Journal of Coastal Research	SI	75	512-516	Coconut Creek, Florida	2016

Spatial-Temporal Variability of the Thermohaline Properties in the Coastal Region of Fernando de Noronha Archipelago, Brazil

RamillaV. Assunção[†*], Alex C. Silva[†], José Martins[‡], and Manuel Flores Montes[††]

[†] Laboratório de Oceanografia Física Estuarina e Costeira - Departamento de Oceanografia
Universidade Federal de Pernambuco
Recife, Brazil

[‡]Spinner Dolphin
Fernando de Noronha Island, Brazil

[††]Laboratório de Oceanografia Química
Departamento de Oceanografia
Universidade Federal de Pernambuco
Recife, Brazil

www.cerf-jcr.org

www.JCRonline.org

ABSTRACT

Assunção, R.V.; Silva, A.C.; Martins, J., and Flores Montes, M., 2016. Spatial-Temporal variability of the thermohaline properties in the coastal region of Fernando de Noronha Archipelago, Brazil. *In:* Vila-Concejo, A.; Bruce, E.; Kennedy, D.M., and Mc Carroll, R.J. (eds.), *Proceedings of the 14th International Coastal Symposium* (Sydney, Australia). *Journal of Coastal Research*, Special Issue, No. 75, pp. 512-516. Coconut Creek (Florida), ISSN 0749-0208.

Brazilian oceanic islands are areas of great environmental, scientific, economic and strategic interest for the country. A better understanding of the thermohaline and hydrodynamic properties is fundamental to complement studies of chemical and biological processes active on the Fernando de Noronha archipelago, located between 03° 52'S and 32° 25'W. The aim of this work was to verify the coastal thermohaline behavior of the most inhabited part of the island, on a seasonal and spatial scale and how it is associated with the nutrient distribution data. Four campaigns were conducted in 2013 and 2014, two during the wet season and two during the dry season. For each period, data were collect at five stations. The results show that during the rainy season temperature increases and salinity decreases in the surface layer. Spatially no large differences are observed. Regarding to nutrient concentration, seasonal concentrations are quite homogeneous in the waters of the archipelago region. The coastal region was characterized by tropical mass water.

ADDITIONAL INDEX WORDS: *Island, nutrient, thermohaline properties.*

INTRODUCTION

Time series oceanographic observations are important not only for identifying processes in ecosystems, but also the effect of climate variability, water circulation, anthropogenic perturbations and the prognostic models used in future climate projections. Some climate change impacts, such as increases in precipitation, frequency and intensity of storms, and warmer ocean temperature, will occur quickly in response to increasing global temperatures (IPCC, 2013).

Over the long term, increases in sea surface temperature (SST) could also reduce circulation patterns that bring nutrients from the deep sea to surface waters. Increases in SST due to global warming are projected to intensify the stratification of the water column and strengthen the barrier to the transfer of nutrients created by thermocline (Gierach, 2013). In the warm pool, projected increases in rainfall will reduce salinity and increase stratification further (Ganachaud *et al.*, 2011).

The coastal and insular area around Fernando de Noronha Archipelago is a strategic area for monitoring climate change effects in Northeast Brazil. It also plays a key role in the process of reproduction, dispersal and colonization of marine organisms in the entire Tropical South Atlantic (REVIZEE, 2006).

Considering the importance of understanding the dynamic around the archipelago, this study aims to investigate for the first time changes in the spatiotemporal thermohaline pattern and the nutrient distributions in the coastal area of the Fernando de Noronha Archipelago.

Study Area

The Fernando de Noronha archipelago is formed by 21 islands and islets, located in the South Equatorial Atlantic Ocean, between 03°52'S and 32°25'W. Its main island, which has the same name of the archipelago, comprises 91% of the total area of the archipelago (Figure 1).

Due to the morphological layout of the island, that is composed by two sides which are more or less exposed to the action of winds and ocean currents, two types of sea can be highlighted around the island, the inside sea, which is more protected and the outside sea, more exposed.

The climate of the archipelago is tropical (Awi of Koppen classification system) and influenced by the Atlantic Ocean. There are two well-marked seasons, the rainy from March to

DOI: 10.2112/SI75-103.1 received 15 October 2015; accepted in revision 15 January 2015
*Corresponding author: ramillassuncao@hotmail.com

July and the dry from August to January (Almeida, 2006; Mohr *et al.*, 2009).

The archipelago is washed by the waters brought by the central branch of the South Equatorial Current (cSEC), flowing from east to west, which extends from the surface up to a nominal depth of 100 m, and by the South Equatorial UnderCurrent (SEUC), which moves in direction from west to east. The cSEC is located between the SEUC (3°S-5°S), and the South Equatorial Counter Current (6°S-9°S) (Peterson and Stramma, 1991).

