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Northward migration of Red Knots *Calidris canutus rufa* and environment connectivity of southern Brazil to Canada

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Short Communication

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Summary

During their northward migration, Red Knots *Calidris canutus rufa* stop at the Lagoa do Peixe National Park in the extreme south of Brazil to build up fat reserves for their journey to their Canadian breeding grounds. We tracked five Red Knots with PinPoint Argos-75 GPS transmitters to investigate differences in migration strategies from this stopover. Tracked birds used two different routes: the Central Brazil route and the Brazilian Atlantic Coast route. One bird flew 8,300 km straight from Lagoa do Peixe to the Delaware Bay (USA). Another bird stopped in Maranhão (north-east Brazil) and a third one used a yet unknown environment for the species, the mouth of the Amazon River at Baía Santa Rosa, Brazil. These two birds made short flights, covering stretches of 1,600 km to 3,600 km between stop-overs, where they stayed from 4 to 18 days. Our study highlights the occurrence of intrapopulation variation in migratory strategies and reveals the connectivity of environments that are essential for the viability of *rufa* Red Knot populations.

Introduction

The Western Atlantic subpopulation of Red Knot (*Calidris canutus rufa*) breeds in the Canadian Arctic Archipelago and migrates to the southern hemisphere to overwinter (Baker et al. 2005; Niles et al. 2008; Lathrop et al. 2018). In Canada (Loi sur les especes menacees ou vulnerables, RLRQ cE-12.01) and USA the *rufa* Red Knot is listed as "Endangered" and "Threatened with extinction", respectively (US Endangered Species Act in 2014). In Brazil, where the species overwinters, it is listed as "Critically Endangered" (Red Book of Endangered Brazilian Fauna of 2018), respectively, reflecting the ongoing declines of the species in these countries. The subspecies global population is an estimated 42,000 specimens, and 15,000–20,000 individuals are considered long-distance migrants, while the rest performs short migrations (Niles et al. 2010; Andres et al. 2012). Short-distance migrants migrate to the Gulf of Mexico and the northern coast of South America (Maranhão, Brazil), while the long-distance group flies all the way to Tierra del Fuego, in the extreme south of Argentina and Chile (Baker et al. 2005).

Due to the energy expenditure of their long flights, Red Knots depend on the existence of stop-over sites with an abundance of food and resting areas along their migratory routes (Harrington et al. 2010; Burger et al. 2012). During long-distance migrations, Red Knots stop along the mid coast of Rio Grande do Sul and at the Lagoa do Peixe National Park, Brazil to forage, rest, and perform post-reproductive feather moult (Harrington et al. 1986; Scherer and Petry 2012; Niles et al. 2010). The passage of Red Knots occurs during the northbound migration in late March and early April and during the southbound migration in September and October (Harrington et al. 1988; Scherer and Petry 2012; Niles et al. 2008). Some individuals may remain in Lagoa do Peixe for extended periods as seasonal residents. These are primarily young individuals or adult birds that do not migrate for reasons not yet understood (Lara-Resende and Leeuwenberg 1987; Martínez-Curci et al. 2020). As Lagoa do Peixe and the coast of Rio Grande do Sul are one of the last stops before the extended flights to North America, these two areas have been considered critical to the viability of the *rufa* Red Knot (Oliveira et al. 2016).

Compared with the well-documented migration route of *rufa* Red Knots along the Atlantic coast of the USA (Burger et al. 2012; Niles et al. 2012; Newstead et al. 2013), the migration route in South America is still poorly understood and mainly based on flag resightings. Niles et al. (2010) used geolocation tracking devices to access the southbound movements of Red Knots from Delaware Bay and detected the general use of the Central Brazil and Brazilian Atlantic coast routes. However, the length of flights and the use of stop-overs on the northward migration are

even more poorly understood. The present study aimed to fill this knowledge gap by investigating *rufa* Red Knot migration routes starting in Lagoa do Peixe, southern Brazil, using PinPoint Argos-75 GPS Transmitters (Lotek Wireless, Ontario, Canada) (Argos 2018). Migratory patterns, flight paths, stop-over duration, and distances travelled were analysed.

