



Soft-bottom polychaetes from the Brazilian harbors of Mucuripe and Pecém (state of Ceará) and Santos (state of São Paulo)

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Abstract: The analysis of polychaete fauna from 20 soft-bottom samples collected in different shallow sectors of Mucuripe, Pecém and Santos harbors provided a list of 34 different taxa, totaling 366 individuals. A comparison with recent published data revealed the first occurrence of two polychaete genera and 10 species in Ceará state. Distribution by station, depth and type of sediment was also provided. Despite the considerable knowledge of polychaete fauna from the coast of Brazil especially in the southeastern region, little attention has been given to the harbor areas, which are under influence of anthropogenic impacts. This study represents an important inventory of polychaete fauna found in three harbors from the northeastern (Mucuripe and Pecém, State of Ceará) and southeastern (Santos, state of São Paulo) regions of Brazilian coast.

Keywords: Annelida, benthos, biodiversity, macroinfauna, tropical environments

INTRODUCTION

Polychaetes are known as the main characteristic group of soft-bottom macrofauna. They present a large variety of strategies and feeding types, occupying different levels of the marine food web (Fauchald and Jumars 1979), a significant contribution to the secondary production of benthic environments, and serve as important food source for many demersal fishes and invertebrates (Amaral et al. 1994; Petti et al. 1996). Some species of polychaetes can rapidly colonize stressed environments by either natural or anthropogenic factors; their short life cycle, high fertility and reduced body size allow them to occupy new habitats (Ugland et al. 2008; Dauvin and Ruellet 2009), constituting important health indicators of marine and estuarine areas.

The port activities have been reported to induce several negative environmental impacts and stress on marine ecosystems, including the discharges of contaminants, introduction of exotic species through ballast water, and dredging, which promotes the sediment removal and defaunation (NRC 1997). Thus, besides of changing the way that natural variables influence benthic species, these activities may represent a relevant factor to the distribution of benthic species.

Brazilian coast has 34 seaports and some studies have demonstrated degradation of sediment quality associated to port areas, with negative effects on benthic fauna (Bemvenuti et al. 2005; Abessa et al. 2008; Choueri et al. 2009). Most investigations focused on ecotoxicological aspects of sediment contamination and their effects on soft-bottom communities, and thus, the record of the species has been poorly explored. Therefore, it is important to give more attention to the specific composition of different groups of benthic communities, such as polychaeta, and their susceptibility to environmental hazards.

In order to provide taxonomic information of soft-bottom communities in port areas of Brazil, which can assist risk assessments and ecological studies, this article aimed to inventory the polychaete fauna found in three harbors from the Brazilian coast: Mucuripe and Pecém, both located in the state of Ceará (northeast) and Santos, located in the state of São Paulo (southeast).

MATERIAL AND METHODS

Study site

The climate in Ceará coast is marked by a tropical wet with predominance of trade winds in an east to west direction, which determines the sediment transport direction (Jimenez et al. 1999; Nogueira et al. 2005). Regarding the sedimentary aspects, the coast of Ceará

