Revista de Biología Marina y Oceanografía 40(2): 101 – 108, diciembre de 2005

First survey of macroinfauna in the Mar del Plata Harbor (Argentina), and the use of polychaetes as pollution indicators

Primeros datos de la macroinfauna del puerto de Mar del Plata (Argentina), y el uso de poliquetos como indicadores de contaminación

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Abstract.- Harbors share a number of similar problems, such as water and sediment pollution. In this work we analyze spatial variation of macroinfauna, with special emphasis in polychaete abundance to characterize the environmental health of Mar del Plata Harbor. Twelve stations were sampled with replicated 0.05 m^2 van Veen grabs, with environmental variables from the water column and sediments in December 2001. Polychaetes (23 of 35 taxa) constituted 62% of the total abundance. A multi dimensional scaling analysis and a redundancy analysis showed three groups of stations: one at the mouth of the port, with healthy environmental conditions and characterized by *Mediomastus* sp., Maldanidae and *Aglaophamus uruguayi*; other in the inner harbor, with poor environmental conditions and inhabited only by *Capitella "capitata"* sp., and a third intermediate and more diverse group with *Polydora* spp., *Tharyx* sp., *Mediomastus* sp., *Capitella "capitata"* sp., and *Capitella* sp. Differences among pre-defined groups were significant. It is hypothesized that strong hydrodynamics affects the stations at the mouth, as shown by low organic content and the dominance of sandy sediments. In the inner harbor, poor environmental conditions are due to restricted water movement, prevalence of silt sediments, and high content of pollutants. Abundance of *Capitella* spp. correlated to total organic carbon content, except in the inner harbor. It is possible that high concentrations of hydrocarbons in the inner harbor explain the low abundance of these species, as well as the absence of other benthic animals, and the low diversity values. Polychaetes are useful pollution indicators in this harbor.

Key words: macrobenthic community, indicator species, environmental variables, multivariate analyses

Resumen.- Los puertos comparten numerosos problemas similares, como la contaminación de aguas y sedimentos. En el presente trabajo se analiza la variación espacial de la abundancia y distribución de la macroinfauna, con especial énfasis en poliquetos, para caracterizar la salud ambiental del puerto de Mar del Plata. Doce estaciones fueron muestreadas por medio de dragas replicadas tipo van Veen de 0,05 m^2, junto con variables de la columna de agua y el sedimento, en diciembre de 2001. Los poliquetos (23 de 35 taxones) correspondieron al 62% de la abundancia total. Un análisis de escalamiento multidimensional junto con un análisis de redundancia mostraron tres grupos de estaciones: uno en la boca del puerto, con condiciones ambientales saludables y caracterizado por *Mediomastus* sp., Maldanidae y *Aglaophamus uruguayi*; otro en el interior del puerto, con pobres condiciones ambientales y habitado solo por *Capitella "capitata"* sp., y un tercer grupo intermedio y mas diversificado con *Polydora* spp., *Tharyx* sp., *Mediomastus* sp., *Capitella "capitata"* sp. y *Capitella* sp. La diferencia entre los grupos pre definidos fue significativa. Se postula que el fuerte hidrodinamismo afecta a las estaciones de la boca, como lo demuestra el bajo contenido orgánico y la dominancia de arenas. En el interior del Puerto, las pobres condiciones ambientales son debidas al escaso movimiento de las aguas, presencia de limos y contaminantes. La abundancia de *Capitella* spp. se correlaciona con el contenido orgánico, excepto en el interior del puerto. Es posible entonces que las altas concentraciones de hidrocarburos en el interior del puerto expliquen la baja abundancia de esta especie, así como la ausencia de otros organismos y los bajos valores de diversidad. Los poliquetos son útiles como indicadores de contaminación en este puerto.

Palabras clave: comunidad macrobentónica, especies indicadoras, variables ambientales, análisis multivariado

Introduction

At the end of the 20^{th} century the impact of human activities in natural environment has become a serious problem, affecting costal environments by forming new habitats and communities due to the introduction of a large number of chemicals in the marine environment. These habitats and communities are characterised by different qualitative and quantitative parameters (GESAMP 1993). One of the most affected areas are harbors, due to partial enclosure and high pressure derived from waste waters, urban runoff, chemical input (including nutrients and organic matter), marine transportation and dredged material (for a review see Darbra *et al*. 2005).