Methods

Red Knots were tagged at the Lagoa do Peixe National Park (31° 00'46"S, 50°46'31"W; 31°29'00"S, 51°09'51"W), which includes a complex of coastal lagoons connected to the sea by an inlet, tidal marshes, dunes, and barrier beaches facing the Atlantic Ocean. The park covers 34,000 ha of the coastal plain of the State of Rio Grande do Sul in southern Brazil (Figure 1), and it is located between the municipal areas of Tavares and Mostardas (Oliveira et al. 2016). Since 1986, it has been classified as a Full Protection Conservation Unit (Presidência da Republica, Brasil 1986) and due to its importance for migratory shorebirds, it is internationally recognised as a Biosphere Reserve Site by the Ramsar Convention, to which Brazil is a signatory. The Migratory Wader's Action Plan "PAN Waders" also recognises the importance of Lagoa do Peixe for hemispheric birds and highlights it as a stop-over for migratory shorebirds (ICMBio 2016).

Red Knots were captured at the beach section of the park on 24 April 2019 using a cannon net (Figure 1). Five of the 51 captured individuals were selected for receiving PinPoint GPS Argos 75 tracking devices. Only birds with reproductive plumage and a body mass of >200 g were selected, which is the ideal body mass for an individual to be able to begin or continue its migration (Aldabe et al. 2015). Tags were attached to the back of the birds, 1 cm above the uropygial gland (Scarpignato et al. 2016; Lathrop et al. 2018). An area of c.2 × 1.5 cm was cleared of feathers and devices were glued with high adhesion, long-lasting surgical glue directly on to the skin (Scarpignato et al. 2016) (Figure 2). A drop of blood was collected from the ulnar vein of the birds for molecular sexing. Tags weighed c.3.7 g, which constitutes less than the safety threshold of 3% of the bird's body mass (Cooper et al. 2017). Tags were programmed to record fixes between 25 April 2019 and 4 October 2019, but with particular schedules according to the period (northward migration or breeding). Each bird that had not yet been marked with a flag received a coded blue flag (Brazilian country colour). Birds are hereafter identified by their flag codes (E8A, E7X, E7N, E9Y, and V53).

Total distances (distance from the place where the birds were marked to the last location recorded by the tag, in km), relative distances (distance between one position and the next position), travelling time (days), migration speed (km/day), average flight speed (km/hour), and time (days) spent on the stop-over were calculated for each individual.

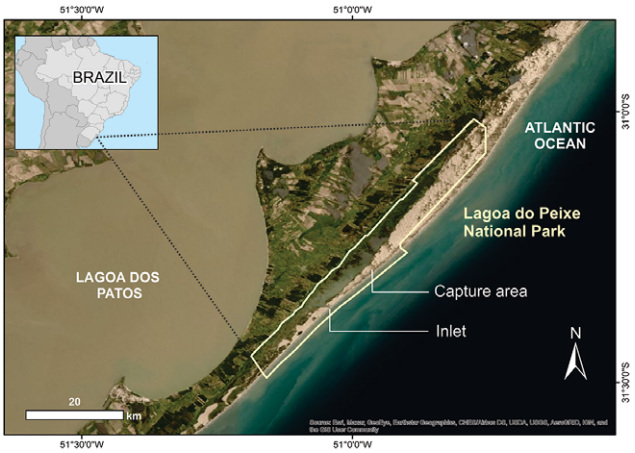

Figure 1. Study Area: Lagoa do Peixe National Park, in Southern Brazil is shown in the marked area, and the capture location is shown with an arrow.

Results

Birds were tracked from 10 to 90 days. Four individuals migrated, while one (E8A) remained at the Lagoa do Peixe National Park during the tracking period. All birds were females (see Supplementary material, Figure S3) and showed variation in migratory parameters and routes (Figure 3 and Table S1). Two females (E7X and E7N) migrated via the Central Brazil route, and the other two (E9Y and V53) migrated along the Brazilian Atlantic coast route (Figure 3). Only one (E7X) was tracked all the way to the Arctic breeding grounds.

