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# Beach Morphodynamics and Clam (*Donax Hanleyanus*) Densities in Buenos Aires, Argentina

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## ABSTRACT

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The studied coastal area is located along the Atlantic Ocean, between the localities of Punta Rasa and Villa Gesell. Twelve monitoring sites were established along the shore.

Two morphologic types of beach profiles were observed. One type located northward composed by fine sand, has a linear configuration profile with low slopes (0.028) and narrow beach (40–70 m width). The other beach type is composed by coarser sand with higher slopes (0.014) and wider beaches (40–80 m), usually presenting a stable berm, and one or two tidal berms.

The mean grain size of the beach sediments where the clam *Donax hanleyanus* occurs varies from fine sand (2.10–2.80 phi) for the north sector (A) to medium to coarse sand (0.70–1.90 phi) in the south sector (B). *Donax hanleyanus* is found in the lower third of the intertidal zone in the transverse profile. A permanent lack of individuals was observed in the northern part of sector A due to the fresh water influence of the Rio de La Plata estuary. The mean density observed was about 400 individuals per square meter and the highest densities were recorded for Mar del Tuyú with 2250 individuals per square meter.

The grain size of the sediments analyzed was not correlated with the occurrence of *Donax hanleyanus,* although it was observed that the presence of coarser sheets with mean grain size of 0.71 phi and standard deviation of 1.07 affect the burrowing capacity of *Donax.*

The life span of *Donax hanleyanus* is greater in the south where they can live up to three years. The growth rates are similar for both areas although in the south a decrease in the growth rates was observed during winter.

It was observed that the grain size and the morphological changes did not condition the presence of *Donax* but affected the mobility of Donax hanleyanus along the transverse beach profile.

**ADDITIONAL INDEX WORDS:** Donax hanleyanus, *densities, population structure, mobility, beach morphodynamic, grain size.*

## INTRODUCTION

The exposed sandy beaches of the world represent high energy environments for their fauna dominated by the physical processes of tides and wave action. A few genera of mollusks, crustaceans and polychaetes dominate such environments, each adapted to exploit actively the apparently severe conditions rather than passively survive their effects. In so doing the successful genera derive benefits such as refuge from predation, reduced competition, or ready availability of food resources, which more than offset the costs incurred in increased activity or in the risk of stranding and desiccation. In consequence some species may reach very high population densities in some areas.

Among mollusks on a world-wide basis, species of *Donax* form by far the most dominant group in such environments. Although restricted by their specialization to beaches, they spread to occupy most available niches within these constraints (Ansell, 1983).

The number of *Donax* species decline with increasing latitude along each major north-south continental coastline. Generally only one species to the north and one to the south on each coastline extends in distribution into the cold temperate region, as in the case of *Donax hanleyanus* Philippi 1847 in the south-west Atlantic (Ansell, 1983).

The most significant common characteristic of all habitats occupied by *Donax* species is that they are high energy environments with strong wave action or high current speed causing frequent sediment disturbance. *Donax* species are well-adapted to maintain their position in such conditions.

Partly aided by the streamlined shell shape, *Donax* species are all rapid and efficient burrowers, achieving complete burial using only a relatively few digging cycles (Trueman,

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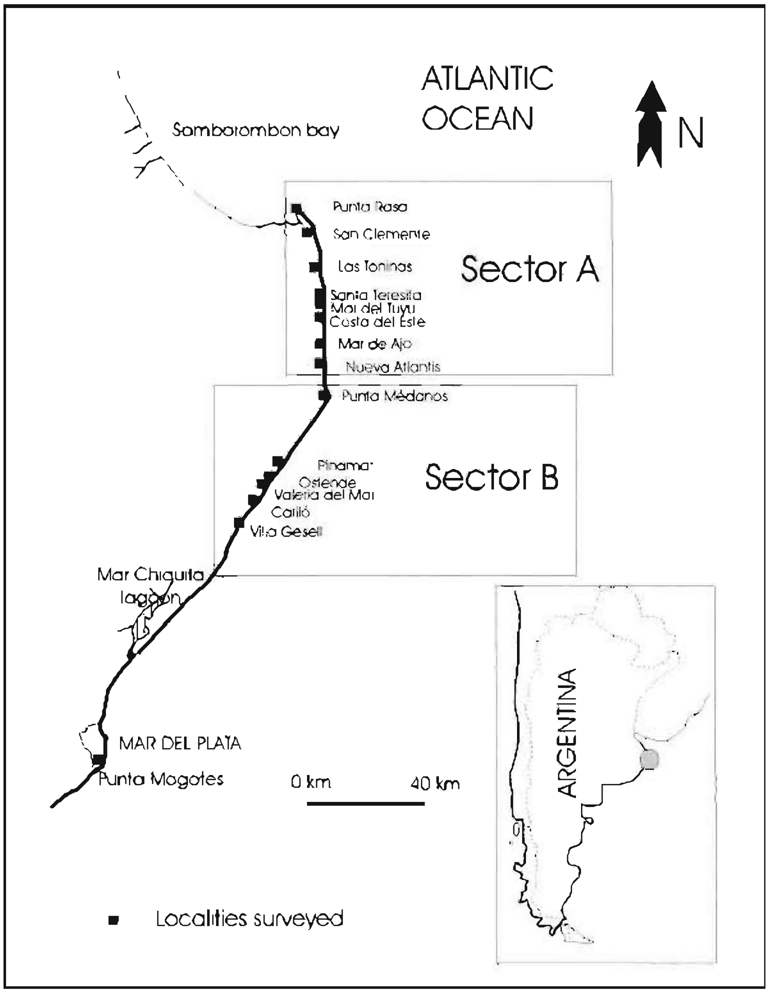

Figure 1. Location map showing the limits of Sector A and Sector B.

*et al.*, 1966; NAIR and ANSELL, 1968; ANSELL and TREVALLION, 1969; TRUEMAN and ANSELL, 1969; TRUEMAN, 1968, 1971). The time from initial penetration to complete burial may be very short in tropical species such as *D. denticulatus* (5–6 secs; TRUEMAN, 1971) or *D. semigranosus* (3–6 secs; MORI, 1938) and is proportionally longer in species living at lower environmental temperatures (ANSELL and TREVALLION, 1969; MCLACHLAN and YOUNG, 1982).

*Donax* species also make powerful recovery movements to regain the surface when accidentally buried too deeply by sand movements and can move over the surface of the sand by leaping (STOLL, 1937, 1947; ANSELL, 1969; ANSELL and TREVALLION, 1969; TRUEMAN, 1971).