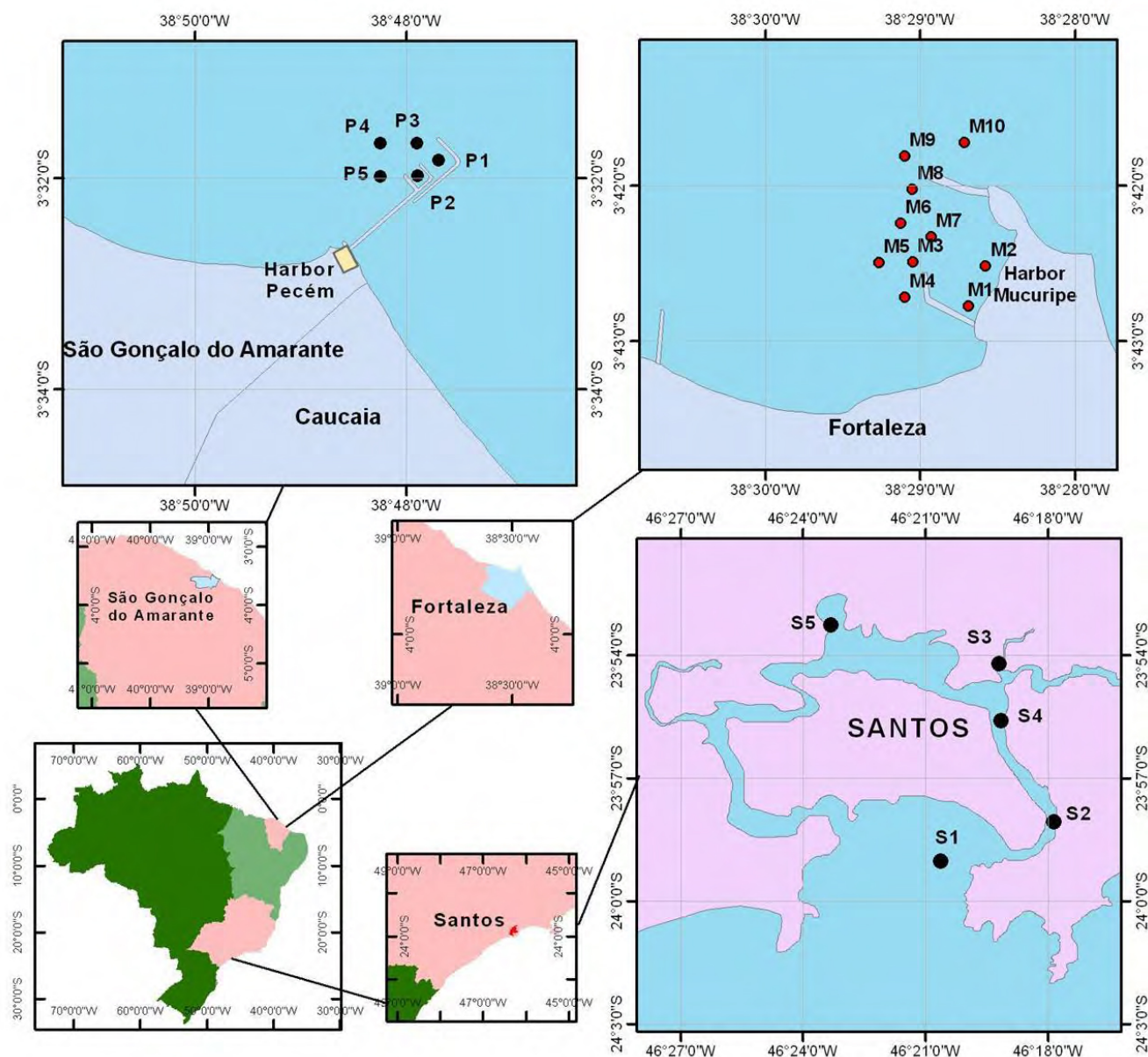


Figure 1. Sites of sediment sampling in Mucuripe, Pecém and Santos harbors.

shows two distinctive compositions: organogenic and terrigenous facies. The first consists of organogenic substrates derived from calcareous algae, contributing with about 75–95% of calcium carbonate deposition (CaCO_3), with high contents of organic matter (OM). The outer shelf sediments are covered by gravel, while the sediments from the inner shelf are predominantly composed of sand with biotrititic gravels and low amounts of mud. Siliclastic material, heavy minerals and clay characterize sediments from terrigenous facies (Freire et al. 2004).

Mucuripe harbor is located within Mucuripe Bay, a coastal portion of Fortaleza City, capital of Ceará state, and its area comprises the access channel, anchorage areas and evolution basins protected by a long jetty (1,900 m). By its turn, Pecém Port Terminal is located in municipal district of São Gonçalo do Amarante, about

60 km west from capital, and is an offshore terminal, constructed 2,000m away from shoreline.

