Abundance and relative growth of *Donax denticulatus* (Bivalvia: Donacidae) at Levisa Beach, Southeastern Cuba

Abundancia y crecimiento relativo de *Donax denticulatus* (Bivalvia: Donacidae) en playa Levisa, costa sur oriental de Cuba

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ABSTRACT

This paper is aimed at describing spatio-temporal variation in abundance, size structure and length-weight relationship of a *Donax denticulatus* population at Levisa Beach on the Southeastern coast of Cuba. From April to September 2008, monthly samples were collected from four stations located along the beach; three strata were established across the intertidal zone of each station. Three replicate sediment samples were collected from each stratum with a 0.025 m^2 PVC corer and sieved with a 1 mm mesh. Mean density ranged from 612.2 to 1366.7 ind. m^{-2}, and no differences were found among the sampled months but rather among strata. There is a relationship between the abundance of recruits, young and adults, and strata. The middle intertidal zone showed the highest proportion of individuals, mainly young and adults. Monthly length frequencies showed that recruits appeared in April and May. Length-weight relationship showed a significant correlation between these variables; however, the allometric coefficient value is different considering different life stages. This population shows potential to be exploited, but some management measures proposed in this paper must be taken into account to ensure sustainability.

Keywords: Population structure, *Donax*, allometry, sandy beaches, zonation.

RESUMEN

Este trabajo fue realizado con el objetivo de describir la variación espacio-temporal de la abundancia, la estructura de tallas y la relación talla-peso de una población de *Donax denticulatus* en playa Levisa en la costa sur oriental de Cuba. Entre abril y septiembre de 2008, se recolectaron muestras mensuales en cuatro estaciones localizadas a lo largo de la playa; en cada estación se delimitaron tres estratos perpendiculares al límite inferior de la zona intermareal. En cada estrato se tomaron tres réplicas de muestras de sedimentos con un cilindro de PVC de 0.025 m^2 de área y el sedimento fue tamizado posteriormente a través de una malla de 1 mm. La densidad media osciló entre 612.2 y 1366.7 ind. m^{-2} y no se encontraron diferencias entre los meses de muestreo, aunque sí existió diferencia de la densidad entre los estratos de la playa. Existe una asociación entre la abundancia de reclutas, jóvenes y adultos, y los diferentes estratos. La parte media de la zona intermareal mostró la mayor proporción de individuos, fundamentalmente jóvenes y adultos. Los histogramas mensuales de frecuencias de longitud de tallas mostraron que los reclutas aparecieron en abril y mayo. La relación longitud-peso mostró que existe una correlación significativa entre estas variables, pero el valor del coeficiente de alometría es diferente, considerando distintos estadios del ciclo de vida. Esta población tiene potencial para ser explotada, pero se deben tener en cuenta algunas medidas de manejo para asegurar su sostenibilidad.

Palabras claves: Estructura poblacional, *Donax*, alometría, playas arenosas, zonación.

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INTRODUCTION

Clams are an important component of the macrofauna on sandy beaches. In all continents, at least one species is collected from exposed beaches as part of recreational, artisanal or commercial fishery (McLachlan *et al*. 1996). In the wider Caribbean region two clam species occur on sandy beaches, *Donax denticulatus* Linné, 1758 and *D. striatus* Linné, 1767, which have the same distribution range and occasionally are sympatric in the same beach. They are more common in the swash zone of sandy beaches with influence of freshwater discharge (Wade, 1967).

The first studies on *D. denticulatus* were conducted by Wade (1967, 1968) in Jamaica and some islands of the Lesser Antilles giving information about their natural history and ecology. This species is an active burrowing migrator that moves across the beach profile with the tides (Trueman, 1971). Population densities, size and shell color vary among beaches, and the influence of organic matter, beach slope and grain size are considered important factors related to those differences (Wade, 1967; Sastre, 1984). In Venezuela beach clams are a fishery resource (McLachlan *et al*. 1996), and studies regarding their growth and reproduction have been conducted (Vélez *et al*. 1985; García *et al*. 2003; Marcano *et al*. 2003).

