MACROFOULING COMMUNITY AT MAR DEL PLATA HARBOR DURING A ONE-YEAR PERIOD (1991-1992)

Silvia Pezzani*, Miriam Pérez** and Mirta Stupak**[1]

*Depto. Biología. Fac. Cs. Exactas y Naturales. Universidad Nacional Mar del Plata. Present address: Depto Cs. Básicas, Universidad Nacional de Luján, CC 221 (6.700) Luján, Argentina

** Laboratorio Incrustaciones Biológicas, CIDEPINT. 52 e/121 y 122 (1900) La Plata, Argentina, Fax 54-21-271537

ABSTRACT

The fouling community was examined from May 1991 to April 1992 at Mar del Plata harbor, Argentina. In this work the recruitment trends of macrosessile foulers and the seasonal developmental sequence of the community for one year were analyzed. Multivariate cluster analysis revealed two underlying trends of recruitment, one from late autumn to spring, and the other from summer to early autumn. *Ciona* had an important functional role in the community, as an adult might enhance the arrivals of some species as secondary space recruiters, but it was also a good interference competitor for primary space occupiers.

During summer, the larvae of *Ciona* were poor competitors for seasonal primary space occupiers. This situation enhances the invasion of calcareous exoskeleton organisms, such as *Balanus* and *Hydroides*. Some differences between the potential arrivals of propagules and their contribution to the developing community were found.

This community developed a pathway similar to that of other fouling communities with solitary ascidian species. Perturbations to diminish or exclude the foundation species abundances as *Ciona*, *Balanus* and *Hydroides* would be necessary to modify the early community structure.

KEY WORDS

macrofouling community, recruitment, structure, ascidian, barnacles.

INTRODUCTION

The changes in epibenthic community structure throughout time may

[1] To whom reprint requests should be sent.

involve several mechanisms. These changes result from the balance between physical and biological interactions. The resident species assemblages may depend on the outcome of the settlement, survival, and life cycles of the earlier and later species /1-13/.

The local current adjacent to the substratum, the conditions in water column and the physical characteristics of the substratum either prevent the attachment of the planktonic propagules or make it more attractive /14-20/. In addition, earlier successional species may enhance or inhibit the arrival of later species by providing suitable or unsuitable environmental conditions. These species may render secondary substratum for others which overgrow them, trap sediments which may enhance the arrival of build sediment tubes invertebrates or provide refuge to predators /21-23/. However, the primary space occupied by early colonists, the predation on planktonic larvae or on settlers, and the filtering out of propagules, may reduce or exclude potential larval settlement or survival of some species in the community /15, 24-29/.

The bare space opened by some disturbances, such as predation or slough off, may be invaded by other species /30/. However, colonization of the open space may be affected or not by its size or shape as well as by biological aspects of the surrounding species /31-35/.

Some studies about descriptive aspects of the first year of the fouling community development were carried out at Mar del Plata harbor /36-39/. They were interrupted and there exists a gap of approximately fourteen years. At the beginning of this decade, some changes in the early fouling composition were observed on ships and floating docks.

The aims of the present paper are to study the recruitment trends of macrosessile foulers, and their contribution to the composition community in order to interpret the initial sequence of events in the community development. Also, to carry out a comparison between this and previous studies at Mar del Plata harbor.

MATERIALS AND METHODS

Mar del Plata harbor is situated in Buenos Aires Province (38° 02'S - 57° 32'W). It is an important harbor which is affected by a naval complex, fishery industries and nautical recreation. The study site was located within the harbor at the Club de Motonáutica (Fig.1).

The study was carried out from May 1991 up to April 1992. Fouling organisms were collected by submerging 128 cm^2 unglazed ceramic tiles (panels). A sample series included three ropes with four panels separated 20 cm one from each other. Thirteen series were vertically hung from a

