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Estudo da distribuição da população de *Calidris canutus rufa* (Aves: Scolopacidae) no Parque Nacional da Lagoa do Peixe, Rio Grande do Sul.

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Abundance and distribution of *Calidris canutus rufa* (Aves: Scolopacidae) in the Lagoa do Peixe National Park, Rio Grande do Sul, Brazil

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Abstract

The Red Knot *Calidris canutus rufa* is one of the species of shorebirds that partakes in huge migration journeys. They breed in the Nearctic and migrate to southern locations including Tierra del Fuego in southern South America to spend boreal winter. Over the last years there has been a severe decline in *C. c. rufa* population due to over-harvesting of their preys and degradation of their habitats. During migration, these birds use several stopover sites to refuel and replenish their energies. One of the main stopover sites in South America is the Lagoa do Peixe National Park, located in the southern state of Brazil, Rio Grande do Sul. Very little is known about the distribution and behavior of this species in the Park. In this study we elaborated a census of *C. c. rufa* in the Lagoa do Peixe National Park from October 2013 to August 2014, and evaluated foraging and roosting behavior in relation to flock size patterns. Results showed about 200 individuals on October 2013 and very few numbers on November and December 2013 and January and February 2014. April was the peak month with around 550 individuals and about 200 birds were seen during the months of May, June and July. The flocks located in the beach were significant smaller than flocks located on the lagoon, and flocks with roosting behavior were significant larger than flocks with foraging behavior. The beach was mainly used for foraging while in the lagoon both behaviors were common. Birds were found to use the beach in small flocks to forage, probably to increase foraging efficiency, while they organized to roost on the lagoon in larger flocks for what we assumed to decrease the risk of predation. There has been a decrease in numbers of *C. c. rufa* when comparing with previous studies in this location and this can be attributed to the world decline of the Red Knot population and several threats the birds encounter in their habitats. Also, the census showed an increased number in the over-summering Red Knots in Lagoa do Peixe National Park, which could be related to sexually immature birds, parasitism, illness or birds that were unable to obtain enough weight to migrate.

Key words: Behavior; habitat use; flock size; census.

Introduction

About 66% of shorebirds, members of the Charadriiformes order, have migration as a critical segment of their annual cycle (WARNOCK *et al.* 2001). The Red Knot *Calidris canutus* (LINNAEUS, 1758) (Scolopacidae) is a Holarctic-breeder species which presents six recognized subspecies (DEY *et al.* 2011). Among which, *Calidris canutus rufa* (WILSON, 1813), is the only known to occur in the Atlantic coast of South America. These birds breed in the middle and high-Artic areas of Northern Canada and begin their 15.000 kilometers migratory journey to spend their non-breeding period mainly in four distinct coastal areas in the Western Hemisphere: (1) Southeastern of the United States, (2) Texas in southern USA, (3) Maranhão in northern Brazil and (4) Tierra del Fuego and Patagonia in southern Chile and Argentina (NILES *et al.* 2008). These non-breeding seasonal locations are marine coastal habitats, usually large wetlands with extensive intertidal foreshores with soft substrates, where they feed mostly on hard-shelled prey such as bivalves, gastropods and sometimes small crustaceans (PIERSMA *et al.* 1993, 2005). During migration, Red Knots populations depend on a very limited number of stopover sites that provide food and shelter necessary for them to continue their journey (NILES *et al.* 2008).

During northward migration, *C. c. rufa* has the Delaware bay, USA, as the last major refueling stopover site, where birds feed mainly on horseshoe crabs eggs (*Limulus polyphemus* (LINNAEUS, 1758), Limulidae) to replenish energy just before breeding season. The over-harvesting of horseshoe crabs and also excessive human disturbance, pollution and degradation of habitats are considered responsible for a decline of 90% on the South America wintering populations of *C.c. rufa* (PIERSMA & BAKER 2000, BAKER *et al.* 2004, MORRISON *et al.* 2004, NILES *et al.* 2008, DEY *et al.* 2011,).

In South America, another prominent stopover site for *C.c. rufa* during its northward migration is the Lagoa do Peixe National Park, located in the southernmost state of Brazil, Rio Grande do Sul. Lagoa do Peixe is a coastal lagoon that provides shelter for more than 220 species of birds, including 22 Nearctic wintering migrants (VALENTE *et al.* 2011). The Park is considered crucial stopover site for several Nearctic migrant shorebirds, including *C.c. rufa* (HARRINGTON *et al.* 1986, RESENDE 1988, FEDRIZZI 2008). However, several studies have shown that the population peaks of *C.c. rufa* in the Lagoa do Peixe National Park have been systematic declining since the mid 80's

and the late 2000's (HARRINGTON *et al.* 1986, RESENDE 1988, BAKER *et al.* 2004, FEDRIZZI 2008).

Although *Calidris canutus* as species presents conservation status 'Least Concern' by the International Union of Conservation of Nature (IUCN, 2014), *C.c. rufa* populations has declined dramatically in the last decades (NILES *et al.* 2008, DEY *et al.* 2011). This species suffers what is currently considered the most precipitous population decline witnessed in the history of avian conservation (BAKER *et al.* 2004, NILES *et al.* 2008) and even so, very little is known about its distribution and habitat use in the Lagoa do Peixe National Park along the year, with the last year-long duration study done almost 30 years ago by RESENDE(1988).

Population biology is the foundation of applied ecology because it provides the data to evaluate the success (or failure) of conservation and management actions. Monitoring populations is integral to gaining protection of species by demonstrating that populations are low and declining (COWELL 2010). Since different migratory species using different habitats may coexist together in one area, it is important to know which species uses which habitats, for future management of the area and protection of the birds (RESENDE, 1988).

