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RESPONSE OF MUSSEL POPULATION TO SEWAGE-IMPACT IN ROCKY-STONY SHORE

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ABSTRACT

In Mar del Plata, a rocky-stony-shore near a sewage discharge develops a community of *Brachidontes rodriguezii*. Samples along a gradient of organic contamination and a control site were selected randomly for studies of density, proportion of adults/seeds, biomass, and length, width and height of mussels. Density of adults, seeds and biomass were significantly lowest nearest to outfall increasing to control sites. In spite of the high mortality of seeds, the surviving mussel seems to have better condition near the sewage outfall. Unexpected allometric results showed greatest values of length, width and height near the outfall rather than in control site. After summer, Biomass and size of mussel were lower as results of increasing sewage discharge.

Key words: assessment, bivalves, allometry, intertidal.

RESUMEN

En la ciudad de Mar del Plata la comunidad intermareal de *Brachidontes rodriguezii* se desarrolla sobre plataformas de tosca ("Caliche") cerca del efluente urbano. Se tomaron muestras al azar a lo largo de un gradiente de contaminación orgánica y un sitio control para estudios de densidad, proporción de adultos y semillas, biomasa, y largo, ancho y alto de los bivalvos. La densidad de adultos, semillas y biomasa fue significativamente más baja cerca del efluente, incrementándose hacia el sitio control. A pesar de la elevada mortalidad de semillas, los bivalvos sobrevivientes parecen tener una mejor condición cerca del vertido. Los registros alométricos proporcionaron resultados inesperados, mostrando los valores más elevados de largo, ancho y alto cerca del efluente y menores en el sitio control. Los registros de biomasa y tamaño de los bivalvos fueron más bajos después del verano como resultado del incremento del vertido orgánico de la ciudad.

Palabras clave: Impacto ambiental, bivalvos, alometría, intermareal.

INTRODUCTION

The pollution can be assessed from practically all organisms-level organization; particularly the macrobenthos have been extensively used in assessing organic pollution (Pearson & Rosenberg, 1978). Intertidal communities under sewage-induced disturbance are often dominated by algae (Bellgrove *et al*., 1997). However, a well developed community of the mussel *Brachidontes rodriguezii* (D´Orbigny, 1846) was found near a sewage effluent in Mar del Plata city (38ºS - 57ºW). This intertidal community reflects both the chronic effect of sewage impact (Vallarino *et al*,. 2002) and the short-term effect due to the increasing of both, the population of the city during summer period (3,000,000 tourists between November-March) and sewage discharge (up to 60 %). Mussels are good indicators and their morphological changes reflect changes in population or environmental conditions (Seed, 1968). These allometric changes in relative shell proportions reflect constrains imposed by optimization of the geometry of internal transport networks (Banavar *et al*., 1999). The intertidal area around sewage discharge of Mar del Plata give us the opportunity to study a stable *B. rodriguezii* population in both natural (not contaminated) and sewage-impacted areas. The aims of this work were: a) assess the effects of the distance from effluent on the density and the biomass of mussels, b) study the size distribution and shape of mussels along contamination gradient and c) evaluate the short-term effect before-after summer season on density, biomass and size variables of mussels.

MATERIALS AND METHODS

Mar del Plata city has a resident population of about 600,000 people, but receives almost 3.000.000 tourists during summer (December-March). Raw sewage effluent discharges in horizontal abrasion platforms of caliche inhabited by a well developed *B. rodriguezii* community. The sewer system (mean rate of 2.8 $m^3\ s^{-1}$ in winter, and 3.5 $m^3\ s^{-1}$ in summer) has only a pre-treatment plant and sewage discharge is released on the intertidal zone.

Salinity ranged between 33.3-33.8 and temperature between 8-21º C, being residual waters of continental shelf. Tidal range is 0.60 m, but 0.90 m in extraordinary tides, and also influenced by winds.

