Factors Associated with the Distribution of the Invasive Bivalve Clams" *Donax Variabilis* (Say,1822)" at the Area of the Mediterranean Coast Preferred by Marine Fish Larvae, New Damietta, Egypt

El-Ghobashy, A.E.[1]; Mahmad, S.Z.[2]; Kandeel, S.K.[3] and El-Ghitany, A.H.[*1]

[1]Zoology Department, Faculty of Science (Damietta), Mansoura University, Egypt.
[2]Oceanography Department, Faculty of Science, Suez Canal University, Egypt.
[3]Zoology Department, Faculty of Science (Fayoum), Fayoum University, Egypt.
[*]asmaa_haris222@yahoo.com

Abstract: New Damietta shore is one of the important areas for collection of the clams as well as mullet, seabass and seabream larvae which are reliable for marine aquaculture in Egypt. *Donax variabilis* was recorded for the first time in Egypt and because of its presence in the area of Damietta Maritime Port, larvae has come stuck with ships from the Atlantic Ocean where they were registered there. The density of *D.variabilis* increased in site I (718 / m^2) than in site II (415 / m^2). Water salinity (33.43 ± 4.59 mg/ L) in site I was less than the salinity of the sea, while it was almost similar to the salinity of the sea (36.94 ± 3.45 mg/ L) at site II. Nutrients concentration at site II were higher than that at site I, where it averaged 0.02 ± 0.01, 0.05 ± 0.03 and 0.26 ± 0.16 at site I and 0.05 ± 0.03, 0.34 ± 0.41 and 0.46 ± 0.36 mg/l at site II for NO_2, NO_3 and PO_4 respectively. Measured *Chlorophyll a* was high at site II (0.25 0.12 mg/m^3) compared to site I (0.25 0.12 mg/m^3), revealing the increase in phytoplankton biomass at site II. Crustaceans and molluscs were the most groups associated with clam's beds. *D.variabilis* cohorts appeared during summer months, this indicates that the population consists of only one spawning event. Length frequency of *D.variabilis* was essentially bimodal during the period of study. Three modes were recorded in June, 2008 at size classes of 7, 11and 20 mm of shell length.

[El-Ghobashy, A.E.; Mahmad, S.Z.; Kandeel, S.K. and El-Ghitany, A.H. **Factors Associated with the Distribution of the Invasive Bivalve Clams" *Donax Variabilis* (Say,1822)" at the Area of the Mediterranean Coast Preferred by Marine Fish Larvae, New Damietta, Egypt.** Journal of American Science 2011; 7(1):1051-1062]. (ISSN: 1545-1003). http://www.americanscience.org.

Key wards: Mediterranean coast- *Donax variabilis*- A biotic factors- Biotic factors

1. Introduction:

A bivalvia can acquire an important role in solving the problem of shortage and high price of animal protein in Egypt. Egyptian beaches has extended over long distances and it has become necessary to look at how the exploitation of bivalvia inhabiting these beaches. Bivalve molluscs are conspicuous members of sandy beaches (McLachlan *et al*., 1996).

The family Donacidae inhabits exposed intertidal sandy beaches and form worldwide, by far, the largest group living in such highly dynamic environments (Ansell, 1983; Brown & McLachlan, 1990). Since this group is present in the seaside which is unstable and have continuous environmental changes.

Biotic (food availability and intraspecific interactions) and a biotic (beach slope, swash energy, sand particle size, salinity, and chemical cues) factors play predominant roles in regulating alongshore distribution patterns (Defeo & de Alava, 1995; McLachlan, 1996; Gime´nez & Yanicelli, 2000 and Lastra *et al*., 2006). Also human activity may represent an additional regulatory agent, acting either directly, by removal of individuals, or indirectly, by removal or disturbance of potential competitors (Defeo and de Alava, 1995; Defeo, 1996a; Schoeman, 1996 and Brazeiro & Defeo, 1999).

Ecological preferences of *Donax* have been studied by Ansell & Lagardere, 1980 and Guillou & Bayed, 1991. McLachlan & Jamarillo (1995) have reviewed the zonation of organisms on sandy shores and have emphasized the strong control exerted on distribution by physical factors and the temporal variability of the component communities. As well as, the population dynamics of *Donax* species have been examined by Guillou, 1982; Maze & Laborda, 1988; Maze, 1990 and Tirado & Salas, 1998.

Clams are important recreational and commercial resources in many countries (McLachlan, et al., 1996). *Donax sp.* spreading in the northern coast of Egypt and be the favorite food among the population in coastal cities. Inshore waters of the Damietta region (North coast of Egypt) support nursery (larval or fry) areas for several commercially important species, especially the common mullet, sea bream and sea bass (El-Ghobashy, 2009). The present study will be the link between its distribution and some important environmental factors. Also, it is focused on the influence of these factors on the same aspects of clam biology.