The objectives of this study are:(1) Elaborate a census of the population of *C.c. rufa* in the Lagoa do Peixe National Park from October 2013 to August 2014, (2) compare local population size with the last studies (HARRINGTON *et al.* 1986, RESENDE 1988, FEDRIZZI 2008) and (3) identify distribution of *C. c. rufa* and habitat use in relation with behavior and flock size patterns.

Material and Methods

Study Area

Lagoa do Peixe National Park (31°20'S; 51°00'W) is located in the Rio Grande do Sul state, in southern coast of Brazil. It is mostly inside Tavares municipality, located between the Atlantic Ocean and the Lagoa dos Patos (**Fig. 1**), the Park was founded in November 5th 1986, and it consists of several lagoons formed along the coast, with Lagoa do Peixe being the biggest one (IBAMA 1999, ANDRADE *et al.* 2003). Lagoa do Peixe is a shallow lagoon with brackish to salt water, and is about 40 kilometers long, 1 kilometer wide and 0.4-1.2 meters deep, varying depending on the season and location. The lagoon is periodically connected to the Atlantic Ocean by a man-made channel called “barra” (**Fig. 2**). The opening of the “barra” is mostly artificial, usually done with the assistance of a tractor. However, when the lagoon becomes too high, it can break through the narrow line of beach and open the connection (RESENDE 1988). This maintains a constant influx of salt water which sustains a rich fauna of invertebrates all year round (NILES *et al.* 2008). During northward migration in March-April and in southward migration in September-October, Red Knots use the lagoon and the ocean beach parallel to the lagoon for foraging and moulting the feathers, and the fat accumulated there is essential for them to reach their destination (HARRINGTON *et al.* 1986). The importance of this area for migrant shorebirds was recognized internationally and in 1991 it was included in the Western Hemispheric Shorebirds Reserve Network (WHSRN) (Wetlands International 1997).

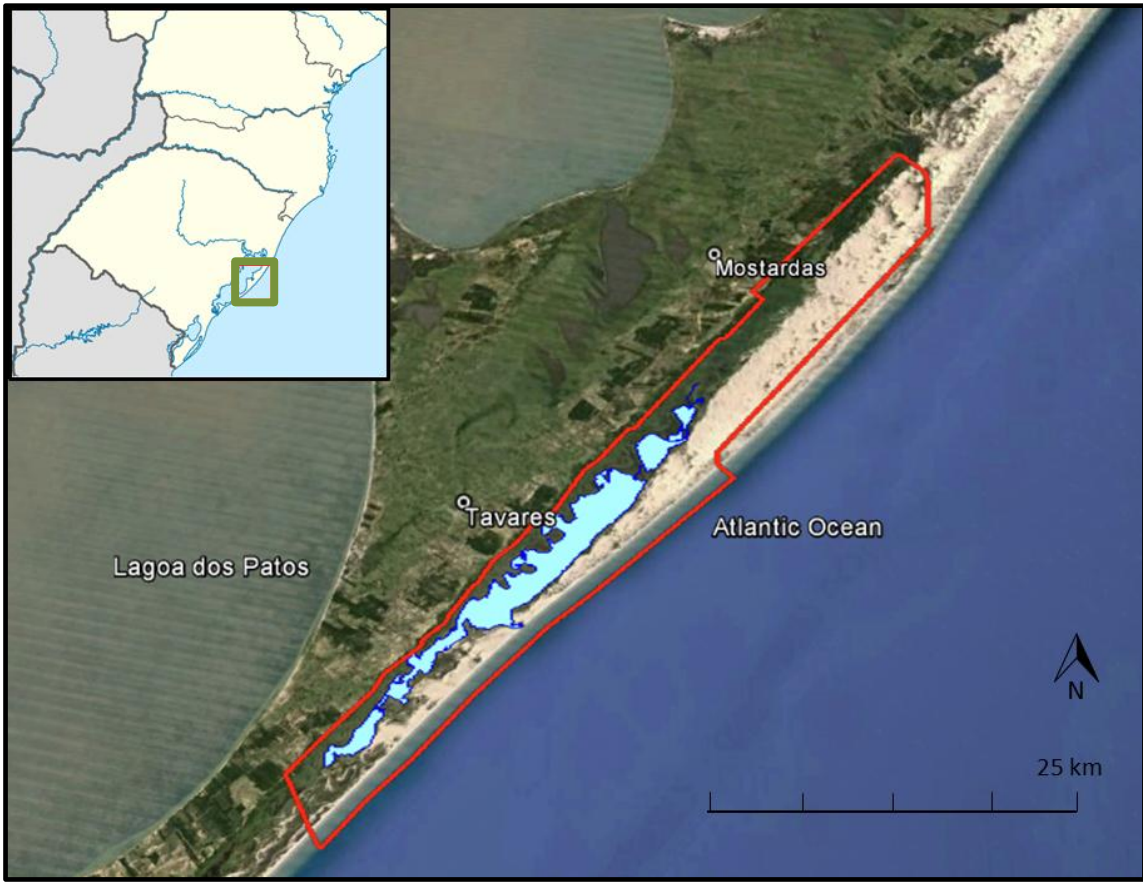


Figure 1. Location of the Lagoa do Peixe National Park (red line) and the Lagoa do Peixe lagoon (light blue).



Figure 2. The “barra” region where the Lagoa do Peixe lagoon (right side) connects with the Atlantic Ocean (left side).

Bird Census

To infer the seasonal fluctuation of the *Calidris canutus rufa* population at Lagoa do Peixe National Park, monthly census expeditions were carried out between October 2013 and August 2014 (Except June due to transport problems). The census was conducted daily and repeated for about 3 to 4 days at two sites: (1) along the beach parallel to the north portion of Lagoa do Peixe and (2) inside the shallow portions of the lagoon, at “barra” region.