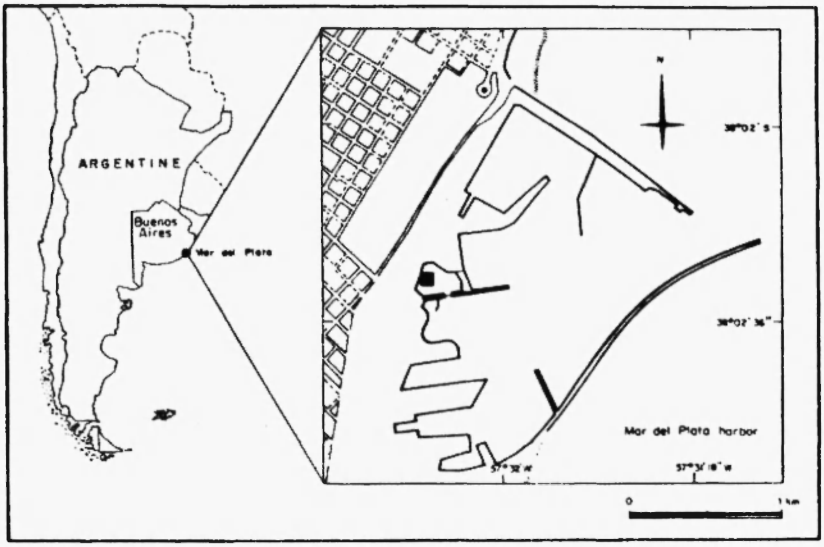

Fig. 1: Site of study and location of test panels series (■).

floating a dock, about 0.3 m to 1.5 m below the water surface to provide the record of macrofouling organisms for four different depths (Fig.2). Every month one series was removed so as to estimate the recruitment of macrosessile species, and was immediately replaced by a clean one (monthly panels). The other twelve series were removed on a monthly basis, one every month, following the development of the established community from the beginning of the exposition (accumulative panels). The front and the back surface of the panels, from the top to the bottom were labeled as: **A**,**a**; **B**,**b**; **C**,**c** and **D**,**d**, respectively. The fouled panels were placed in plastic cages and preserved in 4% neutral solution of formalin in sea water.

The abundance of sessile species was estimated by recording their occurrence on a fifty-cell grid marked in 2.25 cm^2 quadrats over the entire panel; sets of 13 random cells were considered as representative of the whole panel. The outer 1 cm margin of the plates was excluded from examination to avoid an "edge effect" /16/. New sets of random quadrats were used for each panel/replicate/month. Five abundance categories were used: 0%, 1-25%, 26-50%, 51-75% and 76-100%. These categories were based on abundance percentages (averaged from the replicate panels) for each species/panel/month and analyzed by a multivariate clustering method, using the Bray Curtis similarity index (NTSYS-program). Dendrograms were constructed using the unweighted pair group method, arithmetic average (UPGMA) portrayed the similarity between the taxa list of all monthly panels and seasonal accumulative panels.

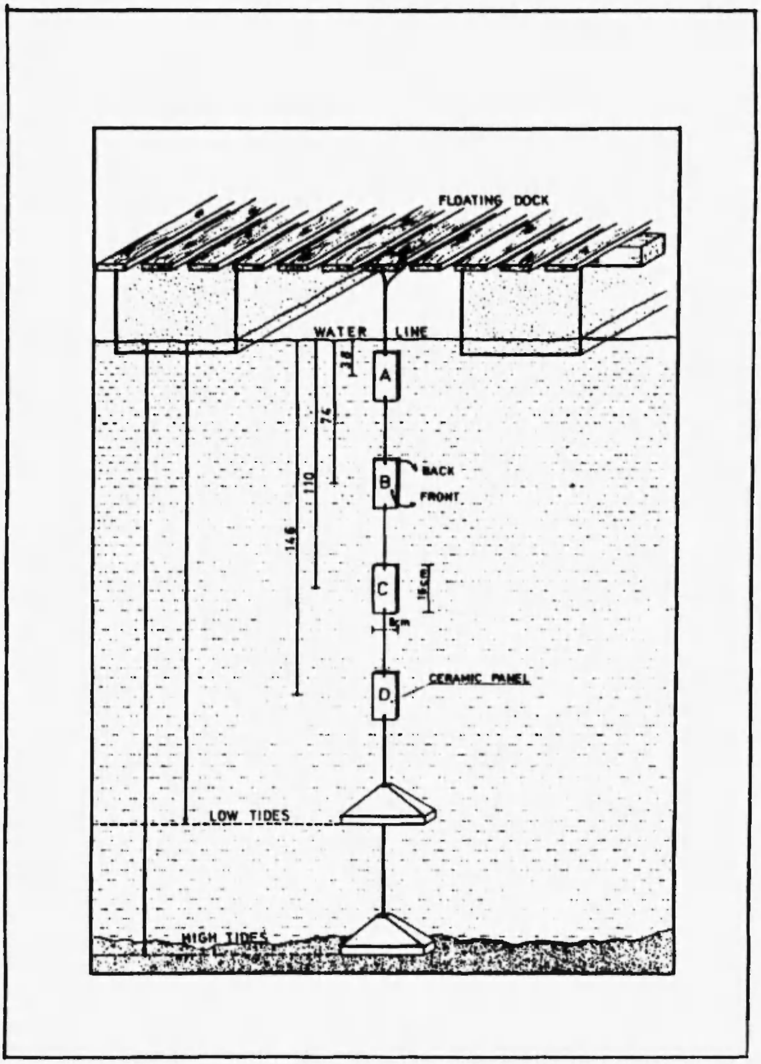

Fig. 2: Ceramic tiles series design.