The Port of Santos is located within the Santos Estuarine System (SES) and is the major port of Latin America. Port activities and the Cubatão industrial complex, through effluent discharges, are the largest known sources of contaminants to SES; in addition, the Port of Santos is going through an expansion, which comprises construction of new terminal areas and dredging to deepen the navigational channel (Torres et al. 2009). The climate in SES can be classified as wet tropical with rainfall levels ranging from 2,000–4,500 mm per year, with high variation from year to year and the regime of winds is dominated by the situation of Doldrums, with eventual winds from southeast, south and east (Moser et al. 2005; Siqueira et al. 2006). Sedimentation results from influence of continental

and marine hydrodynamic processes. The first is given by freshwater drainage and erosion through the rivers that crosses the region, and it is characterized by inputs of terrigenous material; the marine process is controlled by tidal currents and continental shelf erosion. Particle size of sediment deposits ranges gradually from silt to fine sands, and the presence of mangroves have a role of retaining sedimentary material (Fukumoto et al. 2006).

Data collection

Data presented are result of the sampling campaigns within the project “Ecological Risk Assessment in harbors of Ceará” supported by Foundation for Research Support of Ceará State (FUNCAP) and Brazilian National Research Council (CNPQ). In Mucuripe, sediment sampling was carried out in August 2007 in 10 stations: M1 to M5 were located close to commercial docks and tanker piers; M6 and M7 were situated at the access channel and M8, M9 and M10 were positioned in unsheltered areas. In Pecém, the campaign was carried out in January 2008 in 5 stations: P1 and P2 close to the docking piers; P3 and P4 at the access channel; and P5, in unsheltered area. In Santos, the sediment was sampled in November 2007, in five stations: S1, positioned at the Santos Channel mouth; S2, in front of the Containers’ Terminal; S3, at Diana Island; S4, situated in front of Alemoa Terminal and S5, at the Piaçaguera channel near privative terminals of fertilizers and steel industries (Figure 1).

Stations were positioned with GPS (Global Positioning System) and the depth of each station was recorded. Samples of sediment were collected using a vanVeen grab (0.026 m²). Grain size distribution was measured by a wet sieving in 0.063 mm mesh followed by dry sieving of sediments and then data were classified according to Folk and Ward (1957). Levels of CaCO₃ were obtained by HCl digestion and gravimetric method (Gross 1971), and OM content by adapting the method of combustion and gravimetry (Luczak et al. 1997). Biological samples were obtained from a composite sample of 3 replicates (0.078 m²). The sediment was carefully washed and sieved through a 0.5 mm mesh and the retained material was preserved in 70% ethanol. In laboratory, the species were sorted, identified, quantified and checked for the taxonomic status using the WoRMS database (WoRMS Editorial Board 2014). The polychaetes were deposited at the “Biological Collection Prof. Edmundo F. Nonato” (ColBio) of Oceanographic Institute of the University of São Paulo (IO-USP).

RESULTS

Sediment samples from Mucuripe and Pecém were classified, according Folk and Ward (1957), as sandy (fine and very fine), except for M9 and M10, which were classified as medium and coarse sand, respectively (Table

Table 1. Location and sediment characteristics of sampling stations in Mucuripe, Pecém and Santos harbors. CS= coarse sand; MS= medium sand; FS= fine sand; VFS=very fine sand; SC= coarse silt.

Station	Geographic coordinates		Depth (m)	CaCO ₃ (%)	OM (%)	m.d. (phi)	Type
	S	W					
M1	03°42'45"	038°28'40"	7	18.28	5.61	3.65	VFS
M2	03°42'29"	038°28'34"	15	30.26	12.72	2.56	FS
M3	03°42'28"	038°29'02"	15	25.05	5.99	3.69	VFS
M4	03°42'42"	038°29'05"	14	34.96	16.22	2.16	FS
M5	03°42'28"	038°29'15"	11	15.72	3.28	3.51	VFS
M6	03°42'13"	038°29'07"	14	26.60	8.64	2.92	FS
M7	03°42'18"	038°28'55"	9	22.19	12.23	2.44	FS
M8	03°42'00"	038°29'02"	9	9.41	0.96	2.59	FS
M9	03°41'47"	038°29'05"	12	5.74	0.57	1.87	MS
M10	03°41'42"	038°28'42"	12	8.58	0.13	0.29	CS
P1	03°32'03"	038°47'19"	17	36.96	14.87	2.27	FS
P2	03°32'10"	038°47'30"	16	33.76	12.23	2.52	FS
P3	03°31'52"	038°47'32"	17	28.90	14.69	2.40	FS
P4	03°31'50"	038°47'57"	17	26.50	7.71	3.10	VFS
P5	03°32'14"	038°48'02"	15	24.78	2.49	2.80	FS
S1	23°59'59"	046°20'03"	15	10.96	9.91	4.21	SC
S2	23°58'04"	046°17'32"	14	7.99	5.35	3.55	VFS
S3	23°54'26"	046°18'24"	2	10.16	12.22	3.74	VFS
S4	23°55'32"	046°18'43"	3	12.46	13.88	3.96	VFS
S5	23°54'01"	046°22'36"	4	7.54	11.41	4.13	SC

