

NORTHWARD SHOREBIRD MIGRATION ON THE ATLANTIC COAST OF SOUTHERN BRAZIL

BRIAN A. HARRINGTON

Manomet Bird Observatory, Manomet, MA., U.S.A. 02345

PAULO DE TARSO ZUQUIM ANTAS

Centro de Estudos de Migrações de Aves, Caixa Postal 04/034, Brasília-DF CEP 70.000, Brasil

FLAVIO SILVA

Fundação Zoobotânica do Rio Grande do Sul, Parque Zoológico, BR-116 Pravadá 41, C.P. 36, 93.200 Sapucaia do Sul-R.S., Brasil

ABSTRACT

Northward shorebird migration during late April/early May is described at Lagoa do Peixe, a saline lagoon on the Rio Grande do Sul coast in southern Brazil (31°20'S; 51°00'W). Counts and weights of Nearctic species such as *Limosa haemastica*, *Calidris canutus*, and *C. fuscicollis* suggest that Lagoa do Peixe is a staging area of substantial importance to populations of Nearctic-breeding shorebirds. Fat accumulated at the lagoon is essential for completion of direct trans-Amazonian flights to northern South America. Thus Lagoa do Peixe is critical for conservation and protection of several Nearctic shorebird species; additional evidence further suggests it is of considerable importance to Patagonian shorebirds as well. Mariculture development, along with planned highway construction and increased tourism between Porto Alegre (population 1 million) and Tavares, a town close to Lagoa do Peixe, will have strong impacts on the lagoon. Additional study is needed to verify our preliminary conclusions and to improve information for conservation planning.

RESUMO

A América do Sul meridional recebe, durante o inverno boreal, várias espécies de maçaricos e batuíras (famílias Charadriidae e Scolopacidae). Estas aves migram por grandes distâncias (até milhares de quilômetros) de cada vez, parando em locais específicos para descanso e alimentação, recompondo as energias para outro longo voo. De 26 de Abril a 5 de Maio de 1984 foram desenvolvidos trabalhos de campo na região da Lagoa do Peixe (31°20'S; 51°00'W), uma laguna de águas salobras situada na costa atlântica do Rio Grande do Sul. A época escolhida buscava coincidir com a migração setentrional de *Calidris canutus*. O presente trabalho descreve os dados obtidos com esta espécie e outras limnícolas presentes na área, inclusive migrantes patagônicos, indicando que a região estudada é de importância internacional para a conservação de populações de maçaricos e batuíras setentrionais, tais como *C. canutus*. Para maçaricos e batuíras da região andino-patagônica que atingem o Brasil em seus movimentos sazonais área pode ter importância semelhante. Esta porção da costa gaúcha estará sob grande pressão humana nos próximos anos, tão logo uma estrada ligando Porto Alegre a Tavares, a cidade mais próxima de Lagoa do Peixe, termine de ser asfaltada. Esta estrada irá aumentar descontroladamente o turismo e outras atividades humanas no local, com prováveis efeitos negativos sobre o ecossistema. Recomenda-se, ainda, estudos posteriores para verificar-se variações sazonais e anuais. Programas para conservação da área também são extremamente necessários.

Many North American shorebirds routinely migrate to southern South America during the boreal winter. In order to complete their spectacular migrations, a variety of species use stopover areas to feed and fatten before embarking upon long-distance, non-stop flights, which may be several thousand miles long. These stopover areas appear to be a scarce but nonetheless essential commodity for the completion of successful migrations (Senner and Howe, 1984).

The objective of this study was to describe the status of shorebirds, with emphasis on the red knot (*Calidris canutus*), at a coastal lagoon, Lagoa do

Peixe, and adjacent areas of the Atlantic coast in Rio Grande do Sul, Brazil (Fig. 1). The fieldwork period (26 April - 5 May 1984) coincided with the anticipated peak of the knots' northward passage in Brazil. Our findings suggest that this small portion of the Brazilian coast is of outstanding international significance to both North and South American populations of migratory shorebirds.

AREA DESCRIPTION

Lagoa do Peixe (31°20'S; 51°00'W) (Fig. 1) is a brackish coastal lagoon about 140 km south of Porto

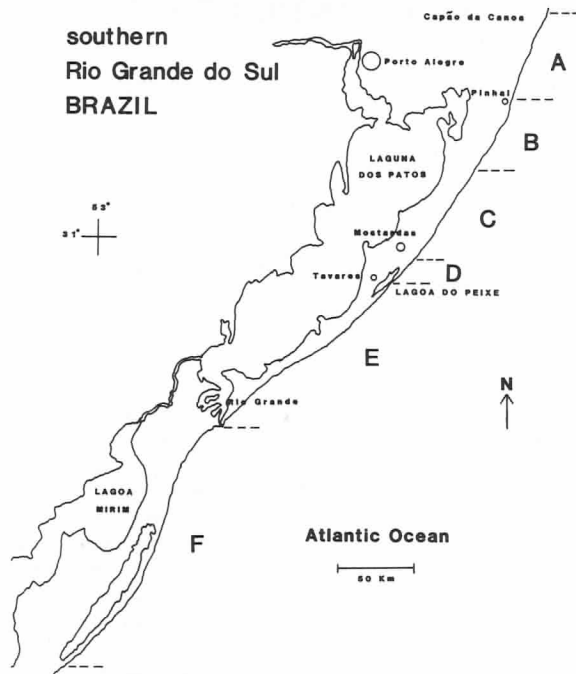


FIGURE 1. The southern coast of Rio Grande do Sul, Brazil, showing sections surveyed and locations of major towns.