Statistical analysis of dominant taxa abundances was done with ANOVA and contrast LSD test (Fisher test) using SYSTAT program. In ANOVAs, the effect of temporal variation of recruitment and the description of trends in community development were examined.

RESULTS

Recruitment

Figure 3 illustrates a dendrogram with the relationships among recruitment

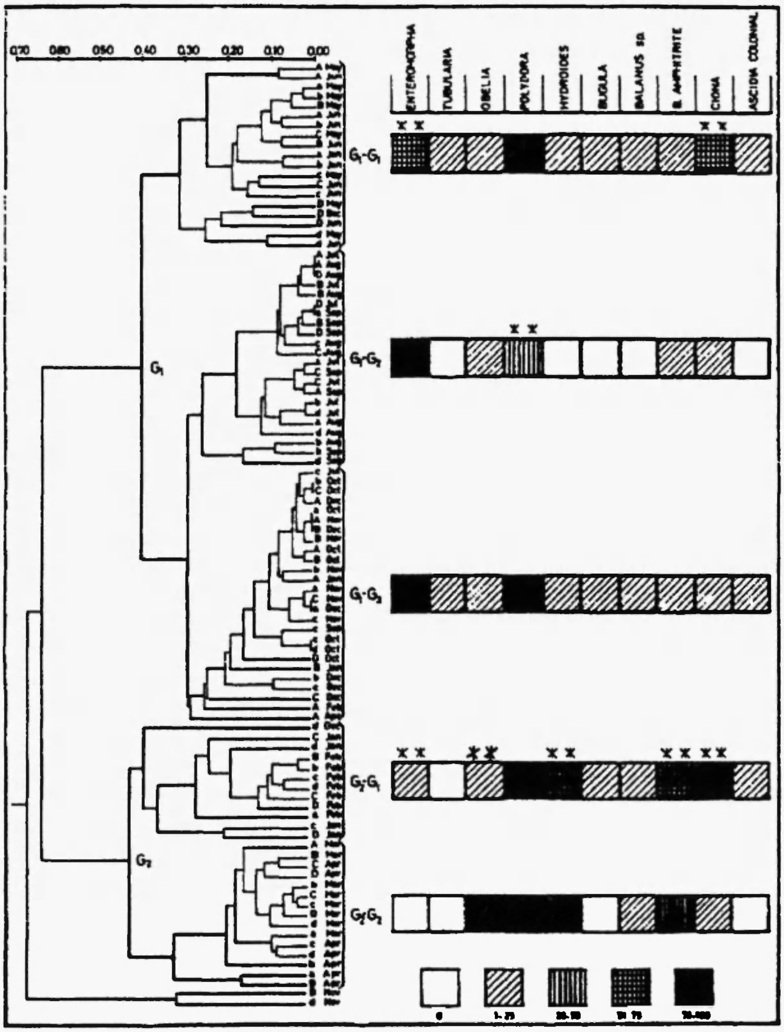

Fig. 3: Dendrogram corresponding to the monthly panels. Groups separated from cluster analysis, G1G1: late autumn, G1G2: winter, G1G3: spring, G2G1: summer, G2G2: early autumn. The right portion of the figure represents the seasonal average percentage abundances. Dominant species tested were significantly different among subgroups, ** = P< 0.01.

panels and the seasonal average percentage abundances of the species with their significant differences. The dendrogram shows two major trends of species composition on primary space. One of these was from late autumn to spring (G1) in which *Enteromorpha intestinalis*, *Polydora ligni* and *Ciona intestinalis* were dominant recruiter species. Another one, from summer to early autumn (G2) was characterized by *Polydora*, *Hydroides elegans*, *Balanus amphitrite*, *Obelia longissima* and *Ciona* arrivals. Both of them were accompanied by *Tubularia crocea*, *Balanus* sp., *Bugula* spp. and colonial ascidians in low abundances.

Enteromorpha recruited from late autumn to summer but the peak of arrivals was reached from July to October (G1G2, G1G3). Although *Polydora* decreased in abundance during winter (G1G2), it is shown as the major potential contribution to the community nearly all the year round. *Ciona* had recruitment peaks in late autumn (G1G1) and summer (G2G1), in other seasons remained at low abundances. Some species had a much more marked seasonal patterns; *B. amphitrite* peaked during summer (G2G1) and *Obelia* and *Hydroides* in early autumn (G2G2).

Some panels were excluded from their major seasonal subgroups and enclosed in other ones due to significant differences in abundance percentages of *Enteromorpha* and *Ciona* arrivals ($P < 0.01$).