1). Calcium carbonates and organic matter levels presented high levels at the deeper stations, especially in sheltered areas, which can be associated with the deposition in both harbors induced by the jetty. These results corroborate the characteristic of sediments from terrigenous facies of this region (Freire et al. 2004; Marques et al. 2008). The sediments collected in navigation channel of Port of Santos presented a predominance of very fine sands, with increasing fine particles (coarse silt) towards the inner estuary not considering the predominance of fine particles in S1. Calcium carbonates were high in S1, S3 and S4, whereas the OM levels were higher in the inner estuary (S3 to S5).

A list of polychaetes and their distribution by station, depth and sediment type are presented in Table 2. A total of 366 individuals were recorded, distributed in 34 different taxa. Some individuals from the families Eunicidae, Glyceridae, Orbiniidae, Paraonidae, Sabellidae and Terebellidae were not possible to identify at genus or species level because of their preserved conditions and some others were identified only at genus level.

The families Ampharetidae, Capitellidae, Cirratulidae, Cossuridae, Eulepethidae, Nereidae, Paraonidae, Sabellidae, Syllidae and Terebellidae were found only in samples from Ceará (Mucuripe and Pecém) while the families Hesionidae, Lumbrineridae and Onuphidae were recorded only in Santos. In the other hand, *Timarete* sp., *Glycera lapidum*, *Glycinde multidentis*, *Magelona papillicornis*, *Sthenolepis grubei* and the spionids occurred in all areas.

Table 2. List of polychaetes and their occurrence at the sampling stations of Mucuripe, Pecém and Santos harbors as indicated in Figure 1. CS = coarse sand; MS = medium sand; FS = fine sand; VFS = very fine sand; SC= coarse silt.

