

DYNAMICS OF *Acartia lilljeborgii* GIESBRECHT, 1889 IN A HEAVILY INDUSTRIALIZED TROPICAL ESTUARY

Glenda Mugrabe^{1*}; Pedro Augusto de Castro Mendes Melo¹; Fernando de Figueiredo Porto Neto²; Andrea Pinto Silva¹; Sigrid Neumann-Leitão¹

¹Departamento de Oceanografia da UFPE, Av. Arquitetura, s/n, Cidade Universitária, 50.670-901, Recife, PE.

²Departamento de Zootecnia da UFRPE, Av. Dom Manuel de Medeiros, s/n, Dois Irmãos, 52.171-900, Recife, PE.

Author for correspondence: glendamugrabe@gmail.com

ABSTRACT

Studies about the dynamics of the Copepoda *Acartia lilljeborgii* Giesbrecht, 1889 were carried out at Suape, Pernambuco, Brazil, in order to use this species as environmental quality indicator, after major changes that occurred throughout the development of this area after industrial enterprises. Suape Bay and the Tatuoca River estuary were studied, from May/2009 to November/2010. Sampling was carried out in two stations (S1 and S2), during spring and neap tides, on low and high tides. Plankton collections were made with a plankton net 300 µm mesh size. Considering the total density of zooplanktonic community, Copepoda represented 78%, and *Acartia lilljeborgii* contributed with 48%, occurring in all samples. The density ranged from a minimum of 1.4 ind.m⁻³ (S2, April/2010, low tide, spring tide) to a maximum of 646.8 ind.m⁻³ (S1, March 2010, high tide, spring tide) with general average of 73.2±166.6 ind.m⁻³. S2 and the low tides showed lower densities and biomasses. Despite of all impacts on Suape Bay, *Acartia lilljeborgii* presented high resilience, maintaining as the dominant species in the last decades.

Key words: Bioindicator, Copepoda, Environmental Quality

RESUMO

Dinâmica de *Acartia lilljeborgii* Giesbrecht, 1889 em um estuário tropical altamente industrializado.

Estudos sobre a dinâmica do Copepoda *Acartia lilljeborgii* foram realizados em Suape, Pernambuco, Brasil, visando utilizar esta espécie como indicadora da qualidade ambiental, após grandes modificações ocorridas em toda área com a implantação de vários empreendimentos industriais. Foram estudados a área

estuarina da baía de Suape o estuário do rio Tatuoca, no período de maio/2009 a novembro/2010. A amostragem foi feita em duas estações (S1 e S2), em marés de sizígia e quadratura, nas baixa-mares e preamares diurnas. As coletas de plâncton foram realizadas com rede cilíndrico cônica, malha de 300 µm. Considerando a densidade total da comunidade zooplanctônica, Copepoda representou 78%, com *Acartia lilljeborgii* contribuindo com 48% e ocorrendo em todas as amostras. A densidade variou de um mínimo de 1,4 ind.m⁻³ (S2, abril/2010, baixa-mar, em maré de sizígia) a um máximo de 646,8 ind.m⁻³ (S1, março/2010, preamar, em maré de sizígia) com média geral de 73,2±166,6 ind.m⁻³. A estação S2 e as baixa-mares apresentaram menores densidades. Apesar de todos os impactos na baía de Suape *A. lilljeborgii* apresentou grande resiliência, mantendo-se como espécie dominante nas últimas décadas.

Palavras-chave: Bioindicador, Copepoda, Qualidade Ambiental.

INTRODUCTION

Estuaries are complex ecosystems and are under challenges in terms of the understanding of natural and anthropogenic effects influencing their biological components. Understanding the relationships between environmental stressors and biological effects is critical for considerate the prevailing conditions and for applying estuarine management (ADAMS, 2002; BEAUGRAND, 2005).

Among the main biological components in estuaries, the copepods represent the most important group of zooplankton (BJÖRNBERG, 1981); they regularly

can correspond to 60 to 95% of the entire biomass in coastal areas (SUÁREZ-MORALES, 1994; LOPES *et al.*, 1998).

Species of the genus *Acartia* are constantly present in this environment (ESCAMILLA *et al.*, 2011), and *Acartia lilljeborgii* Giesbrecht, 1889 have been previously reported as abundant and common in different coastal systems of the Northeastern Brazil (NEUMANN-LEITÃO, 1995; SILVA *et al.*, 2003; SILVA *et al.*, 2004; CAVALCANTI *et al.*, 2008, among others).