Historically, harbors have been intensively studied in the Northern Hemisphere, and also monitored to assess pollution in water and sediments (see Gallager & Keay 1998, Je *et al*. 2003). On the other hand, Southern Hemisphere harbors are poorly known or information is completely haching. In the region only the study of Danulat *et al*. (2002) in the Montevideo harbor (a mixohaline environment) is available. The harbor of Mar del Plata, with a surface of about 1,400,000 m^2, is a relatively new facility (constructed by 1922), but shows pollution of a least total hydrocarbons (ranging from 753 to 9,680 $mg \cdot kg^{-1}$), polycyclic aromatic hydrocarbons (PAH) (up to 46 $ug \cdot g^{-1}$), and copper (between 18 to 950 $mg \cdot kg^{-1}$) in the head of docks (Dyopsa S.A., Dredging International 1999). Many studies of fouling were carried out in the harbor (see Bastida *et al*. 1980) and in the intertidal hard-bottom area (Elías & Vallarino 2001), but infaunal communities remain unknown.

Benthic animals are useful for monitoring environmental quality due to their habitat and life style. Attributes of benthic communities structure (species composition, quantitative parameters, trophic groups and species-indicators) may therefore reflect the quality of marine environments (Pearson & Rosenberg 1978). Assessing patterns in benthic community structure has several advantages over other experimental methods for detection of anthropogenic disturbance. Benthos can integrate conditions over time rather than reflecting conditions just at the time of sampling, so benthic animals are therefore more useful in assessing local effects of monitoring programs (UNESCO 1988). Polychaetes are one of the most useful marine organisms to detect pollution, because they live in the water-sediment interface, layer that is biologically active and chemically reactive (Rhoads & Boyer 1982). Polychaetes have been used in bioassays to monitor toxic compounds, and as pollution indicators (Pocklington & Wells 1992, Reish & Gerlinger 1997, Levin 2000[1]). The presence or absence of some indicator species or even families are currently known as pollution indicators, in particular the presence of the *Capitella "capitata"* complex (Reish 1972, Tsutsumi 1990, Pocklington & Wells 1992) or some spionids (Tsutsumi 1990), or the absence of the genus *Lumbrineris* (Ryggs 1985).

In this work we analyse the spatial variation of subtidal soft-bottom macrobenthic community. Since polychaetes are the dominant infaunal group in the harbor, a special emphasis is made around these organisms in order to use them as potential indicators of pollution for the Mar del Plata Harbor.

Materials and methods

Study area

The Mar del Plata Harbor (38° 02´S, 57° 31´ 30"W) is a semi-enclosed area, limited by two artificial breakwaters and a narrow mouth of about 300 m (Fig. 1). Fine and very fine sand are dominant sediments around the mouth, while silty sediments are characteristics of inner harbor. Mean water depth is low (5 m), and a navigational channel is maintained with dredging (at 10 m). The area has water of low turbidity as well as low salinity, dissolved oxygen and pH. Temperature is higher in summer and lower in winter, respect to the outer area. Organic matter is often high due to industrial and sewage effluents (Bastida 1971).

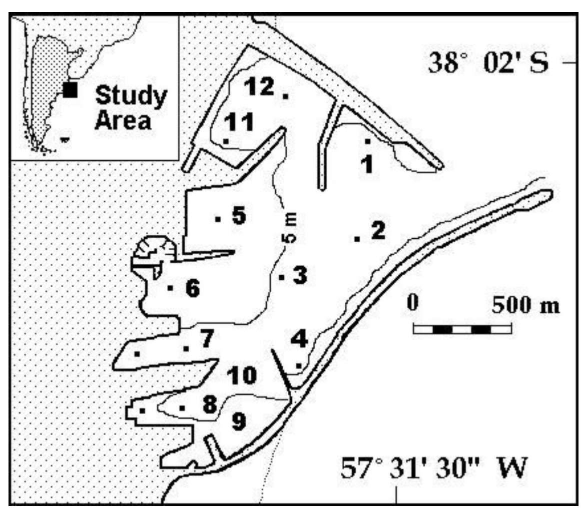

Figure 1

Sampling stations in the Mar del Plata Harbor,Argentina, in December 2001

Estaciones de muestreo en el puerto de Mar del Plata, Argentina, en diciembre de 2001

[1] **Levin LA. 2000**. Polychaetes as environmental indicators: response to low oxygen and organic enrichment. Abstract of 6th International Polychaete Conference, Curitiba, Brazil, August 2-7, 1998.