The beach region has 30 kilometers long, from the Mostardas balneary (31° 9'13.81"S; 50°48'30.28"W) to the “barra” region (31°21'30.44"S; 51° 2'18.63"W). In this, the census was carried out by car, according to VOOREN & CHIARADIA (1990), traveling at approximately 40km/h with two observers. The lagoon region include the transect from the “barra” (from 31°21'30.44"S; 51° 2'18.63"W) to inside of the lagoon (31°20'7.13"S; 51° 1'43.09"W), and was traversed on foot skirting the margin of the lagoon (**Fig. 3**). These areas were selected based on previous studies (HARRINGTON *et al.* 1986, RESENDE 1988, FEDRIZZI 2008). The census was conducted according to BIBBY *et al.* (1992) with line transects and flock counting. Individuals of *C. c. rufa* and their flock size were spotted and counted with the help of a spotting scope (10x40-60) and binoculars (8x40), and their position registered with GPS. As BIBBY *et al.* (1992) suggests, in small roosting and feeding flocks the number of birds were counted directly, whereas for the larger flocks (*i.e.*, >100 birds) photographs were taken and later the individuals were counted on a computer.

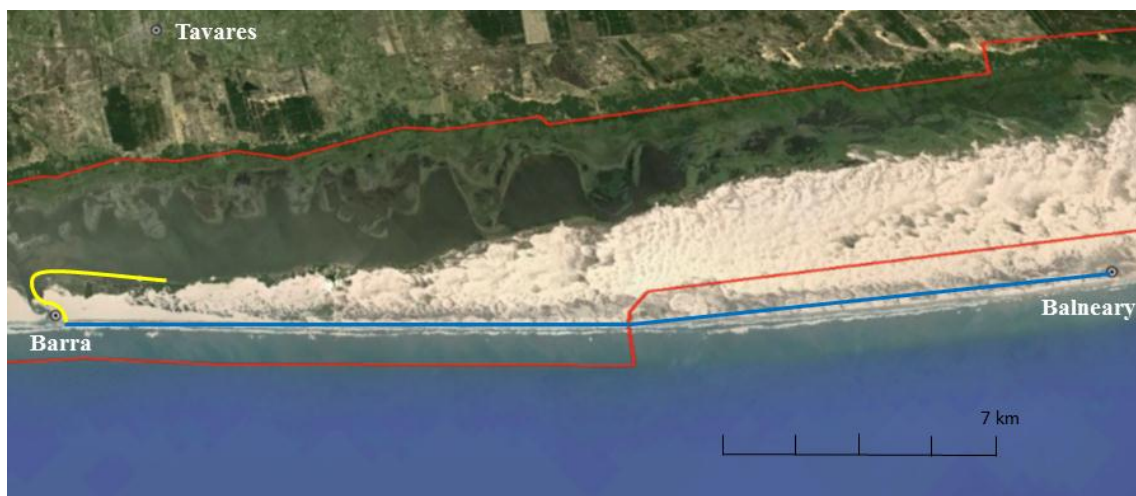


Figure 3. Study area showing the route done by car on the beach (blue line), the route done by foot on the lagoon region (yellow line) and the area of the Lagoa do Peixe National Park (red line).

Behavior, Habitat use and Flock Size

For every flock spotted, two additional characteristics were registered. The first was habitat; all flocks and individuals were put into two different categories of macro-habitat: (1) Beach, including all flocks and individuals that were between the region of the Mostardas balneario and the “barra” region (from 31° 9'13.81"S; 50°48'30.28"W to 31°21'30.44"S; 51° 2'18.63"W) (**Fig. 3**), (2) Lagoon, including all flocks and individuals that were in the “barra” region and inside the lagoon (from 31°21'30.44"S; 51° 2'18.63"W to 31°20'7.13"S; 51° 1'43.09"W) (**Fig. 3**). The second characteristic was behavior; each flock observed was put in one of two behavior categories: (1) Foraging (feeding or searching for food) (**Fig. 4**) or (2) Roosting (resting or preening) (**Fig. 5**) (RESENDE 1988). If one flock was observed having both behaviors, the behavior category considered was the one of the majority (>50% individuals of the flock). To test variation of flock size with behavior and habitat selection, an Analysis of Variance (ANOVA) was conducted using the R software version 3.1.1.



Figure 4. Flock of *Calidris canutus rufa* with foraging behavior.



Figure 5.Flock of *Calidris canutus rufa* with roosting behavior.

Results

Bird Census

Between the months of October 2013 and August 2014, a total of 2960 individuals of *C. c. rufa* distributed in 163 flocks were registered. The average size of the flocks was 18.159 (SD= 27.623), with the largest one having 235 individuals. The months of March and April (austral autumn) showed the highest counts, while the summer months (December, January and February) had the smallest numbers, and winter (May, June and July) showed higher numbers than the summer. June data was provided by the Park workers. August counting was compromised due to weather conditions that made the study areas inaccessible, a single flock of 32 individuals was found in the southern part of the lagoon on this month (**Fig 6**).

