A preliminary analysis of the distribution and spatial/temporal patterns of seabirds in the Laje de Santos Marine State Park (Santos, Brazil) and surrounding waters*

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Abstract

This study investigates the temporal taxonomic variation of the seabird community, and the spatial distributions of seabirds in the Laje de Santos Marine State Park (PEMLS) and surrounding waters, based on shipboard surveys. The increase in the number of seabird taxa during winter is associated to the presence of migratory birds from the south. During summer, only resident species were observed within the park. Analysis of the spatial distributions of taxa using geographic information systems (GIS) identified three different regions within the study area. The first was close to the coast, where birds interact with fishing activities in search for food; the second was the nesting area that provides shelter for the breeding colonies; and the third, which is farther offshore and more exposed, where a higher number of migratory birds were observed during winter surveys. The PEMLS and surrounding waters have characteristics that are important for the study and preservation of seabirds in Brazil and for the South Atlantic Ocean.

Descriptors: Laje de Santos Marine State Park, Seabirds, Seasonality, Spatial Distribution, Geoprocessing.

Resumo

Este trabalho tem como objetivo estudar a variação temporal da composição taxonômica e a distribuição espacial das aves marinhas que podem ser encontradas no Parque Estadual Marinho da Laje de Santos (PEMLS) e o seu entorno, a partir de censos realizados desde uma embarcação. O aumento do número de táxons de aves marinhas durante o inverno está relacionado com a visita de aves migratórias, principalmente oriundas do extremo sul do oceano Atlântico. Durante o verão foram avistadas unicamente espécies residentes do parque. Quanto à análise da distribuição espacial dos táxons a partir de sistemas de informação geográfica (SIG), foram identificadas três regiões diferentes dentro da área de estudo: uma próxima à costa, onde existe interação das aves com as atividades pesqueiras devido à disponibilidade de recursos alimentares de fácil acesso, outra que abrange o ninhal e confere abrigo para as aves que se reproduzem dentro da área de estudo, e uma terceira, mais exposta, onde é possível avistar o maior número de aves migratórias durante o inverno. Desta forma, o PEMLS e o seu entorno apresentam características importantes para o monitoramento e preservação das aves marinhas brasileiras e do Atlântico Sul.

Descritores: Parque Estadual Marinho da Laje de Santos, Aves Marinhas, Sazonalidade, Distribuição Espacial, Geoprocessamento.

Received: June 22, 2016
Approved: September 3, 2017
* Reference article of the Project MAPELMS - Environmental Monitoring of the State Marine Park of Laje de Santos

http://dx.doi.org/10.1590/S1679-87592017129206504

INTRODUCTION

The Laje de Santos Marine State Park (PEMLS is the Portuguese acronym), was created by decree in 1993 (Decree Nº 37537, SÃO PAULO, 1993), and is the first marine conservation unit of the State of São Paulo. Its rectangular area of 5,000 ha contains a variety of marine ecosystems, including Laje de Santos Island and other rocky outcrops and submerged rocks. The creation of this park aimed to provide complete protection to the marine environment, the associated marine biodiversity and species abundance, due to the scientific relevance and the ecological importance of the area. The PEMLS is a feeding, breeding and stopover area on the migratory route of several marine seabird species (CAMPOS et al., 2004), which makes it an extremely important spot for the conservation of seabirds in Brazil.

Seabirds are a highly diverse group of species adapted to live within the sea, which use the available resources in the marine environment (BRANCO, 2004). Many are long-lived species with delayed-breeding, are migratory and often widely distributed. As top predators in the food web, seabirds are good study objects for long term and large scale monitoring of ecosystems and marine environments (PALECZNY et al., 2015; SICK, 1997) as they integrate such environments through demographic parameters.

Among the 35 seabird species reported from the state of São Paulo (OLMOS et al., 1995), 13 were found in the PEMLS (DE CAMPOS et al., 2007). Some of these species have breeding colonies on islands such as the Laje de Santos (CAMPOS et al., 2004), while others only visit the islands during migration (NEVES, 1999). Three of the migratory species commonly seen in the PEMLS are on the International Union for Conservation of Nature (IUCN) Red List of taxa with elevated conservation status (IUCN 2016): The Atlantic yellow-nosed albatross (*Thalassarche chlororhynchos*), listed as endangered; the Black-browed albatross (*Thalassarche melanophris*) and the Magellanic penguin (*Spheniscus magellanicus*), both listed as near threatened.

The main gaps regarding knowledge of many species of seabirds include poor standardization of databases, the absence of data in certain regions and the lack of long term monitoring data on endangered species (SILVEIRA; UEZU, 2010). Difficulties involving seabird studies on the Brazilian coast lead to a paucity of research on these species. Examples of these difficulties are the at-times difficult marine environment conditions during fieldwork, and issues related to data acquisition, planning and access to colonies for studies and monitoring.

Management and conservation of the world's oceans require synthesis of spatial data regarding areas most strongly influenced by anthropogenic activities, in order to map and identify vulnerable areas, sensitive species and to evaluate the impact of human activities on global marine ecosystems (HALPERN et al., 2008).

The main objective of the present study is to monitor the spatial distribution and temporal variation of resident and migratory seabirds in the PEMLS' marine section and surrounding waters, through semi-quantitative surveys in two years of bimonthly monitoring.

MATERIAL AND METHODS

Study Area

The study area lies within the quadrant defined by latitudes -24.000° and -24.400° (7,345,095 mN and 7,301,068 mN) and longitudes -46.370° and -46.070° (360,646 mE and 391,504 mE) (Figure 1). It includes the PEMLS with its emerged and submerged rock formations, the parks surrounding waters, largely coincident with the Itaguaçu sector of the Central Coast Marine Protected Area (created by Decree Nº 53526, SÃO PAULO, 2008), and the area between the PEMLS and Santos and São Vicente bays. It covers areas with different characteristics, such near-shore areas where it is possible to observe coastal seabirds and farther offshore areas where pelagic seabirds can be found.