Methods

Twelve stations (Fig. 1) were sampled on 11 December, 2001, with replicated 0.05 m^2 van Veen grabs (three in each zone for biological analyses, plus one for grain size analyses). Sampling was designed to test the pollution gradient: stations 1, 2 and 3 (outer region) representing places of little or not impact; stations 4 to 8 (middle region) representing places relatively impacted, and stations 9 to 12 (inner region) representing potentially polluted sites.

Environmental variables from the water column (pH, turbidity, depth, and temperature) were measured by a Horiba U-10 equipment. Sediment samples for mean grain size as well as total hydrocarbons were obtained, but resulted lost. Samples of sediment (one for each grab) were analyzed for total organic carbon (TOC) by titration method (Walckley & Black 1963).

Each sample was sieved on board, and the retained macrobenthic organisms (0.5 mm) were fixed with a neutralized solution of formaldehyde (5%). Identification and counting were performed under a stereomicroscope in laboratory.

The significance of the regions outlined a priori (outer, middle, inner regions) was tested with the one-way ANOSIM (analysis of similarities), and the organisms which most contributed to the observed differences among groups were found by means of the SIMPER (similarity percentage) analysis, using the software package PRIMER (Plymouth Marine Laboratory, UK). Mean macrobenthic richness (S), abundance (A), diversity Shannon index (Shannon & Weaver 1963) and Evenness index (Pielou 1969) were calculated by pooling all three replicates. Differences in these parameters were tested by a one-way ANOVA (each parameter vs. regions), followed by the SNK test for post hoc multiple comparison. Ordination was performed with non-metric Multidimensional Scaling (nMDS), using the Bray-Curtis similarity index (Field *et al.* 1982). Analyses were performed with untransformed data of macroinfauna abundances for minimum stress, although the $\log_{10}$ (X+1) produces also a low stress.

Environmental variables were analyzed also by MDS (from a similarity matrix calculated by the Euclidean distance index) with untransformed data. To set down the relationship of environmental variables and the benthic organisms, the BIO-ENV procedure was employed. Finally, a redundancy analysis (RDA) was also performed to relate environmental and biological variables as well as sampling sites. The dimension of the data was reduced by using the subroutine Biplot of the EXCEL worksheet (Lipkovich & Smith 2002). The analysis is based on a singular value decomposition of the centered Y* regressed on columns of the centered X* matrix, Y containing sites in rows and abundance of species in columns (transformed with Log_{10} X+1, because it reduces the length of the axis), and X contains site environmental data (not transformed). This analysis is recommended when samples represent a narrow environmental gradient, and the taxa seem to respond to this gradient in a lineal relationship. The RDA represented the variables that explained best the highest percentage of the variance, while those that represented redundant information were eliminated (Jongman *et al.* 1995).

Results

The environmental pattern (Fig. 2) showed a general gradient of increasing turbidity and TOC from the mouth to the inner harbor, while pH showed the opposite trend. TOC showed lower values in stations 11 and 12 in spite of their inner position, perhaps due to be located near the mouth.

From 35 benthic taxa sampled, 23 were polychaetes (12 families), accounting for 62% of total abundance, but the most abundant taxon was an unidentified species of the nematode *Viscosia* (Table 1).

A multidimensional scaling analysis (MDS) of the average abundance of polychaetes discriminated three groups of stations in agreement to the pre-defined groups: i) one at the mouth of the port, characterised by high environmental energy and the dominance of the polychaetes *Mediomastus* sp., Maldanidae and *Aglaophamus uruguayi*; ii) other in the inner harbor, with poor environmental conditions and inhabited only by *Capitella ´capitata´* sp., and iii) a third intermediate and more diverse group with *Polydora* spp., *Mediomastus* sp., *Capitella "capitata"* sp. and *Capitella* sp.[2] (Fig. 3, Table 2). Differences among groups were significant (global R: 0.807, p= 0.1%).