A major factor in the success of *Donax* in high energy environments is their ability to coordinate these movements to maintain their normal position in the sediment facing of wave disturbance, and to respond to the physical changes in the environment caused by wave and current action.

Recruitment patterns are highly variable both between different species, and in the same species, in different locations, or in different years. Extreme cases of such variability have led to their description as "resurgent populations" (COE, 1953, 1956; MIKKELSON, 1981). This variability in recruitment in part reflects the generally extended periods over which spawning may take place, and in part the importance of unpredictable local hydrographic conditions in determining settlement patterns. Only in areas where there are strong seasonal factors does settlement show a more consistent pattern, and even in those cases there are great differences in settlement density from year to year. Under exceptional conditions recruitment to local beaches may be dependent on the local density of mature spawning stock (DE VILLIERS, 1975), but it is probably more normal for populations to recruit from a common larval pool to which several beach populations may contribute (WADE, 1968).

## GEOLOGICAL SETTING

The studied coastal area is located along the Atlantic Ocean, between the localities of San Clemente del Tuyu and Villa Gesell (Figure 1). It is an open coast, straight with a North South

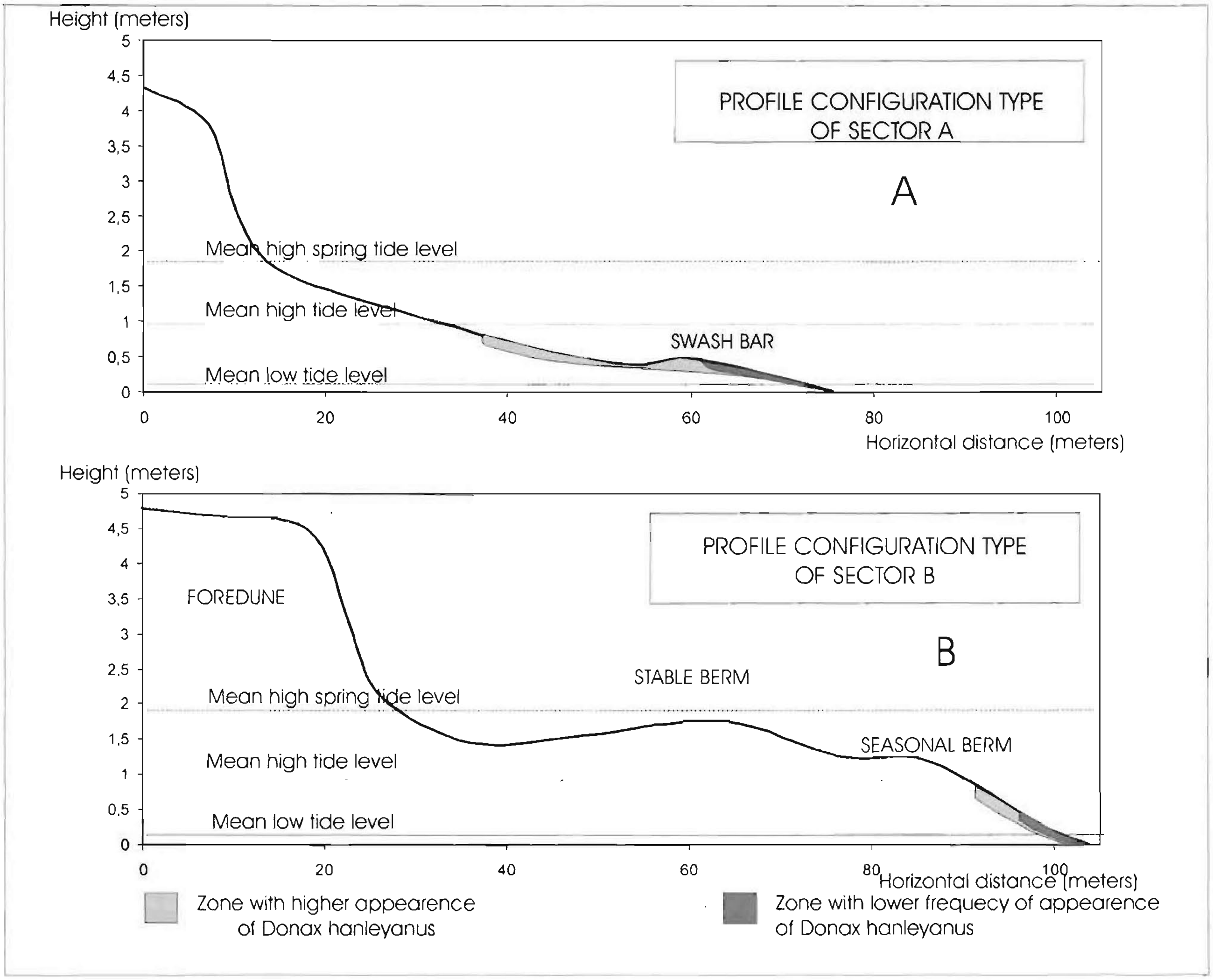

Figure 2. *Donax hanleyanus* distribution along the transverse beach profile with different morphologic and configuration beach types along the coast. A. shows the beach parameters for sector A between Punta Rasa and Punta Médanos and Sector B between Punta Médanos and Mar Chiquita.

shoreline orientation between San Clemente del Tuyu and Punta Medanos and Southwest Northeast between Punta Medanos and Villa Gesell. The shoreline is stable on long term basis (MARCOMINI and LÓPEZ, 1993).

Predominant wave generated longshore current and corresponding net longshore sediment transport are toward the north, with an increasing gradient from Punta Medanos to Punta Rasa, because of a change in the angle between the coastline and the prevailing south-eastern incident wave in this direction. Longshore drift transport range between 300,000 and 1,000,000 $m^3$ per year (CAVIGLIA *et al.,* 1991).

The coast is storm and wave dominated. Southeast storms (surge storms) play a significant role in modifying the beach.

A microtidal regime is characteristic of the studied area. The amplitude of the tide oscillates between 0.91 m (Spring tides) and 0.61 m (Neap tides) (SHN, 1997). These small tidal variations in sea level are negligible in conditions of much larger wind-generated variations.

The coastal area of Buenos Aires is represented by an accresive coast characterized by a dune field of 0.05 km to 5 km width with dunes height that vary between 2 to 25 m. Two units with active and inactive dunes are distinguished along the coast. The active dunes field, with major development at Punta Médanos is composed of barjanoid ridges with E-W orientation. It is spread over a strip of 4 km width from the actual coastline. A pine forest had been planted on several sectors of this active coastal dune field.