Family	Species	Sampling stations	Depth (m)	Sediment type
Ampharetidae	<i>Melinna cristata</i> (Sars, 1851)	M4	14	FS
Capitellidae	<i>Notomastus</i> Sars, 1850	P2	16	FS
Cirratulidae	<i>Aphelocheata</i> Blake, 1991	M4	14	FS
	<i>Chaetozone</i> Malmgren, 1867	P1,P2,M7,S2	9-17	FS, VFS
	<i>Timarete</i> Kinberg, 1866	P5,M5,M7,S1,S2	9-15	FS, VFS, SC
Cossuridae	<i>Cossura candida</i> Hartman, 1955	M2,M3,M7	9-15	FS, VFS
Eulepethidae	<i>Grubeulepis fimbriata</i> (Treadwell, 1901)	P2,P4,M5,M6	11-17	FS, VFS
	<i>Pareulepis multibranchiata</i> Amaral & Nonato, 1984	M7	9	FS
Eunicidae	Unidentified	M8	9	FS
Glyceridae	<i>Glycera lapidum</i> Quatrefages, 1866	P1,M1,M4,M5,M7	7-17	FS, VFS, SC
	<i>Glycera</i> Savigny, 1818	M3,S1	15	VFS, SC
	Unidentified	M1,S5	4-7	VFS, SC
Goniadidae	<i>Glycinde multidentis</i> Müller, 1858	P1,P2,S1,S2,S5	4-17	FS, VFS, SC
	<i>Goniada littorea</i> Hartman, 1950	S1	15	SC
Hesionidae	<i>Hesione picta</i> Müller, 1858	S1	15	SC
Lumbrineridae	<i>Ninoe brasiliensis</i> Kinberg, 1865	S1,S2	14-15	VFS, SC
Magelonidae	<i>Magelona papillicornis</i> (Müller, 1858)	P3,M4,M5,M7,S5	4-17	FS, VFS, SC
	<i>Magelona posterelongata</i> Bolivar & Lana, 1986	M1,M3,M5,M6,M7	7-15	FS, VFS
Nereididae	<i>Ceratocephale</i> Malmgren, 1867	P3,P5	15-17	FS, VFS
	<i>Laeonereis acuta</i> (Treadwell, 1923)	P2,M1,M4,M5,M7	7-16	FS, VFS
Onuphidae	<i>Kinbergonuphis tenuis</i> (Hansen, 1882)	S1,S2	14-15	VFS,SC
Orbiniidae	<i>Naineris setosa</i> (Verrill, 1900)	S1	15	SC
	<i>Scoloplos</i> Blainville, 1828	P1,P2,P3,M1,M5,M7	7-17	FS, VFS
Paraonidae	Unidentified	P1,M7	9-17	FS
Phyllodocidae	<i>Eulalia</i> Savigny, 1822	M1	7	VFS
Pilargidae	<i>Hermundura fauveli</i> (Berkeley & Berkeley, 1941)	S1	15	SC
	<i>Sigambra grubii</i> Müller, 1858	P1,P3,S1,S3	2-17	FS, SC
Sabellidae	Unidentified	M5	11	VFS
Sigalionidae	<i>Sthenolepis grubei</i> (Treadwell, 1901)	P1,P2,M3,M4,M8,S2,S5	4-17	FS, VFS, SC
Spionidae	<i>Laonice</i> Malmgren, 1867	S1	15	SC
	<i>Polydora cf. ligni</i> (Webster, 1879)	M4	14	FS
	<i>Polydora</i> Bosc, 1802	M4,M5	11-14	FS, VFS
	<i>Prionospio pinnata</i> Ehlers, 1901	M1,M2,M3,M4,M7,M8	7-15	FS, VFS
	<i>Prionospio cf. pygmaeus</i> Hartman, 1961	M5,M7,M8	9-11	FS, VFS
	<i>Prionospio</i> Malmgren, 1867	M3,M6	14-15	FS, VFS
Sternaspidae	<i>Petersenaspis capillata</i> (Nonato, 1966)	M2,S4	3-15	FS, VFS
Syllidae	<i>Autolytus</i> Grube, 1850	P5	15	FS
Terebellidae	<i>Nicolea</i> Malmgren, 1866	M5	11	VFS
	Unidentified	M1	7	VFS

Mucuripe accounted 27 taxa in the sheltered areas (M1 to M8) and the most frequent species were *Glycera lapidum*, *Magelona posterelongata*, *Laeonereis acuta* and *Prionospio pinnata*. No polychaetes were collected in M9 and M10. In Pecém 14 taxa were found and the genus *Scoloplos* was the most frequent being reported in P1, P2 and P3. A total of 16 taxa were identified in Santos where *Glycinde multidentis* occurred in S1, S2 and S5.

DISCUSSION

In coastal environments, the main factors determining the structure and function of benthic communities include the inter-relationships among environmental variables, biological aspects and anthropogenic factors. Particle size, salinity, depth and OM levels normally are the main drivers, with high diversity of species related to heterogeneous sediments and the complexity of

habitats formed by the combination of different substrates (Fresi et al. 1983). Mucuripe and Pecém showed the distribution of polychaete species associated with fine sandy sediments (FS to VFS) in the sheltered areas, since no polychaetes were found in coarser sediments from the unsheltered areas (M9 and M10).

In Mucuripe Bay, after the harbor implementation a significant change in the environment has occurred. Before the harbor installation the bay was characterized by the presence of sandy beaches and bars with higher rates of sediment transport, however, after the installation of the rock jetty the sediments transport was changed and creating depositional areas of fine-grained sediment (Maia et al. 1998).

Pecém also presents a rock jetty with similar conditions of sediment transport and deposition and the predominance of fine sand in sheltered areas can be

associated with the hydrodynamic effects of sediment transport induced by jetties, affecting thus the distribution of species in the same way as in the Mucuripe. Unfortunately, no comparisons before-after the construction of both harbors could be performed due to the absence of data from fauna previously the existence of both harbors.

In Santos, the presence of mangroves in the inner estuary has a material retainer function, which explains the higher deposition of CaCO_3 and OM in S3, S4 and S5. The sewage outfall also promotes the input of material to the inner Santos Bay, resulting in the higher levels of mud and OM in S1.