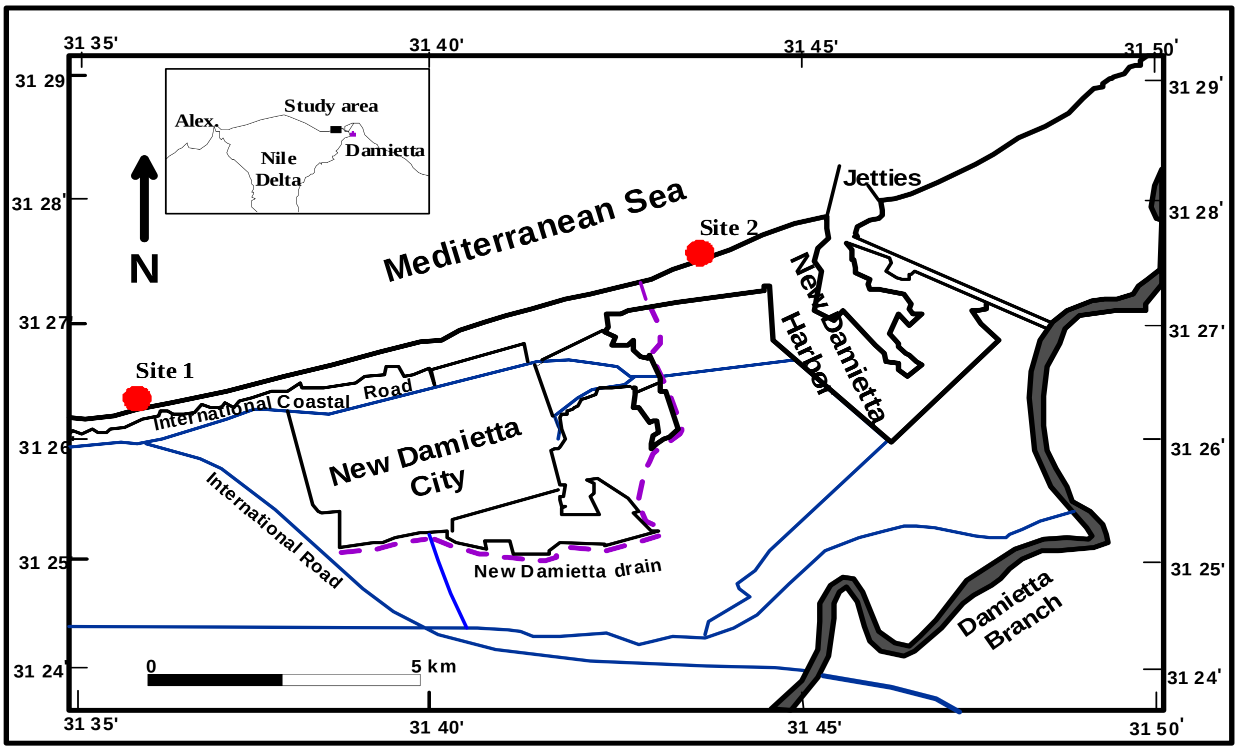
2. Materials and methods

Study area:-

The study area (Damietta shore) is an important part of the Egyptian coast of the Mediterranean Sea characterized by several important characteristics. i.e. fluctuation in the environmental qualities due to their proximity to the channel which reaches the Nile river with the sea as well as draw close to the Damietta Maritime Port. This segment is also the the most important location for collection of marine fish larvae upon which marine aquaculture activities taken place in the region. This area is also close to residential areas and activity of resorts and entertainment (Fig, 1).

Sampling sites:-

In order to determine the extent of *Donax* populations and also to select suitable sampling sites, a general survey of the New Damiettia shore using quadrates was undertaken in May, 2008. Consequently, two sites (Fig,1) were chosen, the first is located west of New Damietta, near the Gamasa drainage canal (31° 26.837 N and 31° 36.547 E) and the second is located east of New Damietta adjacent to Damietta Maritime Port (31° 28.577 N and 31° 44.408 E).



Fig, 1. Map of the sampling sites detected from land sat image.

Water Analysis:-

Monthly surface water samples were collected from the selected stations during the period from May 2008 to June 2009. A Plastic Ruttner water sampler of 2 liters capacity was used for water sampling. Water temperatures were measured using 0.1°C graduated Thermometer. At each station the total water depth and Secchi transparency was measured by the conventional Secchi Disc. The pH value was obtained using a portable pH-meter (Orion, model 6011). Dissolved oxygen (DO) was determined according to APHA (1985) using the Azide modification of Winkler method. Water salinity was directly measured using YSI model 339 (yellow springs) S-CT meter and the results are expressed as (g/L). Nitrate in the samples was determined according to APHA (1989) and Nitrite (Diazotization method) of samples was measured according to

Adams (1990). Total phosphorus in water sample was determined according to APHA (1989). Reactive silica in water sample was determined according to APHA (1989) and EPA (1983). The phytoplankton biomass (*Chlorophyll-a*) measured according to Strickland and Parsons (1972), using the SCOR UNESCO equations.

Sediment Analysis:-

The sediment samples were collected at the two studied sites by drilling to a depth of 50 cm. Sediment were screened with sieves of five grades, following the Wentworth scale: fine sand (125–250 µm); medium sand (250–500 µm); coarse sand (500–1000 µm); very coarse sand (1000–2000 µm); and gravel (>2000 µm). pH, TDS, EC, calcium carbonate were determined in soil extract according to APHA (1992). Organic carbon of the sediment samples was detected according to Adams (1990)

Collection and treatment of animals:-

Donax variabilis was collected in addition to other associated fauna from an area of one cupic meter. The collection was at the time of low tide using a specially designed hand dredge (75 cm wide) similar to that used by local fishermen but incorporating a smaller mesh size bag (3 mm) to survey the presence of smaller individuals which had not yet recruited to the professional fishery. Collected samples were kept in containers filled with 6% neutral formalin and it was brought to the laboratory at the Faculty of science, Damietta, where the investigations were carried out.

Statistics:

The comparison between means and standard errors was tested for significance using ANOVA analysis and Duncan's multiple range tests. In addition, the correlations of physicochemical parameters were assessed using Pearson's correlation analysis. All statistical analyses were calculated, using the computer program of SPSS Inc. (2001, version 11.0 for Windows) at the 0.05 level of significance.

3. Results:

Water salinity (33.43 ± 4.59 mg/ L) in site I was less than the salinity of the sea due to the impact of the Gamasa drainage canal, while it was almost similar to the salinity of the sea (36.94 ± 3.45 mg/ L) at site II. Nutrients (NO_2, NO_3 and PO_4) concentrations at site II were higher than that at site I. Their values were 0.02 ± 0.01, 0.05 ± 0.03 and 0.26 ± 0.16 at site I and 0.05 ± 0.03, 0.34 ± 0.41 and 0.46 ± 0.36 mg/l at site 2 for NO_2, NO_3 and PO_4 respectively. Measured *Chlorophyll a* was increased at site II (0.25 0.12 mg/m3) compared to site I(0.20 0.16 mg/m^3), this shows an increase in phytoplankton biomass at site II. Also electric conductivity (EC) increased in site II than that in site I reflecting the difference in the dissolved salts. It is also clear from the results; that there were very limited differences between the two sites for the rest of the factors were measured (Fig, 2).

Investigation of the sediment granules of the two studied sites indicated that, in site I the percentage of coarse and fine sediment were 1.82 and 3.50 with average diameter of 1.4 Mdφ, while in site II their raters were 1.80 and 3.22 respectively with mean diameter of 1.80 Mdφ. Scales of sediment in both sites were classified as medium sand. Mean percentage of organic content and pH in both sites were more or less similar in both sites. Site I had more bicarbonate, carbonate and organic matter (Table, 1).

