Growth and production of *Donax striatus* (Bivalvia: Donacidae) from Las Balsas beach, Gibara, Cuba

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Abstract: Clams of the genus *Donax* are worldwide the dominating group of the invertebrate community on sandy beaches. They are primary consumers that provide a significant abundance and biomass to the ecosystem. In the Caribbean, *Donax striatus* has an important role for nature and human, nonetheless studies on the population dynamics of this beach clam are scarce and no information exists on secondary production of this species. Growth parameters and secondary production of *D. striatus* were estimated from February 2008 to November 2009 at Las Balsas beach, Northeastern Cuba, in order to provide basic information for management purposes. In each month 45 samples were taken by means of a PVC corer of 0.025 m^2 area and sieved with a 1 mm mesh. Animals were measured and weighted with and without shell. A total of 5 471 specimens were collected during the sampling period. Shell length ranged from 2.7-33.3 mm. Growth parameters estimated from length frequency data were L_∞ = 36.1 mm, K= 0.8/yr and t_0 = 0.2/yr. The growth performance resulted in values of Φ´= 3.02. Life span was 2.4 yrs and mortality rate was 3.07 /yr. In 2008, mean abundance of *D. striatus* ranged between 17.1-770.7 ind./m^2. In 2009 the lowest mean abundance was 34.4 and the highest was 892.5 ind./m^2. During 2009 biomass and production was more than twice higher in comparison with 2008. Individual production showed highest values in the 24 mm shell size (3.74 g/m^2.yr) and 25 mm (0.71 g/m^2.yr), considering mass with shell and without shell, respectively. During 2009 abundance of individuals with 15 mm shell length or more increased resulting in higher biomass and production, compared to 2008. Using the conversion factor of wet mass to ash free dry mass (AFDM), annual production ranged between 2.87-6.11 g AFDM/m^2.yr, resulting in a turnover rate (P/B) between 5.11 and 3.47 in 2008 and 2009, respectively. The rapid growth and high turnover rate of *D. striatus* suggest a rapid recovery of the population. These results support the idea that this beach clam is an important resource at Las Balsas beach. Thus its exploitation must continue with caution, and only at the level of a recreational fishery. Rev. Biol. Trop. 63 (3): 639-646. Epub 2015 September 01.

Key words: *Donax striatus*, growth, mortality, secondary production, biomass, sandy beaches.

Clams of the genus *Donax* are worldwide the dominating group of the invertebrate community on sandy beaches; of the 64 species that have been described until now, about 75 % are to be found in tropical waters, around 22 % lives in temperate areas and a very small amount inhabits coastal upwelling regions (McLachlan & Brown, 2006). As primary consumers, donacids provide a significant abundance and biomass to the ecosystem, being also important for recreational and/or commercial fisheries in many countries (McLachlan et al., 1996).

Donax striatus Linnaeus, 1767, lives in the intertidal zone of sandy beaches of the Caribbean and the South-eastern Atlantic Ocean from Gibara Bay in Cuba to North-eastern Brazil (Wade, 1967). Despite its large distribution range and important role for nature and human (McLachlan et al., 1996) only a few studies concerning this species have been carried out by now. Wade (1967) suggested that variations in shell colour and morphometric is associated with ecological factors such as beach characteristics, food availability and population density. The morphology of the spermatozoa and aspects about spermatogenesis were described by Matos, Matos, Corral, and Azebedo (1995). The structure of a *D. striatus* population in Gibara (Northeastern Cuba) was analysed by Ocaña, Fernández, Silva, González, and García (2010). Furthermore, merely two theses from Venezuela (Farache, 1980; Pigallet de Mahieu, 1984) and two published studies from Brazil (Rocha-Barreira, Batista, Monteiro, & Franklin-Junior, 2002) and Venezuela (Delgado, Reverol, Godoy, & Severeyn, 2003) are available dealing with data of population abundance, structure and growth of *D. striatus*. Besides these studies, biological information of *D. striatus* is scarce and there is no report on secondary production of this species.

