

Using bioassays and benthic community to evaluate the sediment quality at the estuary of Itanhaém river, SP, Brazil

Uso de bioensaios e comunidade bentônica para avaliar a qualidade dos sedimentos no estuário do rio Itanhaém, SP, Brasil

La utilización de bioensayos y comunidad bentónica para evaluar la calidad de sedimentos del estuario del río Itanhaém, SP, Brasil

Robson Seriani*
Denis Moledo de Souza Abessa**
Priscilla Romano***

Fernanda Voietta Pinna****
Christiano Magini*****
Fabiana Lima Silveira***

ABSTRACT: This work aimed to assess the quality of sediments from the estuary of the Itanhaém River using whole sediment toxicity tests with the burrowing amphipod *Tiburonella viscana*; and the analysis of the benthic community. Results showed that the sediments are preponderantly sandy, with low or absence of toxicity to *T. viscana*. The benthic community was poor, composed mainly by opportunistic organisms, including capitellid polychaetes. Its structure was mainly controlled by the environmental variables, as sediment grain size and water properties, but some influence of the toxicity was also observed. The quality of the sediments from the estuary ranged from moderate to good.

KEYWORDS: Estuaries. Geologic sediments. Toxicity tests.

RESUMO: Esta investigação teve como objetivo avaliar a qualidade de sedimentos do estuário do Rio Itanhaém, utilizando teste de toxicidade de sedimento integral com anfípodo escavador *Tiburonella viscana* e análise da comunidade bentônica. Os resultados mostraram que os sedimentos são principalmente arenosos, com baixa ou nenhuma toxicidade sobre *T. viscana*. A comunidade bentônica foi composta principalmente por organismos oportunistas, incluindo poliquetos capitélídeos, tendo sido considerada pobre. Sua estrutura foi controlada principalmente pelas variáveis ambientais, como a granulometria e as propriedades físico-químicas da água, porém uma leve participação da toxicidade pôde ser detectada. A qualidade dos sedimentos do estuário variou entre moderada e boa.

PALAVRAS-CHAVE: Estuários. Sedimentos geológicos. Testes de toxicidade.

RESUMEN: Este trabajo pretendió evaluar la calidad de sedimentos del estuario del Río Itanhaém usando pruebas de toxicidad de sedimento integral con anfípodo escavador *Tiburonella viscana* y el análisis de la comunidad bentónica. Los resultados mostraron que los sedimentos son preponderantemente arenosos, con baja o ninguna toxicidad para *T. viscana*. La comunidad béntica era pobre, formada principalmente por organismos oportunistas, incluso poliquetos capitélídeos. Su estructura fue controlada principalmente por las variables ambientales, como lo son el tamaño de los granos de sedimento y propiedades del agua, pero un poco de influencia de la toxicidad también fue observado. La calidad de los sedimentos del estuario varió de moderado a bueno.

PALABRAS LLAVE: Estuários. Sedimentos geológicos. Pruebas de toxicidad.

Introduction

The coastal ecosystems, particularly the estuaries, present high ecological and economic importance, offering products and services to

the humans. However, due to their geographic characteristics, estuaries have been occupied by urban structures, industrial facilities, ports and harbors, among others. In Brazil, such occupation has been made

disorderedly, resulting in degradation to the estuarine and associated ecosystems.

According to Clark (1997), the discharge of pollutants into the coastal waters is directly related to

* Graduado em Ciências Biológicas. Especialista em Engenharia de Controle da Poluição pela Faculdade de Saúde Pública da USP e Pesquisador colaborador da Universidade Estadual Paulista – UNESP – Campus do Litoral Paulista. E-mail: robsonseriani@yahoo.com.br

** Biólogo. Mestre e Doutor em Oceanografia pelo Instituto Oceanográfico da USP. Professor da UNESP – Campus do Litoral Paulista.

*** Graduada em Ciências Biológicas.

**** Graduada em Ciências Biológicas. Especialista em Saúde Ambiental pela Faculdade de Saúde Pública da USP.

***** Geólogo. Mestre e Doutor em Geologia Regional da Unesp. Professor da Universidade Federal do Ceará.

the land occupation. Once in the aquatic environment, the chemicals tend to sink to the bottom, accumulating in the sediments, where they can be transformed by a variety of physical, chemical and biological processes, which can make them to be released back to the water column. Thus, sediments can be not only a reservoir but also a source of contamination to the aquatic biota (Burton, 1992).