For the population analysis, 4 stations were sampled in a platform of abrasion affected by sewage: Stations 1 (at 50 m from effluent), 2 (at 230 m), 3 (at 450 m) and 4 (at 725 m). The control site: Station C was established at 9000 m north to St 1, because it was physically impossible to access anywhere else location with *B. rodriguezii* population in similar substrate. In two tidal levels (superior and inferior), 4 samples were randomly taken in each level and were obtained by a 78 cm^2 plastic corer. Measurements of length, width and height were obtained from 2 samples (randomly selected) in order to obtain the full range of sizes of the bivalves. Up to 30.000 mussels were measured. Density, biomass and proportion of adults and seeds (< 0.5 mm), from 2 random samples of each level and each station were obtained. Samples came from 8 consecutive samplings (November of 1998 and 1999; June and August 1999; March 1999, 2000 and 2002; December 2001). Salinity, pH, temperature, turbidity and dissolved oxygen were obtained in each station with multiparametric equipment Horiba U10. Also values of sediment among mussels and organic matter in the sediment were registered. The effects of the distance from the effluent (stations), the tidal levels (superior, inferior) and the age of the mussels (adults, seeds) on the density of *B. rodriguezii* were analyzed using generalized linear models (Crawley 1993), assuming a Poisson distribution and a logarithmic link. Differences in biomass of *B. rodriguezii* between stations and tidal levels were evaluated with a two-way ANOVA. Homogeneity of variances and normality were assessed using Levene and Shapiro-Wilks tests respectively, Scheffe test was performed for post-hoc comparisons (Zar, 1999).

Length, width and height were used as variables in two-way ANOVA to test differences between tidal levels and stations. Homogeneity of variances and normality were assessed using Levene and Shapiro-Wilks tests respectively. Although the homogeneity of variances could not be achieved by any transformation in some cases, data were analyzed by ANOVA. (Underwood, 1997). Whenever a difference was established in the ANOVA, multiple comparisons were done by Scheffe test. Length-width and length-height of *B. rodriguezii* were analized by regression models. To evaluate the short-term response of mussels before November and after March, differences in biomass and density of *B. rodriguezii* were evaluated. In the case of density, generalized linear models were used (Crawley, 1993). A Poisson distribution and a logarithmic link were assumed. For biomass a two-way ANOVA were performed. Results were, however, interpreted with caution by a more conservative significance level (α = 0.01).

Length, width and height were used as variables in two-way ANOVA to test differences between station and short-term effect (November-March) as fixed factors.

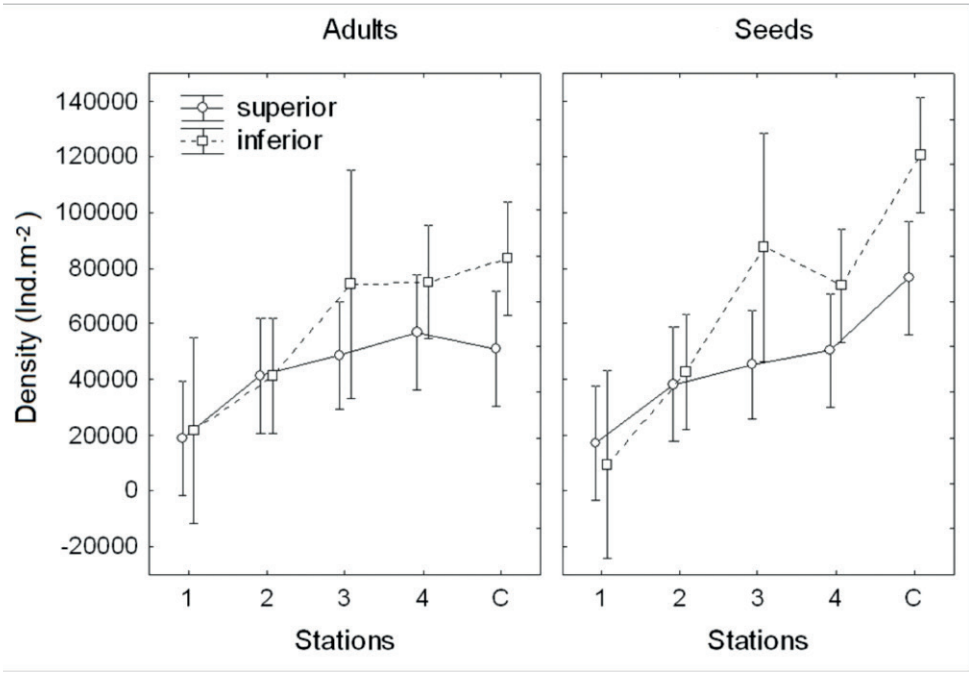

Figure 1:

Density mean of adults (A) and seeds (B) of Brachidontes rodriguezii mussels in the two tidal levels (superior and inferior) along the organic contamination gradient (stations 1-4: putative impacted area, and C: control sites). Vertical bars denote 0.95 confidence intervals.