In Cuba, studies regarding beach clams are scarce. Shell morphometrics and population dynamics of *D. denticulatus* were analyzed in the Carenero Beach (Ocaña & Fernández, 2011; Ocaña *et al.* 2013). Considering that *D. denticulatus* is a potential unexploited resource for fisheries, it is important to conduct further research in order to evaluate stocks on some beaches. The aim of this paper is to describe spatio-temporal variation in abundance, size structure and length-weight relationship of a *D. denticulatus* population on Levisa Beach on the Southeastern coast of Cuba.

MATERIALS AND METHODS

Study area: Levisa Beach, located on the Gulf of Guacanayabo on the Southeastern coast of Cuba, is 1.2 km long, and the beach face is 5-6 m in width (Fig. 1). Sediments are classified as medium size sands and are a mix formed by calcareous material coming from marine organisms and terrestrial sands carried out by the Sevilla River located 4 km north of the beach. The beach face presents a gentle slope and the sublittoral zone is shallow having a mean depth of 0.6 m in the first 100 m from the shore. The tidal regime along the coast is semidiurnal and tides range 0.3-0.8 m. In the area the two climatic seasons are: rainy (May-November) and dry (December-April). During the rainy season the beach receives freshwater discharges from the river and Ciénaga de Managuano located behind the beach. The beach and surrounding areas form part of a proposed Wildlife Reserve to be included in the National System of Marine Protected Areas.

Sampling and laboratory procedures: Monthly stratified

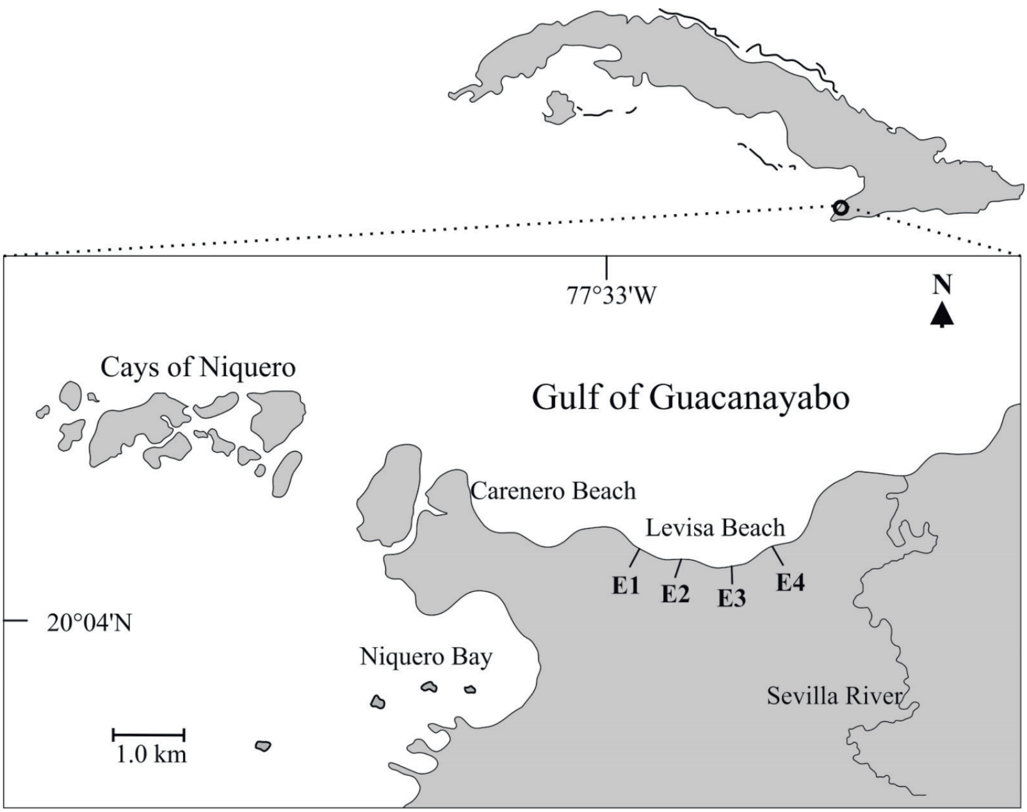

Fig. 1. Location map of Levisa Beach showing sampling stations (E1-E4)
Fig. 1. Mapa de ubicación de playa Levisa mostrando las estaciones de muestreo (E1-E4)

