

# Assessment of the wintering area of Red Knots in Maranhão, northern Brazil in February 2005

ALLAN J. BAKER<sup>1</sup>, PATRICIA M. GONZÁLEZ<sup>2</sup>, INES L. SERRANO<sup>3</sup>, WALLACE R.T. JÚNIOR<sup>3</sup>, MARCIO A. EFE<sup>4</sup>, SUSAN RICE<sup>5</sup>, VERÓNICA L. D'AMICO<sup>6</sup>, MARCIA C. ROCHA<sup>7</sup>, & MARIA EUGENIA ECHAVE<sup>2</sup>

<sup>1</sup>Department of Natural History, Royal Ontario Museum, Toronto, ON Canada M5S 2C6

<sup>2</sup>Fundación Inalafquen, Roca 135, 8520 San Antonio Oeste, Río Negro, Argentina

<sup>3</sup>CEMAVE, Centro Nacional de Pesquisa para Conservação das Aves Silvestres, Br 230, Km 10, Estrada de Cabedelo, Mata da AMEM/IBAMA, S/N, Cabedelo, Paraíba, 58300-000, Brazil

<sup>4</sup>Rua Alzira Rosa Aguiar 274, Rio Vermelho, 8860-380 Florianópolis, Santa Catarina, Brazil

<sup>5</sup>Eastern Shore of Virginia NWR, 5003 Hallett Circle, Cape Charles, VA, USA

<sup>6</sup>Centro Nacional Patagónico, Bvard. Brown 3500, 9120 Puerto Madryn, Chubut, Argentina

<sup>7</sup>Belém, Pará, Brazil

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To assess population size and the conservation status of the Red Knot *Calidris canutus rufa* population in Maranhão, N Brazil, an aerial census and field studies were conducted in February 2005. The aerial count showed a population of 7,575 Knots, which is down about 600 from a previous census in the 1980s. However, the count for all shorebird species combined was only 24,000 compared to 198,600 in the 1980s, paralleling a world-wide trend of population decline in shorebirds. Resightings of colour-banded knots confirmed that this is a separate population from the larger wintering population in Tierra del Fuego. All species of shorebirds captured in Maranhão were found to be infested with feather lice and mites. Body masses of knots in Maranhão were significantly lower than in Tierra del Fuego, and about half the birds were below the hypothesized fat-free mass of the species. Blood and feather samples were taken from 38 Knots for subsequent assessment of virus loads, and for detecting sites where primary feather moult had occurred. This will enable us to establish whether significant mortality is associated with pathogen loads and the energetic demands of delayed moulting. The small size of the Maranhão population and the loss of another 13,000 knots this winter from the Tierra del Fuego population means that both are now endangered. Brochures on the need for Red Knot conservation were designed and printed, and have been circulated among fishing communities and school classes in Maranhão.

## INTRODUCTION

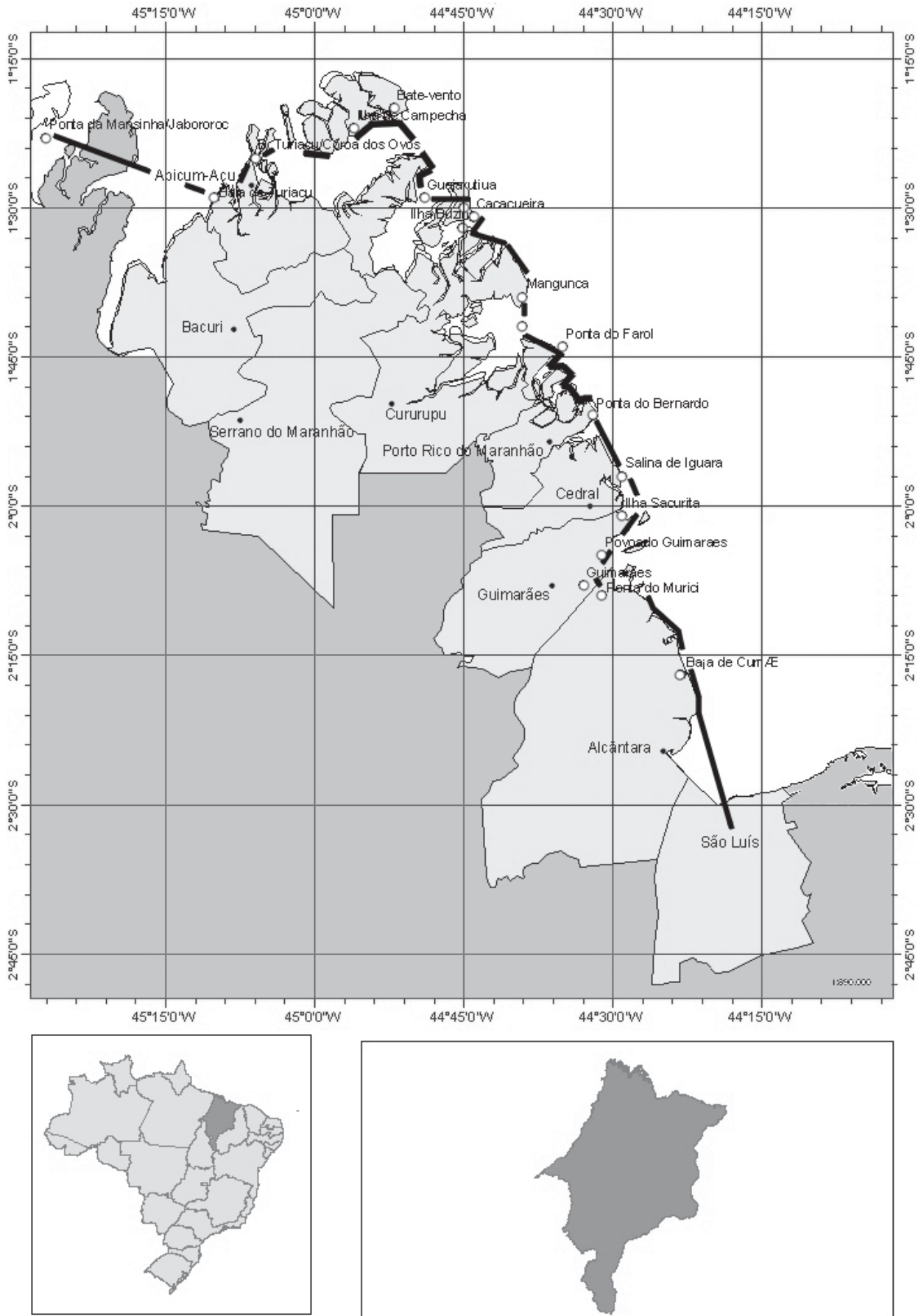
Red Knots *Calidris canutus rufa* migrate south from their arctic breeding grounds in Canada, and spend the non-breeding season in two separate regions in South America, Tierra del Fuego (TDF) in Chile and Argentina, and in Maranhão, N Brazil. Smaller numbers may also spend the season further northwest in French Guiana and Venezuela (Morrison & Harrington 1992). This subspecies is now of conservation priority because peak aerial counts of knots passing through Delaware Bay in the eastern USA on spring passage have declined from 95,000 in the 1980s to 15,345 in 2005 (K. Clark pers. comm.), and the TDF population is in severe decline (Baker *et al.* 2004, Morrison *et al.* 2004). Although the TDF wintering population of knots has been censused aerially for the last four years (Morrison *et al.* 2004), there are recent no counts available of the population that spends the non-breeding season in Maranhão. Thus we do not know