Concerning with the abundance of associated fauna with clam bed, in the study area, it was clear that crustaceas and molluscs were the most dominated. Other groups such as annelids and echinodermates were rarely presented (Table, 2).

The density of D.variabilis per square meter in Site I ranged from 174 individuals during January to 1945 through July, revealing wide monthly changes in its density. In site II a narrow range (333-624 /m2) of fluctuations in D.variabilis were recorded. The fewest number of D.variabilis was during November (333/ m2) and December (322/ m2) while the highest number (624/ m2) was collected during March (Fig, 3). With regards to population structure, a shifting of the peaks from shorter to longer lengths can be observed from the length frequency histograms of D.variabilis (Fig, 4). Length frequency of D.variabilis at site I was essentially bimodal during the period of study. Three modes (including the juvenile one) were recorded in June 2008 at size classes of 7, 11and 20 mm of shell length. These modes represented 0.41, 4.10 and 17.21 % of the total population, respectively. Juvenile cohorts (3 to 7 mm shell length) were collected during the period from June 2008 to August 2008 and during July 2009. The largest length (25.12 mm) of D.variabilis was recorded during June 2009, which represented only 0.89 % of the total population. Growth curves of successive cohorts derived by plotting modal length classes as a function of time are shown in Fig, (6a.) Growth of the different cohorts proceeded with time and the modes of D.variabilis indicated a short life span of this species. D.variabilis cohorts appeared during summer months, this indicates that the population consists of only one spawning event. Monthly average shell length increased of *D.variabilis* at New Damietta shore was 2.4 ± 1.2 mm.

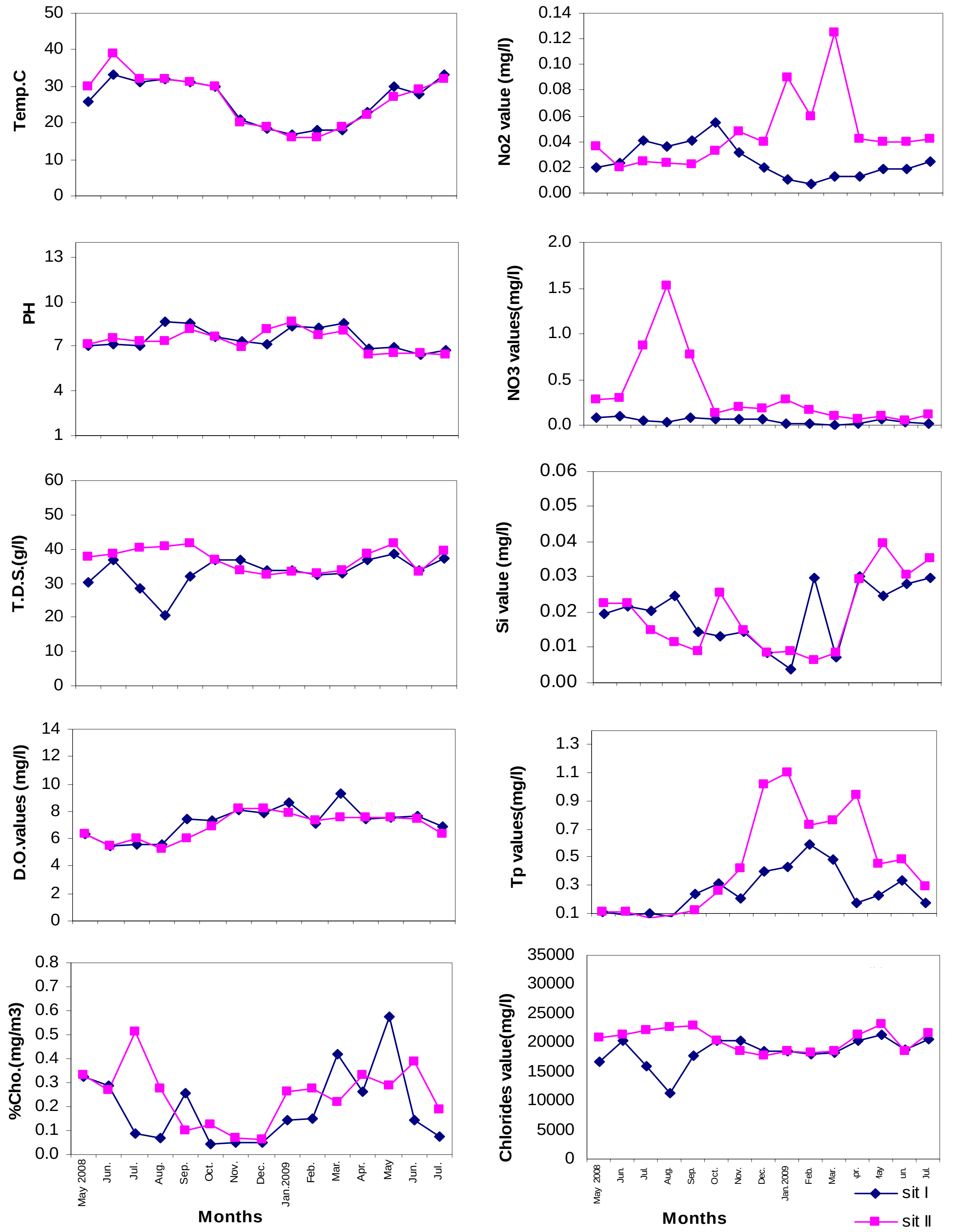
Length-frequency distributions for *D.variabilis* in the sit II (Fig, 5) were mostly bimodal. Three modals (including the juvenile one) appeared during April, August 2008 and July, 2009. Temporal appear of juveniles (< 6 mm shell length) was similar to that in site I. Their percentage occurrence relative to the whole population ranged from 14.84% in June, 2008 to 0.86% in July, 2009. Growth of the different cohorts proceeded with time and the modes of *D.variabilis* indicated also a short life span of this species. *D.variabilis* cohorts appeared during summer months, reflecting also one-spawning event. Monthly average shell length increased of *D.variabilis* at New Damietta shore was 2.4 ± 1.2 mm. The growth pattern of successive cohorts is shown in Fig, 6b. Cessation of growth was observed during winter months. The average growth rates of the different cohorts were 1.65 ± 0.5 mm/month. A highly significant difference ($P<0.002$) was calculated between *D.variabilis* growth rates at the two sampling sites.

