UNIVERSIDADE ESTADUAL DE SANTA CRUZ – UESC
DEPARTAMENTO DE CIÊNCIAS BIOLÓGICAS
PROGRAMA DE PÓS-GRADUAÇÃO EM ZOOLOGIA – PPGZOO

MORENO PEREIRA

OCORRÊNCIA, USO DE HABITAT E ESTRUTURA DE GRUPO DA BALEIA-FRANCA-AUSTRAL, *Eubalaena australis*, EM TORRES, RIO GRANDE DO SUL

ILHÉUS – BAHIA
2020

MORENO PEREIRA

OCORRÊNCIA, USO DE HABITAT E ESTRUTURA DE GRUPO DA BALEIA-FRANCA-AUSTRAL, *Eubalaena australis*, EM TORRES, RIO GRANDE DO SUL

Dissertação de mestrado apresentado ao Programa de Pós-Graduação em Zoologia da Universidade Estadual de Santa Cruz, como requisito parcial para obtenção do título de Mestre em Zoologia.

Orientador: Prof. Dr. Daniel Danilewicz Schiavon
Coorientador: Dr. Federico Sucunza

ILHÉUS – BAHIA

2020

AGRADECIMENTOS

Agredeço imensamento ao apoio e suporte dado pelo meu orientador Daniel Danilwicz e meu coorientador Federico Sucunza que me auxiliaram e guiaram durante essa etapa importante da minha carreira. A UESC e ao programa de pós-graduação em zoologia aplicada e todos os funcinários da instituição que direta ou indiretamente contribuiram para a finalização desse trabalho assim como a FAPESB pelo suporte financeiro dado ao projeto e a pesquisa que fizeram esse trabalho ser possível. Ao GEMARS e toda a equipe pelo apoio e estrutura.

LISTA DE FIGURAS

LISTA DE TABELAS

SUMÁRIO

ARTIGO SERÁ SUBMETIDO AO JOURNAL OF THE MARINE BIOLOGICAL ASSOCIATION OF THE UNITED KINGDOM (JMBA)

OCCURENCE, HABITAT USE AND GROUP STRUCTURE OF THE SOUTHERN RIGHT WHALE, *Eubalaena australis*, IN TORRES, southern Brazilian coast.

Moreno Pereira[1], Federico Sucunza[2], Daniel Danilewicz[1] [2]

[1] Programa de Pós-Graduação em Zoologia (PPGZOO), Universidade Estadual de Santa Cruz (UESC), Campus Soane Nazaré de Andrade, Rodovia Jorge Amado, Km 16, Salobrinho, Ilhéus, Bahia, Brasil.

[2] Grupo de Estudos de Mamíferos Aquáticos do Rio Grande do Sul (GEMARS), Rua Bento Gonçalves, 165, Torres, RS, 95560-000

ABSTRACT

Southern right whales (SRWs), *Eubalaena australis*, aggregate in the south coast of Brazil, mostly off the Santa Catarina (SC), during the reproductive season (austral winter and spring). Over the past few years SRWs have shown signs of recovery and changes in distribution that are reflex of the recolonization in historic grounds pre whaling. In this sense, areas around the highest density of the species are targets of studies that aim to understand patterns of reoccupation, distribution and habitat use such as the north coast of Rio Grande do Sul (RS). Although this region was originally described as a migrator corridor, evidences from the last 20 years demonstrate that the species use the area also for reproduction and parental care. In this context, shore-based surveys were carried out in Torres, southern Brazil, between July 1st to October 30th during the breeding seasons of 2018 and 2019. Here we present data on the habitat use and group structure of SRWs in Torres, and compare the results with the only previous study in the area from 2002. The research team was composed of up to 8 observers who searched for SRWs groups at an advantage point 45m high between 8am and 5pm, except during inclement weather (i.e., rain, wind speed > 20 knots, or visibility < 5 km). A 7×50 reticulated FUJINON binoculars were used to estimate the distance to the whales' group detected as well as to define the group size and group structure. Habitat use and distribution analysis were made through grid maps of 90.000 m² and ANOVA test. 147 SRWs groups were registered in 2018 and 2019 in 212 effort days and 1,396hs of observation with a peak of occurrence in late August (season 2018) and late September (season 2019). Unaccompanied whales (i.e., groups with no calves) represent 56.5% (n=83) of the groups recorded and mother-calf pairs 43.5% (n=64). SRWs groups, in general, seem to have a preference to coastal areas up to 4 km and for the south region of the study area in southwest winds higher than 6 knots. Observation rates (groups per effort hour) were higher in 2018 compared to 2002 and 2019 in the peak months (i.e., August and September). Our data show an increase in the numbers of mother-calf pairs since 2002 and the proximity of the groups to the coast. Mean leg speed of groups was 2.96±2.47 km/h and speed tends to increase with increase distance from the coast. On September and October movements heading south become to increase indicating the ending of breading season. Our data demonstrated that, as a recovery area, Torres has been passing through changes over time, getting an importance also as a nursery site. Moreover, the number of groups in the area seems to vary according to the occupation on the main ground located in SC. We strongly recommend more studies in recovery grounds in Brazil since little is know about the patterns of reocupation in the country.

Key words: recovery, recolonization, nursery site, shore-based surveys, Rio Grande do Sul

INTRODUCTION

The Southern right whale (*Eubalaena australis*) is a migratory species that reproduces in warmer waters of low latitudes during the winter and feeding in cooler waters during the summer (Best *et al.*, 1993). The distribution and abundance of SRWs were strongly affected by whaling in the southern hemisphere between the centuries XVII and XX (IWC, 2001). Despite of the moratorium that ceased commercial whaling since 1986, off the Brazilian coast SRWs were severely depleted by whaling until 1973, leading to the disappearance of the species until the beginning of the 1980s (Palazzo & Carter, 1983). Whaling in Brazil started in 1602 in São Paulo (SP), Rio de Janeiro (RJ) and Santa Catarina (SC) state and it ended because of the catches' declination. Morais *et al*. (2016) show the uncertainty about the number of catches because of the lack of information in order to identify the species. An estimations shows that between 1952 and 1973 350 SWR were killed , mainly mother-calf pairs and immature individuals (Palazzo & Carter, 1983). The restriction of SRWs on the southern region of Brazil is attributed to the populations decline during whaling since the species could be found more frequently on the coast of SP and RJ (Camara & Palazzo, 1986).

In the southwest Atlantic Ocean, SRWs have two main calving grounds – SC/Brazil and Península Valdés/Argentina (Payne, 1986; Groch *et al*., 2005). In Brazil, along the 7,408 km of coast, SRW can be found approximately in 36% of this extension (Figueiredo *et al*., 2019), from southern of Bahia state to RS (Camara & Palazzo, 1986; Greig *et al.*, 2001; Santos *et al.*, 2001). However, its core density area is located at the center-south region of SC (27°25'S, 48°30'W and 28°36'S,48°48'W), with predominately presence of mother-calf pairs (simões-lopes *et al*., 1992; Palazzo & Flores, 1998; Groch *et al.*, 2005). This area is formed by several bays that provide shallow and calm waters due to protection against strong winds, making the region suitable for the occurrence of the species (Elwen & Best, 2004a, 2004b; Barendse & Best, 2014; Seyboth *et al.*, 2015).

SRWs can also be seen frequently off the coast of RS, an intermediate zone between SC and Peninsula Valdés (Argentina), the two highest density areas in the southwest Atlantic Ocean (Simões-Lopes *et al.*, 1992; Danilewicz *et al.*, 2016; Pires Renault-Braga *et al.*, 2018). Most part of continental shelf off RS is extensive, has a gentle slope and the coastline is open and sandy (Greig *et al.*, 2001). Sightings and strandings were reported in RS since 1977 with an increase use by whales (Greig *et al.*, 2001). However, the use and reoccupation patterns of the species in this region have been subject of discussion. Simões-Lopes *et al.* (1991) reported the coast of RS as a migratory corridor that whales use to reach SC. A study conducted in early 2000's demonstrated that groups of SRWs on the coast of Torres, northern coast of RS, can be sighted from July to October, and suggested that the area could have been used as a breeding ground (Danilewicz *et al.*, 2016). Although, Greig *et al*. (2001) argue that sighting and strandings of newborns are evidences that RS coast may represent a calving/nursing area for the species. Currently, two large areas of density are attributed in Brazil for the species. The first one is located between Ouvidor/Rosa beach and Vila/Itapiruba Norte in SC. The second one goes from Itapiruba Sul (SC) to Torres (RS) (Pires Renault-Braga *et al*., 2018).

The recolonization in historically important winter habitat ranges is expected with the increase of SRWs' population in different sites (Groch *et al.*, 2005; Carroll *et al.*, 2013; Barendse & Best, 2014; Seyboth *et al.*, 2015; Crespo & Coscarella, 2018;

Sueyro *et al.*, 2018; Charlton *et al.*, 2019). In the biggest SRWs concentration wintering ground of Peninsula Valdés (Argentina), whales are still increasing their abundance, while the rate of increase is decreasing (Crespo & Coscarella, 2018). This suggests that the area reached its optimal capacity and the groups of whales, mainly unaccompanied whales, are migrating to deep waters and adjacent areas (Crespo & Coscarella, 2018).