the total remaining population of Red Knots, and cannot properly assess its risk of further decline or possible extinction.

On the basis of the alarming decline in population size, funding to study the Maranhão population was applied for and received from the Endangered Species Recovery Fund of Environment Canada and the World Wildlife Fund Canada, and from the Royal Ontario Museum Foundation. The main objectives of this project were as follows:

- 1) To carry out a comprehensive aerial census of the Maranhão area. This was judged to be vital because if the population of knots there was reasonably large (>15,000 birds) then the subspecies is not as threatened as we thought, and some of the decline in TDF could possibly be explained by redistribution of those birds to Maranhão.





**Fig. 1.** Maps showing Maranhão state and its location in northern Brazil (the 15' grid lines are about 27 km apart). The aerial census route flow on this expedition is depicted by the line connecting the locality dots.



- 2) To catch and band knots for future survival and recruitment analyses. Accurate estimates of these vital rates depend upon the collection of adequate capture-recapture studies of individually marked birds.
- 3) To obtain feather samples for molecular sexing of knots and for analysis of isotopes to establish the location of wing moult in this population.
- 4) To further knowledge of this area which is an internationally significant site in the Western Hemisphere Shorebird Reserve Network and a RAMSAR site. Apart from knots, there are large numbers of Willets *Catoptrophorus semipalmatus*, Short-billed Dowitchers *Limnodromus griseus*, Whimbrels *Numenius phaeopus*, Semipalmated Plovers *Charadrius semipalmatus*, Semipalmated Sandpipers *Calidris pusilla*, Wilson's Plovers *Ch. wilsonia*, Greater Yellowlegs *Tringa melanoleuca*, Spotted Sandpipers *Tringa macularia*, Sanderlings *C. alba*, Ruddy Turnstones *Arenaria interpres* and Black-bellied Plovers *Pluvialis squatarola*, attesting to the importance of the area for wintering shorebirds.
- 5) To conduct outreach and education, including visits to our fieldcamps by members of the fishing community and school children to participate in catching and banding the birds. Past experience doing this in Tierra del Fuego has shown it is a very effective way to involve the community and to educate them about conservation.

## AERIAL AND GROUND CENSUS RESULTS

The aerial census was conducted at high water on 5–6 February 2005 at a height of 100–150 metres, thereby flushing flocks of shorebirds off their roosts to aid identification of species and to allow more accurate counts. Two experienced observers (Wallace R.T. Júnior and Ines L. Serrano from the Brazilian Government bird banding agency CEMAVE) did the counting and species identification, as they regularly do this in other wetlands in Brazil. The total aerial count of knots for Maranhão was 7,570, with the main flock at Crôa dos Ovos (*c.* 5,000). The route flown on the two days is shown in Fig. 1, and the aerial count is summarized in Table 1.

