E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2017; 5(3): 335-340

www.fisheriesjournal.com
Received: 12-03-2017
Accepted: 13-04-2017

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Biometric relationships, condition factor and relative weight of *Lingula anatina* (Lamarck, 1801) at Thuy Trieu lagoon, Khanh Hoa, Vietnam

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Abstract
The present study investigated biometric relationships, condition factor (K) and relative weight (Wr) of *Lingula anatina* at two locations: Cam Hai Tay (CHT) and Cam Thanh Bac (CTB) in Thuy Trieu lagoon (Khanh Hoa province, Vietnam). Length - weight relationship equations were $W = 0.0473\ L^{3.1405}$ and $W = 0.0728\ L^{2.7689}$ for *L. anatina* at CHT and at CTB, respectively. The *b* value was isometric for *L. anatina* at CHT, but negative allometric for *L. anatina* at CTB. Length – weight and shell dimension were significant correlation, with r^2 over 0.885. K and K_{mean} were significantly higher in CTB compared to CHT ($P < 0.001$). Relative weight (Wr) values of *L. anatina* did not significantly differ between the two locations (CHT and CTB), and Wr values of *Lingula* at both CHT and CTB were not significantly different from critical value (100). Relationships between K_{mean} and shell size were significantly linear, but with a positive correlation for the population at CHT, and an inverse correlation for the population at CTB.

Keywords: Lingula anatina, growth, length-weight relationship, condition factor

1. Introduction
Brachiopod, genus *Lingula* is a member of family Lingulidae and phylum Brachiopoda which is widely geographically distributed in Pacific and Indian, Atlantic oceans close to the west coast of Africa [1]. *Lingula anatina* (Lamarck, 1801) – local people called Gia Bien - is one of the major components of fishing at Thuy Trieu lagoon, Vietnam. This species are exploited by the fishermen using diving, digging the soil at low tide. *L. anatina* is valuable seafood for human as well as used for aquaculture feed. Despite its wide distribution and the high abundance of this species, and exploitation by local fishermen, there is a limited understanding of the *L. anatina* biology along the coast of Vietnam.

Length – weight relationship (LWR) is a powerful tool which is widely used in fisheries research. As length is easier to measure, LWR can be used to convert calculation of fish weight, based on the known length [2, 3]. In addition, LWR parameter can provide important information about the structure and function of populations in fisheries research [4]. LWR is also a valuable indicator to estimate the life history of fish in regarded to their habitats or regions [5]. Furthermore, knowledge of the biology of commercially important fish in economic terms (size values, i.e. minimum, maximum, and mean; and size relationships, i.e. length – weight) helps for the sustainable exploitation of the natural resources. Population dynamics of brachiopod *L. unguis* was reported in Korea [6] or the ecology and reproduction of *L. anatina* in Australia [7, 8] or distribution of *L. reevii* in the USA [9]. However, to the author knowledge, there is no information on the population biology of brachiopod, *L. anatina* in Vietnam.

Beside the LWR, condition factor (K) is a main parameter used in fishery study, and they have been closely related since they were first proposed [10]. The value of K is calculated from the weight and length, and can be used to estimate changes in nutritional condition. Few studies in recent years have examined the K value for *L. anatina*. Earlier studies show that the K values for other fish and mollusk change by season and locations [10, 11]. In addition, although the biometric parameters and condition factors and relative weight can reflect the well-being status, feeding and physiological condition of a species, no studies that combine analysis of the two indices on lampshell. Possibly variation of length, weight and condition factors occur between locations or populations, but this has never been evaluated on *L. anatina*. Thus, it remains unclear the population characteristics of *L. anatina* in Vietnam.

The aim of the present study is to provide a comprehensive analysis of biological parameters including shell size-weight relationship, shell dimension relationships, condition factor, relative weight and mean condition factor of *L. anatina* populations at Thuy Trieu lagoon. The possible regional variations of size, weight and condition factor were also examined in present study.

