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RESEARCH ARTICLE

A Checklist of phytoplankton species around the Equator in Guaraíras, Galinhos and Diogo Lopes lagoons (Rio Grande do Norte, Brazil)

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Abstract

1 - Coastal lagoons show great fragility and vulnerability to the anthropogenic pressure. The understanding of physical, chemical, geological characteristics and ecological dynamics of lagoons is fundamental for planning the implementation of coastal management strategies in these ecosystems. The intrinsically high variability of phytoplankton communities in transitional environments should be taken into account not only because of phytoplankton ecological importance, but also because of the implications for environmental management.

2 - The aim of this study is a general description of the phytoplankton community in three coastal lagoons situated in the Rio Grande do Norte region, at the Northeast of Brazil.

3 - For the three lagoons, a total of 124 phytoplankton taxa were identified. In terms of species richness, diatoms were the largest group with 92 identified taxa belonging to 46 genera. At the class level, Bacillariophyceae recorded 39 taxa belonging to 18 genera; Coscinodiscophyceae recorded 39 taxa belonging to 21 genera and Fragilariophyceae recorded 14 taxa belonging to 7 genera. The group of the dinoflagellates recorded 15 taxa belonging to 6 genera and the Cyanophyceae was represented by 8 taxa belonging to 5 genera, including *Trichodesmium erythraeum*, a taxon related to toxic blooms.

Keywords: phytoplankton; taxonomic composition; Brazilian coastal lagoons; Rio Grande do Norte.

Introduction

The phytoplankton community, in the aquatic ecosystem, is self-sustainable since there are present heterotrophic and autotrophic organisms (Smetacek, 1988), which perform the function of primary producers and form the basis of the planktonic food web. The organization of the phytoplankton community is determined by physical and chemical characteristics of the environment, including temperature, salinity, light and nutrients availability, and also by loss processes such as grazing and sinking, among others (Margalef, 1963). In particular, in lagoon ecosystem the structure of phytoplankton is also determined by tidal flushing, freshwater input, competition with microphytobenthos and water turbidity among others (Nuccio *et al.*, 2003; Pilkaityte and Razinkovas, 2007). Competition for light and nutrients is a major evolutionary forces inside the phytoplankton structure and determines the composition of the community with prominence of diatoms, dinoflagellates or other groups (Simon *et al.*, 2009). Therefore, the aquatic environment provides a hierarchy of characteristics forces, resulting in variability of planktonic ecosystem over time and space: at ecosystem level, any physical or biological disturbance, variable in the course of time, can create a potential variability in space (Pitcher *et al.,* 1992). The species composition of the phytoplankton community changes over time periods, and the relative abundance of each species might be depend on different particular environmental and biological variables (Härnström *et al.*, 2009). The intrinsically high variability of phytoplankton communities in transitional environments should be taken into account not only because of phytoplankton ecological importance, but also because of the implications for environmental management. Some phytoplankton-related variables (composition, abundance, biomass, frequency and intensity of blooms) are essential for the definition and the classification of water quality (Bernardi Aubry *et al.*, 2013).

Coastal lagoons occupy 13% of coastal areas worldwide, and are often impacted by both natural and anthropogenic influences (Kjerfve, 1994). These areas, as multiple ecotone ecosystems (Basset *et al.*, 2013a), experience forcing from river input, wind stress, tides, precipitation to evaporation balance, surface heat balance and respond differently to these forcing functions (Kjerfve, 1994).

Along the Brazilian coast are remarkably diffuse coastal lagoons. This type of aquatic ecosystem proved to be highly productive due to the characteristics such as low water and continuous input of dissolved and particulate organic matter from the land. The shallowness of the water column and winds allow large variations in terms of materials influencing the movement of the water column and enhancing the interaction between that and benthic compartments (Esteves *et al.*, 2008). The coast of Rio Grande do Norte, located at the Northeastern part of Brazil is undergoing an accelerated process of urbanization (Santos Jr. *et al.*, 2011) and, because of the favorable climatic conditions and the large areas suitable for marine shrimp farming, has become the leading producer and largest exporter in the country (Azevedo *et al.*, 2009). Unfortunately, these environments show great fragility and vulnerability to the anthropic interventions, arising from the complexity of these areas as a result of the intervention earth-air-water (Santiago, 2004). The understanding of characteristic properties and functioning of lagoons, as part of the ecological domain ‘transitional waters’ (Basset *et al.*, 2013b), is important for planning and implementation of coastal management strategies in coastal lagoons (Kjerfve, 1994).

The aim of this study is the general description of the phytoplankton community in three lagoons of the Rio Grande do Norte, at the Northeast of Brazil, providing for new information about the changes occurring in species composition with environmental change.

Materials and Methods

In order to determine the composition of phytoplankton community, 3 lagoon ecosystems were sampled: Galinhos, Diogo Lopes and Guaraíras (Rio Grande do Norte, Brazil) (Fig.1).