Table (1): Sediment characteristics at the two sites in the New Damietta shore.

parameters	Site I	Site II
Coarse sediment >0.5 mm (%wt.)	1.82	1.80
Fine sediment <0.063 mm (%wt.)	3.50	3.22
Median diameter (Mdφ)	1.4	1.8
Wentworth scale	Medium sand	Medium sand
Quartile deviation (QDφ)	0.55	0.465
Categories of sorting	Moderately well sorted	Moderately well sorted
Quartile skewness (Sk_qφ)	0.05	0.04
PH	7.92	7.36
Chlorides	2958.33 mg/l	3481.07 mg/l
T.D.S	40.23 g/l	47.34 g/l
E C	2200 mmhos/cm	2800 mmhos/cm
Mean% Bicarbonate(Hco3) content	2.73	1.66
Mean% Calcium carbonate content	5.1	4.6
Mean% Organic carbon content	1.74	1.65
Mean% Organic matter content	3.51	3.32

Table (2): Monthly variations in the number occurrences of animal groups associated with *D.variabilis* at the two sampling sites.

Animal groups \ Months		May 2008	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan. 2009	Feb.	Mar	Apr.	May	Jun.	Jul.	Total
Annelida	Site 1				1					2			1				4
	Site 2				1			2			2						5
Arthropoda	Site 1	15	31	7	18	6	12	4	9	2	4	1	2	1			112
	Site 2	11	12	34	41	17	31	3	4	1	2	2	12	1	3	6	180
Mollusca	Site 1			1			10	29	19	12	4	6	3	30	5	2	121
	Site 2			5		7	6	12	25	20	10	15	29	41	16	19	205
Echinodermata	Site 1	1										1					2
	Site 2																0
Total	Site 1	16	31	8	19	6	22	33	28	16	8	8	6	31	5	2	239
	Site 2	11	12	39	42	24	37	17	29	21	14	17	41	42	19	25	390


Temp.C
No2 value (mg/l)
PH
NO3 values(mg/l)
T.D.S.(g/l)
Si value (mg/l)
D.O.values (mg/l)
Tp values(mg/l)
%Cho.(mg/m3)
Chlorides value(mg/l)
May 2008
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
Jan.2009
Feb.
Mar.
Apr.
May
Jun.
Jul.
Months
Months
sit I
sit II

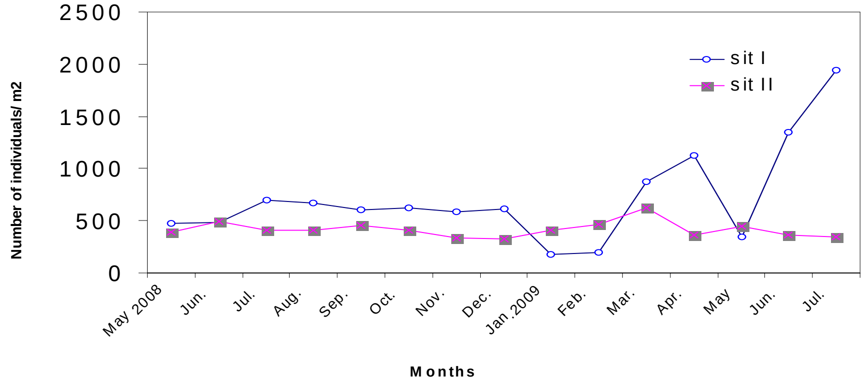


Fig. (3): The monthly change in the number of Donax variabilis /m² at two sites.