It is possible that the increase in Brazilian wintering ground (Groch *et al.*, 2005) is affecting the distribution and abundance in peripherical areas of SC such as the coast of Torres/RS. After 16 years from the last survey conducted in the area (Danilewicz *et al.*, 2016) it is important to evaluate changes in the patterns of habitat use in the area, since the population enhance can led to an increase in number of sightings, changes in distribution and possibly changes in group structure as was verified in others recolonization areas (Arias *et al.*, 2017; Arias *et al.*, 2018; Charlton *et al.*, 2019).

Data on reocupation and habitat use of SRWs in recovery areas in Brazil is still poorly studied. It is important to highlight here that the region of the study has been reported as an importat area for fishing activities close to the shore with a variety of fishing gears including surface fishing nets (Moreno *et al*., 2009) and although some studies were conducted analysing the interections of marine mammals with fishery (Moreno *et al*., 1997; Ott, 1998), none of them focous on these interections with SRWs. Greig *et al*., (2001) reported evidences of anthropogenic interaction in strandings of SRWs. Thus, it is important to establish a satisfactory understanding of the ecology of SRWs in the area in order to prevent the overlapping of potentially impacting human activities with SRWs' distribution (Moreno *et al*., 2009).

In this context, this paper aims to investigate some ecological and social patterns (such as groups size and structure, intra and inter annual variations of occurrence, effects of Beaufort sea state, wind force and direction, coast distance and water depth in the habitat use) and carried out a temporal comparison with data from the last survey in 2002.

METHODS

Study area

Data were recorded from a land-based observation station called "Morro do Farol" in Torres (29°19′S, 49°43′W), RS, southern Brazil. The station is located at an advantage point 45m high. The radius of observation from the land-based station was 10 km, between azimuths 55º and 210º, covering a surface area of 70 km² (Figure 1).

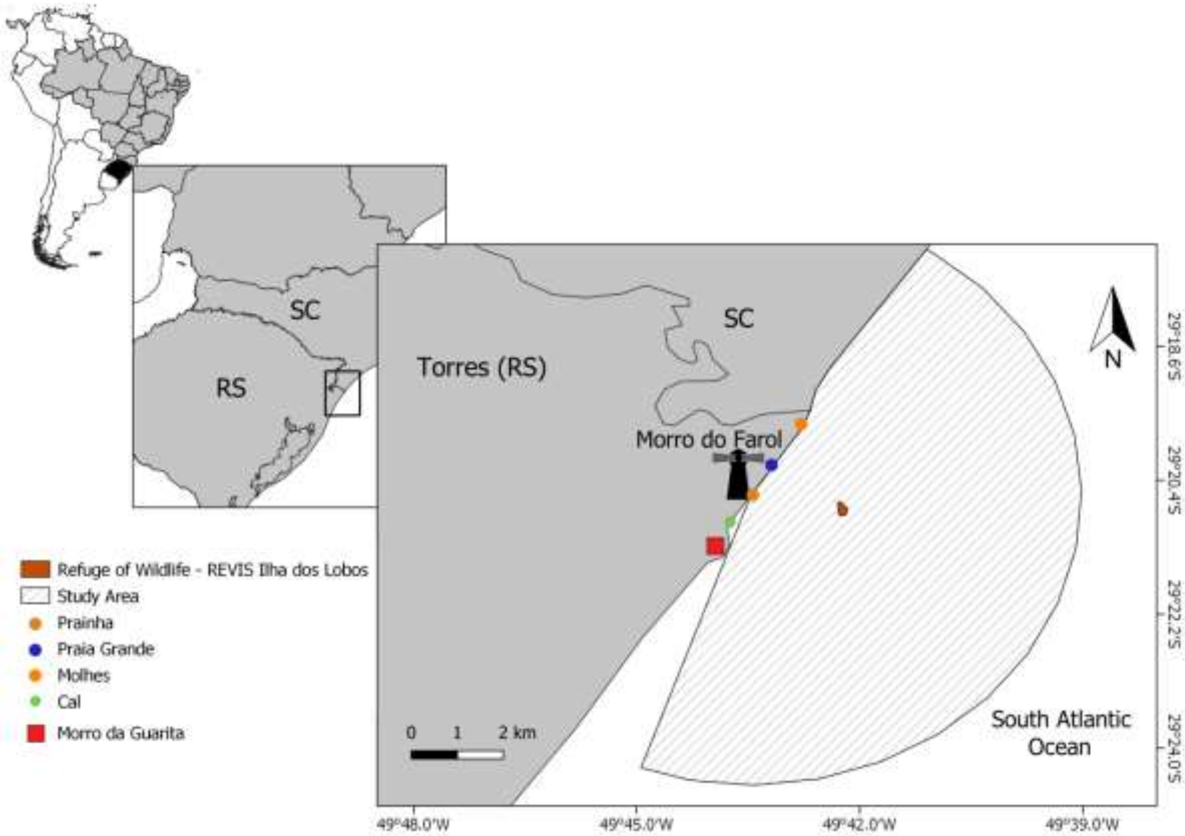

Figure 1. Torres study área located in south Brazil that includes 4 beaches (Prainha, Praia Grande, Molhes and Cal) and the Marine Proteteced Area (Refuge of Wildlife – Ilhas dos Lobos). Surveys occured from a land-based observation station at point 45m high called "Morro do Farol" covering 70 km² (shaded area).

Data collection

Surveys were carried out between 1st July to October 30th in the wintering seasons of 2018 and 2019. A 7×50 reticulated FUJINON binoculars with 0.01° of precision were used to search for whales, define group size, group structure and to determine the vertical declination angle between the observer and the group of whales and the horizontal angle in relation to the magnetic north. The research team (composed by up to 8 observers) rotated continuously among observation, data recorder, and resting positions. In this sense, during the observation there were always two researchers, one at the positions of observer and the other one at data recorder position. Each position lasted up to 1h30min not extrapolating 3 h of activity per researcher per day. The researchers searched for SRWs between 8am and 5pm, except during inclement weather (i.e., rain, wind speed >20 knots, visibility < 5 km). The observations consisted of 15-min scans with the naked eye followed by 5-min scans with 7×50 reticulated binoculars (Danilewicz *et al*., 2016).

The study area covers four beaches of Torres - Prainha, Praia Grande, Praia da Cal and Molhes - a marine protected area (Refuge of Wildlife – Ilha dos Lobos) and presents a cliff on the south region of the study area called "Morro da Guarita" (Figure 1). Information on weather conditions (i.e., Beaufort sea state, wind force - measured with a wind meter, and wind direction) was recorded by the observer at the beginning of each observation period and at hourly intervals or ever an alteration on weather conditions was detected. When a SRWs group was first sighted, the time, horizontal bearing, and vertical angle were recorded. Magnetic compasses in the binoculars provided the horizontal bearings and the 16 reticle marks provided vertical angles relative to the horizon (Rugh *et al*. 1993). Successively time measurements of the horizontal bearing and vertical angle of a group's surfacing provided a series of positions that were assumed to be the migration track of the group.

Groups and position analysis

Groups of SRWs were classified as mother-calf pairs and unaccompanied whales (group of whales with no calves that can be solitary or with two or more adults or juveniles) (Elwen & Best, 2004a). The vertical declination angle and the horizontal angle were recorded at least every 10 minutes for each group and were used to estimate the distance between the observer and the group of whales following Lerczak & Hobbs (1998). Based on the distance between the observer and SRW group and the horizontal angle we georeferenced all the positions of each group using the free software QGIS 3.6.0. Bathymetry was extracted for each fix from ETOPO1 Global Relief (Amante & Eakins, 2009). Statistical analysis related to group sizes, group structure, depth and distance of the groups were conducted only with groups with two or more position recorded.

Since the observation effort was not constant due to weather conditions, an observation rate was calculated by dividing the number of groups sighted per hours of observation. Observation data were stratified according to the distance from the coast (<1 km, 1< 2 km, 2<3 km, 3< 4 km, 4<5 km and > 5 km). Groups less than 0.5 km from the observation point require more than 16 reticle marks and therefore the position for those groups could not be estimated and were discarded for distance, depth and movement analysis. Comparisons between group structure and size were also made with data from 2002 of the same location (Danilewicz *et al.*, 2016) and through ANOVA test and a significance level of $\alpha = 0.05$ was considered for all tests.

In order to obtain an analysis of distribution and use of area on a fine scale, maps were made with grids of 90,000 m² (300m x 300m) to analyze the frequency of the positions of all groups and per groups. Also, to obtain more accurate comparisons with Torres' 2002 data, the effort of June and November are disregarded since no group of whales were seen in those periods during that year.