An analysis of variance with mean abundance, richness, diversity and evenness was carried out *a posteriori* in the groups, showing that outer and inner groups were characterised by low values of all

[2] *Capitella "capitata"* sp. has the first 7 toraxic setigers with capillaries setae in noto and neuropodium, as stated in the original description; but as the species is a complex of sibling species, is often use the notation of "*capitata*" sp. On the other hand, *Capitella* sp. has different pattern of capillaries and hooks in anterior setigers, being possibly a stage of development of the former.

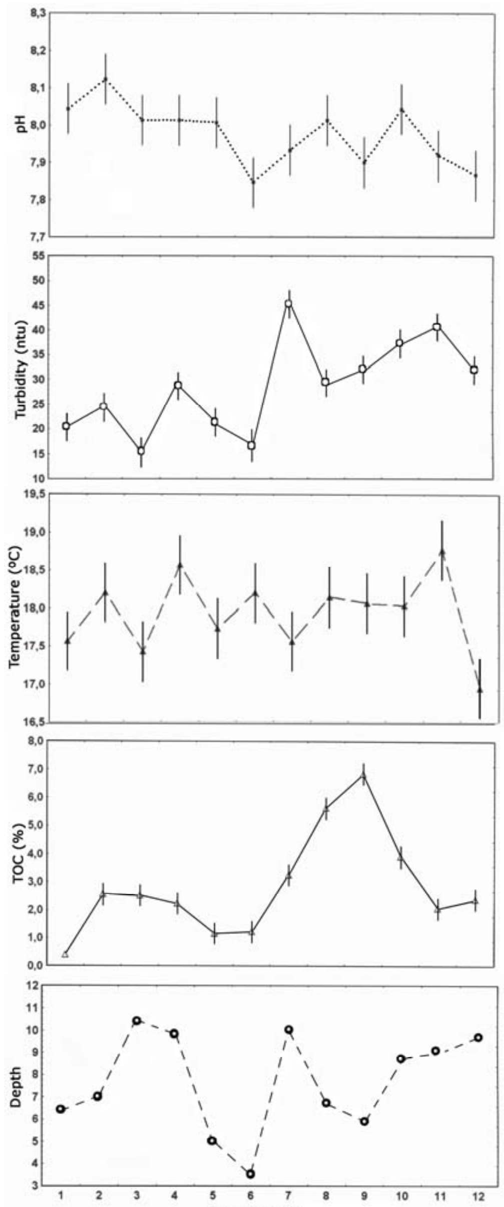

Figure 2

Environmental variables in the stations sampled in December 2001 in the Mar del Plata Harbor. Depth has no variance due to a single observation

Variables ambientales en las estaciones muestreadas en diciembre de 2001 en el puerto de Mar del Plata. La profundidad no tiene varianza debido a una sola observación

parameters, while middle stations showed the highest (Table 3). Differences were significant only for species number (S) and mean abundance (A). Post hoc comparisons showed that outer and inner regions were highly different ($P < 0.01$) from middle region, but not between them.

A first step in the species-environmental variables correlation is to perform a similarity matrix of the environmental variables, followed by a MDS plot (Fig. 4). Correlation between environmental variables and biological pattern showed little significance in the BIO-ENV procedure (the best correlation was temperature and pH, r = 0.38). However, the relationship between total organic carbon (TOC) and several species seems to have major significance that the BIO-ENV.