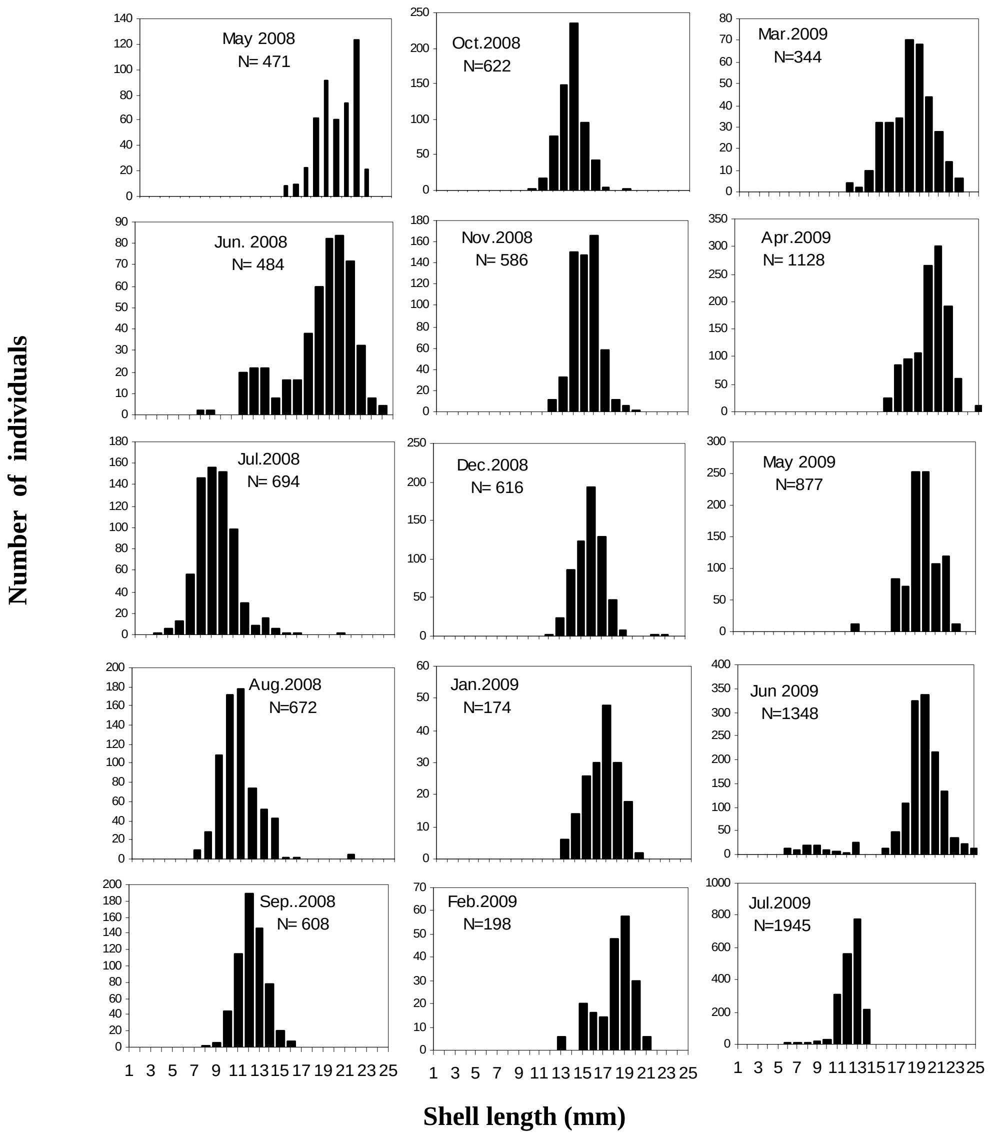


Fig. (4): Monthly size frequency histograms of *D.variabilis* samples collected from site I

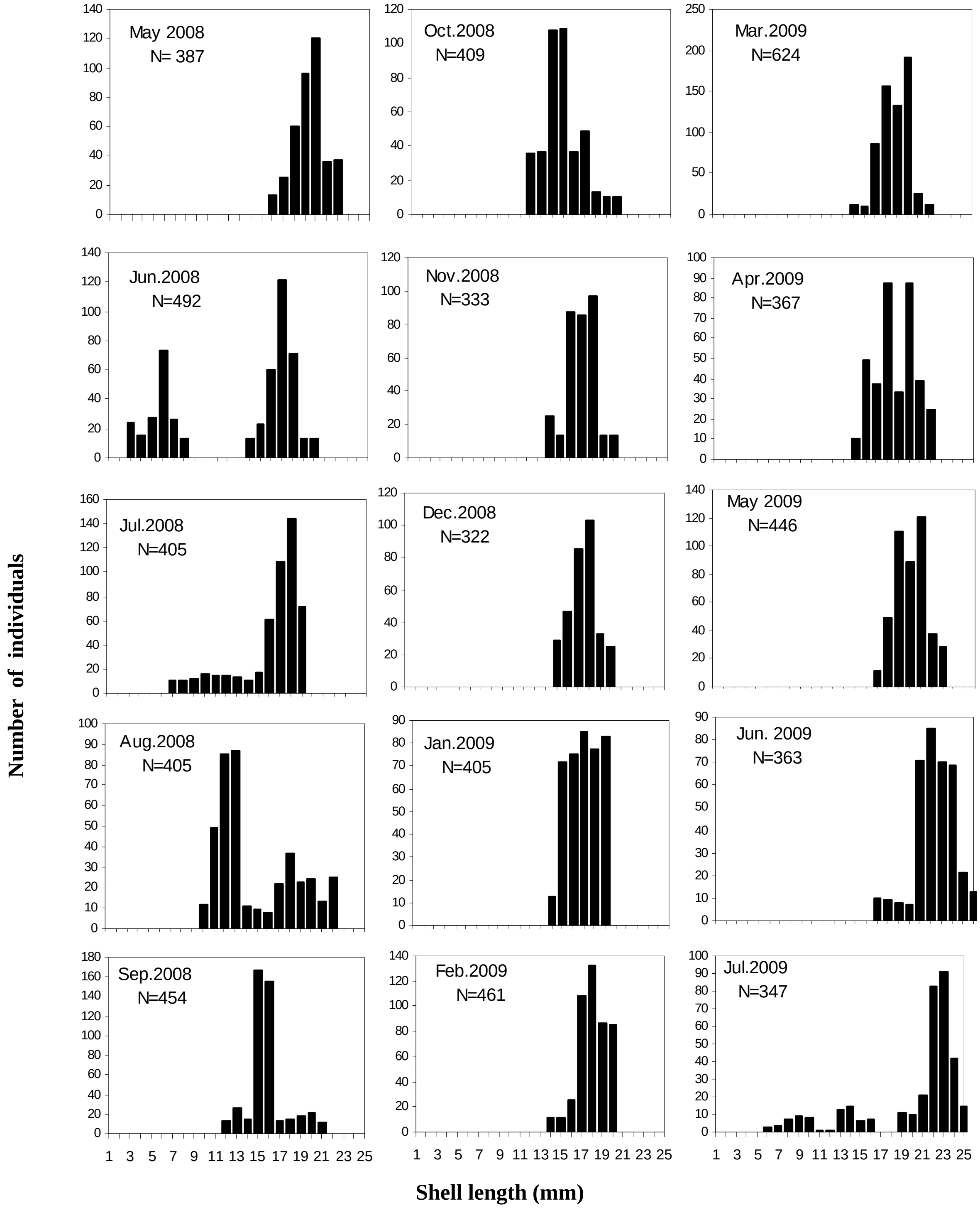
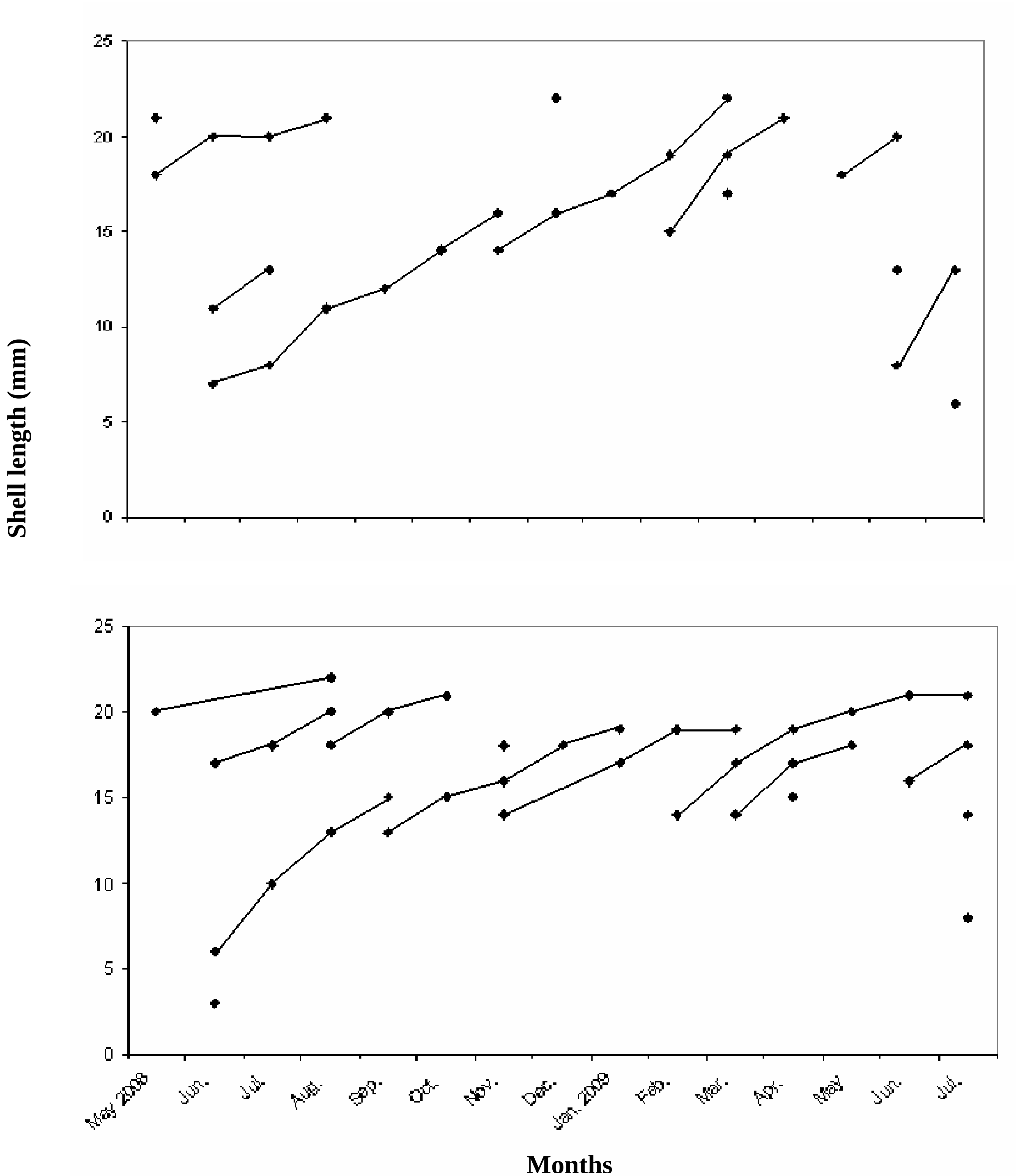