Materials and Methods

Study area and sampling

Lingula anatina (Lamarck, 1801) were collected at two locations: Cam Hai Tay (12º05'56"N, 109°09'25"E, N = 552) and Cam Thanh Bac (12º02'16N, 109º10'43"E, N = 553). Both locations are located at Thuy Trieu lagoon, Khanh Hoa province, Vietnam (Fig. 1). Collected samples were fixed in formalin 10% before transported to the laboratory. Their shell dimensions: shell length (L), shell width (SW) and shell thickness (ST) were measured by callipers to the nearest 0.01 cm. Whole body weight and soft part weight also measured by an electronic balance to the nearest 0.01 g accuracy.

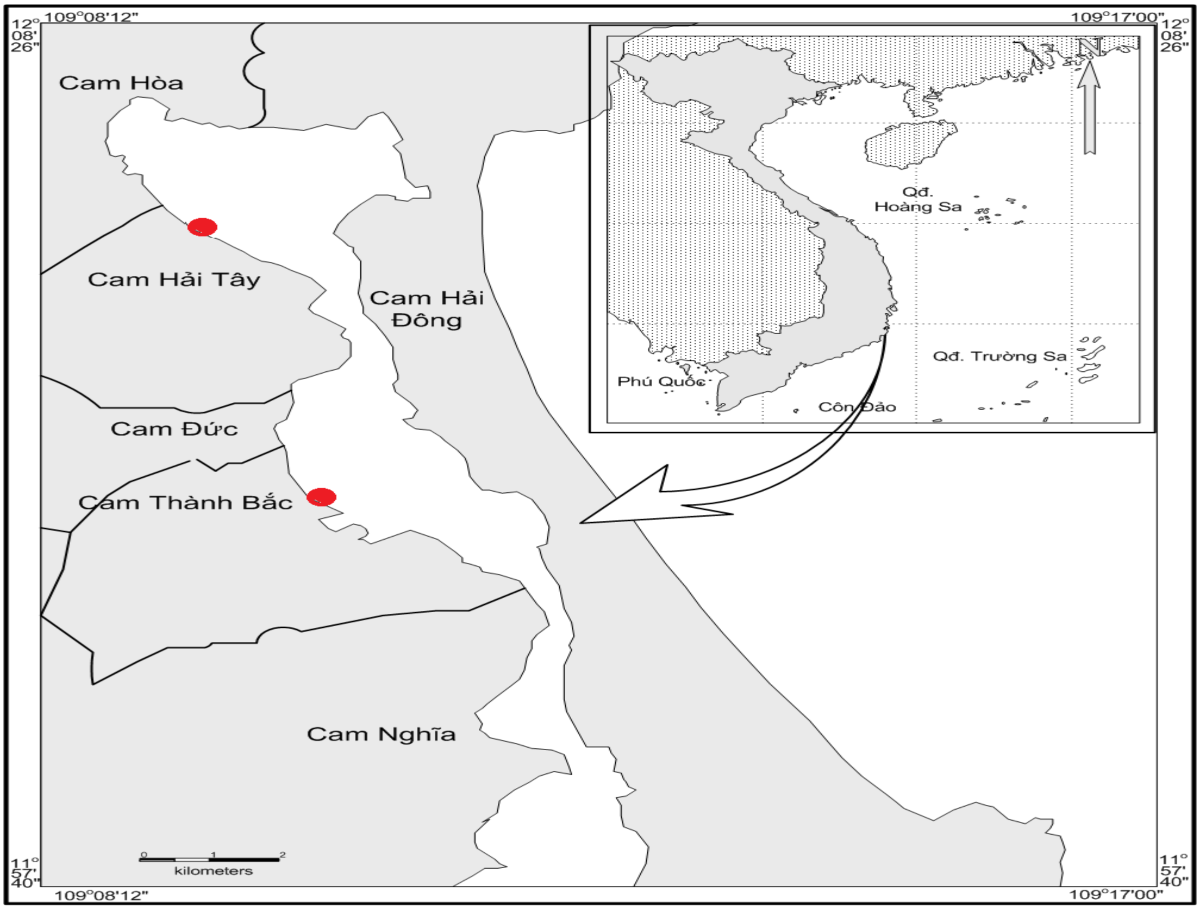

Fig 1: Map of Thuy Trieu lagoon and sampling locations (●).