Three transects were established in the study area. Transect 1 (T1) is demarcated by the vessel's track from São Vicente Bay to point P6. Transect 2 (T2) follows the route defined by the points indicated in Table 1, following the order P6, P1, P2, P3, P4, P5 and P6. Finally, Transect 3 (T3) is the return path from P6 to *São Vicente* Bay (Figure 1).

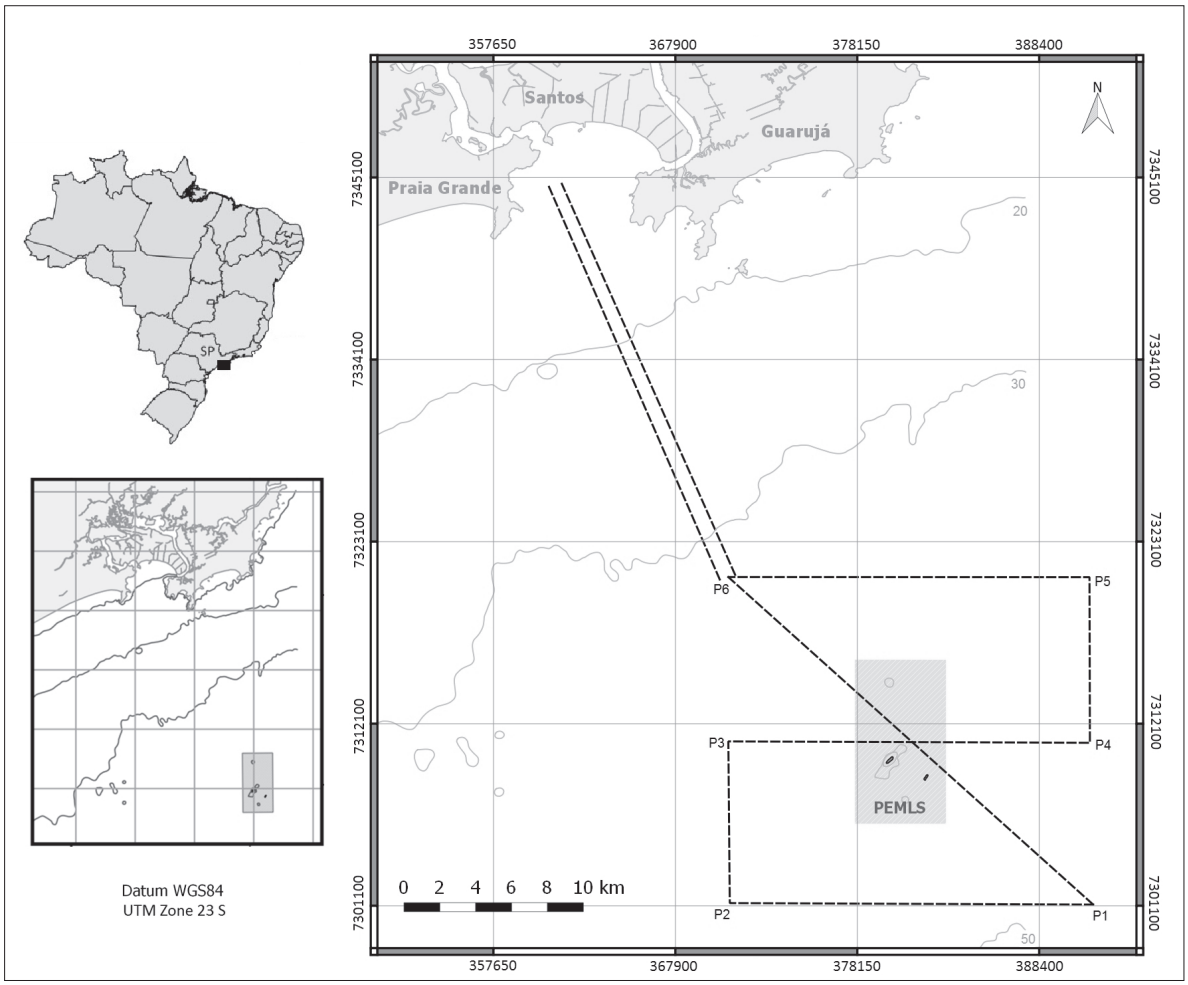

Figure 1. Geographical location of the study area. Dashed lines represent the transects surveyed during the seabird census.

Table 1. Geographical and UTM coordinates (WGS84 datum, UTM Zone 23S) of the points that defined Transect 2 (T2) in the study area.

	Geographical Coordinates		UTM Coordinates (Zone 23S)	
Points	**Latitude**	**Longitude**	**Latitude m(N)**	**Longitude (mE)**
P1	-24.400°	-46.070°	7,301,068	391,504
P2	-24.400°	-46.270°	7,300,897	371,222
P3	-24.310°	-46.270°	7,310,862	371,029
P4	-24.310°	-46.070°	7,311,034	391,427
P5	-24.220°	-46.070°	7,320,999	391,350
P6	-24.220°	-46.270°	7,320,829	371,040

A total of 12 surveys were completed out between June 2013 and June 2015, approximately every two months and covering all seasons.

Observations were made from survey vessels. The sampling units of this study were the "counting stations" that divided each transect into 10-minute navigation/observation intervals. The surveys consisted of counting and identifying all birds, whether flying or resting (an adaptation of the method suggested by Tasker et al. (1984)) during these intervals, observed within a 600-m wide transect defined in accordance with Heinemann (1981).