Fig. (5): Monthly size frequency histograms of *D. variabilis* samples collected from site II



Fig, 6 .The pattern of growth of the component populations of the *D. variabilis* at site I(a) and site II(b)

4. Discussion:

Donax variabilis is the dominant macro fauna on many of the exposed beaches of the south-east United States (Pearse *et al*., 1942). It found from Virginia south to Florida and round into the Gulf of Mexico to Texas (Ruppert & Fox, 1988). In the current study, *D.variabilis* was recorded for the first time in Egypt in the nearby region of the Maritime Damietta Port, there fore it considered as an invasive species from the Atlantic Ocean, where the larvae attached to commercial ships coming into port.

Distribution and density of clams are influenced by environmental changes, whether abiotic and biotic factors as well as to human activity. *D.variabilis* is more vulnerable to abiotic stressors than would be expected of invertebrates from habitats such as tide pools, mudflats or marshes (Grieshaber & Völkel, 1998).The number of *D.variabilis* per cubic meters increased at site I than at site II. The proximity of site II from the maritime port of Damietta increases the disturbances and movements of clams away either vertically or horizontally. Burrowing behaviour is an important adaptation (Brown & McLachlan, 1990 and McLachlan *et al*., 1995). Bivalves inhabiting all types of soft substrates are capable of burrowing easily, but bivalves living on exposed beaches must burrow rapidly and efficiently to avoid physical exclusion of individuals by waves or current action (Brown & McLachlan, 1990 and McLachlan *et al*., 1995). Physical properties of sediment, such as particle size, grain shape, water content and shear strength, affect the suitability of a substrate as a habitat, by influencing the burrowing behaviour and life habits of benthic species (Sanders, 1958 and Trueman, 1971).

D.variabilis, like many Donacidae, is noted for its mobility, and moves up and down the beach with the tide (Turner & Belding, 1957), and displays a pattern of sophisticated responses to waves and wave action (Ellers, 1995a,b). In addition, there is a seasonal cycle of movement, down into the shallow sub-littoral in fall and returning on to the beach as juveniles in late winter (Ruppert & Fox, 1988).

D.variabilis collected from the sampling sites increased during summer months and declined during winter. This similar to that happen, in laboratory experiments that for both adults and juveniles of *Donax*, burrowing time increased in lower temperatures (McLachlan & Young, 1982).

D.variabilis prefer water salinity slightly less than that of the sea, therefore it was collected from the area near the estuaries at New Damietta. Coastal and estuarine systems are highly productive areas that serve as nursery grounds for many marine species of commercial importance, widely distributed on the continental shelf (Beck *et al*., 2001 and Peterson, 2003).

D.variabilis distribution decreased with the increase in the concentration of nutrient elements. Hypoxic conditions owing to extremely high primary production and subsequent oxidative degeneration of organic matter (Van der Plas, 1999 and Fossing *et al*., 2000). With the increase in the density of *D.variabilis*, phytoplankton biomass reduced as a result of its consumption by these clams. Food webs of sandy beaches are mainly based on marine sources, such as phytoplankton, stranded algae, sea grasses and carrion (McLachlan & Brown, 2006).

