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SEASONAL AND LONGITUDINAL VARIATION IN THE ABUNDANCE AND DIVERSITY OF SHOREBIRDS (AVES, CHARADRIIFORMES) ON ATALAIA BEACH IN NORTHEASTERN BRAZIL

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Abstract. – Many Nearctic shorebirds cover vast areas during their annual migrations, and depend on an ample network of stopover and wintering areas for their survival. In this study, long-term data are presented on the occurrence of shorebirds at one such site on the coast of the state of Sergipe in northeastern Brazil. A 5-km long stretch of Atalaia Beach was surveyed each month between July 2003 and May 2006 (1–6 surveys per month, total = 101). The surveys resulted in records of three resident shorebird species (*Vanellus chilensis*, *Charadrius collaris* and *Charadrius wilsonia*) and ten Nearctic migrants (Charadriidae and Scolopacidae). The local abundance of these migrants followed a predictable pattern, with the main influx starting at the end of September, during the boreal autumn (with *Charadrius semipalmatus* arriving slightly earlier). The Semipalmated Sandpiper (*Calidris pusilla*) and the Semipalmated Plover (*Charadrius semipalmatus*) were the most abundant species throughout the study period, peaking at 1200 and 700 birds, respectively, in November–February. Some sanderlings (*Calidris alba*), Ruddy turnstones (*Arenaria interpres*), and Semipalmated plovers (*C. semipalmatus*) almost certainly overwinter at the site, and remained in the study area throughout the year, whereas the bimodal distribution of the White-rumped Sandpiper (*Calidris fuscicollis*) indicates the use of the beach as a stopover during migration to wintering sites further south. Whilst more species were recorded during the first year, counts were lower than in subsequent years, possibly reflecting natural fluctuations in abundance or migration patterns. Overall, the data indicate that the site may be an important stopover or wintering site for populations of at least five species of Nearctic migrants, while it may be visited periodically by a number of other species.

Resumo. – Variação sazonal e longitudinal na abundância e diversidade de aves limícolas (Aves, Charadriiformes) na praia de Atalaia, nordeste do Brasil. – A migração anual de muitas aves limícolas neárticas se distribui ao longo de vastas áreas, sendo a sobrevivência destas aves dependente de uma ampla rede de locais de parada e invernada. neste estudo são apresentados dados de longo prazo sobre a abundância e ocorrência de aves limícolas numa área costeira do estado de Sergipe, nordeste do Brasil. um trecho de 5-km da praia de atalaia foi amostrado mensalmente entre o período de julho de 2003 a maio de 2006 (1–6 amostragens por mês, total de 101 saídas). as observações resultaram no registro de três espécies residentes (*Vanellus chilensis*, *Charadrius collaris* e *C. wilsonia*) e dez espécies de aves limícolas Neárticas (Charadriidae e Scolopacidae). A abundância local seguiu um padrão previsível, com o principal influxo de aves ocorrendo ao final de setembro, durante o outono boreal

(*Charadrius semipalmatus* chegando um pouco antes). O maçarico rasteirinho (*Calidris pusilla*) e a batuíra de bando (*Charadrius semipalmatus*) foram as espécies mais abundantes, principalmente entre novembro–fevereiro, alcançando picos de 1200 e 700 aves, respectivamente. Alguns indivíduos de *Calidris alba*, *Arenaria interpres* e *Charadrius semipalmatus* foram registrados durante todo o ano, permanecendo além do período de invernada, enquanto que a distribuição bimodal de *Calidris fuscicollis* indica o uso da localidade como uma área de parada durante a migração, no deslocamento para áreas mais ao Sul. De forma geral, os dados indicam que a praia de Atalaia é uma importante área para descando-parada e invernada para populações de ao menos cinco espécies de aves limícolas migratórias, sendo que podem ser visitada periodicamente por um número maior de outras espécies. *Accepted 25 October 2010.*

Key Words: Nearctic shorebirds, migration, seasonal abundance, Sergipe, Brazil.

INTRODUCTION

The remarkable flight capacity of many migratory shorebirds enables them to occupy a variety of different habitats over a wide geographical range (Sick 1997, Berthold 1999, Warnock *et al.* 2002, Newton 2008). Over half of all shorebird species are migratory, and during each boreal autumn, millions of individuals depart from their breeding grounds in the Nearctic and Palearctic regions in search of warmer and more productive wintering grounds further south, often in the Southern Hemisphere (Evans 1993, Butler *et al.* 2001, Piersma 2007).

Flock size and stopover strategies vary considerably among species (Warnock *et al.* 2002, Gill 2007), but all depend on an adequate network of foraging and resting sites for their survival in the long term (Myers 1983, Myers *et al.* 1985, Davison & Evans 1988, Butler *et al.* 2001, Leu & Thompson 2002, Piersma 2007). Significant disruption at any one of these sites will normally result in considerable, possibly even fatal disruption of the migratory cycle (Rappole *et al.* 1993, Elner *et al.* 2003, Piersma 2007). Coastal zones are especially important here, and the global distribution of coastal populations appears to be directly related to the productivity of these ecosystems (Butler *et al.* 2001). Obviously, understanding migration patterns and the relative importance of different areas is essential to the development of effective monitoring strategies and conservation procedures (Furness *et al.* 1994, Davidson & Stroud 1996, Meyers *et al.* 2000, Burger *et al.* 2004, Durell *et al.* 2005).