A total of only 22,070 shorebirds were counted from the air in February 2005, as opposed to 198,600 reported for the same area in the mid-1980s by Morrison & Ross (1989) in the *Atlas of the Nearctic shorebirds on the coast of South America*. However, the number of Red Knots in the Maranhão wetlands was down only 575 (7.1%) compared with the counts in the mid-1980s. In contrast, the numbers of Ruddy Turnstones, Black-bellied Plovers and Whimbrels-plus-dowitchers were substantially lower (Table 1). Although it is not possible to count shorebirds roosting on the aerial roots of mangroves during an aerial census, we reduced this source of error by counting only on days with high spring tides that submerged most of the roots and forced most birds

**Table 1.** Aerial counts of shorebirds, gulls and terns in the Maranhão wetlands of N Brazil on 5–6 February 2005, at high tide.

Locality, Lat/Long	Unidentified	Red	Laughing	<i>Sterna</i>	<i>Limno-</i>	Black	Ruddy	Semi-	Black-	
	sandpipers	Knot	Gull	sp.	<i>dromus/</i>	Skimmer	Turnstone	palmated	bellied	
	<i>Calidris</i>	<i>Calidris</i>	<i>Larus</i>		<i>Numenius</i>	<i>Rynchops</i>	<i>Arenaria</i>	<i>Calidris</i>	<i>Pluvialis</i>	
	sp.	<i>canutus</i>	<i>atricilla</i>			<i>nigra</i>	<i>interpres</i>	<i>pusilla</i>	<i>squatarola</i>	
Baía de Cumã (02°17'S, 44°23'W)	75	0	0	0	0	0	0	0	0	
Ponta do Murici (02°09'S, 44°31'W)	355	0	0	0	0	0	0	0	0	
Guimarães (02°08'S, 44°33'W)	300	150	30	15	0	0	0	0	0	
Povoado Guimarães (02°05'S, 44°31'W)	100	0	0	0	0	0	0	0	0	
Ilha Sacurita (02°01'S, 44°29'W)	100	0	0	0	0	0	0	0	0	
Ponta do Bernardo (01°51'S, 44°32'W)	420	75	97	0	270	0	0	0	0	
Ponta do Farol (01°44'S, 44°35'W)	195	0	0	0	0	0	0	0	0	
(01°42'S, 44°39'W)	120	200	270	30	0	0	0	0	0	
Mangunça (01°39'S, 44°39'W)	0	0	33	0	300	35	0	0	0	
Ilha Buzina (01°32'S, 44°33'W)	130	0	0	0	0	0	0	0	0	
Caçacueira (01°31'S, 44°44'W)	220	0	0	0	0	0	0	0	0	
(01°30'S, 44°45'W)	550	400	0	0	300	0	150	0	0	
Guajarutua (01°29'S, 44°49'W)	0	0	0	0	0	0	0	0	0	
Salinas/ Baía do Capim (01°29'S, 44°52'W)	0	0	0	0	0	0	0	0	0	
Valha-me Deus (01°38'S, 44°45'W)	0	0	0	0	0	0	0	0	0	
Bate-vento (01°20'S, 44°52'W)	150	50	0	0	0	0	0	0	0	
Ilha de Campechá (01°22'S, 44°56'W)	300	0	0	0	350	0	0	750	0	
Salina de Iguará (01°57'S, 44°29'W)	0	0	0	0	0	0	0	0	0	
Ilha Jabororoca/ Turirana (01°30'S, 45°05'W)	0	0	0	0	0	0	0	0	0	
Baía de Turiçu (01°29'S, 45°10'W)	2,000	1,500	0	0	500	0	300	0	250	
B. Turiçu/ Crôa dos Ovos (01°25'S, 45°06'W)	3,000	5,000	0	0	1,500	0	500	0	0	
Ponta da Mansinha/ Jabororoca (01°23'S, 45°27'W)	350	200	0	0	250	0	70	0	130	
<b>Totals 2005</b>	Maranhão coast	<b>8,365</b>	<b>7,575</b>	<b>430</b>	<b>45</b>	<b>3,470</b>	<b>35</b>	<b>1,020</b>	<b>750</b>	<b>380</b>
Morrison & Ross (1989) Maranhão coast			<b>8,150</b>			<b>5,321</b>		<b>7,442</b>		<b>8,832</b>



**Table 2.** Counts of shorebirds made from the boat on 10 February 2005 (NR = Not recorded).

Species	B. Turiaçú, Salina dos Ingleses	B. Lençóis, Iguará	B. Lençóis, I. Campechá	Total
Red Knot <i>Calidris canutus</i>	3	500	350	853
Short-billed Dowitcher <i>Limnodromus griseus</i>	250	2,500	200	2,950
Whimbrel <i>Numenius phaeopus</i>	2,000	300	3	2,303
Ruddy Turnstone <i>Arenaria interpres</i>	500	0	2	502
Semipalmated Sandpiper <i>Calidris pusilla</i>	100	3,000	4,000	7,100
Sanderling <i>C. alba</i>	NR	NR	500	500
Black-bellied Plover <i>Pluvialis squatarola</i>	1,800	0	6	1,806
Semipalmated Plover <i>Charadrius semipalmatus</i>	350	0	1,500	1,850
Willet <i>Catoptrophorus semipalmatus</i>	150	0	0	150
Lesser Yellowlegs <i>Tringa flavipes</i>	100	0	0	100
Scarlet Ibis <i>Eudocimus ruber</i>	50	0	500	550

to roost on sand islands. However, small flocks of Willets, Whimbrels and Spotted Sandpipers remained in the mangroves at high water, so our numbers are not a total census. However, even when this is taken into account it is apparent there has been a drastic decline in numbers which parallels large scale losses in many species of shorebirds around the world (Global Flyways Conference, Edinburgh 2004).