To correctly apply this method, it is necessary to respect certain navigation conditions such as constant speed, regular and known direction, favourable weather conditions without rain or fog (horizon must be visible) and good sea conditions: 0 (calm) to 3 (gentle breeze) on the Beaufort scale. As an adaptation of the method, we used a 180° angle of view, thus covering both sides of the vessel (i.e., 300 m on both sides of the vessel). 13 to 15 m long boats from local diving operators were used for the surveys and the observations were carried out during daylight from the upper decks, above the cockpit (vessels' highest point). Observers' eyes were on average 3 m above sea level, with a horizon of approximately 6 km.

Data collected during surveys comprised biological (taxon and number of individuals), navigational (local time, period of observation, latitude, longitude, speed and direction of the boat) and weather information (cloudiness and wind direction), and were recorded on field data sheets (BIOMASS, 1977). Binoculars (8 x 30 and 10 x 50), photographic equipment (*CANON EOS 7D* camera with 70-300 mm lens) and a GPS (*Garmin eTrex* 20) were used in all surveys. The identification of species was undertaken *in situ* by qualified on-board observers and *a posteriori* by photo analysis, both using identification guides (BINI, 2009; HARRISON, 1983; NOVELLI, 1997; VOOREN; FERNANDES, 1989).

After each survey, all navigation and biological information was added to a database. Navigation data included the identification number of the survey, transect and station number, as well as the date, starting and ending times of the counting station (in minutes), vessel direction, navigation speed (in knots and km/h), latitude and longitude (in decimal degrees), cloud coverage, wind direction, and any other relevant observation. Biological data comprised the total number of seabirds per station and the number of individuals of each species per station. Because of the difficulties regarding terns' species identification at sea, all terns were recorded as 'Sternidae'.

Several parameters and derived rates were calculated, for example, the distance covered at each station (distance = navigation speed x time spent at each station). Total and mean speed values, distance covered, number of seabirds and taxa per transect and per km were calculated for each survey. All parameters were plotted on charts in order to analyse the seasonal variations of seabirds' numbers and taxa.

To analyse seabirds' spatial distributions, the geospatial information was plotted on thematic maps using the open source geographic information system (GIS) software *QGIS* (QGIS, 2013). In order to make comparisons among surveys and due to the spatial data's heterogeneity we created a 5 km x 5 km grid. Biological data of the 12 surveys were plotted in the GIS, and stations (based on the location of their starting points) located in a specific cell were grouped, allowing comparison among the main taxa of resident and migratory seabirds observed during surveys.

RESULTS

During the continuous censuses performed throughout 12 surveys, 1,086 seabirds were recorded. The brown booby (*Sula leucogaster*) was the most abundant species, with 744 individuals counted. Terns (Sternidae family) were the second most abundant group, with 146 individuals including South American (*Sterna hirundinacea*), Cabot's (*Thalasseus acuflavidus*) and Royal (*T. maximus*) terns, followed by the Magnificent frigatebird (*Fregata magnificens*), with 81 individuals observed (Figure 2). These three taxa are resident species and represent almost 90% of all birds observed during the surveys. Brown boobies and terns also establish breeding colonies at the Laje de Santos Island.

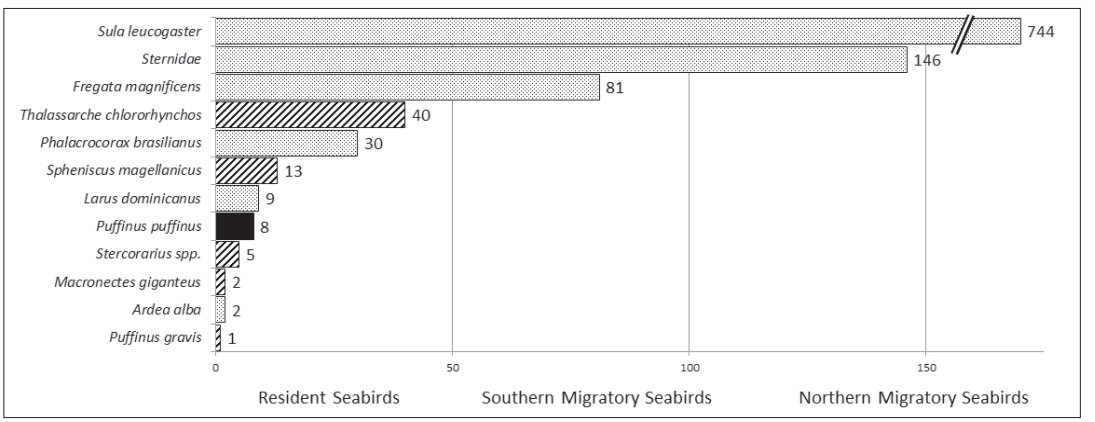

Figure 2. Number of observed individuals during the 12 surveys.

Seasonality

The numbers of individuals (Figure 3) and taxa (Figure 4) recorded on each transect on each survey were examined. By analysing the variation in species richness during the surveys, a seasonality was observed, with an increase in the number of taxa seen during winter months and a decrease in summer months. In contrast, the total number of birds observed does not appear to follow any particular pattern.

Considering these observations, we analysed the seasonality of individual species. Comparing the total number of taxa per season (Figure 5), we found that richness in winter was higher (considering standard deviation) than in warmer seasons (spring and summer).

To understand these differences we compared the seasonality of resident and migratory taxa (Figure 6). Resident taxa were considered almost constant throughout the seasons. The Manx shearwater (*Puffinus puffinus*) was the only migratory species from the Northern Hemisphere and was observed in all seasons. Richness of migratory seabirds from the southern region of the ocean increased during winter surveys (maximum number of taxa = 5), decreased dramatically in spring surveys (number of taxa = 1), was nil in summer and increased again in autumn (number of taxa = 2). During winter surveys, migratory birds from the south accounted for more than 40% of species richness, but in summer, they were totally absent from the survey area.