The coast of Brazil straddles the equator and extends as far south as the austral temperate zone, and encompasses some of the largest estuaries, coastal dune fields and mangrove ecosystems found anywhere in the world. Shorebird migration in Brazil follows the major north-south river basins and the coastline (Antas 1983, Vooren & Brusque 1999). Large seasonal concentrations of waterbirds can be found in particular in the Gulf of Maranhão, on the Amazon coast (Morrison & Ross 1989, Butler *et al.* 2001; Rodrigues 2000, 2007), and in the extreme south of Brazil in the wetland complex of Rio Grande do Sul state (Vooren & Chiaradia 1990, Belton 1994, Vooren & Brusque 1999, Accordi & Hartz 2006), although few data are available for large stretches of the coast, especially in the Brazilian northeast (but see Azevedo-Júnior & Larrazábal 1999, Telino-Júnior *et al.* 2003, Azevedo-Júnior *et al.* 2004, Lyra-Neves *et al.* 2004, Araújo *et al.* 2006, Cabral *et al.* 2007).

One potentially important lacuna is located south of the mouth of the São Francisco River, encompassing the Brazilian state of Sergipe and adjacent areas of Bahia. With the exception of a brief survey (CEMAVE,

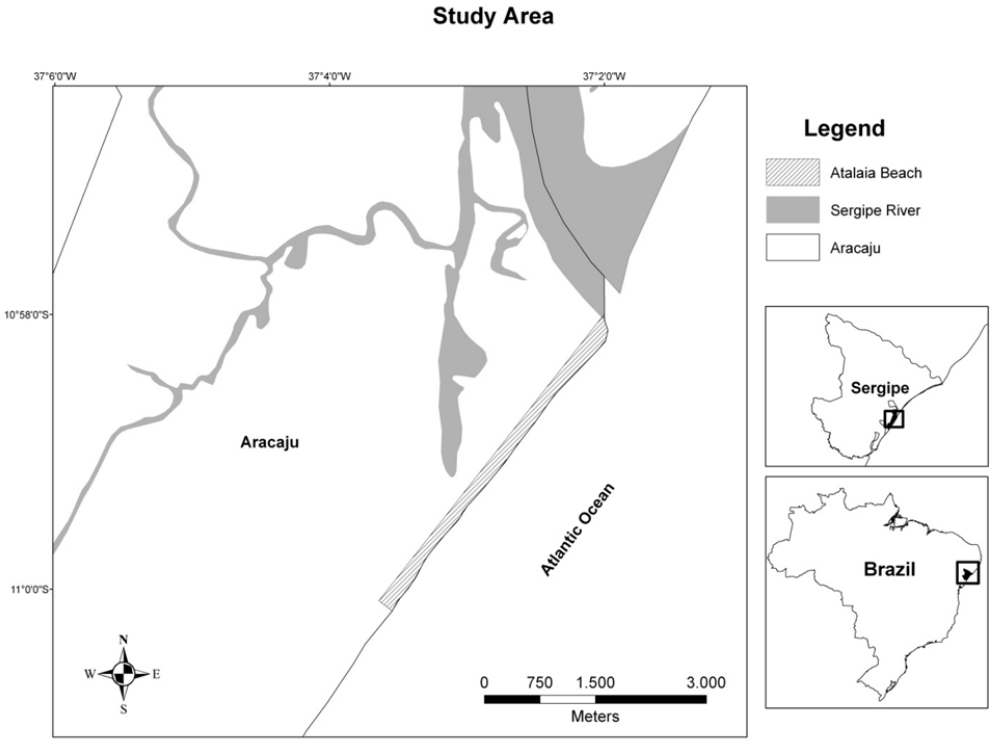

FIG. 1. Map of the study area, showing the transect line surveyed along Atalaia Beach.

1992), virtually nothing was known of the shorebird populations of Sergipe until a few years ago (Almeida 2006, Barbieri, 2007, Almeida & Barbieri 2008). Ongoing research has involved the long-term monitoring of local shorebird populations, which has provided the first detailed information on local diversity, seasonal and migratory patterns, and longitudinal variation, and emphasized the importance of the region as a stopover and wintering area for a number of migratory species.

METHODS

Study area. Atalaia Beach (Fig. 1), in the Brazilian state of Sergipe, lies some 85 km southwest of the mouth of the Rio São Francisco, the largest river in the Brazilian northeast. The coast here is characterized by the low-lying remains of Tertiary coastal plains covered by Quaternary sedimentary deposits, and has two principal landscapes - extensive dune fields and complex estuary systems dominated by mangrove forests. Atalaia Beach is adjacent to the mouth of the Rio Sergipe (10º58'08"S, 37º02'08"W), which forms a complex estuary dominated by mangroves, and borders the urban area of the state capital, Aracaju. The climate is dominated by the semi-permanent South Atlantic anticyclone, which confers relatively calm and stable conditions on the region during most of the year, and is classified as humid tropical with dry summers.