A population of *D. striatus* at Las Balsas beach has been subjected to a recreational exploitation during many decades according local people. Therefore the aim of the present investigation is to estimate the growth parameters and secondary production of *D. striatus* from Las Balsas beach in order to provide information for an optimized management of this resource.

MATERIALS AND METHODS

Study area: Las Balsas is a sandy beach located towards the South part of Gibara Bay in Holguín province, at North-eastern Cuba (21°05'39" N - 76°07'55" W). The beach extends over 1 600 m in length, the mean width of the beach face is 8.8 m and the slope is less than 6 %. The sediment is of terrestrial origin and medium grain size. The tidal cycle in the bay is semidiurnal with a maximum tidal range of 0.6 m. The beach is located between two estuaries of the rivers Gibara at the East and Cacoyugüin at the West, and affected by freshwater seepage, which increases the turbidity of the sea water remarkable during the rainy season (June-October). The sublittoral zone is shallow with a mean depth of 0.5 m to a distance of 150 m from the shoreline.

Sampling: Sampling was carried out monthly from February 2008 to November 2009 during low tide according to a stratified design (Schoeman, Wheeler, & Wait, 2003; Ocaña et al., 2010). Three fixed stations were selected at 300 m intervals along the beach. At each station, five strata were set up perpendicular to the shoreline from the low water mark to the drift line. Distance between consecutive strata varied 1.5-2 m depending on the beach width. On each strata of each station, three replicated samples were taken at 1 m intervals by means of a PVC corer of 0.025 m^2 area and 30 cm height, introduced in the sand to 20 cm depth (Sample Unit, SU). A total of 45 SU (three stations x five strata x three replicates) were taken each month. The sediment was then sieved on a 1 mm mesh. Collected individuals of *D. striatus* were stored in a plastic bag and kept on ice. In the laboratory, shell length (L) of individuals was measured to the nearest 0.1 mm, using a digital calliper. Individuals were grouped in 1 mm size class intervals to obtain monthly length frequencies histograms. A subsample of 390 specimens, covering all size classes, was used to determine length-weight relationships, first measuring the total mass with shell (*TM*, g) in a 1 mg resolution scale, thereafter removing soft tissues to determine wet mass (*WM*, g) after blotting on filter paper.

Growth, longevity and mortality: A series of 20 length-frequency distributions were used for growth estimations, to which a general von Bertalanffy growth function (*VBGF*) (von Bertalanffy, 1938) was fitted throughout the ELEFAN routine of the FiSAT II program package (Gayanilo, Sparre, & Pauly, 2005): $L_t=L_\infty[1\text{-}e^{(-K(t-to)}]$, where L_t is L (mm) at time t, L_∞ is the asymptotic maximum anterior-posterior shell length, K is the growth coefficient and to is the theoretical age at zero length.

Preliminary estimates of L_∞ and K, were used to identify the *VBGF* that best fits the monthly size-frequency data, using the *Rn* value as a criterion of fit, using response surface analysis of ELEFAN I.

To compare growth parameters with other *Donax* species the growth performance index (Φ') (Pauly & Munro, 1984) $\Phi'=2\log(L_\infty)+\log(K)$ and the overall growth performance index (*OGP*) of the length-weight relationship (Pauly, 1979) $OGP=\log[K(L_\infty)^3]$, were calculated.

The theoretical life span t_{max} was estimated by the inverse von Bertalanffy growth equation (Taylor 1958): $t_{max}=[\ln L_{95\%}-\ln(L_\infty-L_{95\%})]/K$, where $L_{95\%}$ represents 95 % of the maximum *L* recorded during field sampling. Mortality rate (*Z*) of the population was estimated using the exponential extinction model, using the length-converted catch curve of the cumulative data of samplings: $N_t=N_t-1(e-Z*\Delta t)$, where N_t is the number of individuals in time *t* and *Z* is the curvature parameter of the equation.