Another striking result from the aerial counts was that only four sites held more than 1,000 shorebirds (Table 1). These were Baía Turiaçú/Crôa dos Ovos (10,000 birds), Baía Turiaçú (4,550), Ilha de Campechá (1,400) and near Caçacueira (1,400). The first two localities also accounted for the largest number of knots (1,500 and 5,000 birds, respectively).

Counts were also made from the expedition boat on 10 February when we motored between three localities (Table 2). In addition to confirming relatively low numbers of shorebirds seen in the aerial censuses, these observations also included 1,850 Semipalmated Plovers and 100 Lesser Yellowlegs *Tringa flavipes*. Thus with the addition of these numbers to the aerial census we counted about 24,000 shorebirds in Maranhão.

### SCANS OF FLOCKS FOR BANDED RED KNOTS

The flocks at the two main islands where we located Red Knots, Crôa dos Ovos and Ilha de Campechá, were scanned with telescopes for individuals identified by either inscribed flags or colour band combinations put on when they were captured in Delaware Bay, Tierra del Fuego, or elsewhere in the flyway including Canadian arctic breeding sites. We were able to read the inscribed flags or individual colour band combinations of 13 Red Knots, all of which were banded in Delaware Bay. Two more Knots had inscribed lime green flags that could not be read with high confidence (Table 3).

In addition to the individually banded shorebirds, we also observed cohort-banded Sanderlings, a Ruddy Turnstone and a Black-bellied Plover (Table 4). All except the Black-bellied Plover were banded in Delaware Bay.

We also made scans of the flocks to determine what proportion of the flocks of Red Knots were banded with flags or colour combinations put on in different years and places. This gave an estimate that 6.0% of the Red Knots were banded, based on pooling the separate scans of a total of 1,420 birds (Table 5). Of the 86 birds with year-cohort combinations, 78 were banded in Delaware Bay and eight were banded previously in Brazil. Most significantly, none of the Red Knots bore the orange flags that we have been putting on at a rate of 300–600 per year in Argentina (Tierra del

Fuego and Río Negro province, Patagonia) since 1997, or red flags that have been put on birds in Bahía Lomas, Tierra del Fuego, Chile since 2002.

Preliminary scans of 781 Red Knots we made at Crôa dos Ovos and Campechá in November 2003 also failed to find any orange-flagged or red-flagged birds, so we conclude that the Maranhão wintering flocks of Red Knots are a separate population from that in Tierra del Fuego. It will therefore be important to study the Maranhão population closely for the next few years and to estimate annual survival. Attempts to monitor survival using data on captured and resighted birds in Delaware Bay have been plagued by the fact that a substantial proportion of the *rufa* population either by-pass the Bay or do not migrate to North America in certain years. The lack of fit to survival models is likely to arise because the Tierra del Fuego and Maranhão populations have different site-specific survival rates (Baker *et al.* 2004). If this is the case, separate in-depth studies of annual survival are required in both populations.

### CANNON NET CATCH AND BANDING RESULTS

Capture-recapture (or capture-resighting) methods of monitoring survival require fairly large numbers of individually marked birds as well as substantial recapture/resighting effort. Therefore to obtain adequate estimates of the annual survival of the Red Knots in Maranhão, it is essential to catch a large number of birds on a regular basis and colour band them so that they are individually recognizable in the field. We therefore planned to band knots on the tibia with blue flags (provided courtesy of the British Trust for Ornithology) inscribed with white alphanumeric characters. Prior to this expedition, CEMAVE staff had mist-netted 12 knots and had applied blue flags, but many more are needed if adequate estimates of annual survival are to be obtained. We therefore planned to use a cannon-net to catch a larger sample. The only site where knots occurred in large numbers, Crôa dos Ovos, is a very small sand island that is difficult for cannon-netting, as the beaches are flat and narrow. During our visit, which was timed to coincide with high spring tides so that birds would be driven out of the mangrove roosting sites, we had extremely high tides and strong winds with accompanying strong wave surges that inundated possible catching sites. This caused a large multispecies flock of shorebirds to crowd on small sandhills, and they were constantly in flight or alighting as the waves washed over the sandhills. We therefore did not attempt any cannon net catches at this site for safety reasons.