Length – Weight, Length – Length relationships and Condition factor

The length – weight relationship (LWR) was expressed by the equation: $W = a L^b$ [10, 12], where W: whole body weight (g), L: shell length (cm), *a:* constant (intercept), *b*: exponent of a length-weight relationship. The LWR equation was then transformed into a linear form: $Log\ W = Log\ (a) + b\ Log\ (L)$ (*b*: slope of regression line, Log *a*: constant). The statistical significance value of regression and coefficient of determination (R^2) were also presented. Furthermore, relationships between shell dimensions were estimated for: i) L/SW; ii) L/ST; iii) SW/ST and performing at both locations.

Fulton's condition factor (K), mean condition factor (K_{mean}) and relative weight (Wr) were calculated as the following formulas: $K = 100 \times W/L^3$ [10, 13]; $K_{mean} = 100 \times a\ L^{(b-3)}$ [10] $Wr = 100 \times W/Ws$ where L: shell length (cm); W: body weight (g), $Ws = a\ L^b$, where *a* and *b* are parameters of LWR equation. *Statistical analysis*

Descriptive statistics were derived using Excel (Microsoft Excel 2007) statistical functions. The analysis of covariance (ANCOVA) was performed to test the difference in length – weight relationship (LWR) of *L. anatina* between the two sampling locations [14]. Analysis of variance (ANOVA) was used to test the difference between condition factor, relative weight and mean weight and mean length of *L. anatina* at the two sampling locations. t-test was applied to confirm whether calculated *b* value significantly differed from the isometric value ($b = 3$) [15]. All statistic tests were performed by using SPSS 18 package software. All the statistical analyses were considered significance when $P < 0.05$.

Results

Length frequency distribution at two locations

The length of *L. anatina* at Cam Hai Tay ranged from 1.13 to 4.61 cm, and at Cam Thanh Bac ranged between 1.33 and 4.27 cm. Average shell length of *L. anatina* at Cam Hai Tay (3.18 ± 0.03 cm) was significantly higher than those at Cam Thanh Bac (2.92 ± 0.19 SE cm) (P < 0.001). (Fig. 2).

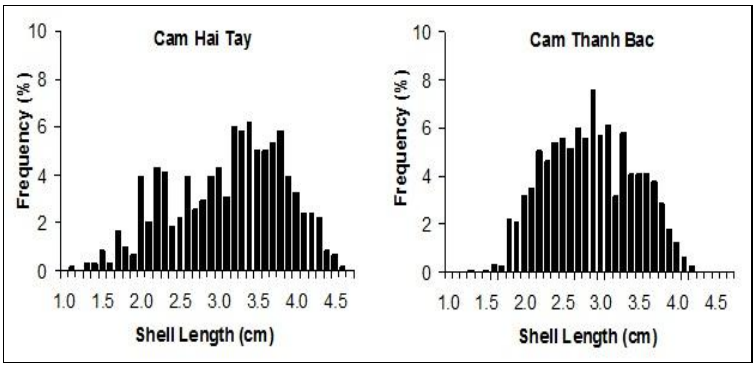

Fig 2: Shell length frequency distribution of *Lingula* at Cam Hai Tay and Cam Thanh Bac, Thuy Trieu lagoon.

Average shell dimensions and weight of *Lingula anatina*

The results of shell size and weight of *L. anatina* at the two sampling locations is presented in Table 1. Shell dimensions (L, SW and ST) of *L. anatina* were significantly higher in Cam Hai Tay than *L. anatina* collected at Cam Thanh Bac (t-test, P < 0.0001). Also, the whole body weight and soft part weight of *L. anatina* at Cam Hai Tay were significantly higher than *L. anatina* at Cam Thanh Bac (t-test, P < 0.0001). (Table 1).

Table 1: Shell size and weight (g) measurement (mm) of *Lingula* from 2 sampling locations. Mean ± SE, L: shell length (cm), SW: shell width (cm), ST: shell thickness (cm), W: whole body weight (g) and W_{soft}: weight of soft part (g).