The beaches are sandy, straight, extended laterally with a variable width between 60 and 140 m and with mean slopes under 2 grades.

## METHODS

Clams were sampled seasonally (each 3 month) from July 1998 to April 2000 in twelve localities between Punta Rasa and Villa Gesell (Figure 1). They were: Punta Rasa, San Cle-

Table 1. *Statistical parameters of the beach sediments where* Donax *was found for sectors A and B.*

SECTOR A

| Frequency Distribution | | Mode | Sorting | | Skewness | | Kurtosis | |
|---|---|---|---|---|---|---|---|---|
| Unimodal | 97% | 3phi | Very well to moderately sorting | 79% | Negative | 93% | Platikurtic | 21% |
| | | | | | | | Mesokurtic | 10% |
| | | | Moderately to poorly sorting | 21% | Near symetrical | 7% | Leptokurtic | 69% |

SECTOR B

| | | Mode | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Polimodal | | | | | | | |
| Frequency Distribution | | Unimodal | Principal | Secondary | Sorting | | Skewness | | Kurtosis | |
| Polimodal | 55% | 2–2.5 | 1–1.5 | 2–2.5 | Moderately to poorly sorting | 60% | Near symmetrical | 44% | Mesokurtic | 48% |
| | | | | | Very well to moderately sorting | 37% | Coarse to very coarsely skewed | 36% | Platikurtic | 30% |
| Unimodal | 45% | | | | | | Fine to very finely skewed | 13% | Leptokurtic | 18% |

mente del Tuyu, Las Toninas, Santa Teresita, Mar del Tuyu, Costa del Este, Mar de Ajó, Nueva Atlantis, Punta Médanos, Pinamar, Carilo and Villa Gesell.

Transverse beach profiles were surveyed on each transect to determine the morphologic features of the beach and the morphodynamic conditions that affected the area during the observation period.

They were seasonally surveyed with a Total station choosing reference points for each transect. Biological and sedimentological data were used with the beach the beach profiles measured to establish *Donax hanleyanus* position.

Clams and sediment samples were collected on the different beach subenvironments beginning at the dune foot to the lower limit of the swash zone. Eight samples were taken at each station with a cilinder metal coring of 6 cm in diameter and 8 cm deep was used to remove the sediments. Each sample was sieved through a 0.5 mm mesh, and the organisms retained were collected and later measured in the laboratory with a vernier caliper along the greater valve length. Superficial sediment samples were collected for grain size analysis and to detect all major changes in morphology along the beach profile (dune base, mid berm, mean spring high tide, mean high tide, mean low tide, bar crest, and swash zone) and to describe the beach morphodynamic and the *Donax hanleyanus* location. Sediments were sieved using U.S. Standard sieves at ½-phi unit intervals. Phi is defined as the negative logarithm of the grain dimension in millimiters to the base 2. Grain size distribution tables, statistics and graphics of frequency, cummulative frequency and probability distribution were carried out for the statistical analysis. Standard grain-size distribution statistic parameters such as mean grain size, median grain size, skewness and kurtosis were also calculated using the graphic method of FOLK and WARD (1957). These results were analysed and related to the abundance and presence of *Donax hanleyanus* on the beach.

## RESULTS AND DISCUSSION

### Beach Morphology

Two sectors were recognised in the studied area, with different morphologic and textural features (Figure 1), north: from Punta Rasa to Nueva Atlántis (Sector A); and south: from Punta Médanos to Villa Gesell (Sector B).

Sector A: the beaches are characterised by a linear configuration profile (Figure 2A) with a beach width that varies from 40 to 70 m. The average beach slope is of 0.028 (1°36′). No stable or seasonal berms are observed. The spring tides reach the base of the dune, frequently generating escarpments after southeast winds. The presence of swash bars in the foreshore is frequently observed with widths from 15 to 20 m and heights of 25 cm.

Sector B: the beaches have slopes of 1 to 2.50 (2°30′) degrees and they are composed by medium to fine sand.

The beach profile configuration is similar to the one described by SPALLETTI (1980), where the different subenvironments are described: backshore, foreshore and shoreface adapted to the hydrodynamic conditions that affect the morphology of each sub-sector, breaker, surf zone and swash zone.

The beach profiles show seasonal changes. Two or more berms join to the stable berm in the winter and disappear in the summer during a year cycle. It was observed that only one berm is stable and is the most sensible parameter to evaluate the natural recovery to erosion. It is preserved during storm episodes and recovers naturally except in sectors where the beach is affected by urbanization (MARCOMINI and LÓPEZ, 1997).

The natural beach profile has (Figure 2B): 1) a stable berm of approximately 40 m long and 0.75 m high, all located in the backshore sector; 2) one or two transitional berms of 20 to 25 m length and 0.5 m height join to the latter one. These latter ones are exceeded by the waves during extraordinary tides or during storm condition, where they would move on