Community development

In late autumn (Fig.4), the initial structure of the fouling community was found to be similar to the assemblage composition of recruitment panels, but in addition, *Ceramium* sp., *Balanus trigonus* and *Bowerbankia gracilis*, were present in low abundances.

In winter (Fig.5), later cohorts of *Ciona* were recruited mainly onto established individuals of themselves, in abundances higher than expected from monthly panels during the same period. *Ciona* grew sharply, became the dominant species on primary space and provided secondary space for recruitment of mainly *Obelia* and *Bugula*. Ascidian-hydroid-bryozoan assemblage provided conditions for the arrivals of sediment-tube-worm *Polydora* and detritivore motile species upon them. *Obelia* in the development community shown higher abundance than its potential recruitment. However, *Polydora* was not successful in invading the development community. Species observed on primary space such as *Enteromorpha*, *Polydora*, *Hydroides* and *Balanus* sp. were kept alive underneath *Ciona* in a low percentage but they did not grow. *Enteromorpha* was the species which showed higher potential arrivals than the other species during this period, but when *Ciona* was present in the development community, the recruitment of *Enteromorpha* did not occur. Other taxa,

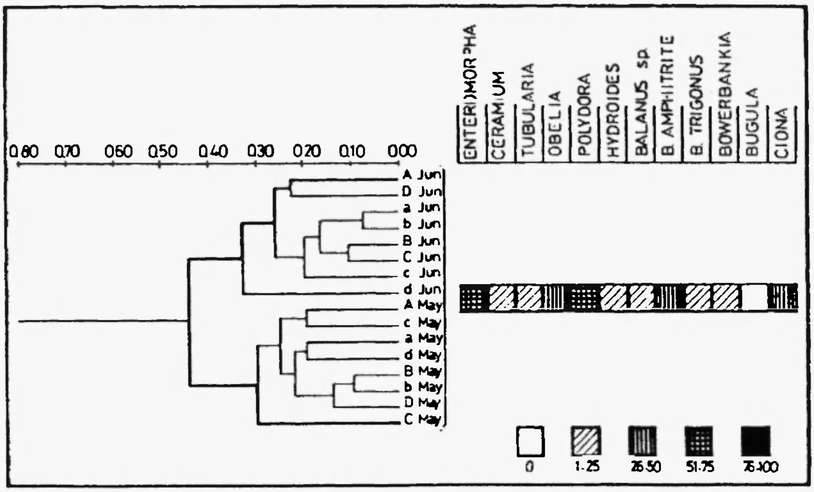

Fig. 4: Dendrogram showing the accumulative panels corresponding to late autumn. The right portion of the figure represents the average percentage abundances.

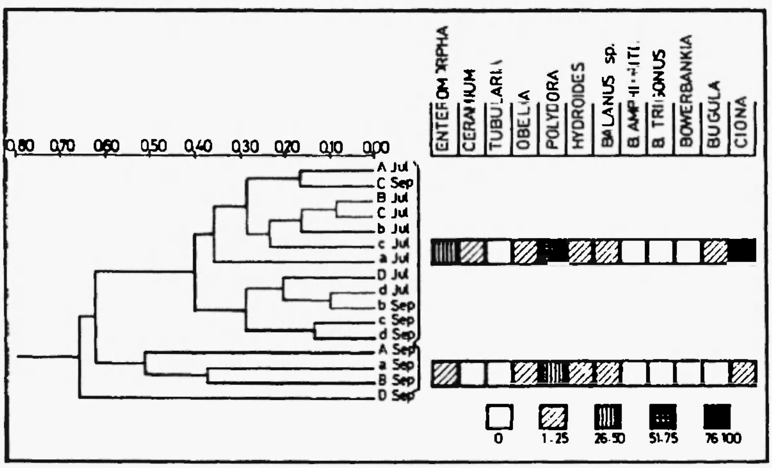

Fig. 5: Dendrogram showing the accumulative panels corresponding to winter. The right portion of the figure represents the average percentage abundances.

such as *Ceramium*, *Tubularia*, *B. amphitrite*, *B. trigonus* and *Bowerbankia* died. In September, *Ciona* began to slough off, took with it the overgrown species and opened new free spaces.

Towards spring (Fig.6), *Ciona* increased in abundance due to the persistence of a few old individuals, and new recruitments of themselves on primary space occurred. Although *Enteromorpha*, *Hydroides*, *Balanus* sp., *B. amphitrite* and *Bowerbankia* recruited, a large amount of bare space persisted because of these taxa attached far from *Ciona* individuals. During this season *Obelia*, *Polydora*, *Bowerbankia* and *Bugula* were overgrowing *Ciona* and increased their abundances.