Many authors suggest that the continuous presence of this species

in impacted environments indicates that they are very resistant and therefore appropriate to be used as a bioindicator of pollution (CRISAFI, 1974; GAJBHIYE *et al.*, 1991; DIAS, 1999).

The bioindicator is an organism that serves to characterize the state of an ecosystem and detect natural and human modifications at the earliest possible stage (LEVINTON, 1995).

This research was conducted to monitor the current conditions during the implementation of the Productive Sector in the Suape area, primarily in relationship to several large industrial installations.

The aim of this work was to assess the quality of the aquatic environment through the use of the density and biomass of the Copepoda *A. lilljeborgii*.

MATERIAL AND METHODS

Study area

Suape Bay is located between 8°15' - 8°30' S and 34°55' - 35°5' W, about 40 km south of Recife City. Climate is warm-humid, pseudotropical (Koppen As') with a mean annual temperature of 24°C

and a rainfall of 1500-2000 mm.yr⁻¹, concentrated from March to August. Humidity is higher than 80%. Predominant winds are from the southeast (NIMER, 1979).

An industrial port complex was created in 1979/1980 in this area to solve the collapse of the State's economy (NEUMANN-LEITÃO *et al.*, 1999).

Before the Suape port complex implementation, four rivers (Massangana, Tatuoca, Ipojuca and Merepe) drained into Suape Bay, itself an estuarine system partly isolated from the ocean by an extensive sandstone reefline. Today, only the Massangana and Tatuoca rivers still drain into Suape Bay. The Ipojuca and Merepe rivers had their connection with the bay interrupted by intensive embankment to build the Port Complex (NEUMANN *et al.*, 1998). The Ipojuca river had strong influence at Suape Bay, because its higher freshwater inflow. In 1989-1990 with the breakage of the reefline to build an internal port in the Suape bay the marine influence increased and higher salinities were registered in the Massangana and Tatuoca rivers (SILVA *et al.*, 2004).

Field methods

Samples were collected from May 2009 to November 2010, in the spring and neap tides, totalizing 20 campaigns. Sampling were conducted during high and low tides at two stations, one located at the mouth of the Tatuoca River (S1) and other at Suape Bay and influenced by the river (S2) (Figure 1). A total of 80 samples were collected. The zooplankton samples were collected with a plankton net with a mesh size of 300 μm , in horizontal surface hauls, during three minutes. The samples were preserved with 4% neutral formalin and stored in plastic bottles, according to the

methodology described by Newell & Newell (1963).

Laboratory procedures

In the laboratory, each sample was diluted to a volume of 500 mL, and then 8 mL were withdrawn using a Stempel pipette, and after placed on a Bogorov plate.

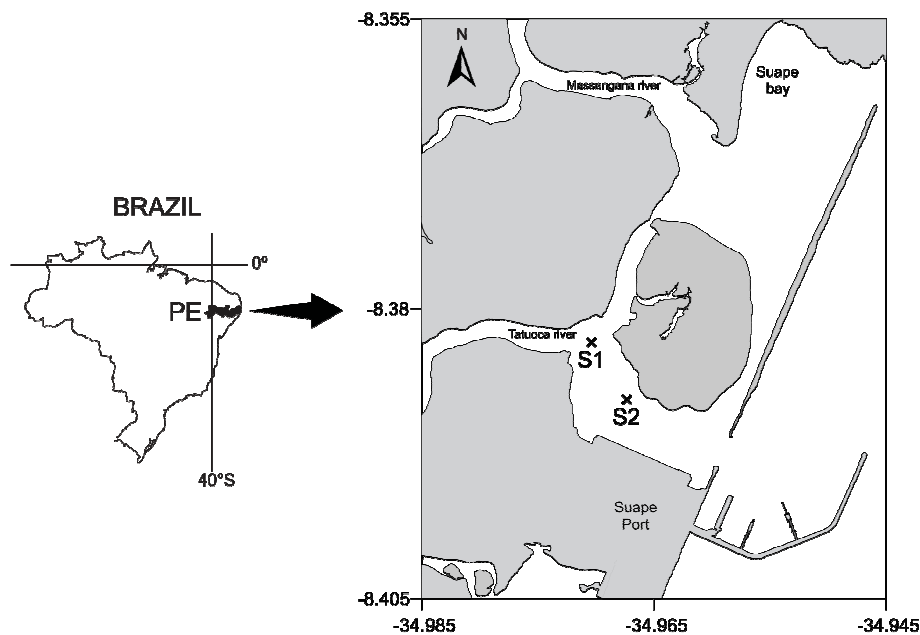


Figure 1. Sampling stations in the Suape area, Pernambuco, Brazil.