Atalaia Beach is wide, flat, and sandy, with low-lying dunes to the west, bordered by an urban area 150 and 550 m from the

TABLE 1. Records of shorebird species in the surveys conducted during the present study. [1]R = resident; NV = northern visitor; LV = local visitor; [2]year 1, numbers of surveys = 41; year 2, n = 32; year 3, n = 28.

Species (common name)	Status[1]	Number of sightings (% of surveys) in:		
		Year 1[2]	Year 2[2]	Year 3[2]
Charadrius collaris (Collared Plover)	R	31 (75.6)	22 (68.6)	10 (35.7)
Charadrius semipalmatus (Semipalmated Plover)	NV	39 (95.1)	32 (100.0)	23 (82.1)
Charadrius wilsonia (Wilson's Plover)	LV	3 (7.3)	4 (12.5)	2 (7.1)
Pluvialis squatarola (Grey Plover)	NV	4 (9.6)	5 (15.6)	-
Vanellus chilensis (Southern Lapwing)	R	28 (68.3)	21 (65.6)	13 (46.4)
Arenaria interpres (Ruddy Turnstone)	NV	38 (92.7)	28 (87.5)	24 (85.7)
Calidris alba (Sanderling)	NV	39 (95.1)	32 (100.0)	27 (96.4)
Calidris canutus (Red Knot)	NV	1 (2.4)	-	-
Calidris pusilla (Semipalmated Sandpiper)	NV	24 (58.5)	24 (75.0)	17 (60.7)
Calidris fuscicollis (White-rumped Sandpiper)	NV	18 (43.9)	20 (62.5)	1 (3.6)
Numenius phaeopus (Whimbrel)	NV	1 (2.4)	1 (3.1)	-
Tringa flavipes (Lesser Yellowlegs)	NV	2 (4.8)	-	-
Tringa melanoleuca (Greater Yellowlegs)	NV	1 (2.4)	-	-

tidal zone. Data were collected along the tidal zone, using a 5-km long transect (Fig. 1) running from the mouth of the Sergipe river (Farol: 10º58'08.5"S, 37º02'08.6"W) south and west to the Tecarmo petroleum complex (11º00'09.8"S, 37º03'29.5"W).

Data collection and analysis. The transect was surveyed on a monthly basis between July 2003 and May 2006, on either foot or bicycle, following the observation procedure for open areas proposed by Bibby *et al.* (1998), in which all the birds detected during the passage of the observer through the study area were identified and counted. Between one and six surveys were conducted per month, in alternating directions. Mean survey duration was 1 h 27 min (range: 53 min–2 h 40 min). The birds were observed with binoculars (7×50 or 10–30×60) and species identified using Hayman *et al.* (1986) and Sick (1997). Scientific names follow Remsen *et al.* (2009).

The number of individuals was recorded through direct counts for flocks of fewer than 100 individuals, and by sampling for larger agglomerations, where the number of

TABLE 2. Mean shorebird count per survey in each year of monitoring at Atalaia Beach, Aracaju – Sergipe, Brazil, ordered according to absolute and relative abundance.

Species	Mean count per survey (% of the total) in:		
	Year 1	Year 2	Year 3
Calidris pusilla	101.8 (31.6)	254.7 (42.3)	120.1 (32.6)
Charadrius semipalmatus	95.7 (29.7)	158.0 (26.3)	89.1 (24.2)
Calidris alba	73.0 (22.7)	124.6 (20.7)	113.6 (30.8)
Arenaria interpres	31.2 (9.7)	42.7 (7.1)	42.5 (11.5)
Calidris fuscicollis	12.1 (3.8)	16.3 (2.7)	0.3 (< 0.1)
Vanellus chilensis	3.6 (1.1)	3.2 (0.5)	1.8 (0.5)
Charadrius collaris	3.0 (0.9)	2.2 (0.4)	1.0 (0.3)
Calidris canutus	0.4 (0.1)	-	-
Charadrius wilsonia	0.4 (< 0.1)	0.3 (< 0.1)	0.2 (< 0.1)
Pluvialis squatarola	0.2 (< 0.1)	0.4 (< 0.1)	-
Tringa flavipes	0.1 (< 0.1)	-	-
Numenius phaeopus	<0.1 (< 0.1)	-	-
Tringa melanoleuca	<0.1 (< 0.1)	-	-
Total	321.7 (100.0)	602.4 (100.0)	368.6 (100.0)

individuals counted in a subsample of the flock was extrapolated by its overall size (Bibby *et al.* 1998). For mixed flocks, this same procedure was followed to estimate the number of individuals of the most common species, and the number of representatives of the remaining species was estimated according to the proportion of the flock attributed to each species.

Longitudinal patterns in the occurrence and abundance of the different species were evaluated by dividing the study period into three years (year 1: July 2003–June 2004; year 2: July 2004–June 2005; year 3: July 2005–May, 2006). The analysis of seasonal variation was based on the monthly counts of each species, with the maximum count being used for months with two or more counts. The yearly sighting rate for each species is given as the percentage of surveys during which the species was recorded, whilst the aggregate number of individuals of each species and its relative contribution to the yearly total were also calculated, following Azevedo-Júnior & Larrazabal (1994) and Telino-Júnior *et al.* (2003).