**Table 3.** Individually banded shorebirds that were resighted in Maranhão in February 2005.

Species	Locality	Date	Flags and bands <sup>1</sup>	Place/Year <sup>2</sup>	Observers <sup>3</sup>
<i>Calidris canutus</i>	Crôa dos Ovos	9 Feb 05	Fl(LPK),-:R,m	NJ04	PG, AB
<i>Calidris canutus</i>	Crôa dos Ovos	9 Feb 05	Fg,YRY:m,O	DE99	PG, AB
<i>Calidris canutus</i>	Crôa dos Ovos	9 Feb 05	Fl(LH),-:O,m	DE03	SR
<i>Calidris canutus</i>	Crôa dos Ovos	9 Feb 05	Fl(LJ),-:G,m	NJ03	SR
<i>Calidris canutus</i>	Crôa dos Ovos	11 Feb 05	Fl(EXY),-:m,-	DE04	VD, ME
<i>Calidris canutus</i>	Crôa dos Ovos	11 Feb 05	Fl(7S),-:O,m	DE03	VD, ME
<i>Calidris canutus</i>	Crôa dos Ovos	10 Feb 05	Fl(M4),-:O,m	DE04	PG, AB
<i>Calidris canutus</i>	Crôa dos Ovos	10 Feb 05	Fl(EEU),-:m,-	DE04	PG, AB
<i>Calidris canutus</i>	Crôa dos Ovos	10 Feb 05	Fg,GR:m,GB	NJ02	PG, AB
<i>Calidris canutus</i>	Crôa dos Ovos	11 Feb 05	Fl(LUV, LUX ?),-:m,-	DE04	PG, AB
<i>Calidris canutus</i>	Ilha de Campechá	12 Feb 05	Fl(4U-AU?),-:O,m	DE03	PG, AB
<i>Calidris canutus</i>	Ilha de Campechá	12 Feb 05	Fl(NAE),-:R,m	NJ04	PG, AB
<i>Calidris canutus</i>	Ilha de Campechá	14 Feb 05	Fl(EMU),-:m,-	DE04	PG, AB
<i>Calidris canutus</i>	Ilha de Campechá	14 Feb 05	Fl(LML),-:R,m	NJ04	PG, AB
<i>Calidris canutus</i>	Ilha de Campechá	14 Feb 05	Fl(EAT),-:m,-	DE04	PG, AB
<i>Arenaria interpres</i>	Crôa dos Ovos	9 Feb 05	m,W:Fw,LG	Canada	PG, AB
<i>Calidris alba</i>	Ilha de Campechá	14 Feb 05	Fl(EUV),-:-,m	NJ04	PG, AB
<i>Calidris alba</i>	Ilha de Campechá	14 Feb 05	Fl(CVN),-:-,m	NJ04	PG, AB
<i>Calidris alba</i>	Ilha de Campechá	14 Feb 05	Fl(ETN),-:-,m	NJ04	PG, AB

<sup>1</sup> Left tibia, left tarsus; right tibia, right tarsus. Flag colour: Fg = green (USA), Fl = lime (also USA), Fw = white (Canada). Flag inscription in parantheses. Color bands: W = White, Y = Yellow, O = Orange, R = Red, G = Green, L = Lime, B = Blue, N = black, m = metal band, - = none.

<sup>2</sup> NJ = New Jersey, DE = Delaware

<sup>3</sup> Observers: Patricia González (PG), Allan Baker (AB), Susan Rice (SR), Verónica D'Amico (VD), María Eugenia Echave (ME).

**Table 4.** Cohort-banded shorebirds, other than Red Knots, observed in Maranhão February, 2005.

Species	Locality	Date	Colour bands	Place/Year	Observers*
<i>Calidris alba</i>	Crôa dos Ovos	9 Feb 05	Fg,B:m,GW	NJ01	SR
<i>Calidris alba</i>	Crôa dos Ovos	10 Feb 05	Fg,O:m,-	NJ04	PG, AB
			Fg,O:m,-	NJ04	PG, AB
			Fg,B:m,GW	NJ01	PG, AB
<i>Arenaria interpres</i>	Crôa dos Ovos	10 Feb 05	Fg,R:m,B	DE02	PG, AB
<i>Pluvialis squatarola</i>	Ilha de Campechá	12 Feb 05	-,YN:m,-		PG, AB
<i>Calidris alba</i>	Ilha de Campechá	13 Feb 05	Fl,-:-,m	NJ04	PG, AB
			Fg,B:m,GR	NJ01	PG, AB
			Fg,R:m,B	DE02	PG, AB

\* Observers and colour bands identified as in Table 3.

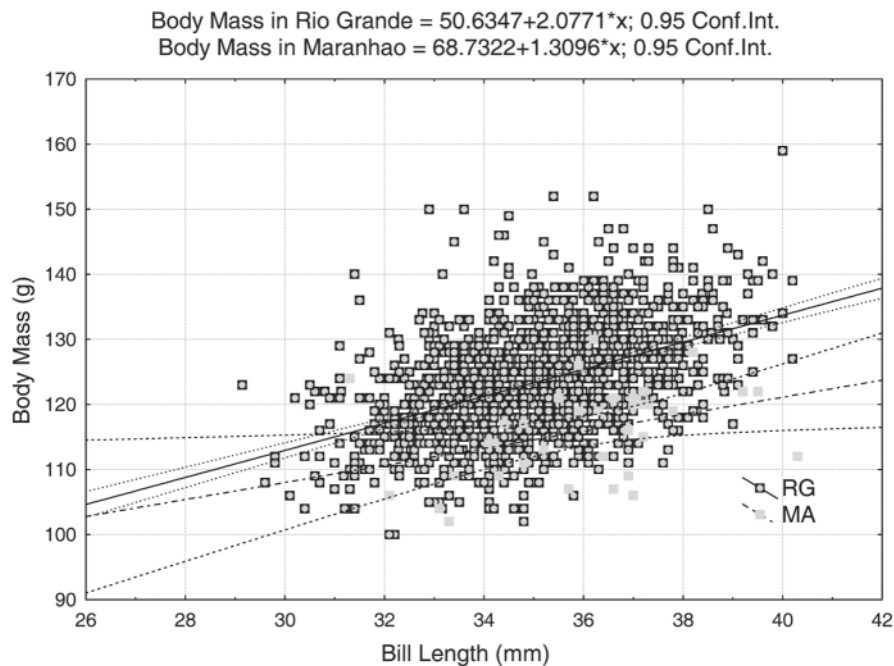
**Table 5.** Resightings of Red Knots with flags and/or colour bands in Maranhão in February, 2005.

