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Studies on the biometry of hatchery-produced and farmed asian pearl oyster *Pinctada imbricata fucata* (Gould, 1850) along the southwest coast of India

Mary Rinju, R.[1*], Anil, M.K.[1] and Sherly Williams, E.[2]

[1] *Research Centre of ICAR-Central Marine Fisheries Research Institute, Vizhinjam - 695 521, Kerala, India*
[2] *Department of Environmental Sciences, Kariavattom Campus, University of Kerala, Thiruvananthapuram - 695 581, Kerala, India*
**E.mail: dr.rmaryrinju@gmail.com*

ABSTRACT

The pearl oyster, *Pinctada imbricata fucata,* one of the major pearl-producing bivalves widely demanded for its lustrous quality pearls, holds a significant status worldwide due to its economic potential in pearl production. The current work is a comprehensive study on the changes in morphometry of hatchery-produced *P. imbricata fucata,* which is farmed at Vizhinjam Regional Centre in the Bay waters. In order to investigate the biometric relationships of *P. imbricata fucata,* statistical analysis was done on its various morphometric parameters, including dorsoventral measurement (DVM) – total weight (TWT), hinge length (HL) – total weight(TWT), dorsoventral measurement (DVM) – thickness (THK), total weight (TWT) – the thickness (THK), dorsoventral measurement (DVM) – shell weight (SWT), total weight (TWT) – shell weight (SWT) – flesh weight(FWGT) – dry flesh weight (DFWT) and total weight(TWT) – flesh weight (FWGT) – dry flesh weight (DFWT) with dorsoventral measurement (DVM). Statistical analysis using least square techniques and correlation analysis were carried out. The scatter diagrams fitted with straight-line obtained during the regression analysis explain high correlation among the concerned variables at $P < 0.001$. Also, it was found that in Vizhinjam waters, the TWT, THK, SWT, FWT and DFWT of *P. imbricata fucata* increased at a rate of 3.02, 1.005, 2.934, 3.157 and 3.048 times in proportion with DVM. The THK, SWT, FWT, DFWT and HL of *P. imbricata fucata* increase proportionally with that of TWT at a rate of 0.324, 0.968, 1.042, 1.008 and 2.95 times, respectively.

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1. Introduction

Pearl oyster *Pinctada imbricata fucata* (A. Gould,1850), a marine bivalve mollusc belonging to the family Pteriidae, native to the shallow waters of the Indo-Pacific, has a high demand in the pearl culture industry. Pteriidae species, particularly abundant in the Indo-Pacific, are predominantly distributed in shallow waters of the tropical and subtropical continental shelf regions around the globe (Southgate and Lucas, 2008).The genus *Pinctada* generally prefers rigid substrates, which are often seen in crevices like rocky, gravel and shelly bottoms, live and dead coral, but individuals are sometimes observed on sandy bottoms (Ranson, 1961; Rao and Rao, 1974; Butler, 1998; Hayami, 2000).

P. imbricata fucata, the Indian pearl oyster, produces fine-quality pearls. It is widely distributed across Asia and occurs on the Eastern Coast of Australia (Gifford *et al.*, 2004). It is well-known for its vibrantly coloured and untreated pearls (Otter *et al.*, 2017). *P. imbricata fucata* was first commercially cultivated in Japan, and Japan dominated its market until the outbreak of the Akoya viral disease in 1996. Dating back to the pioneering work in the early 1900s by Japanese entrepreneur Kokichi Mikimoto, the bivalve mollusc, *P. imbricata fucata,* has long been used to produce Akoya cultured pearls (Strack, 2006).

Considering its importance in pearl culture, a better understanding on the morphometry of this species under sea-based culture system is crucial. Also, it gives an insight into the influence of growing environment in the growth patterns; which is thereby helpful in diagnosing the ideal biometric relationships of oysters. As the optimum size of the nuclei implanted in the oyster directly depends on its cavity size, baseline information on its biometry is critical in the pearl culture industry. In *P. imbricata fucata*, the body and shell are asymmetrical, and the shell appears like a horseshoe (Wada, 1991). According to Bagenal and Tesch (1978), allometric studies occupy a specific space in biological studies, which reflects the growth patterns in several aquatic animals that may express the rates of a wide array of metabolic processes and can be used for describing the interactions between increments in lengths allied with an increase in weight.