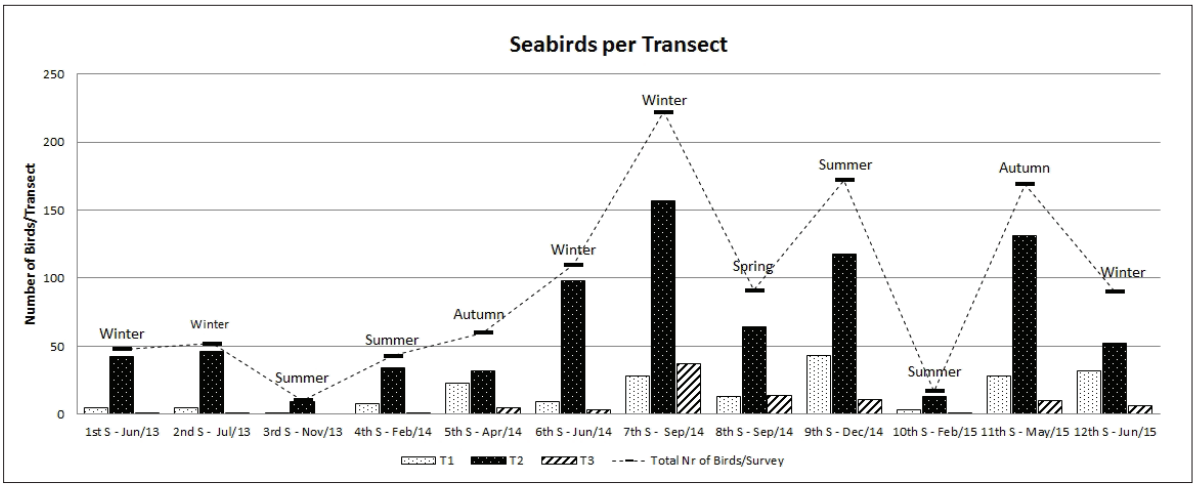

Figure 3. Number of seabirds observed per transect on each survey. The dashed line represents the total number of birds counted on each survey (sum of the three transects).

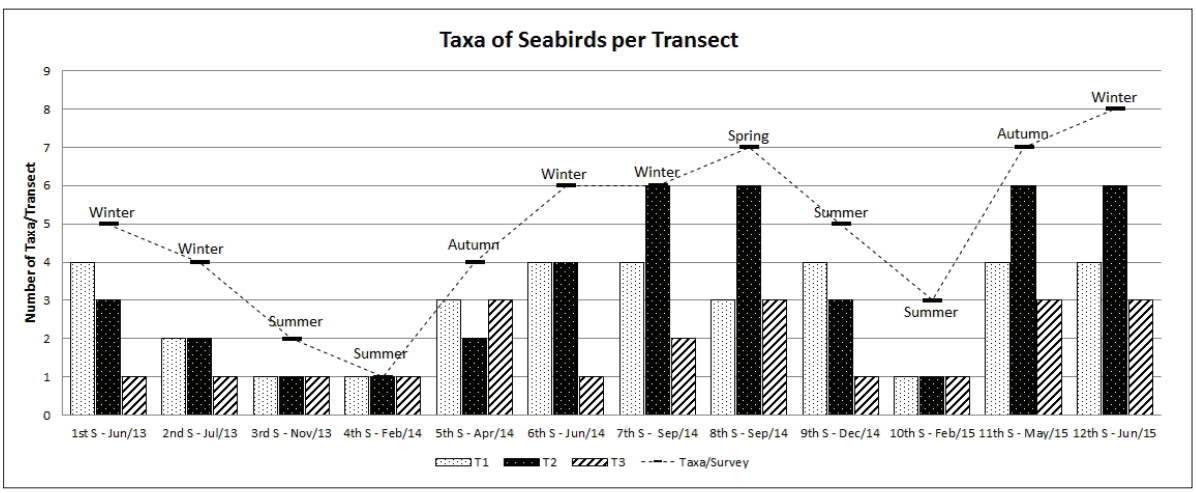

Figure 4. Number of seabird taxa per transect on each survey. The dashed line represents the total number of taxa counted on each survey (sum of the three transects).

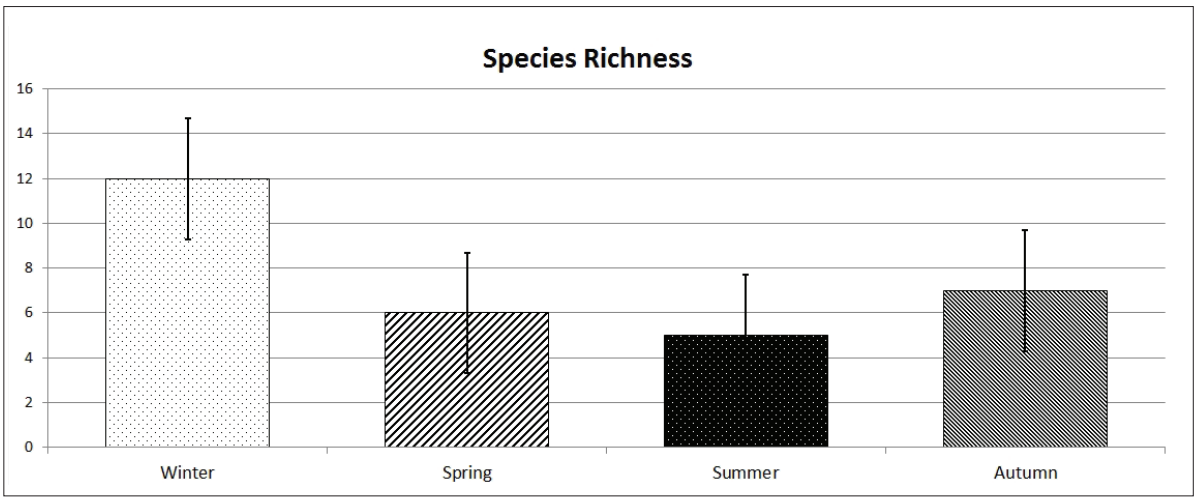

Figure 5. Total species richness by season. Error bars indicate one standard deviation.