samplings were done along the beach from April to September 2008. No samples were collected during the other months due to logistical constraints. Four fixed stations were set, separated 200 m along the beach. At each station three strata (S1, S2 and S3) were delimited following the lower limit of the swash zone, the middle intertidal zone and the drift line, respectively. The distance of each stratum varied according to beach width. In each stratum three replicated PVC cores of 0.025 m^2 (Sampling Unit, SU), with a 1 m separation, were excavated to a depth of 20 cm during low tide. The sediment obtained in each of the 36 SUs was sieved with a 1mm mesh. The clams were separated and kept in labeled plastic bags and then frozen. In the laboratory each clam was measured (anterior-posterior axis of length, L) to the nearest mm using a vernier caliper. Density (ind. m^{-2}, mean ± standard error) was determined extrapolating the number of clams obtained in each SU.

Clams were grouped in 5 mm length size classes to generate monthly frequency histograms. Individuals were regrouped into three categories (recruits: $L < 5$ mm, young: 5 mm $< L <$ 15 mm, and adults: $L > 15$ mm) following

Wade (1968) and Ocaña & Fernández (2011), in order to identify any possible distribution patterns of such population components across strata. Seventy-eight individuals ranging from 7-26 mm length were weighed (g) on a digital scale (1 mg resolution) to estimate the length-weight relationship. The relationship between length and total weight with shell was estimated by the power function $W_t = a*L^b$, where *a* and *b* are constants. This relationship was partitioned to analyze differences in the relative growth among individuals with L < 15 mm, L > 15 mm and L > 20 mm. The exponent *b* of the power function expresses the allometric coefficient. In the W_t/L relationship a value $b = 3$ reflects an isometric growth (Gaspar *et al*. 2002a).

Statistical analyses: Two-way analysis of variance (strata x months) was used to test for spatial and temporal differences in the *D. denticulatus* density. The raw data were log transformed (x + 1) in order to fulfill ANOVA requirements. When significant differences existed, the results of ANOVA were followed by a Scheffé's *post hoc* procedure. To evaluate any relation among population component (recruits, young and adults) and strata, a *Ji*-square (X^2) contingency test was used. The level of association of length and weight was determined by the determination coefficient (r^2). A *t*-test was applied in order to confirm if the allometric coefficient of the length-weight relationship was different from the isometric value ($b = 3$) considering L = 7-26 mm (the full range of individuals weighted), L < 15 mm, L > 15 mm and L > 20 mm. In all statistical analyzes a significance level of $\alpha = 5\%$ was adopted (Zar, 1999).

RESULTS

During the study period, 4570 clams were collected and measured. The smallest recorded individual had an L = 3 mm and the largest individual measured 26 mm. Density ranged from 612.2 ± 211.7 (ind. m^{-2}) in May to 1366.7 ± 524.0 (ind. m^{-2}) in June (Fig. 2). No significant differences were found in density between months ($F_{5,35} = 0.295$, $P > 0.05$), but differences were rather recorded among strata, where the highest density (1677.2 ± 294.2 ind. m^{-2}) was in S2 (ANOVA with Scheffé's - procedure *post hoc* test, $F_{2,71} = 12.75$, $P < 0.05$) (Fig. 3). An interaction effect in density between month and strata was observed.

