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MONITORING OF WHITE-RUMPED SANDPIPER (*CALIDRIS FUSCICOLLIS*) IN LAGOA DO PEIXE NATIONAL PARK, RIO GRANDE DO DUL, BRAZIL

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Resumo. – Monitoramento do maçarico-de-sobre-branco (*Calidris fuscicollis*) no Parque Nacional da Lagoa do Peixe (Rio Grande do Sul, Brasil). – Neste trabalho avaliamos a importância do Parque Nacional da Lagoa do Peixe como local de aumento de reservas energéticas pelos Maçaricos-de-sobre-branco (*Calidris fuscicollis*) para a migração através da análise da proporção de indivíduos em condições fisiológicas para migrar para suas áreas de reprodução a partir de abril e da verificação de diferenças no padrão de condicionamento entre anos de estudo. Também avaliamos se indivíduos realizando mudas teriam uma menor média de capacidade de vôo quando comparados ao restante da população. Em todos os anos de estudo verificou-se tendência de aumento dos valores de potencial de vôo no mês de abril, acentuada a partir do 21º dia do mês, e com a predominância de indivíduos capazes de empreender vôos de 1000 km ou mais a partir do 25º dia do mês. A comparação das taxas de ganho de massa em 2 anos foi similar, com uma média de ganho de 249,125 km/dia. Os indivíduos em muda durante as capturas apresentaram capacidade de vôo próximos dos valores médios dos demais, e alguns acima da média, indicando não haver reflexo do gasto energético para a muda no processo de condicionamento fisiológico para a migração. A análise dos dados de capacidade de vôo, combinados com as distancias entre os locais de registros de Maçaricos-de-sobre-branco no Brasil, indicou a existência de estratégias diferenciadas nas quais as aves iniciam a migração com diferentes capacidades de vôo. Aqueles indivíduos com condicionamento fisiológico para realizar vôos sem parada seguem diretamente aos locais mais distantes, enquanto que aqueles de condicionamento menor realizam paradas em outras localidades brasileiras. Os Maçaricos-de-sobre-branco também utilizam a rota atlântica de migração.

Abstract. – In the present study, the importance of the Lagoa do Peixe National Park as an important stop-over site for migrating white-rumped sandpipers (*Calidris fuscicollis*) was assessed through an analysis of the proportion of individuals in adequate physiological conditioning for migrating to their breeding grounds. A further aim was to determine differences in conditioning patterns between different years and to determine whether individuals in molt have a shorter average flight-range when compared to the remaining population. In all the years studied, there was a tendency toward increased flight potential in April, which was accentuated beginning on the 21st day of the month. There was a predominance of individuals capable of performing flights of 1000 km or more beginning on 25 April. A comparison of body

mass/flight potential gain between two years (1996 and 2001) was similar, with an average gain of 249.125 km/day. Individuals in molt had flight ranges close to the average values for the rest of the population and some had ranges above the average, indicating that molting does not reflect energy expenditure in the physiological conditioning process for migration. The analysis of flight-range data combined with the distances between the locations of White-rumped Sandpiper records in Brazil indicates the existence of differentiated strategies in which the birds begin migration with different flight-range capabilities and those with adequate physiological conditioning for performing continuous flights for as much as 4000 km fly directly to the most distant locations, whereas those with less physical capabilities make stops in other Brazilian locations. The analysis of the records further indicates that the White-rumped Sandpiper also uses the Atlantic migration route. *Accepted 4 July 2010.*

Key words: White-rumped Sandpiper, conservation, flight range, migration.

INTRODUCTION

The White-rumped Sandpiper (*Calidris fuscicollis*) is a small-sized wader that breeds in the Arctic tundra in Canada and migrates to the southern hemispheres in an uninterrupted 4000 km flight across the Atlantic Ocean. It enters South America through Suriname, Venezuela, and Colombia, from where it moves onward, after a short stop, to wintering zones in the southern part of the continent (Harrington *et al.* 1991, Canevari *et al.* 2001). At Lagoa do Peixe National Park in the state of Rio Grande do Sul, southern Brazil, numbers gradually increase in September and October and abruptly increase in mid-November and December (Harrington *et al.* 1991).