The biological effects of pollutants are diverse, and may vary from biochemical and genetic disturbance to ecological unbalance (Reish, 1986). Besides, the damage of aquatic populations can threaten the economic exploration of biological resources, bringing negative effects to the economy and the human health.

The environmental quality can be evaluated by different approaches, as by chemical as by biological perspectives. Toxicity tests and analyses of the structure of biological communities are used to evaluate the environmental quality, once they are inexpensive and show the effects of the whole complex mixture of contaminants to the organisms (Chapman, Long, 1983; Bilyard, 1987).

The Itanhaém River is located on the central shore of the State of São Paulo, Brazil (23°50'-24°15'S, 46°35'00"W) and presents high social, economic and ecological importance. Its hydrographic basin is considered the second larger coastal basin in the State of São Paulo (Sant'Anna, 1999). The Itanhaém River is surrounded by wide mangroves, supporting regional fishing and tourist activities and providing shelter and food for aquatic and terrestrial species (Souza-Pereira, Camargo, 2004).

The lower portion of Itanhaém River and its estuary are influenced by anthropogenic activities, especially the discharge of untreated

sewage from the Itanhaém City urban area (Pereira, 2002). The presence of irregular dumping sites of urban residues in the vicinities constitutes other contamination sources. Chronic sediment toxicity and bioaccumulation of Arsenic (As) in tissues of crabs were already found in Itanhaém river (Carmo et al, 2004). Recently, toxicity in sediments from two sites of this river (Seriani, Silveira, 2005; Seriani, et al, 2006) was observed. Other studies have also correlated the pollution to physical-chemical alterations in the water (Abessa et al, 2006; Camargo, et al, 1996) and in the biological communities (Choueri, 2000).

The objective of this study was to evaluate the environmental quality of the estuary of the Itanhaém River, by using 10-day whole sediment toxicity tests with the burrowing amphipod *Tiburonella viscana* and analyses of the benthic community structure.

Materials and methods

The sediments samples were collected with a "Van Veen" grab sampler at six stations situated in the estuary of the Itanhaém River (Figure 1). The samples for physical and ecotoxicological analyses were immediately cooled. In laboratory, the aliquots for the toxicity tests were refrigerated, whereas those for physical-chemical analyses were frozen.

Independent samples were taken for the benthos and sieved by a 0.5 mm mesh. The retained organisms were identified under microscope till the minimum possible level according Amaral et al, (2006). The dataset was used to calculate the Specific Richness (S); Total Organisms Density; Shannon-Wiever Diversity (H'); Simpson Dominance (J); and Polychaetes Dominance according Abessa (2002), Abel

(1989) apud Seriani et al (2005). Water column samples were collected for the analysis of physical chemical parameters (APHA, 2005). The water temperature was measured by a digital thermometer; the pH was determined by a digital pHmeter; and the salinity was obtained by the use of a hand refractometer. The total ammonia concentration (NH₃-NH₄) was measured by colorimetric method (Koroleff, 1970).

The sediment grain size distribution was measured by the dry sieving method (Suguio, 1973). The calcium carbonate content was analyzed by the difference of weights, before and after digestion in 10% HCl (Gross, 1971). The Organic Matter (OM) content was estimated by weight difference before and after incineration at 600°C for 90 minutes.

The 10-day whole sediment toxicity test was conducted following the method described by Melo, Abessa (2002) for *Tiburonella viscana*. The test-organisms and the control sediment were collected at Engenho d'Água Beach, in Ilha Bela Island.

The environmental, physical-chemical, ecotoxicological and ecological data were integrated by several methods. Multiple Pearson correlations were calculated for the ecological indices X variable ecotoxicological data and sediment characteristics. Variables for which correlation coefficients (r) were above 0.4, when p<0.05, were considered significantly correlated. Another method used to relate the biotic and abiotic data was the Canonic Ordination Analysis, coupled with the Monte Carlo test (Abessa, 2002).