		Mean ± SE	Range	P
L (cm)	CHT	3.18 ± 0.30	1.13 – 4.61	0.000
	CTB	2.92 ± 0.19	1.33 – 4.27	
SW (cm)	CHT	1.48 ± 0.13	0.59 – 2.10	0.000
	CTB	1.32 ± 0.08	0.62 – 1.87	
ST (cm)	CHT	0.60 ± 0.07	0.16 – 0.99	0.000
	CTB	0.56 ± 0.04	0.23 – 0.93	
W (g)	CHT	2.15 ± 0.06	0.09 – 6.64	0.000
	CTB	1.57 ± 0.03	0.18 – 4.52	
W_{soft} (g)	CHT	1.61 ± 0.05	0.04 – 4.43	0.000
	CTB	1.18 ± 0.03	0.12 – 3.36	

Length – weight relationship

The length – weight relationship ($W = a L^b$) was analysed and gained equations: $W = 0.0473 L^{3.1405}$ ($R^2 = 0.9796$, ANOVA, $F = 25371.68$, $P < 0.001$) for *L. anatina* population at Cam Hai Tay and $W = 0.0728 L^{2.7689}$ ($R^2 = 0.9392$, ANOVA, $F = 10292.20$, $P < 0.0001$) for population at Cam Thanh Bac. The calculated value of allometric coefficients (b) in the length – weight relationship were 2.769 and 3.141 for *L. anatina* collected at Cam Thanh Bac and Cam Hai Tay, respectively. (Fig. 3) Linear model of length – weight relationship for *L. anatina* with logarithm transform (Log W = Log a + b Log L) resulted in a high R^2 over 0.939 at the two sampling locations (Table 2). ANCOVA analysis of length – weight relationship at logarithm transformation from showed that the slopes (b values) significantly differ between the two locations ($P < 0.027$). Student's t-test analysis showed that b value of *L. anatina* at Cam Thanh Bac had negative allometric growth (P < 0.05). However, b value of *L. anatina* at Cam Hai Tay was not significantly different from the isometric value ($b = 3$, P > 0.05).

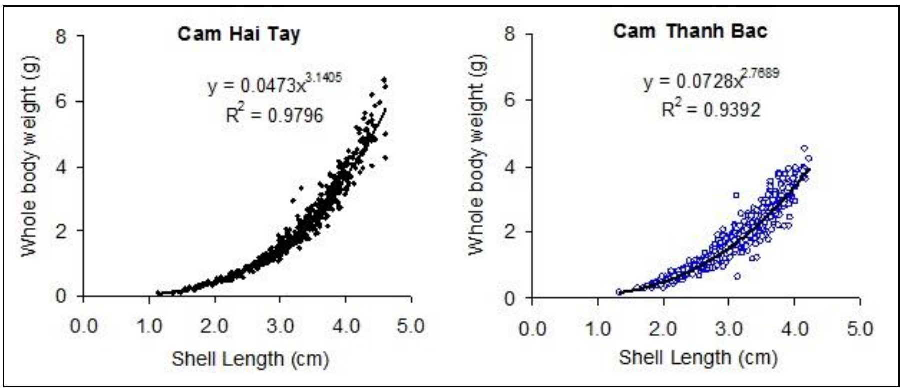

Fig 3: The relationship between shell length and weight ($W = a L^b$) of *Lingula anatina* collected in Thuy Trieu lagoon.

Length – Length relationships of *Lingula anatina*

The LWR parameters, their standard errors and the coefficient of determination ($r2$) of *L. anatina* is shown in Table 2. All relationships between shell length (L), shell width (SW) and shell thickness (ST) were highly significant linear ($P < 0.001$), with correlation coefficients (R^2), were at least 0.885 or over.

Table 2: Length – weight (LWR) and length – length relationship (LLR) of *L. anatina* at Thuy Trieu lagoon. W: whole body weight (g), L: shell

length (cm), SW: shell width (cm) and ST: shell thickness (cm).