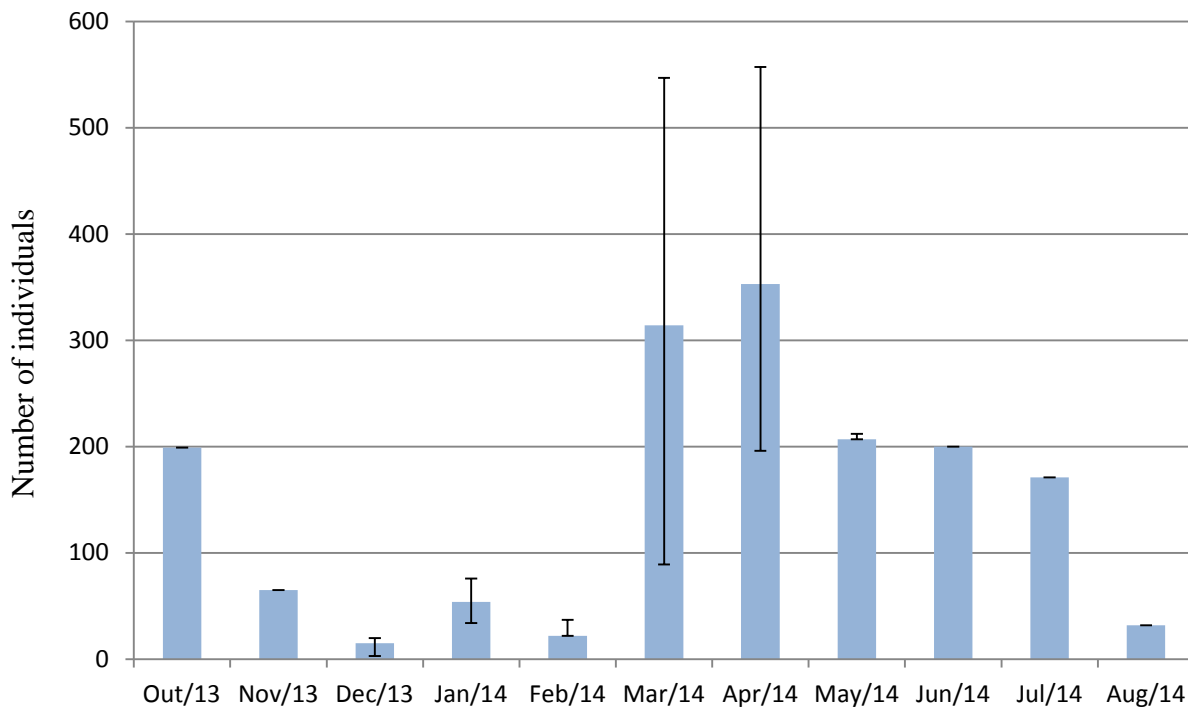


Figure 6. Monthly variation in abundance (data are: median, maximum and minimum) of Red Knots *Calidris canutus rufa* in the Lagoa do Peixe National Park, Rio Grande do Sul, Brazil.

Behavior, Habitat use and Flock Size

From all the individuals of *C. canutus rufa* observed, 54.6% were located at the Lagoon region and 45.4% were in the Beach area. However, the Beach had a higher number of flocks, smaller in size (\bar{x} = 13.714), while the Lagoon had fewer but larger flocks, with a bigger average size (\bar{x} = 24.861) (**Table 1**). In addition, it was observed that 49.5% of individuals were in fewer large flocks in average (\bar{x} = 45.781) while roosting, and the other 50.5% were in much smaller flocks (\bar{x} = 11.412) with foraging behavior (**Table 2**). The beach area was predominantly used for foraging, with only 3 flocks (3.7% of all individuals) using the area for roosting. The birds used the lagoon for both roosting and foraging. Mainly roosting in larger flocks and foraging in smaller ones (**Table 3**).

Table 1. Percentage of individuals, flock numbers and average flock size for each habitat observed.

Location	% of Individuals	Flock number	Average Flock Size
Beach	45.4%	98	13.714 (SD=18.856)
Lagoon	54.6%	65	24.861 (SD=36.285)
Total		163	18.159 (SD=27.623)

Table 2. Percentage of individuals, number of flocks and average flock size for each behavior observed.

Behavior	% of Individuals	Flock number	Average Flock Size
Foraging	50.5%	131	11.412 (SD=16.404)
Roosting	49.5%	32	45.781 (SD=43.347)
Total		163	18.159 (SD=27.623)

Table 3. Percentage of individuals, number of flocks and average flock size for each location and behavior combination.

Location/Behavior	% of Individuals	Flock number	Average Flock Size
Lagoon/Roosting	45.8%	29	46.758 (SD=45.269)
Lagoon/Foraging	8.8%	36	7.222 (SD=7.127)
Beach/Roosting	3.7%	3	36.333 (SD=16.921)
Beach/Foraging	41.7%	95	13.020 (SD= 18.546)
Total		163	18.159 (SD=27.623)

The ANOVA tests showed that there is a significant differences between roosting and foraging flock sizes [$F(1,161) = 52.46, p < 0,01$] (**Fig. 7**) and between beach and lagoon flock sizes [$F(1,161) = 6.584, p < 0.05$] (**Fig. 8**).

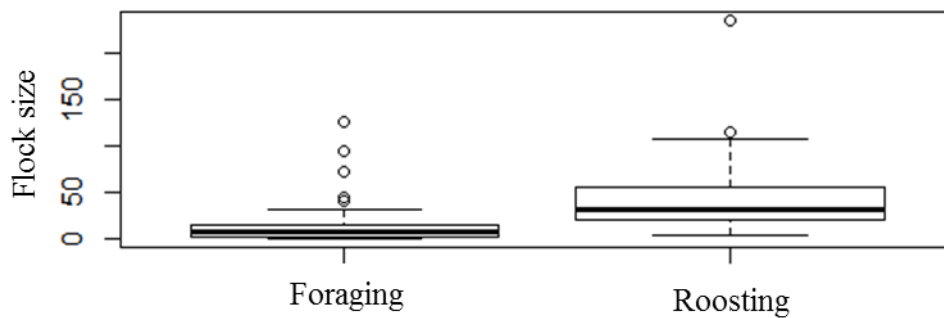


Figure 7. Difference between Foraging and Roosting flock sizes of *Calidris canutus rufa* in the Lagoa do Peixe National Park.