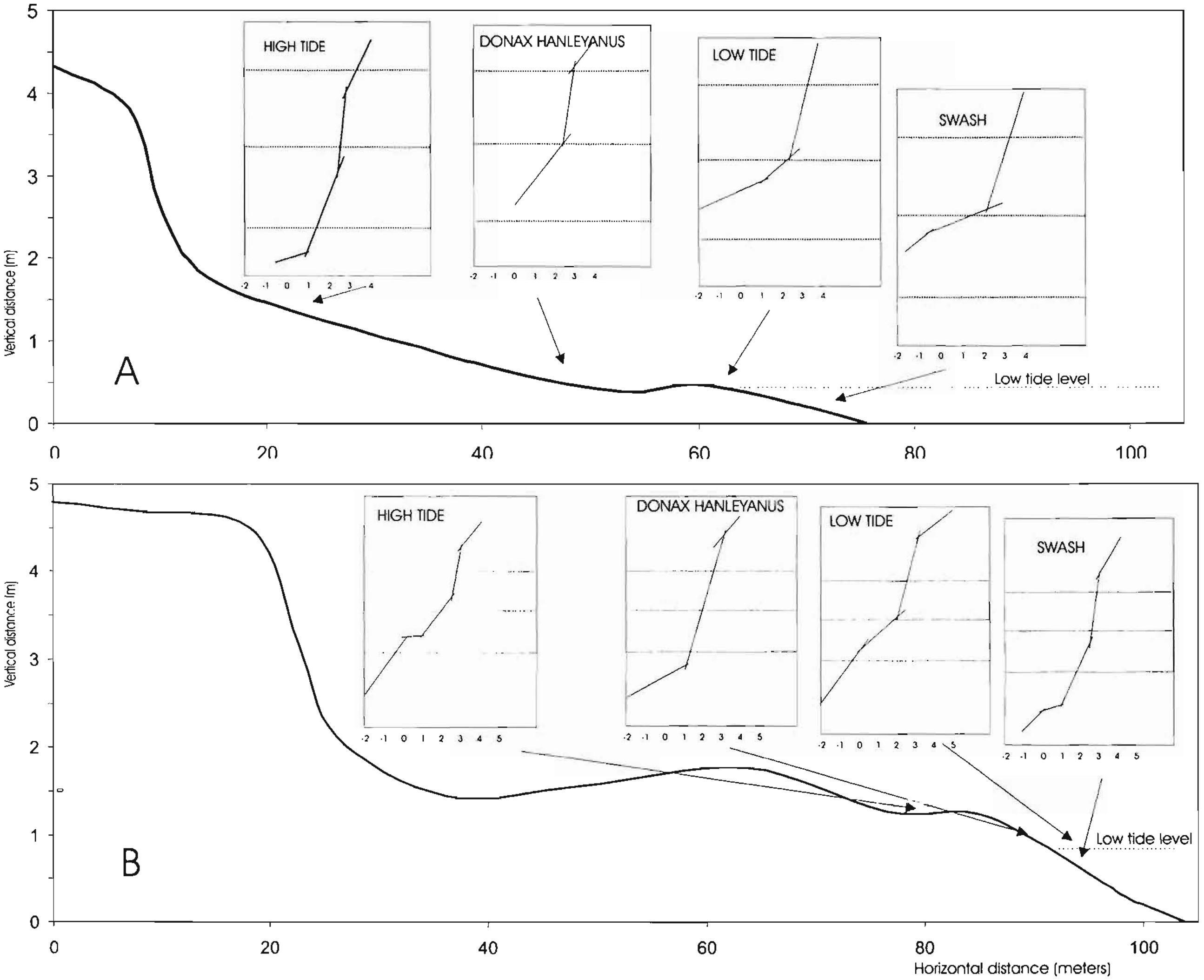

Figure 3. Probability distribution curves for each subenvironment along the transverse beach profile for sector A and B.

to being affected by the action of swash. The beach width varies from 80 to 150 m and the average beach slope is 0.014 (0°48′). The intertidal zone is the zone between the medium level of spring high tide and the medium level of the spring low tide. Underneath this begins the subtidal zone.

WRIGHT *et al.* (1982) and HORN (1993) divided the intertidal sector in three subsections: high intertidal, medium and short. They introduced the medium level of the high and low neap tide as limits. The intertidal slope varies, in general, between 2 and 3 degrees, with an average beach slope 0.048 (2°46′). The foreshore is subject to the hydrodynamic action of the uprush, backwash and the surf depending on the state of the tides. It is important to highlight the concept of spatial and temporal variation in the hydrodynamic that the beach sub-environment suffers, especially due to the continuous migration between subaqueous and subaeolian conditions.

The coastal dune has heights of approximately 5 m from the dune base, ending directly in the backshore. In general the dune does not have a very defined morphology in the coastal sector.

## Sediment Grain Size Analysis

Sector A: the beach samples analyzed are composed of fine sand and present unimodal distributions with mode at 3 phi. Polymodal distributions were observed in the southern limit of sector A (Figure 1) with a principal mode at 3 phi and secondary mode at 1. The sorting varies from very well to moderately sorted, the skewness is usually negative to near symetrical and the kurtosis leptokurtic.

Sector B: The beaches are integrated by fine to medium sand with a mean grain size in medium sand (1–1.5 phi) and usually present unimodal or polimodal distributions. They are frequently well to moderately sorting, platikurtic and with near symmetrical skewness. The statistics parameters can be seen in Table 1.

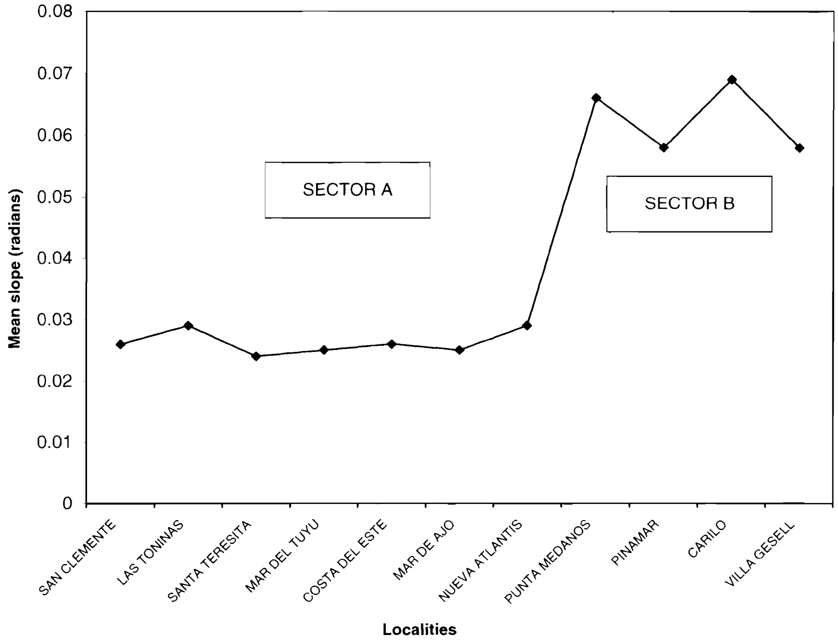

Figure 4. Mean slope of the intertidal subenvironment from north (San Clemente) to south (Villa Gesell).

The beaches showed regular changes on their energetic conditions along the transverse beach profile. Each subenvironment displayed probability distribution curves similar to those studied by Visher (1969) for the southern coast of Carolina (USA). Figure 3 shows the probability distribution curve for each subenvironment along the transverse beach profile for sector A and B (Figure 1).

Usually frequency distributions of sediments with Donax show a very well sorting saltation segment with two breaks at 2.5–3 phi and the other at 2.5 phi (sector A) and 1 phi (sector B).

Although very different energetic conditions were recognized between sectors A and B, *Donax hanleyanus* was observed in both sectors where a very well sorted saltation transport domain the hydrodynamic of the swash along the intertidal beach (Figure 3).

## The Distibution of *Donax hanleyanus* Along the Transverse Beach Profile

The slope of the intertidal sector was used as a parameter to compare the beaches. The obtained values are shown in Figure 4 for each location from north to south respectively. A marked break in the slopes is observed starting in Punta Médanos. A north sector with a smaller medium slope of 0.026 ± 0.002 (1° 36′) and a south sector between Punta Médanos and Villa Gesell with greater variable slopes between 2° 28′ and 3° 29′ and an average slope of 0.063 ± 0.006 (2° 46′) can be seen.