All zooplankton community (data not shown in this article) was identified and the *Acartia lilljeborgii* specimens were counted and measured under a stereoscopic microscope with a micrometer.

Data analysis

The biomass was calculated based on geometric figures that approximated the body shape of individuals of the dominant copepod *A. lilljeborgii*. The biomass was calculated in terms of the volume of an ellipsoid, $\frac{4}{3}\pi r_1 r_2 r_3$, where $r_1 = a/2$, $r_2 = b/2$ and $r_3 = c/2$ according to Lawrence *et al.* (1987). The

biovolume were obtained from the length (a), width (b), and thickness (c) dimensions. Approximately 20 individuals of the *A. lilljeborgii*, chosen at random independently of its developmental stage, were measured in each sample. A mean biovolume was then calculated and converted to wet weight, assuming that $1 \mu\text{m}^3$ of biovolume weights $1 \mu\text{g}$ (LAWRENCE *et al.*, 1987). The dry weight was considered to be 0.1 x wet weight (BOTTRELL *et al.*, 1976), and the carbon content was estimated as 0.4 x dry weight

(POSTEL *et al.*, 2000; ARA, 2001)

(Table 1).

Table 1. Mean data used to calculate the biomass of the principal copepod *Acartia lilljeborgii* at Suape area, Pernambuco, Brazil.

Number of individuals measured	Length (a) μm	Width (b) μm	Thickness (c) μm	Biovolume (mm^3)	Dry weight (mg)	Carbon (mgC)
1600	1004 \pm 105,99	326.5 \pm 47,35	304 \pm 51,09	0.053 \pm 0,0202	0.0053 \pm 0,002	0.002 \pm 0,001

The biomass (B) was then calculated with the following formula: $B = D * C_m$, where D = the density of organisms of *A. lilljeborgii* in the sample and C_m = the average carbon content (weight) of the copepod in question. The data normality was tested (Kolmogorov-Smirnov). Mann-Whitney test ($p < 0.05$) was also used to evaluate the significance of the differences between seasons and between tides (spring x neap and high tide x low

tide), as the data were non-parametric.

RESULTS AND DISCUSSION

Copepoda represented 78% of all the zooplankton community, with an important contribution of *A. lilljeborgii*, which occurred in all samples and represented 48% of the Copepoda community. In the samples, the mean proportion of this species in relation to others Copepoda varying between 1.5% to 98.7% (Figure 2).