Macroinfauna participating specially arthropods and other types of molluscs compete with clams, where as these animals' increased clams' movements to other places. Members of the genus *Donax* are commonly the main primary consumers in soft bottom communities, while they are in turn subject to predation by a wide variety of invertebrates, fish, birds and mammals (e.g. Luzzatto & Penchaszadeh, 2001; Peterson et al 2000 and Salaset al., 2001). Larger macrobenthic invertebrates burrow actively and include representatives of many phyla, but crustaceans, molluscs and polychaete worms are usually dominant and encompass predators, scavengers, filter- and deposit feeders (Defeo *et al*., 2009).

Ramon *et al*. (1995) estimation of the growth rate of *D.trunculus* in the western Mediterranean from an analysis of the length-frequency distributions, showed that there were two recruitments of clams to the population each year, one cohort was recruited during the winter whilst the other entered the population during the summer. Although spawning takes place during summer the season is long enough to show some intra seasonal variability in the gametes emission.

A unimodal pattern of recruitment between May and July was revealed in the present population, presumably owing to the measurement of larger individuals, settled earlier, by means of the mesh size utilized. Also the occurrence of a single annual recruitment has been found in the Atlantic populations (Ansell & Lagardere, 1980 and Guillou & Le Moal, 1980).

Results indicate that a mixture of biotic and abiotic factors mediates recruit abundance, with beach gradient being the most influential, followed by adult and juvenile abundances. The recognition and description of spatial patterns and their temporal dynamics are fundamental to understanding ecological processes that structure biological assemblages (Renshaw & Ford, 1984; Andrew & Mapstone, 1987; Volkaert, 1987; Jones *et al*., 1990;

Morrisey *et al*., 1992; Underwood *et al*., 2000 and Schoemana & Richardson, 2002).

On conclusion, *D.variabilis* is more susceptible to abiotic stressors and it is important concern for the environment in which they live in order to maintain production because of its importance to the people as food and for future culture.

Corresponding author
El-Ghitany, A.H.
Zoology Department, Faculty of Science (Damietta), Mansoura University, Egypt.
asmaa_haris222@yahoo.com

5. References:

1. Adams,V.D. (1990): Water and Wastewater Examination Manual. Lewis publishers, New York. 116-148 pp.
2. Andrew, N.L. & Mapstone, B.D.(1987): Sampling and the description of spatial pattern in marine ecology. Oceanogr. Mar. Biol. Annu.Rev.(25): 39–90.
3. Ansell, A. D. (1983): The biology of the genus *Donax*. In A. McLachlan, T. Erasmus & W. Junk (Eds.), Developments in hydrobiology, Sandy beaches as ecosystems (19): 607–635.
4. Ansell, D.A.& Lagardere,F. (1980): Observations on the biology of *Donax trunculus* and *Donax vittatus* at Ile d'Oleron (French Atlantic coast). Mar. Biol. 57:287-300.
5. APHA (American Public Health Association) (1992): Standard Methods for the Examination of Water and Wastewater, Washington DC, 18th edition.
6. APHA, (1985): Standard methods. 16 th Edition, American Public Health Association, Washington, DC.
7. Beck, M.W; Heck, K.L. Jr; Able, K.W; Childers, D.L. & others (2001): The identification, conservation, and management of estuarine and marine nurseries for fish and invertebrates.BioScience (51):633– 641
8. Brazeiro, A. & Defeo, O. (1999): Effects of harvesting and density dependence on the demography of sandy beach populations: theyellow clam, Mesodesma mactroides of Uruguay.Mar. Ecol.Prog.Ser. (182):127–135.
9. Brown, A.C. & McLachlan, A. (1990): Ecology of Sandy Shores, Elsevier, Amsterdam, p. 328.
10. Defeo,O. & de Alava, A. (1995): Effects of human activities on long- term trends in sandy beach populations: the wedge clam *Donax hanleyanus* in Uruguay. Mar. Ecol., Prog.Ser.(23):73–82.
11. Defeo,O.(1996): Experimental management of an exploited sandy beach bivalve population. Rev. Chil. Hist. Nat. (69):605–614.
12. Defeo.O.A.; McLachlan, A.B.; Schoeman, D.S.C.; Schlacher,T.A.D.; Dugan J.E.; Jones,A.F.; Lastra, M.G. & Scapini, F.H.(2009): Threats to sandy beach ecosystems: A review, Estuarine, Coastal and Shelf Science (81): 1–12.
13. El-Ghobashy, A. E. (2009): Natural fish fry food of seven commercial species in the Egyptian Mediterranean water. Wor. App. Sci. J., 7(3):320-331.
14. Ellers,O. (1995a): Behavioral control of swash-riding in the clam *Donax variabilis*. Biol. Bull. Mar. Biol. Lab. (Woods Hole) 189, 120–127.
15. Ellers,O. (1995b): Discrimination among wave-generated sounds by a swash-riding clam. Biol. Bull. Mar. Biol.Lab. (Woods Hole) (189): 128 – 37.
16. EPA (Environmental protection Agency) (1983): "Method for chemical Analysisof water and wastes".U.S. Environ.protec.Agency,EPA- 690/4-79-020,Cincinnati,OH.
17. Fossing, H; Ferdelman,T.G. & Berg, P. (2000): Sulfate reduction and methane oxidation in continental margin sediments influenced by irrigation (South-East Atlantic off Namibia). Geochim Cosmochim Acta (64):897–910.
18. Gime´nez, L. & Yanicelli, B. (2000): Longshore patterns of distribution of macroinfauna on a Uruguayan sandy beach: an analysis at different spatial scales and of their potential causes. Mar. Ecol., Prog. Ser. (199): 111 – 125.
19. Grieshaber, M.K. & Volkel, S. (1998): Animal adaptions for tolerance and exploitation of poisonous sulfide. Annu. Rev. Physiol.(60):33– 53.
20. Guillou, J. & Bayed, A. (1991): Contraintes du milieu sur les populations de *Donax trunculus* L. et *Donax venustus* Poli du littoral atlantique marocain. Oceanologica Acta. (14): 291–298.