Biomass and production: Length-weight relationships, using *TM* (g) and *WM* (g), were determined by nonlinear regression analysis using the exponential equation: *TM*, *WM* = $a*L^b$, where a and b are constants. Monthly abundance (ind./m^2, mean ± standard error) was estimated extrapolating the number of clams collected in each of the 45 SU. Total annual production *P* (g/m^2.yr), considering *TM* and *WM*, was computed using all pooled samples by the mass specific growth rate method (Crisp, 1984) from the data of abundance, size-class frequencies, *VBGF* parameters and length-weight relationships: $P = \Sigma N_i*M_i*G_i$, where N_i is mean abundance (ind./m^2) in length class *i*, M_i is the mean individual weight in length class *i* and G_i is the mass-specific growth rate: $G_i = b_{(TM,\ WM)}*K*((L_\infty/L_i)-1)/[yr]$, where *b* is the exponent of length-weight relation an L_i is the mean length of individuals at size class *i*. In addition, mean annual biomass was estimated by: $B = \Sigma N_i*M_{i,}$ and annual renewal rates (*P*/*B*) of the population were calculated from total annual production and mean annual biomass. Logistical issues impeded me to determine ash-free dry mass (*AFDM*), so to compare my results with other *Donax* populations, annual renewal rates were converted to ash-free dry mass (*AFDM*) using the conversion factor *AFDM*/*WM* = 5.8 % (Ricciardi & Bourget, 1998).

RESULTS

Growth, longevity and mortality: A total of 5471 specimens were collected during the sampling period. The smallest recorded individual measured *L*= 2.7 mm and the largest *L*= 33.3 mm. Growth parameters, using ELEFAN I routine best fits (*Rn*= 0.15), were as follows: L_∞ = 36.1 mm, *K*= 0.8/yr and t_0 = 0.2/yr; these parameters were used to construct the growth curve of *D. striatus* population at Las Balsas beach (Fig. 1). The growth performance resulted in values of Φ'= 3.02 and *OGP*= 4.57. The estimated theoretical life span was 2.4 yrs.

The instantaneous mortality rate was 3.07/yr calculated from the length-converted catch curve for the study period; the regression

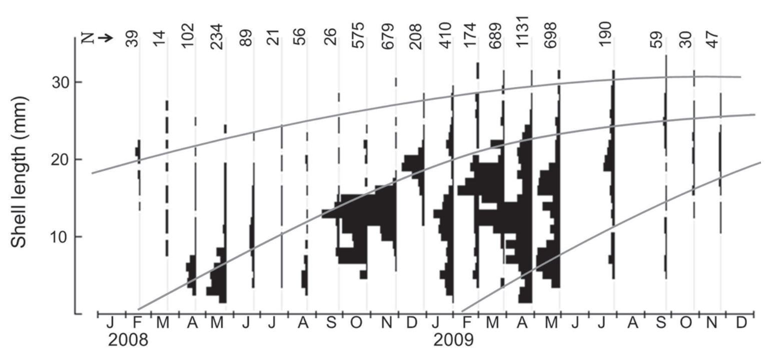

Fig. 1. Growth curves (grey lines) of *D. striatus* estimated by the FISAT II program from monthly length-frequency data (black histograms) for the period February 2008 to November 2009.

equation is as follows: $ln(N/\Delta t)= 10.72\text{-}3.07t$ ($R^2 = 0.98$). In 2008 mortality was 3.30/yr ($R^2 = 0.97$), and in 2009 the estimated mortality rate was 2.85/yr ($R^2 = 0.98$).

Biomass and production: In order to estimate the production of the Cuban *D. striatus* population, b values of the length-weight relationships were 3.26 and 3.18 for *TM* and *WT,* respectively (Fig. 2).

In 2008, abundance of *D. striatus* (mean ± se) ranged between 17.1 ± 3.7 and 770.7 ± 443.1 ind/m^2. In 2009 the lowest abundance was 34.4 ± 15.2 and the highest 892.5 ± 34.4 ind/m^2. During 2009 biomass and production was more than twice higher in comparison with 2008 (Table 1).

