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Research Note

Morphometric relationships of the siphon clam *Panopea globosa* (Bivalvia: Hiatellidae) in the southeasternmost of the Gulf of California, Mexico

Relaciones morfométricas de la almeja sifón *Panopea globosa* (Bivalvia: Hiatellidae) en la parte más al sureste del Golfo de California, México

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Abstract.- The morphometric relationships of the siphon clam *Panopea globosa* from Sinaloa, Mexico, were analyzed from February 2014 to April 2015. A total of 370 specimens were collected, measured (shell length, width, and height) and weighed (body weight, tissue weight, and shell weight). The coefficient of determination indicated variation in the fitting of morphometric variables among measured traits. The type of relative growth for all morphometric relationships was negative allometry. This is the first report on morphometric relationships of *P. globosa* from Sinaloa, Mexico.

Key words: Morphometrics, relative growth, siphon clam, fisheries management

Introduction

Sustainable fishery management relies on obtaining morphological measurements of exploited organisms, and a complete assessment includes shell size (length, height and width) and body weight through the study of morphometric relationships among variables (Syda-Rao 2007, Grizzle *et al.* 2017). The bivalve *Panopea globosa* (Dall, 1898), commonly known as "siphon clam" or "geoduck", is a subtropical species endemic to the Gulf of California (Hendrickx *et al*. 2005) and constitutes one of the most recent and important clam fisheries in the northwestern of Mexico (Calderón-Aguilera *et al*. 2010). Aragón-Noriega *et al.* (2012) mentioned that landings increased from 49 mt in 2002 to 2,000 mt in 2011 in the states of Baja California and Sonora, Mexico. The available information on this species focuses basic aspects of wild populations specifically from the central Gulf of California and the Pacific coast of Baja California, Mexico. It deals with its biology (Aragón-Noriega *et al*. 2007), morphometrics, age, and growth (Calderón-Aguilera *et al*. 2010, Cruz-Vázquez *et al*. 2012), fishery status (Aragón-Noriega *et al*. 2012), spatial distribution and abundance (Cortéz-Lucero *et al*. 2014), density and population structure (Aragón-Noriega *et al*. 2016). Recently, Góngora-Gómez *et al*. (2016) reported the first record of *P. globosa* in Sinaloa's state, at the southeastern coast of the Gulf of California. Due to the increasing demand for geoduck clams in the Asian market and the lack of baseline information on recent beds of *P. globosa* in the Gulf of California, studies on its population structure and morphometrics are required to develop a fishery management plan for this species in Sinaloa, Mexico.

Therefore, the aim of the present study was to establish morphometric relationships of the geoduck clam *P. globosa* from the southeasternmost of the Gulf of California, as preliminary information for establishing of a sustainable fishery management plan.

Materials and methods

Morphometrics of *P. globosa* were investigated using specimens collected from Altata Bay, Navolato (24°20'-24°35'N and 107°20'-107°55'W), Sinaloa, Mexico. The geoduck clams were sampled monthly (n= 20-37) at 0.4-4.0 m depth through scuba diving (Góngora-Gómez *et al*. 2016) from February 2014 to April 2015. Shell measurements and body weight of clams were recorded with a digital caliper (0.01 mm) and a precision balance (0.1 g). Individual biometric variables included: shell length (SL, maximum distance between the anterior and posterior margins), shell height (SH, maximum distance between the hinge to the furthermost edge), and shell width (SW, maximum distance at the thickest part of the two valves). Weight measurements (total body wet weight BwW, tissue wet weight TwW, and shell wet weight SwW) were obtained after separating the shell from the soft tissue and blotting them dry in absorbent paper prior to weighing.

The morphometric relationships of shell measurements and weighings of geoduck clams were estimated by fitting the power function W= aL^b. The goodness of fit was described using the determination coefficient, r^2 (Sokal & Rohlf 1981). The relative growth between variables (isometry *vs*. allometry) was analysed through the allometric coefficient (regression slope – b) of the morphometric relationships (Vasconcelos *et al.* 2018). When comparing variables with the same units (both linear), isometry occurs when b is not statistically different from 1, but when variables have different units (linear and ponderal), isometry occurs when b is not statistically different from 3. The b values obtained in linear regressions were significantly different from the isometric value (b= 1 or 3) or allometric range (negative allometry: $b < 1$ or 3, or positive allometry or $b > 1$ or 3) when a t-test (H_0: b= 1 or 3) with a confidence level of 95% was applied, expressed by the following equation (Lleonart *et al*. 2000):

$$t= (b-1)/Sb,$$

where, t is the t-test value, b is the regression slope and Sb is the standard error of the regression slope.

