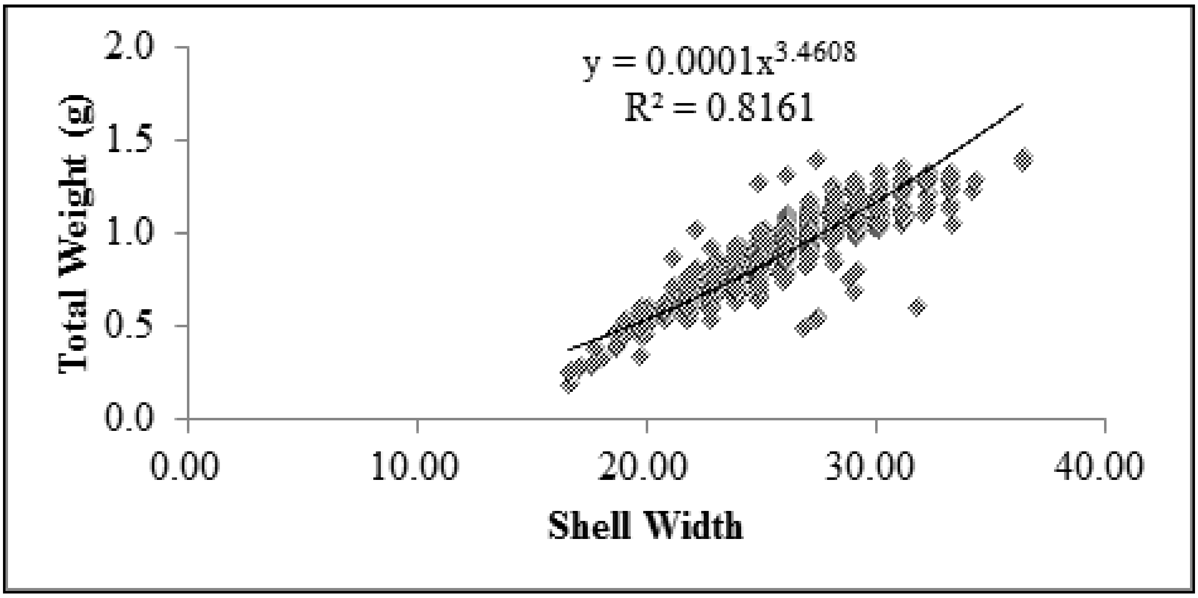

Fig. 6. TW and SWD relationship of *G. tumidum* (N = 700).

Discussions

Tumid venus clam (*Gafrarium tumidum*) is one of the bivalve molluscs found inhabiting coastal waters along Lagonoy Gulf which has biological and as well as economic importance. Efforts conducted to conserve this species have been done in other countries as well as in the Philippines. One of the main essential conservation strategies is to conduct biological characteristics of the species in its natural environment. In the present study, 700 individuals of *G. tumidum* were collected for various analyses. Modal class of 25.02 mm in *G. tumidum* was the most dominant (>50%), which is larger than the length-at-first maturity reported by Jagadis and Rajagopal (2007) to be 22.3 mm.

The weight-length relationship is a practical index of the condition of an organism; it could also be used for comparison of the same species between regions (Petrakis *et al.* 1995). In the present work, length (SH and SW) and weight measures (TW) were significantly related ($R^2 = 0.80$) indicating that as the animal grows, its weight increases with respect to increasing length. These changes in bivalve shell growth and shape are directly influenced by environmental parameters, food availability (Seed and Suchanek, 1992), and endogenous/physiological factors (Beukema and Meehan, 1985; Claxton *et al.*, 1998; Franz, 1993; Dame, 1972; Fuiman *et al.*, 1999; Hinch and Bailey, 1988; Akester and Marterl, 2000; Claxton *et al.*, 1998; Newell and Hidu, 1982).