In the pearl oyster culture technique, hatchery production is a better solution for the supply of oysters rather than just depending on wild stocks. A spat size of at least 3mm is required to minimize mortality (Chellam *et al.*, 1991) during field culture. As a result of growth, changes occur in the ratio of the various parts of an organism (Reiss, 1989), and the studies involved in the change in morphometry of an organism is the biometrics. In the twentieth century, the success of pearl oyster farming in the South-Pacific and Indo-Pacific islands resulted in increased demand, interest, and research on its biology and environments in most countries of tropical seas. In India, studies on the biometric relationships of bivalves were given considerable attention, but mostly concerning commercially exploited wild stocks (Hemachandra and Thippeswamy, 2008, Jayalakshmy *et al.*, 2013, Nagvenkar *et al.*, 2014).

No previous studies were reported on the biometry of *P. imbricata fucata* in Vizhinjam waters. The present paper deals with the biometric relationship studies of *P. imbricata fucata* and explains the results. The current work is a detailed study on the changes in morphometry of *P. imbricata fucata* hatchery-produced and farmed at Vizhinjam Regional Centre over time. The study site was Vizhinjam Bay, which is situated along the southern coast (76˚59' E; 8˚22'30" N) of Kerala.

2. Materials and Methods

Following the method described by Anil *et al.* (2014), the larvae of *P. imbricata fucata* were produced by the strip spawning method in the laboratory of Vizhinjam Research Centre of CMFRI. Larvae were reared in the hatchery in one-tone FRP tanks for 103 days until they reached an average dorso-ventral measurement (DVM) of 3.99 mm, hinge length (HL) of 3.94 mm, thickness (THK) of 1.25 mm and weight (WGT) of 0.008 g. Then, the larvae were transferred to the sea and reared in plastic baskets and box cages, depending on their age and growth (Rinju *et al.*, 2020).

Twenty-five oysters were randomly selected from each age group, and morphometric data was recorded on their dorsoventral measurement (DVM), hinge length (HL), thickness (THK), total weight (TWT), shell weight (SWT), flesh weight (FWT) and dry flesh weight (DFWT). Monthly data was taken for two years (June 2015 to May 2017). Statistical analysis was done on the biometry of oysters, including the relationship between DVM - TWT, HL - TWT, DVM - THK, TWT - THK, DVM - SWT, TWT - SWT - FWGT- DFWT and TWT - FWGT - DFWT with DVM using least square techniques and correlation analysis was also done using the SPSS software.

The dimensional relationships were calculated and represented by the equation;

$Y = a \pm Bx$ (Hile, 1936, Bagenal and Tesch, 1978)

Where,

Y = dependent variable,

x = independent variable,

a = constant and equal to the intercept of the straight line with the Y-axis;

B = the coefficient of allometry.

The statistical method (least square method) was used, and the coefficients "a" and "b" were calculated by plotting log Y (dependent variable) against log X (independent variable) following the formula:

$\text{Log } Y = \text{Log } a \pm b \log X$ (Hile, 1936, Bagenal and Tesch, 1978)

To measure dry meat weight, flesh from the shells was removed using forceps and a scalpel, and the excess moisture was blotted using blotting paper, weighed and then dried in a hot air oven at a constant temperature of 72°C for 24 hours. And this is how the dry flesh weight of oysters was taken. In some samples, dead and live organic growths were found settled over the oyster shells and before taking them for biometric studies, the attached biofoulers were scraped off, and the shells were cleaned. A digital vernier calliper (to the nearest 0.1 mm) was used to measure shell dimensions, and an electronic balance (Sartorius, d = 0.1 mg) was used for recording the weight.