In summer (Fig.7), from February to April, *Ciona* decreased to low abundance allowing the invasion of *Hydroides* and *B. amphitrite*. Additionally, these species became the major occupiers by their fast growth and provided secondary space for new recruits of themselves and other species, such as, mainly, *Obelia* and *Polydora*. The species of *Balanus* settled on primary space underwent high mortality due to heavy overgrowth of some species which smothered them. *Hydroides* grew up off the substratum and its survival was higher.

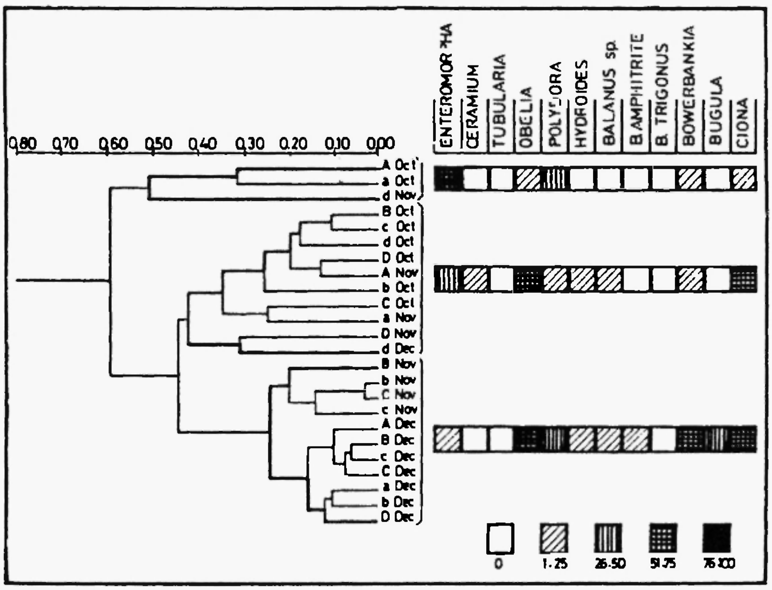

Fig. 6: Dendrogram showing the accumulative panels corresponding to spring. The right portion of the figure represents the average percentage abundances.

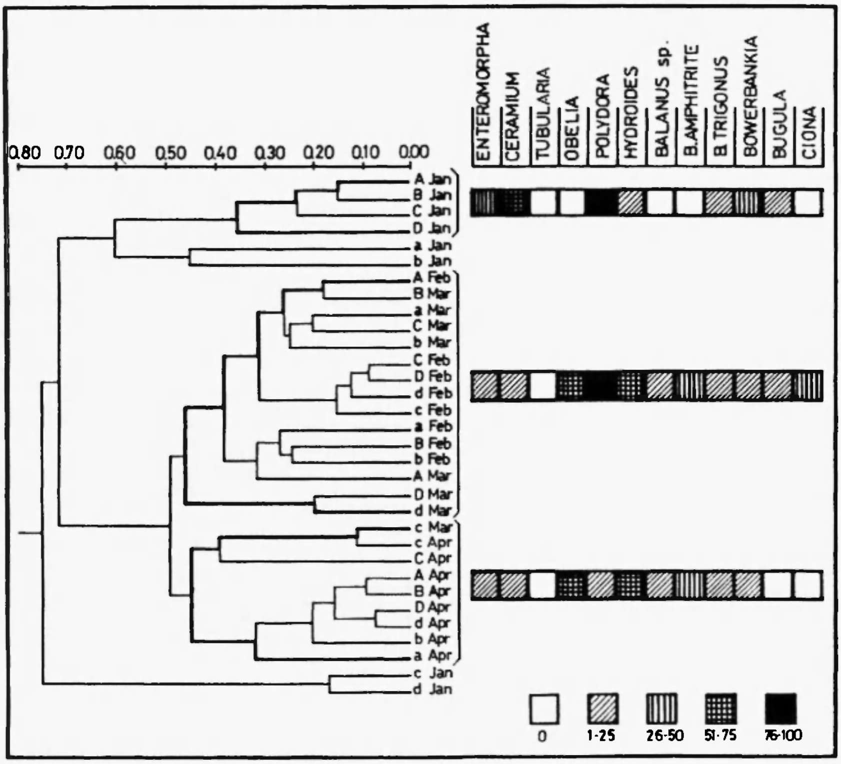

Fig. 7: Dendrogram showing the accumulative panels corresponding to summer-early autumn. The right portion of the figure represents the average percentage abundances.

Recruitment and composition of the community: A comparison

The most dominant species showed some interactions by significant differences in mean abundance percentages between the potential recruitment and its contribution to the resident assemblage species (Fig.8).