The structure of the water column that surrounds Noronha usually presents a characteristic profile of the South Atlantic waters, with the presence of the following water masses: Tropical Surface Water (TSW), South Atlantic Central Water (SACW), Antarctic Intermediate Water (AAIW) and the North Atlantic Deep Water (NADW) (Stramma and England, 1999; Silva *et al.*, 2005).

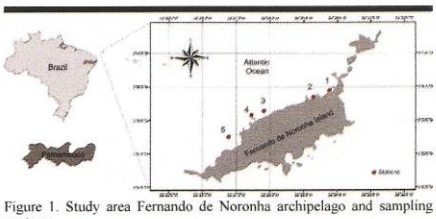

Figure 1. Study area Fernando de Noronha archipelago and sampling stations.

Fernando de Noronha is a marine national park protected legally by the Institute of Environmental Preservation of the Brazilian government - Chico Mendes Institute for the Conservation of the Biodiversity - ICMBio. The island is considered of utmost importance not just for maintenance of local biodiversity, but also as a feeding and rest area for large pelagic fishes that perform transoceanic migrations, such as tuna and billfish.

METHODS

The data were collected during four oceanographic campaigns in the portion of the inside sea in Fernando de Noronha Island. Two campaigns were in 2013 (July and December) and two in 2014 (June and November). For each year samples were collected during both rainy and dry seasons.

The physical parameters (temperature, salinity and density) along the water column were obtained from CTD equipment - Sea Bird Electronics (SBE) 911plus. The CTD is equipped with a centrifugal pump and high resolution sensors for conductivity measurements (resolution = 0.00004sm^{-1}), temperature (resolution = 0.0003°C) and pressure (resolution = 0,068db). Moreover, the raw data were processed, added to a database and then discussed.

In addition, water samples were collected to analyze the vertical distribution profiles and concentration of chemical parameters. Ninskin bottles were used to collect samples in the depths of the mixed layer. The samples were then stored in plastic bottles (previously decontaminated) kept frozen until the analysis.The dissolved inorganic nutrients (ammonia - NH_3, nitrite -NO_2 and nitrate -NO_3), the phosphorous - PO_4 and silicate - SiO_2 were analyzed through the method described by Grashoff *et al.* (1983) and Strickland and Parsons (1972).

RESULTS

Based on *in situ* observations obtained during four campaigns realized in July and December 2013 and in June and November 2014, temperature and salinity profiles were represented for the five stations distributed in the coastal region of the island (Figure 2A).

Temperature values obtained with CTD for the five stations distributed on the coast of Fernando de Noronha show that, in general, there were no large spatial variations of the vertical profiles within the same period. The minimum and maximum values during the rainy season of the year 2013 were respectively 27.42°C (Sta.2) and 27.70°C (Sta.3). For the same period of the year 2014 (June 2014), the minimum and maximum values obtained were 27.81°C (Sta.5) and 29.23°C (Sta.1), respectively.

The analysis of the profiles shows that, during the rainy season (Figure 2), sea surface temperature (SST) increased about 1°C, which was not observed during the dry season, neither spatially in a same period. As for salinity, temperatures collected during the rainy season of 2014 showed values slightly higher when compared to the previous year.

By analyzing the temperature values obtained during the dry season in 2013 and 2014, no significant difference was observed from one year to the next. Temperature recorded during 2013 reached maximum and minimum values of 27.53°C (Sta. 1) and 26.66°C (Sta. 5), respectively. It could also be highlighted that higher temperature values were obtained at stations 1 and 2. However, their profiles presented opposite patterns, as in Sta.1 temperature decreases with depth, contrary to what happens in Sta.2. Temperature recorded during 2014 reached maximum and minimum values of 27.10°C (Sta. 1) and 26.53°C (Sta. 4), respectively.

Likewise by analyzing the vertical distribution of sea surface salinity (SSS) in all stations during a same period, no significant difference was observed. For both years salinity values were higher during the dry season than during the rainy season.

By representing the thermohaline peers, adding sigma-t contours, a characteristic T-S diagram of sea state was obtained (Figure 2B). This diagram allows analyzing and identifying water masses, coastal region features the island as well as the degree of mixing between them. According to the data, the water mass surrounding to shallower coastal region of the island is the Tropical Surface Water (TSW). The T-S diagram shows different characteristics of TSW, water mass with higher salinity and lower temperature during the dry season and lower salinity and higher temperature during the rainy season.

