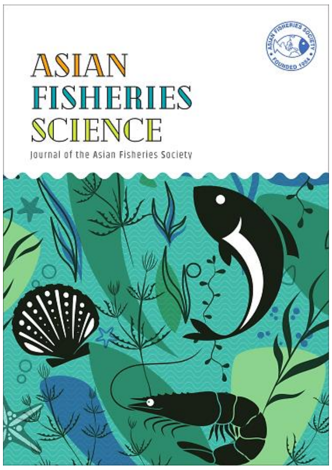

Morpho-biometric Relationship, Relative Condition Factor and Meat Yield of Distant Scallop *Bractechlamys vexillum* (Reeve, 1853) in Asid Gulf, Philippines

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Abstract

Understanding the relationships of morphometric and biometric characters of a species allows the prediction of one trait from the other and generate a measure of relative condition. These relationships were studied for the Distant scallop *Bratechlamys vexillum* (Reeve, 1853) in Asid Gulf. Representative samples collected during the dry season (May 2018, n = 99) and wet season (September 2018, n = 100) were used to analyse these relationships through models of simple linear and power regression analyses, revealing allometric growth patterns. For both periods, it was revealed that shell width (SW) is a slightly better predictor than the height (SH) for total weight (TW) (R^2 = 0.90 and 0.92) and the adductor muscle weight (AW) (R^2 = 0.78 and 0.80). The strong functional relationship was also observed between TW and AW (R^2 = 0.80 and 0.81). The relative condition factors (K_n) were high in both seasons. High meat yields were also observed in May (12.77 %) and September (14.26 %). The significant difference in meat yields ($P < 0.05$) can be a result of the seasonal difference manifested by the dynamics of energy partitioning during gametogenesis and spawning. These biological metrics are vital inputs in analysing mariculture prospects for the resource and a contribution to the scarce information on the biology of the species.

Keywords: functional relationships, growth pattern, allometry

Introduction

The Distant scallop *Bractechlamys vexillum* (Reeve, 1853) is one of the five commercially harvested true scallops, Family Pectinidae, found in Asid Gulf, Philippines. This species was previously identified as *Decatopecten striatus* (Schumacher, 1817) in the studies of Soliman and Dioneda (2004) and Bobiles and Soliman (2018). It is an economically important resource that comprises 57 % of the 11,000 tonnes total scallop production from the gulf in 2003 (Soliman and Dioneda, 2004). This high production, however, can be translated as a prelude to overexploitation, and such has been reported by Bobiles and Soliman (2018). The same research recommended the need to set-up management policies and scallop pilot culture as a viable technology and management measure. Knowledge of the morpho-biometric relationships of the bivalve is essential in pursuing these approaches.

Relatively little is known about the relationships of the morphometric and biometric characters of the Distant scallop. An important implication of the relationship of these biological characters is pertinent to resource management measures. For instance, the determination of the length-weight relationship (LWR) is the first step in obtaining accurate estimates of harvestable biomass (Newell and Hidu, 1982; Aragon-Noriega et al., 2007; Rothschild et al., 2009) and sustainable harvest level (Lai and Helser, 2004). The LWR, when combined with estimates of growth, can be used to estimate production-to-biomass ratios and the fraction of production dedicated to somatic and reproductive output (Hennen and Hart, 2012). This aspect has practical implications as it is relatively more accessible and requires less time to gather shell height data than weight data, particularly the soft tissue part (e.g., adductor muscle and meat yield). In aquaculture, the knowledge in LWR helps optimised breeding strategy; thus, improving the economic value of bivalves (Jun-hui et al., 2010; Zhong-ming et al., 2010). The relationship of morphometric and biometric characters in pectinids is generally described as allometric, having one character growing faster than the other. Allometric relationship has been reported for the pectinids species like *Amusium pleuronectes* (Linnaeus, 1758) (Del Norte, 1988), *Placopecten magellanicus* (Gmelin, 1791) (Schick et al., 1992; Sarro and Stokesbury, 2009; Hennen and Hart, 2012), *Chlamys nobilis* (Reeve, 1852) (Jun-hui et al., 2010; Zhong-ming et al., 2010), *Chlamys opercularis* (Linnaeus, 1758) (Taylor and Venn, 1978) and *Flexopecten glaber* (Linnaeus, 1758) (Berik et al., 2017). With a LWR, the weight can be estimated with the given length. The condition factor in the equation is a measure of the "well-being" or "fatness" of a species (Le Cren, 1951; Froese, 2006).