Results

The sediments from the estuary were composed mainly by fine san-

Table I. Sediment properties from the estuary of the Itanhaém River (grain size distribution, organic matter (OM) and calcium carbonate – CaCO₃)

	Sediment grain size retained by the different diameter of sieves (%)							OM (%)	CaCO ₃ (%)
	> 1.7 mm	600 µm	425 µm	300 µm	150 µm	75 µm	< 75 µm		
St 1	1.40	0.20	0.10	1.80	17.40	74.10	5.00	2.6	6.0
St 2	0.00	0.00	0.00	0.90	2.80	96.30	0.00	2.4	7.0
St 3	4.06	1.20	3.50	21.60	58.90	10.70	0.04	1.6	1.9
St 4	0.00	0.00	0.20	1.10	11.90	86.50	0.30	9.2	5.7
St 5	0.00	0.00	0.20	1.00	22.10	76.50	0.20	6.0	3.3
St 6	0.06	0.00	0.10	1.32	16.35	81.75	0.42	14.2	4.3
Control	0.00	0.10	4.60	16.40	44.00	33.00	1.90	4.8	3.5

ds (Table I), excepting those from the Station 2, which were predominantly muddy. The calcium carbonate (CaCO₃) contents in the samples ranged between 1.9 and 7.0 %, with higher values occurring in the sediments from stations 1 and 2. The organic matter con-

tents ranged from 1.6 to 14.2%. High values were observed in the samples from stations 4 and 6.

The water physical-chemical parameters are shown in the Table II. Salinities ranged between 0 and 2 ‰, with higher values observed in the mouth of the estuary. The

low values demonstrated the high fluvial influence, which was due to the high summer precipitation rates. Temperatures of the waters ranged from 22 to 25°C, whereas the pH ranged between 5.46 and 6.70. The total ammonia contents were low in the most of stations,

Table II. Physical-chemical characteristics of the water column in the estuary of Itanhaém River, SP, Brazil (during the dropping tide)

Sampling Station	Temperature (°C)	pH	Salinity (‰)	NH ₄ -NH ₃ (ppm)
St 1	23.5	6.06	0.0	0.25
St 2	22.0	5.46	0.0	0.25
St 3	23.0	5.53	0.0	0.25
St 4	25.0	6.70	0.0	1.50
St 5	23.0	5.96	0.5	0.25
St 6	22.0	5.97	2.0	0.25

Table III. Number of macrofaunal organisms collected in the estuary of Itanhaém River, in the Summer 2005

Taxonomic group	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Tanaidacea (<i>Kalliapseudes.schübarti</i>)	42	0	0	0	0	0
Chaetopteridae	5	0	0	1	0	0
Goniadidae (<i>Ophioglycera</i> sp.)	2	0	0	1	0	0
Gastropoda (<i>Anachis.obesa</i>)	1	1	0	0	0	0
Orbinidae sp1	0	4	0	0	0	1
Paraonidae sp1	0	1	0	0	0	0
Capitelidae sp 1	6	31	0	0	0	0
Capitelidae sp 2	2	2	0	0	0	0
Capitelidae	7	0	0	0	0	0
Decapoda	0	0	0	1	0	0

Table IV. Ecological indices calculated for each sampling station

Station	Specific Richness	Shannon Diversity (H')	Simpson Dominance	Polychaetes Density (%)	Density (orgs*m ⁻¹)
St 1	7	1.21	0.37	33.84	2500
St 2	5	0.75	0.53	97.43	1500
St 3	0	NC	NC	0	0
St 4	3	1.09	0.00	66.67	115.38
St 5	0	NC	NC	0	0
St 6	1	NC	1.00	100	38.46

NC = Not calculable.

with a higher concentration in the water from the station 4.

In the bioassay, no significant toxicity was observed (Figure 2). High survival variability between replicates occurred for some samples. Some authors interpret this as a possible signal of effects (Seriani, Silveira, 2005); but for the present investigation this hypothesis could not be confirmed. However, chro-

nic toxicity was previously detected in this estuary (Carmo et al, 2004), showing that this statement may be possible, thus, further studied are required.

The results of benthic community structure are summarized in the Tables III and IV. The benthos was poor, and only ten taxonomic groups were identified, comprising 1 tanaid species (*Kalliapseudes schü-*

bartii), 1 gastropod species (*Anachis obesa*), 1 unidentified larvae of decapod and 7 different polychaetes (Table III). Capitellids were found in stations 1 and 2. No benthic organism was collected in the stations 3 and 5, thus, not all the ecological indices were calculated for these stations.