RESULTS

A total of 101 surveys was conducted during the study period, resulting in the identification of 13 shorebird species belonging to the families Charadriidae and Scolopacidae, of which 10 are trans-equatorial migrants from the Nearctic (Table 1). Three other species (*Vanellus chilensis*, *Charadrius collaris*, and *C. wilsonius*) were considered to be residents, given the presence of breeding sites and juveniles adjacent to the study area.

A mean count of 321.7 individuals was recorded per survey during the first year of monitoring (Table 2), rising to 602.4 in year 2, and then declining again in the third year to a value close to that of year 1. Variation in monthly counts (Fig. 2) is clearly related to systematic seasonal fluctuations in the abundance of the Nearctic migratory species, which are observed in the study

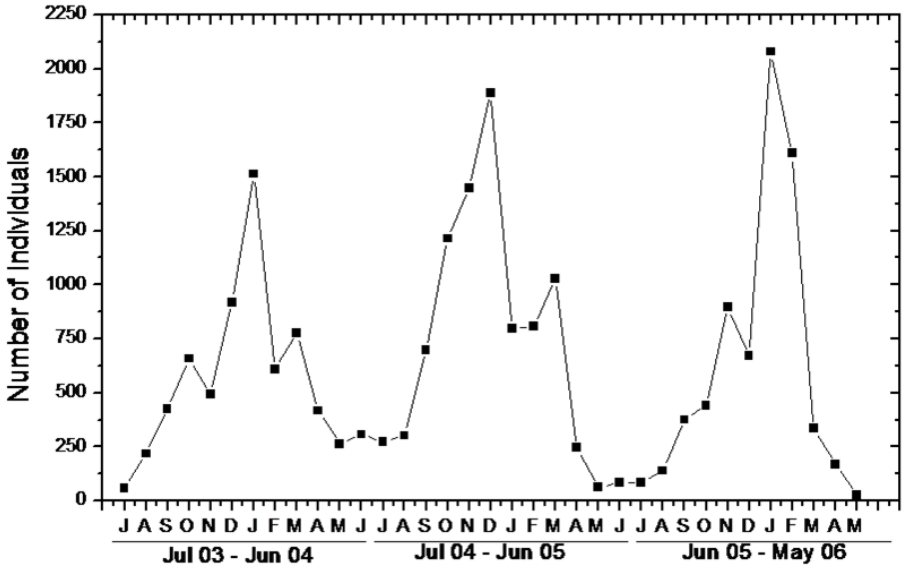

FIG. 2. Maximum monthly counts of shorebirds on Atalaia Beach during the study period.

area predominantly in the non-reproductive wintering period between September and March. The highest counts were recorded in the middle of this period in all three years, with 1512 individuals in year 1 (January), 1888 in year 2 (December), and 2080 in year 3 (January).

Although the local shorebirds (*V. chilensis*, *C. collaris*, and *C. wilsonius*) were recorded in all three study years, they were relatively rare, together accounting for only approximately 5% of the total number of shorebirds (Table 2). Collared plovers and Southern lapwings were sighted at similar rates in the first two years, but declined considerably in the third year. Both species were most abundant during the first year (Figs 3 and 4).

The predominant shorebird species, in terms of both frequency (Table 1) and abundance (Table 2) were the migratory *Charadrius semipalmatus*, *Calidris pusilla*, *Calidris alba*, *Calidris fuscicollis*, and *Arenaria interpres*. Four other species were sighted only once or twice and, with the exception of the Whimbrel, were recorded only in year 1 (Table 1). All these records were collected in the final third of the year, between August and December. In addition, only one individual was recorded per sighting for each of the species except the Red Knot, *Calidris canutus*, which was recorded in a flock of 16 individuals. While observed slightly more frequently, the Grey Plover (*Pluvialis squatarola*) was observed in smaller numbers, i.e., pairs and singletons.

While these records suggest an unusual concentration of these rarer species in year 1, it seems more likely that other, more random factors were involved, not least because the few sightings were amply distributed within the five-month period. One factor here is probably the difference in sampling effort among years, with 27% and 32% fewer surveys being conducted in years 2 and 3, respectively, in comparison with year 1. In year 3, in particular, only 10 surveys were conducted between August and December, whereas 19