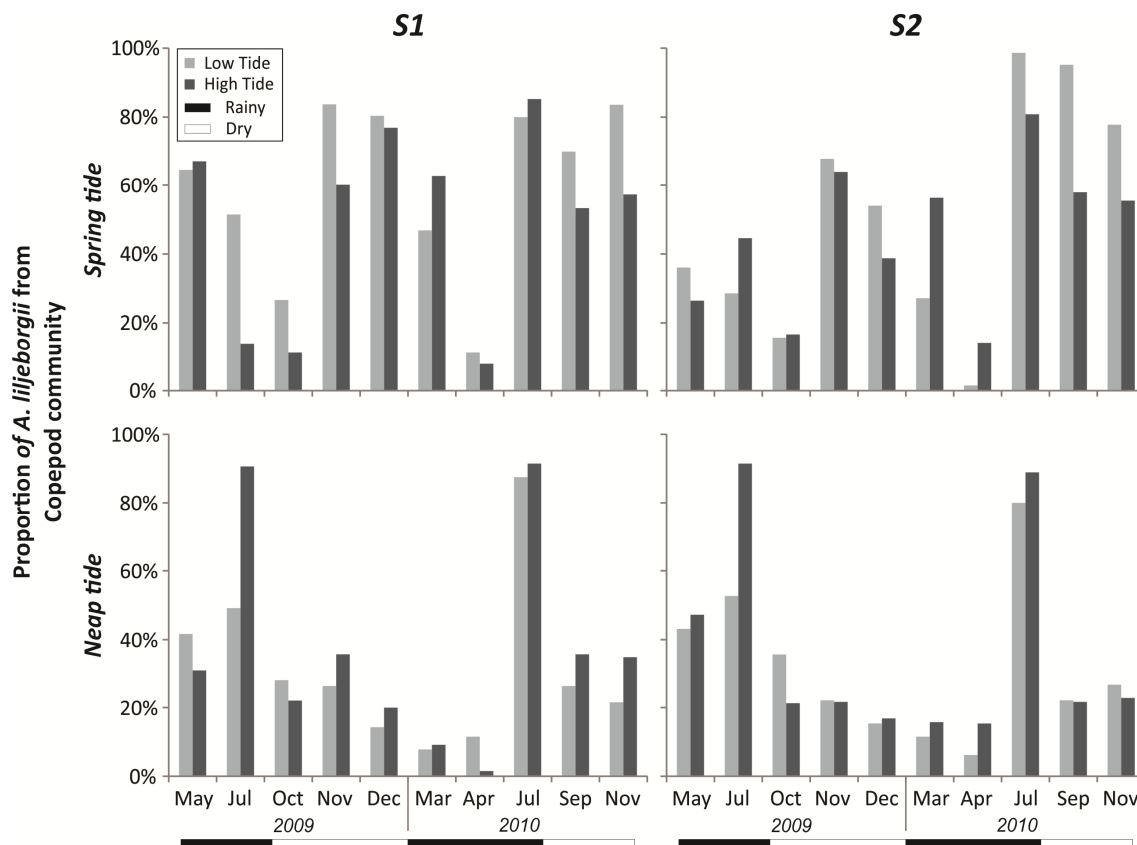


Figure 2. Proportion of *Acartia lilljeborgii* from Copepoda community in Suape area, Pernambuco, Brazil, from May 2009 to November 2010.

This proportion was higher in spring tide than neap one (Figure 2). This species was the dominant in studies carried out in the same area ten years ago, when it was used the same net mesh size (SILVA *et al.*, 2004) and 20 years ago when a 65 μm mesh size was employed (NEUMANN-LEITÃO *et al.*, 1992). However, 26 years ago Paranaguá (1986) using a 65 μm mesh size found that the dominant species was *Parvocalanus crassirostris* (F. Dahl, 1894), which was also abundant in the others mentioned studies. The

changes observed may be caused by the innumerous alterations in the area (reefs breakage, tides circulation, higher sedimentation processes, increase in salinities, decrease in water transparency with clear changes in the phytoplankton) (KOENING *et al.*, 2003; NEUMANN-LEITÃO, 1994; NEUMANN *et al.*, 1998; NEUMANN-LEITÃO *et al.*, 1999).

According to Pessoa *et al.* (2009) Suape Bay showed great changes in zooplankton community structure, from a typical estuarine

community to a coastal neritic one due higher marine influence.

Average Density was $73.27 \pm 116.66 \text{ ind.m}^{-3}$, with a minimum of 1.44 ind.m^{-3} (April/2010, spring tide, S2, low-tide) and a maximum of $646.82 \text{ ind.m}^{-3}$ (March/2010, spring tide, S1, high-tide) (Figure 3).

Spring tide was significantly higher than neap tide (Mann-Whitney test; $p < 0.001$). In the same way, rainy season presented significantly higher densities than dry season (Mann-Whitney test; $p = 0.006$). No difference were registered between high and low tides (Mann-Whitney test; $p = 0.124$) and between stations (Mann-Whitney test; $p = 0.348$). The density values were relatively low when compared with others tropical estuaries. For instance, Ara (2001) studying the Cananéia estuary,

found densities 6 times higher than in our study. However, this low densities was already registered to the Suape bay in 1992 (NEUMANN-LEITÃO *et al.*, 1992) and in 2004 (SILVA *et al.*, 2004) and could be possibly a consequence of the high load of suspended material caused by the continuous dredging at Suape Port (JONGE, 1983; NEUMANN-LEITÃO & MATSUMURA-TUNDISI, 1998; NEUMANN *et al.*, 1998), that would affect the primary productivity due to light intensity reduction (KOENING *et al.*, 2002).

Another cause of this low abundance could be related to the destruction of mangrove in the area (BRAGA *et al.*, 1989) which affects the availability of organic detritus, thus limiting another food source for the zooplankton.