The results of the multiple correlation analyses are shown at the

Table V. Correlation coefficients (r) between the ecological indices and the abiotic and ecotoxicological data, for the estuary of Itanhaém River (p = 0.05)

Variable	Specific Richness	Shannon-Diversity	Simpson Dominance	Polychaetes Density (%)	Total Density (orgs*m ⁻¹)
<i>T. viscana</i> survival				0.72	
Temperature (°C)		0.55	-0.71		
pH		0.46	-0.64		
CaCO ₃ (%)	0.85	0.80	-0.73	0.69	0.68
Organic Matter (%)				0.51	-0.51
Gravel (%)	-0.44	-0.41		-0.60	
Gross sand (%)				-0.57	
Medium sand (%)	-0.44	-0.42	0.40	-0.54	
Mud (%)	0.44			0.51	0.42

Table V. Some correlations were observed between abiotic and biotic variables; they will be further explored in the Discussion section of this paper.

The result of the canonic ordination analysis is summarized in the Fig 3. The first two axes explained about 89.12% of variances. The

following taxonomic groups showed correlation with the 1st Axis (p = 0.05): *K. schubartii* (-0.401); *Anachis obesa* (-0.412); Capitellidae sp2 (-0.412) and Capitellidae (-0.401). The taxa Orbinidae (0.482); Paronidae (0.475) and *Capitella capitata* (0.442) presented correlation with the 2nd Axis. None of the groups

showed correlation to the two Axes, whereas Goniadidae, Chaetopteridae and Decapoda did not correlate to any axis. Among the abiotic variables, the CaCO₃ and OM contents correlated to the 1st Axis (-0.637 and 0.482, respectively), whereas amphipod survival (0.583), mud (0.935) and fine- very fine sands

contents (-0.918), water temperature and pH (-0.640 and 0.642, respectively) correlated to the 2nd Axis.

The ordination analyses showed the formation of a group containing the stations 3, 4, 5 and 6, with weak relation to the 1st axis (Figure 3). The station 4 presented weak correlation to the 2nd axis as well. The station 1 was strongly correlated to the 1st axis and weakly to the 2nd axis, whereas the station 2 presented strong correlation to the 2nd axis and weak to the first one.

Discussion

The tanaid *Kalliapseudes schübartii* occurred only at Station 1, where it was the predominant species. The sediment of this station was composed by fine sands, with muds and high percent of CaCO₃. Such peracarid crustacean seems to have preference for this kind of substrate, as previously reported for Lagoa dos Patos, Southern Brazil (Capitoli et al, 1978). Besides, *K. schübartii* was dominant in the estuary of Cubatão River, a polluted site, being considered a pollution-tolerant species (Nipper et al, 1990). Together with *K. schübartii*, capitolid polychaetes were present in relatively high densities. According to Lana et al (1989), the association of *K. schübartii* and capitolid polychaetes occurs in estuaries from the S-SE coast of Brazil, especially when there is deposition of fines and OM. Moreover, this species was previously found at the Itanhaém River, in organically rich sediments (Choueri, 2000).

The Station 2 was located approximately at 1 km distance from the Station 1, receiving the discharges of a sewage pipe. The sediments were composed by fine sands and high CaCO₃ contents. In spite of the relatively high amphipod survival in the toxicity test

(70%), the benthic assemblage showed characteristics of impacted environment, with high incidence of bioindicators of organic pollution, especially capitelids (Pearson, Rosenberg, 1978).

The sediments of the Stations 3 and 5 showed no fauna. This could be due to their sandy composition and the action of tidal currents, which cause physical instability. Abessa (2002) related the absence of fauna in the São Vicente estuary to these factors, in areas without toxicity or contamination. In spite of it, in these two stations, the survival of *T. viscana* in the bioassay was relatively low (65 and 53%, respectively). Once chronic toxicity was already reported for sediments from this estuary, the results observed here may be reflecting not only the physical instability, but also some long-term effects, not measured in this study.

In the Station 4, the benthic fauna was represented by few organisms. The concentration of total ammonia in the water column was considered relatively high (1.5 mg L⁻¹), and the organic matter contents in the sediment was high. Carmo et al (2004) reported the discharge of sewage close to this station, and the results obtained in the present study can be reflecting the influence of such discharge on the benthic community. The Station 6 was located in the mouth of the estuary, receiving thus more marine influence. Its diversity was extremely low and the macrofauna was composed only by orbinid polychaetes.