3. Results

3.1. Dimensional Relationships

From the results, the scatter diagrams obtained during the regression analysis were fitted with a straight line, which shows a high correlation between the concerned variables. The regression lines obtained were statistically significant at $P< 0.001$. Also, it is clear from the results that, in Vizhinjam waters, the TWT, THK, SWT, FWT and DFWT of *P. imbricata fucata* increases proportionally with that of DVM at a rate of 3.02, 1.005, 2.934, 3.157 and 3.048 times, respectively. In the case of other factors, i.e., THK, SWT, FWT, DFWT and HL increase at a rate of 0.324, 0.968, 1.042, 1.008 and 2.95 times correspondingly with TWT.

The dimensional relationships between the concerned variables (DVM - TWT, DVM - THK, DVM - SWT, DVM - FWT, DVM - DFWT,TWT - THK,TWT - SWT, TWT - FWT, TWT - DFWT and HL - TWT) are shown in (Fig. 1 to 10). The correlation coefficients obtained were very high, which signifies a high positive association between the concerned variables in all size groups.

The regression equation deriving the TWT – DVM relationship is;

$$\text{Log } Y = -8.913 + 3.020 \text{ Log } X$$

Where, X = dorsoventral measurement (DVM) in mm and Y = total weight (TWT) in g.

The regression equation deriving the THK – DVM relationship is;

$$\text{Log } Y = -1.117 + 1.005 \text{ Log } X$$

Where, X = dorsoventral measurement (DVM) in mm and Y = thickness (THK) in mm.

The regression equation deriving the SWT – DVM relationship is;

$$\text{Log } Y = -9.241 + 2.934 \text{ Log } X$$

Where, X = dorsoventral measurement (DVM) in mm and Y = shell weight (SWT) in g.

The regression equation deriving the FWT – DVM relationship is;

$$\text{Log } Y = -10.54 + 3.157 \text{ Log } X$$

Where, X = dorsoventral measurement (DVM) in mm and Y = flesh weight (FWT) in g.

The regression equation deriving the THK – TWT relationship is;

$$\text{Log } Y = 1.871 + 0.324 \text{ Log } X$$

Where, X = total weight (TWT) in g and Y = thickness (THK) in mm.

The regression equation deriving the DFWT – DVM relationship is;

$$\text{Log } Y = -12.02 + 3.048 \text{ Log } X$$

Where, X = dorsoventral measurement (DVM) in mm and Y = dry flesh weight (DFWT) in g.

The regression equation deriving the SWT – TWT relationship is;

$$\text{Log } Y = -0.574 + 0.968 \text{ Log } X$$

Where, X = total weight (TWT) in g and Y = shell weight (SWT) in g.

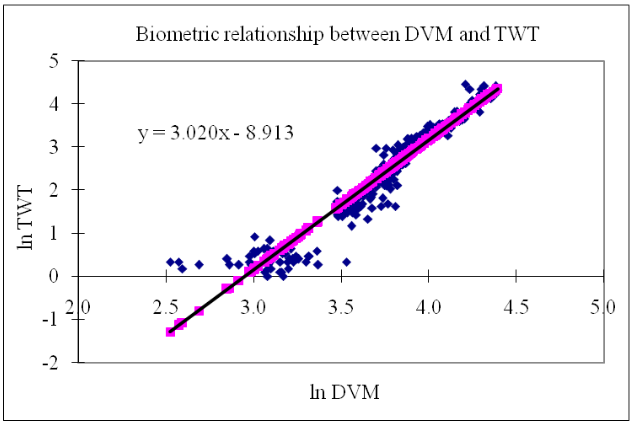
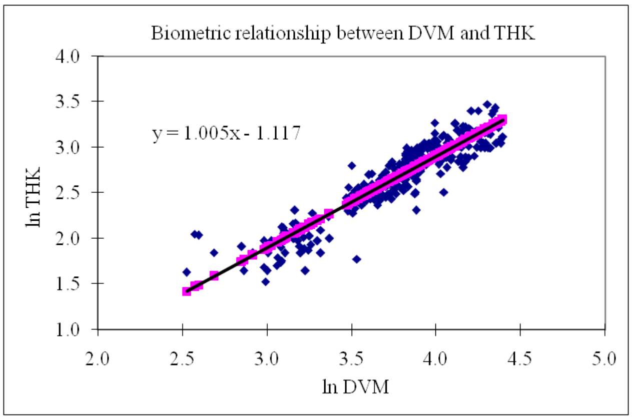


Fig. 1.