Study Area

The state of Rio Grande do Norte in the Brazilian Northeast has some typical morphological features such as dunes, cliffs, salt pans, riverine-marine plains and coastal ponds. The coastal region is long 410 km (11.888 km^2). In this area there are many tidal channels, forming hypersaline environments (Santiago *et al.*, 2005). The regional climate

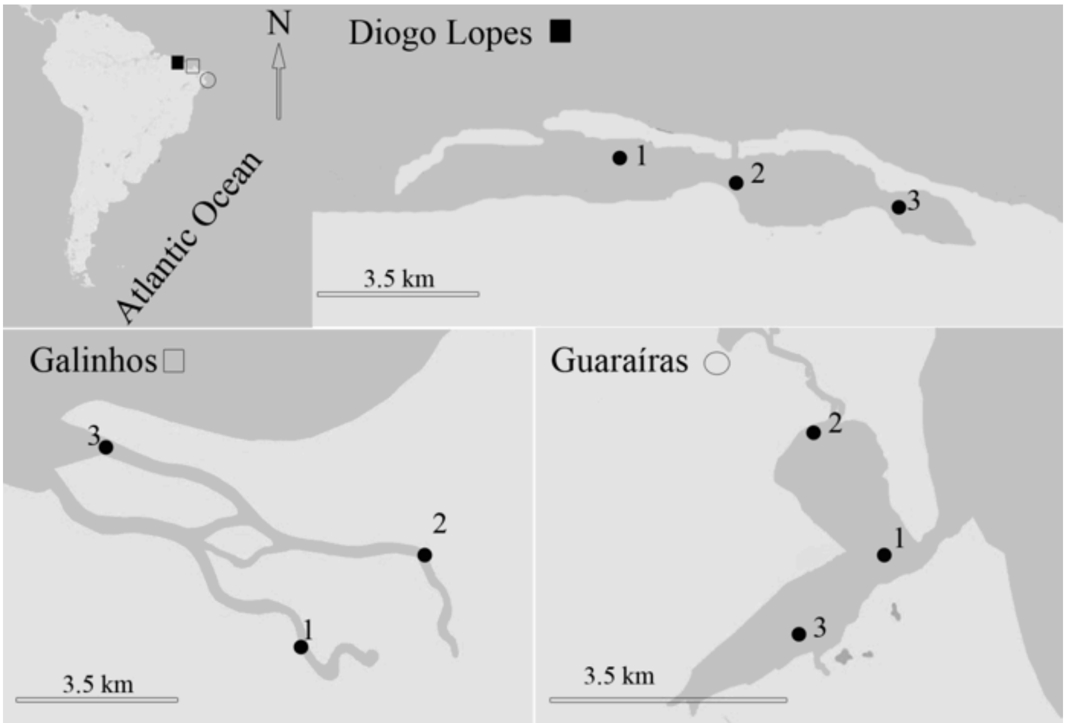

Figure 1. Localization of sampling points in the three Brazilian lagoons.

is classified as humid tropical, and annually received a rainfall of 1,400 to 1,700 mm, with two distinct seasonal periods of precipitation: a dry season that normally extends between September and February, and a rainy season from March to August. The coast is formed by cliffs and extensive dune fields. Beside this, the area is undergoing an accelerated process of urbanization (Santos Jr. *et al.*, 2011).

Galinhos Lagoon

Galinhos is an estuarine lagoon (Pisa Sal river), with a maximum length of 6.9 km and depth reaching 6 m at high tide. The water is very salt, with a salinity of 38. The dominant climate in this area is dry with summer rain and scarce rainfall, from March to April. The average annual rainfall is 600 mm because the Intertropical Convergence Zone, defined by the convergence of the winds from north and south hemispheres. The air temperature has an annual average of 26.8°C. The daily relative humidity is around 70%, being lower in the months from June to November, coinciding with the season of low rainfall (Santiago *et al.*, 2005).

Diogo Lopes Lagoon

This estuarine lagoon is formed at the mouth of the Piranhas-Açu river when it converges to the Atlantic Ocean. The depth reaches 5 m at the high tide and the maximum length is 13 km. The area is characterized by a high incidence of light energy, uniform thermal regime, high temperatures and mild variations throughout the year, because of the low latitude, local altitude and strong oceanic influence (Santos, 2003).

Diogo Lopes is part of the “Reserva de Desenvolvimento Sustentável Estadual Ponta do Tubarão”, a sustainable development reserve, with projects aimed at sustainable development, the ecotourism and the sustainable fisheries. This way, the local population can learn methods for a better use of terrestrial and marine ecosystems (Instituto de Desenvolvimento Sustentável e Meio Ambiente, IDEMA, 2003).

Guaraíras Lagoon

Guaraíras is a shallow lagoon subject to intense human impacts, including shrimp aquaculture, urban expansion and agricultural activities, and is therefore vulnerable to eutrophication. Guaraíras is part of a lagoon complex called the "Complexo Lagunar Estuarino Nísia Floresta-Papeba-Guaraíras", consisting of three interconnected lagoons of which Guaraíras is the largest. The lagoon is about 7 km long, and is a shallow estuarine lagoon with depths ranging from 0.5 to 2 m and up to 11 m in the narrow channels. The lagoon is part of the Rio Jacú hydrographic basin, and this river supplies the main inflow of fresh water, in the innermost part of the lagoon (Almeida *et al.*, 2012).