Results and discussion

The regression slope varied from 0.310 for the SH-SW relationship, to 1.562 for the TwW-SH relationship. Considering BwW *versus* shell measurements, the higher coefficient of determination (r^2= 0.37) was obtained for the BwW-SW relationship, indicating that BwW-SW may be the most suitable morphometric relationship for describing this species instead of BwW *versus* SH or SL when sampling geoduck directly in the field and without an analytical balance. On the contrary of most of bivalves in which internal organs are totally covered by the valves, the inequilateral valves of adult *P. globosa* present a dehiscent periostracum that partially covers the mantle edge and prolongs into siphonal sheath (Coan & Valentich-Scott 2012). Therefore, BwW could also be affected by the different stages of gonad maturation expressed with measurement of SW. Based in the morphological traits, it is possible that similarly to other geoduck species studied by Aragón-Noriega *et al*. (2007) and Calderón-Aguilera *et al*. (2010), sexually mature specimens would be found within the population of *P. globosa* from Sinaloa. In fact, Aragón-Noriega (2015) estimated sizes at 50% maturity for *P. globosa* of 91.9 mm SL and 90.9 mm SL for females and males, respectively, coinciding with the size range analyzed in this study. Nevertheless, histological evidence is needed to further confirm this statement.

Shell measurements varied from 87.3 to 168.2 mm for SL, and from 267 to 1039.5 g for BwW (Table 1). Compared with the mean SL (147.7 mm) and BW (533.3 g) for the *P. globosa* population sampled by Aragón-Noriega *et al*. (2007) in Guaymas-Empalme Bay, Sonora, and for the *P. generosa* population studied by Calderón-Aguilera *et al*. (2010) in San Quintín-Isla Coronado Bay, Baja California (SL= 132 mm and BW= 763.6 g), the *P. globosa* population from Altata-Ensenada Pabellones lagoon, Sinaloa, comprised smaller specimens (SL= 123.1 mm and BW= 615.4 g). Since no juvenile geoducks were found, it is possible to state that the present population was dominated by adult individuals, which corroborates the aforementioned authors and Gribben & Creese (2003) who described similar population size structures.

The coefficient of determination (r^2) ranged from 0.085 for the SwW-SW relationship, to 0.411 in the SwW-TwW relationship (Table 2). Although there were significant correlations among all morphometric relationships, the relationships of SWI *versus* SL, SWE and TWM displayed the lower coefficients of determination indicating a reasonably higher variability between these variables, which could be partially explained by factors such as sediment type and water content within the tissues. Goodwin & Pease (1991) mentioned that gravel or shell substrata affected the shape of geoduck shells and the burial depth of *P. abrupta*, which could lead to lighter specimens with misshapen shells. We observed that sediment type at the Altata-Ensenada Pabellones lagoon system is constituted by a range of substrata from small shells and gravel, as well as fine sandy sediments. Thus, shell and tissue traits are susceptible to vary when geoducks are collected from

Table 1. Descriptive statistic parameters of the siphon clam *Panopea globosa* (N= 370) / Parámetros estadísticos descriptivos de la almeja sifón *Panopea globosa* (N= 370)

	Shell length (mm)	Shell height (mm)	Shell width (mm)	Body weight (g)
Mean	122.9	80.9	70.9	618.6
SD*	8.7	6.0	6.9	130.5
Minimum	87.3	61.6	45.4	267.0
Maximum	168.2	101.2	98.7	1039.5
CV (%)	7.1	7.5	9.7	21.1

*SD = Standard deviation; CV = coefficient of variation

Table 2. Morphometric relationships of the geoduck clam *Panopea globosa* / Relaciones morfométricas de la almeja sifón *Panopea globosa*