The table 1 presents the concentration values obtained for the essential nutrients used in the primary productivity: ammonia (NH_3), nitrite (NO_2), nitrate (NO_3), phosphate (PO_4) and silicate (SiO_2). The results show that no significant differences were observed for nutrient concentrations, both spatially and temporally.

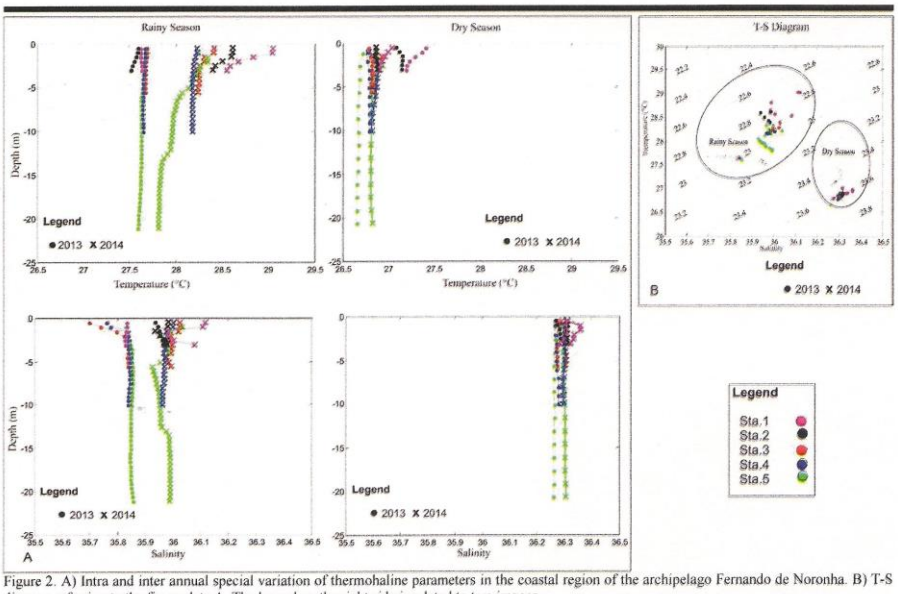

Figure 2. A) Intra and inter annual special variation of thermohaline parameters in the coastal region of the archipelago Fernando de Noronha. B) T-S diagram referring to the figure data A. The legend on the right side is related to two images.

Table 1. *Nutrient concentrations determined for each of the five stations. Ammonia (NH_3), nitrite (NO_2), nitrate (NO_3), phosphate (PO_4) and silicates (SiO2) in µmol.L-1. Amounts related the surface (S) and bottom (B). ND refers to values below the detection limit of the apparatus.*

			RAINY SEASON					DRY SEASON				
STATION	YEAR		NH3	NO2	NO3	PO4	SIO2	NH3	NO2	NO3	PO4	SIO2
1	2013	S	0.02	0.07	0.05	0.24	0.80	0.02	0.07	0.05	0.24	0.80
		B	--	0.08	ND	0.06	2.68	0.00	0.05	0.13	0.32	1.77
2	2013	S	0.01	0.02	0.10	0.23	1.16	0.01	0	0.03	0.23	1.16
		B	--	0.03	0.05	0.10	1.55	--	--	--	--	--
3	2013	S	0.01	0.12	0.10	0.12	1.44	ND	0.12	ND	0.12	1.44
		B	--	0.17	0.22	0.12	1.55	0.01	0.04	ND	0.18	0.76
4	2013	S	0.02	0.03	0.03	0.14	2.65	0.02	0.03	0.03	0.14	2.65
		B	--	0.01	ND	0.09	1.49	0.01	0.01	ND	0.18	1.09
5	2013	S	0.01	0.02	0.1	0.23	1.16	0.01	0.01	ND	0.17	1.03
		B		0.03	ND	0.08	2.50	0.01	0.00	0.21	0.13	0.96
1	2014	S	0.10	0.13	0.41	0.15	3.98	0.11	0.02	0.28	0.41	2.54
		B	--	--	--	--	--	--	--	--	--	--
2	2014	S	0.06	0.05	0.01	0.23	2.02	0.02	0.02	0.11	0.12	5.48
		B	--	--	--	--	--	0.08	0.02	ND	0.14	1.62
3	2014	S	0.03	0.17	0.22	0.12	1.55	0.02	0.02	0.11	0.12	2.05
		B	0.05	0.05	ND	0.13	1.96	0.04	0.02	ND	0.14	ND
4	2014	S	0.02	0.01	ND	0.09	1.49	0.02	0.02	0.01	0.11	1.91
		B	0.03	0.02	ND	0.09	0.95	0.02	0.02	0.07	0.13	1.25
5	2014	S	0.04	0.03	ND	0.08	2.50	0.02	0.02	ND	0.07	0.92
		B	0.02	0.03	ND	0.08	2.28	0.02	0.02	0.59	0.12	8.71