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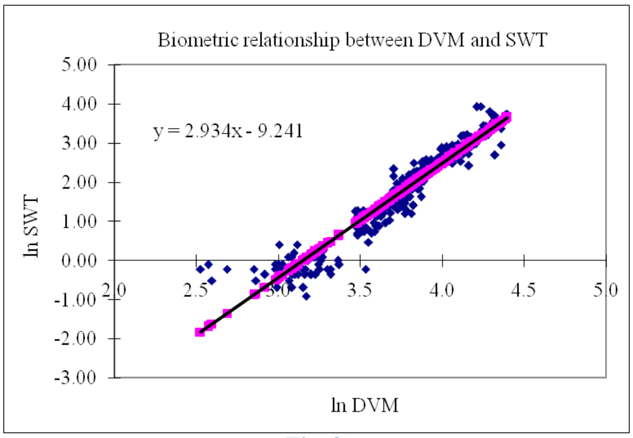

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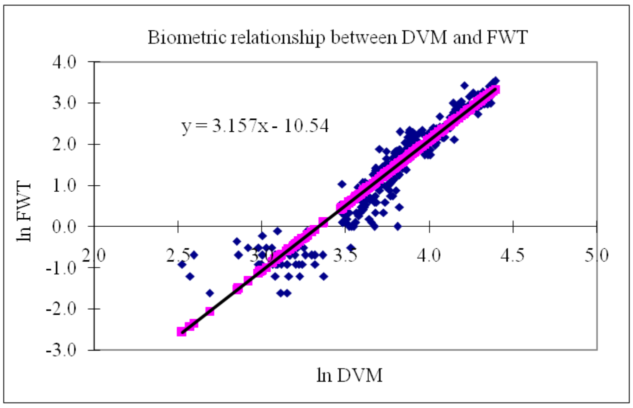

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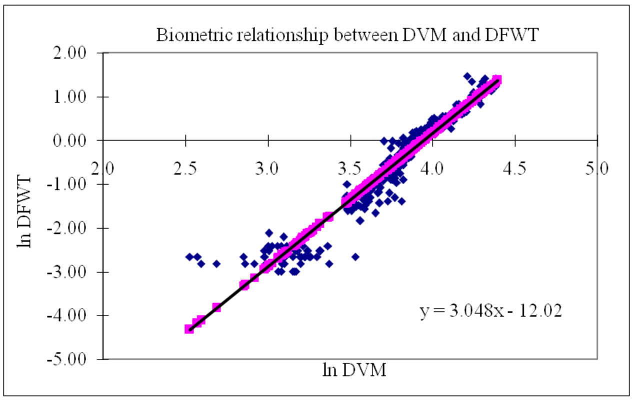

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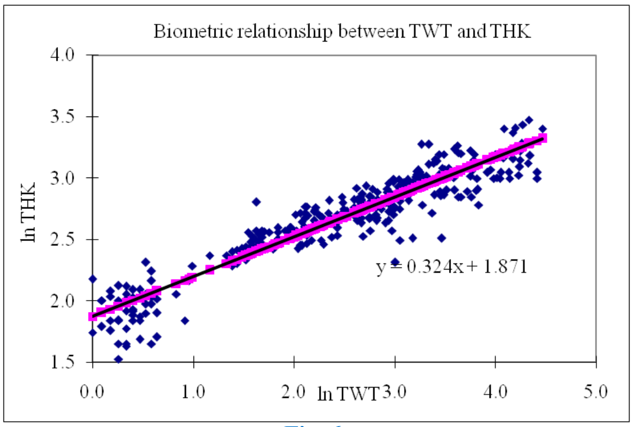