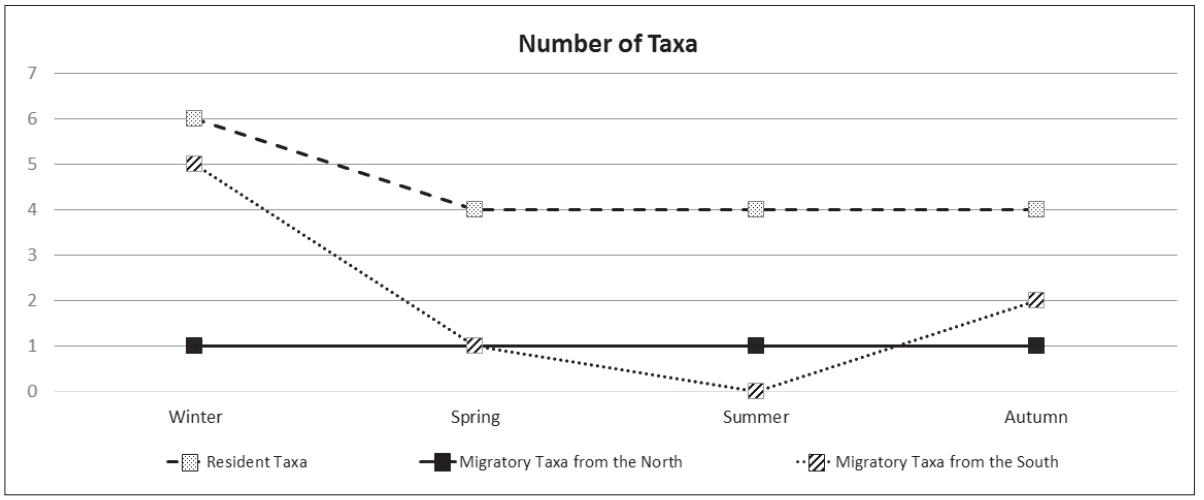

Figure 6. Number of resident and migratory seabird taxa by season.

Spatial Distribution

The starting points of the 421 counting stations monitored over the 12 surveys and their distribution in the grid cells are shown in Figure 7. Seabirds were seen at 211 of these stations, a sighting rate of 50%. This relatively low rate of observation might be related to the 10-minute navigation/observation intervals.

Spatial distribution maps of the three main resident taxa of the PEMLS (Brown booby, terns and Magnificent frigatebird) are shown in Figures 8, 9 and 10, respectively. Observations of the Manx shearwater (Figure 11) and the Atlantic yellow-nosed albatross (*Thalassarche chlororhynchos*; Figure 12), were also produced.

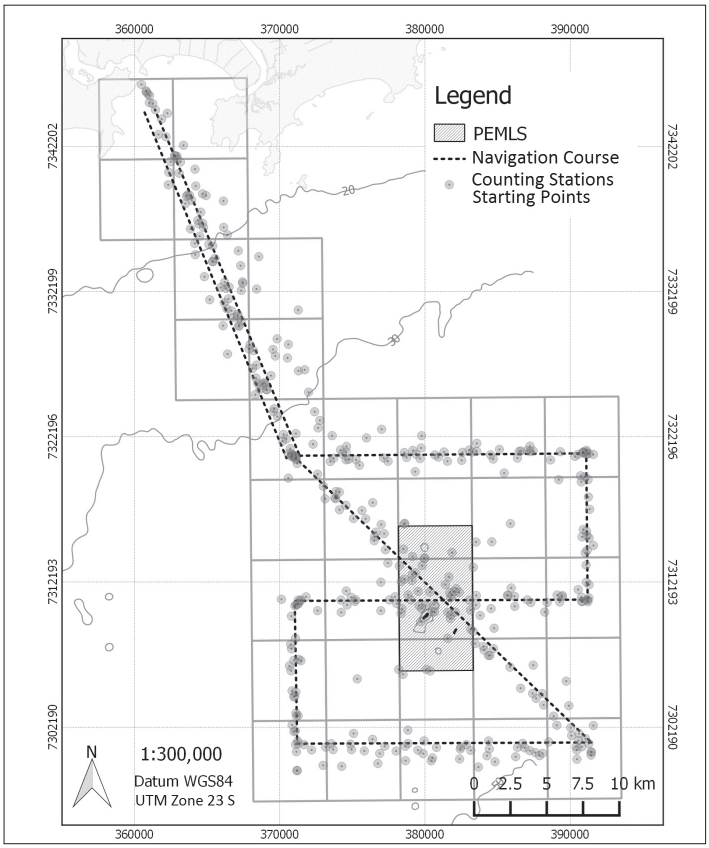

Figure 7. Starting points of the seabird observing stations monitored during the 12 surveys, showing the grid with 5 km x 5 km cells used for analyses.