This significant change in the slope values does not affect the presence of *Donax hanleyanus* in the transversal profile of the beach, although it is related to distribution and mobility.

In Figure 2 the distribution and abundance of *Donax hanleyanus* for different types of beach profiles are observed. In the north sector (Figure 1, sector A) the dispersion is wider (aproximately 25 m), comprising a fringe which goes from low tide to high tide although it is more often localised to the front of season swash bars.

In the south sector (Figure 1, sector B and 2B)(of mayor slope) the distribution is confined to a narrower fringe. Its major abundance was registered in the inferior third of the intertidal, at a distance of 5 to 8 m above the average low tide level and it occupies a fringe of approximately 2 m thick.

## Longshore Grain Size Parameters Variation

A mean value was calculated to characterise each one of the more representative statistical parameters based on grain size analysis of the sediments where the presence of *Donax hanleyanus* was recorded.

The obtained values for mean, standard deviation, skewness and kurtosis are shown on Figure 5 A. The most representative parameters are the mean and sorting. In the north sector the sediments where *Donax* is registered show a mean grain size in fine sand (2 to 3 phi) and the standard deviation varies from very well sorted to moderately well sorted (0.25 to 0.58 phi). In the sector located to the south of Nueva Atlantis (Sector B) the mean grain size is in medium sand and the sorting varies from poorly to moderalety sorted. The skewness and kurtosis do not posses very significant variations.

In spite of the clear differences obtained in the statistical parameters in both sectors (coarser and poorly sorted sediments in the south sector), the presence of clam has been

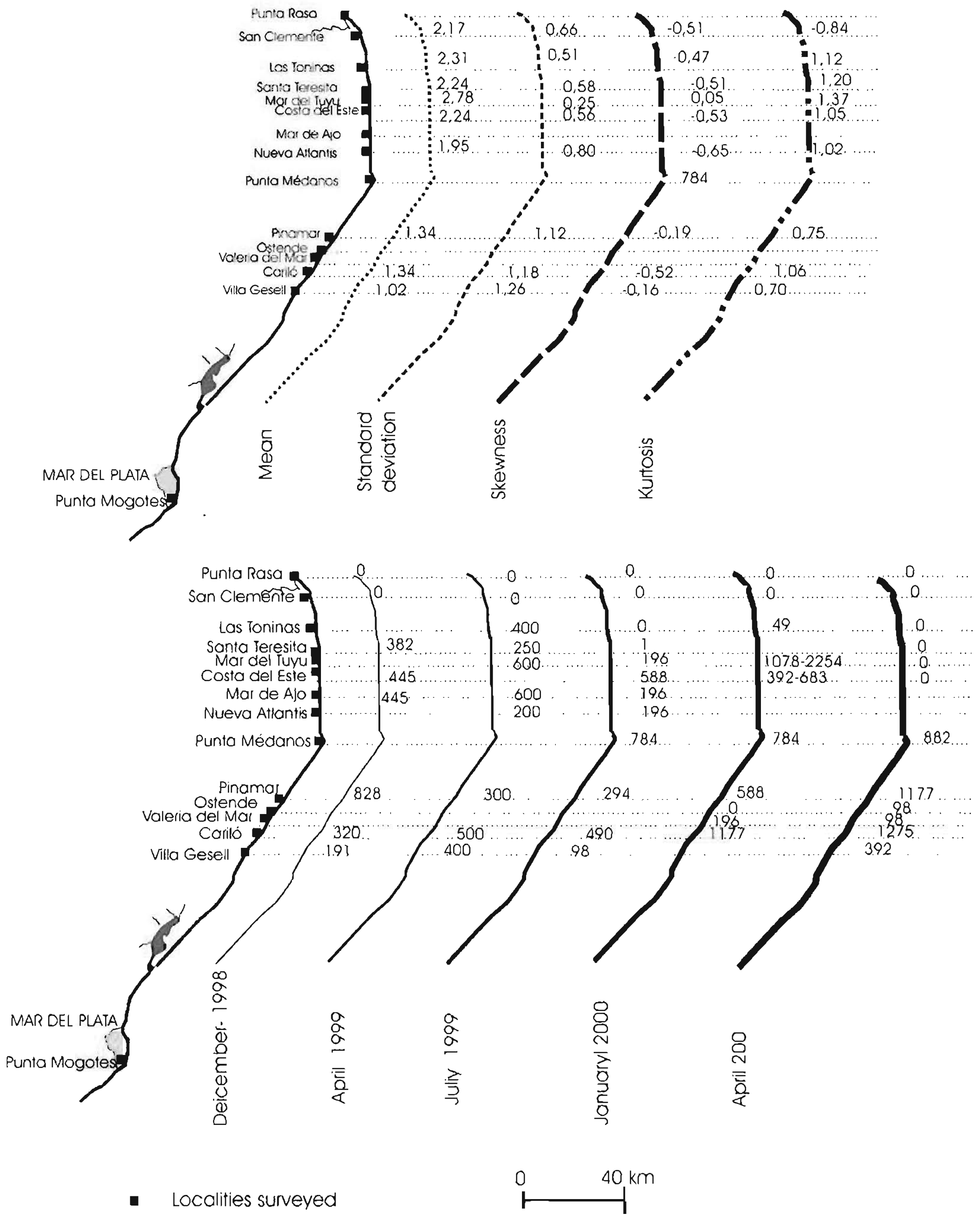

Figure 5. Top. Grain size parameters of the sediments of the intertidal zone where *Donax hanleyanus* was found. Bottom. Densities of *Donax hanleyanus* along the coast expressed in individuals per square meter for the different sampling periods (1998–2000).

registered in both sediment types with density fluctuations that were independent of the grain size variations.