The mean abundances of *Ciona* on the development community were significantly greater than its potential recruitment nearly all the year round ($P < 0.01$), except for summer when *Ciona* changed its behavior.

Enteromorpha abundances during the higher recruitment period diverged significantly with its community contribution ($P < 0.01$). This is in agreement with the dominant period of *Ciona* on primary space and when they began to slough off in spring, because of their interactions in developing community.

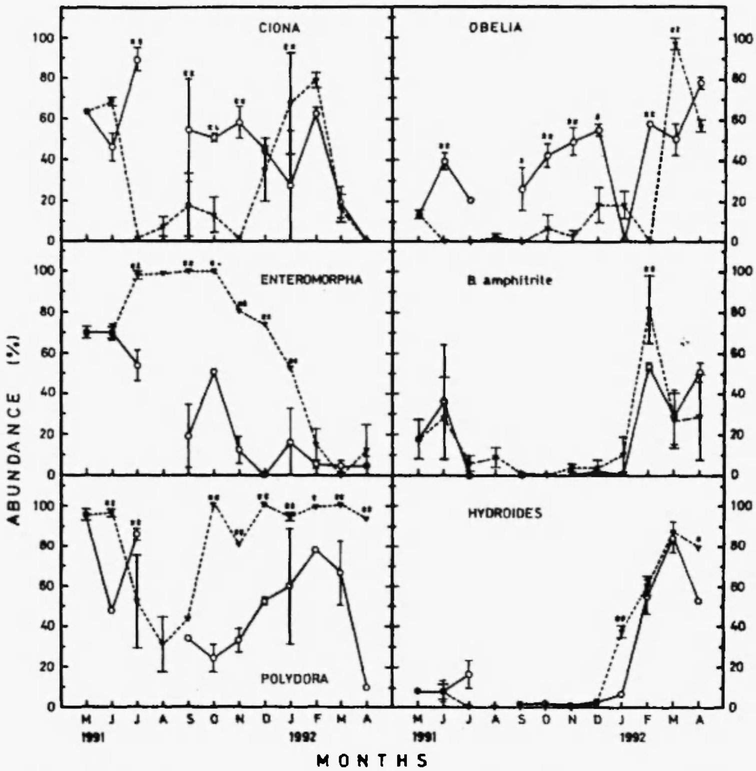

Fig. 8: Mean abundance percentages, standard deviation and levels of significance of monthly and accumulative panels. Monthly panels (...V...), accumulative panels (-o-), * = P< 0.05, ** = P< 0.01.

Polydora and *Obelia* overgrew *Ciona* and had different patterns of abundance between the potential recruitment and their contribution to the structure of the community. Although *Polydora* showed a heavy recruitment nearly all the year round, its lower abundances in the developing community (P< 0.01) were mainly due to *Ciona* sloughing off. In spite of *Obelia* having a low recruitment on monthly panels its arrivals were enhanced on persistent *Ciona* individuals, so that significant differences in abundances were shown (P< 0.01).

B. amphitrite and *Hydroides* showed similar general patterns of recruitment and development of the community. However, the abundance of *B. amphitrite* was lesser in the community composition than its recruitment peak (P< 0.01), due to overcrowding and overgrowth of the assemblage species. In contrast, the differences in *Hydroides* were just at the beginning of the seasonal peak when *Ciona* occupied enough primary space and affected their arrivals ($P < 0.01$), and at the end of this peak *Hydroides* began to decrease due to overcrowd mortality ($P < 0.05$).

DISCUSSION

In this study at Mar del Plata harbor, the species which mostly defined the community structure were *Ciona* from late autumn to spring and *Balanus* and *Hydroides* from summer to early autumn. *Ciona* as well as *Balanus* and *Hydroides* were overgrown by the same species assemblages.