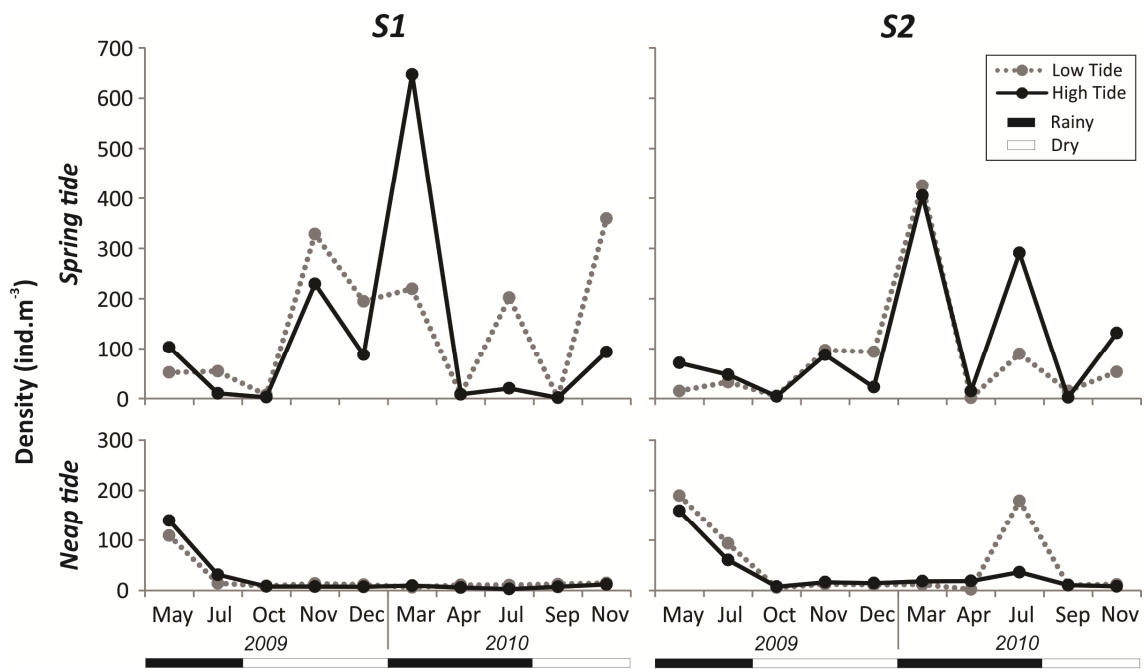


Figure 3. Density of *Acartia lilljeborgii* in the Suape area, Pernambuco, Brazil, from May 2009 to November 2010.

A. lilljeborgii showed the biomass mean value of $1.8 \pm 2.9 \text{ mgC.m}^{-3}$ varying from 0.04 mgC.m^{-3} (April/2010, spring tide, S2, low-tide)

to 116.6 mgC.m^{-3} (March/2010, spring tide, S1, high-tide (Figure 4). In general, S1 and the spring tide showed higher density and biomass.