Sampling design and identification

Sampling has followed a hierarchical design according to the criteria adopted for a large scale survey, which is currently in progress in various worldwide eco-regions (POR Strategic Project) (see, Durante *et al.*, 2013; Roselli *et al.*, 2013; Stanca *et al.*, 2013b; 2013c; for other world eco-regions) (for further information see the web site: http://phytobioimaging.unisalento.it/en-us/studysites/samplingdesign.aspx).

The study was carried out during four days of November 2012. Three sampling stations were set up for each site inside in each lagoon. At each station, three samples for the phytoplankton study were collected using a 6µm net.

The water samples were fixed with Lugol's solution. Phytoplankton analysis was carried out on preserved subsamples. Taxonomic identification was performed on a sub-sample of 400 cells at 400× magnification under an inverted microscope (Nikon Eclipse T*i*-S) connected to a video interactive image analysis system (L.U.C.I.A, Version 4.8, Laboratory Imaging Ltd., Prague) with a lower detection limit of 5 µm following Utermöhl's method (Utermöhl, 1958). For more detailed identification was used an inverted microscope Nikon Eclipse T*i*-E coupled with an image analysis system (NIS–Elements AR Nikon Instruments software, version 3.06).

Taxonomic identification of the nano-microphytoplankton was done using specific manuals and appropriate monographs: Van Heurck, 1880-1885; Rattray, 1888; Wolle, 1894; Boyer, 1926; Cupp, 1943; Graham and Bronikovsky, 1944; Crosby and Wood, 1958, 1959; Wood *et al.* 1959; Wood, 1963; Balech, 1964, 1973; Gopinathan, 1975; Rampi and Bernhard, 1978, 1980; Dodge, 1982; Ricard, 1987; Sournia, 1986, 1987; Balech, 1988; Chrétiennot-Dinet, 1990; Round *et al.* 1990; Tomas, 1997; Bérard-Therriault *et al.*, 1999; Faust and Gulledge, 2002; Cortés-Altamirano and Sierra-Beltrán 2003; Hallegraeff *et al.*, 2003; Tenenbaum *et al.*, 2004; Cox, 2006; Ferrari *et al.*, 2007; Sar *et al.*, 2007; Okolodkov, 2008; Haraguchi and Odebrecht, 2010; Lee and Lee, 2011.

The "cf." qualifier was used to indicate specimens that were similar to (or many actually be) the nominate species. Taxa which contain "undet." (undetermined) identifier were likely to be algal entities, but could not be identified as any knows genus. In some cases, species were broken out into separate taxa based on size (e.g., Dinophyceae undet .> 20 µm).

During phytoplankton identification, sometimes is not possible to identify the organism to the species level, though recognizing common characteristics within a group of cells belonging to the same genus. In this case, to identify that organism in the phytoplankton list is reported the name of the genus followed by numbered "sp." (e.g. *Chaetoceros* sp.11, *Chaetoceros* sp.12, etc).

The complete list, including all numbered species, is available on the website www.phytobioimaging.unisalento.it.

Results and Discussion

For the three lagoons, a total of 124 taxa were identified, among which 44 to the species level and 64 to the genus level (Appendix 1). For 16 taxa, the identification to the genus level was not achieved.

The phytoplankton community of the all lagoons shows the same structure, with a predominance of diatoms (96% of the total number of cells). For this group, 92 taxa were identified belonging to 46 genera. The most numerous class was Bacillariophyceae, with 39 taxa identified belonging to 18 genera; Coscinodiscophyceae recorded 39 taxa belonging to 21 genera and Fragilariophyceae recorded 14 taxa belonging to 7 genera. The class Dinophyceae (dinoflagellates) was represented by 15 taxa belonging to 6 genera and the Cyanophyceae was represented by 8 taxa belonging to 5 genera, including *Trichodesmium erythraeum* Ehrenberg, related to toxic blooms when in large scale (Krishnan et al., 2007). For the other classes, Dictyochophyceae and Chlorophyceae were represented by 2 taxa, in both cases, belonging to a single genus. Only one taxon was recorded for both Euglenophyceae and Prasinophyceae, respectively. The identification was not achieved to the genus level for Cryptophyceae and phytoflagellates.