During the spring migration (return to the northern hemisphere), the White-rumped Sandpiper may carry out either long-distance flights with no stops and short-distance flights with multiple stops. The species passes through Central America, occasionally reaching the Antilles and Mexico, and arrives to the mid United States where flocks congregate in a few restricted locations, such as Cheyenne Bottoms, Kansas (Canevari *et al.* 2001). It is known that the White-rumped Sandpiper occurs throughout all of Brazil (Sick 1997), though several occurrence records are punctual. The strategies used for northward migration are not well known. A number of authors have suggested that the species performs uninterrupted flights between southern Brazil and the coast of Venezuela at distances of over 4000 km, using the Central Brazil and Pantanal Wetlands/Central Amazon routes (Antas 1983, Harrington *et al.* 1986, Erize *et al.* 2006). For such uninterrupted long-distance flights, animals require important metabolic reserves of energy.

Energetic demands by sandpipers during long flights have been studied by a number of authors (McNeil 1969, McNeil & Cadieux 1972a, b; Davidson 1984, Page & Middleton 1972, Dunn *et al.* 1988, Castro & Myers 1988, 1989; Harrington *et al.* 1991). Consequently, the existence and conservation of habitats suitable to provide high quality food are prerequisites to successful migrations. The determination of these habitats and their protection are essential to the conservation of sandpipers. Furthermore, monitoring programs are recommended to evaluate the tendencies of habitat use through the time enabling to answer the following questions: how is the population of a species changing on a site? Where are the most important areas for a species? (Sutherland 2006).

Considering the annual concentration of thousands of migratory birds at Lagoa do Peixe, the Brazilian government established in 1986 the Lagoa do Peixe National Park to protect this important habitat.

The qualification of a certain habitat as suitable to provide adequate food to accumulation of fat reserves can be better done, than

just seeing birds feeding, by measuring their body mass increment during their stay in that habitat. One way to assess whether the environment can supply the energy reserves necessary to the conditioning of the birds for migration is by estimating the flight-range capabilities of the birds in these locations to determine whether they are in adequate physiological condition for the journey upon departure time. Furthermore, flight-range comparisons among periods may also enable to evaluate an eventual loss of habitat quality.

The method proposed by McNeil & Cadieux (1972a, b) for estimating the flight range of some species of Charadriiformes uses body mass and wing length data and is the most commonly used method in Brazil (Harrington *et al.* 1986, 1991, Antas & Nascimento 1990, Azevedo-Júnior *et al.* 2002).

Based on data obtained between 19 April–8 May 1984, Harrington *et al.* (1986) concluded that Lagoa do Peixe National Park is an important, substantial stop-over site for migrating Nearctic wader species, including the White-rumped Sandpiper. According to the authors, the fat the species accumulates at Lagoa do Peixe National Park is essential for enabling direct trans-Amazon flight while heading northward. Harrington *et al.* (1986) also concluded that the body mass gained by white-rumped sandpipers at Lagoa do Peixe indicates a flight range of as much as 7500 km; the average body mass of the last 10 individuals analyzed was sufficient for a flight to the Great Plains of North America, where the birds make a final stop before flying on to the Arctic.

According Harrington *et al.* (1991), the migration system of this small sandpiper (body length c. 18 cm) makes it vulnerable to the loss of strategic habitats for migration. This requires measures to ensure the quality maintenance of such environments.

Though there are relevant works about White-rumped Sandpiper biology and the importance of Lagoa do Peixe for this species (e.g., Antas 1983, Harrington *et al.* 1986, Morrison & Ross 1989, Harrington *et al.* 1991), they are punctual and do not enable an evaluation of the habitat quality tendencies through time. With the aim of assessing the importance of Lagoa do Peixe National Park for the accumulation of energy reserves (fat content) for the migration of the White-rumped Sandpiper, we determined the proportion of individuals in adequate physiological condition for migrating to their breeding grounds beginning in April using data collected in ten different years from 1994 to 2007. Considering that the process of molting requires additional energetic resources (Ginn & Melville 1995), further aims were to determine whether there were differences in gain rates and flight capabilities between the different years studied and whether individuals undergoing molting had a shorter average flight range when compared to the remaining population. Relating flight-range capabilities to the location of sites where the species has been registered we were also able to discuss their migration strategies and review the known migratory routes.