Scan	Locality	Date	Time	No. checked	Number of banded birds, from:	
					Delaware Bay, USA	Brazil
1	Crôa dos Ovos	9 Feb 05	812	272	9	1
2	Crôa dos Ovos	9 Feb 05	921	134	10	2
3	Crôa dos Ovos	10 Feb 05	951	377	24	3
4	Crôa dos Ovos	11 Feb 05	957	194	9	0
5	Crôa dos Ovos	11 Feb 05	1100	234	12	2
6	Ilha de Campechá	12 Feb 05	748	34	2	0
7	Ilha de Campechá	12 Feb 05	815	21	1	0
8	Ilha de Campechá	12 Feb 05	900	60	3	0
9	Ilha de Campechá	14 Feb 05	1200	94	8	0
<b>Totals</b>				<b>1,420</b>	<b>78</b>	<b>8</b>

Instead, after motoring in the boat seven hours further east we located a smaller flock of about 250 Red Knots on the island of Campechá. Attempts to cannon net Red Knots on

the first two days on the island were unsuccessful, as very few birds roosted there and we had to contend with heavy rain showers. Mist nets set at night caught 45 shorebirds





**Figure 2.** Plot of body mass versus bill length in samples of adult Red Knots captured in Rio Grande (Tierra del Fuego) and Maranhão. 95% confidence intervals are shown around each regression line.

which were banded and released, but no knots were caught. On the final day of fieldwork 60 knots landed near the catching area, and we managed to catch 38 in the cannon net along with 4 Black-bellied Plovers and 3 Sanderlings. This is the largest sample of knots caught in one attempt in Maranhão, and it yielded some very valuable data. Three birds were already banded, one from Maranhão in 2004 (Flag AJ) and the other two from Delaware Bay (band numbers 1513-36488 and 812-90563, see Table 5). No juveniles were captured, three were thought to be immatures and the remaining 35 were adults. All birds were banded with inscribed flags as well as individual colour band combinations to increase the chances of resighting them in future.

### BODY MASS AND ECTOPARASITES

Body masses of the 38 Red Knots captured in Maranhão were of interest because they give a general indication of body condition at a time when the hemispheric population is rapidly approaching endangered status. Comparisons of the Maranhão sample with samples captured from the Tierra del Fuego population over the past five years show that the Maranhão Red Knots are significantly lighter (analysis of covariance,  $F(1, 1401) = 54.46, p = 0.0000$ ) when using bill length as a covariate to standardize for any differences in body size between the populations that may exist because of different sex-ratios (Fig. 2).

The difference in the mean body masses along with their 95% confidence intervals are shown in Fig. 3. The 2004 sample collected in Rio Grande was late arriving at this site, and most birds were in mid wing moult, a condition in which body mass is either lost because of the energetic cost of flying with less efficient wings or shed to maintain flying efficiency and thereby avoid predators (Swaddle & Witter 1997). Even so, these southernmost birds are on average about 6 g heavier than their non-moulting counterparts in Maranhão. The mean mass (and 95% confidence intervals)

of the Maranhão sample was below the estimated fat-free mass for Red Knots (Baker *et al.* 2003), suggesting that they are energetically limited. Some birds were so thin that their breast muscles were reduced markedly and the keel was prominent through the skin.

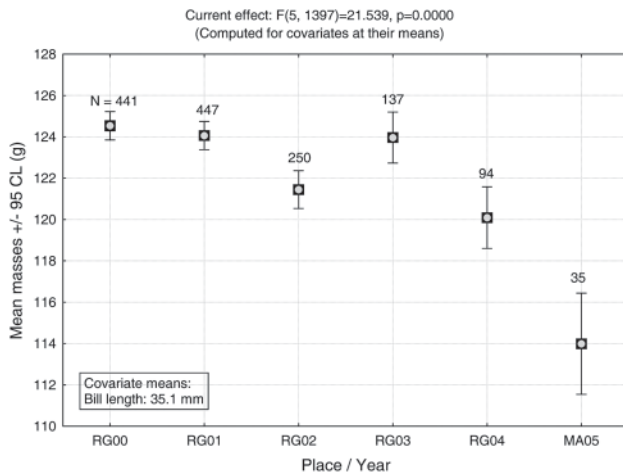
Birds in poor condition as indicated by low body mass are more prone to infection by parasites and pathogens (Booth *et al.* 1993). To examine whether the Red Knots in Maranhão had a higher incidence of parasites and pathogens we took blood samples for molecular detection of endoparasites. The blood samples will also be used to sex each bird with a simple molecular sex test, so that sex-specific survival can be estimated in future. Additionally we estimated the number of ectoparasites (lice and mites) on the wing feathers of each bird. All estimates were made by CEMAVE biologist Wallace Rodriguez Tellino Junior who is researching ectoparasite loads in shorebirds in Brazil. All 38 knots had a high infestation of ectoparasites, and they also had suffered feather damage characterized by holes in the vanes. There appears to be a severe ectoparasite infestation of shorebirds in Maranhão, but heavier birds were also afflicted and there is no significant negative correlation with body weight (Fig. 4).