Movement analyses

The sequences of the positions taken from QGis 3.6.0 provided us a series of fixes that correspond to the migration trails of each group. More than 90% of our sightings were registered up to 4 km from the coast. In this sense, for this analysis we discarded all positions recorded distant more than 4 km and/or groups with less than three positions recorded. We calculated five parameters of movement analyses usually used in humpback whales studies – Leg speed, Net speed, Linearity, Reorientation rate and Net Course (Peter *et al.*, 1995; Barendse *et al.*, 2010; Gonçalves *et al.*, 2018).

Leg speed: Mean of speeds calculated between two consecutive positions divided by the distance between two positions and the time taken to travel between them (Barendse *et al.*, 2010). We assume the maximum speed for SRWs as 15 km/h (Bannister *et al.*, 1999) thus speeds above that value were discarded.

Net speed: Result from the division of the linear distance between the first and last positions (net distance) and the total time of the track (Barendse *et al.*, 2010).

Linearity: Index calculated by the division of the total distance between the first and last positions (net distance) by the sum of the distances between each position (cumulative distance) of the track. Values of the index range from 0 to 1 with values closer to 0 representing more circular paths and values closer to 1 represent more direct trajectories (Barendse *et al.*, 2010).

Reorientation rate: Sum of all absolute values of change of bearing between two consecutive positions, dividing by the total time of the track. Higher values of reorientation indicate more erratic paths (Smultea & Würsig, 1995)

Net Course: True bearing in degrees considering the first and last position of each track (Barendse *et al.*, 2010).We stratified the study region into three areas according to the coastline orientation: north (from 55º to 105º), south (from 165º to 210º) and other directions (between 106º and 164º).

RESULTS

Research effort and rates

The total time of observation effort for both years was 1,396 hs in 212 days (2018 = 679 hs, 2019 = 717 hs). We recorded a total of 147 groups of SRWs and 1,985 positions resulting in a total of 136 migration tracks. Minimum and maximum distances from the coast were 0.04 km and 7.52 km respectively, with an average distance of 1.66±1.42 km. Speed varied from 13.9 to 0.03 km/h (2.9 km/h±2.3).

Observation rate varied throughout the seasons and among the years. The highest observation rate in 2018 was 0.35 groups/h and it was registered in August. In 2019 and 2002, the highest rate was registered in September and was 0.13 and 0.18 respectively. Beaufort sea state seems to not affect detectability at least until sea state ≥ 5 (X^2 = 7.5346, p = 0.110193).

Groups

The first group sighted in 2018 and 2019 was in July 12th and August 8th, respectively. A total of 113 groups were sighted in 2018 while 34 groups were recorded in 2019 and 66 in 2002. The peak of occurrence of SRWs groups varied among the years, with one peak in late August of 2018, two peaks in 2019, late August and late September, and two peaks in 2002, early August and early September (Figure 2).

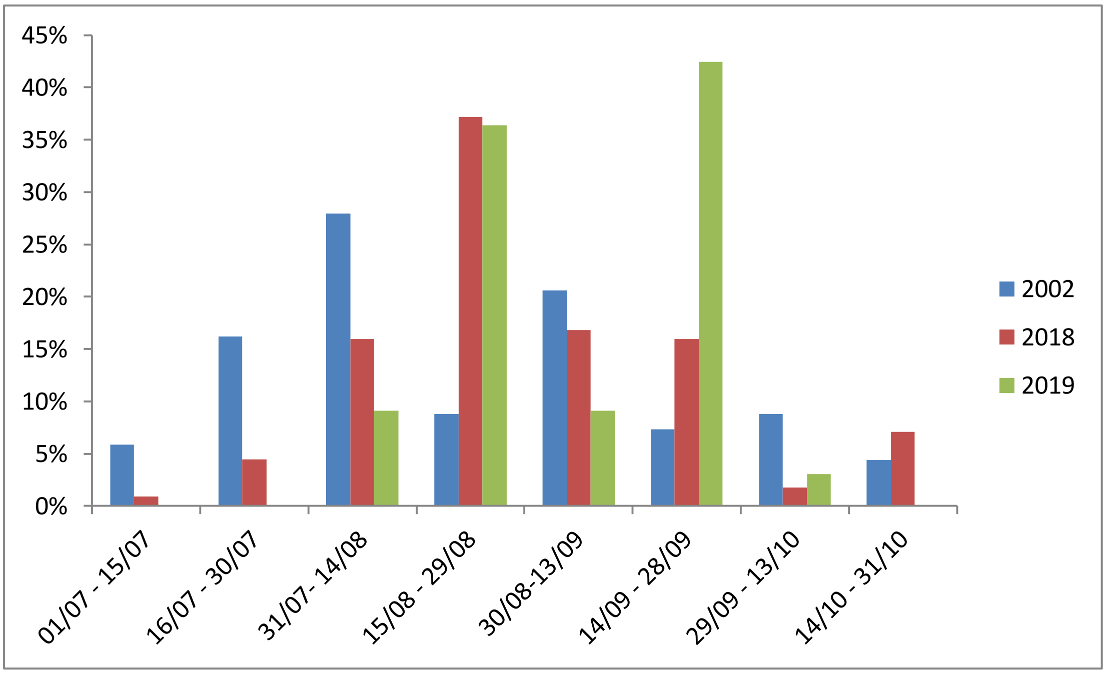

Figure 2. Variation of sighted groups and peaks of occurrence according to month among the breeding seasons of 2002 (Danilewicz, *et al.*, 2016), 2018 and 2019

From the total of 147 SRWs groups with more than two positions recorded in 2018-19, 56.5% (n=83) were unaccompanied and 43.5% (n=64) were mother-calf pairs. Although the total number of unaccompanied whales were higher than mother-calf pairs, in 2019 the number of both groups were the same (n=17). The mean group size in 2018 and 2019 was 1.5 (SD= 0.5, range = 1 - 3 individuals).

The number of mother-calf pairs increased significantly from 2002 to 2018 (X^2 = 4.1384; *p*=0.041). Groups of unaccompanied whales with two individuals were recorded in all years and with three individuals just in 2018 and 2002. The proportion of unaccompanied groups with 3 individuals declined from 6.06% (*n*=4) in 2002 to 1.76% (*n*=2) in 2018 and were absent in 2019. However, groups with two individuals declined from 24.2% (*n*=16) in 2002 for 7.07% (*n*=8) in 2018 and raised again in 2019 to 14.7% (n= 5). The number of solitary whales varied among the years, with an increment from 2002 (n= 28, 42.4% of the total) to 2018 (n= 55, 48.6%) and a decline in 2019 (n = 12, 35.2%).

When we analyzed the numbers of mother-calf pairs and unaccompanied groups per month in all of the years (including 2002) it is possible to observe variations among years on periods when the number of unaccompanied groups and mother-calf pairs start to decrease as well as reach their peak. (Figure 3).

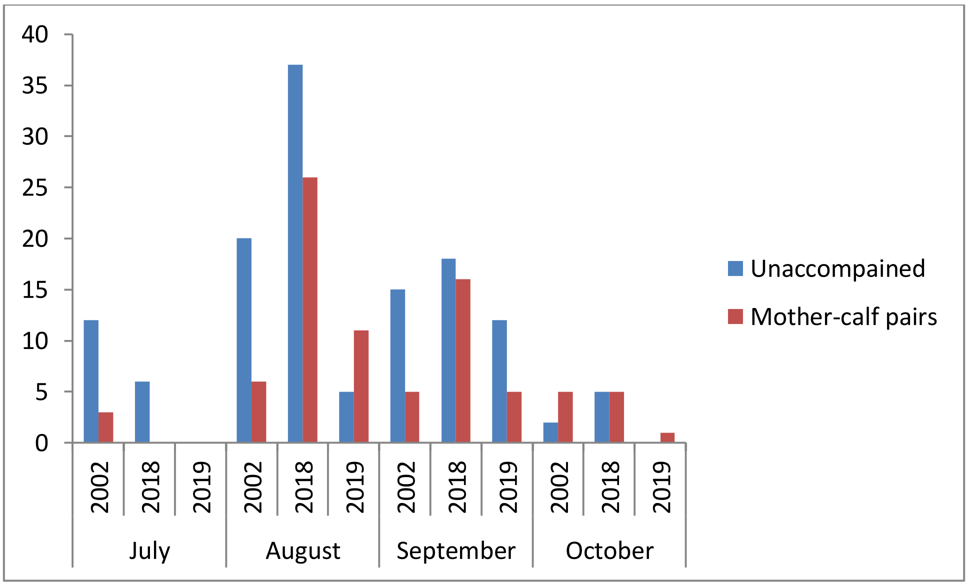

Figure 3. Variation of numbers in Mother-calf pairs and unaccompanied groups along the months according to the breeding seasons of 2002 (Danilewicz, *et al.*, 2016), 2018 and 2019)

Area utilization

The occurrence of SRW groups in relation to the distance from the coast varied significantly between years (*p*=0.0001 *t* = -7.5224). In 2002, groups were further from the coast ($\bar{x}$=2.4 km SD=1.66) than in 2018 ($\bar{x}$= 0.8 km SD=0.62) and 2019 ($\bar{x}$=1.12 km SD=0.75). On the last two seasons (2018-19) distance from the coast varied between 0.5 and 7.23 km. Most positions were concentrated up to 1 km from the coast (Figure 4).