21. Guillou, J. & Le Moal, Y. (1980): Aspects de la dynamique des populations de *Donax vittatus* et *Donax trunculus* en baie de Douarnenez. Annls Inst oceanogr, Paris (56):55-64
22. Guillou, J.(1982): Variabilite´ des populations de Donax Trunculus et Donax vittatus en baie Douarnenez. Neth. J. Sea Res. 16, 88– 95.
23. Jones, G.P.; Ferrell, D.J. & Sale, P.F. (1990): Spatial pattern in the abundance and structure of mollusca populations in the soft sediments of a coral reef lagoon. Mar. Ecol., Prog. Ser. (62):109– 120.
24. Lastra,M; de La Huz, R.; Sa´nchez-Mata, A.G. ; Rodil, I.F. ; Aerts, K.; Beloso, S. and Lo´pez ,J.(2006): Ecology of exposed sandy beaches in northern Spain: Environmental factors controlling macrofauna communities Jour.of Sea Res.(55): 128– 140
25. Linkages in tidal river estuaries.Rev.Fish. Sci. (11):291–313.
26. Luzzatto, D. & Penchaszadeh, P. E. (2001): Regeneration of the inhalant siphon of *Donax hanleyanus* Philippin 1847 (Bivalvia, Donacidae) from Argentina. J. Shellfish Res. 20(1):149-153.
27. Maze, R.A. & Laborda, A.J. (1988): Aspectos de la dinfimica de poblacion de *Donax trunculus* L. (Bivalvia: Donacidae) en la Rfa de Barquero (Lugo, NW. Espafia). Inv. Pesq. (52):299-312.
28. Maze,R.A. (1990): Estimacio´ n de la produccio´ n del bivalvo marino *Donax trunculus* L. en la rı´a de in El Barquero estuary (Galicia) - estimation of secondary production of the marine bivalve *Donax trunculus* L. in El Barquero estuary (Galicia). Iberus (9): 155–160.
29. McLachlan, A & Jaramillo, E (1995): Zonation on sandy beaches. Oceanography and Marine Biology an Annual Review (33): 305-335.
30. McLachlan, A. & Brown, A.C. (2006): The Ecology of Sandy Shores, second. Elsevier, Amsterdam, 373 pp.
31. McLachlan, A. & Young, N. (1982): Effects of low temperature on the burrowing rates of four sandy beach molluscs. J. Exp. Mar. Biol. Ecol. (65):275-284.
32. McLachlan, A. (1996): Physical factors in benthic ecology: effects of changing particle size on beach fauna.Mar.Ecol.,Prog.Ser. (131): 205– 217.
33. McLachlan, A.; Dugan,J.; Defeo, O.; Ansell, A.; Hubbard, D.; Jaramillo E. & Penchaszadeh,P. (1996): Beach clam fisheries.Oceanogr. Mar. Biol. Annu. Rev. (34):163–232.
34. McLachlan, A.; Jaramillo, E.; Defeo, O.; Dugan, J.; de Ruyck, A. & Coetzee, P. (1995): Adaptations of bivalves to different beach types. J. Exp. Mar. Biol. Ecol. (187):147–160.
35. Morrisey, D.J.; Howitt, L.; Underwood, A.J. & Stark, J.S. (1992): Spatial variation in soft-sediment benthos.Mar.Ecol., Prog.Ser.(81): 197– 204.
36. Pearse, A.S., H.J. Humm and G.W. Wharton. 1942. Ecology of sand beaches at Beaufort, North Carolina. Ecol. Monogr. (12):135-190.
37. Peterson, C.H.; Hickerson, D.H.M. & Johnson, G.G. (2000): Short-term consequences of nourishment and bulldozing on the dominant large invertebrates of a sandy beach. J. Coastal Res. (16): 368–378.
38. Peterson,M.(2003): A conceptual view of environment-habitat production
39. Ramon, M.; AbelloÂ, P. & Richardson,C.A. (1995). Populations structure and growth of *Donax trunculus* (Bivalvia: Donacidae) in the western Mediterranean.Mar.Biol.(121):665-671.
40. Renshaw, E. & Ford,E.D.(1984): The description of spatial pattern using two-dimensional spectral analysis.Vegetatio (56): 75–85.
41. Ruppert, E.E. and Fox, R.S.(1988): Seashore Animals of the Southeast, University of South Carolina Press,Columbia, SC
42. Salas, C., Tirado, C., & Manjon-Cabeza, M. E. (2001): Sublethal foot predation on Donacidae (Mollusca: Bivalvia). J.Sea. Res. (46): 43–56.
43. Sanders,H.L.(1958): Benthicstudies in Buzzards bay.I.Animal sediment relationships. Limnol. Oceanogr. (3): 245–250.
44. Schoemana,D.S. & Richardsonb,A.J. (2002): Investigating biotic and abiotic factors affecting the recruitment of an intertidal clam on an exposed sandy beach using a generalized additive model. J. Exper. Mar.Biol.Ecol.(276): 67– 81.
45. Schoemana,D.S.(1996): An assessment of a recreational beach clam fishery: current fishing pressure and opinions regarding the

initiation of a commercial clam harvest. S. Afr. J. Wildl.Res. (26): 160– 170.

46. Standard Methods for the examination of Water and wastewater (1989). 17 th edn.,American Public Health Association, Washington, D.C.
47. Strickland, J.D.H. and T.R. Parsons, 1972. A practical handbook of seawater analysis, 2 nd edn., 176: 1-310: Fish. Res. Bd. Can. Bull.
48. Tirado, C. & Salas, C.(1998): Reproduction and fecundity of *Donax trunculus* L., 1758 (Bivalvia: Donacidae) in the littoral of Malaga (Southern Spain). J. Shellfish Res. (17):169–176.
49. Turner, H.J. & Belding, D.L. (1957): The tidal migrations of *Donax variabilis* Say. Limnol. Oceanogr. (2): 120–124.
50. Underwood,A.J.; Chapman, M.G.& Connell, S.D.(2000): Observations in ecology: you can't make progress on processes without understanding the patterns. J. Exp. Mar. Biol. Ecol. (250): 97– 115.
51. Van der Plas,A.(1999): Monitoring of marine chemical processes in the marine environment off Namibia (1990–1999).Abstract, International Workshop on Monitoring of Anaerobic Processes in the Benguela Current Ecosystem off Namibia.
52. Volkaert,F.(1987): Spatial pattern of soft-bottom Polychaeta off Nova Scotia, Canada.Mar.Biol.(93): 627– 639.

12/25/2010