Galinhos Lagoon

A total of 61 taxa were identified in the Galinhos lagoon. The most representative class was Bacillariophyceae with 20 taxa, belonging to 10 genera. Within these, most numerous genus was *Pseudo-nitzschia* with 4 taxa identified. Coscinodiscophyceae was second dominant class, with 19 taxa belonging to 13 genera. The genus *Cyclotella* was the most representative, with 3 taxa identified. Next, the classes Dinophyceae appear with 10 taxa belonging to 3 genera. The genus *Prorocentrum* was the most representative, with 4 taxa. Fragilariophyceae recorded 7 taxa and 5 genera. Inside the last class, the most representative species *Thalassionema nitzschioides* (Grunow) Mereschkowsky responds for almost 50% of all phytoplankton community of Galinhos lagoon. For the other classes: 2 taxa were found for Dictyochophyceae, both belonging to the same genus; Cryptophyceae, Cyanophyceae and phytoflagellates identification was not achieved to the genus level. These last three classes represent 10% of the community, in terms of numerical abundance.

Diogo Lopes Lagoon

Among the three lagoons studied, Diogo Lopes lagoon shows the highest species richness, with 81 taxa identified. The most representative class was Bacillariophyceae with 25 taxa belonging to 15 genera. The most representative genus was *Nitzschia*, with 3 taxa recorded. In terms of numerical abundance, however, the taxon *Navicula* spp. was the most numerous, representing 21% of the phytoplankton community found in this lagoon. The second most representative class was Coscinodiscophyceae with 23 taxa belonging to 12 genera. The most representative genus was *Chaetoceros*, with 7 taxa identified. However, the most numerous taxon was *Cyclotella* sp.3, responding for 12% of the total phytoplankton, in terms of cells numerical abundance. 11 taxa (4 genera) were identified for Dinophyceae and the most representative genus was *Prorocentrum*, with 4 taxa identified. Fragilariophyceae recorded 10 taxa (7 genera). The genus *Thalassionema* was the most representative, with 3 taxa identified. On the other hand, *Ceratoneis closterium* was the most representative taxon, contributing to 27% of total cells numerical abundance. For this lagoon, the class

Cyanophyceae was represented by 8 taxa among which *Trichodesmium erythraeum*. The class Chlorophyceae recorded 2 taxa belonging to one only genus. Cryptophytes and phytoflagellates were not identified to the genus level.

Guaraíras Lagoon

78 taxa were identified in Guaraíras lagoon. The most representative class, as happened in the other lagoons, was Bacillariophyceae with 25 taxa belonging to 14 genera. The most representative genus was *Nitzschia*, with 4 taxa identified. For the class Coscinodiscophyceae were identified 24 taxa, belonging to 15 genera and the most representative was *Chaetoceros*, with 4 taxa identified. Nevertheless, the taxon *Cyclotella* sp.1 was the most representative, responding by 55% of the total number of cells sampled in the lagoon. Two genera of Fragilariophyceae (13 taxa, 7 genera) had equal representation, *Grammatophora* and *Thalassionema*, with 4 taxa recorded in each. The class Dinophyceae recorded 9 taxa (5 genera). The most representative genus was *Prorocentrum* with two taxa. Euglenophyceae, Dictyochophyceae and Prasinophyceae recorded only one taxon, respectively. The class Cyanophyceae was represented by 2 taxa, one of them *Trichodesmium erythraeum* Ehrenberg, also found in Diogo Lopes lagoon. Because of the small size of the cells, cryptophytes and phytoflagellates were not identified to the higher taxonomic level.

Conclusion

The massive presence of diatoms indicates, as expected in a shallow lagoon environment, a non-stable area with high bottom influence. In marine environments, the presence of diatoms represents an water column unstable and subject to high mixing. This group is characteristic of areas with natural eutrophication and suspension of nutrients accumulated on the bottom (Tenenbaum *et al.*, 2007).

For a Brazilian coastal area, particularly for a shallow area, Masuda (2009) found the predominance of elongated and chain-form diatoms. According to the author, these “shapes” have a better response to unstable environments when compared to others cells shapes; on the other hand selective effects of phytoplankton cell shape and size have already been observed (Stanca *et al.*, 2013a). In two of the three lagoons here studied, the elongated forms are present in large numbers and represent, in one of them, 50% of the whole community.

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References

Almeida LR, Costa IS, Eskinazi-Sant'Anna EM 2012. Composition and abundance of zooplankton community of an impacted estuarine lagoon in Northeast Brazil. *Brazilian Journal of Biology* 72(1): 13-24.

Azevedo AOD, Holanda JS, Scudelari AC 2009. Dynamic of Heavy Metals in the Shrimp Farm Environment. *Journal of Coastal Research* 56(2): 1174-1178.

Balech E 1964. Tercera contribucion al conocimiento del genero «*Peridinium*». *Revista del Museo Argentino de Ciencias Naturales “Bernardino Rivadavia”* 1(6): 179-330.

Balech E 1973. Cuarta contribucion al conocimiento del genero «*Protoperidinium*». *Revista del Museo Argentino de Ciencias Naturales "Bernardino Rivadavia"* 3(5): 347-368.

Balech E 1988. *Los Dinoflagelados del Atlantico Sudocidental*. Instituto Español de Oceanografia (Publicaciones especiales), Madrid, Spain.