Alegre, the fourth largest city in Brazil. Although located in a coastal zone of substantial recreational potential, there currently is no good road to Lagoa do Peixe, nor to nearby towns, so the lagoon and surrounding countryside are rural and not developed for tourism.

Lagoa do Peixe is periodically (about once every year) connected by man-made channels to the Atlantic Ocean. The water is less than 5 cm deep over much of the lagoon area, but in some locations may be 3 m deep. Because of the shallow depths, slight shifts of wind direction or speed have a major effect on the area and location of exposed flats used by shorebirds for foraging. The northeastern part of Lagoa do Peixe is connected to a series of smaller lakes which are less saline and deeper; the southern end is also connected to wetlands, but where Lagoa do Peixe ends and other water bodies begin is not clear.

METHODS

Our major objective was to locate and catch red knots during early stages of their northward migration. This required that we first locate an area where knots were abundant and where we could

establish a base of operation for ground survey and banding studies.

We used a Cessna 172 to fly over virtually the entire Rio Grande do Sul coastline at a 20-50 m altitude. We kept track of our approximate location by using time and conspicuous landmarks (lighthouses, lagoons, etc.) shown on maps. Using the time records, observations were grouped in zones between major landmarks (Fig. 1).

Large and/or distinct species such as oystercatchers (*Haematopus palliatus*), stilts (*Himantopus melanurus*), knots and godwits (*Limosa haemastica*) were readily identified, but small plovers and some sandpipers were not always detectable or identifiable (see below). An aerial survey was made on 19 April, and based upon the results we quickly confirmed that Lagoa do Peixe would be a good study site. Additional aerial surveys were made over parts of the same route on 26 April and on 8 May. Ground surveys, made within 24 h of each aerial survey, were used to compare species composition and numbers of shorebirds with those seen from the aircraft.

Rocket nets were impractical because of the flat and wet terrain at Lagoa do Peixe. Mist nets were effective when set in and near shallow waters and mud flats, especially at night. Captured birds were examined for molt; weight, bill and wing lengths also were measured. Individuals were aged by plumage characteristics when possible. Bills normally were measured from the proximal end of the nares to the bill tip (see Prater et al., 1977, for recommended technique). Wing measurements are natural chords of the unflattened wing.

Habitat studies were made as time allowed, including (i) censuses on a 9-ha transect of representative lagoon habitats (water, temporary mudflats, beach and inundated grassy areas), (ii) censuses along an ocean beach transect (approximately 18 km long, 50 m wide), and (iii) a census transect (ca. 500 m long by 100 m wide) between the beach and the lagoon in the erstwhile ocean inlet. Preliminary food studies were made by observing foraging habits, inspecting small numbers of stomachs and by "grab sampling" invertebrates in favored and less heavily used feeding areas. Grab sampling was useful to verify identification of prey seen during observations of shorebird feeding.

RESULTS

These accounts are for species we found commonly; others are listed at the end of the species accounts.

Haematopus palliatus.—American oystercatchers were commonly but not evenly distributed along the Rio Grande do Sul beaches (Table 1). During aerial surveys on 19 and 26 April we found only 25 individuals on sections A and B (see Fig. 1), less than 0.5 birds per km of beach, whereas densities were much higher (maximum of 10.7/km) though variable in sections C and D. Parametric comparisons of average flock size between zones were not significant, but flocks of 10 or more birds occurred statistically more often ($X^2 = 15.1$, $P < 0.01$, 1 d.f.) than smaller flocks in the northern than in the southern half of the survey area. At Lagoa do Peixe we found oystercatchers most often on the Atlantic shore, but they commonly used lagoon habitats for roosting.

Himantopus melanurus.—Common stilts are found most commonly in non-marine habitats in southern Brazil, so it was somewhat surprising to find large numbers on some sections of the coastline. Before 5 May we found fewer than 25 on surveys of virtually the entire Rio Grande do Sul coast south of Capão da Canoa. On 5 and 8 May, however, the species were abundant between Mostardas and Capão da Canoa (Fig. 1), especially north of Pinhal, where densities approached eight birds per km. At Lagoa do Peixe stilts were common, particularly along shorelines of the northern half of the lagoon.