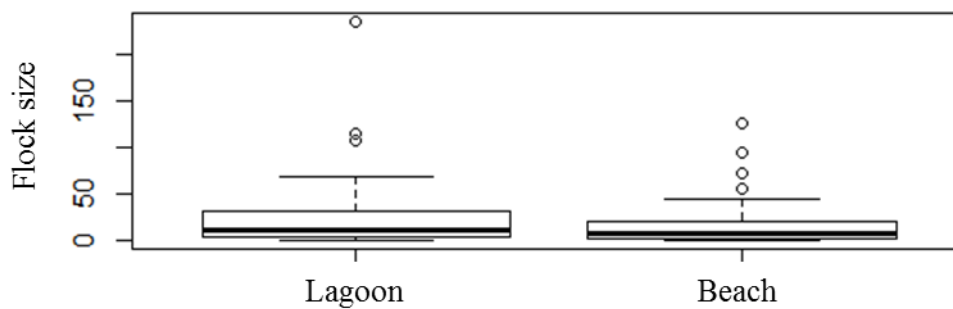


Figure 8. Difference between flock sizes of *Calidris canutus rufa* in the beach and in the lagoon region of the Lagoa do Peixe National Park.

The months of November, December, January and February had a fairly uniform distribution (**Fig. 9**). The flocks were located mostly foraging and roosting in the lagoon region, with only 2 flocks on the beach. March and April showed a heavy activity on the beach including the area outside the park zone, where they were mostly foraging in small flocks and using the lagoon region to roost in larger flocks (**Fig. 10**). The months of May and July showed activity on both the beach and the lagoon region, with predominant foraging behavior on the beach in small flocks (**Fig. 11**). Looking at all months together in (**Fig. 12**), it is possible to see a pattern in behavior, habitat use and flock size. The beach was mainly used for foraging in small flocks while the lagoon region had some small flocks foraging and was used by the larger flocks for roosting.

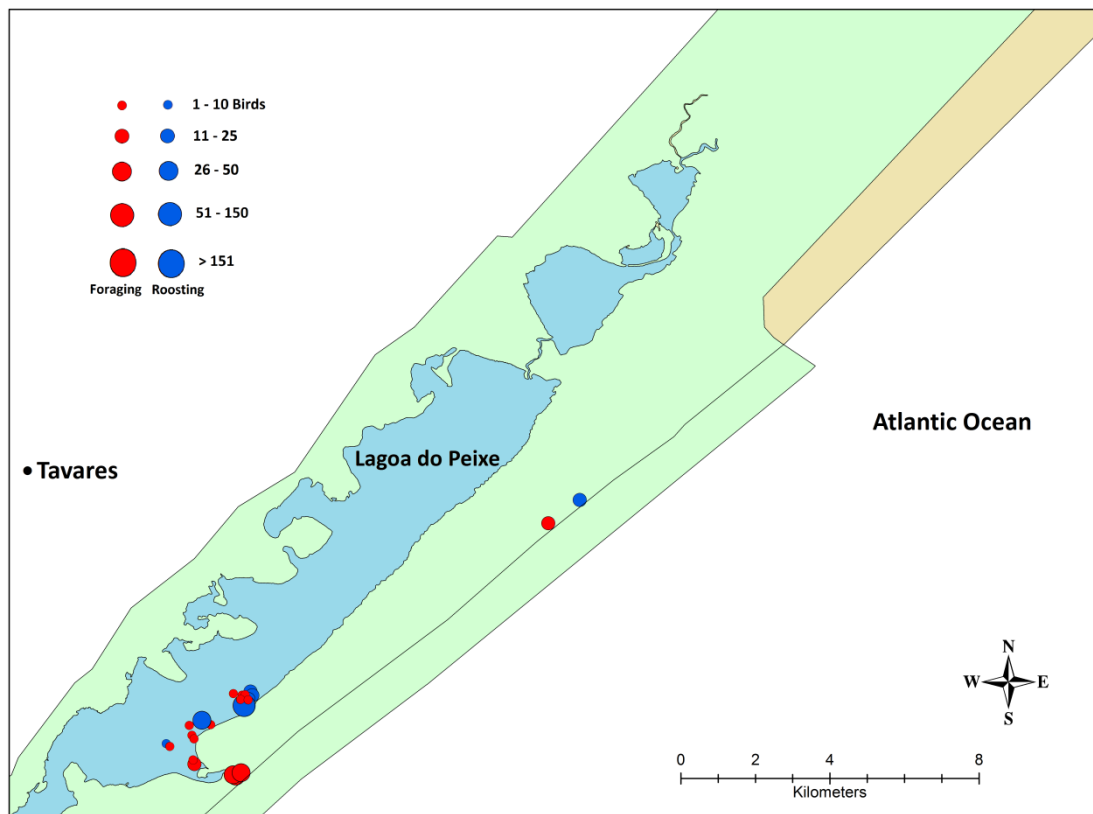


Figure 9. Distribution, behavior and flock sizes of *Calidris canutus rufa* from November 2013 to February 2014.