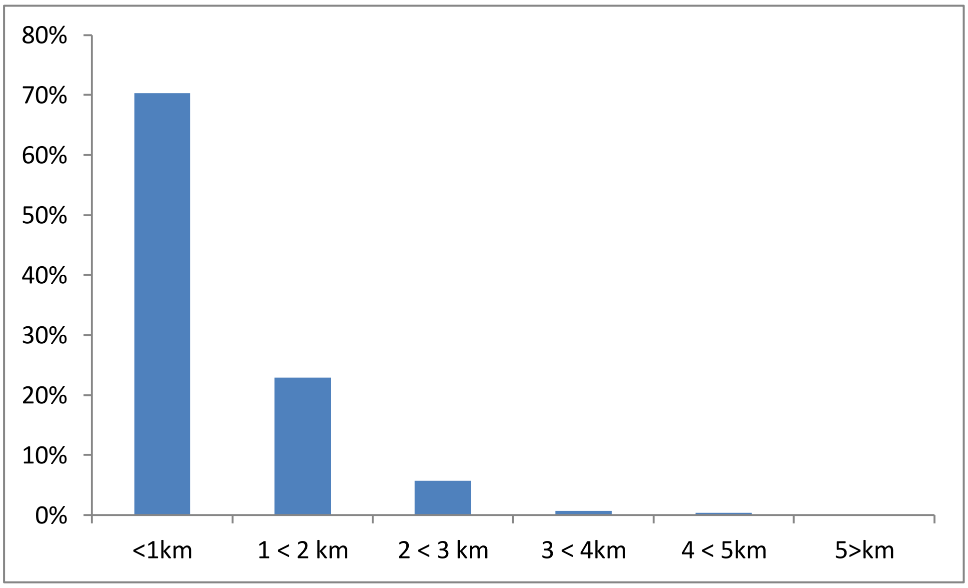

Figure 4. Frequence of whales' positions related to the distance from the coast, in kilometers (km), during the breeding seasons of 2018 and 2019.

Distance from coast did not varied among months within the same year (F=2.19, *p*=0.08). However, our data showed that mother-calf pairs were significantly closer to the coast ($\bar{x}$ =0.6, SD = 0.4) than unaccompanied groups ($\bar{x}$ = 1.1, SD = 0.7) in 2018 (F=244.7, p < 0.01) and 2019 (F=3.54, p=0.05). Mean coastal distance from 2018 and 2019 per month is summarized in Table 1.

Table 1. Mean distance (km) from the coast per month according to the breeding seasons of 2018 and 2019

Year	July	August	September	October	Total
2018	1.24 ±0.79	0.82 ±0.64	0.67 ±0.46	1.08 ±20.82	0.80 ±0.62
2019	0	1.21 ±0.8	1.04 ±0.65	0.31 ±0.19	1.12 ±20.75

Whales were sighted from waters 2.5 to 20 m deep (median= 7.44, $\bar{x}$= 7.17., SD=3.02). SRWs groups occurred in shallower waters in 2018 ($\bar{x}$=6.9, SD=2.8) than in 2019 ($\bar{x}$=8.2, SD=3.5) (F=56.72, p< 0.01). Variation among months was also significant showing that in the middle of the season of 2018 (August and September) whales were using more shallower waters than in the beginning and ending of the same season (F =18.05, p <0.01). In 2019 this analysis was not performed due to the absence of groups in July and low number of groups in October (Table 2). Mother-calf pairs used significantly more shallow waters than unaccompanied whales in both 2018 (F=120.12, p<0.01) and 2019 (F=6.89, p<0.01) seasons.

Table 2. Mean water depth occurrence of SRWs groups per month according to the breeding seasons of 2018 and 2019.

Year	July	August	September	October	Total
2018	8.93 ±4.11	6.79 ±2.83	6.69 ±2.36	8.12 ±3.37	6.93 ±2.82
2019	0	8.48 ±4.17	8.14 ±2.35	5.3 ±0.27	8.25 ±3.59

SRWs appear to change the occurrence pattern through the years. In 2018, SRW groups appear to use the coast more continuously than 2002 and 2019 (Figure 5). Moreover, 2002 present a sparser pattern of positions in contrast to 2018 and 2019 which present a more homogenous distribution (Figure 5). This sparse pattern was also a characteristic of unaccompanied groups which used more areas further from the coast compared to mother-calf pairs which aggregate more in the area between Cal and Praia Grande beaches (Figure 6).

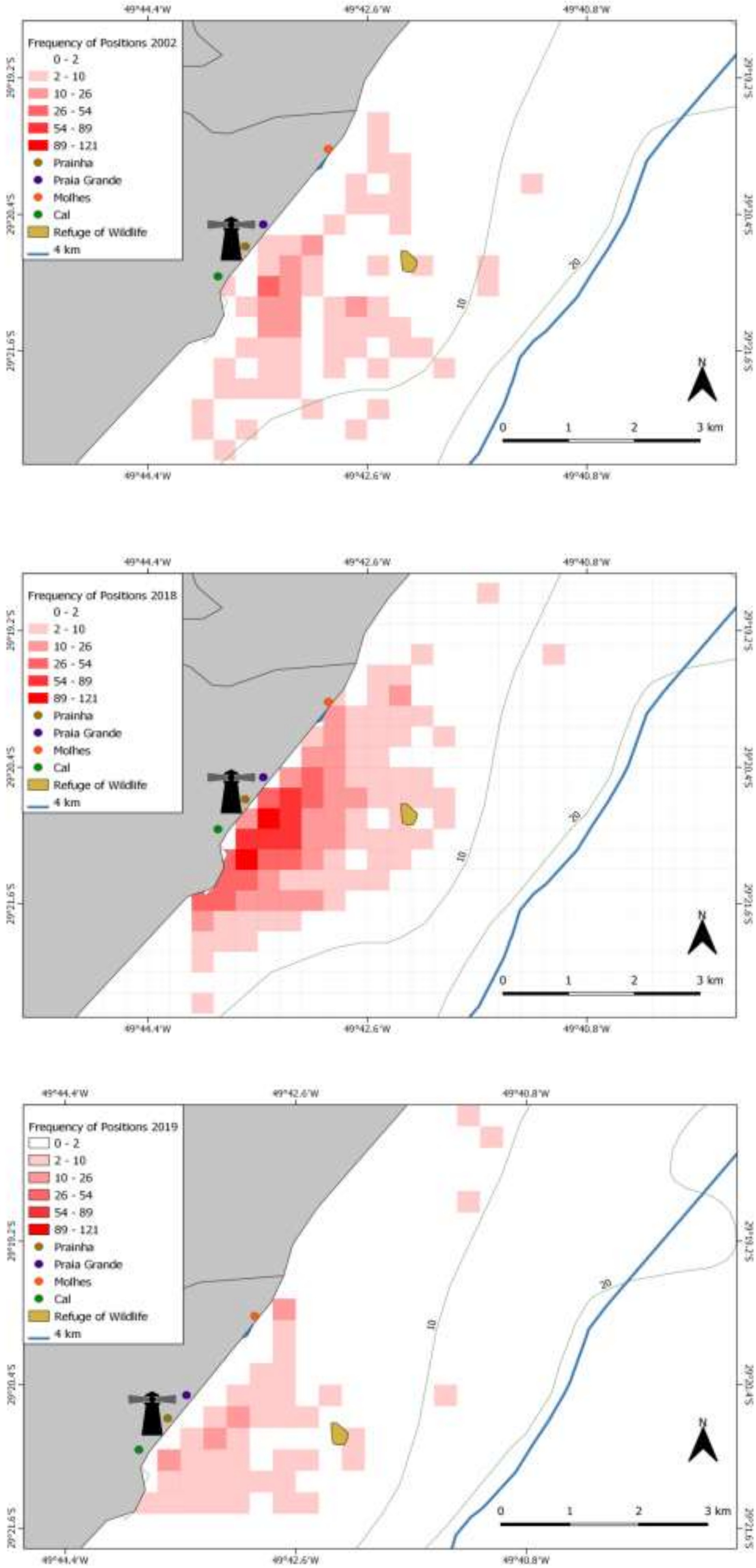

Figure 5. Grid map (90,000 m²) of SRWs positions frequency in the study area (that includes four beaches and the refuge of Wildlife - Ilha dos Lobos) on the breeding season of 2002, 2018 and 2019