We also checked five other species of shorebirds caught in mist nets to see if they had ectoparasites. All 45 specimens had ectoparasites, indicating that the infestation is widespread among over-wintering species.

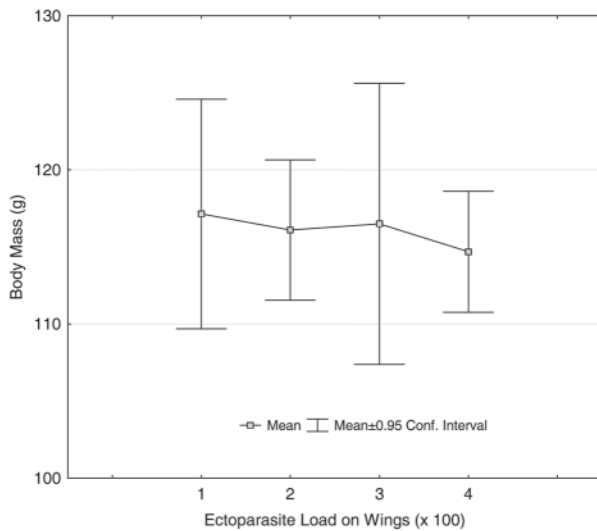
### FEATHER AND BLOOD SAMPLES

Feather samples are proving to be invaluable indicators of where birds moult their flight feathers, as the isotopes in them vary geographically and thus can indicate localities where they over-winter (Atkinson *et al.* in press). Additionally, it has been shown recently that some late breeding passerines incur the energetic cost of moulting while they are migrating. The result is that their subsequent breeding plumage is paler than other birds breeding earlier in the season that





**Fig. 3.** Differences in mean body masses of samples of adult Red Knots from Rio Grande (RG, 2000–2004) and Maranhão (MA, 2005).



**Fig. 4.** Ectoparasite loads and body mass of Red Knots in Maranhão. Loads were assessed by counting lice and mites on two primaries and extrapolated to all flight feathers of the wing. The loads were then classified into four broad categories: 1 = 1–100, 2 = 101–200, 3 = 201–300, 4 = 301–400.

moult before they migrate (Norris *et al.* 2004). Since mate choice is often based on the brightness of plumage, there may be fitness consequences to late moulting while on migration. In Red Knots, we already know that populations can be identified by differences in the ratio of carbon and nitrogen isotopes in their wing feathers, which vary according to the location where they moult (Atkinson *et al.* in press). We therefore took small samples of the 6th primary covert and of the innermost primary, which are being sent to the British Trust for Ornithology for analysis in a collaborative project. The isotopes in the innermost primary will tell us whether or not they began moulting on migration, and the location (i.e. Florida, possibly the Caribbean, Central America, or Maranhão). At the time of writing, preliminary results have been obtained by searching the isotope data base for Red Knots captured in Delaware Bay in May 2004, and resighted again in Maranhão in 2005. The isotope signatures

of the four knots satisfying this condition are very close to those of the birds seen in Florida, South Carolina and Georgia. Red Knots at these localities are thought to be a different subspecies, *C. c. roselaari*. If this is substantiated by larger sample sizes later in 2005 then not only is the *C. c. rufa* population smaller than currently thought but *C. c. roselaari* is also a threatened subspecies numbering about 10,000–12,000 birds. A flock of this size is seen in autumn on the Atlantic coast of Georgia and South Carolina each year, and then disperses into Florida, and possibly the Caribbean. We may be able to add Maranhão to that list of over-wintering sites when isotope results are obtained.

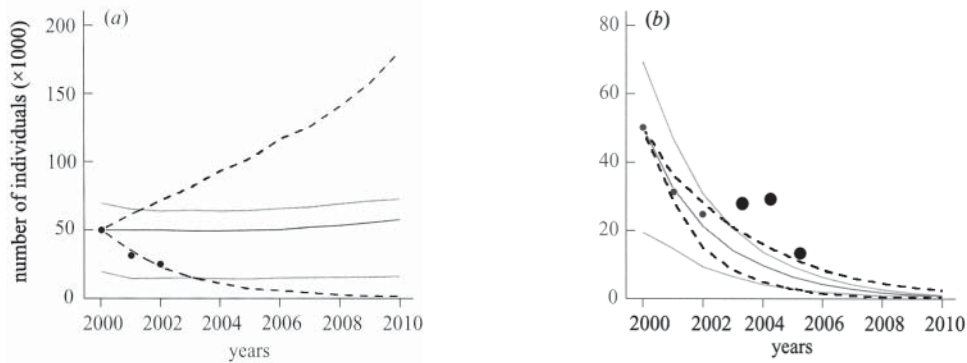
Pathogens such as viruses are known to cause large mortalities in birds (e.g. West Nile virus). Reports of kills of shorebirds in N Brazil have been circulating, possibly associated with the spread of West Nile virus southwards into Brazil from Central America. We therefore took blood samples from all Red Knots and will analyze them with PCR using primers designed to detect avian influenza, avian malaria and possibly West Nile virus. Recent research on shorebirds has shown that tropical wintering populations have a much higher incidence of parasites and pathogens than do cool temperate ones, especially in species in freshwater habitats (Mendes *et al.* 2005). If this proves to be the case in Maranhão, then the population needs special attention in population restoration planning.