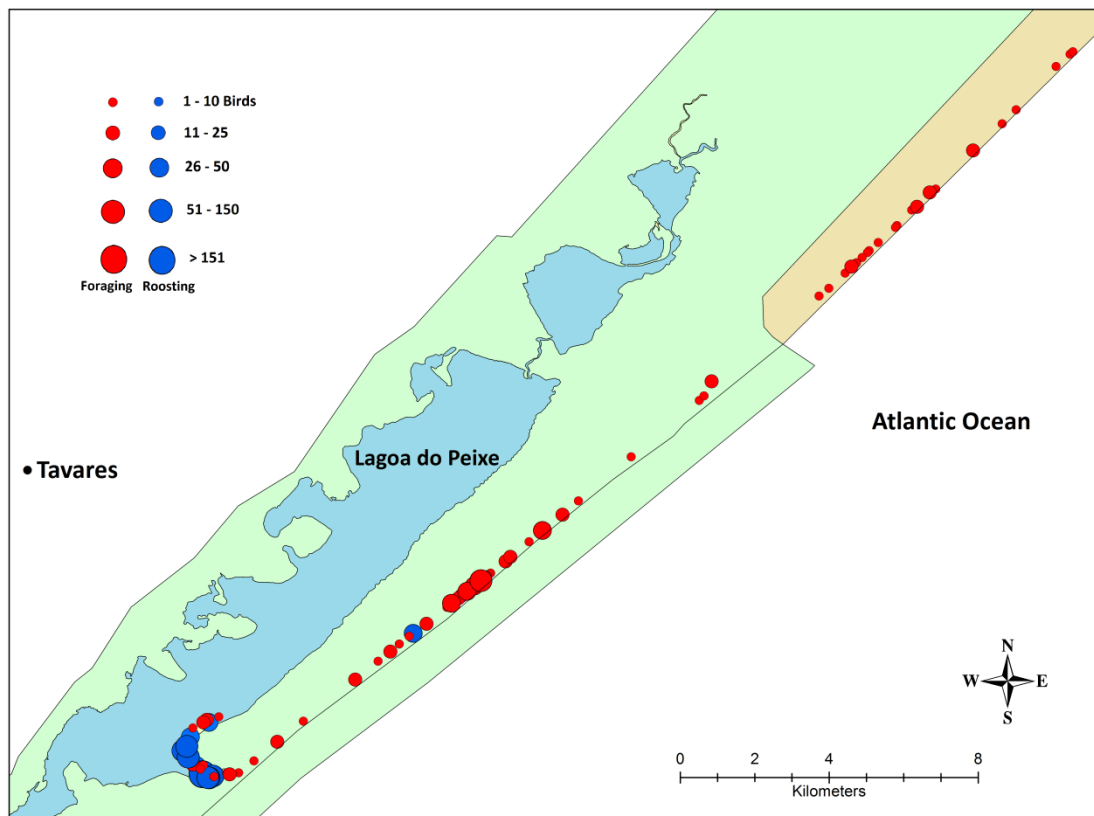


Figure 10. Distribution, behavior and flock sizes of *Calidris canutus rufa* on March and April 2014.

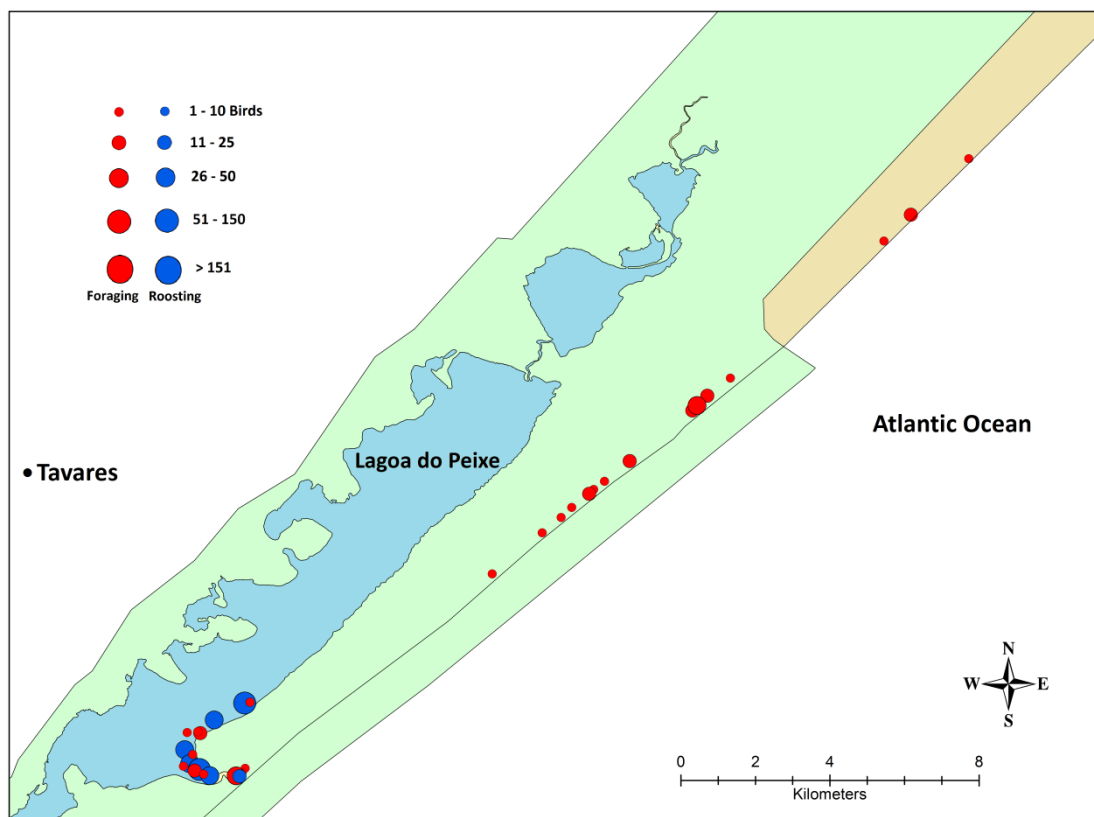


Figure 11. Distribution, behavior and flock sizes of *Calidris canutus rufa* on May and July 2014.