Bird E7X was tracked between 30 April and 10 June, when the tag sent its last fix. The bird made a non-stop, 8,289 km long flight from Lagoa do Peixe to Delaware Bay (north-east coast of the USA). It left Lagoa do Peixe on 30 April and took 14 days to reach Delaware Bay, flying over the Pantanal region, the Amazon Forest, and the Caribbean Sea (Figure 3). Stopover time at Delaware Bay was at least six days before departing to James Bay (Canada) and flying another 1,658 km. From James Bay, the bird flew an extra 1,206 km in nine days, reaching its breeding grounds at Southampton Island (Nunavut, Canada) around 10 June. Distances between fixes ranged from 1,206 to 4,916 km. Migration speed ranged from 105 km/day to 1,229 km/day, and the estimated flight speed reached a maximum of 51 km/hour. The total distance covered by this female was 11,170 km during a period of 45 days.

Bird E7N was tracked from 26 April to 20 May. Initially, it followed a similar route to E7X and also flew over the Pantanal (Figure 3). However, afterwards she made a turn to the north-east of Brazil and, after travelling 3,280 km in six days, she made two stops, one near the Xingu River and the other at Caxiuna Bay, State of Pará (Figure S1b). E7N remained in the region for four days before travelling another 614 km to the coast of Maranhão on 8 May, where she remained for at least 14 days until the tag stopped sending data. Relative distances ranged from 614 km to 1,646 km and the migration speed ranged from 307 km/day to 817 km/day. The estimated flight speed was 34 km/hour and the total distance covered by this female during a period of 12 days was 4,050 km.

Bird V53 was tracked between 26 April and 6 May. It migrated along the Brazilian coastal route, leaving Lagoa do Peixe on 26 April and, after six days, had a fix recorded at the coast of Bahia, north-east Brazil (Figure 3). From there it flew 1,619 km to the east in two days and arrived at Santa Rosa Bay, in the mouth of the Amazon River, Pará, on 6 May (Figure S1a). The bird stayed at this location for at least four days before the last fix was recorded. Relative distance ranged from 214 km to 2,028 km and the migration speed between 54 km/day and 1,014 km/day. Maximum estimated flight speed was 42 km/hour and total distance covered was 3,873 km.

The device from bird E9Y recorded only two fixes, one in south-western Brazil and another one off the Atlantic coast of Suriname. The bird covered a total distance of 4,524 km, during a period of 16 days.

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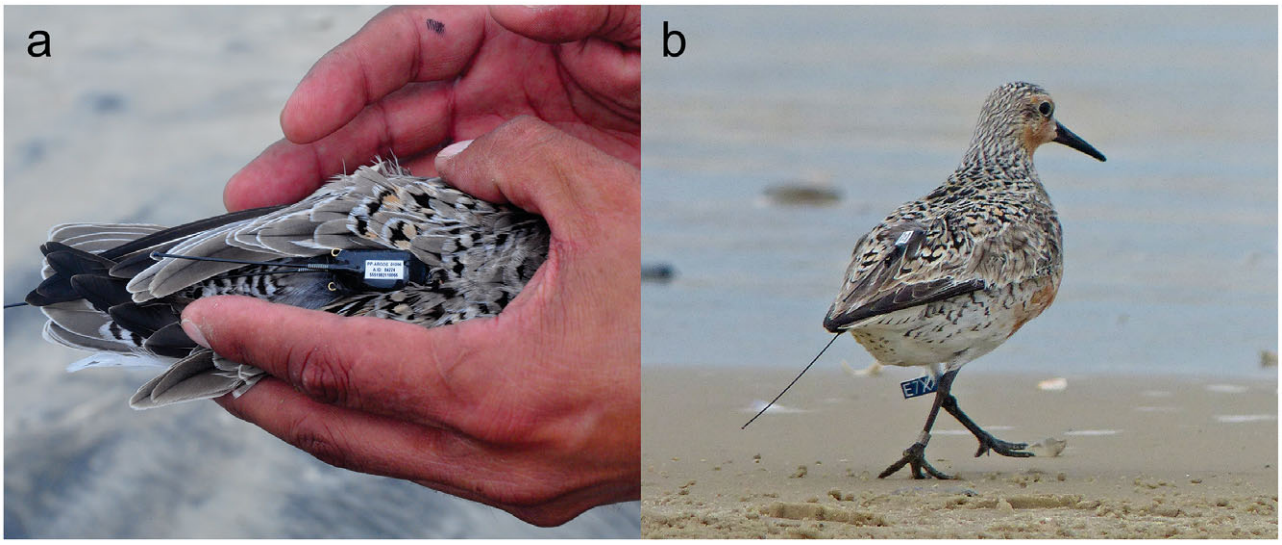

Figure 2. a) PinPoint GPS device attached to the back near the uropygium; b) Red Knot carrying the transmitter.