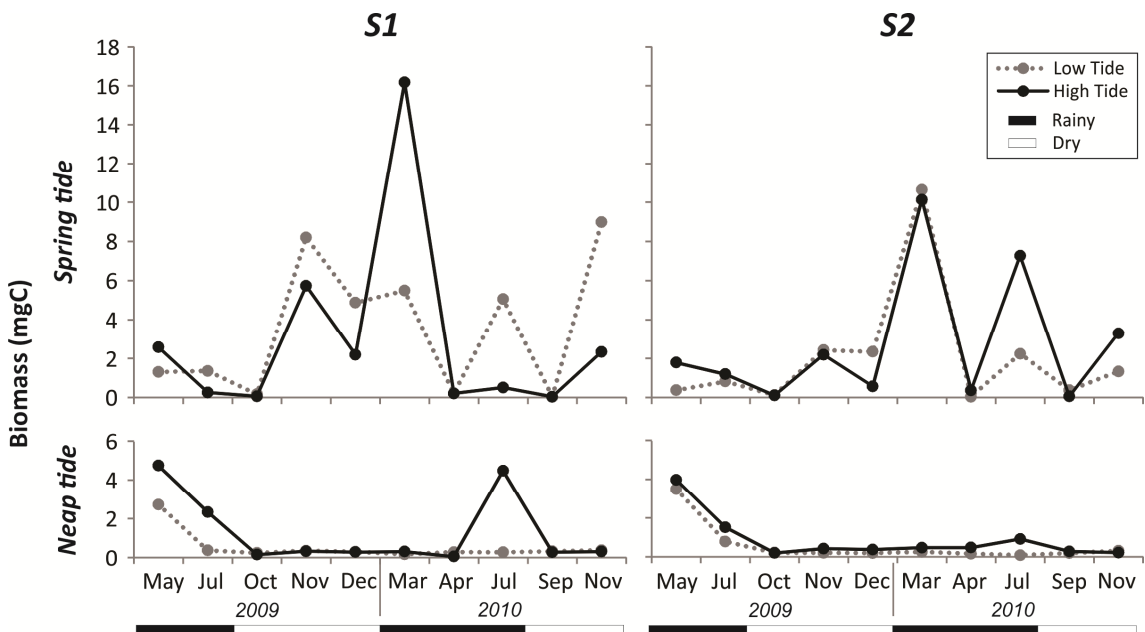


Figure 4. Biomass of *Acartia lilljeborgii* in the Suape area, Pernambuco, Brazil, from May 2009 to November 2010.

Species of *Acartia* may be considered a key link in the carbon fluxes in estuarine ecosystems (DURBIN & DURBIN, 1981; MARQUES *et al.*, 2006). In Brazilian estuaries *A. lilljeborgii* is a characteristic copepod (BJÖRNBERG, 1981) and has been recorded in almost all estuaries (NEUMANN-LEITÃO, 1995). This species has a dispersion center in areas of higher salinity (MATSUMURA-TUNDISI, 1972) and is indicative of coastal waters influence (BJÖRNBERG, 1981). This copepod represented the largest proportion of biomass at Botafogo (55%) and Carrapicho (56%) estuaries, in northern Santa Cruz Channel, Pernambuco, Brazil, with $8.2 \pm 8.8 \mu\text{gC m}^{-3}$ and $32.2 \pm 47.3 \mu\text{gC m}^{-3}$, respectively (NEUMANN-LEITÃO, 2010). In the Vitória Bay (Southeastern Brazil) *A. lilljeborgii* dominated during all the studied period and co-occurred with the congeneric *Acartia tonsa* which is more abundant in the upper portion of the estuary (STERZA & FERNANDES, 2006). At Nueces estuary (Texas, USA), *A. tonsa* was predominant and represented

approximately 50% of the total mesozooplankton (BUSKEY, 1993).

Despite of all impacts on Suape area, *Acartia lilljeborgii* presented high resilience, maintaining as the dominant species in the last decades.

ACKNOWLEDGMENTS

We are grateful to FACEPE, CAPES and CNPq for a scholarship to the first and second author and for supporting the research. We are grateful to Dr. José Zanon Passavante, Dr. Fernando Antônio Feitosa and Dra. Tâmara de Almeida e Silva for their important suggestions.

REFERENCES

- Adams, S.M. 2002. Biological indicators of aquatic ecosystem stress. American Fisheries Society, Bethesda, MD, 644 p.
- Ara, K. 2001. Temporal variability and production of the planktonic copepods in the Cananéia Lagoon estuarine system, São Paulo, Brazil. II. *Acartia lilljeborgii*. Plankton Biology and Ecology, Japan, 48 (1): 35-45.

Beaugrand, G. 2005. Monitoring pelagic ecosystems using plankton indicators. *ICES Journal of Marine Science*, London, 62: 333-338.

Björnberg, T. K. S. 1981. Copepoda, p. 587-679. In: D. Boltovskoy, (Ed.). *Atlas del zooplancton del Atlántico Sudoccidental y métodos de trabajos con el zooplancton marino*, INIDEP, Mar del Plata, 936p.

Bottrell, H.H.; Duncan, A.; Gliwicz, Z. M.; Grygierek, E.; Herzig, A.; Hillbricht-Ilkowska, A.; Kurasawa, H.; Larsson, P.; Weglenska, T. 1976. Are view of some problems in zooplankton production studies. *Norwegian Journal of Zoology*, Oslo, 24:19-456.

Braga, R. A. P.; Uchoa, T. M. M. & Duarte, M. T. 1989. Impactos ambientais sobre o manguezal de Suape-PE. *Acta Botânica Brasilica*. XL Congresso Nacional de Botânica, Anais. Cuiabá, 3 (2): supl. 9 a 27.