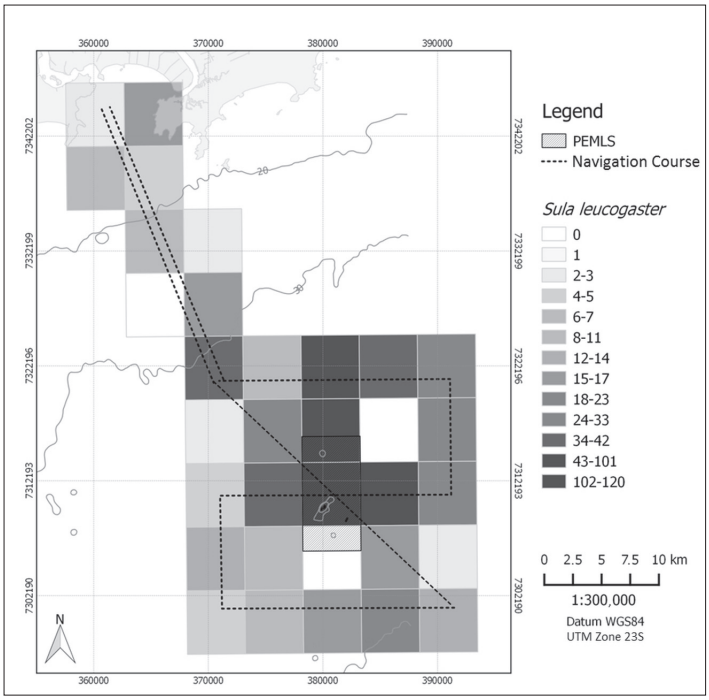

Figure 8. Number of brown booby (*Sula leucogaster*) individuals counted in each grid cell during the 12 surveys.

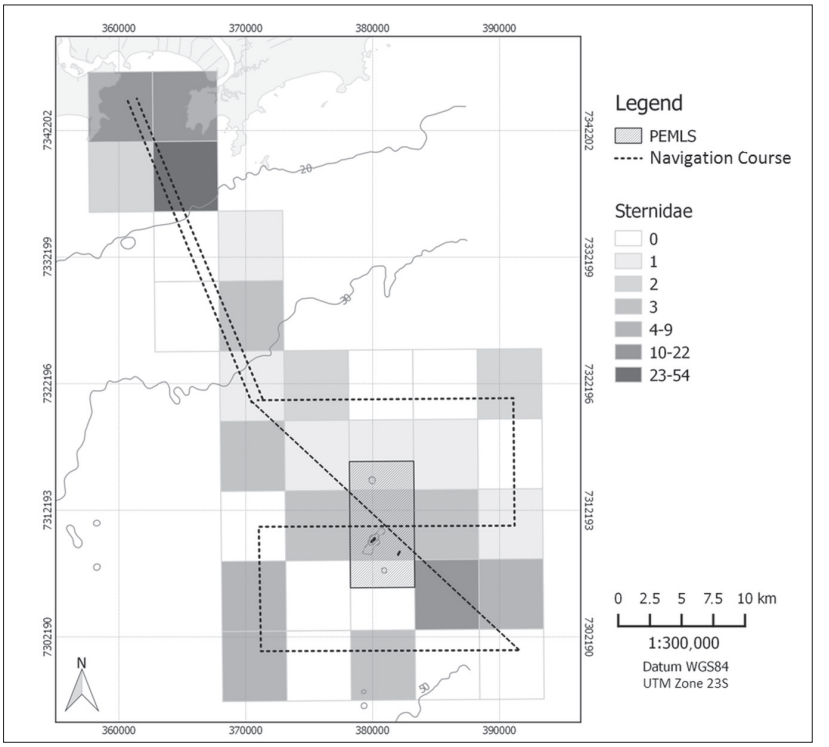

Figure 9. Number of terns (*three species, see Methods*) counted in each grid cell during the 12 surveys.

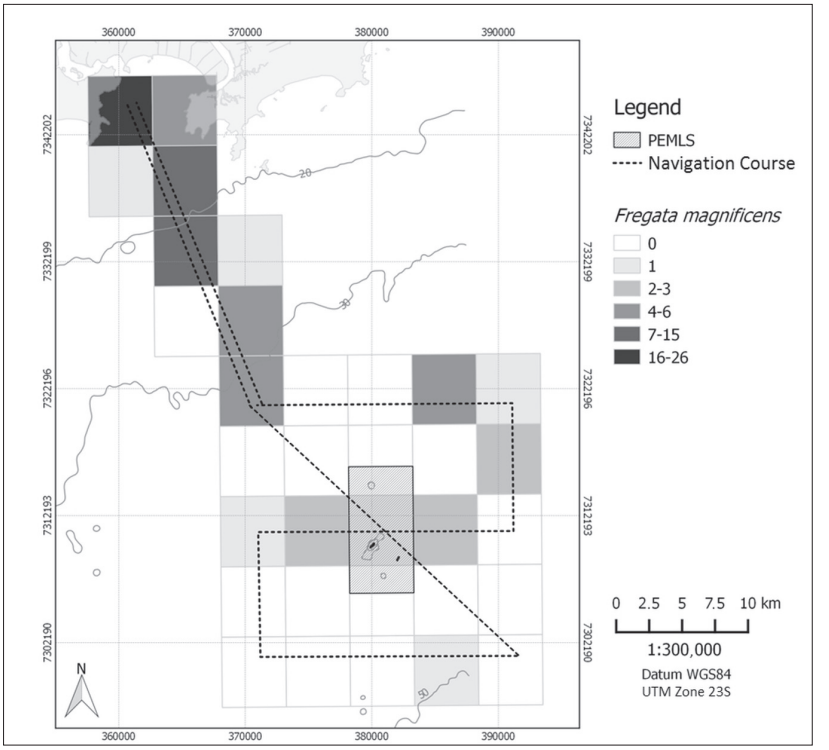

Figure 10. Number of Magnificent frigatebirds (*Fregata magnificens*) counted in each grid cell during the 12 surveys.