METHODS

Study area. Lagoa do Peixe National Park encompasses 33,400 ha distributed among the cities of Tavares, Mostardas, and São José do Norte in the state of Rio Grande do Sul, southern Brazil. It is located between the Atlantic Ocean and Lagoa dos Patos. The area extends from 31°00'46" S to 31°29'00"S and 50°46'31"W to 51°09'51"W. Lagoa do Peixe lake is approximately 40 km long and 1 km wide and is connected with the open sea through a 1.5km bar. The average maximum depth (approximately 80 cm) is reached in winter; depths as much as 2 m occur only near the bar connecting it to the ocean.

At c. 60 cm a.s.l. the lake is salty throughout most of the year. In periods of increased

rainfall, the water rises and the fragile natural barrier that separates the lake from the ocean breaks. In summer, the connection is artificially maintained with the use of tractors. This dynamic allows the influx of nutrients, animals, and algae from the ocean, thereby permitting the development of a rich fauna that serve as a food source for a number of species, including both resident and migratory birds (Andrade *et al.* 2003, Ibama 2007).

Additional comments and statistical procedure. Catches of sandpipers using mistnets (mesh size 36 and 61 mm) were performed during fieldwork promoted by CEMAVE (National Research Center for the Conservation of Wild Birds) in 12-day periods from 1994 to 1999 as well as in 2001, 2003, 2006, and 2007 in the months of April, May, and November; most catches were performed in April (72%). No sampling was done in 2000, 2002, 2004, and 2005. The White-rumped Sandpiper is found on the beach as well as along the bar and in the lagoon interior. Considering that most birds move frequently from the beach to the lagoon using the bar entrance the mist nets were mounted transversely on the bar 500 meters away from the beach. For measuring body masses, dynamometer scales with an accuracy of 1 g were used. Each captured individual was identified and classified with regard to age following Hayman *et al.* (1986), then birds were banded with standard bands from CEMAVE (Ibama 1994). The wing chord length was measured to the nearest 0.1 cm using a ruler. Molting contour feathers (head, back and belly) and flight feathers (remiges and rectrices) were recorded. Birds molting the tenth primary remige were not considered in the wing measurements.

The calculations for estimating flight capability were performed based on the equations presented by McNeil & Cadieux (1972a), as described by Azevedo-Júnior *et al.* (2002). Flight capability in miles/hour (FR) can be calculated using the following equation: FR = F x S x 9.1 kcal/FM, with F = fat mass (g) and S = flight speed (mph), the latter estimated as 50 mph for the White-rumped Sandpiper (McNeil & Cadieux 1972a). The 9.1 multiplication factor originates from the fact that fat has an average caloric content of 9.1 kcal/g (Johnston 1970). FM is the flight metabolism in kcal/hours and can be estimated through the following equation: log FM = log 37.152 + 0.744 x log W ± 0.074, in which W is the fresh body mass (kg) (Raveling & Lefervre 1967). In the equation proposed by McNeil & Cadieux (1972a), the calculation of FR requires knowledge on fat mass (F, in g), which may be indirectly obtained from the difference given by F = FW–Y, in which FW is the total mass (g), Y is the mass without fat (g) and can be estimated from the equation Y = a + b.X, in which X is the wing chord (cm). McNeil & Cadieux (1972a) found a significant correlation between mass without fat (Y) and wing chord (X) for a number of migratory bird species, such as the White-rumped Sandpiper. For this species, the estimator for Y is given by the equation Y = 5.66 + 2.63 X.

Thus, the original equation for FR may be transformed into FR = [(FW – (a + bx)) S 9.1 kcal] [Antilog (log37.152 + 0.744 log (W ± 0.074))]$^{-1}$, allowing the flight capability to be estimated from fresh mass and wing chord measurements taken in the field. Flight capability values were originally calculated in miles and then converted to kilometers. Wing chord values were converted from millimeters to centimeters. Statistical and graphical analyses were calculated with MS Excel 2003®.