Basset A, Barbone E, Elliott M, Li B-L, Jorgensen SE, Lucena-Moya P, Pardo I, Mouillot D 2013a. A unifying approach to understanding transitional waters: fundamental properties emerging from ecotone ecosystems. *Estuarine, Coastal and Shelf Science*, http://dx.doi.org/10.1016/j.ecss.2012.04.012

Basset A, Elliott M, West RJ, Wilson JG 2013b. Estuarine and lagoon biodiversity and their natural goods and services. *Estuarine and Coastal Shelf Science*, http://dx.doi.org/10.1016/j.ecss.2013.05.018

Bérard-Therriault L, Poulin M, Bossé L 1999. Guide d'identification du phytoplancton marin de l'estuaire et du Golfe du Saint-Laurent incluant également certains protozoaires. *Publication Spéciale Canadienne des Sciences Halieutiques et Aquatiques* 128: 1-387.

Bernardi Aubry F, Acri F, Bianchi F, Pugnetti A 2013. Looking for patterns in the phytoplankton community of the Mediterranean microtidal Venice Lagoon: evidence from ten years of observations. *Scientia Marina* 77(1): 47-60.

Boyer CS 1926. Supplement: Synopsis of North American Diatomaceae. Part I. Coscinodiscatae, Rhizoselenatae, Biddulphiatae, Fragilariatae. *Proceedings of the Academy of Natural Sciences of Philadelphia* 78: 1-228.

Chrétiennot-Dinet MJ 1990. *Atlas du Phytoplancton Marin Vol. III: Chlorarachniophycées, Chlorophycées, Chrysophycées, Cryptophycées, Euglenophycées, Eustigmatophycées, Prasino phycées,Prymnésiophycées, Rhodophycées et Tribophycées*. Éditions du C.N.R.S., Paris.

Cortés-Altamirano R, Sierra-Beltrán AP 2003. Morphology and taxonomy of *Prorocentrum mexicanum* and reinstatement of *Prorocentrum rhathymum* (Dinophyceae). *Journal of Phycology* 39: 221–225.

Cox EJ 2006. *Achnanthes* sensu stricto belongs with genera of the Mastogloiales rather than with other monoraphid diatoms (Bacillariophyta). *European Journal of Phycology* 41: 67-81.

Crosby LH, Wood EJF 1958. Studies on Australian and New Zealand diatoms I. – Planktonic and allied species. *Transaction of the Royal Society of the New Zealand* 85: 483–530.

Crosby LH, Wood EJF 1959. Studies on Australian and New Zealand diatoms II. – Normally epontic and benthic genera. *Transaction of the Royal Society of the New Zealand* 86: 1–58.

Cupp EE. 1943 *Marine Plankton Diatoms of the West Coast of North America*. Otto Koeltz Science Publishers, Koenigstein, Germany.

Dodge JD 1982. *Marine Dinoflagellates of the British Isles*. Her Majesty's Stationery Office, London, UK.

Durante G, Stanca E, Roselli L, Basset A 2013. Phytoplankton composition in six extreme Northern Scotland lagoons (Orkney Islands). *Transitional Water Bulletin* 7 (2): 159-174.

Esteves FA, Caliman A, Santangelo JM, Guariento RD, Farjalla VF, Bozelli RL 2008. Neotropical coastal lagoons: An appraisal of their biodiversity, functioning, threats and conservation management. *Brazilian Journal of Biology* 68(4): 967-981.

Faust MA, Gulledge RA 2002. Identifying harmful marine dinoflagellates. *Contributions from the United States National Herbarium* 42: 1-144.

Ferrari F, Knechtel Procopiak L, Benaion Alencar Y, Alvim Veiga Ludwig T 2007. Eunotiaceae (Bacillariophyceae) em igarapés da Amazônia Central, Manaus e Presidente Figueiredo, Brasil. *Acta Amazonica* 37 (1):1-16

Gopinathan CP 1975. On new distributional records of plankton diatoms from the Indian Seas. *Journal of the Marine Biological Association of India* 17(1): 223-240.

Graham HW, Bronikovsky N 1944. The Genus *Ceratium* in the Pacific and North Atlantic Oceans. Biology V. Carnegie Institution of Washington Publication 565, Washington, D. C.

Hallegraeff GM, Anderson DM, Cembella AD 2003. *Manual on harmful marine microalgae.* UNESCO, Paris.

Haraguchi L, Odebrecht C 2010. Dinophysiales (Dinophyceae) no extremo Sul do Brasil (inverno de 2005, verão de 2007). *Biota Neotropica* 10(3): 101-114.

Härnström K, Karunasagar I, Godhe A 2009. Phytoplankton species assemblages and their relationship to hydrographic factors-a study at the old port in Mangalore, coastal Arabian Sea. *Indian Journal of Marine Sciences* 38(2): 224-234.

Instituto de Desenvolvimento Sustentável e Meio Ambiente do RN, Reserva de Desenvolvimento Sustentável Estadual Ponta do Tubarão, IDEMA 2003. Available from: http://www.idema.rn.gov.

br/contentproducao/aplicacao/idema/unidades_de_conservacao/gerados/ponta_do_tubarao.asp

Kjerfve B 1994. Coastal Lagoons In Kjerfve B, Baruch BW (ed). *Coastal Lagoon Processes*. Elsevier Science Publishers. Elsevier Oceanography Series, 60: 1-8.