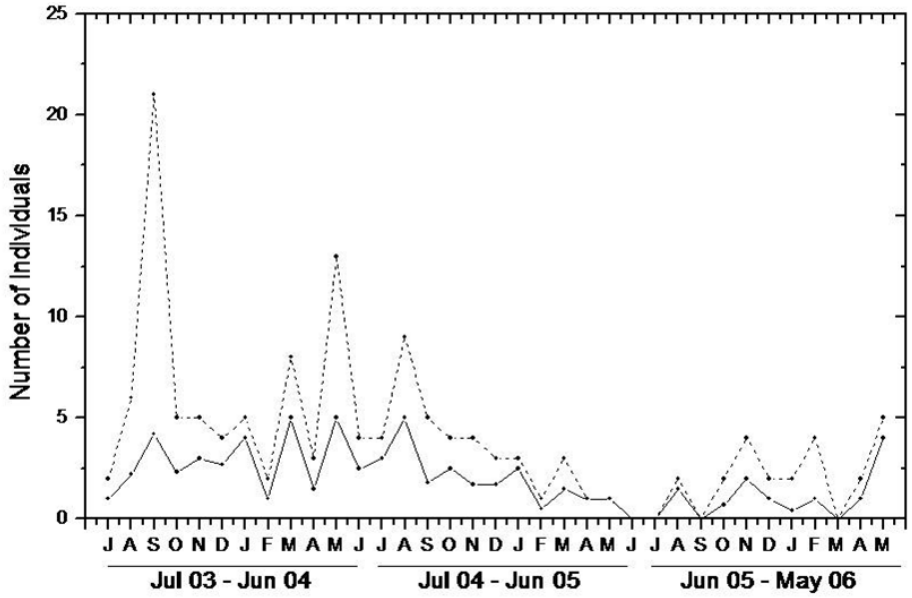

FIG. 3. Mean (solid line) and maximum (dotted line) monthly counts of *Charadrius collaris* at Atalaia Beach during the study period.

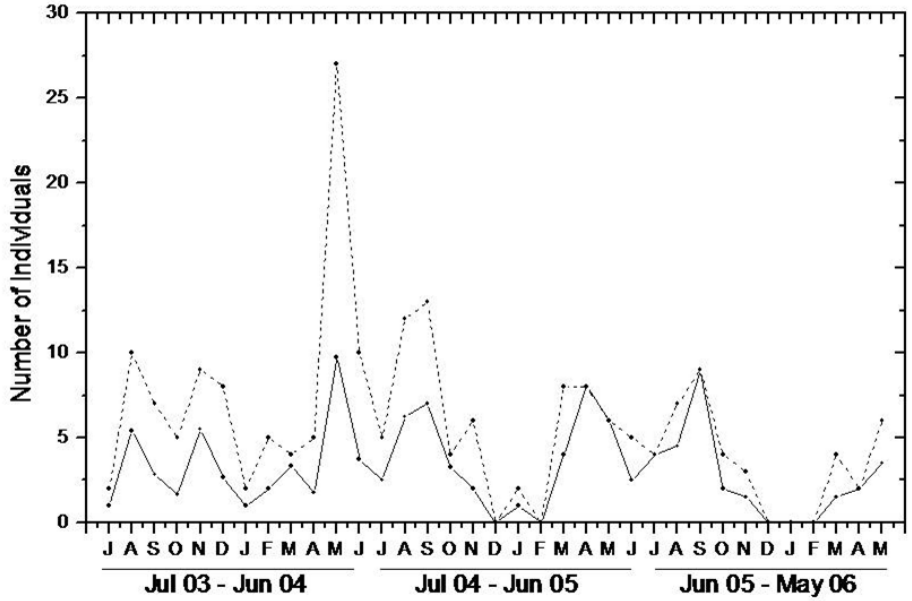

FIG. 4. Mean (solid line) and maximum (dotted line) monthly counts of *Vanellus chilensis* at Atalaia Beach during the study period.

TABLE 3. Number of surveys conducted per month during the study period.

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Year 1	2	5	6	3	2	3	2	3	4	4	4	4
Year 2	4	4	4	4	3	3	2	2	2	1	1	2
Year 3	1	2	1	3	2	2	5	4	4	2	2	-

were carried out in the same period in year 1 (Table 3).

While sighting rates for the most common species varied only slightly across years (Table 1), mean counts were highest in year 2, and remained relatively high in year 3, in comparison with the first year (Table 2). The White-rumped Sandpiper (*Calidris fuscicollis*) represents an intermediate condition, with mean abundance similar to that of the common species in years 1 and 2, but equivalent to that of the rare species in year 3. The remaining four species were all observed on at least half, and in some cases, all of the surveys conducted in a given year (Table 1). The determinants of this variation are unclear, but it may be at least partly due to random sampling effects, given that the number of individuals counted per survey tended to vary considerably during any given month (Figs 5–9).

All five common species presented a similar pattern of seasonal variation in abundance, with pronounced peaks during the boreal winter months (Figs. 5–9). Each species presented a distinctive pattern of variation, however, in variables such as maximum flock size, which ranged from less than 100 individuals in *Calidris fucicollis* (Fig. 5) to over 1000 in *C. pusilla* (Fig. 6). Similarly, only two species - *Calidris alba* (Fig. 7) and *Charadrius semipalmatus* (Fig. 8) - were recorded during all months (although *Arenaria interpres* (Fig. 9) was also present throughout the year), whereas the abundant *Calidris pusilla* was normally absent between July and September. A common pattern in many cases was a more accentuated peak in abundance during the autumn migration, when the birds are arriving from the northern hemisphere, in comparison with the spring one, but also a secondary peak after March. This suggests the passage of migrants that have passed the winter further south, and are using Atalaia as a stopover site on their way back north.