In order to determine the occurrence of a differentiated increase in the proportion of individuals ready to migrate in April, the sampled values for each April in the years studied were grouped into four class intervals corresponding to April 1–10, 11–20, 21–25, and 26–30. The aim of the more detailed temporal ranges in the last third of April was to test the

TABLE 1. Mass of *Calidris fuscicollis* individuals caught in Lagoa do Peixe National Park, Rio Grande do Sul, between 1994 and 2007 according to temporal grouping.

Class interval	N	Mass (g)			
		Mean	Minimum	Mximum	SD
November	79	36	36	45	3.5
1-10 April	34	40.5	40.5	51	4.9
11-20 April	119	40.1	40.1	56	5.7
21-25 April	101	47.8	47.8	64	6.7
26-30 April	20	52	52	61.5	5.7
May	27	53.5	53.5	63	5
All	380	43	43	64	7.7

statement made by Harrington *et al.* (1991) regarding the increase in body mass at the end of the month.

A linear regression model was used to compare data on average flight capability (km) and date (days following 1 April). ANCOVA was used for the comparison of the regression lines (Zar 1996). Due to the size of the samples, the regression between average flight capability data and days following 1 April was only performed for the years 1996 and 2001.

From consultations of references (Nascimento & Larrazábal 2000, Azevedo-Júnior *et al.* 2002, Larrazábal *et al.* 2002, Azevedo-Júnior *et al.* 2004, Cabral *et al.* 2006) and the databank of the National Banding System (SNA-CEMAVE), the locations with increased concentrations of white-rumped Sandpipers in Brazil were plotted on a map using the ArcGis® version 9.2. These locations were considered to serve as stopping points for the migration of the birds heading northward. After marking the points, distances were calculated in straight lines between locations using Google Earth® version 4.2.

RESULTS

In the present study, 381 adult individuals were caught (275 birds in April 1994 to 1999, 2001 and 2007, 27 in May 1998 and 1999, and 79 in November 2006 and 2007). Wing chord data used to estimate flight-range capability (n = 380) varied between 11.5 cm and 13.5 cm (mean = 12.4 cm ± 0.36 cm). Mean values of body mass varied between 36 g and 53.5 g (Table 1). The lowest and highest flight-range capability values in November, April, and May of the study years were 57 km and 1228 km, 18 km and 4136 km, and 628 km and 3690 km, respectively. Among the birds caught in November, only 27.5% had a flight range for migration and, among these, only 45% (or 12.4% of the total number) would be able to fly over 500 km. Among the birds caught in April, 44% had a flight-range capability for migration in the first third of the month, 38% had a flight-range capability for migration in the second third of the month, and 95% had a flight-range capability for migration in the last third of the month (Fig. 1).

Figure 2 displays mean flight-range values for the White-rumped Sandpiper caught in each year by five-day intervals and the individual values of birds in the molting stage. presents the regression values between mean flight capability and the days following 1 April. The comparison between the data from 1996 and 2001 ($F_{(1;96)}$= 62.93; $P < 0.0001$) indicates significant differences regarding the average arrival date of the birds (regression