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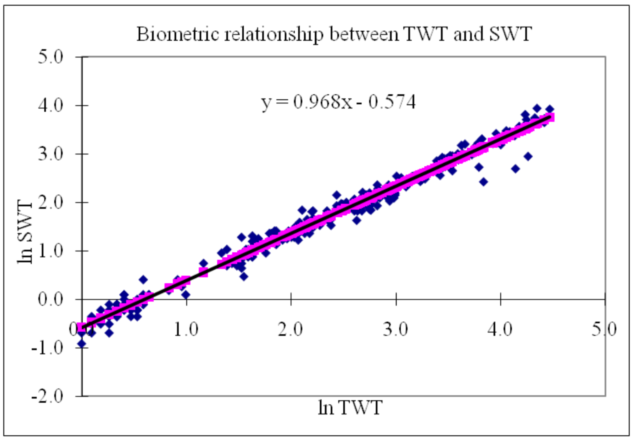

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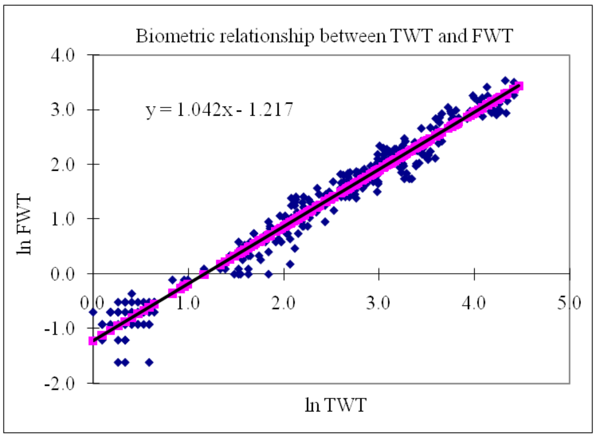

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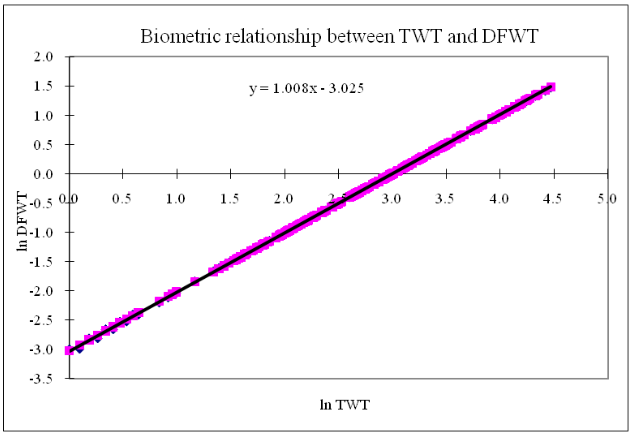

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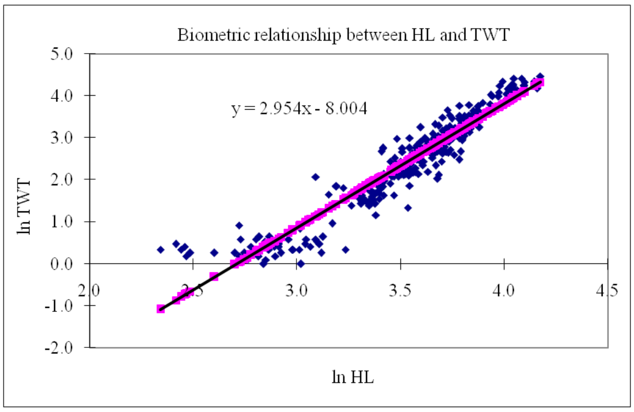

Fig. 10.

The regression equation deriving the FWT–TWT relationship is;

Log Y = - 1.217 + 1.042 Log X

Where, X = total weight (TWT) in g and Y = flesh weight (FWT) in g.

The regression equation deriving the DFWT – TWT relationship is;

Log Y = - 3.025 + 1.008 Log X

Where, X = total weight (TWT) in g and Y = dry flesh weight (FWT) in g.

The regression equation deriving the HL – TWT relationship is;

Log Y = - 8.004 + 2.95 Log X

Where, X = total weight (TWT) in g and Y = hinge length (HL) in mm.