Table 1

List and mean dominance (%) of all macroinfaunal taxa in the Mar del Plata Harbor, Argentina

Listado y dominancia media (%) de todos los taxones macroinfaunales en el puerto de Mar del Plata, Argentina

Taxa	Dominance
Viscosia sp. (Nem)	37.05
Polydora spp. (Pol)	32.22
Capitella ´capitata´ sp. (Pol)	12.09
Capitella sp. (Pol)	10.10
Mediomastus sp. (Pol)	2.32
Tharyx sp. (Pol)	1.70
Corophium insidiosum (Cru)	0.94
Neanthes succinea (Pol)	0.73
Nemertina	0.33
Caulleriella alata? (Pol)	0.29
Parandalia tricuspis (Pol)	0.24
Aglaophamus uruguayi (Pol)	0.22
Jassa falcata (Cru)	0.22
Ninoe brasiliensis (Pol)	0.21
Cirratulus sp. (Pol)	0.18
Sigambra cf. *tentaculata* (Pol)	0.14
Maldanidae (Pol)	0.12
Schistomeringos rudolphi (Pol)	0.12
Lumbrineris tetraura (Pol)	0.10
Prionospio spp. (Pol)	0.10
Polynoidae (Pol)	0.06
Pitar rostratum (Mol)	0.06
Ammonia parkinsoniana (For)	0.06
Oligochaeta sp.1	0.06
Glycera americana (Pol)	0.05
Oligochaeta sp.2	0.05
Idothea baltica (Cru)	0.04
Nereididae (Pol)	0.04
Spionidae (Pol)	0.04
Syllidae (Pol)	0.03
Paraprionospio pinnata (Pol)	0.03
Oligochaeta sp.3	0.03
Cyrtograpsus angulata (Cru)	0.03
Ophiuroidea	0.02

Nem: Nematoda; Pol: Polychaeta; Mol: Mollusca; Cru: Crustacea; For: Foraminifera

Table 2

SIMPER analysis (analysis of similarities) in groups outlined by ANOSIM, showing the organisms which most contributed to the observed differences among groups

Análisis SIMPER (análisis de similaridades) en los grupos delimitados por el ANOSIM, mostrando los organismos que más contribuyeron a las diferencias observadas entre grupos

Species	Group Av. Abund.	Av. Abund.	Av. Diss.	Diss./SD	Contrib %	Cum. %
Av. Dissimilarity: 74.50	**Outer**	**Middle**				
Polydora spp.	0.22	108.00	26.35	1.37	35.37	35.37
Viscosia sp.	47.50	90.90	19.38	1.38	26.01	61.38
Capitella sp.	0.00	29.73	11.98	0.79	16.08	77.45
Capitella “capitata” sp.	0.28	24.13	9.05	1.12	12.15	89.60
Mediomastus sp.	7.67	3.07	2.24	1.25	3.01	92.61
Av. Dissimilarity: 91.06	**Outer**	**Inner**				
Viscosia sp.	47.50	7.75	44.84	1.43	49.24	49.24
Capitella “capitata” sp.	0.28	20.88	20.74	1.39	22.78	72.02
Mediomastus sp.	7.67	0.25	11.12	0.91	12.21	84.23
Capitella sp.	0.00	5.63	4.49	0.85	4.93	89.17
A. uruguayi	1.11	0.00	2.37	0.65	2.60	91.77
Av. Dissimilarity: 83.37	**Middle**	**Inner**				
Viscosia sp.	90.90	7.75	29.62	2.07	35.53	35.53
Polydora spp.	108.00	1.38	27.88	1.40	33.44	68.96
Capitella sp.	29.73	5.63	12.11	0.74	14.53	83.49
Capitella “capitata” sp.	24.13	20.88	8.23	1.10	9.87	93.36

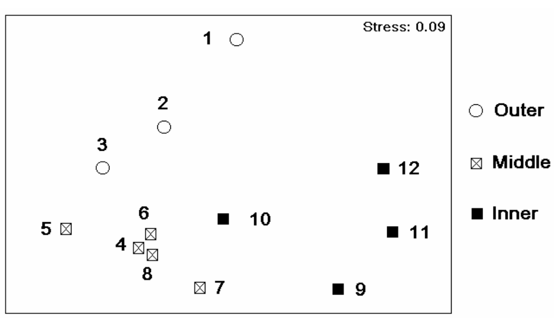

Figure 3

Multidimensional scaling of untransformed biological data (abundance of all macrobenthic infaunal species) from the Mar del Plata Harbor in December 2001

Análisis de escalamiento multidimensional sobre datos biológicos no transformados (abundancia de todas las especies macrobentónicas) del puerto de Mar del Plata en diciembre de 2001