Krishnan AA, Krishnakumar PK, Rajagopalan M 2007. *Trichodesmium erythraeum* (Ehrenberg) bloom along the southwest coast of India (Arabian Sea) and its impact on trace metal concentrations in seawater. *Estuarine, Coastal and Shelf Science* 71: 641-646.

Lee SD, Lee JH 2011. Morphology and taxonomy of the planktonic diatom *Chaetoceros* species (Bacillariophyceae) with special intercalary setae in Korean coastal waters. *Algae* 26(2): 153-165.

Margalef R 1963. On certain unifying principles in ecology. *The American Naturalist* 97(897): 357-374.

Masuda LSM2009. Composição e distribuição dos organismos fitoplactônicos na região do Banco de Abrolhos, Bahia.(MSc) Thesis, Universidade Estadual de Santa Cruz, Ilhéus, Brazil.

Nuccio C, Melillo C, Massi L, Innamorati M 2003. Phytoplankton abundance, community structure and diversity in the eutrophicated Orbetello lagoon (Tuscany) from 1995 to 2001. *Oceanologica Acta* 26(1): 15-25.

Okolodkov YB 2008. *Protoperidinium* Bergh (Dinophyceae) of the National Park Sistema Arrecifal Veracruzano, Gulf of Mexico, with a key for identification. *Acta botánica mexicana* 84: 93-149.

Pilkaityte R, Razinkovas A 2007. Seasonal changes in phytoplankton composition and nutrient limitation in a shallow Baltic lagoon. *Boreal environment research* 12(5): 551-559.

Pitcher GC, Brown PC, Mitchell-Innes BF 1992. Spatio-temporal variability of phytoplankton in the southern Benguela upwelling system. *African Journal of Marine Science* 12: 439-456.

Rampi L, Bernhard R 1978. *Chiave per la determinazione delle Diatomee pelagiche Mediterranee*. Comitato Nazionale Energia Nucleare, CNEN-RT/B10, 80, 8, Roma.

Rampi L, Bernhard R 1980. *Chiave per la determinazione delle Peridinee pelagiche Mediterranee*. Comitato Nazionale Energia Nucleare, CNEN-RT/B10, 80, 8, Roma.

Rattray J MA, B.Sc., F.R.S.E.A 1888. Revision of the Genus *Auliscus* Ehrb. and of some allied Genera. *Journal of the Royal Microscopical Society* 8(6): 861–920.

Ricard M 1987. *Atlas du phytoplancton marin. Vol. 2: Diatomophyceés*. Centre National de la Recherche Scientifique, Paris.

Roselli L, Stanca E, Ludovisi A, Durante G, Souza JSD, Meltem Dural, Tahir Alp, Gioni S, Ghinis S, Basset A 2013. Multi-scale biodiversity patterns in phytoplankton from coastal lagoons: the eastern Mediterranean Sea. Transitional Water Bulletin 7 (2): 202-219.

Round FE, Crawford RM, Mann DG 1990. *The diatoms. Biology and morphology of the genera*. Cambridge University Press, USA.

Santiago MF 2004. Ecologia do fitoplâncton de um ambiente tropical hipersalino (rio Pisa Sal, Galinhos, Rio Grande do Norte, Brasil), (MSc) Thesis, Universidade Federal de Pernambuco, Recife, Brazil.

Santiago MF, Passavante JZO, Silva-Cunha MGG 2005. Caracterização de parâmetros físicos, químicos e biológico em ambiente hipersalino, estuário do rio Pisa Sal (Galinhos, Rio Grande do Norte, Brasil). *Tropical Oceanography* 33(1): 39-55.

Santos DAS 2003. Mapeamento da área submersa da laguna de Diogo Lopes - Barreiras (RN), Degree's Report, Universidade Federal do Rio Grande do Norte, Natal, Brazil.

Santos Jr. OF, Scudelari AC, Costa YD, Costa CM 2011. Sea cliff retreat mechanisms in northeastern Brazil. *Journal of Coastal Research* 64: 820-824.

Sar EA, Sunesen I, Fernández PV 2007. Marine diatoms from Buenos Aires coastal waters (Argentina) II. Thalassionemataceae and Rhaphoneidaceae. *Revista Chilena de Historia Natural* 80: 63-79.

Simon N, Cras A-L, Foulon E, Lemée R 2009. Diversity and evolution of marine phytoplankton. *Comptes Rendus Biologies* 332: 159-170.

Smetacek V 1988. Plankton Characteristics. In Postma H, Zijlstra JJ *Ecosystems of the World-Continental Shelves*, Elsevier, Amsterdam, Netherlands, 93-130.

Sournia A 1986. *Atlas du phytoplancton marin. Volume I: Introduction, Cyanophycées, Dictyochophycées, Dinophyceés et Raphidophycées*. Éditions du C.N.R.S., Paris.