Belton (1984) noted local movements of common stilts to the northeast coast of Rio Grande do Sul in May or June. We apparently witnessed the start of this movement as numbers on the northern coast increased steadily towards the end of our field work (Table 2). Myers and Myers (1979) noted a similar movement of common stilts to marine habitats on the Argentine pampas during April.

TABLE 1. Numbers of American oystercatchers found during six coastal surveys of Rio Grande do Sul, Brazil. See Figure 1 for locations.

	Survey Type ^a	Coastal Section ^c					
		A	B	C	D	E	F
19 April	A	ns ^b	0	313	194	441	767
26 April	A	0	25	180	3	ns	ns
1 May, 0930 h	G	ns	ns	ns	0	ns	ns
1 May, 1100 h	G	ns	ns	ns	0	ns	ns
4 May, 1530 h	G	ns	ns	ns	2	ns	ns
5 May, ca 1100 h	G	ns	48	190	3	ns	ns
8 May, ca 1400 h	A	0	26	77	1	ns	ns
Distance (km)		59	55	70	18	170	210

^a A = aerial survey, G = ground survey

^b ns = not surveyed

^c see Fig. 1 for locations

Vanellus chilensis.—Southern lapwings were uncommon in the marine habitats of the Lagoa do Peixe region, but were scattered in nearby upland habitats. One individual was captured and banded (Table 3).

Charadrius (Zonibyx) modestus.—We infrequently found rufous-chested dotterels on the Atlantic beach, but they comprised about 5% of the shorebirds at Lagoa do Peixe. The species was most common on lagoon shores (Table 4), most abundantly on shorelines with halophytic plants, but also on mud and sand flats, and less often in shallow water.

Most captured individuals were less than 1 year old judging by softness of the plumage, light edgings on dorsal feathers, and subdued colorations. Average measurements of five birds are given in Table 3.

Rufous-chested dotterels were about the seventh most common shorebird of the habitats we surveyed at Lagoa do Peixe (Table 3). During evening twilight, however, we commonly saw flocks of up to 200 small charadriids suspected to be rufous-chested dotterels flying towards the beach from shores and pasturelands west of the lagoon, indicating the species was considerably more common than our figures suggest. Belton's (1984) earliest record for this southern visitor is 16 April; by the end of April we found them to be common at Lagoa do Peixe. Repeated sightings of birds marked by us suggested a low turnover rate and gave little indication of onward migration.

Charadrius semipalmatus.—Semipalmated plovers were the sixth most common shorebird at Lagoa do Peixe (Table 4). Highest densities occurred on beaches and flats of the filled inlet between the lagoon and the ocean, but the species was numerically most common on the ocean beaches, especially before 2 May. On the lagoon shores, densities and numbers were highest on sand and mud flats where numbers per unit area exceeded those in shallow water by about 3:1.

On 28 April, most birds foraging on the ocean beach (20 of 24) had worn and faded dorsal

TABLE 2. Counts of common stilts on the Rio Grande do Sul coast, Brazil, April-May 1984.

	North of Pinhal (to Capão da Canoa)		South of Pinhal (to Mostardas)	
	No. of km surveyed	No. stilts per km	No. of km surveyed	No. stilts per km
19 April	0	—	143	0
28 April	59	0	143	0.1
5 May	10	4.6	143	1.99
8 May	60	7.5	143	1.39

TABLE 3. Biometrics of shorebirds caught at Lagoa do Peixe, Rio Grande do Sul, Brazil, April-May 1984.

Species	Number	Weight (g)			Bill (mm) ^a			Wing (mm)		
		n	\bar{x}	S.D.	n	\bar{x}	S.D.	n	\bar{x}	S.D.
<i>V. chilensis</i>	1	1	234	—	0	—	—	0	—	—
<i>C. modestus</i>	6	6	80.5	7.5	6	16.6	2.2	6	140.2	10.1
<i>C. semipalmatus</i>	1	1	56	—	1	11.4	—	1	122	—
<i>C. collaris</i>	1	1	30	—	1	13.8	—	1	99	—
<i>C. falklandicus</i>	19	19	64.7	6.1	18	15.4	0.6	18	123.4	3.7
<i>P. squatarola</i>	5	5	292.5	12.4	4	31.3	1.5	4	191.5	2.7
<i>L. haemastica</i>	1	1	320	—	1	81.6	—	1	215	—
<i>C. canutus</i> ^b	12	11	149.9	15.5	12	30.7	1.5	12	159.2	4.9
<i>C. canutus</i> ^c	280	280	202.4	19.4	277	31.5	1.5	278	166.3	5.2
<i>C. fuscollis</i>	41	40	55.9	5.9	41	21.7	1.7	41	119.8	3.4
<i>C. pusilla</i>	11	9	32.2	6.6	11	17.5	1.6	11	94.7	3.4
<i>C. alba</i>	8	8	84.6	14.8	8	22.4	2.1	8	124.0	3.9

^a proximal end of nares to tip

^b basic plumage birds, see text

^c alternate plumage birds, see text

TABLE 4. Ratios of shorebirds counted in different habitats in the vicinity of Lagoa do Peixe, Brazil, 29 April-4 May 1984.