## OUTREACH AND EDUCATION

A very important part of this expedition was outreach through educational programmes with the local fishing community, and with schools. For this purpose, a colour brochure was designed in Argentina by Patricia González, Fundación Inalafquen in collaboration with Rocío Landívar, the graphic designer, Marcio Efe and Wallace R.T. Júnior, and 500 copies were printed in Portuguese for distribution in Maranhão. This brochure was a great hit with the fishing community on Ilha de Campechá, who were trapping shorebirds for food in 2003. They seem to have stopped this practice, and in 2005 were extremely helpful to us in locating beaches with shorebirds. They were also excited participants in the cannon net catch, and watched throughout the process of banding the birds and taking feather and blood samples. The brochure was invaluable in explaining to them the migration of shorebirds in general and Red Knots in particular, as they had no idea of the long distances traversed annually by this species.

Unfortunately, the timing of the expedition meant that schools were closed during our visit. We therefore could not visit schools in the area as we had planned. However, we were able to include a high school teacher and biologist (Claudia Matos) from the city of San Luis in our field team. He has undertaken the task of visiting schools, talking to classes, and distributing brochures. Additionally, the captain of the boat we hired volunteered to visit primary schools and distribute brochures in the town of Cururupú. Our aim next year is to arrange a visit by school children from either a high school or senior primary school to our fieldwork camp, and to engage them in our work. We have been extremely successful in doing this in Tierra del Fuego, and many of the students have progressed to university studies as the years have passed. This builds a group of highly trained personnel who can be actively involved in conservation and the protection of the highly vulnerable sites that migratory shorebirds depend on for their survival.





**Fig. 5.** Predicted population trends and associated 95% confidence limits of adults (dashed lines), predicted population trend of juveniles (lower grey line) and the sum of these two (top grey line) for 10 years from 2000, with **(a)** constant adult survival of 85% and juvenile survival being half that of adults ( $\lambda = 1$ ) and **(b)** constant adult survival of 56% and juvenile survival being half that of adults ( $\lambda = 0.66$ ). The small dots represent the aerial censuses of the over-wintering flock of adults in Tierra del Fuego during 2000–2002, and the large dots are the counts in 2003–2005. The 95% upper and lower confidence limits are based on 1,000 bootstrap iterations. Modified from Baker *et al.* (2004).

## POPULATION DECLINE IN TIERRA DEL FUEGO AND ENDANGERED SPECIES STATUS

At about the same time that we were in Maranhão, Guy Morrison and Ken Ross of the Canadian Wildlife Service were making an aerial census of Red Knots in Tierra del Fuego. This showed a population of only 17,653 compared with 30,778 at the same time in 2004. Unless a substantial proportion of the birds were missed – and there seems no reason to suppose that this is so – this loss of 13,000 birds increases the risk of extinction of the Red Knot as modelled in the ‘worst case’ scenario published in Baker *et al.* (2004) (Fig. 5b).

In conclusion, as the result of the contemporaneous Maranhão and Tierra del Fuego censuses and associated studies in early 2005 before the northern migration had commenced, it is now established that both locations harbour separate populations that are both endangered and the risk of extinction is greatly enhanced. If further studies using genetic markers and feather isotopes place the two populations in separate subspecies then the case is even more urgent because both will have even smaller population sizes, and consequently lower amounts of adaptive genetic variation. The resightings of Red Knots in Maranhão that were colour-banded on passage through Delaware Bay in spring each year suggests that possibly one quarter of the flocks in the Bay in 2004 were from this northern Brazilian population. If this extrapolation is approximately correct it suggests that a large number of Red Knots from Tierra del Fuego did not migrate through the Bay in 2004, either avoiding it or aborting migration in South America. In either case, the disruption to the normal migratory schedule is expected to have deleterious effects on population growth through declines in reproductive success and recruitment (Piersma & Baker 1999). Thus, we have entered a bid with COSEWIC in collaboration with Guy Morrison of CWS to have the Red Knot listed as an endangered species in the Americas.

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Ilha Campechá from the air. We cannot netted knots here.



Claudia Matos (high school teacher), Marcio Efe (CEMAVE), Verónica D'Amico (Ph.D. student, Argentina) and Susan Rice (USFWS, Virginia). The boat is motoring in the tidal channel between the mangrove forests, which grow to a height of 20 m.



Expedition camp set up in unused huts on Crôa dos Ovos.



Expedition team processing a cannon net catch in a hut during a heavy tropical downpour on Ilha de Campechá.



María Eugenia Echave (zoology student, Argentina) taking a small feather sample for later isotope analysis in the United Kingdom.



A newly banded Red Knot with just a trace of the red breeding plumage.