DISCUSSION

While 13 species of shorebird were recorded during the present study several others are expected to occur within the study area (Cordeiro 2008), and the Willet (*Tringa semipalmata*) has in fact been recorded there, both by CEMAVE (1992) and by the present authors, outside the study period and in local mangroves (Almeida 2006, Barbieri, 2007, Almeida & Barbieri 2008). Overall, the present study emphasizes the predominance of Nearctic migrants in the shorebird community of the study area, in terms of both the number of species and individuals. The beach may nevertheless represent an important breeding area for local shorebirds (*Vanellus chilensis*, *Charadrius collaris*, and *C. wilsonius*), given that nests of *V. chilensis* were observed in April–June, and juveniles of all three species were recorded in July-August.

The local abundance of migratory shorebirds followed a predictable pattern, with the main influx starting at the end of September, during the boreal autumn (*Charadrius semipalmatus* slightly earlier). The longitudinal variation in shorebird numbers may also reflect local displacements between other beaches or

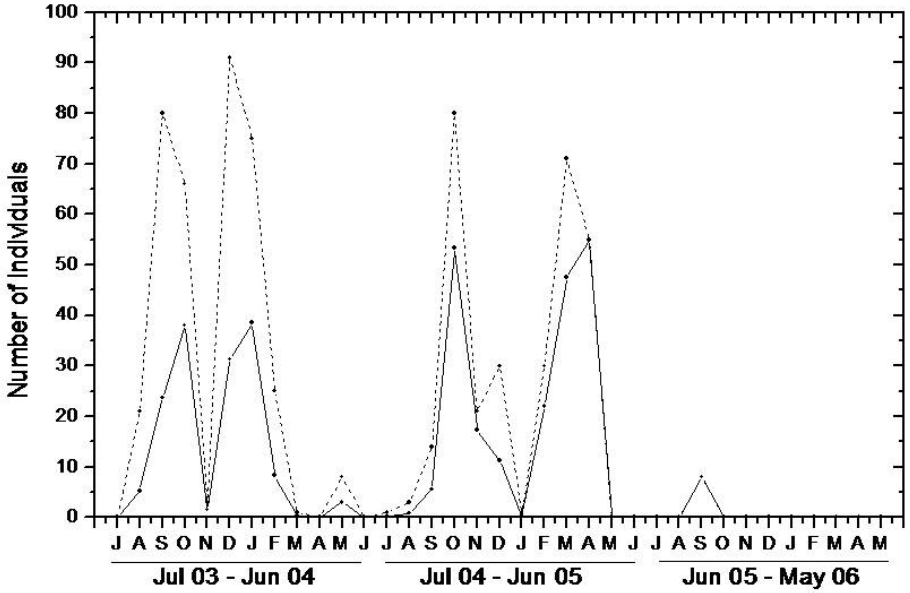

FIG. 5. Mean (solid line) and maximum (dotted line) monthly counts of *Calidris fuscicollis* at Atalaia Beach during the study period.

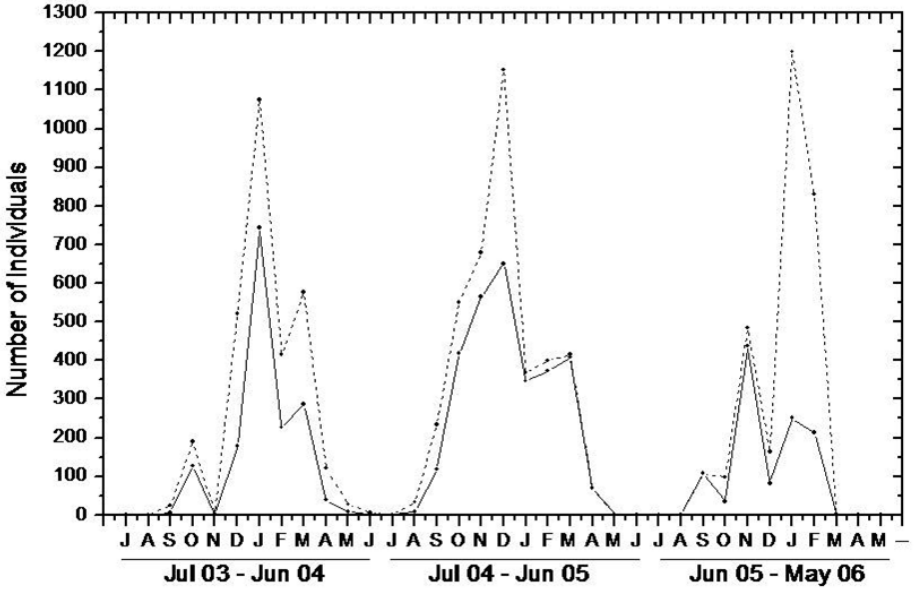

FIG. 6. Mean (solid line) and maximum (dotted line) monthly counts of *Calidris pusilla* at Atalaia Beach during the study period.

TABLE 4. Comparison of the occurrence of shorebird species on two beaches in northeastern Brazil.