The slope (b) in all the test variables reveals an allometric relationship. For instance, SH and SW show negative allometry (b<3) indicating that the *X* is increasing relatively faster than *Y* which in the case of *G. tumidum*, shell width is growing faster than the shell height. Similar findings were reported in the mussel *Mytilus edulis* (Yonge and Campbell, 1968), wherein shell width frequently exceeds shell height. Such condition is evident to those species living in a crowded environment, wherein the direct contact with neighboring individuals retard the normal extension of the mantle outwards in the plane of the valves. Shell secretion can therefore continue only at the inner faces of the shell rim, thus gradually forcing the valves into a more circular (and therefore wider) configuration (Brown *et al.*, 1976). This characteristic of *G. tumidum* as far as other bivalves may have an essential benefit, especially in a crowded environment, as a wedged shape profile effectively elevates the posterior current flow among conspecifics (Yonge and Campbell, 1968). The gradual allometric changes in shell morphology of bivalves were usually associated with the maintenance of physiological favourable surface area to volume ratios rather than with changing environmental conditions (Gosling, 2003). Wave impact, trophic conditions and water depth are also believed to influence shell proportions in bivalves (Seed, 1980). On the other hand, total weight (TW) and the length measures (SH and SW) show positive allometry in both cases (b>3) indicating that *Y* (TW) is increasing faster than the *X* (SH and SW). In bivalves, as far as in other invertebrates, shell increment slows down with increasing age (Brown *et al.,* 1976). With decrease and increased feeding efficiency, it is tissue growth rather than shell growth that tends to fluctuate. The main factor that influences the variability in the growth of bivalves is the food supply; without this, sustained growth is impossible (Seed and Suchanek, 1992).

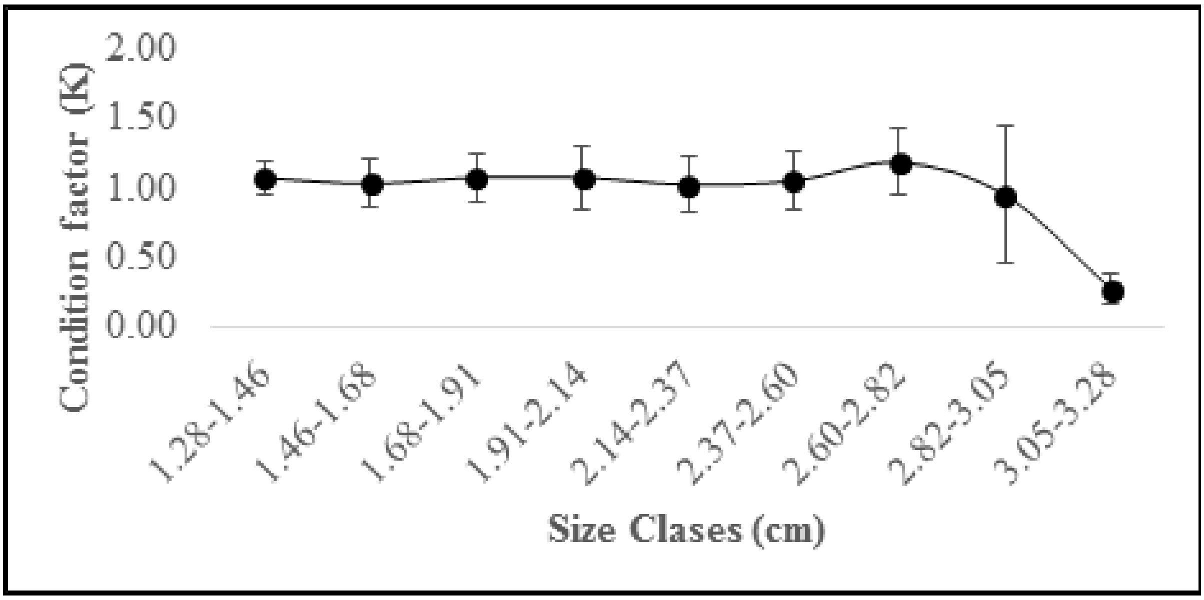

Fig. 7. Condition factor (K) per Shell height (cm) class of *G. tumidum*. Error bas show the standard deviation, (N=700).

The condition factor (K) of an organism reflects the physical and biological condition of the environment where they inhabit (Le Cren, 1951). This also indicates the changes in food reserves and, therefore, an indicator of the general condition of an organism such as bivalves (Sutton *et al.,* 2000). In the present study, the value of the condition factor per shell height and weight class were calculated. Results revealed that *K* of the species varies according to the shell height and weight classes. ANOVA results revealed that *K* shows significant differences in both cases ($P<0.05$). Specifically, the K value in the class size of 2.60-2.82 cm was significantly higher than the rest of the class size indicating higher *K* values as the animal increases its length, which is expected that the *K* value of juvenile *G. tumidum* (SH<22.3) is lower than that of the adults. This indicates better conditions in adults for activities that require higher energy costs, such as gametogenesis and reproduction (Andrade *et al.*, 2015). On average, regardless of class size, the general condition factor of *G. tumidum* off Tayhi coast was 0.97 which is slightly lower than unity (K=1) indicating a slightly slender or lean body condition. One probable cause of the low *K* recorded for *G. tumidum* may possibly attribute to the reproductive condition (gonad condition, Mac Gregoer, 1959) of the species, wherein more than 50 percent of the collected individuals were capable of reproduction. However, verification of the reproductive development of the species was not determined in the present study. Aside from the reproductive condition of the species, habitat differences in food quantity could also be the possible attribute for such condition of *G. tumidum* which are found inhabiting higher on a salt marsh in mangrove areas of Tayhi coast. According to Peterson and Black, 1987, mussels living on a higher salt marsh or on the up-shore may be food limited. This is because less food can be filtered due to limited submergence time and the water that is being filtered by up-shore mussels was already filtered by the down-shore mussels. Therefore, an empty stomach due to limited food availability from the environment may induce a decreasing value of K (Percin and Akyol, 2009).