The Shannon Diversity (H') showed positive correlation with the water temperature and pH, whereas the dominance correlated negatively to both variables. The survival of *T. viscana* correlated positively to the mud contents and negatively to the fine and very fine sands contents. This parameter also

showed positive correlation with the polychaetes density, probably due to the sediment physical properties. Biotic integrity seemed to respond positively to the increase in the sediment grain size, whereas the polychaetes density showed an opposite behavior (Table V). The correlations showed that water properties and sediment grain size are influencing directly the benthic macrofauna.

In order to understand indirect relationships between biotic and abiotic data, multivariate analysis was applied (Figure 3). The results also indicated the influence of sediment and water properties and indirect effects of contamination (i.e., the toxicity) on the benthic community structure.

Gray (1974) refers to the sediment properties as the main factors responsible for the structure of benthic communities, and that the grain size composition is a major importance factor, because it influences the porosity, permeability, presence of organic compounds, and dissolved oxygen levels. In this investigation, the correlations between the ecological indices and the different sediment fractions, CaCO₃ and OM contents are in agree to such findings, and suggested that fine and CaCO₃ rich sediments tend to be more diverse and present more species. This finding is corroborated by the fact that *K. schubartii*, Capitellidae, Capitellidae sp2, and *A. obesa* have been influenced by the CaCO₃ and OM contents, whereas Paraonidae, *C. capitata* and Orbinidae were influenced by toxicity, mud content and related negatively to the water temperature and pH.

Read et al (1978) suggested that sediments with high levels of mud tend to be more diverse, allowing the heterogeneity of the habitats. However, due their electric charges or molecular affinity, the contami-

nants can be adsorbed to the mud particles or to OM, being transferred to the benthic organisms. Similar phenomena was already described for this estuary (Carmo et al, 2004), with higher levels of Arsenic in tissues of crabs occurring in the areas where the OM contents in sediments were higher. In this study, the relationships between the ecotoxicological and ecological data were not very clear, either suggesting absence of impacts or slight disturbances, as dominance of *C. capitata* and low biological diversity. According to Nipper et al (1998), when sediments present moderate levels of contamination the results

can be highly variable. Thus, their interpretation must consider the interference factors, especially in estuaries, where the environmental characteristics are variable and unpredictable (Kennish, 1990).

The benthic community structure of the Itanhaém River estuary was similar to that observed for the São Vicente Estuary (Abessa, 2002), a low to mildly contaminated area. In both estuaries, the benthos was composed by few organisms, normally opportunistic ones, inhabiting sandy substrates, with some stations showing absence of animals. Such communities are greatly influenced by the physi-

cal properties of sediments and water, but some influence of toxicity was also observed. Despite the quality of the sediments can be considered as ranging from moderate to good, sewage discharges represent a threat to Itanhaém River estuary, once they may cause eutrophication, red tides and introduction of pathologic organisms. Recently, this estuary was found to be a shark nursery and feeding area (Gadig et al, 2001), highlighting its economic and ecological importance. The presence of contamination sources shows the need of continuing studies at this site, aiming to preserve its biological resources.