Sournia A 1987. *Atlas du phytoplancton marin, Volume 2 : Diatomophycées*, par M. Ricard. Éditions du C.N.R.S., Paris.

Stanca E, Cellamare M, Basset A 2013a - Geometric shape as a trait to study phytoplankton distributions in aquatic ecosystems. *Hydrobiologia* 701: 99-116.

Stanca E, Roselli L, Cellamare M, Basset A 2013b. Phytoplankton composition in the coastal Magnetic Island Lagoon, Western Pacific Ocean (Australia). *Transitional Water Bulletin* 7 (2): 145-158.

Stanca E, Roselli L, Durante G, Seveso D, Galli P, Basset A. 2013c. A checklist of phytoplankton species in the Faafu Atoll (Republic of Maldives). *Transitional Water Bulletin* 7 (2): 133-144.

Tenenbaum DR, Villac MC, Viana SC, Matos MCFG, Hatherly MMF, Lima IV, Menezes M 2004. *Phytoplankton Identification Atlas – Sepetiba Bay, Brazil.* 1. ed. International Maritime Organization, London, UK.

Tenenbaum DR, Gomes EAT, Guimarães GP 2007. Microorganismos planctônicos: pico, nano e micro. In: VALENTIN, J. L. *Características hidrobiológicas da região central da Zona Econômica Exclusiva brasileira (Salvador, BA, ao Cabo de São Tomé, RJ)*. Série Documentos REVIZEE/SCORE-Central. Brasília, Brazil.

Tomas RC 1997. *Identifying Marine Phytoplankton*. Academic Press, San Diego, California, USA.

Utermöhl H 1958. Zur Vervollkomnung der quantitativen Phytoplankton Methodik. *Mitteilungen der Internationalen Vereinigung für Limnologie* 9: 1–38.

Van Heurck H 1880-1885. *Synopsis des Diatomées de Belgique.* Ed. H. Van Heurck, Anvers.

Wolle F 1894. *Diatomaceæ of North America, illustrated with twenty-three hundred figures from the author's drawings on one hundred and twelve plates*. Comenius Press, Bethlehem, USA.

Wood EJF, Crosby LH, Cassie V 1959. Studies on Australian and New Zealand Diatoms. III. – Descriptions of further discoid species. *Transaction of the Royal Society of the New Zealand* 87: 211–219.

Wood EJF 1963. Dinoflagellates in the Australian Region II. Recent Collections. *Division of Fisheries and Oceanography Technical Paper* 14: 509-563.

Appendix 1 - List of taxa identified during sampling period in the three Brazilian lagoons.

Lagoon	**Galinhos**	**Diogo Lopes**	**Guaraíras**
Bacillariophyta			
Bacillariophyceae			
Achnanthes cf. *longipes*		x	
Achnanthes spp.		x	
Amphiprora spp.		x	x
Amphora spp.		x	
Bacillaria paxillifera (O.F. Müller) T. Marsson 1901	x	x	x
cf. *Achnanthes* sp.		x	
Cocconeis scutellum Ehrenberg 1838	x	x	x
Cocconeis spp.	x	x	x
Diploneis crabro (Ehrenberg) Ehrenberg 1854	x	x	
Diploneis spp.	x	x	x
Entomoneis alata (Ehrenberg) Ehrenberg 1845	x	x	x
Eunotia cf. *depressa*			x
Fragilariopsis sp.			x
Fragilariopsis sp.1	x	x	x
Fragilariopsis sp.2	x	x	x
Membraneis cf. *challengeri*		x	
Meuniera membranacea (Cleve) P.C.Silva in Hasle & Svertsen 1996			x
Navicula transitans Cleve 1883	x	x	x
Navicula spp.	x	x	x
Nitzschia cf. *sigma*		x	x
Nitzschia sigmoidea (Nitzsch) W.Smith		x	x
Nitzschia spp.	x	x	x
Pinnularia spp.		x	
Plagiotropis cf. lepidoptera	x		
Plagiotropis spp.			x
Pleurosigma angulatum W.Smith 1852	x		
Pleurosigma sp.1	x		
Pleurosigma spp.	x	x	x
Pseudo-nitzschia seriata (Cleve) H.Peragallo in H.Peragallo & M.Peragallo 1899	x		
Pseudo-nitzschia sp.3	x		
Pseudo-nitzschia sp.4	x	x	
Pseudo-nitzschia spp.	x	x	x
Surirella spp.		x	x
Bacillariophyceae centrales undet.			x
Bacillariophyceae pennales undet.	x	x	
Bacillariophyceae undet. 1			x

Appendix 1 - Continued.