The relationship of shell height to meat weight in scallops varies seasonally requiring separate allometric equation for each season or month (Rothschild et al., 2009; Sarro and Stokesbury, 2009). Two seasons prevail in the Philippines that occur from June to October (wet season) and November to May (dry season) which influence scallop harvesting and spawning period. The peaks of scallop harvesting occur from January to July in Asid Gulf (Soliman and Dioneda, 2004), March to May in South Gigantes and December to May in North Gigantes (Acabado et al., 2018). The two seasons also coincide with the observed minor (August) and major spawning periods (December to February) of scallop in the adjacent Visayan Sea (Morillo-Manalo et al., 2016). Thus, in this study, the morpho-biometric characteristics of *B. vexillum* are represented during the wet and dry seasons. This research described the mathematical relationship of length-weight, weight-weight, and length-length of the Distant scallop. The relative condition factor and meat yield of the species were also described for the two seasons. The clear understanding of the relationships of these morphometric and biometric characters of *B. vexillum* serves as vital inputs for future mariculture and management initiatives.

Materials and Methods

Study site

Asid Gulf is bordered by the Municipalities of Cawayan, Placer, Esperanza Milagros, and Balud in the province of Masbate and available in Figure 1. Scallops are one of the commercially harvested species in the gulf. Scallop fishers are mostly concentrated in Naro Island in the municipality of Cawayan, Masbate. Harvested scallops in Asid Gulf are landed in Naro Island where the shuckling and pre-processing of the scallop adductor muscle is undertaken. A detailed description of the scallop fishery in Asid Gulf in 2007 and 2017 has been reported by Bobiles and Soliman (2018) that covered monthly monitoring of the fishery.

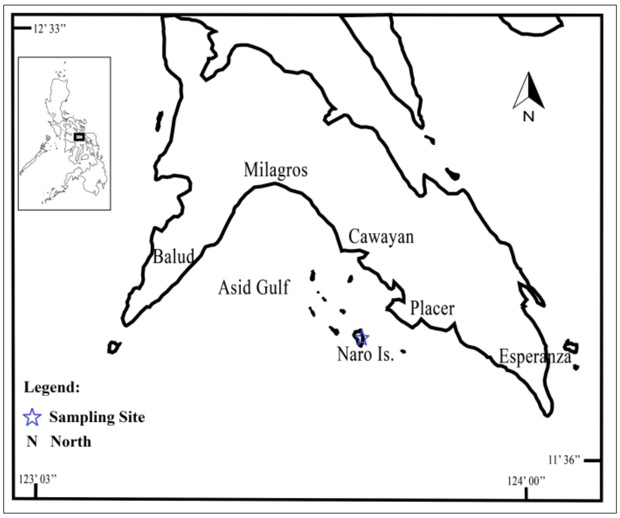

Fig. 1. Asid Gulf (Philippine map inset) showing the five municipalities bordering the gulf including the location of Naro Island as the sampling site for the study.

Data collection

The dry season (November to May) and wet season (June to October) were represented during the collection of scallop samples. Samples were randomly collected from piles of scallop landings in Naro Island in May 2018 (n = 100), representing samples for the dry season. Representative samples for the wet season were collected in September 2018 (n = 100). The samples were preserved in 10 % formaldehyde solution, packed in styrofoam boxes and immediately transported to Bicol University Tabaco Campus (BUTC) Fish Population Dynamics Laboratory for processing and analysis. In the laboratory, the scallops were washed and cleaned of any fouling and clinging organisms and debris. Shell height (SH) (i.e., maximum anterior-posterior axis) and shell width (SW) (i.e., maximum dorso-ventral axis) were measured to the nearest 0.01 mm using a digital vernier caliper. Measuring scheme for SH and SW is provided in Figure 2. The total weight (TW) was measured as the whole wet weight of the scallop. The soft tissue parts were dissected and each adductor muscle weight (AW) was taken. The TW and AW were measured using a digital balance with an accuracy of 0.01 g.

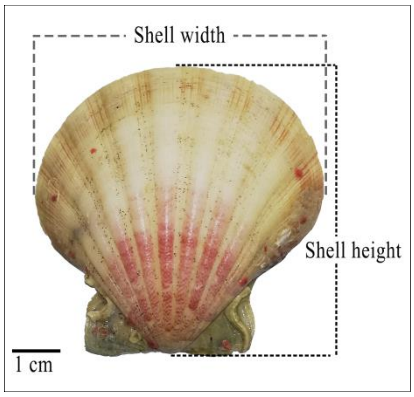

Fig. 2. *Bractechlamys vexillum* showing measuring schemes for shell height and shell width.