When *Ciona* was dominant, the contribution of the species to the assemblage composition was different from the potential recruitment, due to interactions with early community structure. This species during its establishment and fast growth monopolized the primary space, entrapped sediments, provided vertical structure and secondary substratum which seemed to enhance or to inhibit the recruitment of some species, as well as to depress the growth of other ones. *Ciona* attached directly onto established individuals in a higher density than the settlement observed for monthly-panels; this suggests that recruitment might be enhanced by conspecific adults. Moreover, the presence of *Ciona* enhanced the arrivals of other secondary space occupiers such as *Polydora* mainly. Other species like *Ceramium* and *Bowerbankia* were found only in established communities. This suggests that these species preferred to arrive on established species assemblages rather than on free space available. This is in accordance with other communities where the recruitment of some species is less frequent or does not occur until the substratum is occupied by previous colonists /22, 28, 40, 41/. On the other hand, the vertical structure developed by *Ciona* may constitute a physical barrier by blocking contact between different propagules and the substratum. This is in agreement with the ascidian *Styela* which resists invasion of other species in a fouling community /8, 21, 26, 42/. In addition, Dean /28/, based on structural mimic, suggested that tunicates and hydroids inhibit the arrival of barnacles and tube-worms by structural effects. Moreover, when *B. amphitrite*, *B. trigonus* and *Bowerbankia* were attached on primary space, they were not able to expose their feeding apertures above ascidian and consequently died. Osman /43/ and Otsuka and Dauer /11/ pointed out that suspension-feeder species are able to survive in the community when the feeding apertures remain open to the water column. Standing /24/ reported in Bodega Harbor that when barnacles are beneath ascidians, they smother. When *Ciona* reached a large size and began to slough off the arrival of the potential species on bare space might also be inhibited by a whiplashing effect. Similar effects of kelp canopies on benthic invertebrate larvae were reported by Lewis /44/ and Duggins /45/.

The main annual change began when *Ciona* sloughed off and perturbed the community in late spring. This tunicate took the overgrown species and rendered open space steadily. Then,the bare substratum was invaded by species with calcareous exoskeleton, such as barnacles and serpulids. *Ciona* larvae were poor competitors when *Hydroides* and *Balanus* had a heavy arrival of recruiters. Otsuka and Dauer /11/ suggested that adults of *Balanus* are effective competitors to the recruitment and establishment of *Molgula* ascidian by knocking off the latter with their opercula. This is in agreement with other fouling communities which seem to develop similar pathways when solitary ascidians are present. Sutherland /8, 21/, in Beaufort, observed the replacement of solitary ascidian *Styela* by the bıyozoan *Schizoporella*. Otsuka and Dauer /11/, in Lynnhaven Bay, found the replacement of solitary ascidian *Molgula* by the bryozoan *Membranipora* and the barnacle *Balanus* sp.. Greene and Schoener /13/ in Manchester reported the replacement of ascidians by the barnacle *Balanus* and the tube-worm *Serpula*.

In regard to previous works carried out in 1966-69, 1969-70, 1973-74 and 1976-77 /36-39/, some changes may be distinguished in the study area. *Enteromorpha* preferred the deeper levels during the colder months and the upper ones in warmer seasons when fisheries industries increased their disposal of organic waste matter into the sea. In contrast, *Tubularia crocea* and *Bugula stolonifera* were found with lesser abundance than other studies. In spite of *B. amphitrite* enlarging the settlement cycle up to the winter months, it was not able to invade the community due to its low abundances and the presence of *Ciona*. Some species have not registered in the present period but were present with different abundances in other ones. The following taxa can be mentioned: *Bryopsis plumosa*, *Chaetomorpha* spp., *Ulothrix pseudoflacca*, *Ulva lactuca*, *Ectocarpus* sp., *Polysiphonia* sp., *Mytilus platensis*, *Pachysiphonaria lessoni*, *Serpula vermicularis*, *Ficopomatus enigmaticus*, *Hydroides plateni*, *Conopeum* sp. and other species with a low abundance.

In spite of the changes which have occurred in the local macrofouling community, a drastic modification of its structure depends on a sufficiently intense and long perturbation to diminish or exclude the establishment of *Ciona* during autumn and winter, and *Balanus-Hydroides* in summer.

ACKNOWLEDGEMENTS

The authors would like to thank the Comisiòn de Investigaciones Cientificas de la Provincia de Buenos Aires (CIC), the Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) for their support. We would also wish to thank the Club de Motonáutica of Mar del Plata for the permission to use their marine testing site, and to Dr. Cecilia Elsner, Mrs. Viviana Segura, and Ms. Mónica Garcia for their valuable assistance.