Monthly length frequencies showed that recruit individuals appeared in April and May. Individuals from 10-20 mm length predominate in most months, except in April (Fig. 4). All population components were distributed across the beach; however, there is a significant relation between size class and strata ($X^2 = 125.99$, d.f. = 4, $P < 0.001$). The middle intertidal zone showed the greatest proportion of individuals, mainly young and adults. Adults dominated in S1, while young individuals reached the greatest proportion in S2 and S3 (Fig. 5).

The analysis of the length-weight relationship showed that there exists a significant positive correlation between these variables but the value of the allometric coefficient is

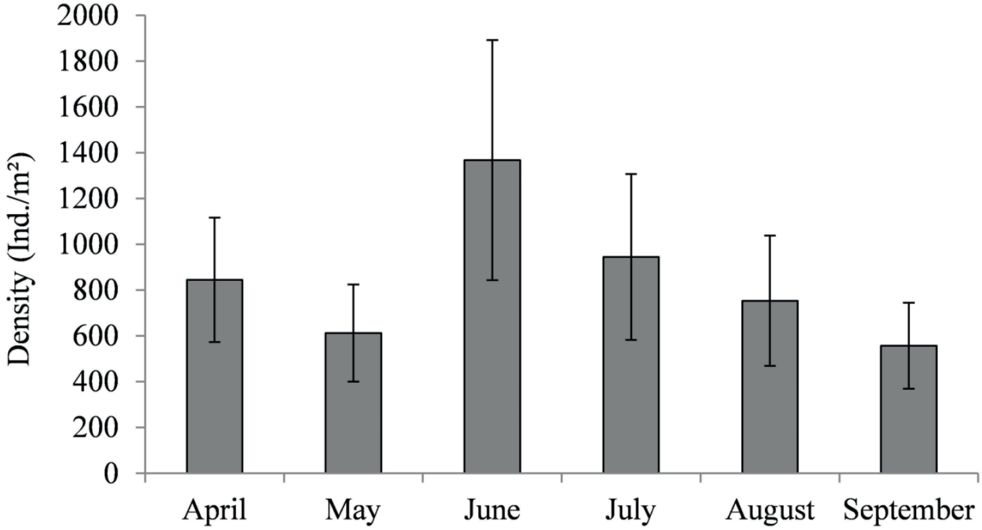

Fig. 2. Monthly population density (mean ± SE) of *Donax denticulatus* at Levisa Beach
Fig. 2. Densidad poblacional mensual (media ± SE) de *Donax denticulatus* en playa Levisa

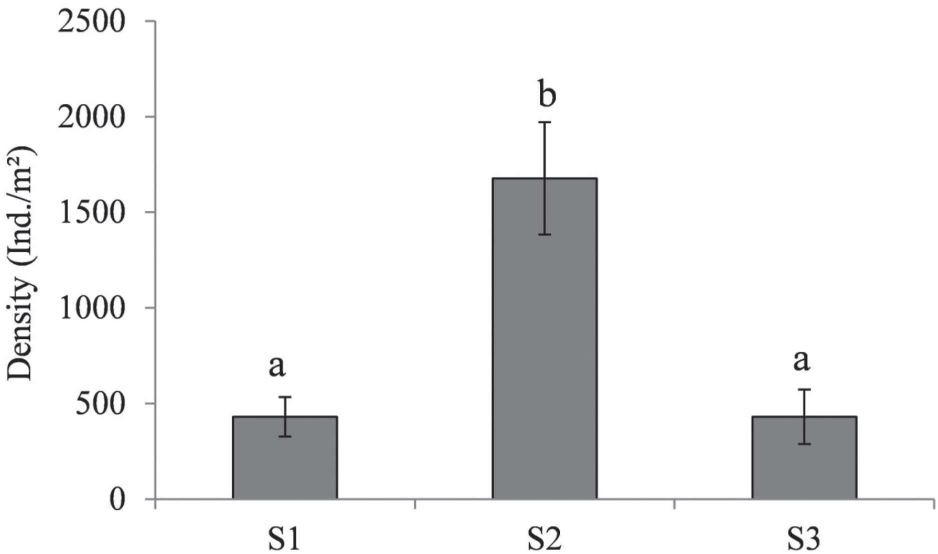

Fig. 3. Density (mean + SE) per stratum (S1, S2 and S3) of *Donax denticulatus* at Levisa Beach. Letters above the bars indicate statistical differences among strata
Fig. 3. Densidad (media + SE) por estrato (S1, S2 y S3) de *Donax denticulatus* en playa Levisa. Las letras sobre las barras indican diferencias significativas entre estratos