### Textural Sediment Changes

Although the recognised sediments grain size do not effect the clam habitat, discontinuities in the granulometry of the sediments have been observed in surface and depth that would condition the burial. These changes in grain size are generally due to the entrance of swash bars after storms. We observed that these bars are usually composed by coarser sediments with a high content of shells that hinders the burrowing, not only because of the increase in grain size but mostly because of the change in the shape of the grain with transition of spherical to plain clasts. As the distribution of these banks restrict the burial capacity, the organism looks for an alternative site to be buried downdrift. There is also evidence of these changes in vertical cuts. After the entrance of the bar the natural system is re-established and layers

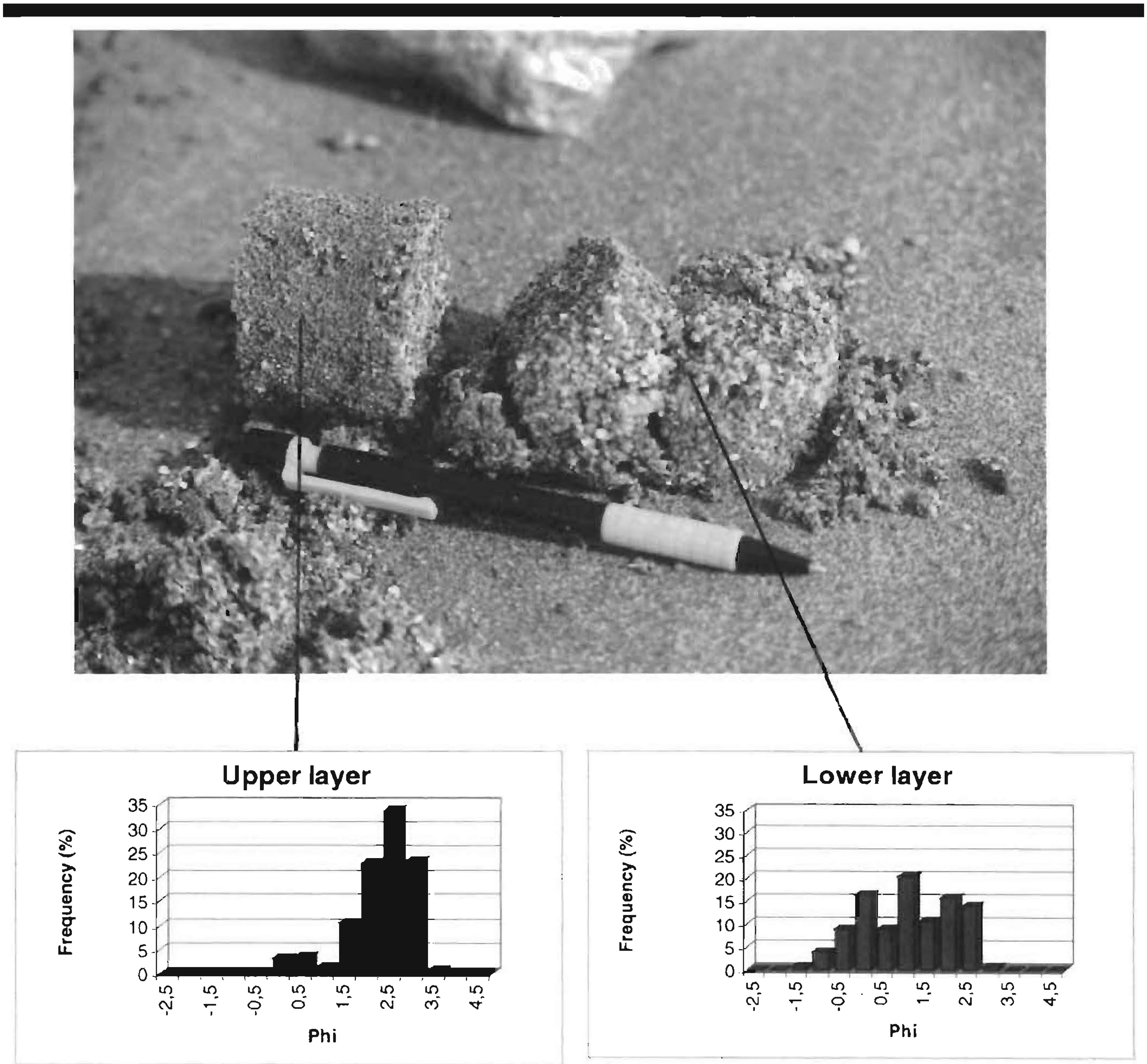

Figure 6. Photograph showing sediment distribution in layers on the intertidal zone where the presence of a coarse bank limits the burrowing of *Donax hanleyanus*.

composed of finer sediments bury the bar. In these cases, wich are very frequent in the south sector, the clam crosses the upper layer and finds an obstacle for its burial in the coarser layer generally located from 4 to 5 cm deep. The larger individuals penetrate the coarser sediment layer from 1 to 2 cm.

In the Figure 6 a photograph shows the different layers described and the textural features of each one.

### Densities and Population Structure

Figure 5B shows *Donax hanleyanus* population density distribution, both seasonally and geographically. The maximum density recorded was 2254 ind. Sq.m. in Mar del Tuyú in April 2000. Densities generally varied between 200 and 1000 ind. Sq.m, except for Punta Rasa and San Clemente (northern geographic localities of the studied area), where *D. hanleyanus* was never found, which corresponds with the high influence of Rio de la Plata freshwater in this zone.

In the studied coast the banks distribution is heterogeneous, distinguishing beach sectors with permanent presence (Pinamar, Cariló, north Villa Gesell) and other beach sectors where its appearence corresponds to a certain season (north sector).