Buskey, E. J. 1993. Annual pattern of micro- and mesozooplankton abundance and biomass in a subtropical estuary. *Journal of*

Plankton Research, United Kingdom, 15 (8): 907-924.

Cavalcanti, E.A.H., Neumann-Leitão, S.; Vieira, D.A.N. 2008. Mesozooplâncton do sistema estuarino de Barra das Jangadas, Pernambuco, Brasil. *Revista Brasileira de Zoologia*, Curitiba, 25: 436-444.

Crisafi, P. 1974. Some responses of planktonic organisms to environmental pollution. *Revue Internationale d'Océanographie Médicale*, Nice, 34: 145–154.

Dias, C.O. 1999. Morphological abnormalities of *Acartia lilljeborgi* (Copepoda, Crustacea) in the Espírito Santo Bay (E.S., Brazil). *Hydrobiologia*, The Hague, 394: 249-251.

Durbin, A.G., Durbin, E.G., 1981. Standing stock and estimated production rates of phytoplankton and zooplankton in Narragansett Bay, Rhode Island. *Estuaries*, Frankfurt , 4: 24-41.

Escamilla, b. J.; ordóñez-lópez, u.; suárez-morales, e. 2011. Spatial and seasonal variability of *Acartia*

(Copepoda) in a tropical coastal lagoon of the southern Gulf of Mexico. *Revista de Biología Marina y Oceanografía*, Viña del Mar, 46 (3): 379-390.

Gaibhije, S.N., Stephen, R.; Vijayalakshmi, N.R.; Desai, B.N. 1991. Copepods of the nearshore waters of Bombay. *Indian Journal Marine Science*, New Delhi, 20: 187-194.

Herzig, A. 1984. Fundamental requirements of zooplankton. *Production Studies*. Institute of Austrian Academy of Science, Áustria, 83p.

Jonge, V. N. 1983. Relations between annual dredging activities, suspended matter concentrations and the development of the tidal regime in the Ems estuary. *Canadian Journal of Fisheries and Aquatic Science*, Ottawa, 40 (Supl.1): 289-300.

Koenig, M. L.; Eskinazi-Leça, E.; Neumann-Leitão, S.; Macêdo, S. J. 2002. Impactos da construção do porto de Suape sobre a comunidade fitoplanctônica no estuário do rio Ipojuca (Pernambuco-Brasil). *Acta*

Botânica Brasilica, Feira de Santana, 6 (4): 407-420.

Koenig, M.L., Leça, E.E., Neumann-Leitão, S., Macêdo, S.J.D. 2003. Impacts of the construction of the Port of Suape on phytoplankton in the Ipojuca River estuary (Pernambuco-Brazil). *Brazilian Archives of Biology and Technology*, Curitiba, 46: 73-81.

Lawrence, S.G.; Malley, D. F.; Findlay, W.J.; Maciver, M.A.; Delbaere, I. L. 1987. Method for Estimating Dry Weight of Freshwater Planktonic Crustaceans from Measures of Length and Shape. *Canadian Journal of Fishery and Aquatic Science*, Ottawa, 44: 264-274.

Levinton, J. S. 1995. *Marine Biology: function, biodiversity, ecology*. Oxford University Press, Oxford, 420p.

Lopes, R.M.; Vale, R.; Brandini, F.P. 1998. Composição, abundância e distribuição espacial do zooplâncton no complexo estuarino de Paranaguá durante o inverno de 1993 e o verão de 1994. *Revista*

Brasileira de Oceanografia, São Paulo, 46: 195-211.

Marques, S.C., Azeiteiro, U.M., Marques, J.C., Neto, J.M., Pardal, M.A. 2006. Zooplankton and ichthyoplankton communities in a temperate estuary: spatial and temporal patterns. *Journal of Plankton Research*, United Kingdom, 28(3): 297–312.

Matsumura-Tundisi, T. 1972. Aspectos ecológicos do zooplâncton da região lagunar de Cananéia com especial referência aos Copepoda (Crustacea). Instituto de Biociências, Univ. de São Paulo. São Paulo, Tese de Doutorado.