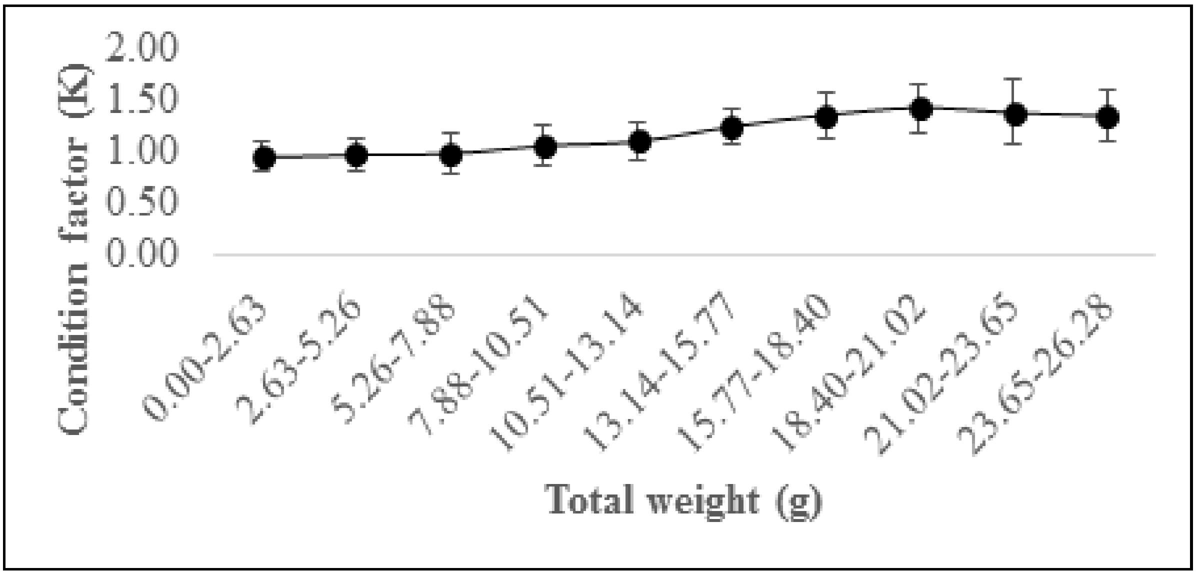

Fig. 8. Condition factor (K) per weight (g) class of *G. tumidum*. Error bars show the standard deviation, (N=700).

Knowledge of morphometrics such as the length-weight relationship of a species is an essential parameter in fisheries and fish biology. This parameter is used in fishery science to calculate the whole condition of the organism as well as the environment to compare populations between different regions. Therefore, strategies for managing the resource can be formulated using the length-weight measures of an organism.

Conclusions

The geographical distribution of an organism in the environment plays an important role in its condition index, especially in the bivalve. This is evident in *G. tumidum* having a condition factor of less than the unity (K=1) as a function of fluctuating food availability. Juvenile *G. tumidum* (<22.3) is already part of the current exploitation in the area which is detrimental to population growth. Therefore, the management scheme of this vulnerable resource is essential for its conservation and sustainability.

Recommendations

With the high frequency of catch belonging to juvenile stage, size selectivity in collecting this species (>22.3) should be done to allow the juvenile to reach maturity and reproduce even once before harvesting. Although basic information on length-weight relationships and condition factor were provided, fluctuations of these factors require further study; the explicit relationship between morphometrics and environmental parameters are yet to be revealed. In addition, further studies on the population dynamics of the species considering additional stations, should be conducted to properly represent the total population of the species in the Lagonoy gulf.

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