Table 3

Mean richness (S), abundance (A), evenness (J´) and diversity (H´) of all macroinfaunal species in the three groups of stations

Riqueza media (S), abundancia (A), equitatividad (J´) y diversidad (H´) de toda la macroinfauna en los tres grupos de estaciones

Group	S	A	J´	H´ (log_2)
Mean outer	7.67	60.00	0.42	1.25
Mean middle	9.67	246.50	0.60	1.84
Mean inner	4.00	12.33	0.50	1.01

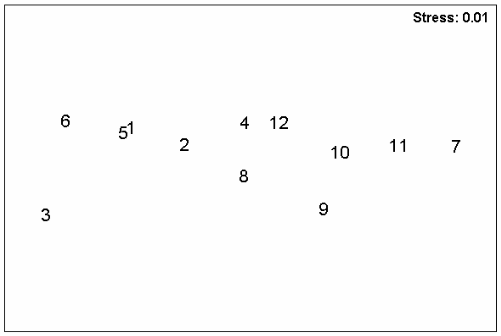

Figure 4

Muldimensional scaling (based on the euclydean distance matrix) of untransformed environmental data from the Mar del Plata Harbor in December 2001

Análisis de escalamiento multidimensional (basado en una matriz de distancias euclideas de datos ambientales no transformados del puerto de Mar del Plata en diciembre de 2001

In order to find a better representation of environmental and biological data, a redundancy analysis was performed to establish the relationship between these data and the sampling sites (Fig. 5), resulting in an appropriate representation (total variance explained was 90.57%). Axis 1 (63.08% of the variance) represents the environmental stress, grouping stations of the mouth of the harbor (1, 2 and 3) in the right-lower corner, and the stations of inner region (9, 10, 11 and 12) in the left. High values of pH (normal seawater values), as well as maldanid polychaetes, the nematode *Viscosia* sp. and *Aglaophamus uruguayi* are related to outer stations, while turbidity and total organic carbon (TOC) are related to inner stations, with *Capitella* sp. and *Capitella "capitata"* sp. Middle stations form a continuum from one to another group, reflecting intermediate environmental conditions. Must be noted that most infaunal species were removed by the redundancy analysis. Only the nematode *Viscosia* sp. and several polychaete species remained as characteristics of the three regions.

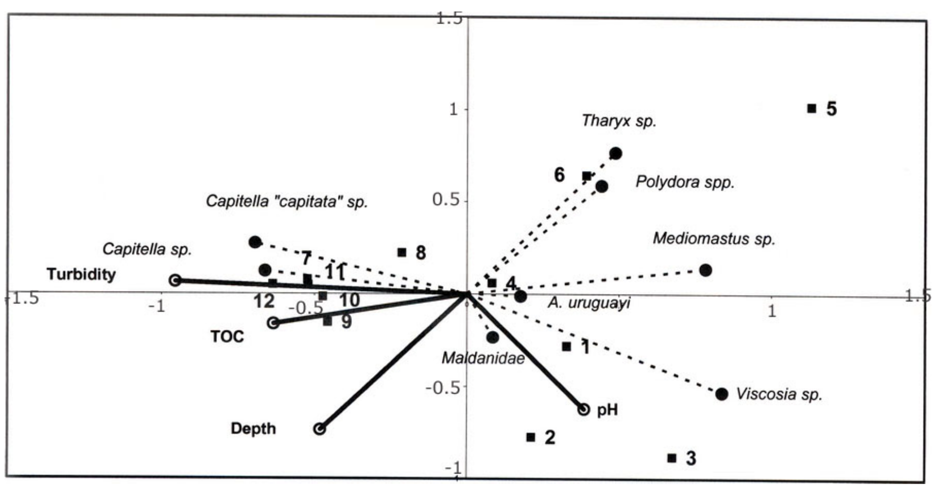

Figure 5

Redundancy analysis of environmental and biological data with sampling sites (stations) in the Mar del Plata Harbor

Análisis de redundancia de variables ambientales y biológicas con los sitios de muestreo (estaciones) en el puerto de Mar del Plata

Discussion

Analysis of environmental data with no parametric methods showed little correlation with the biological pattern. However, redundancy analysis showed a good representation of sampling sites, spatial pattern of polychaetes species and the gradient in environmental variables.