Regarding the occurrence of species, recent literature was checked and data were compared with records provided for Patos Lagoon (Bemvenuti et al. 2005), the states of Santa Catarina (Almeida et al. 2012) and Paraná (Lana et al. 2006), São Sebastião Channel (Pires-Vanin et al. 2014), São Paulo continental shelf (Paiva 1993), Guanabara Bay (Santi and Tavares 2009) and Vitória Bay Estuarine System (Nalesso et al. 2005). All taxa that occurred in this study were previously found in those regions. It means that the polychaete fauna mainly from harbors of Ceará (Mucuripe and Pecém) is similar to those of South and Southeast Brazilian coast and, in the case of Santos, the data only corroborate the occurrence of typical fauna of the region.

On the other hand, based on recent data records (Franklin Jr et al. 2006; Amaral et al. 2013; Pagliosa et al. 2014), we highlight the first occurrence in Ceará state of 10 polychaete species (*Mellina cristata*, *Cossura candida*, *Pareulepis multibranchiata*, *Glycera lapidum*, *Magelona posterelongata*, *Sthenolepis grubei*, *Polydora* cf. *ligni*, *Prionospio pinnata*, *Prionospio* cf. *pygmaeus* and *Petersenaspis capillata*) and two polychaete genera (*Aphelochaeta* and *Ceratocephale*).

These new records will contribute to the NONATO network, an interactive data base on Polychaete distribution of Southwestern Atlantic Ocean (SWAO), formed by researchers from Brazil, Uruguay and Argentina (Pagliosa et al. 2014). The authors stated that there are many early studies and grey literature related to biodiversity information, which is difficult to retrieve, whereas current data are more readily accessible in scientific e-journals and abstract indexes and data repositories.

In this sense, we emphasize that the records presented here increase the knowledge of fauna of polychaete from the Brazilian coast, especially in Ceará State, due to new occurrences. In addition, these areas are under influence of environmental impacts from urbanization, industrial and harbor activities, and thus, these data can also assist in ecological risk assessment and ecotoxicological studies of sediment contamination by providing information on potential non-target organisms from benthic fauna, such as the polychaetes.

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LITERATURE CITED

- Abessa, D.M.S., R.S. Carr, E.C.P.M. Sousa, B.R.F. Rachid, L.P. Zaroni, Y.A. Pinto, M.R. Gasparro, M.C. Bicego, M.A. Hortellani, J.E.S. Sarkis, and P. Muniz. 2008. Integrative ecotoxicological assessment of a complex tropical estuarine system, pp. 125–159, in: N. Hoffer (ed.). Marine pollution: new research. New York: Nova Science.
- Almeida, T.C.M., J.M. Vivan, B.H. Pessler and P. Lana. 2012. Polychaetes of the north-central Santa Catarina state, Brazil. Check List 8(2): 204–206. <http://www.checklist.org.br/getpdf?SLO35-11>
- Amaral, A.C.Z., E.F. Nonato and M.A.V. Petti. 1994. Contribution of the polychaetous annelids to the diet of some Brazilian fishes. Mémoires du Muséum National d'Histoire Naturelle 162: 331–337.
- Amaral, A.C.Z., S.A.H. Nallin, T.M. Steiner, T.O. Forroni and D.F. Gomes. 2013. Catálogo das espécies de Annelida Polychaeta do Brasil. http://www.ib.unicamp.br/museu_zoologia/sites/www.ib.unicamp.br/museu_zoologia/files/Cat%C3%A1logo_Polychaeta_Brasil_Amaral_et_al_2013_1a.pdf
- Bemvenuti, C.E., L.G. Angonesi and M.S. Gandra. 2005. Effects of dredging operations on soft bottom macrofauna in a harbor in the Patos lagoon estuarine region of southern Brazil. Brazilian Journal of Biology 65(4): 573–581. doi: 10.1590/S1519-69842005000400003
- Choueri, R.B., A. Cesar, R.J. Torres, D.M.S. Abessa, R.D. Morais, C.D.S. Pereira, M.R.L. Nascimento, A.A. Mozeto, I. Riba and T.A. Delvalls. 2009. Integrated sediment quality assessment in Paranaguá estuarine system, southern Brazil. Ecotoxicology and Environmental Safety 72(7): 1824–1831. doi: 10.1016/j.ecoenv.2008.12.005
- Dauvin, J. and T. Ruellet. 2009. The estuarine quality paradox: Is it possible to define an ecological quality status for specific modified and naturally stressed estuarine ecosystems? Marine Pollution Bulletin 59(1–3): 38–47. doi: 10.1016/j.marpolbul.2008.11.008
- Fauchald, K. and P.A. Jumars. 1979. The diet of worms: a study of polychaete feeding guilds. Oceanography Marine Biology Annual Review 17: 193–284.
- Franklin Jr, W., R.C.A. Sousa and A.R.G. Silva. 2006. Polychaeta; pp. 145–168, in: Biota marinha da costa oeste do Ceará. Matthews-Cascon, H. and T.M. Lotufo (orgs). Brasília: Ministério do Meio Ambiente (MMA), Série Biodiversidade.
- Freire, G.S.S., S. Lima, L.P. Maia and L.D. Lacerda. 2004. Geochemistry of continental shelf sediments of the Ceará coast, NE Brazil; pp. 365–378, in: Lacerda, L.D., R.E. Santelli, E.K. Duursma and J.J. Abrão (eds.). Facets of Environmental Geochemistry in Tropical and Subtropical Environments. Springer Verlag, Berlin.
- Fresi, E., M.C. Gambi, S. Focardis, R. Bargagli, F. Baldi and L. Falliacci. 1983. Benthic community and sediment types: a structural analysis. Marine Ecology 4(2): 101–121. doi: 10.1111/j.1439-0485.1983.tb00290.x
- Fukumoto, M.M., M.M. Mahiques and M.G. Tessler. 2006. Bottom Faciology and Sediment Transport in Santos Bay, Southeastern