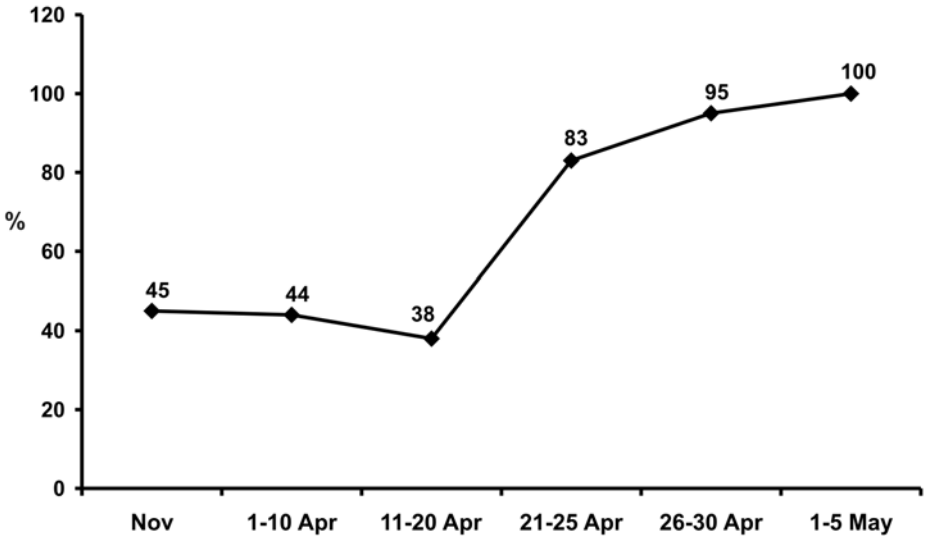

FIG. 1. Variation of percentage of White-rumped Sandpiper individuals caught in Lagoa do Peixe National Park, Rio Grande do Sul, with flight-range capability for migration in April and May.

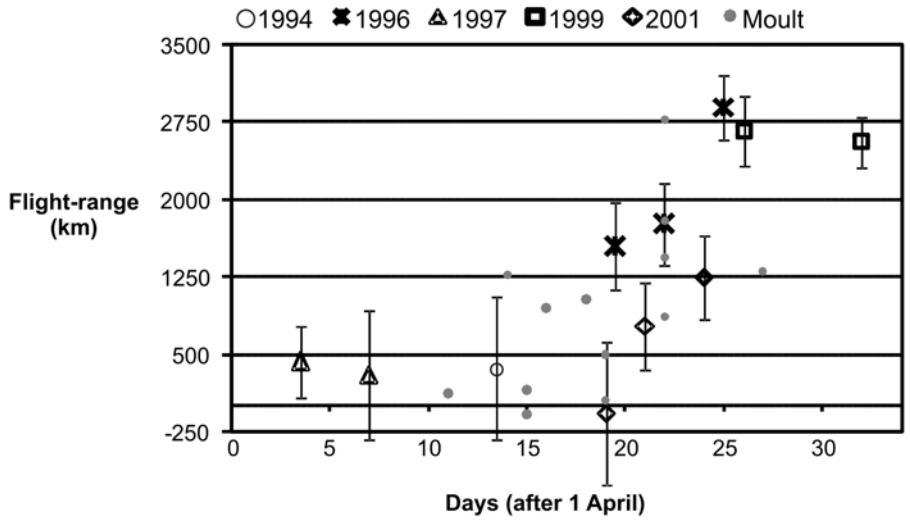

FIG. 2. Mean flight-range capability values of White-rumped Sandpiper individuals caught in each year in Lagoa do Peixe National Park, Rio Grande do Sul, per 5-day intervals and individual values of birds in molting process.

lines with different intercepts). The results of the parallelism test ($F_{(1;194)}$= 0.033; P = 0.856) reveal that the birds gained flight-range capabilities at the same rate in both years (regressions with same declivity), with a mean gain of 249.125 km/day.

Data for flight-range capabilities for migration in April and May grouped in 1000-

TABLE 2. Linear regressions between mean flight capability (km) and day (days following 1 April) for *Calidris fuscicollis* caught in the Lagoa do Peixe National Park, Rio Grande do Sul, in 1996 and 2001.

Year	Intercession (a)	Inclination (b)	*F*	DOF	*P*
1996	-3381.76	242.68	15.515	1 ; 70	0.0004
2001	-4866.62	255.57	38.099	1 ; 124	< 0.0001

km intervals show that some birds had already attained a capability above 1000 km in the first third of April (Fig. 3).

When analyzing the distances between the points of White-rumped Sandpiper records along the coast we found that most are contained in mean intervals of 450 km (SD ± 410), ranging from 84 km to 1640 km (Fig. 4).