Individual production showed highest values in the 24 mm shell size (3.74 g/m^2.yr) and 25 mm (0.71 g/m^2.yr), considering *TM* and *WM* respectively (Fig. 3). During 2008 the 13 mm size class contributed with the highest density and production (Fig. 4A), whereas in 2009 individuals of 13 mm contributed with

TABLE 1
Biomass (B) and production estimation (P) of *D. striatus* from Las Balsas beach in 2008 and 2009

	Total Mass (g/m2.yr)		Wet Mass (g/m2.yr)		Ash Free Dry Mass (g/m2.yr)	
Year	B	P	B	P	B	P
2008	54.86	254.49	9.68	49.47	0.56	2.87
2009	171.07	579.96	30.37	105.32	1.76	6.11

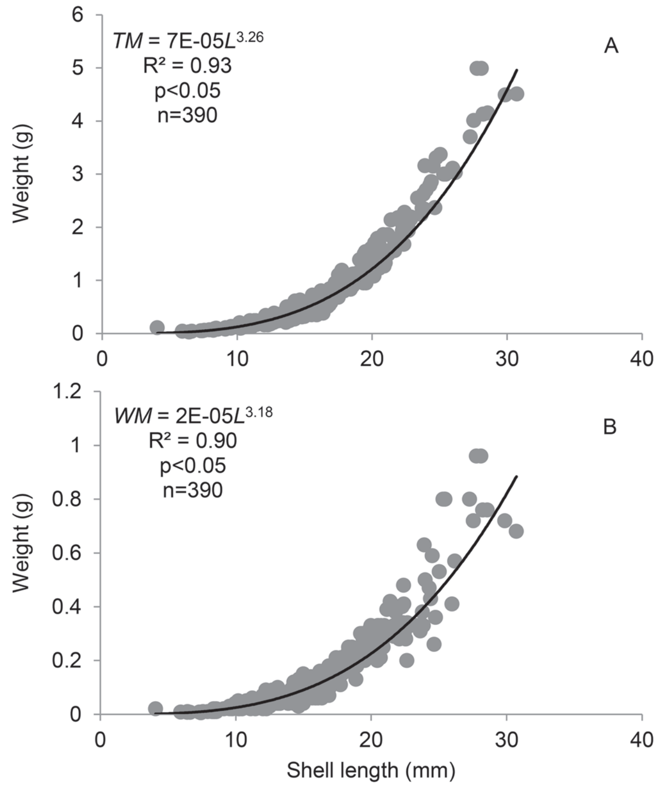

Fig. 2. Length-weight relationship and model fit considering total mass (A) and wet mass (B) of *D. striatus* from Las Balsas beach.

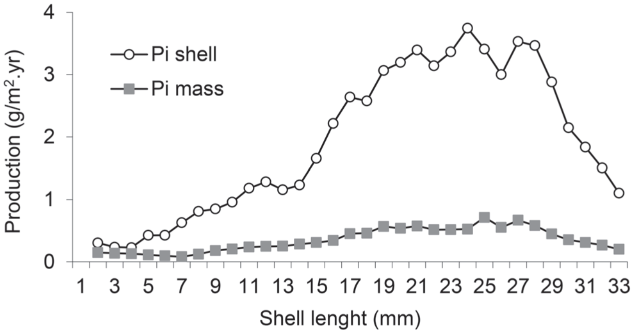

Fig. 3. Individual somatic production for different length classes of *D. striatus* from Las Balsas beach. Pi shell: individual somatic production for total mass with shell, Pi mass: individual somatic production for wet mass.