It is hypothesized that strong hydrodynamics affects the stations of the mouth, as shown by low organic content. During sieving, dominance of sandy sediments was evident in outer stations. Sandy sediments characterise the outer region (Bastida 1971). In the inner harbor poor environmental conditions are due to restricted water movement. The prevalence of flocculent sediments was also observed during sieving (black mud with strong odor of hydrocarbons) and high values of organic matter were measured. Inner docks have a high proportion of clay (almost 50%) and high levels of PAH´s (Dyopsa Dredging International 1999). The intermediate condition allowed for a higher species diversity and richness.

Although TOC increased from the mouth to inner harbor, this correlation was not observed in the BIO-ENV analysis, as well as with the other environmental variables, that did not correlate with polychaete abundance. Abundance of *Capitella* spp. was highly correlated to TOC (as shown by the RDA), but their abundance is reduced in the inner regions. Although the *Capitella* complex is considered a classical indicator of organic enrichment, this taxon also showed a high sensibility to toxic compounds (Reish & Gerlinger 1997). It is possible that high concentrations of hydrocarbons in the inner harbor (as shown by Dyopsa S.A. Dredging International 1999 results) explain the low abundance of this species as well as the absence of other benthic animals.

Connell (1978) proposed the intermediate disturbance hypothesis that predicts that the highest diversity will be at intermediate intensities of disturbance, or at both intermediate frequency and intensity of disturbance (Sousa 2001). Diversity as well as richness, total abundance and evenness shows the greatest values in intermediate stations of the Mar del Plata Harbor. Along the environmental gradient, outer stations are subject to high water dynamics, the inner stations present high pollution levels, and intermediate stations show an intermediate degree of stress of both hydrodynamics and pollution gradient. At intermediate stations and in the outer region, the most dominant species is the nematode *Viscosia*. Species of this genus are considered omnivores/carnivores (group 2B) (Kennedy 1994, Commito & Tita 2002), but other nematodes have been mentioned also as predators of the polychaetes *Capitella* (Dang & Sun 1997). In laboratory cultures it has been observed *Viscosia* sp. feeding on dead or dying *Capitella* (Rivero MS, pers. obs). It is possible that predation at intermediate disturbance levels plays also a role in structuring bottom communities in this harbor.

A priori grouping probed to be right, except for station 10. However, different behavior of this station could be explained by the major depth, heavy marine transportation and periodical dredging. This leads to a major circulation and lower levels of pollutants. Due to these factors, this station belongs to the middle group.

The redundancy analysis allows to reduce the number of biological and environmental variables, since they are correlated with each other. In our analysis all non polychaetes species were excluded, except the nematode *Viscosia* that characterises the outer not polluted region. In the outer region is also present an unidentified species of Maldanidae. These worms are present in sediments with low organic matter content of a great polluted harbor (Gallagher & Kay 1998). Other polychaete species present in the outer region are *Aglaophamus uruguayi* and *Mediomastus*. Areas highly polluted by organic matter are characterised by the classical indicator of organic pollution: the polychaete *Capitella* complex. At intermediate levels of organic enrichment, the polychaetes *Tharyx*, *Polydora* and the *Capitella* complex are dominant.

Our results agree with the analysis performed with the entire community (Rivero *et al*. 2003[3]), showing that polychaetes constitute a good tool for assessing a pollution gradient in this environment.

Acknowledgments

To the crew of the ARA Luisito, the school ship of the Escuela Nacional de Pesca. To the personal of Obras Sanitarias Sociedad de Estado (OSSE) who participated in sampling and laboratory analyses of environmental variables. Drs. Silvia I. Incorvaia (INIDEP) and Catalina Pastor (CENPAT) helped in identification of nematodes. This study was financed by the Laboratorio de Bioindicadores Bentónicos (Departamento de Ciencias Marinas, UNMdP). Three anonymous reviewers have improved the manuscript. This work was read in the VIII International Polychaete Conference. Madrid (Spain), 5-9 July, 2004.

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Recibido en agosto de 2004 y aceptado en agosto de 2005