Lagoon	Galinhos	Diogo Lopes	Guaraíras
Bacillariophyta			
Bacillariophyceae			
Bacillariophyceae undet. 2			x
Bacillariophyceae undet. 3			x
Coscinodiscophyceae			
Auliscus sculptus (W.Smith) Brightwell			x
Bellerochea horologicalis Stosch 1980		x	
Bellerochea spp.	x		
Biddulphia spp.	x	x	x
Cerataulina pelagica (Cleve) Hendey 1937	x		
Chaetoceros didymus Ehrenberg 1845		x	
Chaetoceros laevis G.Leuduger-Fortmorel 1892		x	x
Chaetoceros simplex Ostenfeld in Ostenfeld & Schmidt 1901	x	x	
Chaetoceros wighamii Brightwell 1856		x	
Chaetoceros sp.11		x	x
Chaetoceros sp.12		x	x
Chaetoceros spp.	x	x	x
Coscinodiscus spp.			x
Cyclotella cf. *litoralis*	x		x
Cyclotella sp.1	x	x	x
Cyclotella sp.3	x	x	x
Cymatosira spp.	x		
Dactyliosolen fragilissimus (Bergon) Hasle in Hasle & Syvertsen 1996	x		
Guinardia delicatula (Cleve) Hasle in Hasle & Syvertsen 1997	x	x	x
Guinardia striata (Stolterfoth) Hasle in Hasle & Syvertsen 1996			x
Lithodesmium undulatum Ehrenberg 1839			x
Melosira nummuloides C.Agardh 1824		x	
Melosira spp.		x	
Odontella cf. *longicornis*		x	
Odontella sinensis (Greville) Grunow 1884		x	
Odontella spp.	x	x	x
Paralia spp.	x	x	x
Paralia sulcata (Ehrenberg) Cleve 1873	x	x	x
Pleurosira laevis (Ehrenberg) Compère			x
Rhizosolenia setigera Brightwell 1858	x	x	x

Appendix 1 - Continued.

Lagoon	Galinhos	Diogo Lopes	Guaraíras
Bacillariophyta			
Coscinodiscophyceae			
Rhizosolenia spp.	x		
Skeletonema costatum (Greville) Cleve 1873		x	
Terpsinoë musica Ehrenberg			x
Terpsinoë sp.			x
Thalassiosira sp.4			x
Thalassiosira spp.	x	x	x
Thalassiosiraceae undet.	x		
Triceratium cf. *favus*	x		
Tropidoneis spp.		x	x
Fragilariophyceae			
Asterionellopsis glacialis (Castracane) Round in Round, R.M.Crawford & D.G.Mann 1990	x	x	x
Ceratoneis closterium Ehrenberg 1839	x	x	x
Climacosphenia sp.		x	x
Grammatophora cf. *serpentina*			x
Grammatophora marina (Lyngbye) Kützing 1844	x	x	x
Grammatophora oceanica Ehrenberg 1840			x
Grammatophora spp.	x	x	x
Licmophora flabellate (Grev.) C.Agardh 1831		x	
Licmophora spp.	x	x	x
Podocystis spp.			x
Thalassionema nitzschioides (Grunow) Mereschkowsky 1902	x	x	x
Thalassionema pseudonitzschioides (G.Schuette & H.Schrader) G.R.Hasle		x	x
Thalassionema synedriforme (Greville) G.R.Hasle	x	x	x
Thalassionema spp.			x
Chlorophyta			
Chlorophyceae			
Scenedesmus sp.3		x	
Scenedesmus sp.8		x	
Prasinophyceae			
Pyramimonas spp.		x	x
Cryptophyta			
Cryptophyceae			
Cryptophyceae undet.2		x	x
Cryptophyceae undet.	x		

Appendix 1 - Continued.

Lagoon	Galinhos	Diogo Lopes	Guaraíras
Cyanobacteria			
Cyanophyceae			
Anabaena spp.		x	
Gomphosphaeria aponina Kützing		x	
Merismopedia spp.		x	
Spirulina cf. *tenerrima*		x	
Trichodesmium erythraeum Ehrenberg		x	x
Cyanophyceae undet.1		x	
Cyanophyceae undet.2		x	
Cyanophyceae undet.3	x	x	x
Dinophyta			
Dinophyceae			
Ceratium teres Kofoid 1907			x
Gymnodinium spp.			x
Oxytoxum spp.		x	
Prorocentrum micans Ehrenberg 1834	x	x	x
Prorocentrum rhatymum Loeblich, Sherley & Schmidt, 1979	x	x	
Prorocentrum scutellum Schröder 1900	x		
Prorocentrum sp.1		x	
Prorocentrum spp.	x	x	x
Protoperidinium sp.4	x		
Protoperidinium spp.	x	x	x
Scrippsiella trochoidea (Stein) Balech ex Loeblich III 1965		x	
Scrippsiella spp.	x	x	x
Dinophyceae athecate undet.1 (>20µm)	x	x	x
Dinophyceae thecate undet.1 (>20µm)	x	x	x
Dinophyceae thecate undet.2 (<20µm)	x	x	x
Euglenophyta			
Euglenophyceae			
Euglena spp.			x
Ochrophyta			
Dictyochophyceae			
Dictyocha fibula Ehrenberg 1839	x		
Dictyocha spp.	x		
Other			
Phytoplagellates undet.	x	x	x