There is evidence that the banks show different horizontal

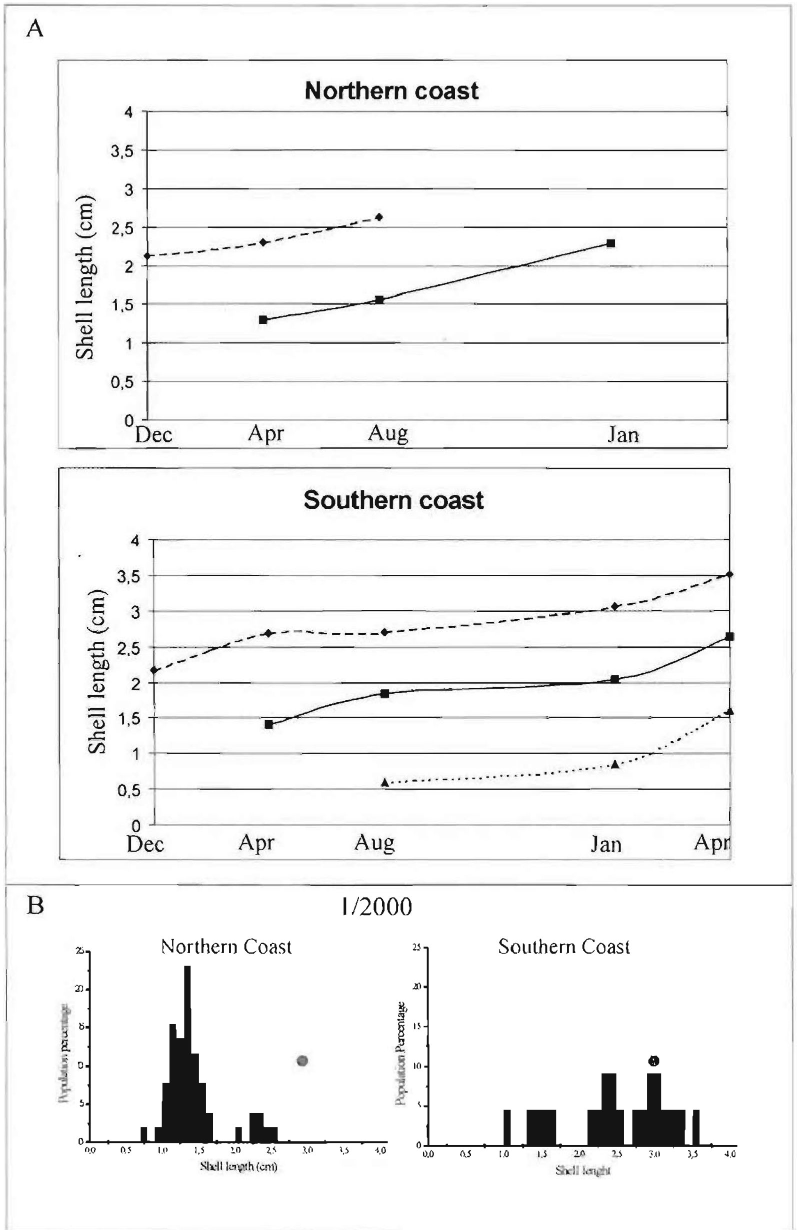

Figure 7. A. Modal peaks of *Donax hanleyanus* size (shell length) frequencies distribution through time for Sector A and Sector B. B. Comparison between the size frequency distribution of *Donax hanleyanus* in Sector A and Sector B, for January 2000. Dots are indicating the missing sizes > 27.0 mm in Sector A.

mobility along the coast in the different studied coastal sectors. The recognised banks in the south sector do not reflect horizontal mobility, while in the north sector they are very vulnerable to seasonal changes and storm conditions.

Beach clams of the genus *Donax* often show tidal migrations (ANSELL 1983). The beaches with major slope show a minor mobility *of Donax hanleyanus* along the transversal profile (lower third of the intertidal sector), while those of minor slope show more vertical mobility (intertidal sector). The emergence and movement of *Donax* was observed as the sea level increased from low tide to medium tide.

In Figure 7A the observed peaks in the size-frequency distribution of the population are shown in the different sampled times. Peaks of shell length at different times corresponding to a specific recruitment event are connected by lines. For the interpretation of the growth rates we used the shell length age in PENCHASZADEH and OLIVIER (1975). In the northern beaches we detected two recruitment events while in the southern beaches we detected three. The slopes of all curves are comparable, but in southern beaches where the seasonal effect is stronger, we noted a decrease in the growth rate for the winter period. The population shell length structure in January 2000 differs notably between north and south beaches (Figure 7B) pointing at the recruitment event marked by rhombuses in Figure 6A. The missing bars are shown for the north samples, while in the south there are large individuals (> 27.0 mm) still living later than April 2000 (dots over Figure 7B). This means, assuming equal growth rates, that *Donax hanleyanus* is surviving two years in the northern beaches and three years in southern beaches.

## DISCUSSION

*Donax hanleyanus* has been reported for fine to coarse sandy beaches. As other small clams with low densities, *Donax hanleyanus* distinguished intermediate reflective—dissipative beaches (McLachlan *et al.,* 1995). Nevertheless *Donax hanleyanus* is common also on reflective beaches with coarse sediments and sharp slopes of the coast of Uruguay (Pollovero, 1984) and has been reported as an important species on the dissipative sandy beaches, with gentle slopes and fine grain size of Brazil (Gianuca, 1983) and Argentina (Penchaszadeh and Olivier, 1975).

Stability and low variation in grain size observed over the study period in the localities inhabited by *Donax hanleyanus,* has been also reported for the sandy beaches in Israel with *Donax trunculus.* (Neuberger—Cywiak *et al.,* 1990).

Field observations reveal the existence of alterations to the coastal environment due to human activity (Marcomini and López, 1997). This can affect the *Donax hanleyanus* natural habitat, *e.g.* sewage ending in the beaches. Another factor causing alteration to the natural configuration of the beach is the circulation of vehicles and tourism compacting the sand. Mining activities (sand extraction) and not regulated refilling on the beach also impact in the natural ecosystem.

Human activity, such as the exploitation of the sympatric bivalve *Mesodesma mactroides,* was demonstrated to affect the population density (recruits as well as juveniles and adults) of *Donax hanleyanus* in Uruguay (Defeo and Alava, 1995). These authors have also concluded that salinity and other variations caused by human activity such as the amount of sediment and sewage carried by freshwater discharges from drainage systems will produce a less suitable habitat for *Donax hanleyanus.*

## CONCLUSIONS

The presence of *Donax hanleyanus* was recorded in the sandy beaches of the Buenos Aires littoral between the towns of Las Toninas and Punta Mogotes. In the town of San Clemente del Tuyú and Punta Rasa no individuals were obtained.

*Donax hanleyanus* inhabits the beach profile in the lower third of the intertidal sector. In the studied coast the banks distribution is heterogeneous, distinguishing beach sectors with permanent presence (Pinamar, Cariló, north Villa Gesell) and other beach sectors where its appearence corresponds to a certain season (north sector).

There is evidence that the banks show different horizontal mobility along the coast in the different studied coastal sectors. The recognised banks in the south sector do not reflect horizontal mobility, while in the north sector they are very vulnerable to season changes and storm conditions.

The granulometric variations in the coastal sector studied do not effect the existence of *Donax hanleyanus,* but in many cases temporarily limit its presence by hindering its burial capacity at the surface and at lower depth (due to presence of banks composed by shell fragments)

Although the morphology and beach slope differ in the sampled localities, it does not condition the habitat but rather directly affects the mobility of *Donax hanleyanus* along the transverse beach profile in the tidal cycles.

The beaches with major slope show a minor mobility of *Donax hanleyanus* along the transversal profile (lower third of the intertidal sector), while those of minor slope show more vertical mobility (intertidal sector).

The emergence and movement of *Donax* was observed as the sea level increase from low tide to medium tide.

The human activities and urbanization in coastal areas condition the presence and density of the *Donax haleyanus.*

The growth rates defined by Penchaszadeh and Olivier (1975) were corroborated in this paper and a higher longevity (three years) for the individuals living in the south was observed.