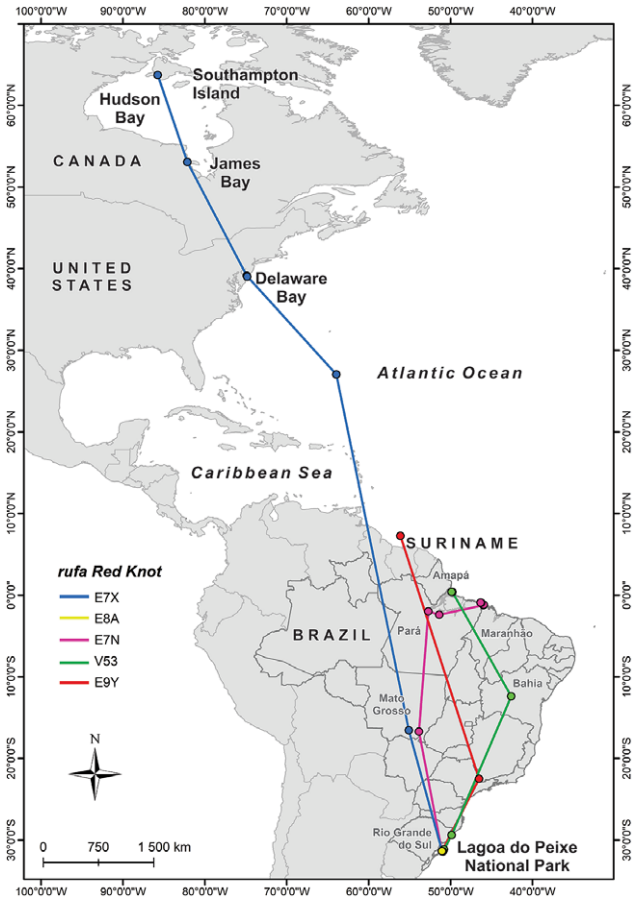

Figure 3. Migratory route taken by Red Knot from the Lagoa do Peixe National Park - Brazil. The route of each bird is marked with different colors and the points are the recorded locations.

Red Knots connected Lagoa do Peixe to Delaware Bay and the coast of Maranhão (Brazil), Caxiuana Bay, the interior of Pará and Santa Rosa Bay – mouth of the Amazon River – coast of Pará with the boundary of the State of Amapá (Brazil) (Figure 3 and Figure S1). Differences in covered distances and travel times for all females are shown in Figure S2.

Discussion

Our results reveal the occurrence of intrapopulation variation in migratory strategies of Red Knots. Despite slight variations, two major routes from Lagoa do Peixe were observed: the Central Brazil route (Pantanal, Amazon) and the Brazilian Atlantic coast route (Baker et al. 2005; Niles et al. 2010; Oliveira et al. 2016). Differences in migratory strategies within the same population of birds have been reported elsewhere (Alves et al. 2016). An individual's body mass and unfavourable climatic conditions can influence the direction that birds take along their migratory journey (Niles et al. 2012; Covino et al. 2015). In addition, quantity and quality of prey at foraging sites and risk of predation at stopovers can play an important role in migration strategies (Burger et al. 2012).

Bird E7X confirmed a direct connection between Lagoa do Peixe and Delaware Bay on a direct flight of approximately 8,300 km. Although the first fix in Delaware was registered only on 10 May, we estimated that the bird arrived earlier. Based on the average flight speed (51 km/hour) calculated between its first (30 April, Mato Grosso) and second fix (2 May, Sargasso Sea), we estimate that E7X left Lagoa do Peixe on 29 April and arrived in Delaware Bay on 6 May. The estimated average flight speed is within the average of 50–60 km/hour already observed for long-distance migratory flights in birds (Newstead et al. 2013; Bishop et al. 2016). Our estimate is also consistent with previous studies, which found that an 8,000 km route from southern Brazil to the coast of North Carolina was covered in 6 days (Niles et al. 2010). The arrival date in Delaware Bay (6 May) matches data from previous studies, which registered Red Knots arriving in early May and departing after 26 May (Niles et al. 2012; Burger et al. 2018). Assuming this estimated arrival date, E7X appears to have stayed in Delaware Bay for a period of c.23 days, since the next record was made on 1 June in James Bay (Ontario, Canada). This estimate is compatible with previous studies (1–19 days) (González et al. 2006; Newstead et al. 2013). James Bay is a well-known stop-over for Red Knots, from where birds can fly directly to Hudson Bay (Niles et al. 2012; Andres et al. 2012). Red Knots typically take 2–3 days to complete the route from Delaware Bay to James Bay (Newstead et al. 2013; Andres et al. 2012), which falls within our estimate. The bird's last stop was in the south of Southampton Island (Nunavut, Canada),