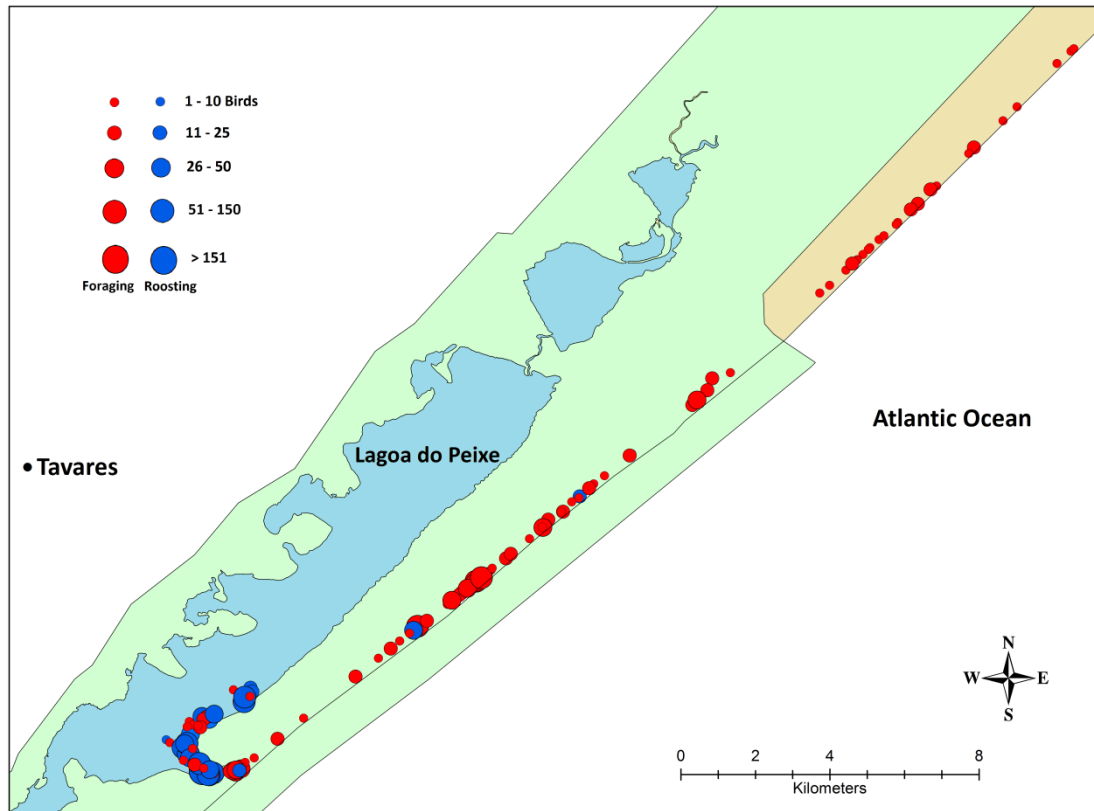


Figure 12. Distribution, behavior and flock sizes of *Calidris canutus* between October 2013 and July 2014.

Discussion

Bird Census

Numbers of *C. c. rufa* were very low in the months of November and December of 2013 and January and February of 2014 in comparison to October 2013. This happened probably because there were still some birds in the southward migration route using the area as refueling site. They were mostly concentrated in the lagoon around the “barra” region (**Fig. 9**). The number of birds decreased drastically by November (**Fig. 6**) when they departure to Tierra del Fuego, were about 90% of *C.c. rufa* population spend austral summer (NILES *et al.* 2008). The low numbers of Red Knots in the summer months was also registered by RESENDE (1988) with 4 individuals in January.

As expected, March and April were the peaks of *C. c. rufa* numbers in Lagoa do Peixe when a great part of the Red Knot population that was wintering in Tierra del Fuego use the area as a stopover site during northward migration, mainly for roosting and accumulating fat (HARRINGTON *et al.* 1986, FEDRIZZI 2008, NILES *et al.* 2008). Their most frequent preys in the beach in the region of Lagoa do Peixe were Coleopterans and the Bivalves *Donax hanleyanus* Philippi, 1847 (Donacidae) and *Mesodesma mactroides* DESHAYES, 1854 (Mesodesmatidae) (FEDRIZZI 2008). It is known that April is a month of peak recruitment for *D. hanleyanus* in the coast of the state (GIL & THOMÉ 2004) and this synchronizes with the great abundance of *C. c. rufa* in these months (HARRINGTON *et al.* 1986). However, in comparison to previous studies, the numbers of *C. c. rufa* in this study were very low. In April of 1984 HARRINGTON *et al.* (1986) estimated over 11.000 Red Knots in all extension of the Lagoa do Peixe area. Three years later, in 1987, also in April, RESENDE (1988) registered about 7.000 Red Knots concentrated in a south part of the lagoon, and in 2005, FEDRIZZI (2008), registered around 5.300 individuals. In March and April of 2014, approximately 550 Red knots were seen (**Fig. 6**).

Part of this great decrease in numbers could be due to differences in sampling effort, since during migration the abundance of birds can suffer significant changes in just a few days. Another factor that could have influenced the numbers was the inaccessibility of one potential area located southwest of the “barra” region in these months. Despite that, part of it may reflect the *C. c. rufa* population decline. In Tierra del Fuego, where the majority of the population spends boreal winter, there has been a tremendous decline

in Red Knot numbers. In the 1980s, the count was around 100.000 individuals (MORRISON&ROSS1989), it declined to 27.000 in 2002 (BAKER *et al.* 2004) and in 2011 it was reduced to 9.800 individuals (DEY *et al.* 2011). This reinforces the idea that the numbers of Lagoa do Peixe also decreased drastically, following the worldwide population pattern.

While the main reason attributed to the decline is the dwindling supply of their most important food resource, the horseshoe crabs eggs (*Limulus polyphemus*) in Delaware Bay, several disturbances in many of their stopover sites also threatens these birds (BAKER *et al.* 2004, NILES *et al.* 2008), including at Lagoa do Peixe. In this place, it is the periodic exchange of water with the sea that allows invertebrates to colonize the lagoon and provide food for the birds, and any interference such as nearby farmers draining their land could be a threat for the Red Knots. Also, during this study, several people were found in the beach harvesting bivalves, including *M. mactroides*, inside the prohibited area in the Park, probably to use them as fishing bait. This activity could also impact the population of *C. c. rufa*, since they intensively use the beach area for foraging in the months of March and April (**Fig 10**). Another threat is the uncontrolled *Pinus* sp. afforestation around the lagoon area. This invasive species completely changes the local landscape and can compromise the environment protection by competing with native vegetation and lowering the water level (NILES *et al.* 2008, PORTZ *et al.* 2011), affecting the Red Knots. All these factors could also have a significant effect in this sharp decrease of numbers of *C. c. rufa* at Lagoa do Peixe National Park.