	Between Ocean and Lagoon (old inlet)		
	Ocean Beach		Lagoon Shores
<i>C. modestus</i>	0	2	164
<i>C. collaris</i>	5	2	10
<i>C. semipalmatus</i>	104	18	101
<i>C. falklandicus</i>	24	9	390
<i>P. squatarola</i>	0	1	74
<i>A. interpres</i>	48	2	10
<i>L. haemastica</i>	0	0	285
<i>C. canutus</i>	132	0	893
<i>C. fuscollis</i>	116	29	1,316
<i>C. pusilla</i>	0	22	37
<i>C. alba</i>	463	0	3
	892	85	3,283

plumages, and dingy, ill-defined breast bands indicating they probably were less than 1 year old and still wearing first basic plumage. Elsewhere most semipalmated plovers were in definitive alternate plumage.

Semipalmated plovers on the ocean beaches fed mostly on small, thin polychaete worms 3-5 cm long which appeared similar to those caught by sanderlings, although the semipalmated plovers foraged higher on the beach. We did not see the prey of semipalmated plovers in the lagoon.

In the course of banding operations we caught one semipalmated plover (Table 3). Numbers of semipalmated plovers declined steadily during our fieldwork. On 1 May there were 71 along Section D (18 km, Fig. 1), but just three were along the same

beach on 5 May. Similarly, before 3 May we often found 5-25 on our 9-ha study plot, but later we never found more than five. Belton (1984) describes semipalmated plovers as a scarce, non-breeding summer visitor in Rio Grande do Sul.

Charadrius collaris.—We found collared plovers most commonly on ocean beaches, particularly along a thinly populated beach (Section C, Fig. 1) north of Lagoa do Peixe where densities averaged 3.1/km on 5 May. The beaches parallel to Lagoa do Peixe (Section D) held an average of 1.0/km, approximately the same density as we found on the populated beach near Pinhal (Section B). The overall densities of collared plovers between Pinhal and Lagoa do Peixe were approximately the reverse of those found for double-banded plovers (see below). At Lagoa do Peixe, collared plovers were uncommon (Table 4); only one bird was caught (Table 3).

Charadrius falklandicus.—Double-banded (Falkland) plovers were the fourth most common shorebird we found at Lagoa do Peixe. The species also was common on Atlantic beaches (Table 4), particularly those parallel to Lagoa do Peixe (density = 5.8 individuals/km). To the north, however, densities declined to 0.7/km in the 70 km stretch north of Lagoa do Peixe (Section C, Fig. 1), and then to 0.2/km in the vicinity of Pinhal. Numbers remained high in the lagoon study transect, even when the surface area of water increased and the amount of exposed mud flat decreased; thus the densities varied from 1.9/ha to 11.2/ha of exposed flat. During the same period numbers on the ocean beach increased markedly: in Section D (Fig. 1), for example, our count varied

from 23 on 1 May to 105 on 5 May. It appears that birds moved from lagoon to beach habitats as mud flats became covered by water when the wind was from the north, and/or that new migrants were arriving from the south.

Average measurements of 18 captured *C. falklandicus* are given in Table 3.

Pluvialis squatarola.—Although our counts show black-bellied plovers as the eighth most common species (Table 4) at Lagoa do Peixe, these numbers probably underestimate their relative abundance. The species was common on the lagoon shores, particularly north and south of our transects. Most were foraging in shallow water or on shoreline mud flats, and appeared to be catching the same species of small snail (*Heleobia* sp.) that *Calidris canutus* and other shorebirds were eating.

Plumages of most black-bellied plovers were a mix of basic and alternate feathers, but a few were in fresh, definitive alternate plumage. The average weight of the five birds we caught (Table 3) indicated sufficient fat reserves for at least a 5,500-km, non-stop flight (McNeil, 1969).

Peak numbers of black-bellied plovers during northward migration in Venezuela (McNeil, 1970) occur during the second half of April; in Texas the peak numbers are from April through May (Oberholzer, 1974), and in Massachusetts they are during late May (BAH, unpubl.). Therefore, the majority at Lagoa do Peixe were probably late migrants or perhaps birds that would not be migrating to the nesting grounds (cf. Eisenman, 1951). Belton's (1984) latest records of birds in breeding plumage in Rio Grande do Sul are on 11 April.

Black-bellied plovers were uncommon and widely scattered on the ocean beaches. Because individuals are easily missed during aerial surveys, we calculated density estimates only from ground survey counts; the highest density was 0.3 birds/km along sparsely inhabited coast 70 km N of Lagoa do Peixe (Section C, Fig. 1). Elsewhere we found fewer than 0.1 birds/km of beach.