Statistical analysis

Data processing was initially undertaken by removing implausible outliers. The interquartile range (IQR) defined as the difference between the 75th (F_U), and 25th (F_L) quartile was determined using the multiplier value of 2.2. In identifying outliers, the inner fences are provided by the formulas $IF_L = F_L - (2.2 \times IQR)$ and $IF_U = F_U + (2.2 \times IQR)$ (Hoaglin et al., 1986). Observations below IF_L and above IF_U are considered outliers.

The relationships of SH to SW and TW to AW were analysed using simple linear regression. The mathematical form of the length-weight relationship ($W = aL^b$), where W is the weight and L (the length) was determined through power regression analysis. The test for the length-weight allometric relationship was done using the t-test equation $t_s = |b - 3| / S_b$, where t = test value, b = slope and S = standard error of the slope (b) (Sokal and Rohlf, 1987). For the length-length and weight-weight relationship, a t-test was done using the equation $t_s = |b - 1| / S_b$ (Sokal and Rohlf, 1987). The b values that are significantly differing from the isometric value of b = 3 (Pauly, 1984) for power regression and b = 1 for linear regression are considered allometric.

The relative condition factor (K_n) of an individual scallop was computed using the formula $K_n = W/aL^b$ (Le Cren, 1951) to account for the allometry in the length-weight relationship (Froese, 2006). Meat yield (%) was computed as the ratio AW/TW multiplied by 100. The t-test was used to determine the significant difference in relative condition factors and meat yields between samples collected in May and September. All statistical analysis was undertaken at 0.05 level of significance using Microsoft Excel ver. 16.0.

Results

The data cleaning phase yielded 99 samples for May and 100 samples for September for the final analysis. For the samples in May, the size ranged from 34.55 mm to 73.32 mm SH weighing from 11.91 g to 62.06 g TW. In September, sizes were from 41.22 mm to 68.49 mm SH, and weights of 13.94 g to 60.24 g TW (Table 1). The morpho-biometric relationships of *B. vexillum* were all found to be significant ($P < 0.0001$) showing strong functional relationships for May (R^2 = 0.76 – 0.96) and September (R^2 = 0.78 – 0.96) (Table 2). Since there are almost the same number of samples during the periods studied (i.e., N = 99 for May and N = 100 for September) a direct comparison of the equations with the same units has been performed.

Length-weight relationships

Both SH and SW showed strong functional relationships with TW and AW. However, higher values of coefficients of determination (R^2) were observed in SW-TW as compared to SH-TW in both months.

Table 1. Descriptive statistics of the morphometric and biometric characters of *Bractechlamys vexillum* in May and September.

Month	Measurement	N	Mean ± SE	Min	Max
May	SH (mm)	99	55.11 ± 0.63^a	34.55	73.32
	SW (mm)	99	54.33 ± 0.71^b	33.20	74.05
	TW (g)	99	34.19 ± 1.01^c	11.91	62.06
	AW (g)	99	4.38 ± 0.15^d	1.33	9.20
September	SH (mm)	100	55.66 ± 0.49^a	41.22	68.49
	SW (mm)	100	55.19 ± 0.54^b	40.34	69.14
	TW (g)	100	34.67 ± 0.77^c	13.94	60.24
	AW (g)	100	4.93 ± 0.12^e	1.93	8.90

SH: Shell height, SW: Shell width, TW: Total weight, AW: Adductor muscle weight.
a, b, c, d, e: same superscript for May and September signifies no significant difference in the mean ± SE.

Table 2. Relationship of shell morphometrics and weight measures of *Bractechlamys vexillum* with parameters of allometric equations from samples collected in May and September.

Month	Relationship	*a*	*b*	R^2	*P*
May	SH × SW	-6.2607	1.10	0.96	< 0.0001
	SH × TW	0.0016	2.48	0.89	< 0.0001
	SH × AW	0.0002	2.55	0.76	< 0.0001
	SW × TW	0.0047	2.22	0.92	< 0.0001
	SW × AW	0.0004	2.31	0.81	< 0.0001
	TW × AW	-0.0957	0.13	0.81	< 0.0001
September	SH × SW	-4.0795	1.07	0.96	< 0.0001
	SH × TW	0.0024	2.37	0.88	< 0.0001
	SH × AW	0.0002	2.49	0.78	< 0.0001
	SW × TW	0.0054	2.18	0.90	< 0.0001
	SW × AW	0.0005	2.26	0.78	< 0.0001
	TW × AW	0.1075	0.14	0.80	< 0.0001

SH: Shell height, SW: Shell width, TW: Total weight, AW: Adductor muscle weight.