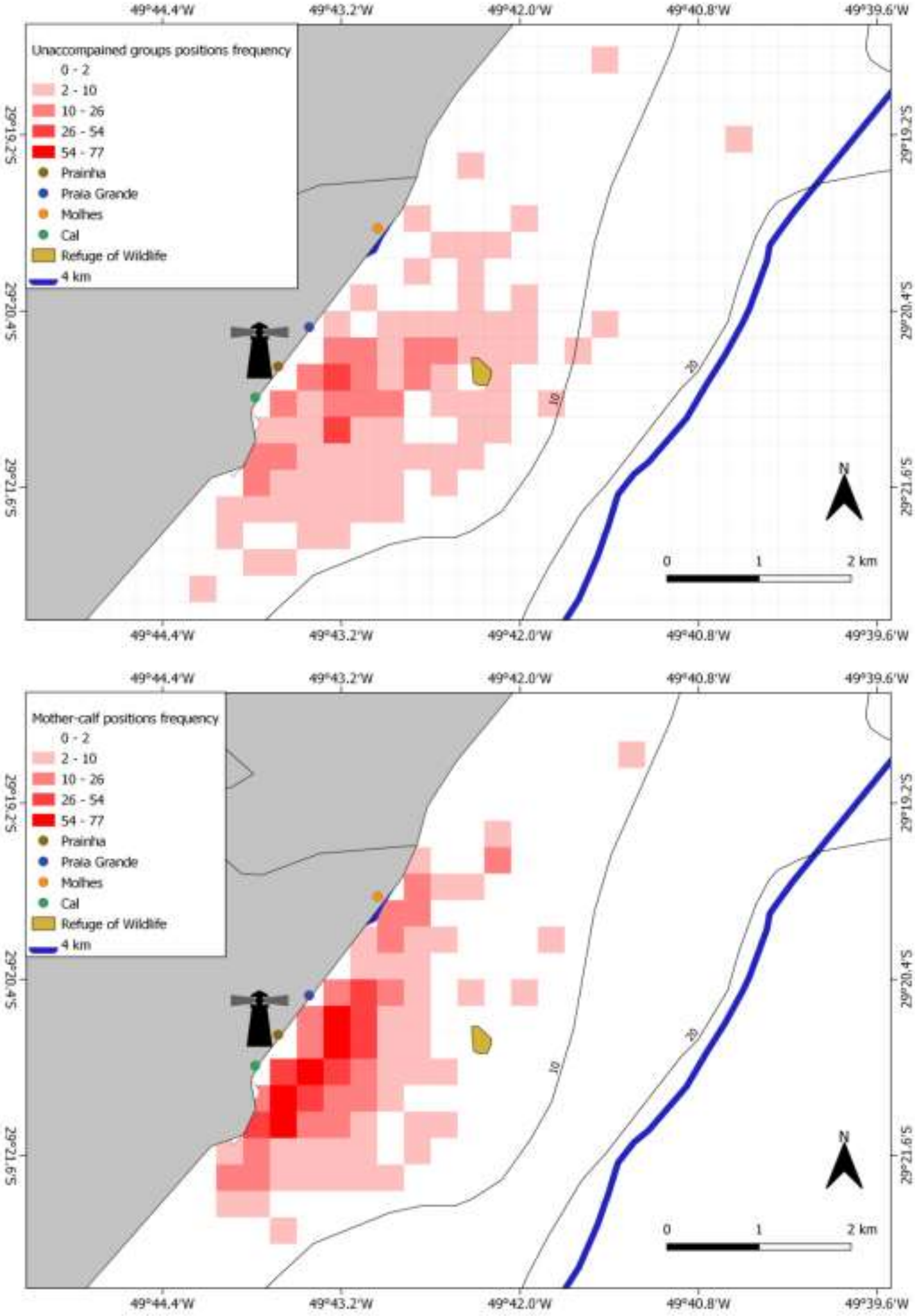

Figure 6. Grid map (90,000 m²) of SRWs positions frequency per group (mother with calves and unaccompained groups) in the study area (that includes four beaches and the refuge of Wildlife - Ilha dos Lobos) on the breeding season of 2018 and 2019

Regarding the influence of wind direction and intensity on group positions, it is noted that when winds are higher than 6 knots and between the angles 200º and 240º (Southwest winds) the frequency of positions of groups (analyzed trough grid maps) tend to stay close to the cliff "Morro da Guarita" located in the south region of the study area. Compared to other types of winds, under southwest winds groups present more aggregate positions than northeast, south (> 6 knots) and north winds (up to 6 knots – north winds higher than 6 knots were not registered) (Figure 7).

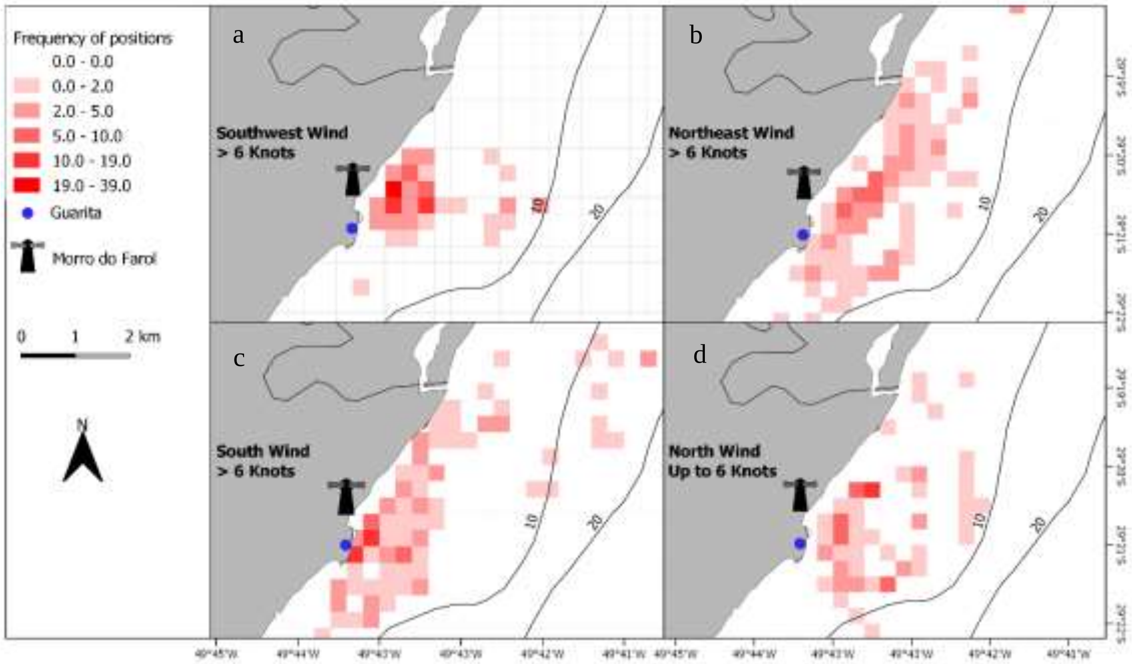

Figure 7. Grid map (90,000 m²) of SRWs positions frequency under the influence of different types of winds (a-Southwest wind > 6 knots b-Northeast wind > 6 knots c- South wind > 6 Knots and d- North wind up to 6 Knots) in the study area on the breeding season of 2018 and 2019.

Movement parameters

Reorientation rate: The mean reorientation rate was 0.90±0.95º/min. There was no significant difference in reorientation rates between 2018 and 2019 (t=-0.2953, p=0.76) neither between mother-calf pairs and unaccompanied groups (t=0.1154, p=0.90). Reorientation rate also did not vary among months (F= 0.7769, p=0.50773).

Leg and net speed: Mean leg speed of groups was 2.96±2.47 km/h and mean net speed was 1.39±1.43 km/h. There was a positive correlation between these two variables (r=0.61, p < 0.00001). Leg speed did not vary between years (t= -0.00077, p= 0.999386), groups (t=-0.27223, p=0.392834) or among months (F= 0.30613, p=0 .820955).

Swimming speed varied according to the distance from the coast (figure 8). It seems that the speed increases after 1 km from the coast (F=34.4636, p<0.0001) and increases again after 4 km (F=6.1589, p<0.05).

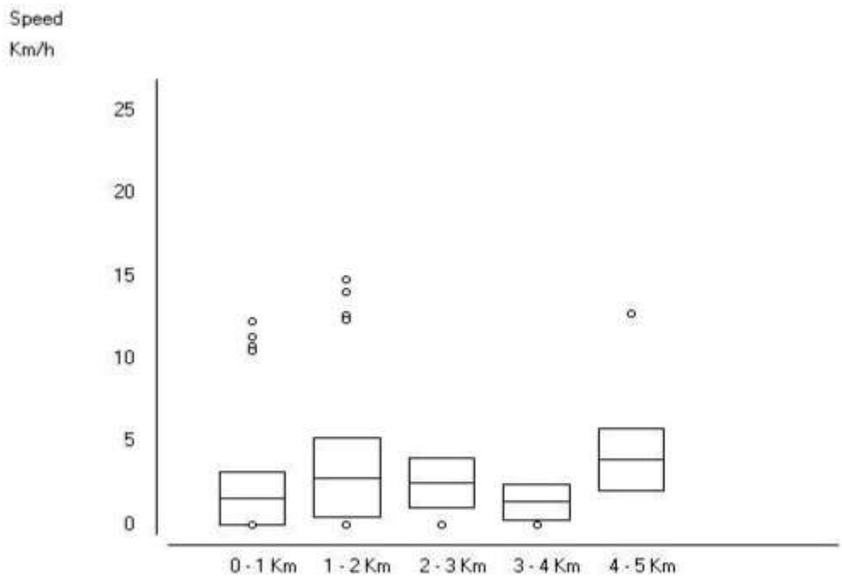

Figure 8. Box plot of leg speed(km/h) among coast distance intervals. The minimum and maximum values are represented at the extremities, the center line represents the median.