Parameters	Morphometric equation	r^2	SE of *b* (95% CI of *b*)	Relative growth (*t*-test)
SL - SH	SL= 11.528 $SH^{0.538}$	0.331*	0.030 (0.508-0.568)	- allometry
SL - SW	SL= 41.522 $SW^{0.254}$	0.127*	0.038 (0.216-0.292)	- allometry
SH - SW	SH= 21.579 $SW^{0.310}$	0.165*	0.042 (0.268-0.352)	- allometry
BwW - SL	BwW= 1.035 $SL^{1.324}$	0.174*	0.707 (0.617-2.031)	- allometry
BwW - SH	BwW= 0.726 $SH^{1.531}$	0.266*	0.950 (0.581-5.481)	- allometry
BwW - SW	BwW= 1.720 $SW^{1.376}$	0.370*	0.797 (0.579-2.173)	- allometry
SwW - SL	SwW= 0.118 $SL^{1.338}$	0.246*	0.077 (1.261-1.415)	- allometry
SwW - SH	SwW= 0.363 $SH^{1.211}$	0.230*	0.112 (1.099-1.323)	- allometry
SwW - SW	SwW= 6.735 $SW^{0.563}$	0.085*	0.108 (0.455-0.671)	- allometry
TwW - SL	TwW= 0.206 $SL^{1.495}$	0.162*	0.412 (1.083-1.907)	- allometry
TwW - SH	TwW= 0.286 $SH^{1.562}$	0.202*	0.578 (0.984-2.140)	- allometry
TwW - SWI	TwW= 9.496 $SWI^{0.790}$	0.545*	0.545 (0.245-1.335)	- allometry
BwW - SwW	BwW= 47.656 $SwW^{0.589}$	0.251*	0.430 (0.186-0.992)	- allometry
BwW - TwW	BwW= 37.873 $TwW^{0.493}$	0.334*	0.075 (0.418-0.568)	- allometry
SwW - TwW	SwW= 5.447 $TwW^{0.465}$	0.411*	0.008 (0.457-0.473)	- allometry

r^2= Determination coefficient; SL= shell length (mm); SH= shell height (mm); SW= shell width (mm); BwW= body wet weight (g); SwW= Shell wet weight (g); TwW= tissue wet weight (g); SE= standard error; *b*= regression slope; *t*= Student's test; CI= confidence interval; $*P < 0.05$

heterogeneous substrata (Aragón-Noriega *et al*. 2007). Wet weights may have also contribute to trait variations since geoduck retain water inside the mantle cavity and in within the tissues (Gribben & Creese 2003). The present specimens were maintained alive in seawater and transported to the laboratory before weighing in order to avoid variability in total weight and tissue wet weight. The higher slope (*b*= 1.562) was obtained for the TwW-SH relationship, whereas the lowest slope (*b*= 0.310) was recorded in the SH-SW relationship. In the present study, the *b* values of all BwW - shell measurements relationships were between 1.324 to 1.531, being quite different (0.03 to 5.97) from those reported by Aragón-Noriega *et al*. (2007). These differences may be a consequence of distinct hydrological and sedimentological features between different geographical areas (Gaspar *et al*. 2002), which would affect morphological traits of the species.

Since *b* values for the morphometric relationships between the same type of variables (*i.e.*, linear vs. linear and ponderal *vs.* ponderal) were below 1 (*b*= 0.254-0.589) and those relationships between different types of variables (*i.e.,* linear *vs.* ponderal) were less than 3 (*b*= 0.563-1.562), a strong negative allometry describes the type of growth of the studied population of *P. globosa*. Specifically, the negative allometry ($b < 1$) in the relationships between shell measurements suggests that geoduck development is expressed more in terms of shell height and width than in shell length, which in practice means that bivalves become wider, reflecting a morphological adaptation that could improve burial depth on the bottom substrata (Lauzier *et al*. 1998), allowing geoducks to accommodate a longer siphon extending to the sediment surface. Calderón-Aguilera *et al.* (2010) obtained a mean *b* value of 2.428 for *P. generosa* in the coast of Baja California state, suggesting that species and environmental conditions, among other factors, could influence the morphometric traits of this bivalve genus.

In conclusion, morphometric relationships suggested likely effects of external and internal factors. The geoduck population sampled in the Altata-Ensenada Pabellones lagoon system is constituted by large individuals, for which measurement of SW rather than SL and SH was more consistently proportional to BwW. Due to the increasing importance of this fishery in Sinaloa, more biological/ecological information is needed to develop sustainable exploitation strategies. The present data provides valuable information for fisheries assessment and management, constituting the basis for future research.

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