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which is a known breeding site for the species (Lyons et al. 2018; Lathrop et al. 2018).

Bird E7N connected Lagoa do Peixe to the Maranhão recesses, the overwintering area of short distance *rufa* migrants and a known important stop-over for long-distance migrants (Atkinson et al. 2005; Baker et al. 2005). E7N used unreported areas for this species; one wetland in the Extractive Reserve "Forever Green" between the Amazon and Xingu River and one in the Caxiuanã National Forest, in the southern portion of Caxiuanã Bay, both in the State of Pará. It appears that E7N was foraging in this inland area, since the two fixes recorded at the site indicated that it spent at least four days circulating in the area before heading to the Maranhão coast, where she stayed for another 14 days. However, such a long stay in Maranhão is unusual and represents a delayed migration and higher exposure to risks occurring at the area, which could compromise her reproductive success (Alves et al. 2016; Bishop et al. 2016).

Bird V53 apparently adopted a different migration strategy. We assume it continued in short flights along the Atlantic coast (Table S1), since it only covered 214 km within two days, a short distance compared with other birds. Santa Rosa Bay, at the mouth of the Amazon River, was used by this bird for at least four days. Use of this remote area as a stop-over has never been documented for the species. Selection of a stop-over site that is further north in Brazil highlights the occurrence of a wider stopover area for the population, since it is located between areas where the species usually stops: the State of Maranhão and the coast of French Guianas and Suriname (Baker et al. 2005; Navedo and Gutiérrez 2019).

The single two locations from bird E9Y with such a spatial gap between them make it hard to know if it made any stops between the location where it was tagged and the last position off the Suriname coast. However, considering the migration speed (345 km/day), it was probably not a direct flight, and it is possible that the bird used the Maranhão recesses before crossing Central America.

The distances of displacement of the tracked birds (1,600–3,400 km) are similar to other studies with the same species: 2,000 km (Bishop et al. 2016), 2,300 km (Carmona et al. 2013), and 3,300 km (Niles et al. 2010). Medium-sized migratory birds such as Red Knots can fly small 1,000–3,000 km (Brown et al. 2017) or long distances, averaging from 5,000 to 8,000 km (Brown et al. 2017; Hill and Renfrew 2019). Our study corroborates Niles et al. (2010) study, which states that *rufa* Red Knots employ two migration strategies: direct long-distance flights from the south of Brazil to the USA and short-distance flights with stops either inland or along the Atlantic coast before jumping off northward. Our data confirm the relevance of several major stop-overs to the migration success, such as Lagoa do Peixe and the Maranhão coast, but also of minor stop-overs to support birds along their migratory routes. The use of Santa Rosa Bay as a minor stop-over is intriguing and more information about which habitats birds are using is needed. Migratory bird species play a key role in the connectivity of these environments (Gonzáles et al. 2006; Lyons et al. 2018; Finch et al. 2017), and we show that Red Knots connect national and international areas along its route.

Our study shows that the Lagoa do Peixe National Park also serves as a temporary residence for birds that for some unknown reason interrupt migration. There are several hypotheses to explain this pause, such as juvenile individuals, poor physical condition, and stop-over risks such as chemical contamination by pollutants and parasite load (Martínez-Curci et al. 2020). However, E8A already had a breeding plumage and an ideal weight to migrate, so, it is possible that the bird suffered some contamination and weakened quickly after being tagged and so did not migrate. Either way, these data highlight the importance of Lagoa do Peixe for Red Knots even outside the migration season.