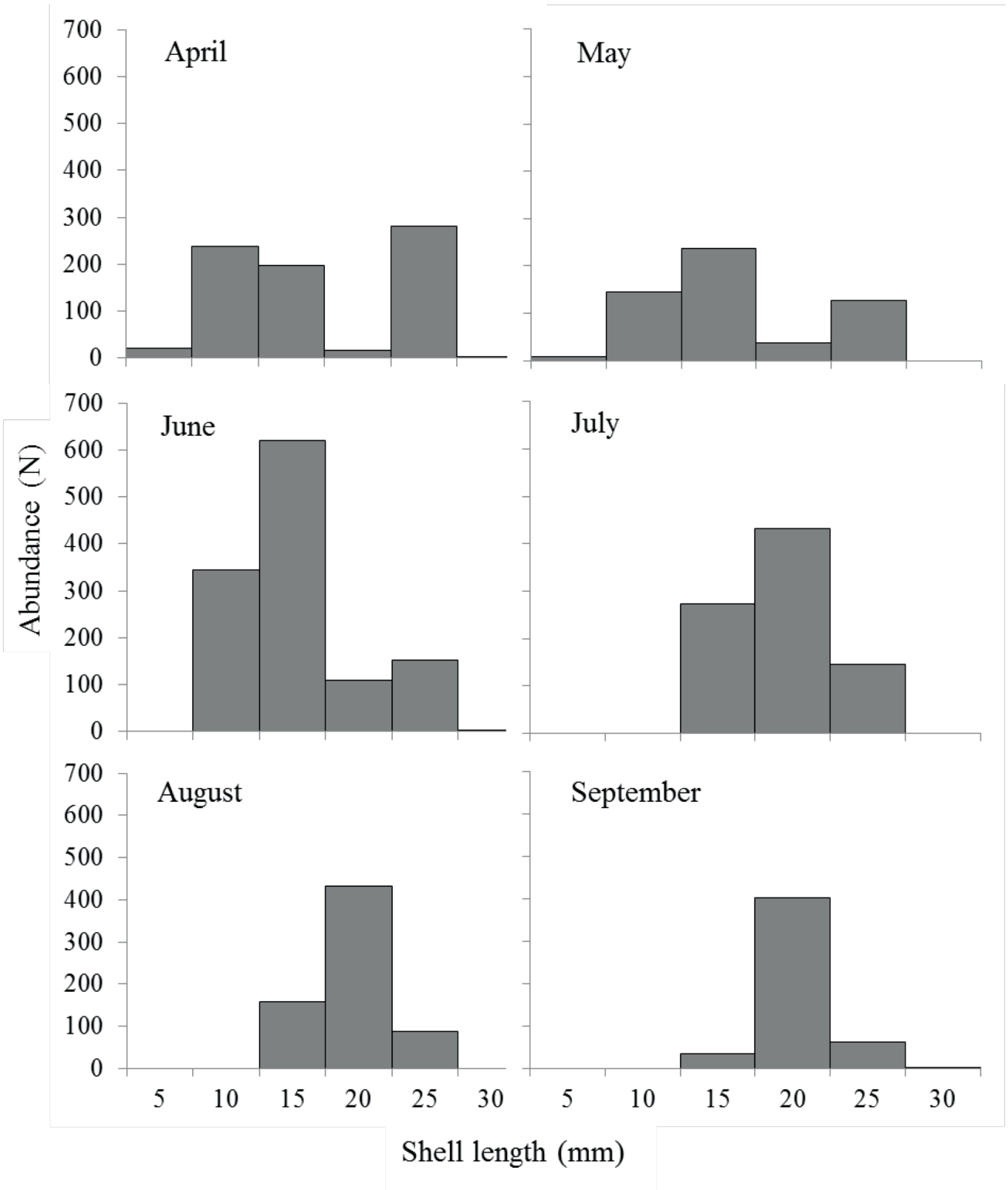

Fig. 4. Length-frequency distribution of *Donax denticulatus* at Levisa Beach from April to September 2008