RESULTS AND DISCUSSION

The environmental parameters showed a gradient from sewage discharge to the Control site (station C). Salinity was very low in the proximity to the effluent, but from Station 1 similar values to the rest of the stations. During March, the values of Salinity in the impacted site (station 1) decreased because the tourism during summer due to the enlargement of the flow by the treatment plant. The temperature had similar values to historical averages for the area in November and March (see Lopez Gappa *et al.*, 1990). The pH values were higher in November (mean values between: 8.1-8.4) than in March (mean values between: 7.8-8), showing the greatest differences in the impacted site. High levels of turbidity had no change in the site close to the effluent. Dissolved oxygen (DO) show a similar pattern to pH without variation between months. The decrease DO was higher during the month of March. The minimum amount of retained sediment was found in the station 1 (the nearest to the effluent), while intermediate stations (2 and 3) had larger amounts, and decreased to intermediate values at stations 4 and C (control site). During November the sediment amount was higher than March. Total organic carbon (TOC) in the sediment on March was lower (mean values between: 0.1-0.4 %) than November (mean values: 0.3-1.1%), with maximum values at station 1 (1.1%) and lower at station 3 (0.1%).

Total density of *B. rodriguezii* increased from sewage discharge to control site (Fig. 1). However, there were a differential proportion of adults and seeds in tidal levels and stations. Stations 1 and 2 have not shown differences in adult/seed proportion between levels, but in stations 3, 4 and Control there was a significant increase of seeds in inferior level. In the same way seeds were more abundant in stations far from the effluent. Differences in density were significant between the stations and tidal levels (station: Wald statistic=64.82, $P < 0.0001$; level: Wald statistic=4.01, $P = 0.045$).

The biomass increased from near the outfall to station 4 and the control site at the inferior level, however the biomass have not shown differences between stations at the superior level (Fig. 2) (two-way ANOVA, $F_{4,130}=4.75$, $P < 0.01$). Post-hoc test showed that stations 1 and 2 were significantly different (lower) to control station at the inferior level ($P < 0.05$).

Length, width and height of *B. rodriguezii* decreased from sewage discharge to control site and these variables were significantly different between stations (length: $F_{4,130}=6.94$, $P < 0.01$; width: $F_{4,130}=5.09$, $P < 0.01$ and height: $F_{4,130}=8.13$, $P < 0.01$), but not between levels ($P > 0.01$ in all cases). *A posteriori* comparison showed station 1 highly significant different with station 4 and the