Arenaria interpres.—Ruddy turnstones were uncommon. Highest numbers were found repeatedly along a short stretch of ocean beach about 10 km N of the Lagoa do Peixe inlet. Small numbers with brightly colored, fresh alternate plumages were occasionally found on flats and shorelines of the filled inlet; these were eating flies and perhaps flesh of dead crabs. Belton's (1984) latest record of adult ruddy turnstones is 1 March.

Limosa haemastica.—Hudsonian godwits were the fifth most common species observed (Table 4) with

more than 1,000 counted at Lagoa do Peixe during our visit. We found none elsewhere.

About 70% of the Hudsonian godwits were in fresh alternate plumage and appeared to be adults; the remainder were in basic or combinations of basic and alternate plumage. One alternate-plumage bird was caught on 1 May (Table 3).

Although relatively little is known about the northward migration of Hudsonian godwits, peak numbers occur in Texas between late April and late May (Oberholzer, 1974), and first birds return to arctic nesting areas during the first week of June (Hagar, 1966). The fact that many birds with alternate plumage were still in southern Brazil during early May suggests a rapid migration between southern stopover sites and North America. During 27-29 May 1974, Belton (1984) found much smaller numbers of Hudsonian godwits at Lagoa do Peixe, almost all of which were in basic plumage.

Hudsonian godwits appear to be more abundant at Lagoa do Peixe during the southward migration than during late April/early May (FS, unpubl.). However, our survey may have missed the peak of northward migration. In Argentina, BAH (unpubl.) found peak numbers of Hudsonian godwits in Chubut during mid-April. Belton (1984) reported fewer than we found in Rio Grande do Sul, apparently because he did not visit Lagoa do Peixe during the peak migration period. The combined information indicates that Lagoa do Peixe is a key stopover area for Hudsonian godwits. Unlike knots (see below), godwits were not found on other lagoons or in any other habitats of Rio Grande do Sul. Likewise, Belton (1984) reported few godwits in Rio Grande do Sul from sites other than Lagoa do Peixe.

Foraging by Hudsonian godwits was almost entirely by probing in shallow water. Individuals normally made exploratory probes to about one third the length of the bill; about 80% of the time they continued to probe to the full bill length and almost invariably captured prey. We saw nothing to suggest prey were in short supply. The most likely major prey was a long, narrow, unidentified bivalve (0.75-4.5 cm long) which we frequently found live in core samples of lagoon mud and shells common on lagoon shores.

Calidris canutus.—We found red knots most commonly in habitats associated with Lagoa do Peixe, but they also were common on the ocean beach (Table 4). In the lagoon, knots usually foraged in areas covered by water or less often on recently exposed flats covered by algae.

Aerial surveys showed that knots were concentrated in two areas—oceanside beaches for 30 km S of Pinhal, and the southern third of Lagoa do Peixe. On the oceanside beaches, small clams (*Donax* sp.) were the major prey, with small crustaceans (*Emerita* sp.) taken less often. Knots apparently selected sections of beach where smaller size classes of *Donax* were available. Grab sampling indicated that *Donax* were abundant where we found knots, but were absent, scarce, or too large in areas without knots.

At Lagoa do Peixe knots remained in shallow sections of the lagoon 24 h a day as long as the wind blew from the south. The principal prey was a small snail (*Heleobia* sp.), extremely abundant in southern parts of the lagoon but less common to the north. *Heleobia* were readily available at the south end when southerly winds kept the water shallow. Knots foraged there in loose flocks during daylight. On 29 April, we estimated that more than 11,000 knots and 5,000 other shorebirds were feeding on 30-40 ha. This was estimated to be 80% of the knots at Lagoa do Peixe that day.

Most knots at Pinhal and at Lagoa do Peixe were in full alternate (breeding) plumage at the end of April. The proportion in basic or mostly basic plumage subsequently increased, because either more basic-plumaged birds arrived in the study area and/or because alternate-plumaged birds departed; we suspected the latter.

The basic-plumage knots which we caught tended to have shorter wings ($P < 0.01$, *t*-test) and lower weights ($P < 0.01$, *t*-test) than the alternate-plumage knots (Table 3). The basic-plumage birds were probably less than 1 year old and still retained juvenile primaries, rather worn and frayed (hence shorter) after 9-10 months. In contrast, the breeding-plumage knots had new primaries (Prater et al., 1977), almost certainly less than 3 months old. (Indeed a few individuals had outermost primaries still growing.) In addition to the wear factor, juvenile knots, even with fresh plumages, have shorter wings than breeding-age knots. As for the lower weights, many (most?) of the gray knots remain in the Rio Grande do Sul region during the boreal summer (Belton, 1984), so it is unlikely that they undergo pre-migratory fattening.

The mean of all weights in our sample exceeds our estimate of the average fat-free weight (120 g, cf. Dick and Pienkowski, 1979) by about 55% and is higher than we have found in samples numbering in the hundreds at other sites where we have worked (Argentina, Florida, New Jersey or Massachusetts); four of the captured knots weighed 250 g or more,

or approximately 90% more than our estimate of the average fat-free weight.