DISCUSSION

The predominance of low body mass values in November - the arrival period of the birds to the southern part of the continent - corresponds to the energy expenditures during migration, despite the brief stop-over in the northern part of South America (Canevari *et al.* 2001). The existence of individuals with a flight-range capability of > 500 km may be the result of unused migration reserves (Harrington *et al.* 1991).

The variation in body mass in 10-day class intervals during the first two thirds of April and five-day intervals during the last third of April and beginning of May indicates an increase in gain beginning in the last week of April, which is similar to that described by Harrington *et al.* (1991). Upon analyzing the evolution of the proportion of individuals with a flight-range capability for migration, there was a tendency toward an increase until 25 April. Beginning on 26 April, all individuals had a flight-range capability for migration, which reinforces what was observed in the analysis of the data on body mass.

Data on the flight range of individuals in the molting process during the catches were generally near the mean values for the remaining birds and some were even above the average, indicating no reflection on energy spending for molting in the physiological conditioning process for migration. Harrington *et al.* (1991) found no significant differences in mass in different molting stages.

The mean flight-range values followed the same pattern observed in relation to body mass variation and the proportion of individuals with a positive potential in all study years. There was a tendency toward an increase in values in the month of April, which was accentuated beginning on the 21st, with a predominance of individuals capable of performing flights ≥ 1000 km beginning 25 days following 1 April. The comparison of data on average flight capability with the days following 1 April between 1996 and 2001 using the linear regression model yielded that the birds arrive to Lagoa do Peixe in different days depending on the year. After arrival they begin to accumulate fat, with similar body mass gain rates between the two years (average flight capacity gain of 249.125 km/day). Such results confirm the importance of Lagoa do Peixe as a stopover site for the White-rumped Sandpiper (as previously indicated by Harrington *et al.* 1986, 1991) and indicate that Lagoa do Peixe maintained a similar capacity for supplying energy reserves in the two years studied.

Long distance migration of shorebirds can be accomplished following different strategies. White-rumped Sandpiper migration occurs through long distance flights and by using multiple stops. This combination may

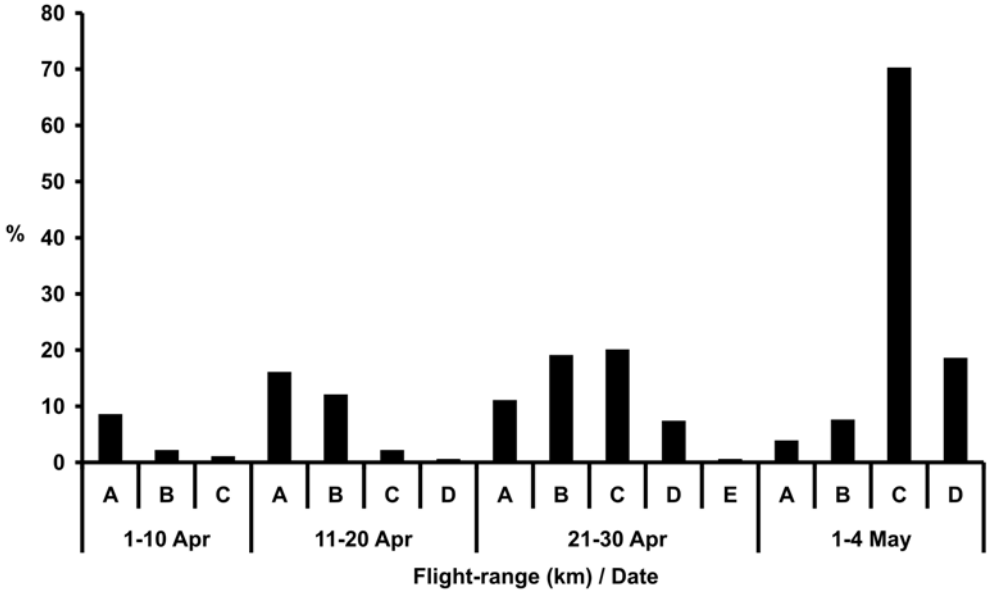

FIG. 3. Percentage of White-rumped Sandpiper individuals with flight-range capability for migration caught in the Lagoa do Peixe National Park, Rio Grande do Sul, in April and May, grouped in 1000-km intervals: A = 1–1000 km, B = 1001–2000 km, C = 2001–3000 km, D = 3001–4000 km, E = 4001–5000 km.