Neumann-Leitão, S.; Gusmão, L. M. O.; Nascimento-Vieira, D. A. 1992. Zooplâncton dos estuários dos rios Massangana e Tatuoca, Suape (PE - Brasil). *Brazilian Archives of Biology and Technology*, Curitiba, 35: 341-360.

Neumann-Leitão, S. 1994. Impactos antrópicos na comunidade zooplanctônica estuarina, Porto de Suape - Pernambuco – Brasil. Escola de Engenharia de São

Carlos, Univ. de São Paulo, São Paulo, Tese de Doutorado.

Neumann-Leitão, S. 1995. Resenha literária sobre o zooplâncton estuarino no Brasil. *Trabalhos Oceanográficos da Universidade Federal de Pernambuco*, Recife, 23: 25-53.

Neumann-Leitão, S.; Matsumura-Tundisi, T. 1998. Dynamics of a perturbed Estuarine Zooplanktonic Community: Port of Suape, PE, Brazil. *Verhandlungen Internationale Vereinigung Limnologie*, Stuttgart, 26: 1981-1988.

Neumann, V. H.; Medeiros, C.; Parente, L.; Neumann-Leitão, S.; Koenig, M. L. 1998. Hydrodynamism, sedimentology, geomorphology and plankton changes at Suape area (Pernambuco - Brazil) after a port complex implantation. *Anais da Academia Brasileira de Ciências*, Rio de Janeiro, 70 (2): 313-323.

Neumann-Leitão, S.; Koenig, M.L.; Macêdo, S.J.; Medeiros, C.; Muniz, K.; Feitosa, F.A.N. 1999. Plankton disturbance at Suape estuarine area- Pernambuco – Brazil after a

Port Complex implantation, p. 47-56.
In: J. L. Usó, C. A. Brebbia (Eds.).
Second International Conference on
Ecosystems and Sustainable
Development.

Neumann-Leitão, S. 2010. O
zooplâncton como indicador da
qualidade ambiental de dois
estuários do Brasil tropical.
Universidade Federal de
Pernambuco, Departamento de
Oceanografia, Recife. Tese Titular.

NEWELL, G. E.; NEWELL, R. C.
1963. Marine plankton: practical
guide. Hutchinson Educational,
London, 224p.

Nimer, E. Pluviometria e recursos
hídricos dos estados de
Pernambuco e Paraíba. SUOREN,
Rio de Janeiro, 117p.

Paranaguá, M. N. 1986.
Zooplankton of the Suape area
(Pernambuco-Brazil). Trabalhos
Oceanográficos Universidade
Federal de Pernambuco, Recife, 19:
113-124.

Pessoa, V.T.; Neumann-Leitão, S.;
Gusmão, L.M.O.; Silva, A.P.; Porto-
Neto, F.F. 2009. Comunidade
zooplanctônica na baía de Suape e

nos estuários dos rios Tatuoca e
Massangana, Pernambuco (Brasil).
Revista Brasileira de Engenharia de
Pesca, São Luís, 4(1): 80-94.

Postel L, Fock H and Hagen W
2000. Biomass and Abundance,
p.83-192. In: HARRIS, R.P.; WIEBE,
P.H.; LENS, J.; SKJOLDAL, H.R.
and HUNTLEY, M. (Eds.) ICES
Zooplankton Methodology Manual,
Academic Press, London, 684p.

Silva, T.; Neumann-Leitão, S.;
Schwamborn, R.; Gusmão, L. M.;
Nascimento-Vieira, D. A. 2003. Diel
and seasonal changes in the
macrozooplankton community of a
tropical estuary in Northeastern
Brazil. Revista Brasileira de
Zoologia, Curitiba, 20: 439-446.

Silva, A. P.; Neumann-Leitão, S.;
Schwamborn, R.; Gusmão, L. M.;
SILVA, T. A. 2004.
Mesozooplankton of an impacted
bay in North Eastern Brazil.
Brazilian Archives of Biology and
Technology, Curitiba, 47(3): 485-
493.

Sterza, J.M.; Fernandes, L.L. 2006.
Zooplankton community of the
Vitória Bay estuarine system

(Southeastern Brazil):
Characterization during a three-year
study. Brazilian Journal of
Oceanography, São Paulo, 54(2-3):
95-105.

Suárez-Morales, E. 1994.
Copépodos pláncnicos de la Bahía
de Chetumal, México (1990-1991).
Caribbean Journal of Science,
Mayagüez, 30: 181-188.