Six of the 308 knots captured at Lagoa do Peixe carried North American bands, and an additional North American band was recovered from a knot killed by a raptor. This suggests that 2% of the knots at the lagoon between 29 April and 2 May were banded; the birds were difficult to approach closely; therefore, the 2% value could not be confirmed by visual searches with telescopes. Near Pinhal, however, we were able to check about 3,000 knots; only one was banded (wearing color marks from New Jersey). These searches were made both before and after the banding period at Lagoa do Peixe, and were from close ranges so that any marker, even a solitary metal band, would have been visible.

A number of the 308 knots banded at Rio Grande do Sul were subsequently found along the Delaware Bay coastline in the United States (L. E. Leddy, E. P. Mallory, pers. comm.). Fifty sightings of Brazil-marked birds were made between 15 and 21 May, involving an unknown number of individuals. Another Brazil-marked knot was seen on the Virginia coastline during this same period (M. A. Howe, pers. comm.). The exchange of banded knots between southern Brazil and the United States Atlantic coast, where all knots are thought to be of the race *C. c. rufa* (American Ornithologists' Union, 1957), suggests that the knots in Rio Grande do Sul are of this same race.

We estimated a minimum of 11,000 knots at Lagoa do Peixe and an additional 10,000 in the region of Pinhal. These apparently were separate groups because we saw no connecting flight lines, no routine movement by the knots at Lagoa do Peixe, and no marked birds from Lagoa do Peixe at Pinhal. The sum of 21,000 birds is conservative as it does not consider turnover, numbers of birds arriving before/after our survey, or birds that may have been north of our survey area.

Morrison and Harrington (1979) estimated that the population size of *C. c. rufa* was in the order of a few tens of thousands. BAH (unpubl.) now believes the number is closer to a few hundred thousand. It is thus likely that at least 5-10% of the world *C. c. rufa* population was present in Rio Grande do Sul during northward migration. These numbers, high weights, recoveries and sightings of banded birds, and contrast of these findings to similar survey work in Argentina (BAH, unpubl.) all suggest that the Rio Grande do Sul coast is a major migration staging area for *C. c. rufa*.

***Calidris fuscicollis*.**—White-rumped sandpipers were the most common shorebird in the study area

during late April and early May (Table 4). At Lagoa do Peixe most individuals were in lagoon habitats where they were about equally common on flats or in shallow water. White-rumped sandpipers also were the third most common shorebird on the ocean beaches, where highest densities occurred between Pinhal and Lagoa do Peixe, with notably fewer to the south. Numbers on beaches near Lagoa do Peixe increased steadily until early May, but did not change substantially on the lagoon shores.

White-rumped sandpipers at Lagoa do Peixe foraged largely by visual means. Although we did not identify the prey, the sandpipers associated with other shorebirds eating small snails (*Heleobia* sp.). Most white-rumped sandpipers on the ocean beach foraged in fresh water springs on the upper beach as well as in the wave-wash zone.

Evidence suggests that the white-rumped sandpipers in Rio Grande do Sul were staging in preparation for a long-distance flight to the north. First, birds had steadily increasing average weights between 27 April and 4 May (Table 3). The overall average weight (56 ± 6 g) was high compared to weights found by McNeil (1969) in Venezuela, and were closer to weights at the Magdalen Islands, Gulf of St. Lawrence, an area where white-rumped sandpipers stage prior to non-stop, southward flights between Canada and South America (McNeil and Cadieux, 1972). Second, the turnover rate of white-rumped sandpipers at Lagoa do Peixe evidently was low inasmuch as the resighting rate of our color-marked birds was higher than for any other shorebird we marked. Finally, numbers of white-rumped sandpipers increased steadily along the ocean beaches between 19 April and 4 May, but then dropped rapidly between 5 and 8 May.

On the central Argentine coast, white-rumped sandpipers were abundant during late March and the first week of April, but numbers dropped between 8 and 13 April, and very few remained on 22 April (BAH, unpubl.). Belton (1984) noted that white-rumped sandpipers were abundant in Rio Grande do Sul from February "well into April". In northeastern South America, Spaans (1978) reported peak numbers of northward migrants during the first half of May, but the spring flight involved considerably fewer birds than during autumn. Conversely, in Venezuela, McNeil (1970) found much higher numbers during northward migration, with peak numbers between late April and late May; in Kansas, E. F. Martínez (International Shorebird Surveys, unpubl.) found peak numbers between 17 and 21 May during three springs (1980-1982) of weekly surveys.