LLR	Locations	a	b	SEa	SEb	R^2	ANOVA, F test	Sig. of regression
Log W = a + b* Log L	Cam Hai Tay	- 1.325	3.140	0.010	0.020	0.980	25443.117	0.000
	Cam Thanh Bac	- 1.138	2.769	0.013	0.027	0.939	10292.197	0.000
L = a + b* SW	Cam Hai Tay	- 0.291	2.345	0.022	0.015	0.977	24974.812	0.000
	Cam Thanh Bac	- 0.041	2.258	0.020	0.015	0.962	23888.623	0.000
L = a + b*ST	Cam Hai Tay	0.516	4.460	0.026	0.041	0.953	11692.051	0.000
	Cam Thanh Bac	0.684	4.024	0.024	0.042	0.904	8967.148	0.000
SW = a + b*ST	Cam Hai Tay	0.370	1.859	0.013	0.021	0.931	7827.126	0.000
	Cam Thanh Bac	0.349	1.734	0.012	0.020	0.885	7403.139	0.000

Condition factors, relative weight and mean condition factor of *L. anatina*

Condition factor (*K*) and mean condition factor (K_{mean}) significantly differ (P <0.001) between the two populations of *L. anatina*, with a higher value in Cam Thanh Bac (K= 5.768, K_{mean} = 0.057) and lower value in Cam Hai Tay (K = 5.583, K_{mean} = 0.055). However, relative weight (Wr) was not significantly different between the two populations (P = 0.646) and W_r values of the two population did not significantly differ from 100 (P ≥ 0.079). Table 3.

Table 3: Condition factor (K), relative weight (W_r) and K_{mean} value of *L. anatina* collected at 2 locations at Thuy Trieu lagoon.

	Locations	Mean ± SE	t-test	Sig. (2-tailed)
K	CHT	5.583 ± 0.029	- 4.114	0.000
	CTB	5.768 ± 0.033		
W_r	CHT	100.61 ± 0.005	- 0.459	0.646
	CTB	100.96 ± 0.005		
K_{mean}	CHT	0.055 ± 0.001	- 11.818	0.000
	CTB	0.057 ± 0.001		

Relationship between mean condition factor and shell size of *L. anatina*

The parameters of K_{mean} and shell length (L) relationship, standard errors, the coefficient of determination (R^2), significance of regression is shown in Table 4 and Fig. 3. All relationships between K_{mean} and H were significant linear. All relationships were highly significant (P ≤ 0.001), with correlation coefficients (R^2) were greater than 0.993.

Table 4: K_{mean} – shell size relationship of *L. anatina* at Thuy Trieu lagoon. K_{mean}: mean condition factor; L: shell length (Log L, cm). SE*a* and SE*b*: standard deviations of *a* and *b* values.

	Locations	a	B	SEa	SEb	R^2	ANOVA, F test	Sig. of regression
K_{mean} = a + b* Log L	CHT	0.047	0.018	0.000	0.000	0.993	1126457.03	0.000
	CTB	0.712	- 0.031	0.000	0.000	0.995	833694.57	0.000

Discussion

This is the first study provides a useful information for fishery management of *Lingula anatina* including length – weight relationship parameters, condition factor, relative weight and relationship between mean condition factor and size of Brachiopod, *L. anatina* at Thuy Trieu lagoon.

Among biometric relations, length – weight relationship (LWR) is a powerful tool, popularly presented by scientists and researchers as useful tools in fishery biology [16, 17]. The parameters of LWR are beneficial to predict weight from length, computation of condition index, assessment of stock and estimation of biomass [17]. However, LWR is influenced by various factors such as the presence of food, feeding ratio, gonad development, spawning period, season, sex and habitat [18, 19]. However, all of which were not measured in the present study. The LWR of *L. anatina* in this study were highly significant and the length and weight were different between the two sampling sites. However, LWR of *L. anatina* in India was not significantly correlated, the similar size was record among population, also the relative condition is less than 1, indicating for inappropriate environment for *L. anatina* [20]. In the present study, Wr were not significant than 100, showed suitable environment for *L. anatina* growth.