DISCUSSION

Data of precipitation (obtained by the Agência Pernambucana de Águas e Clima – APAC, a state agency on water and climate) are presented in Figure 3. By comparing the seasonal variation of monthly precipitation between 2013 and 2014, we could observe that for both years, higher levels of average precipitation for the rainy season were observed during the same period corresponding to higher SST and lower salinity values. In 2013 it presented a delay in the rainfall period compared to the year 2014 and the historical series (years 2003-2012).

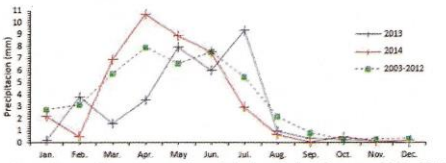

Figure 3. Monthly averages of precipitation during the years 2013–2014 and during the nine previous years (2003-2012).

Analysis of the SST monthly averages obtained by the MODIS-Aqua Satellite images with 4km resolution provided by NASA (Figure 4), corroborates the values found in this study, by identifying a warming of surface water during the rainy season (June and July) compared to the dry season.

Near Fernando de Noronha Archipelago, the SST obtained during the rainy season, for the month of June 2014, showed higher average value (27.8°C), compared to average monthly SST obtained for the month of July 2013 (27.5°C).

In June 2013 (not demonstrated in the figure) the SST near Fernando de Noronha Archipelago is 27.9°C.

During the rainy season low SSS is associated with warmer sea temperatures in the Atlantic Tropical. The salinity in the tropical ocean is projected to decrease due to the intensified hydrological cycle (Durack *et al.*, 2012).

The nutrient contents analyzed in the mixed layer exhibited concentrations specific to oligotrophic areas. The values obtained are near to the minimum detection level, and in many cases below this value, especially in relation to ammonia concentrations. This is one of the first products of organic matter mineralization, which is quickly oxidized to the more stable form, nitrate, also found in low concentrations, however higher than ammonia.

By comparing the median concentrations of nutrients, a subtle rise could be observed during the rainy season for both years, except for phosphate. Silicate was the nutrient that showed the highest variation between seasons, as well as greatest concentrations.

Silicate is an essential component, however, it does not enter into the cycle of organic matter but is an important component in the composition of the diatomaceous shells and exoskeletons of other organisms. Silicate does not fit between the most utilized components from a biological point of view, further, this element degrades slower, depending on alternating periods of greater or lesser use, according to population growth (Flores Montes, 2003).

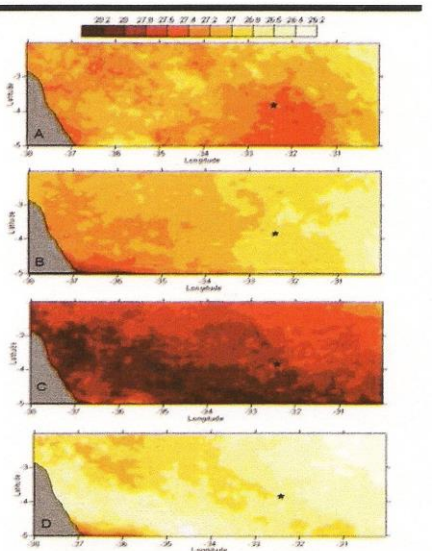

Figure 4. Satellite images showing the average variation of Sea Surface Temperature (SST) obtained during the months related to the four campaigns conducted in this study. A) July 2013; B) December 2013; C) June 2014; D) November 2014. The location of the archipelago (star) is identified in the images.

In terms of interannual seasonality, higher nutrient concentrations were detected in 2014, excepted for phosphate. Phosphate was the second nutrient with larger proportions. According to Aidar *et al.* (1993), phosphate ion regeneration is very fast in the water column, and can act as the limiting nutrient.

The variation of nutrient concentrations in the water column was quite low, however, there was, in general a small positive gradient from the bottom to the surface of the stations.

CONCLUSIONS

Variations of temperature and salinity in the surface layer were collected and analyzed during dry and rainy seasons. Results show that lower temperatures and higher salinity values were observed during the dry period for both years of 2013 and 2014. During rainy season low salinity was observed, which could be associated with warmer sea temperatures in the Atlantic Tropical near Fernando de Noronha Archipelago.