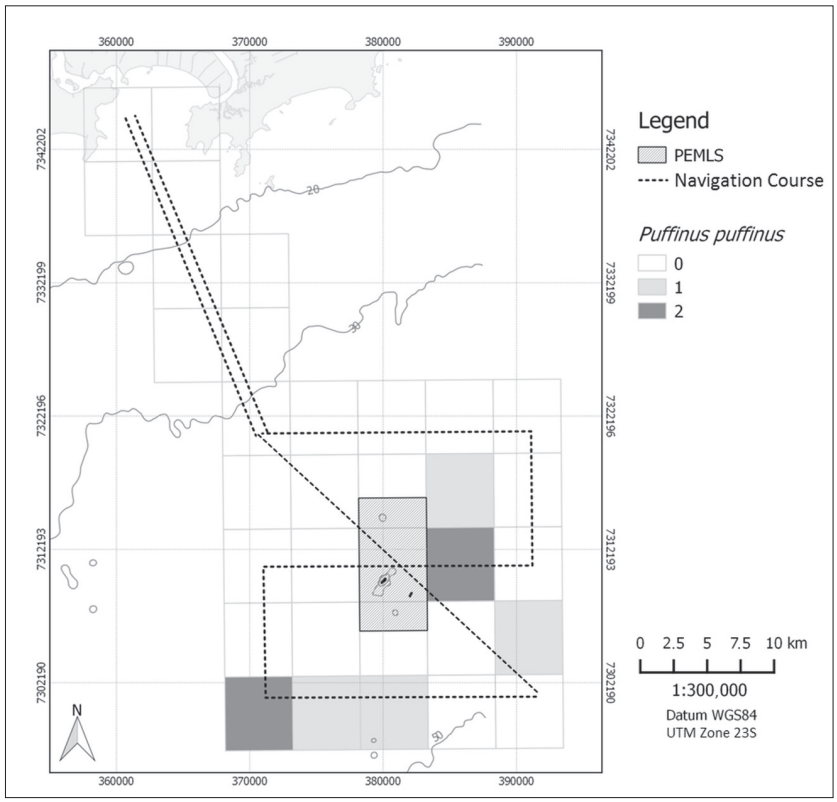

Figure 11. Number of Manx shearwater (*Puffinus puffinus*) counted in each grid cell during the 12 surveys.

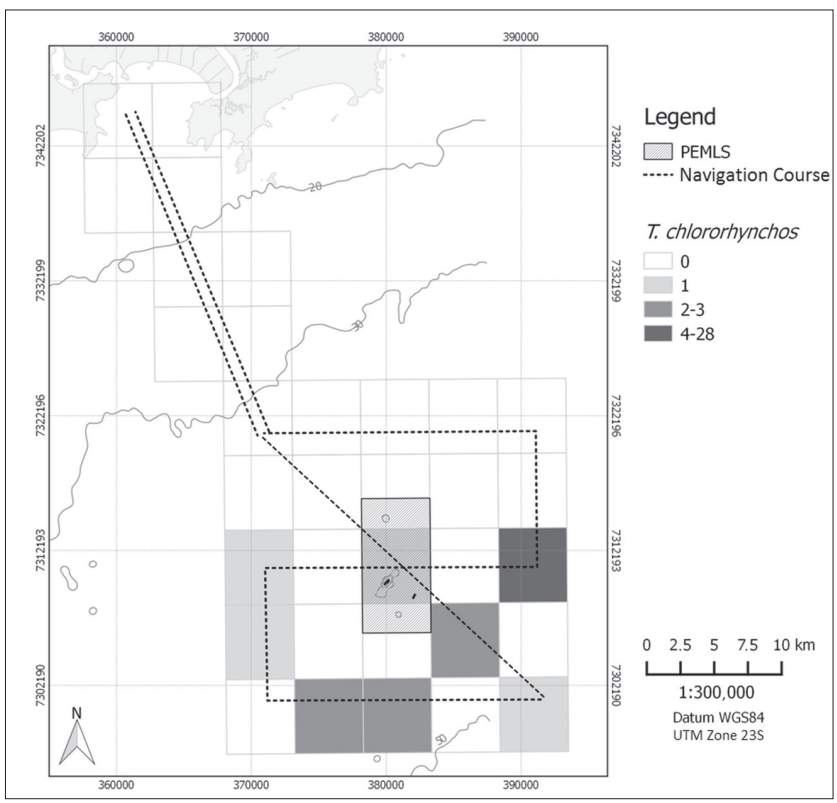

Figure 12. Number of Atlantic yellow-nosed albatross (*Thalassarche chlororhynchos*) counted in each grid cell during the 12 surveys.

The Brown booby is widespread within the study area, but it is sighted more frequently in the surrounding of the Laje de Santos Island, particularly on its northern and eastern sides, which are more sheltered from the regional predominant winds (field observation). Also, after breeding seasons, juvenile individuals were sighted flying around the island.

Terns also presented a wide distribution within the survey area, however, they were more abundant near the coast of the mainland. The frigatebirds were more numerous near the coastland and in areas where *Sula leucogaster* were more frequently observed.

Manx shearwaters and Atlantic yellow-nosed albatrosses were seen in the area between the Laje de Santos Island and the 50 m isobath, the outermost studied area.

DISCUSSION

We identified seasonal variation on the species composition during the study period: a higher number of taxa was observed during winter; decreased in spring, reach the minimum during summer; and increased again in autumn. These results suggest that seasonal variation is associated with the visit of migratory seabirds such as albatrosses and petrels from the south. This is consistent with the work of earlier researchers in this study area (NEVES, 1997; CAMPOS et al., 2004; OLMOS et al., 2005) who observed that migratory birds from the extreme south, which reproduce during the austral summer, migrate north during winter where food resources are relatively more abundant.

The brown booby, a resident species that nests on the Laje de Santos Island and has stable colonies all over the year, was well represented throughout the study area, with higher concentrations in the proximities of the island (the colony's nesting area). On several occasions, flocks of brown booby were seen flying between the nearby mainland and the Laje de Santos Island and/or between near rock formations and the nesting area. These observations suggest that these birds tend to feed around the nesting area, rather than farther from the colony.