Figure 1. Estuary of the Itanhaém River, showing the sampling stations

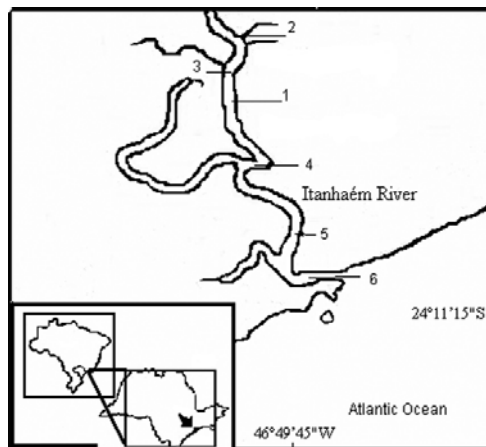


Figure 2. Results of the whole sediment toxicity tests with *T. viscana*

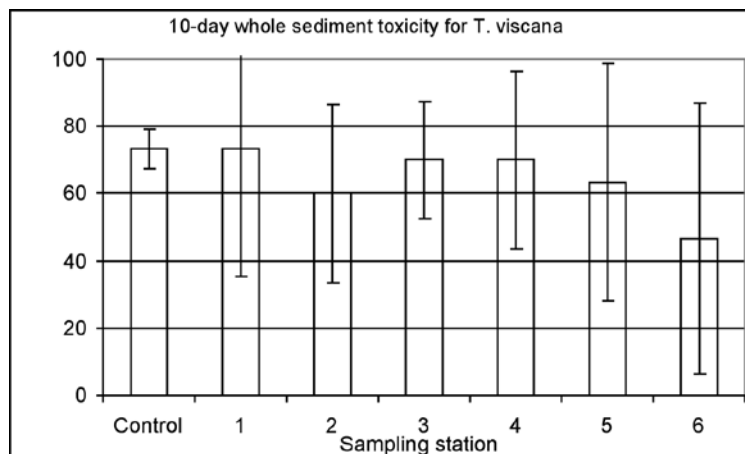
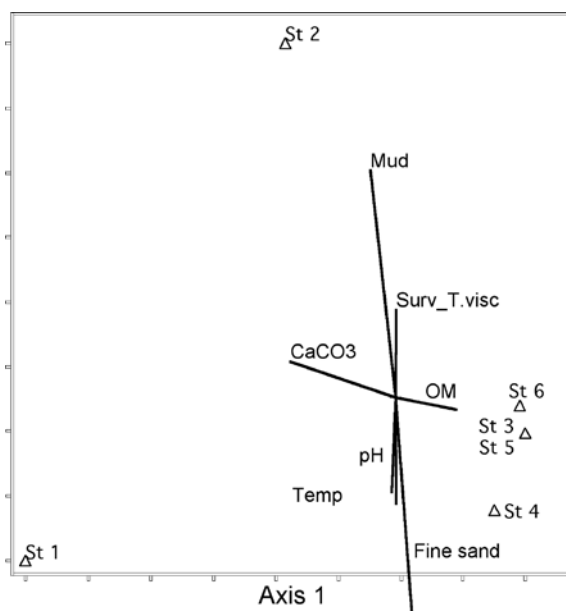


Figure 3. Spacial distribution of stations and variables, reduced to two dimensions, from the canonic ordination analysis, using the abiotic and biotic matrices



REFERENCES

- Abessa DMS. Avaliação da qualidade de sedimentos do Sistema Estuarino de Santos, SP, Brasil [tese]. São Paulo: Instituto Oceanográfico da Universidade de São Paulo; 2002. 295p.
- Abessa DMS, Pinna FV, Romano P, Seriani R, Silveira LM, Magini C. Water Quality at the estuary of the Itanhaém river, SP, Brazil. [CD ROM]. In: Proceedings of Environmental and Health World Congress; 2006; Santos, SP, Brasil. p. 42-5.
- Amaral CZ, Rizzo AE, Arruda EP. Manual de identificação dos invertebrados marinhos da região sudeste-sul do Brasil. São Paulo-SP 2006;(3):89-91.
- American Public Health Association (APHA), American Water Works Association (AWWA), Water Pollution control Federation (WPCF). Standard methods for the examination of water and wastewater. 21th ed. Washington, DC.: 2005.
- Bilyard GR. The value of benthic infauna in marine pollution monitoring studies. *Mar Poll Bull.* 1987;18(11):581-3.
- Burton GA. Assessing contaminated aquatic sediments. *Environ Sci Technol.* 1992;26(10):1862-75.
- Camargo AFM, Ferreira RAR, Schiavetti A, Bini LM. Influence of physiography and human activity on limnological characteristics of lotic ecosystems of the South coast of São Paulo, Brazil. *Acta Limnol Bras* 1996;8:231-43.
- Capitoli RR, Bemvenuti CE, Gianuca NM. 1996, Estudos de ecologia bentônica na região estuarina da Lagoa dos Patos. I - As comunidades bentônicas. *Atlântica*, 3. p. 5-22.
- Carmo CV, Martins LMP, Abessa DMS, Crespo MLL. Contaminação química, toxicidade de sedimentos hídricos e acúmulo de metais em caranguejos de manguezais de Itanhaém. *Mundo Saúde* 2004;28(4):450-5.
- Chapman PM, Long ER. The use of bioassays as part of a comprehensive approach to marine pollution assessment. *Mar Poll Bull.* 1983;14(3):81-4.
- Choueri RB. Níveis de poluição orgânica em três pontos da bacia do rio Itanhaém (litoral sul paulista) [monografia]. Rio Claro, SP: Instituto de Biociências, Universidade Estadual Paulista Júlio de Mesquita Filho; 2000. 29p.
- Clark RB. *Marine Pollution*. New York: Oxford University; 1997. 161p.
- Gadig OBF, Motta FS, Namora RC. Projeto Cação: a study of sharks caught by artisanal fisheries in Sao Paulo, Southern Brazil. *Shark News* 2001;14:11-11.
- Gray JS. Animal sediment relationships. *Oceanogr Mar Biol Ann Rev.* 1974;12:223-61.