The nutrient data showed a nutritional deficit. Changes in nutrient concentration were very small from one period to another, between the stations and in the water column. Therefore

it is not possible to identify correlations with changes of the thermohaline properties.

The coastal region of Fernando de Noronha, in the inside sea region is characterized by the presence of Surface Tropical Water.

ACKNOWLEDGMENTS

This study had the support of the projects: 1) Study of Carbon Cycle Balance in the coastal region and its ocean transportation potential, with emphasis on the coast of Pernambuco (Edital FACEPE-FAPESP); 2) Total Organic Carbon transport and its interaction with the marine acidification processes, in ocean and estuarine-coastal environments northern and northeastern Brazil; and (3) Monitoring of Sea conditions off the coast of NE Brazil MC-MAR/NE (Edital FACEPE).

LITERATURE CITED

Aidar, E.; Gaeta, S.A.; Gianesella-Galvão, S.M.F.; Kutner, M.B.B., and Teixeira, C., 1993. Ecossistema costeiro subtropical: nutrientes dissolvidos, fitoplâncton e clorofila *a* e suas relações com as condições oceanográficas na região de Ubatuba, SP. *Publicação especial do Instituto Oceanográfico de São Paulo*, Brazil, 10, 9-43.

Almeida, F.F.M., 2006. Ilhas oceânicas brasileiras e suas relações com a tectônica atlântica. *Terra Didática*, 2, 3-18.

Durack, P.J.; Wijffels, S.E., and Matear, R.J., 2012. Ocean salinities reveal strong global water cycle intensification during 1950 to 2000. *Science*, 336(6080), 455-458.

Flores Montes, M. J., 2003. Fatores que influenciam na produtividade dos oceanos: a importância do fluxo de difusão dos nutrientes para a biomassa do fitoplâncton na região oceânica do nordeste brasileiro. Universidade Federal de Pernambuco, Tese de Doutorado (Recife, Brasil), 179p.

Ganachaud, A.; Gupta, A.S.; Orr, J.C.; Wijffels, S.E.; Ridgway, K.R.; Hemer, M.A.; MaesC.; Steinberg, C.R.; Tribollet, A.D.; QiuB., and Kruger J.C., 2011. Observed and Expected Changes to the Tropical Pacific Ocean, in: Bell, J.D.; Johnson J.E., and Hobday A.J. (Eds.), *Vulnerability of Tropical Pacific Fisheriesand Aquaculture to Climate Change, Secretariat of the Pacific Community*, Noumea, New Caledonia, 101-187.

Gierach, M. M.; Messié, M.; Lee, T.; Karnauskas, K.B.; and Radenac, M.-H., 2013. Biophysical responses near equatorial islands in the Western Pacific Ocean during El Niño/La Niña transitions. *Geophys. Res. Lett.*, 40(20), 5473-5479.

Grashoff, K.; Ehrhardt, K.M.; and Kremling, K., 1983. *Methods of Seawater Analysis*. 2 nd edn. Verlag Chemie, Weinheim, Germany, 317p.

IPCC (Intergovernmental Panel on Climate Change). 2013. *Climate change 2013: The physical science basis.* Working Group I contribution to the IPCC Fifth Assessment Report. Cambridge, United Kingdom: CambridgeUniversity Press. www.ipcc.ch/report/ar5/wg1.

Mohr, L.V.; Castro, J.W.A.; Costa, P.M.S., and Alves, R.J.V., 2009. *Ilhas oceânicas brasileiras: da pesquisa ao manejo*. Vol. II, MMA Secretaria de Biodiversidade e Floresta, Brasilia, Brasil, 496p. (In Portugese)

Peterson R.G., and Stramma, L., 1991. Upper-level circulation in the South Atlantic Ocean. *Prog. Oceanogr.*, 26(1), 1-73.

REVIZEE. 2006. *Avaliação do Potencial Sustentável de Recursos Vivos na zona Econômica Exclusiva*. Ministério do Meio Ambiente, Brasil, 303p. (In Portugese)

Silva, A.C.; Araújo, M., and Bourlès, B., 2005. Variação sazonal da estrutura de massas d'água na plataforma continental do Amazonas e área oceânica adjacente. *Revista Brasileira de Geofisica*, 23(2), 145-157. (In Portugese)

Stramma, L., and England, M., 1999. On the water masses and mean circulation of the South Atlantic Ocean. *J. Geophys. Res.*, 104(C9), 20863-20883.

Strickland J. D. H; Parsons T. R., 1972. A practical handbook of seawater analysis. 2nd edn, *Fish Res. Bd. Can. Bull.*, Ottawa, Bulletin, 167, 1-311.