Although it wasn't possible to establish a statistical relationship with meteorological parameters, we observed a tendency for Brown boobies to return to the sheltered side of Laje de Santos Island on days when the wind was more intense. The regions where the Brown booby is less abundant correspond to the exposed side of the island and the anchorage area of the Port of Santos (according to the Brazilian Navy's nautical chart Nº 1711, DHN, 2016).

Terns were also observed all over the year, therefore the highest concentrations of terns were observed near the mainland coast, which can be related to the higher and continuous availability of food in this region, especially due to the large volume of discards from small fishing boats. Further, terns were only seen on Transect 2 during their breeding season (CAMPOS et al., 2004). During this period, individuals were observed leaving the nesting area on the Laje de Santos Island to the open sea in search for food. These birds were seen, on several occasions during the breeding season, together with Manx shearwater while fishing.

Magnificent frigatebirds were seen in higher concentrations around the Brown boobies' nesting area on Laje de Santos Island, and particularly near to the mainland coast, in the Xixová-Japuí State Park surrounding, where fishing boats are usually seen. This distribution pattern is probably associated to the feeding behaviour of frigatebirds, which steal food from other birds (e.g. Brown booby and terns) and take advantage of the discards from fishing vessels.

The migratory seabirds most frequently sighted during this study were Manx shearwaters and Atlantic yellow-nosed albatrosses. Both species were observed only in the region between the Laje de Santos Island and the 50 m isobath, indicating that these oceanic seabirds prefer deeper water areas, more distant from the coast. The presence of migratory seabirds from distant breeding colonies shows that the importance of the PEMLS extends far beyond its boundaries. Atlantic yellow-nosed albatrosses, which are endemic to the Tristan da Cunha archipelago and Gough Island in the South Atlantic Ocean between Uruguay and South Africa, appear to be regular visitors to the PEMLS and its surroundings. Similarly, Black-browed albatrosses (*Thalassarche melanophris*), native from the Malvinas/Falklands and South Georgia in the subantarctic region, also visit regularly the PEMLS area (NEVES, 1997), although no individuals were sighted in the present study.

These and other species of albatrosses and petrels (order Procellariiformes) are protected birds and constitute the most threatened seabird group worldwide (CROXALL et al., 2012). They thus receive and require governmental and nongovernmental attention, and count on instruments for establishment of priority actions for their conservation.

Among these instruments, the Agreement for the Conservation of Albatrosses and Petrels (ACAP), of which Brazil has been a member since 2008, stands out. Since 2006, actions directed to this group of seabirds in Brazil

have been established by the National Action Plan for the Conservation of Albatrosses and Petrels (PLANACAP is the Portuguese acronym; NEVES et al., 2006) which identifies the national strategies for conservation of these threatened species. Since the PEMLS area is frequently visited by these protected species, its importance transcends national borders and its maintenance concurs with the actions of both ACAP and PLANACAP.

Three important regions for seabirds were identified in the study area. The first was close to the mainland coast, where we observed interaction between seabirds and the commercial and artisanal fishing fleets. The second surrounded Laje de Santos Island, which offers shelter and food for the seabirds breeding on it. The third region, more exposed, was where migratory seabirds, adapted to rougher sea conditions, were more often seen during surveys for this study.

The use of a geographic information system allowed this study to make inferences and identify correlations regarding the habits of monitored seabirds and the regions within the study area.

This regionalisation may be the most important result in terms of guidance regarding the future management of the park. We recommend that the management actions of this conservation unit consider, whenever possible, this spatial distribution and the seasonal occurrence of seabird species.

One of the purposes of studying the seabirds distribution within the Environmental Monitoring of the Laje de Santos Marine State Park Project (MAPEMLS is the Portuguese acronym), to which this study is a contribution, was to verify the methodological suitability of ship-based surveys in coastal areas (water depths less than 50 m) establishing standard methodology for this type of study in protected areas. The results show that the census method used, together with GIS, is fully applicable and suitable for the monitoring of seabirds in transitional areas between the coast and the open sea.

In light of the fact that some migratory species previously seen in the area and studied by earlier researchers were not observed in the present study, we recommend an increased survey frequency, especially during winter months when the use of the PEMLS is at its highest by migratory seabird species.

The spatial distribution analysis of species using thematic maps represents an extremely useful tool to determine regional patterns. Through the overlaying of distribution data with human water use (e.g. anchorage areas, fishing areas, submarine gas pipelines, navigation routes, submarine sewage outfalls, etc.) and modelling data, it is possible to determine the most vulnerable areas regarding real and potential anthropogenic impacts, and therefore, establish contingency plans for each impact. Moreover, the association between spatial data and information about seasonal variation of migratory species, or even breeding periods of resident species, would be helpful to direct sampling efforts in further studies in order to obtain a more detailed understanding of the population dynamics of the study area.

Therefore, the creation of geo-referenced databases and a constant supply of new data, along with the popularization of open source software, constitute together a means of great potential to aid sampling design, management and monitoring of coastal and ocean waters, and consequently for the conservation of the marine ecosystems and biodiversity.

ACKNOWLEDGEMENTS

This study was undertaken within the MAPEMLS project, coordinated by the Aquatic Studies and Research Foundation – FUNDESPA and Petrobras, in collaboration with the Albatross Project-Projeto Albatroz, sponsored by Petrobras via their Environmental Program. The authors wish gratefully to acknowledge the participation of the PEMLS administration, the captains and crews of the *Wreck-Hunter, Pé-de-pato, Cachalote* and *Anekim* vessels for their logistic support and Sorraylla Rahim de Sá for her efforts during the sampling as well as her collaboration in the monitoring.

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