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References

Aldabe J., Rocca P., Gonzalez P., Caballero-Sadi D. and Baker A. (2015). Migration of endangered Red Knots *Calidris canutus rufa* in Uruguay: Important sites, phenology, migratory connectivity and a mass mortality event. *Wader Study* **122**, 221–235.

Alves J.A., Dias M.P., Méndez V., Katrínardóttir B. and Gunnarsson T.G. (2016). Very rapid long-distance sea crossing by a migratory bird. *Scientific Reports* **6**, 1–6.

Andres B.A., Smith P.A., Morrison R.G., Gratto-Trevor C.L., Brown S.C. and Friis C.A. (2012). Population estimates of North American shorebirds. *Wader Study Group Bulletin* **119**, 178–194.

Atkinson P.W. Baker A.J., Bevan R.M., Clark N.A., Cole K.B., Gonzalez P.M. et al. (2005). Unravelling the migration and moult strategies of a long-distance migrant using stable isotopes: Red Knot *Calidris canutus* movements in the Americas. *Ibis* **147**, 738–749.

Argos C.L.S. (2018). Argos User's Manual. Available at https://www.argos-system.org (accessed 26 February 2021).

Baker A.J., González P.M., Serrano I.L., Júnior W.R., Efe M.A., Rice S. et al. (2005). Assessment of the wintering area of Red Knots in Maranhão, northern Brazil, in February 2005. *Wader Study Group Bulletin* **107**, 10–18.

Bishop M.A., Buchanan J.B., McCaffery B J. and Johnson J.A. (2016). Spring stopover sites used by the red knot *Calidris canutus roselaari* in Alaska, USA: Connectivity between the Copper River Delta and the Yukon–Kuskokwim River Delta. *Wader Study* **123**, 143–152.

Brown S., Gratto-Trevor C., Porter R., Weiser E.L., Mizrahi D., Bentzen R. et al. (2017). Migratory connectivity of Semipalmated Sandpipers and implications for conservation. *The Condor* **119**, 207–224.

Burger J., Niles L., Jeitner C. and Gochfeld M. (2018). Habitat risk: Use of intertidal flats by foraging red knots (*Calidris canutus rufa*), ruddy turnstones (*Arenaria interpres*), semipalmated sandpipers (*Calidris pusilla*), and sanderling (*Calidris alba*) on Delaware Bay beaches. *Environmental Research* **165**, 237–246.

Burger J., Niles L.J., Porter R.R., Dey A.D., Koch S. and Gordon C. (2012). Migration and over-wintering of red knots (*Calidris canutus rufa*) along the Atlantic coast of the United States. *The Condor* **114**, 302–313.

Carmona R., Arce N., Ayala-Perez V., Hernández-Alvarez A., Buchanan J.B., Salzer L.J. et al. (2013). Red Knot *Calidris canutus roselaari* migration connectivity, abundance and non-breeding distribution along the Pacific coast of the Americas. *Wader Study Group Bulletin* **120**, 168–180.

Cooper N.W., Hallworth M.T. and Marra P.P. (2017). Light-level geolocation reveals wintering distribution, migration routes, and primary stopover locations of an endangered long-distance migratory songbird. *Journal of Avian Biology* **48**, 209–219.

Covino K.M., Holberton R.L. and Morris S.R. (2015). Factors influencing migratory decisions made by songbirds on spring stopover. *Journal of Avian Biology* **46**, 73–80.

Finch T., Butler S.J., Franco A.M. and Cresswell W. (2017). Low migratory connectivity is common in long-distance migrant birds. *Journal of Animal Ecology* **86**, 662–673.

González P.M., Baker A.J. and Echave M.E. (2006). Fundación Inalafquen. Annual survival of Red Knots (Calidris canutus rufa) using the San Antonio Oeste stopover site is reduced by domino effects involving late arrival and food depletion in Delaware Bay. *El Hornero* **21**, 109–117.

Harrington B.A., Antas P.T.Z. and Silva, F (1986). Northward shorebird migration on the Atlantic coast of southern Brazil. *Vida Silvestre Neotropical* **1**, 45–54.

Harrington B.A., Hagan J.M. and Leddy L.E. (1988). Site fidelity and survival differences between two groups of New World Red Knots (*Calidris canutus*). *The Auk* **105**, 439–445.