REFERENCES

1. J.P. Sutherland and R.H. Karlson, *3° Int. Congr. Mar. Corr. Foul.*, Maryland, USA, 906-929 (1973).
2. S.A. Levin and R.T. Paine, *Proc. Nat. Acad. Sci. (USA)*, 71, 2744-2747 (1974).
3. B.A. Menge and J.P. Sutherland, *Am. Nat.*, **110**, 351-369 (1976).
4. R. Karlson, *J. Exp. Mar. Biol. Ecol.*, **31**, 225-239 (1978).
5. B.A. Menge, *Oecologia (Berlin)*, **34**, 1-16 (1978).
6. W.P. Sousa, *Oecologia (Berlin)*, **45**, 72-81 (1980).
7. A.M. Ayling, *Ecology*, **62** (3), 830-847 (1981).
8 J.P. Sutherland, *Am. Nat.*, **118** (4), 499-519 (1981).
9. P.N. Chalmer, *J. Exp. Mar. Biol. Ecol.*, **58** (1), 73-85 (1982).
10. B. Field, *J. Exp. Mar. Biol. Ecol.*, **57** (1), 25-33 (1982).
11. C.M. Otsuka and D.M. Dauer, *Estuaries*, **5** (1), 10-22 (1982).
12. C.H. Greene and A. Schoener, *Oecologia (Berlin)*, **55**, 289-297 (1982).
13. C.H. Greene and A. Schoener, *6th Intern. Congr. Mar. Corr. Foul., Marine Biology*, Athens, Greece, 221-235 (1984).
14. G.B. Williams, *J. Mar. Biol. Ass. U K*, **44**, 397-414 (1964).
15. P.K. Dayton, *Ecol. Monogr.*, **41**, 351-389 (1971).
16. M.S. Foster, *Mar. Biol.*, **32**, 331-342 (1975).
17. G.R. Russ, *J. Exp. Mar. Biol. Ecol.*, 42, 55-69 (1980).
18. J.H. Connell, *J. Exp. Mar. Biol. Ecol.*, **93**, 11-45 (1985).
19. H.P. Possingham and J. Roughgarden, *Ecology*, 71 (3), 973-985 (1990).
20. J.C. Marques, L.B. Rodrigues and A.J. Nogueira, *Vie Milieu*, 43 (2-3), 177-187 (1993).
21. J.P. Sutherland, *Am. Nat.*, 108 (964), 859-873 (1974).
22. D.L. Breitburg, *Oecologia (Berlin)*, **65**, 173-184 (1985).
23. C.M. Young, *Mar. Biol.*, 91, 513-522 (1986).
24. J.D. Standing, "Fouling community structure: effects of the hydroid, *Obelia dichotoma*, on larval recruitment". In: G.O. Mackie, (ed), *Coelenterate Ecology and Behavior*. Plenum Press, 155-164 (1976).
25. J.B. Jackson, *Am. Nat.*, **111**, 743-767 (1977).
26. J.P. Sutherland, *Ecology*, **59** (2), 257-264 (1978).

27. T.A. Dean and L.E. Hurd, *Oecologia (Berlin),* 46, 295-301 (1980).
28. T.A. Dean, *J. Exp. Mar. Biol. Ecol.,* 53 (2-3), 163-180 (1981).
29. J.P. Sutherland, *Ecology*, 71 (3), 955-972 (1990).
30. G.W. Smedes and L.E. Hurd, *Ecology*, 62 (6), 1561-1572 (1981).
31. R. Paine and S.A. Levin, *Ecol. Monogr.*, 51, 145-178 (1981).
32. P.K. Dayton, V. Currie, T. Gerrodette, B. Keller, R. Rosenthal and D. Tresca, *Ecol. Monogr.*, 54, 253-289 (1984).
33. C.M. Young and N.J. Gotelli, *Ecology*, 69 (3), 624-634 (1988).
34. M.H. Posey and A.H. Hines, *Ecology*, 72 (6), 2155-2169 (1991).
35. A.J. Boulton, C. Peterson, N.B. Grimm and S.G. Fisher, *Ecology*, 73 (6), 2192-2207 (1992).
36. R.O. Bastida, *Corrosión y Protección*, 2 (1), 21-37 (1971).
37. R. Bastida and H. Adabbo, *Corrosión y Protección*, 8 (5), 1-14 (1977).
38. R. Bastida, M.T. de Mandri, V.L. de Bastida and M. Stupak, *Proc. V Congr. Int. Corr. Mar. e Incrust., Biologia Marina,* Barcelona, España, 299-320 (1980).
39. M.E. Stupak, R.O. Bastida and P.J. Arias, *CIDEPINT-Anales*, 173-231 (1980).
40. E.C. Haderlie, *Veliger*, 17, 1-35 (1974).
41. R.W. Osman, "Artificial substrates as ecological islands," In: J. Cairns, (ed.) *Artificial Substrates.* Ann. Arbor Sci. Public., Massachusetts, 71-114 (1982).
42. J.P. Sutherland and R.H. Karlson, *Ecol. Monogr.*, 47, 425-446 (1977).
43. R.W. Osman, *Ecol. Monogr.*, 47, 37-63 (1977).
44. J.R. Lewis, *The Ecology of Rocky Shores,* English Univ. Press, London, 323 pp (1964).
45. D.O. Duggins, J.E. Eckman and A.T. Sewell, *J. Exp. Mar. Biol. Ecol.*, 143, 27-45 (1990).