Fig. 4. Distribución de las frecuencias de longitudes de *Donax denticulatus* en playa Levisa desde abril a septiembre de 2008

different taking into consideration different life stages. Individuals with L < 15 mm had a negative allometric growth, while individuals with L > 15 mm had a positive allometric growth. In the case of individuals with L > 20 mm, relative growth resulted in an isometric relationship (Table 1).

Table 1. Length-weight relationship considering different class sizes of *D. denticulatus* from Levisa Beach. SE = standard error; *b* = allometry coefficient; * $P < 0.05$
Cuadro 1. Relación longitud-peso considerando diferentes clases de tallas de *D. denticulatus* de playa Levisa. SE = error estándar; *b* = coeficiente de alometría; * $P < 0.05$

Class size	N	Allometric equation	Determination coefficient (r^2)	SE of *b*	Relationship (*t* test)
7-26 mm	78	$W=0.0001L^{3.041}$	0.988*	0.034	Isometry
< 15 mm	23	$W=0.0003L^{2.814}$	0.973*	0.065	- Allometry
> 15 mm	55	$W=0.0004L^{3.169}$	0.960*	0.033	+ Allometry
> 20 mm	31	$W=0.0002L^{2.957}$	0.883*	0.069	Isometry

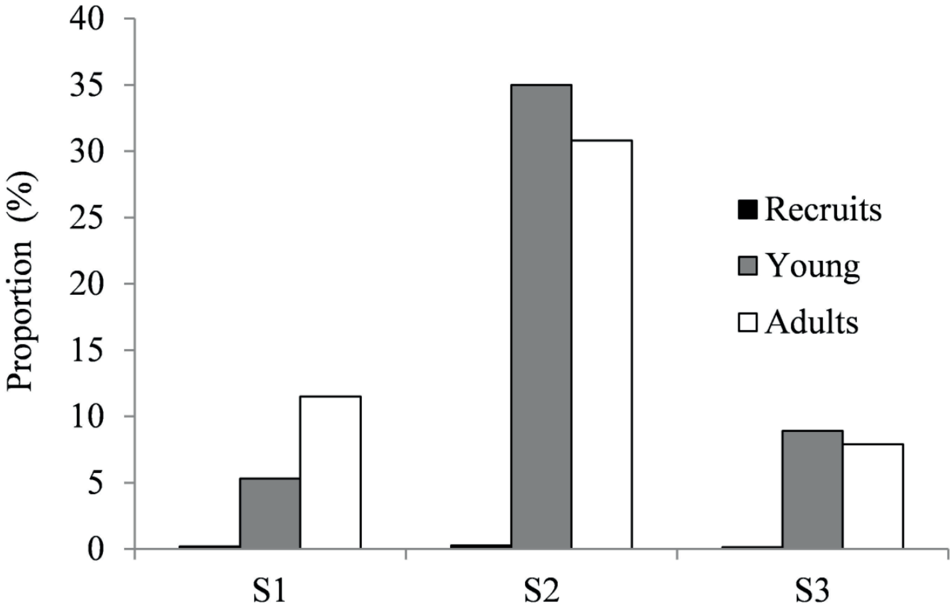

Fig. 5. Proportion of individuals by population components (recruits, young and adult specimens) per stratum (S1, S2 and S3) of *Donax denticulatus* at Levisa Beach
Fig. 5. Proporción de individuos por componentes de la población (reclutas, jóvenes y adultos) por estrato (S1, S2 y S3) de *Donax denticulatus* en playa Levisa