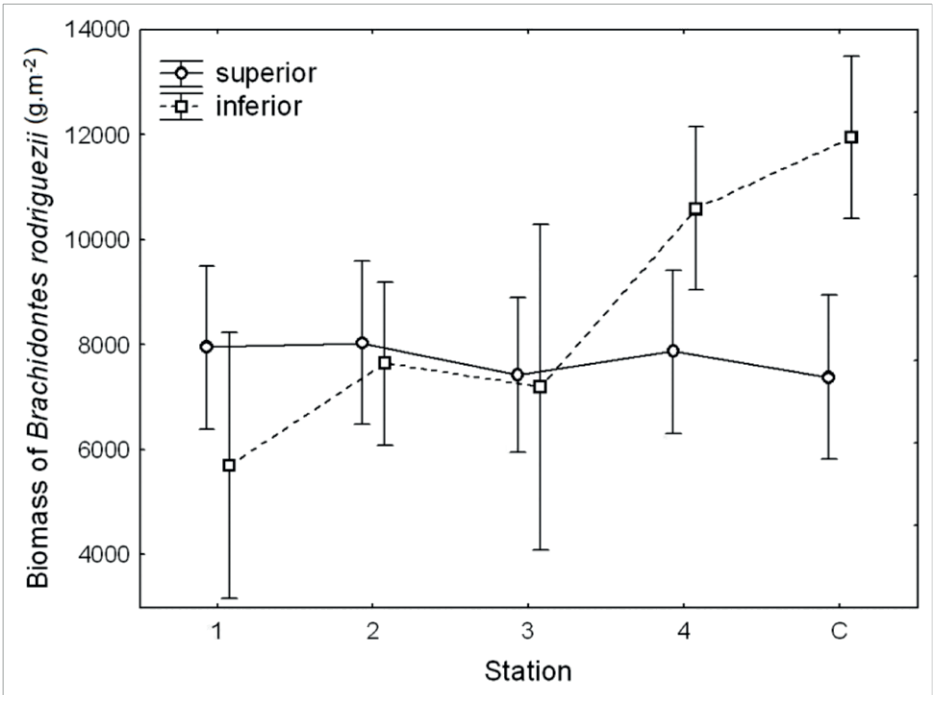

Figure 2:

Biomass of Brachidontes rodriguezii mussels in the two tidal levels (superior and inferior) along the putative gradient (stations 1- 4) and in the control site (C).

Control site. There were a positive relationship between length-width and length-height in all areas ($R^2 > 0.9$, $P < 0.05$ in all cases). In addition, there were significant differences among the slopes for the different regression models (length-width and length-height) in: a) Superior level-Impacted area, b) Inferior level-impacted and c) Inferior level-control site ($P < 0.05$ in all cases) but not in Superior level-control site ($P = 0.15$).

Differences in the short-term period were evident in the biomass of March ($F_{1,100}=9.32$, $P = 0.003$) but not in the density (Wald statistic= 0.01, $P = 0.92$). Size variables of mussels were significantly low during March, particularly from station 2 to control site (Length: $F_{1,100}=25.78$, $P < 0.01$; Width: $F_{1,100}=18.70$, $P <0.01$ and Height: $F_{1,100}=22.49$, $P <0.01$).

Density and biomass of *B. rodriguezii* decreased in sewage impacted sites. Stations closest to outfall have significantly low density and biomass of adults and seeds. Unexpected high length, as well as width and height of shells, were found increasing toward the outfall, while control sites have the lowest values. With respect to the short-term effect, biomass and size variables of mussel were lower in March than in November. When the volume of the flow released of the treatment plant increase the community changes according to above mentioned. When the discharge increases the dominance of *B. rodriguezii* reduce, decreasing the abundance and richness in surrounding areas during the summer and increasing the affected area from 250 to 1,000 m south of the effluent (Vallarino & Elías, 2006).

In a spatial study Vallarino *et al.* (2002) have shown that community was density-dependent of the degree of sewage impact. Not impacted sites are dominated by mussels, reaching between 70 to 90 % of the total number of individuals. Sewage impact reduce the dominance of mussels and favors the occurrence of species tolerant to organic contamination producing higher diversity and evenness in impacted sites rather than in control sites. The sewage discharge could produce different degrees of disturbance along the pollution gradient. The impact is great near the outfall, but at intermediate distances (around 400 m) the impact is less severe.

In inferior level of station 1 the biomass is lower than in station 4 and control site. This greatest biomass in not impacted areas could be explained by major immersion time. The same immersion time in sewage impact areas produce the lowest biomass, be associated with a great stress.

Recruitment occurs almost all the year in this community, with evident peaks in spring and autumn,

but mussel larvae can spend about three month in the plankton (Seed, 1969). Sewage impacted areas shown very low density of seeds. In spite of this high mortality, the surviving mussel seems to have better condition near the sewage outfall. The great size of mussels and the retained sediments in the matrix allow functioning as ecosystem engineer in spite of the impact.