The relationship of SW-AW also showed higher R^2 value in May. The same value of R^2 was observed for both SW-AW and SH-AW in September. The relationships of SW-TW (Fig. 3) and SW-AW (Fig. 4) showed a curvilinear growth pattern for both months. The pattern of growth for the length-weight relationships was revealed to be negative allometric in both months ($b < 3$, at $P < 0.05$).

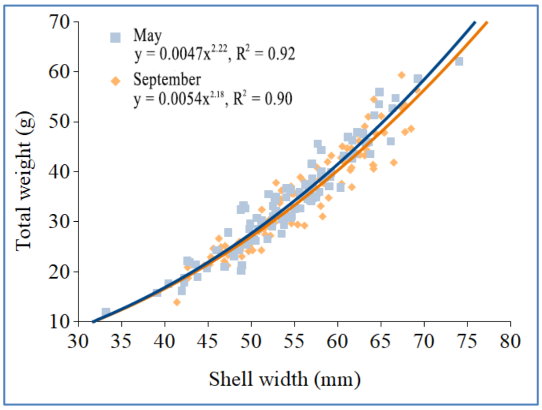

Fig. 3. Curvilinear growth of shell width in relation to total weight of *Bractechlamys vexillum* in May and September.

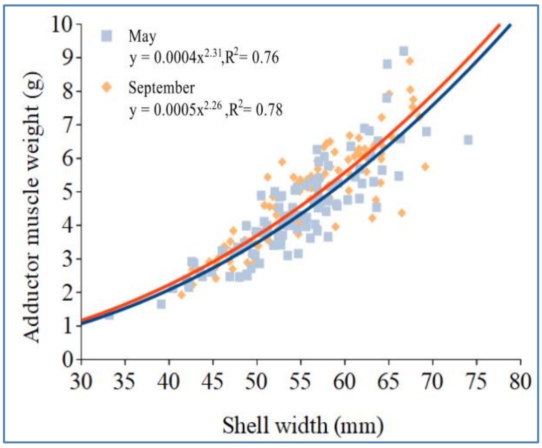

Fig. 4. Curvilinear growth of shell width in relation to adductor muscle weight of *Bractechlamys vexillum* in May and September.

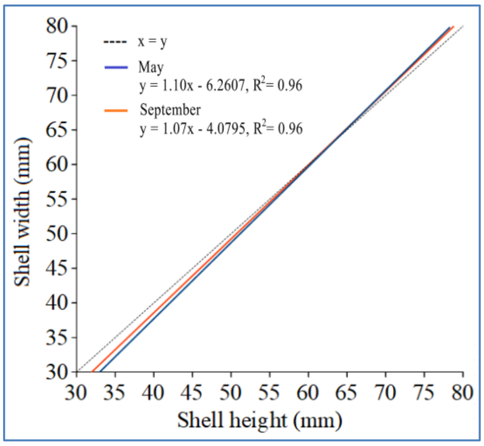

Fig. 5. Linear relationship of shell height and shell width of *Bractechlamys vexillum* in May and September with reference to the isometric line (x = y).

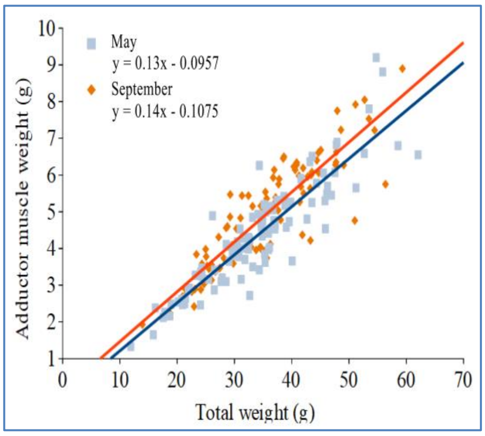

Fig. 6. Linear relationship of total weight and adductor muscle weight of *Bractechlamys vexillum* in May and September.