Species	Percentage of surveys during which the species was observed (in 2004-2005) at:	
	Atalaia	Piaçabuçu
Charadrius collaris	70.0	100.0
Charadrius semipalmatus	97.5	80.0
Charadrius wilsonia	10.0	40.0
Pluvialis squatarola	12.5	70.0
Vanellus chilensis	70.0	30.0
Arenaria interpres	85.0	60.0
Actitis macularius	Absent	10.0
Calidris alba	97.5	100.0
Calidris pusilla	67.5	100.0
Calidris fuscicollis	55.0	Absent
Numenius phaeops	2.5	Absent
Tringa semipalmata	Absent	20.0

mangroves (Almeida 2006). Populations of some species, such as *Calidris alba*, *A. interpres*, and *Charadrius semipalmatus* almost certainly overwinter at the site, and were in fact present throughout the year, whereas the bimodal distribution of *Calidris fuscicollis* indicates clearly the use of the beach as a stopover. The individuals observed between May and August were juveniles or sub-adults that were unable to attain the metabolic threshold necessary in order to continue their migration.

While peaks in abundance tended to be smaller during the first months of the year (January–March), a secondary peak was observed from March onwards, which indicates the passage of migrants returning from wintering grounds further south. In addition, as migrants from different breeding populations in the Arctic Circle tend to follow distinct routes during the winter and spring migrations (Antas 1983, Boland 1991, Piersma 2007), it seems likely that in at least some species, individuals observed on different occasions represented distinct breeding populations. Some marked birds, in particular *C. alba* and *A. interpres*, were observed with colored bands and flags (green, light green, blue and orange) representing the USA, Suriname, Brazil and Argentina, respectively.

While the same general pattern of variation was recorded in all three study years, there were also contrasting tendencies among years. In particular, while the first year produced the largest number of species, it was also characterized by relatively reduced abundance for most species. Much of this variation likely reflects the vagaries of the sampling procedure – among other factors already mentioned, large flocks of species such as *Calidris pusilla* and *Charadrius semipalmatus*, were sometimes observed resting in the dunes located in the western half of the beach on days in which the species had not been recorded during surveys.

An additional distribution pattern noted during the study refers to the presence of human beachgoers, who are especially abundant in the southern half of the transect during the Austral summer (October to March), coinciding with the peak of shorebird abundance. Surprisingly, shorebirds were generally at least as abundant in the transect sectors with the highest concentrations of beachgoers (Almeida 2006), and did not appear to be disturbed overtly by the proximity of humans, in stark contrast with the pattern observed at sites in North America (Burger & Gochfeld 1991, Thomas *et al.* 2002, Burger *et al.* 2004), where the birds tend to avoid people. Preliminary observations indicate that the birds on Atalaia Beach may be exploiting scraps of food discarded by visitors.

Although detailed comparisons with other sites are hampered primarily by methodological differences, it is possible to review some of the disparities and similarities with the study of Cabral *et al.* (2007). This survey took place in the APA Piaçabuçu, a protected area

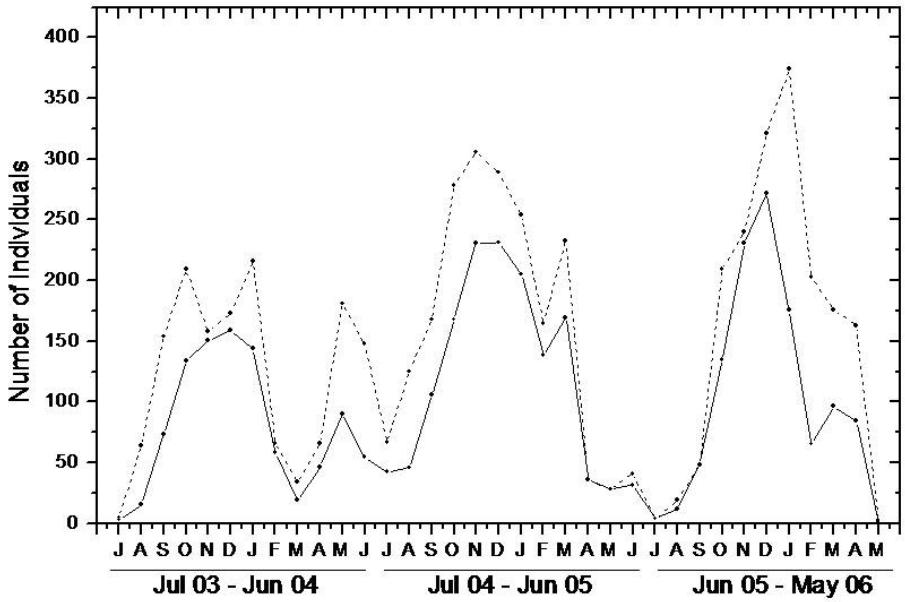

FIG. 7. Mean (solid line) and maximum (dotted line) monthly counts of *Calidris alba* at Atalaia Beach during the study period.