These accounts suggest that white-rumped sandpipers have a rapid migration between southern Brazil, northeastern South America, and the central plains of the United States. The northward migration apparently begins with gradual movement between Argentina and Brazil, but then is followed by rapid flights. Thus, Rio Grande do Sul appears to be a staging area where fat is accumulated before a flight between southern and northern South America. Antas (1984) noted that reports of white-rumped sandpipers are rare from Amazonia during northward as compared to southward migration, owing to the flooding of river-bottom habitats. Judging from the less common occurrence of the species in Suriname during May than August-September (Spaans, 1978), and the relatively higher April-May than August-September occurrence in Venezuela (McNeil, 1970), it appears that a non-stop, overland flight may take place between southern Brazil and the Caribbean coast of Venezuela, a distance of roughly 4,700 km. The weights at Lagoa do Peixe indicated a potential flight range of 7,500 km (McNeil, 1969); the average weight of the last 10 captured was sufficient for a flight to the United States Great Plains (McNeil, 1969).

Calidris pusilla.—Semipalmated sandpipers, although uncommon, were found routinely on mud and sand flats near our 9-ha study plot. Some semipalmated sandpipers are known to winter south to southern Argentina (AOU, 1957), but heretofore the species was unreported in southern Brazil (Antas, 1984; Belton, 1984).

Bill measurements (exposed culmen) of a small sample of unsexed semipalmated sandpipers at Lagoa do Peixe (Table 3) averaged 19.4 ± 1.3 mm, closely matching the 19.8 ± 1.4 mm average that Harrington and Morrison (1979) reported from the mid-Atlantic coast of the United States during northward migration.

The average weight of the individuals in our small sample was 32.2 ± 6.6 g. Because it is likely that only the heaviest birds were ready to migrate northward, we used the average of the five heaviest birds to estimate the flight range capacities using the formulae of McNeil and Cadieux (1972). The estimate exceeded 4,000 km, sufficient for a flight to northern South America.

Calidris alba.—Sanderlings were relatively common (hundreds) on the oceanside beaches in the vicinity of Lagoa do Peixe during the first few days of our fieldwork, but were scarce in the lagoon itself. Foraging on the beach was entirely in the wave-wash zone where most prey seen were thin

polychaete worms. *Emerita*, an amphipod, also were captured, but only one for every 10 or so worms.

At least 110 of 125 sanderlings studied on 28 April had about 50% alternate feathers in the dorsal plumage, while 15 had an essentially basic dorsal plumage. All 125 birds were entirely white on the ventral side, including the neck.

Eight sanderlings caught on the ocean beach on the night of 9 April had a high average weight (84.6 g, Table 5), suggesting that a long migration flight, with a potential span of 3,500 km (McNeil and Cadieux, 1972), was imminent. In contrast, the average weight of 93 adult sanderlings during autumn in Massachusetts was 62.1 ± 12.8 g (BAH unpubl.).

No sanderlings were found in a search of 15 km of ocean beach on the night of 3 May, and numbers found during the day were much lower than they had been on 28-29 April. These observations, compared with those described by Belton (1984), suggest that most northbound sanderlings had left Rio Grande do Sul by the time our fieldwork started.

Other Shorebirds.—The following species were seen rarely during our fieldwork at Lagoa do Peixe: tawny-throated dotterel (*Eudromias ruficollis*), common snipe (*Gallinago gallinago*), willet (*Catoptrophorus semipalmatus*), lesser yellowlegs (*Tringa flavipes*), least sandpiper (*Calidris minutilla*), short-billed dowitcher (*Liminodromus griseus*) and Wilson's phalarope (*Steganopus tricolor*).

DISCUSSION

Boreal Shorebirds

Numbers of Hudsonian godwits at Lagoa do Peixe were higher than has ever been reported during northward migration anywhere. Indeed, no other major stopover site is known for this species between southern Brazil and the United States gulf coastal plain, where peak numbers generally are found at scattered locations during late April and early May (International Shorebird Surveys, unpubl.). This fact and the apparently close timing of migration in southern Brazil and the United States mid-west, suggests the possibility of a non-stop flight connecting the two regions.

A similar situation exists for red knots; no appreciable numbers of migrants are known between Rio Grande do Sul and the United States mid-Atlantic and Gulf coasts. Spaans (1978) found few in Suriname during the first half of May. McNeil (1970) found no spring knot migration on the

TABLE 5. Weight of white-rumped sandpipers caught at Lagoa do Peixe, Rio Grande do Sul, Brazil.

1984 Date	n	\bar{x}	SD
27-28 April	18	53.0	4.4
28-30 April	12	55.7	5.2
03-04 May	10	61.5	5.2

Venezuelan Caribbean coast east of Caracas. Near Maracaibo, however, Casler and Lira (1979) found hundreds in March and April during a systematic three-year survey of the west shore of Golfo de Venezuela; notably, however, they found very few during May.

The spring passage of knots on the Texas coast builds up to substantial numbers during the second half of April, with peak numbers during early May (International Shorebird Surveys, unpubl.). Little is known of the origin of these birds. None marked in Argentina or Brazil, however, have been reported from Texas in spite of searches by at least three shorebird research groups; in contrast, there have been about 75 sightings on the United States mid-Atlantic coast.