During the present study, variations were observed in the DVM - TWT of various age groups, which was found to be influenced by the flesh weight of the animal. Current results also showed that the concerned correlates TWT - DVM and DFWT - DVM follow an isometric growth mode (b = 3). FWT - DVM follows a positive allometric pattern (b > 3), and THK - DVM, SWT - DVM, THK - TWT, SWT - TWT, FWT - TWT, DFWT -TWT and HL - TWT follow a negative allometric form of growth (b < 3). Results of the One-Way ANOVA tests were found to be statistically significant at P < 0.001 (Table 1). Correlation analysis results were found to be statistically significant at ** P < 0.001 (Table 2).

The slope (b), values of intercept (a) and correlation coefficients (R) of the biometric relationships for various size groups of *P. imbricata fucata* in Vizhinjam waters are given in Table 3.

Table 1. The One way ANOVA results on the dimensional relationships of *P. imbricata fucata* oysters of different size groups (**P < 0.001).

Variables		Df	SS	MS	F	Significance F
DVM – TWT	Regression	1	368.3716	368.3716	3487.035	1.6E-166
	Residual	298	31.48083	0.10564		
	Total	299	399.8524			
DVM - THK	Regression	1	40.82045	40.82045	1640.759	3.3E-123
	Residual	298	7.413943	0.024879		
	Total	299	48.23439			
DVM - SWT	Regression	1	347.6157	347.6157	3032.949	3E-158
	Residual	298	34.1547	0.114613		
	Total	299	381.7704			
DVM – FWT	Regression	1	402.4833	402.4833	2507.808	3.9E-147
	Residual	298	47.82664	0.160492		
	Total	299	450.31			
DVM - DFWT	Regression	1	375.2066	375.2066	3514.064	5.6E-167
	Residual	298	31.8183	0.106773		
	Total	299	407.0249			
TWT – THK	Regression	1	42.01541	42.01541	2013.287	1.4E-134
	Residual	298	6.218981	0.020869		
	Total	299	48.23439			
TWT – SWT	Regression	1	374.9188	374.9188	16306.6	3.3E-262
	Residual	298	6.851569	0.022992		
	Total	299	381.7704			
TWT – FWT	Regression	1	434.4823	434.4823	8180.339	1E-218
	Residual	298	15.82767	0.053113		
	Total	299	450.31			
TWT- DFWT	Regression	1	406.9453	406.9453	1523943	0
	Residual	298	0.079576	0.000267		
	Total	299	407.0249			
HL – TWT	Regression	1	360.1729	360.1729	2704.962	1.5E-151
	Residual	298	39.67949	0.133153		
	Total	299	399.8524			

Table 2. Multivariate Pearson correlation coefficient between different shell biometry of *P. imbricata fucata* in Vizhinjam waters

Parameters	DVM	HL	THK	TWT	SWT	FWT	DFWT
DVM	1						
HL	0.961**	1					
THK	0.898**	0.898**	1				
TWT	0.915**	0.876**	0.821**	1			
SWT	0.884**	0.850**	0.798**	0.974**	1		
FWT	0.894**	0.854**	0.772**	0.963**	0.927**	1	
DFWT	0.915**	0.876**	0.821**	1.000**	0.974**	0.963**	1

** $P < 0.001$

Table 3. The slope (b), values of intercept (a) and correlation coefficients (R) for the linear relations in different size groups of *P. imbricata fucata* in Vizhinjam waters.

Sl. No.	Variables	Slope "b"	Y-intercept "a"	R
1	TWT – DVM	3.020	- 8.913	0.9598
2	THK – DVM	1.005	- 1.117	0.9199
3	SWT – DVM	2.934	- 9.241	0.9542
4	FWT– DVM	3.157	-10.54	0.9454
5	THK–TWT	0.324	1.871	0.9333
6	DFWT–DVM	3.048	- 12.02	0.9601
7	SWT–TWT	0.968	- 0.574	0.9909
8	FWT–TWT	1.042	- 1.217	0.9822
9	DFWT–TWT	1.008	- 3.025	0.9999
10	HL – TWT	2.95	-8.004	0.9490