- Brazil. Journal of Coastal Research 39(SI): 1737–1740.
- Gross, M.G., 1971. Carbon determination; pp. 573–596, in: R.E. Carver, (ed.). Procedures in Sedimentary Petrology. New York: Wiley-Interscience.
- Jimenez, J.A., L.P. Maia, J. Serra and J. Morais. 1999. Aeolian dune migration in NE Brazil. *Sedimentology* 46(4): 689–701. doi: [10.1046/j.1365-3091.1999.00240.x](https://doi.org/10.1046/j.1365-3091.1999.00240.x)
- Lana, P.C., C.S.G. Santos, A.R.S. Garraffoni, V.M. Oliveira and V. Radashevsky. 2006. Checklist of polychaete species from Paraná state (Southern Brazil). *Check List* 2(3): 30–63. doi: [10.15560/2.3.30](https://doi.org/10.15560/2.3.30)
- Luczak, C., M. Janquin and A. Kupka. 1997. Simple standard procedure for the routine determination of organic matter in marine sediment. *Hydrobiologia* 345(1): 87–94. doi: [10.1023/A:1002902626798](https://doi.org/10.1023/A:1002902626798)
- Maia, L.P., J.A. Jimenez, J.S. Raventos and J.O. Morais. 1998. The coastline of Fortaleza city. A product of environmental impacts caused by the Mucuripe harbor. *Arquivos de Ciências do Mar* 31(1–2): 93–100. http://www.labomar.ufc.br/images/stories/arquivos/ArqCienMar/V31_1998/acm_1998_31_1-2_10.pdf
- Marques, W.S., A.N. Sial, E.A. Menor, V.P. Ferreira, G.S.S. Freire, E.A.M. Lima and V.A.V. Manso. 2008. Principal component analysis (PCA) and mineral associations of litoraneus facies of continental shelf carbonates from northeastern Brazil. *Continental Shelf Research* 28(20): 2709–2717. doi: [10.1016/j.csr.2008.09.005](https://doi.org/10.1016/j.csr.2008.09.005)
- Moser, G.A.O., S.M.F. Giancesella, J.J.B. Alba, A.L. Bérnago, F.M.P. Saldanha-Corrêa, L.B. Miranda and J. Harari. 2005. Instantaneous transport of salt, nutrients, suspended matter and chlorophyll-a in the tropical estuarine system of Santos. *Brazilian Journal of Oceanography* 53(3–4): 115–127. doi: [10.1590/S1679-87592005000200003](https://doi.org/10.1590/S1679-87592005000200003)
- Nalesso, R.C., J. Joyeux, C.O. Quintana, E. Torezani and A.C.P. Otegu. 2005. Soft-bottom macrobenthic communities of the Vitória Bay Estuarine System, South-Eastern Brazil. *Brazilian Journal of Oceanography* 53(1–2): 23–38. doi: [10.1590/S1679-87592005000100003](https://doi.org/10.1590/S1679-87592005000100003)
- Nogueira, M.L., V.A. Augusto, R.M.B. Castelo-Branco, D.L. Castro. 2005. Caracterização Geoambiental e Hidrogeológica da Zona Portuária do Pecém/CE. *Revista de Geologia*. 18(2): 203–213.
- NRC. National Research Council. 1997. Contaminated sediments in ports and waterways: cleanup strategies and technologies. Washington, D.C.: National Academy press. 318 pp.