- Gross MG. Carbon determination. In: Carver RE, editor. Procedures in sedimentary petrology. New York: Wiley-Interscience; (197?). p. 573-96.
- Kennish, MJ. Ecology of estuaries aspects. Boca Raton: CRC; 1990.
- Koroleff, F. Direct determination of ammonia in natural waters as indophenol blue. Cons int Explor Mer, 1970. Information on techniques and methods for sea water analysis, 3.
- Lana PC, Almeida MVO, Freitas CAF, Couto ECG, Conti LMP, Gonzalez-Pernti AL, Silva MHC, Pedroso LA. Estrutura espacial de associações macrobênticas sublitorais da gamboa do Perequê. Nerítica 1978;4(1/2):19-136.
- Melo SLR, Abessa DMS. Testes de toxicidade com sedimentos marinhos utilizando anfípodos como organismo-teste. In: Nascimento IA, Sousa ECPM, Nipper MG, editors. Ecotoxicologia marinha: aplicações no Brasil. Salvador: Artes Gráficas; 2002. p. 163-77.
- Nipper MG. Problemas de poluição em organismos. In: Anais do 2º Simpósio de Ecossistemas da Costa Sul e Sudeste Brasileira. Águas de Lindóia: ACIESP; 1990. v. 3, p. 24-42.
- Nipper MG, Roper DS, Williams EK, Martin ML. Sediment toxicity and benthic communities in mildly contaminated mudflats. Environ Toxicol Chem. 1998;17:502-10.
- Pearson TH, Rosenberg R. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanogr Mar Biol Ann Rev. 1978;16:229-311.
- Pereira, LA. 2002, Análise ambiental da bacia do Rio Itanhaém baseada na relação entre os aspectos limnológicos com fisiografia, uso da terra e sistema hidrológico – SP [tese]. Rio Claro, SP: Instituto de Geociências e Ciências Exatas, Universidade Estadual Paulista Júlio de Mesquita Filho. 78p.
- Read PA, Reshaw T, Anderson KJ. Pollution effects on intertidal macrobenthic communities. J Appl Ecol. 1978;15(1):15-31.
- Reish DJ. Benthic invertebrates as indicators of marine pollution: 35 years of study. In: IEE Oceans '86 Conference Proceedings. Washington, DC., 1986. p. 885-8.
- Seriani, R, Silveira, FL. Toxicidade de sedimento e estrutura da comunidade bentônica no diagnóstico da qualidade ambiental do estuário do Rio Itanhaém-SP, Brasil [trabalho de conclusão de curso]. São Paulo: Centro Universitário São Camilo; 2005. 58p.
- Seriani R, Silveira FL, Pinna FV, Romano P, Abessa DMS. Toxicidade de água e sedimentos e estrutura da comunidade bentônica do estuário do Rio Itanhaém, SP, Brasil: bases para a educação ambiental. Mundo Saúde 2006;30:628-33.
- Souza-Pereira PE, Camargo AM. Efeito da salinidade e do esgoto orgânico sobre a comunidade zooplânctônica, com ênfase nos copépodos, do estuário do rio Itanhaém, Estado de São Paulo. Acta Scientiarum Biol Sci. 2004;26(1):9-17.
- Suguio K. Introdução à sedimentologia. São Paulo: Edgar Blücher; 1973. 317p.
-

Recebido em 5 de abril de 2008
Versão atualizada em 14 de maio de 2008
Aprovado em 27 de junho de 2008