DISCUSSION

Contrary to reports for other *Donax* populations in the Caribbean (Sastre, 1984; McLachlan *et al*. 1996; Ocaña *et al*. 2010) showing temporal differences in abundance, *D. denticulatus* at Levisa Beach had no significant changes in abundance throughout the study period. The same pattern was observed by Ocaña *et al.* (2013) with this species at Carenero Beach. However, the population at Levisa reaches higher densities. Since, in general, *Donax* species are subjected to episodic fluctuations of abundance related to recruitment and natural mortality (Le Moal, 1993; Defeo & Alava, 1995), no fluctuations of the population from Levisa Beach could be related to the season of our survey. Monthly size-class histograms showed that recruitment only occurred in April-May, and it is possible that this population has a reproduction period during March-May, as reported in Carenero Beach (Ocaña *et al.* 2013) near Levisa, contrary to some other populations that showed continuous recruitment throughout the year (Wade, 1968; Vélez *et al.* 1985; Marcano *et al*. 2003). Nonetheless, more extensive sampling is needed in successive years to reveal the *D. denticulatus* recruitment pattern in Southeastern Cuba. Abundance of the clam population in this area is higher than populations from Jamaica (Wade, 1968), Puerto Rico (Sastre, 1984) and Venezuela (García *et al*. 2003).

Higher abundance was found in the middle intertidal zone, indicating that a pattern of zonation exists, and is consistent with time. Many truly intertidal species of *Donax* display aggregation across the beach profile, but the relative position is variable, depending upon the susceptibility of each species to variations in environmental conditions (Brazeiro & Defeo, 1996). The degree of association of each population component with different strata of the beach may reflect migrations related to ontogenetic development. One of the accepted explanations is that zonation by size represents a mechanism to avoid intraspecific competition (McLachlan *et al*. 1996). It is suggested that the middle intertidal zone is a more favorable habitat for intertidal species because individuals are not constantly exposed to the continuous wave action, the zone is always saturated and the sediment is medium sized compared to the lower and upper zones; consequently, organisms do not have to divert a lot of energy to maintain their position and to avoid being washed by waves (Ocaña *et al*. 2010).

When analyzing all size classes, relative growth reflects isometric relationship; nevertheless, this relationship is variable among different life stages. Young individuals tend to grow faster in length than in weight, and from 15 mm individuals become heavier indicating that from this size, individuals attain sexual maturity. In bivalves where the gonadal growth and maturation result in increasing bulkiness of soft body and consequent high body weights, such sudden shifts in *b* values indicate onset of maturation and gonadal growth (Joseph & Madhyastha, 1982). Taking into account that *b* values change depending on the organism's developmental stage (Wilbur & Owen, 1964), for *D. denticulatus*, it is not useful to consider a simple allometric model for the entire class sizes of the population.

Allometric relationships have been used in bivalve populations subject to commercial fisheries as a method to determine the minimum catch size of the individuals (Gaspar *et al.* 2002b). Gonadal analyses are sometimes expensive and time consuming; consequently, the use of length-weight relationships of *Donax* species could be a tool that provides basic information for management purposes. In the *D. denticulatus* population from Levisa Beach, the relative growth becomes isometric at the 20 mm length; therefore, this size could be used as the minimum catch size allowing clams to reproduce at least once. In Venezuela the minimum catch size proposed was 19 mm for this species (Marcano *et al*. 2003).

The population studied at Levisa Beach shows potential to be exploited by recreational collectors. However, given that the beach is located in a proposed protected area, some management measures must be taken into consideration. First, the clams must be included in the management plan of the area in the event it is approved as a Wildlife Reserve. For the moment, if any collection occurs, it must be done from the lower limit of the beach to the middle intertidal zone where adult clams are more abundant. According to our results, it is recommended to gather clams from June to September because, during this season, there are no new recruits and the catch must be made by hand without using any gear that could affect the survival rate of *D. denticulatus*.

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