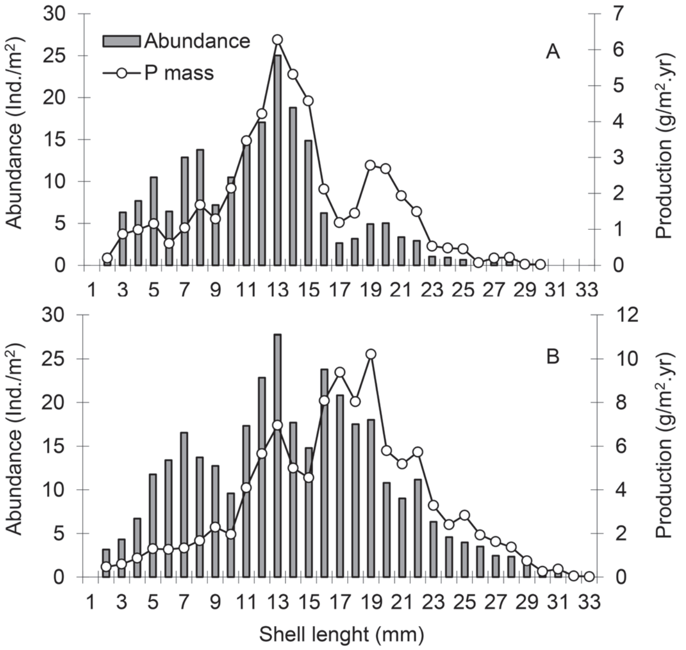

Fig. 4. Mean abundance and somatic production for 2008 (A) and 2009 (B) for different length classes of *D. striatus* from Las Balsas Beach. P mass: population somatic production for wet mass.

the higher abundance too, but the higher production were reported for the 19 mm size class (Fig. 4B). Considering *AFDM*, the renewal rate was 5.11 in 2008 and 3.47 in 2009.

DISCUSSION

The maximum shell length (*L*= 33.3 mm) of the Cuban *D. striatus* population, recorded during this study, is the largest currently known length of this species. Wade (1967) commented that *D. striatus* seldom reaches 35 mm but the populations studied by this author did not show evidence of individuals larger than *L*= 30 mm. In this population there is low abundance of specimens reaching *L* ≥ 30 mm, one of the reasons being probably that they are fished throughout the year, and then a higher probability of fishing mortality in the selection by size is combined with natural mortality.

The estimated *K* value for this population is higher than the one reported by Farache (1980) in a Venezuelan beach (0.29/yr) but lower than that estimated in a Brazilian beach (1.16/yr) by Rocha-Barreira et al. (2002). The growth rate calculated for this population is relatively high. Herrmann et al. (2009) made a compilation of several studies on different species of *Donax* to compare growth among them in different climatic areas. According to these data, *D. striatus* from Las Balsas beach had higher growth performance than populations of other *Donax* species inhabiting the same climate region. These values match with other species of the same genus located in temperate zones, but that have reach longer shell sizes; this could be explained by the estimation method used in this study (Ocaña, Apín, & Cala, 2013). Growth estimates based on length-frequency data may be biased for tropical species which present continuous recruitment along the year (Sparre & Venema, 1997).

Most species of *Donax* have longevity of one or two years, whereas mortality is often high, particularly in tropical species (Ansell, 1983). The life span of 2.4 yrs calculated in this study is higher than precedent values found in other populations of the same species and even higher than *D. denticulatus* that has the same distribution range. Other populations of *Donax* in the Caribbean (Wade, 1968; Vélez, Venables, & Fitzpatrik, 1985; McLachlan et al., 1996; Rocha-Barreira et al., 2002; Marcano, Prieto, Lárez, & Salazar, 2003; Ocaña et al., 2013) do not last two years. Mortality rate obtained for *D. striatus* was higher than other tropical species such as *D. incarnatus* (Thippeswamy & Mohan Joseph, 1991) and *D. dentifer* (Riascos & Urban, 2002), was similar compared with *D. obesulus* (Velarde & Aguilar, 2008), and lower than a population of *D. denticulatus* from South-eastern Cuba (Ocaña et al., 2013). It is necessary to remark that this study estimated the total mortality rate for the population of Las Balsas beach. Because there are no official catch statistics, the fishing mortality could not be estimated. High mortality could be related with the direct impact of removing organisms, and the alteration of habitat features due to human trampling that could affect young individuals as suggested by Rocha-Barreira et al. (2002).