Linearity: Linearity mean value of groups sighted was 0.54±0.31. Linearity did not change along the months within seasons (F=0.91376, *p*= 0.43626) neither between groups composition (*t*=0.0126, *p*=0.494942) or years (*t*= -0.19998, *p*= 0.841803).

Net Course: The proportion of SRWs groups heading south was slightly than the other categories (South = 35.55%, North= 34.07%, Other directions = 30.37%) (Figure 9).

Moreover, mother-calf groups showed more movements towards south than unaccompanied groups (Figure 10).

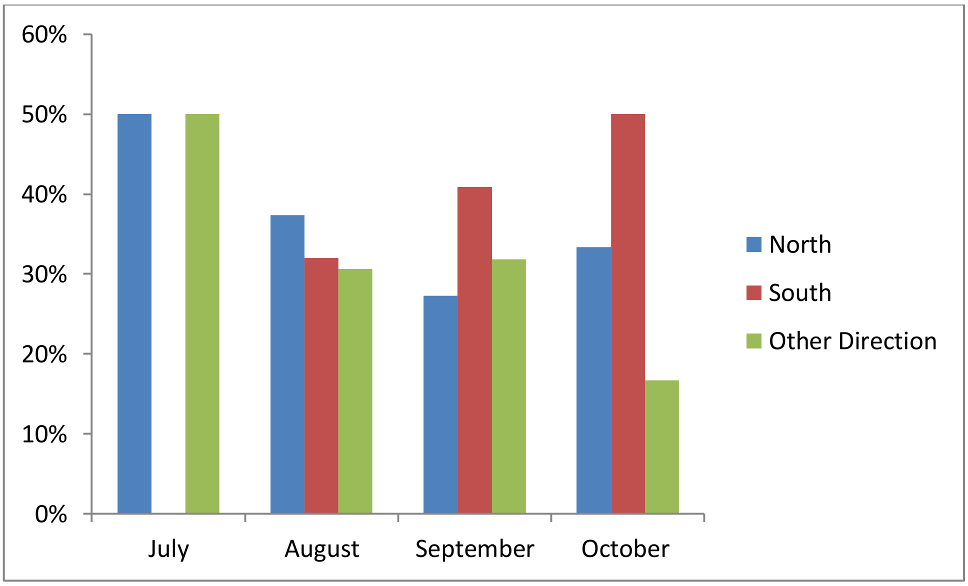

Figure 9. Percentage of groups heading to the three different classes of directions (north, south and other directions) per month of the SRW reproductive season of 2018 and 2019.

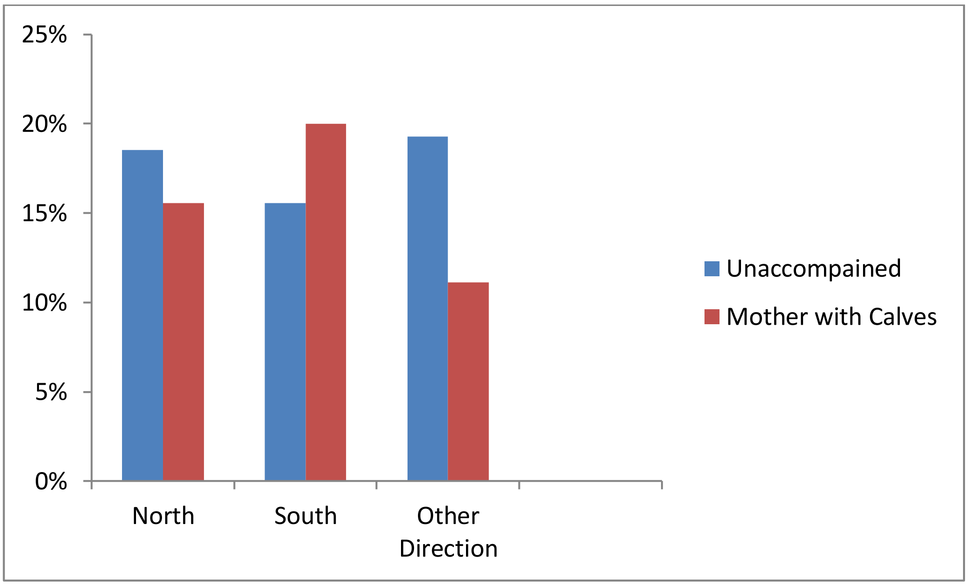

Figure 10. Percentage of groups heading to the three different classes of directions (north, south and other directions) per class of the SRWs groups (Mother with calves and unaccompanied groups) during the reproductive season of 2018 and 2019.

DISCUSSION

Our results corroborate previous studies that report peaks of occurrence between August and September with an increase in the number of mother-calf pairs during these months (Seyboth *et al.*, 2015; Danilewicz *et al.*, 2016; Arias *et al.*,2018; Sueyro *et al.*, 2018). In addition, our results indicate that groups of SRWs leave the study area around early October and have a group structure similar to the ones observed in other areas of reoccupation such as San Matías Gulf in Argentina (Arias *et al.*, 2017, 2018) and Fowlers bay in south Australia (Charlton *et al.*, 2019), with a higher proportion of unaccompanied groups. This pattern is not observed in in high density areas of SC where mother-calf pairs area the most frequent groups (Groch, 2005; Groch *et al.*, 2005; Seyboth *et al.*, 2015).

Changes in habitat use for SRWs were reported also in South Africa (Best, 2000). Movements among different aggregation areas are expected within the same reproductive season (Arias *et al.*, 2017), as well as expansions of area use in peak periods, which have a more continuous distribution of groups (Pires Renault-Braga *et al.*, 2018). This fact can explain variations on distribution and occupation of the area throughout the seasons which shows that in peak month's groups tend to use the coast more continuously than on the initial and final months of the season. Moreover, at the end of the season in 2018 we registered an increase in the distance from the coast. This fact can be associated to the dispersal of groups associated with movements away from the coast (Burnell & Bryden, 1997).

A large majority of the groups were sighted up to 4 km from the coast, corroborating with the occurrence pattern observed in other wintering grounds (Elwen & Best, 2004a; Payne, 1986) and in reoccupation grounds (Charlton *et al.*, 2019). Our results shown similarities in habitat use with Head of Bight (Australia) with groups using preferentially areas up to 2 km from de shore and less than 20 m of depth (Charlton, *et al.*, 2019). Although it is commonly reported that SRWs present a different habitat selection for mother-calf pairs and unaccompanied groups (Arias *et al.*, 2018;Suyero *et al.*, 2018; Elwen & Best, 2004a, 2004b; Figueiredo *et al.*, 2019;

Rowntree *et al*., 2001,2018, Best, 1986) areas of reoccupation do not show a clear pattern of distribution (Danilewicz *et al*., 2016; Arias *et al*., 2018;Arias *et al*., 2017; charlton *et al*., 2019). Our data, however, shown differences in the distributions of groups, following a different pattern of distribution that are described for areas of reoccupation, with mother-calf pairs using areas closer to the shore than unaccompanied groups.

SRWs use different types of areas according to their activity - feeding, nursering, calving and breeding (IWC, 2001). Despite recent papers indicating the region of Torres/RS as an important breeding ground for SRWs (Pires Renault-Braga *et al*., 2018; Danilewicz *et al*., 2016), the significantly increase in the number of mother-calf pairs indicate that Torres/RS is also important as a nursering site. Increased numbers of mother-calf pairs was also observed in a reoccupation site in Australia, where the number of mothers with calves enhanced from 3 to 63 in 20 years (Charlton *et al.*, 2019).