Length-length relationship

Shell height and shell width have the strongest linear relationship ($R^2 = 0.96$). Positive allometric growth pattern was observed in this relationship for May and September samples ($b > 1$, at $P < 0.05$). Smaller sized *B. vexillum* showed higher size increase in SH in relation to SW, however, as the regression line crossed the line x = y (SW = 62.00 mm), SW becomes the more superior metric (Fig. 5) reversing the trend.

Weight-weight relationship

Total weight revealed to be a good predictor of adductor muscle weight, where AW increased significantly ($P < 0.001$) as TW increased. The coefficients of determination were 0.81 and 0.80 for May and September, respectively. The linear relationship of TW and AW is shown in Figure 6.

Relative condition factor (K_n)

The relative condition factor (K_n) of *B. vexillum* in May ranged from 0.77 to 1.25 with mean ± SD of 1.004 ± 0.089. In September, K_n ranged from 0.72 to 1.25 (1.01 ± 0.097, mean ± SD). Mean K_n for the two periods are not significantly different ($P > 0.05$). The mean K_n values indicate that that species is relatively fat and is in good condition in both periods.

Meat yield

In May, the meat yield ranged from 8.32 % to 18.67 % (12.77 ± 1.69 %, mean ± SD). The meat yield in September varied from 9.33 % to 22.41 % with a mean ± SD of 14.26 ± 1.98. The mean meat yield in May is significantly lower compared to meat yield in September ($P < 0.05$). Nevertheless, the values for meat yields were generally high in both May and September.

Discussion

Tropical environments are characterised by minimal seasonal variation in primary productivity and climate that is needed to trigger significant changes in gametogenesis and spawning (Parsons et al., 1977; Raymont, 1980). Samples between the wet and dry seasons in Asid Gulf did not have significant differences in length, weight, R^2 of the relationships and relative condition factors of *B. vexillum*. In two Philippine sites, the spawnings of the scallop *Chlamys senatoria* (Gmelin, 1791) (Morillo-Manalo et al., 2016) off Gigantes Island, facing the sampling areas of the present study, and the moon scallop *Amusium pleuronectes* (Del Norte, 1988) in Lingayen Gulf, were protracted or continuous throughout the year that resulted from minimal variation in environmental conditions. In Asid Gulf, the dry season (March to May) represents a peak of scallop production (Bobiles and Soliman, 2018) and in the adjacent south Gigantes Island (Acabado et al., 2018). The wet season coincides with the minor spawning peak for Philippine pectinids that is within or close to September (Del Norte, 1988; Morillo-Manalo et al., 2016). Climate seasons in Asid Gulf exert similar effects to the morphometric and biometric characters of the Distant scallop.

The generated empirical equations of morphometrics and weight measures are particularly useful in predicting one variable trait from another trait implying their functional relationships. SH and SW are highly correlated with TW and AW. However, SW was revealed to be a slightly better predictor than SH for both TW and AW based on the higher R^2. According to Hennen and Hart (2012), this relationship is important in scallops since it allows the easy conversion of shell length data into biomass, weight and the soft tissue parts (e.g., adductor muscle). In Distant scallop and other pectinids, the adductor muscle is the main marketed portion so providing an easy way to estimate AW has an economic significance. The relationships of shell morphometrics and weight were revealed to be negative allometric in both periods ($b < 3$ at $P < 0.05$). Negative allometry signifies faster growth in length (SH and SW) as compared to weight (TW and AW). However, allometric growth has been reported for other pectinids like *A. pleuronectes* (Del Norte, 1988) and *C. opercularis* (Taylor and Venn, 1978). The empirical equations obtained in the present study are the first to be reported for this species, thus no comparison can be made for the same species, but practical and technical importance of the findings is demonstrated.

The weight-weight linear relationship of TW and AW yielded high values of R^2. Similar findings were observed for the scallop *P. magellanicus* (Hennen and Hart, 2012). The relationship of whole weight and meat weight allows the conversion of these two units to set catch quotas or trip limits for scallopers who land whole scallops (with shells and soft tissues intact) and those that land only the scallop's meat or adductor muscle. In Asid Gulf, scallop divers land whole scallops only and the removal of soft tissue parts or shuckling is undertaken upon landing of catches. 'Hard' resource management measures like imposing catch quotas and size limit are yet to be implemented. As a first strategy toward this end, a closed season policy has been enforced beginning 2011 by the local government of Cawayan where it is prohibited to gather scallops from December to March in the municipal waters. Implications of the TW-AW relationship can enhance technical inputs to forge future management options as well as mariculture prospects.