4. Discussion

The study of the relationship between differences in one body parameter (Gimin *et al.*, 2004) to the other which is termed allometry, provides significant information regarding the comparative growth of various body parameters in an animal. The allometric relationship is considered the most reliable method for marine bivalves to determine the growth pattern and harvesting size for maximizing aquaculture production (Hemachandra and Thippeswamy, 2008; Ashwin *et al.*, 2013). *P. imbricata fucata*, one of the chief sources of natural and cultured pearls, holds a significant position in the world's pearl culture industry, meeting the demand for both mother-of-pearls and pearls. Since ancient times, it has been one of the world's greatest sources of natural pearls. This is the first work that has attempted to examine the biometry of the pearl oyster species *P. imbricata fucata* under a culture system along the southwest coast. And the work is mainly done to understand the changes in morphometry of oysters over time. The present study gives a clear-cut picture of the biometry of *P. imbricata fucata* in Vizhinjam waters. Results showed a straight-line relationship, which was found to be statistically significant at $P < 0.001$.

Knowledge of the allometry of shell and soft body characters is essential for understanding the growth of species (Gould, 1966).The present study's results, which were carried out in different ages of *P. imbricata fucata,* show a very high correlation between the concerned growth parameters. During the present study, a significant correlation was observed for the dependent variables i.e., TWT, THK, SWT, FWT and DFWT with DVM; in the cases where DVM was taken as an independent variable. Previously, Alagarswami and Chellam (1977) conducted studies on the dimensional relationships of *P. fucata* from the Gulf of Mannar and suggested the dorsoventral, hinge line anteroposterior, and the thickness measurements are in a linear relationship of the form $y = a + bx$. The shell volume enlargement occurs during the growth of marine bivalves, letting the individual produce more visceral mass that considerably increases during the maturation and reproductive phases of the animal. De Paula and Silveira (2009) reported that the relationship between shell length and other dimensions in bivalves could provide an idea of the pattern of shell growth or its dimensional changes. Another independent variable considered for the current study was the TWT and the chosen variables viz., THK, SWT, FWT and DFWT were found to be highly correlated with TWT.

In biometric relationship studies, the rate of change of the relative animal body shape during the growth process was expressed by the constant "b", which is also known as the coefficient of allometry or coefficient of regression (Laxmilatha, 2008). Current results showed that the value of exponent "b" for the correlate, flesh weight vs. dorsoventral measurement exceed '3.00', which indicates a positive allometric pattern of growth. As the flesh weight represents the integrated response of entire physiological activity of the organisms, it is a useful indicator for pearl oyster health and suitability of the environment. And so, growth information is of great interest for pearl farming (Pouvreau *et al.*, 2000). Also, the relationship of total weight and dry flesh weight against DVM was found to be in an isometric growth pattern (i.e., b = 3). Other parameters viz., thickness, shell weight, flesh weight, dry flesh weight and hinge length against total weight were taken into consideration and confirmed that the values of exponent "b" which was found as less than 3; indicating a negatively allometric growth mode. And the significance "F" for TWT versus DFWT was found to be zero, which implies that the means in every group is equal.

Oyster thickness is a key factor and most important morphological character in the aquaculture of many Pinctada species because it directly affects the size and number of the inserted pearl nuclei (Hwang *et al.*, 2007). With an increase in the THK: DVM ratio with age, *P. fucata* has been described as the most convex of all species of pearl oysters (Hynd, 1955). Along with the weight, thickness also holds a critical place in predicting nuclei size in *P. imbricata fucata* (Mohamed *et al.*, 2006). According to Chellam (1988), with the age of oysters, thickness also increases in *P. fucata*. It is one of the important parameters that decides the size of the nuclei that can be implanted, which determines the size of the pearl produced. From the present study results, it is obvious that the relationship of thickness (b = 1.005) and shell weight (b = 2.934) versus dorsoventral measurement follows a negative allometric pattern of growth. Since the shell increment and deposition of nacreous matter on the implanted nucleus are strongly correlated, shell dimensions hold a significant role in providing information regarding pearl growth (Coeroli and Mizuno, 1985). And the use of regression analysis to explain the allometric relationship between various biometric characters is found to be most suitable (El-Sayed *et al.*, 2011).