Rowntree *et al*. (2001) reported changes in patterns of habitat use by the SRWs argentine population with the establishment of new nursering grounds and changes in the coast occupation and extension on areas, besides of groups shifting to other reproductive grounds. Reoccupation areas initially appear to play an important role in socialization and reproduction of SRWs groups with a higher proportion of solitary individuals at the beginning and subsequently the increase on the numbers of mothers with calves over the years (Arias *et al*., 2017; Charlton *et al*., 2019). Occupation of new grounds are expected initially with the presence of unaccompanied groups since is noted that most groups moving among areas are solitary individuals or mating groups (Sueyro *et al.*, 2018; Arias *et al* 2018; Crespo & Coscarella, 2018). Although females have a high degree of philopatry, the relocation of these groups may not be noticeable in large-scale studies but, in fine-scale studies, groups of mothers with calves do not necessarily return to the same ground (Best, 2000; Elwen & Best, 2004a, 2004b). It seems that Torres are passing through the same stages of other reoccupation grounds first with the presence of few groups with calves always moving north and register of mating behavior (Simões-Lopes *et al.*, 1992), followed by a high number of unaccompanied groups compared with mother-calf pairs with no differences of distributions between groups (Danilewicz *et al.*, 2016) and nowadays an increase in the number of mother-calf pairs with differences in distribution according to water depth and distance from the coast.

Moreover, SRWs can switch their wintering grounds for many reasons including topographic changes (Rowntree *et al*., 2001), variation in food (krill) availability (Seyboth *et al*., 2016), population growth (Arias *et al*., 2017) and areas reaching their optimal occupation capacity (Crespo & Coscarella, 2018). It's not clear yet how population growth of SRWs in Brazil is affecting their occurrence in other regions, especially in areas adjacent to SC, the biggest density area of Brazil. Suyero *et al* (2018) reported that the reoccupation process of SRWs in Argentine waters started in the middle 2000's affecting their habitat use, mostly regarding the types of groups in the reoccupation areas. The same processe was reported in South Africa in early 2000's by Best (2000). In this sense, monitoring programs such the one carried out in Torres/RS are fundamental to better understand how SRWs will reoccupy historical areas along the Brazilian coast.

When we look to the number of groups among the seasons of 2002, 2018 and 2019 it is possible to see a variation on the months of arrivals and departures, as well as on their peak of occurrence. These variations had already been reported in Argentina (Crespo *et al*., 2019) and Australia (Burnell & Bryden, 1997; Charlton *et al*., 2019).There are many explanations for variations in the number of groups among seasons and arrival-departure timing. Crespo *et al*. (2019) argue that these variations may be related to the surface water temperatures at feeding sites and to years of high influence of el ninõ. Influence of temperature and climate factors also is discussed by Burnell & Bryden (1997) as triggers in Australia where they argue that warmer waters can have affect thermoregulation aspects of the animals. Warmer waters have a direct impact on sea-ice extent and duration which affects krill reproduction and competition with salps. The lack on krill availability may affect directly marine food web (Loeb *et al*., 1997) including SRWs reproductive success (Seyboth *et al*., 2016). Seyboth *et al*. (2016) found a positive correlation between the number of SRWs calves and krill densities near an important feeding ground (South Georgia) for the Brazilian population. Links between krill abundance and ice extent have also been made on studies for humpback whales (*Megaptera novaeangliae*) as well as discussions about its effects on migration and number of groups on reproductive seasons (Gonçalves, *et al.*, 2018) and body condition (Braithwaite *et al*., 2015).

Another factor that can explain variations on the number of groups is density resources pressures such as space. In this sense, saturation capacities in higher density grounds can led to dispersal of this areas in years of high abundance (Charlton *et al.*, 2019).Optimal capacity area was also reported in Argentina and it is one of the potential causes proposed for relocation of groups (Crespo & Coscarella, 2018). The highest occurrence of SRWs off SC in 2018 (Instituto Australis) could cause the dispersion of some groups to south adjacent areas, like Torres/RS, which no occur in 2019.

When observing the variations in distribution among 2002, 2018 and 2019, it is possible to notice that in 2018 and 2019 there were a more continuous use off the coastal region than in 2002. This variation in distribution among the years can be attributed to the exploratory process associated with the population growth of the species (Arias *et al*., 2017), since the process of exploring new areas would began in the early 2000’s (Sueyro *et al*., 2018; Best, 2000).

Wind intensity and direction seem to affect whales’ distribution only for southwest winds higher than 6 knots, when whales used more the protected zone "Morro do Guarita" of the study area. In SC, whales tend to avoid bays facing certain directions according to wind components (Seyboth *et al.*, 2015). In South Africa, was demonstrated preferences for bays according to wind protection as well (Elwen & Best, 2004a, 2004b). Even though, Torres does not present a bay, the “Morro da Guarita” could represent a barrier against strong southwest winds. The aggregation of positions close to “Morro da Guarita” on strong southwest winds suggests that whales’ groups could be using the cliff as a protection.

Our results of movementes parameters showed speeds within the range (1.1-3.7 km/h) expected for coastal movements of SRWs registered in Head of the Great Australian Bight on the southern coastline of Australia (Burnell, 2001), although a little bit higher from what was registered in South Africa (Best, 2000). As observed for for humpack whales on a recovery breeding ground in Bahia (Gonçalves *et al.*, 2018), the leg speed of SRWs increased with the distance from the coast. Linearity did not change along the seasons. More linear trajectories could indicate the beginning of migration back to feeding grounds (Gonçalves *et al*., 2018), however our data do not shown a clear patter between the beginnig and the end of the reproductive season. Although, there was a variation on the proportions of groups headings along months, whales moving to the north tended to decrease along the seasons, while movements to the south increased mainly in September and October showing the beginning and ending of the reproductive season. In addition, it is interesting to note that unaccompanied groups were mostly seem heading north while mother with calf groups were more common heading south. This could be related to the fact that a portion of the females whales gave birth (probably at the main ground in SC) and were sighted in Torres already with their offspring during their migration to the feeding areas.

Our data demonstrated that Torres/RS present characteristics of a reocupation area, which has been passing through changes over time related to the increment of SRWs population. The increasing number of mother-calf pairs demonstrates that the area is also important as a nursery ground. Once Torres has an artisanal and medium-scale fishing community(Moreno *et al*., 2009), our data should be used to plan management strategies to minimize the overlap betweenSRWs and fishing activities. Moreover, we strongly recommend more studies in recovery grounds in Brazil since little is know about the patterns of reocupation in the country and, with the continous growth of population, whales will keep realocating to old or new areas and it will increase conflits with anthropic activities.

REFERENCES

Amante, C., & Eakins, B. W. (2009). ETOPO-1 1 arc-minute global relief model: Procedures, data source and analysis.U.S. Department of Commerce., NOAA Technical Memorandum NESDIS NGDC-24., 19pp.

Arias, M., Coscarella, M. a., Svendsen, G., Romero, M.A., Curcio, N., Sueyro, N., Crespo, E.A., and Gonzalez, R. (2017). Changes in the distribution and abundance of Southern Right Whale Eubalaena australis in San Matías Gulf (Patagonia , Argentina). *International Whaling Commission*.

Arias, M., Coscarella, M.A., Romero, M.A., Sueyro, N., Svendsen, G.M., Crespo, E.A., and González, R.A.C. (2018). Southern right whale Eubalaena australis in Golfo San Matías (Patagonia, Argentina): Evidence of recolonisation. *PLOS ONE* 13, e0207524.

Arias, M., Coscarella, M.A., Romero, M.A., Svendsen, G.M., Reinaldo, M.O., Curcio, N.S., Crespo, E.A., and González, R.A.C. (2018). Impact of whale-watching on Southern Right Whale (Eubalaena australis) in Patagonia: Assessing the effects from its beginnings in the context of population growth. *Tourism Management Perspectives* 27, 1–9.

Bannister, J.L., Kemper, C.., and Warneke, R.. (1999). The Action Plan for Australian Cetaceans. *Australian Nature Conservation Agency* 272.

Barendse, j., Best, p.b., Thornton, m., Pomilla, c., Carvalho, i. & Rosenbaum, h.c(2010). Migration redefined ? Seasonality , movements and group composition of humpback whales Megaptera novaeangliae off the west coast of South Africa. *African Journal of Marine Science* 32, 37–41.

Barendse, J., and Best, P.B. (2014). Shore-based observations of seasonality, movements, and group behavior of southern right whales in a nonnursery area on the South African west coast. *Marine Mammal Science* 30, 1358–1382.

Best, P. B. (2000). Coastal distribution, movements and site fidelity of right whales Eubalaena australis off South Africa, 1969–1998. *South African Journal of Marine Science* 22, 43–55.

Best, Peter B. (2000). Coastal distribution, movements and site fidelity of right whales *Eubalaena australis* off South Africa, 1969–1998. *South African Journal of Marine Science* 22, 43–55.

Best, Peter B, Payne, R., Rowntree, V., Palazzo, J.T., and Both, M.D.C. (1993). Long-range movements of south atlantic right whales E*ubalaena australis*. *Marine Mammal Science* 9, 227–234.

Best, Peter B, Sekiguchi, K., and Findlay, K.P. (1995). A suspended migration of humpack whales Megaptera novaeangliae on the west coast of South Africa. *Marine Ecology Progress Series* 118, 1–12.