In previous studies, it was registered a rapidly decrease in *C. c. rufa* population to almost zero individuals in the subsequent months of May and June, as the Red Knots departure to the Arctic for the breeding season, with only a few birds staying in Lagoa do Peixe to spend the boreal summer (RESENDE 1988, FEDRIZZI 2008). This study also showed a rapid decrease in numbers from April to May, but the numbers didn't decrease as expected (**Fig. 6**). Instead, about 200 individuals of *C. c. rufa* stayed in the area for the months of May, June and July (**Fig. 11**), a much larger quantity than the expected residents of December, January and February (RESENDE 1988). Also, the Park workers reported that in June 2013, over 600 Red Knots were spotted in the area. Although very little is known on about over-summering birds, it is common for sexually immature first-year shorebirds to over-summer (spend the boreal summer on the wintering grounds) (MCNEIL *et al.* 1994), but this event was never registered for Lagoa do Peixe

with such large quantities of Red Knots, as the area is not even considered an important wintering ground for this birds, only a stopover site. There are several reasons why this could be happening; first, as mentioned, these individuals could be sexually immature first-year birds that arrived with the wave of northward migration departing Tierra del Fuego in March and stayed at the lagoon, which has a less severe winter than Tierra del Fuego. Second, these individuals could also have not entered in pre-migratory moulting and fattening in time, due to reduced food availability, illness or hormonal imbalance for example (WALLACE 1955, MCNEIL *et al.* 1994). And finally, another factor that could prevent Red Knots from migrating and over-summering is infestation by parasites. As MCNEIL *et al.* (1994) showed, trematode endoparasitism is an important factor in over-summering behavior for the Greater Yellowlegs (*Tringa melanoleuca*, (GMELIN 1789) Scolopacidae), but no studies were conducted on *C. c. rufa*. In addition, in 2005 some Red Knots were found in Maranhão with a heavy infestation of ectoparasites, and they had less than the usual fat-free mass for *C. c. rufa* individuals (NILES *et al.* 2008). All these factors should be taken into account when trying to understand this phenomenon, as almost nothing is known about the over-summering Red Knots in the Lagoa do Peixe National Park, and further investigation is clearly needed. Further studies of the population fluctuation on years to come are fundamental to better understand the biology of this species and apply management actions for conservation.

Behavior, Habitat use and Flock Size

It is possible to observe a pattern when looking at the flock sizes for different behavior and habitat use of *C.c. rufa* in Lagoa do Peixe National Park. The data showed that flocks in the beach are significantly smaller than the flocks on the lagoon region (**Table 1, Fig. 8**) and that the Red Knots organize themselves in smaller flocks for foraging and larger ones for roosting(**Table 2, Fig. 7**).They use the beach mainly for foraging in small flocks, and the lagoon for roosting in larger flocks while foraging in smaller ones (**Table 3**). There are several reasons that might explain these patterns; as shown in the (**Fig. 12**), the great majority of Red Knots that are in the beach are wide spread along the coast in smaller flocks foraging. Two main factors probably have an influence in the size of these flocks; first, even though being in larger flocks increase the chance of finding high prey-density locations, when birds forage in flocks there is a significant

reduction in intake rate associated with several facets of intraspecific competition (GOSS-GUTARD1984), since they are sharing the same microhabitat. This is probably the reason why they were spread across almost the entire beach coast in the northward migration periods of March and April (**Fig. 10**). Also, when in high number flocks, the birds have a higher chance of alerting the preys, reducing the food availability (COLWELL 2010), which could happen when the Red Knot prey on Coleopterans. The lower number of foraging flocks in March-April in the lagoon region could be an indication of a difference in prey density (Harrington *et al.* 1986) found that *Donax* sp. were abundant where the Red Knots were found, but absent, scarce or too large (which cannot be swallowed by the bird) in areas without the birds. In addition, almost no Red Knots were found foraging in the beach on austral summer months (December, January, February) (**Fig. 9**) and very few on austral winter months (May and July) (**Fig. 11**). This reinforces the idea of synchronization between the peak recruitment periods for bivalves and peak population periods of *C. c. rufa* in Lagoa do Peixe, as seen in the area for *Calidris alba* (PALLAS, 1764) and *Calidris fuscicollis* (VIEILLOT, 1819) (Scolopacidae) and its preys (FEDRIZZI2008).

The great majority of large flocks were found roosting in the lagoon (**Fig. 12**). The lagoon region seems to be the only area with wide open flat spaces where large flocks can rest. The main benefit of flocking in larger groups is to avoid predation (COWELL 2010) and the openness of the habitat can be an important factor to detect approaching predators (POMEROY *et al.* 2006). It is possible that the Red Knots choose to roost in places with low density of predators. During this study however, several Peregrine Falcons (*Falco peregrinus* (TUNSTALL 1771), Falconidae) were spotted only in the lagoon region, but not enough data was collected to analyze this factor. CRESSEL & QUINN 2004 showed that there is a direct relation in probability of capture by predators and flock size of Common Redshanks (*Tringa tetanus* (LINNAEUS 1758), Scolopacidae) as smaller flocks had a higher probability of being predated than larger flocks. This can be attributed to not only a higher probability of escaping but also to the benefit of being able to early detect the predators when in larger groups.

Understanding a species social organization patterns such as habitat use and behavior can provide important information for management implications, helping the overall efforts for conservation of the shorebirds biodiversity.

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