In this study, SH-SW regression exhibited the strongest relationship among others that is typical in traits expressed with the same unit (i.e., mm in this case). The highest R^2 is expected in the length-length (morphometric) relationship. This is especially true since higher variations in soft tissue have been reported in different species of scallops (Ansell, 1974; Comely, 1974; Taylor and Venn, 1978, 1979; Barber and Blake, 1981; Macdonald and Thompson, 1985; Brokordt et al., 2000; Beltrán-Lugo et al., 2006). In the relationship of SH and SW, it can be observed in Figure 5 that the regression lines of samples from both May and September crossed the isometric line ($x = y$) at 62.00 mm at 43–45 g total weight. It means that as the shell grows, there is a change in the proportion of SH and SW which reverses from before and after the intersection point. Thus, in smaller individuals, height is greater than the width, but as it increases in size, the width grows faster than the height. In older individuals, SW tends to be slightly longer than SH. This type of growth is positive allometry where SW grows relatively faster than SH. A similar result was observed for the species *C. opercularis* from Clyde Sea (Taylor and Venn, 1978). Biologically, the intersection point may present significance to reproduction because it coincides with the size-at-maturity of the species estimated at 60 mm (Soliman and Dioneda, 2004). The reversal of the faster growth in length in favour of SW occurs passed this intersection point. In bivalves, the shape of the shell is less affected by the fluctuation of the ambient environment as compared to the weight (Seed, 1968; Thompson and Macdonald, 2006; Singh, 2016) whereby the growth dynamics of every metric poses an interesting biological study.

The relative condition factor (K_n) determined in this study shows the status of the "well-being" of the Distant scallop. K_n measures the deviation of the actual weight of the individual species from the hypothetical weight based on the length-weight relationship (Le Cren, 1951). Thus, a K_n value that is equal to or greater than 1.0 would indicate that the species is relatively "fat" or "plump". In this study, the mean relative condition factor for samples collected in May and September is 1.004. Furthermore, the mean relative condition factor of *B. vexillum* in May is not significantly different from that of September ($P > 0.05$). Therefore, it can be concluded that for dry and wet seasons, the scallops are relatively "fat" and in good condition. Although K_n was originally used to determine conditions in fishes, it has been used successfully in bivalves like *Anadara gubernaculum* (Reeve, 1844) (Fauzan et al., 2018), *Perna viridis* (Linnaeus, 1758) and *Meretrix meretrix* (Linnaeus, 1758) (Sharma et al., 2005) because it is both simple and appropriate (Bolger, 1989).

The calculated mean meat yield of the scallops is significantly lower in May as compared to September. In scallops, meat yields vary seasonally in relation to gametogenesis and reproduction (Barber and Blake, 2006, 2016) and may explain the difference between months. However, this aspect was not investigated in the present study. Further studies are necessary to determine the reproductive cycle of *B. vexillum* and its influence on meat yield. Nevertheless, the meat yield in the two periods is considered high. The adductor muscle usually makes up about 10 % of the total scallop weight (Naidu, 1987). In this study, meat yields of *B. vexillum* in May (12.77 %) and September (14.26 %) were revealed to be high. It means good quality adductor muscles are extracted from the species during the dry and wet seasons. This finding is particularly significant as income from scallops is primarily determined from the quality and quantity of the adductor muscle. Other parts like gills, gonads, and intestines are now being bought by local residents as food for pigs, but the price is still very low. The average meat yield in *B. vexillum* (12.77–14.26 %) is similar to the scallop *F. glaber* (8.61-15.02 %) across seasons of the year (Berik et al., 2017). The high meat yield and relative condition factor are good qualities of a species as mariculture prospect. Based on the observed morpho-biometric characteristics of *B. vexillum*, the species is a suitable candidate for scallop mariculture.

Conclusion

This study represents the first examination of the relationships of morphometrics and biometric characters of *B. vexillum*. The length-weight, length-length, and weight-weight regressions in *B. vexillum* generated useful values in predicting one trait from another since functional relationships exist among them. Shell width proves to be a slightly better predictor than shell height for total weight and adductor muscle weight. Biometrics of the species with economic significance such as the high relative condition factor and meat yield are important findings for culture development. Further studies on the species are necessary to understand the dynamics of growth as influenced by other environmental covariates like depth, fishing pressure, population density and reproduction. The intensive fisheries, urgency for effort reduction and the necessity for culture techniques development are noteworthy and should form the basis for future research.

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