Braithwaite, J.E., Meeuwig, J.J., Letessier, T.B., Jenner, K.C.S., and Brierley, A.S. (2015). From sea ice to blubber: linking whale condition to krill abundance using historical whaling records. *Polar Biology* 38, 1195–1202.

Burnell, S. R. (2001). Aspects of the reproductive biology, movements and site fidelity of right whales off Australia. Journal of Cetacean Research and Management (Special Issue) 2:89–102.

Burnell, S.R., and Bryden, M.M. (1997). Coastal residence periods and reproductive timing in southern right whales, Eubalaena australis. *Journal of Zoology* 241, 613–621.

Camara, I.C., and Truda Palazzo Jr, J.T. (1986). Novas informacoes sobre a presencia de Eubalaena australis no sul do Brasil. *Resumenes de La Primera*

Reunion de Expertos En Mamiferos Acuaticos de America Del Sur 13.
Carroll, E.L., Childerhouse, S.J., Fewster, R.M., Patenaude, N.J., Steel, D., Dunshea, G., Boren, L., and Baker, C.S. (2013). Accounting for female reproductive cycles in a superpopulation capture–recapture framework. *Ecological Applications* 23, 1677–1690.
Charlton, C., Ward, R., McCauley, R.D., Brownell, R.L., Guggenheimer, S., Salgado Kent, C.P., and Bannister, J.L. (2019). Southern right whales (Eubalaena australis) return to a former wintering calving ground: Fowlers Bay, South Australia. *Marine Mammal Science* 000, mms.12611.
Charlton, C., Ward, R., McCauley, R.D., Brownell, R.L., Salgado Kent, C., and Burnell, S. (2019). Southern right whale (*Eubalaena australis*), seasonal abundance and distribution at Head of Bight, South Australia. *Aquatic Conservation: Marine and Freshwater Ecosystems* 29, 576–588.
Crespo, E., and Coscarella, M. (2018). The Southwestern Atlantic Southern Right Whale, *Eubalaena australis*, population is growing but at a decelerated rate.
Danilewicz, D., Moreno, I.B., Tavares, M., and Sucunza, F. (2016). Southern right whales (Eubalaena australis) off Torres, Brazil: Group characteristics, movements, and insights into the role of the Brazilian-Uruguayan wintering ground. *Mammalia* 81, 225–234.
Elwen, S.H., and Best, P.B. (2004a). Environmental factors influencing the distribution of southern right whales (*Eubalaena australis*) on the south coast of south africa i: broad scale patterns. *Marine Mammal Science* 20, 567–582.
Elwen, S.H., and Best, P.B. (2004b). Environmental factors influencing the distribution of southern right whales (*Eubalaena australis*) on the south coast of south africa ii: within bay distribution. *Marine Mammal Science* 20, 583–601.
Figueiredo, G.C.E., Goya, S.C.Y., and Santos, M.C.D.O. (2019). Southern right whales in the South-western Atlantic Ocean: proposed criteria to identify suitable areas of use in poorly known reproductive grounds. *Journal of the Marine Biological Association of the United Kingdom* 99, 1231–1236.
Gonçalves, M.I.C., De Sousa-Lima, R.S., Teixeira, N.N., Morete, M.E., De Carvalho, G.H., Ferreira, H.M., and Baumgarten, J.E. (2018). Low latitude habitat use patterns of a recovering population of humpback whales. *Journal of the Marine Biological Association of the United Kingdom* 98, 1087–1096.
Gonçalves, M.I.C., Sousa-Lima, R.S. de, Teixeira, N.N., Carvalho, G.H., Danilewicz, D., and Baumgarten, J.E. (2018). Movement patterns of humpback whales (Megaptera novaeangliae) reoccupying a Brazilian breeding ground. *Biota Neotropica* 18.
Greig, A., Secchi, E., Zerbini, an, and Rosa, L. (2001). Stranding events of southern right whales, Eubalaena australis, in southern Brazil. *J. Cetacean Res. Manage* 157–160.
Groch, K. R., Palazzo, Jr., J.T., Flores, P.A.C., Adler, F.R., and Fabian, M.E. (2005). Recent rapid increases in the right whale (Eubalaena australis) population off southern Brazil. *Latin American Journal of Aquatic Mammals* 4, 41–47.
Groch, Karina Rejane. (2000). *Ocupação preferencial de áreas de concentração pela Baleia Franca Austral,* Eubalaena australis *(Desmoulins, 1822), CETACEA, MYSTICETI, no litoral sul do Brasil.*
Groch, Karina Rejane. (2005). *Biologia Populacional e Ecologia Comportamental de Baleia Franca Austral, Eubalaena australis, (Desmoulins, 1822), CETACEA. MISTICETI, no litoral sul do Brasil*. *Ecologia*.
IWC. (2001). Report workshop on the comprehensive assessment of right whales: A

worldwide comparison. *Cetacean Research and Managment* 2, 1–60.

Loeb, V., Siegel, V., Holm-Hansen, O., Hewitt, R., Fraser, W., Trivelpiece, W., and Trivelpiece, S. (1997). Effects of sea-ice extent and krill or salp dominance on the Antarctic food web. *Nature* 387, 897–900.

Morais, I.O.B. de, Danilewicz, D., Zerbini, A.N., Edmundson, W., Hart, I.B., and Bortolotto, G.A. (2016). From the southern right whale hunting decline to the humpback whaling expansion: a review of whale catch records in the tropical western South Atlantic Ocean. *Mammal Review* 47, 11–23.

Moreno, I. B.; Ott, P. H. & Danilewicz, D. (1997). Análise preliminar do impacto da pesca artesanal costeira sobre Pontoporia blainvillei no litoral norte do RS, sul do Brasil. In: PINEDO, M. C. & BARRETO, A. S. eds. Anais do 2º Encontro sobre Coordenação de Pesquisa e Manejo da Franciscana. Rio Grande, FURG. p.31-41.

Moreno, I.B., Tavares, M., Danilewicz, D., Ott, P.H., and Machado, R. (2009). Descrição da pesca costeira de média escala no litoral Norte do Rio Grande do Sul: Comunidades pesqueiras de Imbé/Tramandaí e Passo de Torres/Torres. *Boletim Do Instituto de Pesca* 35, 129–140.

Ott, P. H. (1998). Análise das capturas acidentais da toninha, Pontoporia blainvillei, no litoral norte do Rio Grande do Sul, sul do Brasil. Master Thesis. Porto Alegre, Pontifícia Universidade Católica do Rio Grande do Sul. 120p.

Palazzo Jr, J.T., and Carter, L.A. (1983). *A Caça de Baleias no Brasil*.

Payne, R. (1986). Long term behavioural studies of the southern right whale (*Eubalaena australis*). *Report of the International Whaling Commission, Special Issue*.

Perrin, W.F., Wursig, B., and Thewissen, J.G.M. (2009). *Encyclopedia of Marine Mammals*. *Encyclopedia of Marine Mammals*. Elsevier.

Pires Renault-Braga, E., Rejane Groch, K., de Carvalho Flores, P.A., Secchi, E.R., and Dalla-Rosa, L. (2018). Area usage estimation and spatiotemporal variability in distribution patterns of southern right whales, Eubalaena australis , of southern Brazil. *Marine Ecology* 39, e12506.

Rowntree, V., Payne, R., and Schell, D. (2001). Changing patterns of habitat use by southern right whales (*Eubalaena australis*) on their nursery ground at Península Valdés, Argentina, and in their long-range movements. *Journal of Cetacean Research and Management Special Issue* 133–143.

Santos, M.C. de O., Siciliano, S., de Souza, S.P., and Altmayer Pizzorno, J.L. (2001). Occurrence of southern right whales (Eubalaena australis) along southeastern Brazil. *Journal of Cetacean Research & Management Special Issue.* 2, 153–156.

Seyboth, E., Groch, K.R., Dalla Rosa, L., Reid, K., Flores, P.A. de C., and Secchi, E.R. (2016). Southern Right Whale (*Eubalaena australis*) Reproductive Success is Influenced by Krill (*Euphausia superba*) Density and Climate. *Scientific Reports* 6, 1–8.

Seyboth, E., Groch, K.R., Secchi, E.R., and Dalla Rosa, L. (2015). Habitat use by southern right whales, *Eubalaena australis* (Desmoulins, 1822), in their main northernmost calving area in the western South Atlantic. *Marine Mammal Science* 31, 1521–1537.

Simões-Lopes, P.C., Palazzo Jr, J.T., Both, M.C., and Ximenez, A. (1992). Identificação, movimentos e aspectos biológicos da baleia franca austral (*Eubalaena australis*) na costa sul do Brasil.

Smultea, M. A., & Würsig, B. (1995). Behavioral reactions of bottlenose dolphins to the Mega Borg oil spill, Gulf of Mexico 1990. Aquatic Mammals, 21(3), 171’81.

Sueyro, N., Crespo, E., Arias, M., and Coscarella, M. (2018). Density-dependent changes in the distribution of southern right whales (Eubalaena australis) in the breeding ground Peninsula Valdés..