Harrington B.A., Loch S., Niles L. and Kalasz K. (2010). Red Knots with different wintering destinations: differential use of an autumn stopover area. *Waterbirds* **33**, 357–363.

Hill J.M. and Renfrew R.B. (2019). Migratory patterns and connectivity of two North American grassland bird species. *Ecology and Evolution* **9**, 680–692.

ICMBio (2016). *Relatório Anual de Rotas e Areas de Concentração de Aves Migratórias no Brasil*. Cabedelo, PB: CEMAVE/Brasília: Instituto Chico Mendes de Conservação da Biodiversidade.

Lara-Resende S. and Leeuwenberg F. (1987). Ecological Studies of Lagoa do Peixe. Final Report to WWF-US, Washington.

Lathrop R.G., Niles L., Smith P., Peck M., Dey A., Sacatelli R. et al. (2018). Mapping and modeling the breeding habitat of the Western Atlantic Red Knot (*Calidris canutus rufa*) at local and regional scales. *The Condor* **120**, 650–665.

Lyons J.E., Winn B., Keyes T. and Kalasz K.S. (2018). Post-breeding migration and connectivity of red knots in the Western Atlantic. *The Journal of Wildlife Management* **82**, 383–396.

Martínez-Curci N.S., Isacch J.P., D'amico V.L., Rojas P. and Castresana G.J. (2020). To migrate or not: drivers of over-summering in a long-distance migratory shorebird. *Journal of Avian Biology* **51**, e02401. doi: 10.1111/jav.02401.

Navedo J.G. and Gutiérrez J.S. (2019). Migratory connectivity and local site fidelity in red knots on the southern Pacific coast of South America. *Aquatic Conservation: Marine and Freshwater Ecosystems* **29**, 670–675.

Newstead D.J., Niles L.J., Porter R.R., Dey A.D., Burger J. and Fitzsimmons O.N. (2013). Geolocation reveals mid-continent migratory routes and Texas wintering areas of Red Knots *Calidris canutus rufa*. *Wader Study Group Bulletin* **120**, 53–59.

Niles L.J., Burger J., Porter R.R., Dey A.D., Koch S., Harrington B. et al. (2012). Migration pathways, migration speeds and non-breeding areas used by northern hemisphere wintering Red Knots *Calidris canutus* of the subspecies rufa. *Wader Study Group Bulletin* **119**, 195–203.

Niles L.J., Burger J., Porter R.R., Dey A.D., Minton C.D., González P.M. et al. (2010). First results using light level geolocators to track Red Knots in the Western Hemisphere show rapid and long intercontinental flights and new details of migration pathways. *Wader Study Group Bulletin* **117**, 123–130.

Niles L.J., Sitters H.P., Dey A.D., Atkinson P.W., Baker A.J., Bennett K.A. et al. (2008). Status of the red knot, *Calidris canutus rufa*, in the Western Hemisphere. *Studies in Avian Biology* **36**, 1–185.

Oliveira A.D., Barbosa A.E.A., Sousa A.E.B.A., Lugarini C., Lima D.M., Nascimento J.L.X. et al. (2016). *Relatório Anual de Rotas e Areas de Concentração de Aves Migratórias no Brasil*. Cabedelo, PB: CEMAVE/Brasília: Instituto Chico Mendes de Conservação da Biodiversidade.

Presidência da Republica, Brasil (1986). Decreto nº 93.546, de 6 de novembro de 1986. Planalto, Brasília. Available at http://www.planalto.gov.br/ccivil_03/decreto/1980-1989/1985-1987/D93546.htm (accessed 30 November 2019).

Scarpignato A.L., Harrison A.L., Newstead D.J., Niles L.J., Porter R.R., van den Tillaart M. et al. (2016). Field-testing a new miniaturized GPS-Argos satellite transmitter (3.5 g) on migratory shorebirds. *Wader Study* **123**, 240–246.

Scherer A.L. and Petry M.V. (2012). Seasonal variation in shorebird abundance in the State of Rio Grande Do Sul, Southern Brazil. *The Wilson Journal of Ornithology* **124**, 40–50.

https://doi.org/10.1017/S0959270923000308 Published online by Cambridge University Press