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## LITERATURE CITED

Ansell, A.D., 1969. Leaping movements in the bivalvia. *Proceedings Malacological Society London,* 38, 387–399.

Ansell, A.D., 1983. The biology of the genus *Donax. In:* McLachlan, A. and Erasmus, T. (eds.) *Sandy beaches as Ecosystems.* W. Junk, The Hague, pp 607–635.

Ansell A.D. and Trevallion, A., 1969. Behavioural adaptations of intertidal molluscs from a tropical sandy beach. *Journal Experimental Marine Biology Ecology,* 1, 220–235.

Caviglia, F.L., Pousa, J.L. and Lanfredi, M.L., 1991. A determination of the energy flux constrant from the dredge records. *Journal of Coastal Research,* 7 (2):543–549.

Coe, W.R., 1953. Resurgent population of littoral marine invertebrates and their dependence on ocean currents and tidal currents. *Ecology,* 34, 225–229.

Coe W.R., 1956. Fluctuations in populations of littoral marine invertebrates. *Journal Marine Research,* 15, 212–232.

Defeo O. and Alava A., 1995. Effects of human activities on long-term trends in sandy beach populations: The wedge clam *Donax hanleyanus* in Uruguay. *Marine Ecology Progress Series,* 123, 73–82.

De Villiers, G., 1975. Growth, population dynamics, a mass mortality and arrangament of white sand mussels, *Donax serra* Roding, on beaches in the south-western Cape Province. *Investigative Report Sea Fisheries Branch Replic Southern Africa,* 109, 1–31.

Folk, R.L. and Ward, W.C., 1957. Brazos river bar: a study in the significance of grain size parameters. *Journal of Sedimentary Petrology,* 27, 3–26.

Gianuca N.M., 1983. A preliminary account of the ecology of sandy beaches in southern Brazil. *In:* McLachlan, A. and Erasmus, T.

(eds) *Sandy Beaches as Ecosystems*. The Hague, Junk, pp. 413–419.

HORN, D.P., 1993. Sediment dynamics and macrotidal beach. *Journal of Coastal Research,* 9, 189–208.

MCLACHLAN, A.; Jaramillo, E.; Defeo O.; Dugan, J.; de Ruyck, A. and COETZEE, P. (1995). Adaptations of bivalves to different beach types. *Journal of Experimental Marine Biology and Ecology.* 187, 147–160.

MCLACHLAN, A. and YOUNG, N., 1982. Effects of low temperature on the burrowing rates of four sandy beach molluscs. *Journal Experimental Marine Biology and Ecology,* 65, 275–284.

MIKKELSEN, P.S., 1981. A comparisin of two Florida populations of the coquina clam, *Donax variabilis Say,* 1822. (Bivalvia Donacidae) I. Intertidal density, distribution and migration, *Veliger,* 23, 230–239.

MARCOMINI, S.C. and LÓPEZ, R.A., 1993. Coastal Protection Effects at Buenos Aires, Argentina. *Proceedings of The Eighth Symposium on Coastal & Ocean Management* (Coastal Zone 93, Nueva Orleans. U.S.A.), 3, 2724–2738.

MARCOMINI, S.C. and LOPEZ, R.A., 1997. Influencia de la urbanización en la dinámica costera, Villa Gesell, provincia de Buenos Aires, República Argentina. *Revista de la Asociación Argentina de Sedimentología,* 4, 2, 79–96.

MORI, S., 1938. Characteristic tidal rhythmic migration of a muss, *Donax semignosus* Dunker, and the experimental analysis of its behaviour at the flood tide, *Zoological Magazine Tokio,* 50, 1–12.

NAIR, N.B. and ANSELL, A.D.,1968. Characteristics of penetration of the substratum by some marine bivalve molluscs. *Proceedings Malacological Society London,* 38,179–197.

NEUBERGER-CYWIAK, L.; ACHITUV, Y., and MIZRAHI, L., 1990. The ecology of *Donax trunculus* Linnaeus and *Donax semistriatus* Poli from the Mediterranean coast of Israel. *Journal of Experimental Marine Biology and Ecology.* 134: 203–220.

PENCHASZADEH, P. E. and OLIVIER, S.R., 1975. Ecología de una población de berberecho (Donax hanleyanus) en Villa Gesell, Argentina. *Malacología,* 15,1, 133–146.

POLLOVERO, M., 1984. Estudio sobre biocenología y dinámica de la población de "Berberecho", *Donax hanleyanus* (Philippi 1845) en la zona de playa Arachania, La Paloma, Depto. de Rocha, Uruguay. BS thesis (Lic. Oceanogr. Biolog.), Universidad de la República, Montevideo.

SERVICIO DE HIDROGRAFIA NAVAL, Argentina, 1997. *Tabla de Mareas.* pp.125

SPALLETTI, LUIS A., 1980. Paleoambientes sedimentarios en secuencias silicoclásticas. *Asociación Geológica Argentina,* Serie B. Didáctica y complementaria N°8. pp.99.

STOLL, E.,1937. Beobachtungen uber die Fortbewegung bei einigen grabenden muscheln, *Revue Suisse, Geneve,* 44, 383–390.

STOLL, E.,1947. Sur le mode de locomotion del quelques mollusques marins, *Travaux Station Biologique Roscoff* (Paris), N° 16 (1938), 5–29.

TRUEMAN, E.R.,1968. A comparative account of the borrowing process of species of *Mactra* and of other bivalves, *Proceeding of the Malacological Society of London,* 38 (2) 139–151.

TRUEMAN, E.R.,1971. The control of burrowing and the migratory behavior of *Donax denticulatus* (Bivalvia, Tellinacea), *Journal Zoological Society London,* 165, 453–459.

TRUEMAN, E.R.; BRAND, A.R., and DAVID, P.,1966. The dynamics of burrowing of some common littoral bivalves. *Journal Experimental Biology,* 44, 469–462.

TRUEMAN, E.R. and ANSWELL, A.D.,1969. The mechanism of burrowing into soft substrata by marine animals, *Oceanography Marine Biology Annual Review,* 7, 315–366.

VISHER, G.S., 1969. Grain size distribution and depositional processes. *Journal of Sedimentary Petrology,* 39, 1077–1106.

WADE, B.A.,1968. Studies on biology of the West-Indian beach clam, *Donax denticulatus* Linne.2 Life History, *Bulletin of Marine Science,* 18:876–901.

WRIGHT, L.D.; NIELSEN, P.; SHORT, A.D., and GREEN, M.O., 1982. Morphodynamics of a macrotidal beach. *Marine Geology,* 50, 97–128.