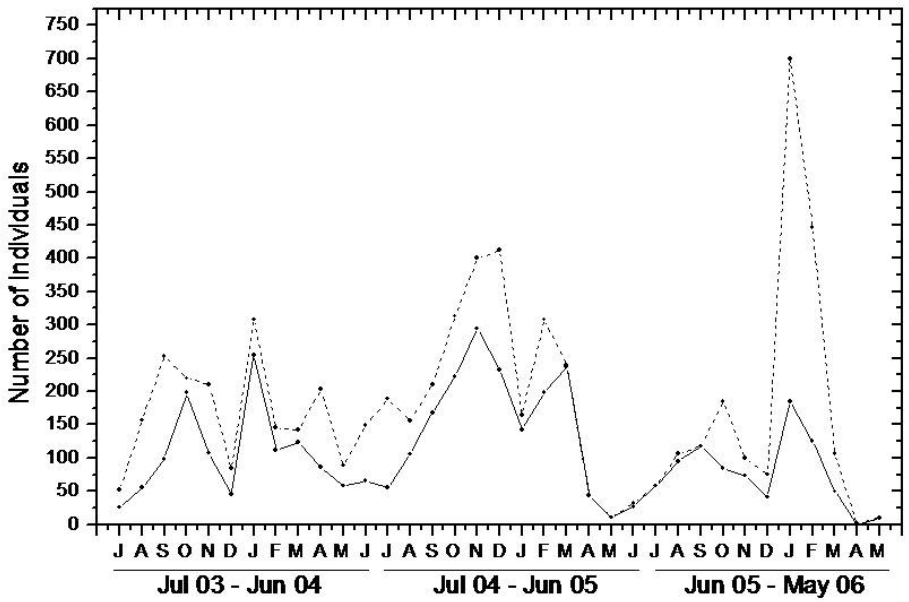

FIG. 8. Mean (solid line) and maximum (dotted line) monthly counts of *Charadrius semipalmatus* at Atalaia Beach during the study period.

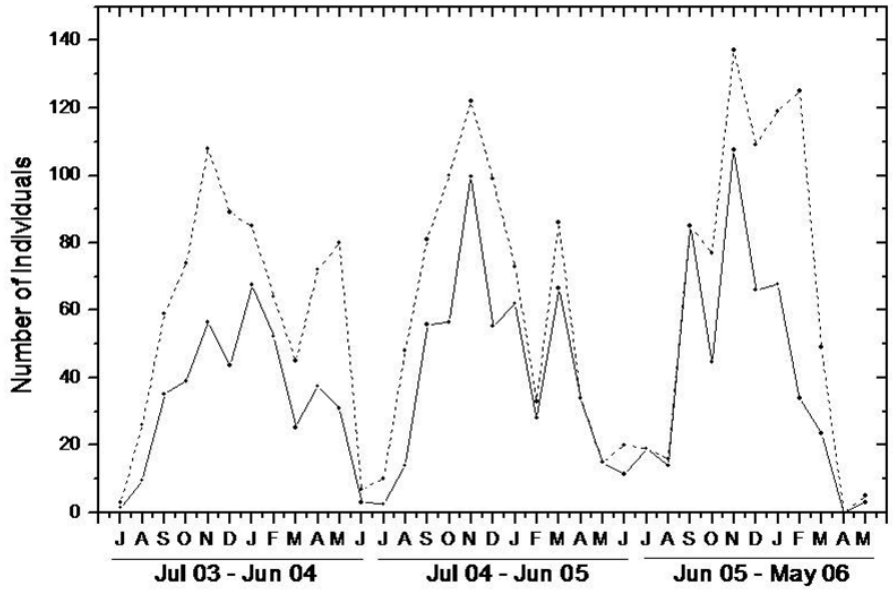

FIG. 9. Mean (solid line) and maximum (dotted line) monthly counts of *Arenaria interpres* at Atalaia Beach during the study period.

located on the left bank of the São Francisco estuary in Alagoas state (80 km northeast of Atalaia Beach), between June 2004 and September 2005. During the same period of the present study, all but two of the species recorded at Piaçabuçu were recorded on Atalaia beach (Table 4), whereas *Calidris fuscicollis* and *Numenius phaeopus* were not observed at the former site. As mentioned above, *Tringa semipalmata* has also been observed at Atalaia. The other three other species observed at this site were recorded in surveys in late 2003, and for this reason, were excluded from this comparison. Terns (*Sterna hirundo*, *Thalasseus sandvicensis*) were notable absentees from both sites, in contrast with Coroa do Avião Island, further north in Pernambuco (Telino-Júnior *et al.* 2003), where they are relatively abundant.

While a few of the species – in particular *Calidris alba* – were equally common at both sites (Table 4), there were also marked contrasts, which may reflect specific ecological factors. While three of the species that were absent at one of the sites were relatively rare at the other, for example, *Calidris fuscicollis* was among the most common species at Atalaia, at least during this study period. The values recorded for *Charadrius wilsonia*, *Pluvialis squatarola*, and *Vanellus chilensis* at the two sites also contrasted widely, although the overall balance of different species was relatively similar. This suggests that, despite the urban setting of the present study site, its shorebird populations have yet to suffer significant anthropogenic impacts, although long-term monitoring and preemptive contacts with the relevant local environment agencies may become increasingly important in order to guarantee the site's role as a stopover and wintering site for Nearctic shorebirds.

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