The value of the exponent *b* provides information on *L. anatina* growth. In this study, *b* value of the two populations falls between 2.5 and 3.5, indicating appropriate size range of *L. anatina* specimens to obtain reliable data [21]. According to Froese [10] there are two possibilities in a population, when *b* value less than 3: 1) the number of individuals increase their body size are dominant or 2) small individuals have a better nutrition condition. In the present study, *b* values population at Cam Thanh Bac was less than 3 and the size was smaller than *L. anatina* in Cam Hai Tay. Perhaps, this is because environmental condition at Cam Thanh Bac is more appropriate for the development of smaller size *L. anatina*. This is in accordance to study done by Anderson and Neumann [4], who stated that *b* values can vary among geographical regions. The variation in the *b* value for the same species could be attributed to a difference in sampling, sample size or length ranges [22]. In the present study, the difference of *b* value could be because of the difference in size and weight of *L. anatina* at two sampling locations. However, other environment and other factors should also be considered addressing the other impacts. Value of b were less than 1 for all *L. anatina* collected at different sites in India [20].

Condition factor (K) can be very important to fisheries managers. The value of K can be computed from length and weight data, providing external measures of the overall condition of the fish. The K value also indicates the mature size, spawning size and food condition [23, 24]. Condition factor is also considered as an indicator for health and general well-being of fish in relation to environment [25].

High condition factor (K) may show suitable environmental conditions (such as habitat conditions, much prey availability) and low K values indicate for a low optimal environment [26]. The K values of *Lingula* at the two studied sites were over than one which indicates that *Lingula* at Thuy Trieu are in good condition. The assumption to estimate fish condition index are different. Fulton's condition factor assumes fish has an isometric growth (b = 3) [27]. Since each species of fish have different body shapes, it is difficult to compare K values between fish species [4]. The relative condition factor (K_{rel}) assumed the b values are identical to compare condition among populations. Recently, numerous researches have proposed relative weight (*Wr*) in the management and conservation of fishes, particularly those species are threatened or endangered [28, 29]. Relative weight (*Wr*) has several advantages over K and K_{rel}. This is because *Wr* does not depend on measurement units. Also, *Wr* values can be compared fish at different size and among populations [13, 26]. Values of *Wr* falling below 100 for suggest problems such as low food availability or a high number of predators; while *Wr* value is over 100 showing a food surplus or low predatory density in the habitat [30].

In the present study, *Wr* values of *L. anatina* were not significantly different from 100 for the two studied populations, showing the balance habitat with food availability and low predator quantity [4]. In addition, it might be indicated that the water quality was still adequate to support *L. anatina* communities. However, the larger size of *L. anatina* in Cam Hai Tay has a lower condition factor than smaller size of *L. anatina* in Cam Thanh Bac. This corresponded to the b value of *L. anatina* at Cam Hai Tay was greater than 3 while b value of *L. anatina* at Cam Thanh Bac was lesser than 3. Possibly, younger population of *L. anatina* habited in Cam Thanh Bac and older population of *L. anatina* distributed at Cam Hai Tay. Another possibility Cam Thanh Bac is better for the nursing area while Cam Hai Tay is a better condition for the bigger size of this species.

In conclusion, the present results on length-weight relationships and condition factor of *L. anatina* will be useful for researchers and fishery managers and research on population dynamic. To our knowledge, LWR and K of *L. anatina* were first studied in Vietnam. Therefore, these results will be useful baseline data for fishery researchers and conservationists to propose suitable regulations for sustainable fishery management and conservation *L. anatina* stocks in the region and for comparison with research in the future. However, further study on seasonal variations of environmental condition, reproduction, sex ratio and interaction of those of biology of *L. anatina* should be conducted.

Acknowledgements

This study was funded by Khanh Hoa province. The author would like to give many thanks to Nguyen T.K.B. and Huynh, M.S. for their help. The author also would like to thanks Mrs Nguyen T.D.T. and Le B.T. (Khanh Hoa DOST) and Mrs Nguyen T.H. (Khanh Hoa DARD) and the colleagues at Institute of Institute of Oceanography for their great supports.

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