Abundance varies between years, thus mean annual biomass and secondary production were more than double in 2009 when compared with 2008. This result suggests that there is not a clear seasonal pattern of abundance in this population. Herrmann et al. (2009) found that abundance of *D. hanleyanus* varied between years at two of the three studied beaches, therefore it could be possible that the inter-annual variation of abundance is population-specific instead of species-specific. In this population there is a coincidence that size classes with higher abundance had higher contribution to the total production in the studied period. In 2009 the abundance of individuals with $L \geq 15$ mm increased in relation with 2008, this result could be explained by climatological events occurred during 2008 (Ocaña et al., 2010) that might cause higher mortality of adults individuals or their migration to the subtidal zone, so they could not be collected in my sampling in 2008.

Values of biomass and production are higher than those obtained for other tropical species such as *D. incarnatus*, *D. spiculum* (Ansell, McLusky, Stirling, & Trevallion, 1978) and *D. dentifer* (Velarde & Aguilar, 2008). Secondary production of *D. striatus* is higher than the overall median estimated by Petracco, Cardoso, and Turra (2013) to bivalves of sandy beaches. High renewal rate matches with values of some tropical species according to Herrmann et al. (2009), nevertheless is lower than *P*/*B* rate reported for *D. incarnatus*, *D. spiculum* (Ansell et al., 1978) and for *D. denticulatus* (Vélez et al., 1985; Ocaña et al., 2013). The rapid growth and high turnover rate of *D. striatus* suggest a rapid recovery of the population. These results support the idea that this beach clam is an important resource at Las Balsas beach. Thus its exploitation must continue with caution, and only at the level of a recreational fishery.

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RESUMEN

Crecimiento y producción de *Donax striatus* (Bivalvia: Donacidae) en playa Las Balsas, Gibara, Cuba. Los estudios sobre la dinámica poblacional de la almeja de playa *Donax striatus* son escasos y no existe información sobre la producción secundaria de alguna población de esta especie. Los parámetros del crecimiento y la producción secundaria de *D. striatus* fueron estimados a partir de datos de muestreo obtenidos entre febrero 2008 y noviembre 2009 en playa Las Balsas en la zona norte oriental de Cuba para aportar información básica para su manejo. Cada mes se recolectaron 45 muestras usando un núcleo de PVC de 0.025 m^2, el sedimento fue tamizado en malla de 1 mm. Los individuos recolectados fueron medidos y pesados con concha y sin concha. La longitud de la concha fue de 2.7-33.3 mm. Los parámetros de crecimiento estimados a partir de las frecuencias de tallas fueron: L_∞= 36.1 mm, K= 0.8/año y t_0 = 0.2/año. El índice de crecimiento fue de Φ'= 3.02. El tiempo de vida estimado de 2.4 años y la mortalidad 3.07/año. En 2008 la abundancia media de *D. striatus* fluctuó entre de 17.1-770.7 ind/m^2. En 2009 la menor abundancia fue de 34.4 y la mayor de 892.5 ind/m^2. En 2009 la biomasa y la producción fueron más del doble que las estimadas en 2008. La mayor producción somática individual fue aportada por individuos de 24 mm (3.74 g/m^2.año) y 25 mm (0.71 g/m^2.año), considerando la masa total con concha y sin concha respectivamente. Durante 2009 la abundancia de individuos de 15 mm de longitud o más, se incrementó resultando en mayor biomasa y producción en comparación con 2008. Usando el factor de conversión de peso húmedo a peso seco libre de cenizas (PSLC), la producción anual en 2008 fue de 2.87 y en 2009 fue 6.11 g PSLC/m^2.año, lo que resulta en una tasa de renovación (P/B) de 5.11 en 2008 y 3.47 en 2009. Estos resultados apoyan la idea que la almeja de playa es un recurso importante y su explotación debe continuar con cautela y solo a un nivel de una pesquería recreativa.

Palabras clave: *Donax striatus*, crecimiento, mortalidad, producción secundaria, biomasa, playas arenosas.

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