be an advantageous strategy to overcome problems associated to choosing an inadequate feeding area what would have negative consequences for migration or reproduction (Harrington *et al.* 1991, Berthold 1996, Canevari *et al.* 2001). The data obtained during this study suggest that some individuals are already able to start long distance migrations on early April. The location of individual records along the coast at average distances of 450 km suggests that flocks start migration from Lagoa do Peixe throughout April and May. They attain feeding stops to accumulate new fat deposits at different distances from Lagoa do Peixe according to their starting flight-ranges. Nevertheless, the migration peak occurs during the final third of the month when the majority of birds exhibit sufficient conditioning to migration in long-distance flights, which is similar to findings described by Harrington *et al.* (1986). However, we did not observe a dominance of individuals leaving Lagoa do Peixe National Park with a nonstop flight capacity of 4700 km or 7400 km as found by Harrington *et al.* (1986). This difference may be consequence of lower food availability at Lagoa do Peixe during the study period compared to that available during the 1980s, despite the apparently stable capacity of this habitat for supplying energy reserves during our study.

One important aspect found in the analysis of White-rumped Sandpiper records in Brazil was that, despite the emphasis on the use of only the Central Brazil and Pantanal/Central Amazon migratory routes as described by Antas (1983), there was a massive concentration of stopping points along the Brazilian coastline. These records, together with the lack of a predominance of individuals with a flight-range capability > 3000 km, indicate that besides the known