The sightings of marked knots moving between Brazil and the eastern United States indicate that at least 7,670 km are traversed in less than 3 weeks. Records from American Birds and Audubon Field Notes from 1940 to 1980, and from regional bird watchers' journals, show a 7-10 day lag between the peak passage of knots in Georgia and the Carolinas and the peak of numbers in Virginia and on Delaware Bay.

In 1984, numbers of knots at Lagoa do Peixe started decreasing on 2 May. The first Brazil-marked knots were seen in New Jersey 13 days later, on 15 May, with additional sightings by 17 and 18 May. If knots' ground speed were a low 60 km/h (Longstreet, 1930), a direct flight between Rio Grande do Sul and South Carolina would require 5 days, giving an estimated arrival date of 7 May. This is 4 days short of the mean date of peak knot migration on the southeast United States Atlantic coast noted above. Although the flight speed probably is more rapid, it still appears that some red knots could fly directly to the United States Atlantic coast from Rio Grande do Sul, or that if stops occur enroute, they are brief, and not long enough for accumulation of much fat for continued migration. In short, the fat gained in Rio Grande do Sul appears crucial to the northward migration of knots between southern Brazil and the United States Atlantic coast.

Finally, our information suggests that white-rumped sandpipers also are staging on the southern Brazil coast before rapid northward migration. Because we know little of its population size, we can not assess whether Rio Grande do Sul is crucial to the overall population. Similarly, because the time of our work followed the northward passage time of other boreal shorebirds, we are unable to evaluate the importance of Rio Grande do Sul to species like the black-bellied plover, greater (*Totanus melanoleuca*) and lesser yellowlegs, and sanderling, any or all of which may have been present in high numbers before our fieldwork.

Austral Shorebirds

We did not find austral shorebirds concentrating to the same degree as boreal migrants. However, further studies, particularly of rufous-chested dotterels, could show high concentrations. Also, one resident species, the common stilt, showed sharply increased numbers on the northeastern Rio Grande do Sul coast during the last few days of our fieldwork, suggesting a major shift from non-marine to restricted marine habitats.

Critical Stopover Areas

Recent studies (e.g., Morrison, 1984; Morrison and Harrington, 1979; Senner and Howe, 1984) have suggested that many New World shorebirds use key staging areas during their migrations. Such areas may sometimes be used by substantial proportions of hemispheric species' populations as places where fat is accumulated prior to continued migration. It is becoming clearer that key areas are used traditionally (Senner and Howe, 1984; Smith and Houghton, 1984), and perhaps that few alternative sites exist. Major staging areas therefore appear critical to the welfare of populations which concentrate at them.

Virtually all published information on critical migration staging areas in the New World has come from North America, and mostly from autumn migration (see Senner and Howe, 1984, and references therein). Little information has been published on key stopover areas in South America and on austral breeding species of shorebirds, although recent surveys have delineated important wintering areas (Morrison, 1984; Morrison et al., 1985). This report explores the question with respect to one site in southern Brazil which is used as a staging ground by North American migrants and as a wintering and migration zone for Patagonian and locally-breeding species. Our results clearly show

that boreal shorebirds concentrate at stopover areas in South America just as they do in North America.

A key question in the conservation of shorebirds' critical staging areas is why concentration areas exist and whether alternative sites exist. Our aerial surveys in Rio Grande do Sul covered roughly 580 km of Atlantic shoreline, partial coverage of no less than 30 coastal ponds and lagoons, well over 600 km of pampas upland, including cattle range land, rice fields, marshes and sloughs. Nowhere did we find numbers of shorebirds that compared to those at Lagoa do Peixe and the nearby coastal beach.

Lagoa do Peixe apparently attracts birds for two principal reasons. First, the lagoon is shallow and is used for nocturnal roosting, apparently offering protection from predators. Second, the lagoon has high populations of invertebrates, especially molluscs and crustaceans and small fishes, and so offers abundant food resources for birds.

Lagoa do Peixe and Lagoa dos Patos are the only major lagoons in Rio Grande do Sul which are regularly connected to the ocean. Lagoa dos Patos is much deeper and less saline than Lagoa do Peixe and does not have shallow waters like Lagoa do Peixe. The water level of Lagoa do Peixe has been managed by farmers and fishermen for at least 15 years, and perhaps since ca. 1940 when the local fishing village was established. Little is known of the birdlife prior to Belton's (1984) and Silva's (unpubl.) studies during the middle 1970's. Whether the water level management influences shorebirds is unknown and needs further study. Whatever the case, it is clear that Lagoa do Peixe is an area of substantial international importance to a group of birds which ranges freely between the southernmost and some of the northernmost land of the Western Hemisphere. Increased tourism and other development are likely to impact shorebirds when planned construction of a paved road from Porto Alegre (population over 1 million) is completed. Further study on a year-round basis and development of wildlife conservation programs is needed.

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