- Pagliosa, P.R., J.G. Doria, D. Misturini, M.B.P. Otegui, M.S. Oortman, W.A. Weis, L. Faroni-Perez, A.P. Alves, M.G. Camargo, A.C.Z. Amaral, A.C. Marques and P.C. Lana. 2014. NONATObase: a database for Polychaeta (Annelida) from the Southwestern Atlantic Ocean. Database Vol. 2014: article ID bau002. doi: [10.1093/database/bau002](https://doi.org/10.1093/database/bau002)
- Paiva, P.C. 1993. Anelídeos poliquetas da plataforma continental norte do Estado de São Paulo: I - padrões de densidade e diversidade específica. *Boletim do Instituto Oceanográfico* 41(1–2): 69–80. doi: [10.1590/S1679-87591993000100006](https://doi.org/10.1590/S1679-87591993000100006)
- Petti, M.A.V., E.F. Nonato and P.C. Paiva. 1996. Trophic relationships between polychaetes and brachyuran crabs on the Southeastern Brazilian Coast. *Revista Brasileira de Oceanografia* 44(1): 61–67. doi: [10.1590/S1413-77391996000100007](https://doi.org/10.1590/S1413-77391996000100007)
- Pires-Vanin, A.M.S., P. Muniz and S. Bromberg. 2014. Inventory of the marine soft bottom macrofauna of São Sebastião Channel, southeastern Brazilian continental shelf. *Check List* 10(4): 795–807. doi: [10.15560/10.4.795](https://doi.org/10.15560/10.4.795)
- Santi, L. and M. Tavares. 2009. Polychaete assemblage of an impacted estuary, Guanabara Bay, Rio de Janeiro, Brazil. *Brazilian Journal of Oceanography* 57(4): 287–303. doi: [10.1590/S1679-87592009000400004](https://doi.org/10.1590/S1679-87592009000400004)
- Siqueira, G.W., E.S. Braga, M.M. Mahiques and F.M. Aprile. 2006. Determinação da matéria orgânica e razões C/N e C/S em sedimentos de fundo do estuário de Santos -- SP/Brasil. *Arquivos de Ciências do Mar* 39(1): 18–27. http://www.labomar.ufc.br/images/stories/arquivos/ArqCienMar/V39_2006/acm_2006_39_02.pdf
- Torres, R.J., D.M.S. Abessa, F.C. Santos, L.A. Maranhão, M.B. Davanzo, M.R.L. Nascimento and A.A. Mozeto. 2009. Effects of dredging operations on sediment quality: contaminant mobilization in dredged sediments from the Port of Santos, SP, Brazil. *Journal of Soils and Sediments* 9(5): 420–432. doi: [10.1007/s11368-009-0121-x](https://doi.org/10.1007/s11368-009-0121-x)
- Ugland, K.I., A. Bjørgesæter, T. Bakke, B. Fredheim and J.S. Gray. 2008. Assessment of environmental stress with a biological index based on opportunistic species. *Journal of Experimental Marine Biology and Ecology* 366(1–2): 169–174. doi: [10.1016/j.jembe.2008.07.021](https://doi.org/10.1016/j.jembe.2008.07.021)

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