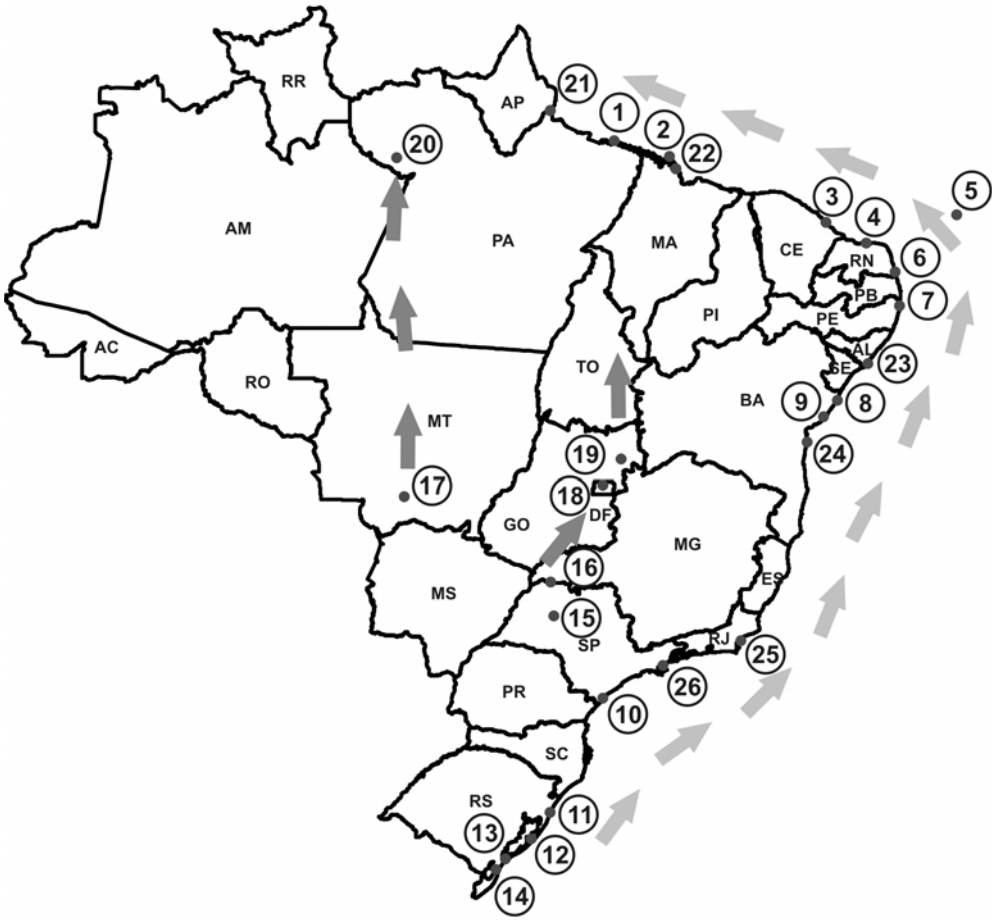

FIG. 4. Location of White-rumped Sandpiper records in Brazil and known migration routes for the species; Pantanal/Central Amazon and Central Brazil routes according to Antas (1984). For localities and coordinates, see Appendix 1.

routes the White-rumped Sandpiper also uses the Atlantic route, where there is a greater amount of suitable locations for obtaining additional energy reserves for the return trip to the Arctic.

This new information contributes to the evaluation of the environmental quality of habitats used by birds on the Lagoa do Peixe National Park and demonstrates the need to strengthen the monitoring program on the national level in order to obtain a better knowledge on stop-over sites and their environmental quality. This will also contribute toward conservation strategies directed to the maintenance and protection of these important refuge areas for the White-rumped Sandpiper and other migratory species.

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APPENDIX 1.

1 = Maçarico Beach, Salinópolis, Pará (47°20'0"W, 0°30'0"S), 2 = Maiau Island, Cururupu, Maranhão (45°0'0"W, 1°10'0"S), 3 = Canoé Salt Pit, Beberibe, Ceará (37°50'0"W, 4°20'0"S), 4 = Galinhos, Rio Grande do Norte (36°10'0"W, 5°0'0"S), 5 = Fernando de Noronha, Island, Pernambuco (32°20'0"W, 3°50'0"S), 6 = Barra do Cunhaú, Canguaretama, Rio Grande do Norte (35°0'0"W, 6°10'0"S), 7 = Coroa do Avião, Igarassu, Pernambuco (34°50'0"W, 7°49'0"S), 8 = Mangue Seco, Jandaíra, Bahia (37°30'55"W, 11°44'34"S), 9 = Cetrel, Camaçari, Bahia (38°10'0"W, 12°40'0"S), 10 = Cananéia, São Paulo (47°50'0"W, 25°0'0"S), 11 = Presidente Beach, Tramandaí, Rio Grande do Sul (50°10'0"W, 30°0'0"S), 12 = Lagoa do Peixe National Park, Mostardas, Rio Grande do Sul (50°57'0"W, 31°10'0"S), 13 = Lagoa do Nicola, Rio Grande, Rio Grande do Sul (52°3'0"W, 32°4'0"S), 14 = Taim Ecological Station, Santa Vitória do Palmar, Rio Grande do Sul (52°36'5"W, 32°39'37"S), 15 = N. Avanhandava Dam, Penápolis, São Paulo (50°10'0"W, 21°20'0"S), 16 = Água Vermelha I Dam, Mira Estrela, São Paulo (50°0'0"W, 19°40'0"S), 17 = Poconé, Mato Grosso (56°30'0"W, 16°10'0"S), 18 = Brasília National Park, Brasília, Distrito Federal (47°50'0"W, 15°40'0"S), 19 = Cana Brava, Flores de Goiás, Goiás (47°0'0"W, 14°40'0"S), 20 = Rio Trombetas Biological Reserve, Oriximiná, Pará (56°50'0"W, 1°20'0"S), 21 = Parazinho Island, Amapá (51°04'12"W, 0°00'54"S), 22 = Reentrâncias Maranhenses, Cururupu, Maranhão (44°35'51"W, 1°44'30"S), 23 = Piaçabuçu, Alagoas (36°21'58"W, 10°27'31"S), 24 = Jaguaripe, Bahia (38°47'20"W, 13°8'0"S), 25 = Macaé, Rio de Janeiro (41°47'8"W, 22°22'18"S), 26 = Ubatuba, São Paulo (45°4'11"W, 23°26'5"S).