The results of the present study also exemplify the growth mode of *P. imbricata fucata* in Vizhinjam waters. Clear - cut information on the allometry, condition indices and biometric traits of marine bivalves are essential to determine their growth pattern and harvesting size (Noor *et al.*, 2021). Current results indicate a very high correlation between the established morphometric relationships and the correlation coefficients (R) obtained were ranged from 0.9199 to 0.9999, which was found to be highly significant ($P < 0.001$).Previously, Alagaraja (1962) pointed out the role of length-weight relationships in predicting pearl fishery. Rao (2007) conducted studies on the dimensional relationships of *Pinctada fucata* (Gould) under a long term onshore rearing system and pointed out the importance of these studies in planning bead size for seeding operations. Earlier works published by Devanesan and Chidambaram (1956) on the length-weight relationship of pearl oysters of Gulf of Mannar described a linear relationship for each year group separately. In other species, (*P. margaretifera* and *P. radiata*) also discussed the relevance of biometric studies in the pearl industry (Abraham *et al.*, 2007; Moussa, 2013). In other species, Abraham *et al.*, 2007(*P. margaretifera*), Moussa, 2013 (*P. radiata*) also discussed the relevance of biometric studies in the pearl industry.

For calculating the growth and production of an organism, allometric relationship is often used (Meher *et al.*, 2006). Age is presumably the essential endogenous factor affecting the growth of a bivalve (Moussa, 2013). And the morphometry of the shell could reflect the level of growth rate in molluscs (Alunno-Bruscia *et al.*, 2001). From the current study results, it can be understood that the TWT, THK, SWT, FWT and DFWT of *P. imbricata fucata* in Vizhinjam waters increases at a rate of 3.02, 1.005, 2.934, 3.157 and 3.048 times in proportion with DVM. The site and its interaction with the environment are important determinants of growth and shell dimensions in the case of *P. fucata* (Mohamed *et al.*, 2006). Earlier, size related variations were reported in the length and weight of *P. fucata* in the mainland waters of India by Alagaraja, 1962; Chellam, 1988; Mohamed *et al.*, 2006. Wada (1984) previously discussed on the inheritability in shape and size of shell in *P. fucata martensii* in different areas of Japan. From the present results it was also clear that the THK, SWT, FWT, DFWT and HL of *P. imbricata fucata* increase proportionally with that of TWT at a rate of 0.324, 0.968, 1.042, 1.008 and 2.95 times respectively in Vizhinjam waters. Due to the stronger correlation showed by the dependent variables to DVM and TWT, these two independent variables might be taken as the most useful biological variables of *P. imbricata fucata*.

It is due to the physiological conditions and environmental factors that, in nature, some individuals of the same age or lengths exhibit differences in their weights (Seed, 1968; Winberg, 1971; Lee, 1986; Gasper *et al.*, 2002). Length - weight relationship studies aid in the estimation of biomass from commercial processing data (El-Sayed *et al.*, 2011) and also helps predict a population's age structure. Lim *et al.*(2020) conducted studies on the length-weight relationship and relative condition factor of pearl oyster, *P. fucata martensii* cultured in the Tieshangang Bay of the Beibu Gulf and opined that the bay was healthy and suitable for pearl oyster farming. According to Grkovic *et al.* (2019), differences in biometric parameters are decisive for consumers' purchase decisions and directly influence the aspect of mussels. For selecting high growth lines and improving selection efficiency in *P. fucata* through breeding practices, shell height that has the closest relationship with bodyweight could be considered a vital factor (CaiGang, 2015). And this may increase the market - value of pearl oysters with large mantle size.

P. imbricata fucata is valued for its shells; its lustrous nacre is used in the mabe and spherical pearl production technology. In the present study, the independent variables such as dorso-ventral measurement (DVM) and total weight (TWT) may be considered as the most useful biological variables to predict shell biometry, because of the higher correlation coefficient values; exhibited by the dependent variables with them. Hence, present findings on the biometric relationships of *P. imbricata fucata* from Vizhinjam waters will be helpful in the commercial utilization of this species for pearl production, as the size of the oyster holds a crucial factor in the spherical and mabe pearl production.

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5. References

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