In *Mytilus* shell morphology is greatly influenced by growth rate and density. Probably exert their effect through physical compression which is maximum in localities of fast growth and high density and least in areas of slow growth and low density. High compression leads to an elongate form whereas low compression results in higher, more triangular shaped shells (Seed, 1968). Since all environmental conditions vary in both time and space, wide variation in shell morphology is to be expected, even in animals from the same locality. Transplantation experiments indicate that variation in shell morphology is essentially phenotypic. Smaller mussels from widely different habitats show remarkable similarity in shell morphology (Alunno-Bruscia *et al.*, 2001). Variation of size and shape of *B. rodriguezii* along the pollution gradient is not expected. The Argentine Sea is considered oligotrophic, and a supply of food could be biostimulating and reflected in length of animals. However, near the outfall the amount of organic matter could be excessive producing negative effects on growth. Transplanted mussels in Hindell and Quinn (2000) shown significant smaller *B. rostratus* in sewage impacted area of Australia respect the control site. These differences were due to a combination of smaller maximum size of individual mussels, and higher number of mussels recruits (< 5 mm). The mussel population of *B. rodriguezii* has the opposite response, been mussels greater in length, width and height in impacted sites with few mussels recruits. On the other hand, a control site is characterized by smaller individuals and great number of recruits. These results could be due to a combination of density-dependent relationship within the mussels, enhanced growth and differential mortality of recruits. Mussels cover (Elías *et al.*, 2009) and densites (Vallarino *et al.*, 2002) are lowest in sewage-impacted sites. Although excess of organic matter seems to be benefit for mussel growth and associated fauna (Elías *et al.*, 2003; 2006) is negative for the mussel population.

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REFERENCES

Alunno-Bruscia M, Bourget E, Fréchette M (2001). Shell allometry and length-mass-density relationship for *Mytilus edulis* in an experimental food-regulated situation. Marine Ecology Progress Series 219: 177-188.

Banavar JR, Maritan A, Rinaldo A (1999). Size and form in efficient transportation networks. Nature 399: 130-132.

Bellgrove A, Clayton MN, Quinn GP (1997). Effects of secondarily treated sewage effluent on intertidal macroalgal recruitment processes. Marine & Freshwater Research 48: 137-146.

Crawley MJ (1993). GLIM for Ecologists, 379 pp. Blackwell Science, Oxford.

Elías R, Rivero MS, Vallarino EA (2003). Sewage impact on the composition and distribution of Polychaeta associated to intertidal mussel beds of the Mar del Plata rocky shore, Argentina. Iheringia, Serie Zoología 93: 309-318.

Elías R, Rivero MS, Palacios JR, Vallarino EA (2006). Sewage-induced disturbance on polychaetes inhabiting intertidal mussel beds of *Brachidontes rodriguezii* off Mar del Plata (Southwestern Atlantic, Argentina). Scientia Marina 70(3): 187-196.

Elías R, Sanchez MA, Jaubet ML, Rivero MS, Vallarino EA (2009). Do treatment sewage plants really work? The intertidal mussels' community of the southwestern Atlantic shore (38º S, 57º W) as a case study. Revista Biología Marina & Oceanografía 44: 357-368.

Hindell JS, Quinn GP (2000). Effects of sewage effluent on the population structure of *Brachidontes rostratus* (Mytilidae) on a temperate intertidal rocky shore. Marine Freshwater Research 51: 543-551.

López-Gappa JJ, Tablado A, Magaldi NH (1990). Influence of sewage pollution on a rocky intertidal community dominated by the mytilid *Brachidontes rodriguezii*. Marine Ecology Progress Series 63: 163-175.

Pearson TH, Rosenberg R (1978). Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanography and Marine Biology: An Annual Review 16: 229-311.

Seed R (1968). Factors influencing shell shape in the mussel *Mytilus edulis*. Journal of Marine Biological Association United Kingdom 48:561-584.

Seed R (1969). The Ecology of *Mytilus edulis* (Lamellibranchiata) on exposed Rocky Shore. I. Brreding and Settlement. Oecologia 3: 277-316.

Underwood AJ (1997). Experiments in ecology: Their Logical Design and Interpretatión Using Analysis of Variance, 496 pp. Cambridge University press, Cambridge.

Vallarino EA, Rivero MS, Gravina MC, Elías R (2002). The community-level response to sewage impact in intertidal mussel beds of the Southwestern Atlantic, and the use of the Shannon index to assess pollution. Revista de Biología Marina y Oceanografía 37: 25-33.

Vallarino EA, Elías R (2006). High-diverse lowly variable sewage-impacted community, low-diverse highly variable natural community: The paradox of the intertidal mussel beds of temperates areas of the SW Atlantic (38° S, 57° W). Current Trends in Ecology 1: 77-91.

Zar JH (1999). Bioestatistical Analysis. Prentice-Hall: 718 pp. Upper saddle River.

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