USE OF GEOLOCATORS TO DEFINE MIGRATORY PATHWAYS OF RED KNOTS IN LOUISIANA: 2018

A Report of the:

Barataria-Terrebonne National Estuary Program

and

Coastal Bend Bays & Estuaries Program

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Prepared for the:

US Fish & Wildlife Service

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Red Knots on Gulf beach of Grand Isle, Louisiana. Photo credit: Barbara Keeler.

Report submitted to US Fish & Wildlife Service, upon completion of Cooperative Agreement # F16AP00835

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December 2018

BACKGROUND

Since spring 2014, Coastal Bend Bays & Estuaries Program (CBBEP) has been partnering with Barataria-Terrebonne National Estuary Program (BTNEP) on a project to assess the migratory connectivity of Red Knots (*Calidris canutus*) occurring on the offshore barrier islands of Louisiana. This has involved capture and marking (with uniquely-engraved leg flags) of several hundred individuals during the spring season coupled with resight surveys. This effort has demonstrated rather high fidelity in selection of Louisiana as a spring staging site. Resights during other seasons indicate some proportion of these birds are present in fall and some winter locally. However, additional reports of Louisiana-marked birds along the Pacific coast of Panama, Peru, and Chile indicate there are at least two primary migratory strategies utilized by knots present in spring in Louisiana. The primary goal of this project was to deploy tracking devices to determine migratory pathways, wintering areas, and subspecific status of Red Knots in Louisiana.

METHODS

Birds were trapped using a small transportable "box net" which is identical in concept to more commonly-used cannon nets, with the exception that the net is contained within a metal "box" between the two cannons. To capture birds, flocks were identified and the net placed nearby on the beach, with the opening oriented towards the ocean. Upon capture, birds were immediately removed from the net and held in shaded holding cages prior to processing. Processing included measurements of exposed culmen, total head, wing chord and tarsus, and weighing. Additionally, a ~2cm clip of the distal tip of the 6th primary covert was removed for future use in stable isotope analysis. A federal metal band was placed on the lower right leg, and a small flag engraved with a unique three-digit alphanumeric code placed on the upper left leg to facilitate future field identification. Geolocators were attached to the upper right leg.

Figure 1. Red Knot LA(198) feeding, prior to recapture. The geolocator is visible on the right leg. Photo credit: Barbara Keeler.

Geolocators are devices that record ambient light levels, which allow a researcher to infer the general position of the bird throughout the annual cycle. They are archival, meaning that they do not transmit data but have to be recovered through retrapping at a future date. We deployed a total of 50 Intigeo W65A9-SEA geolocators manufactured by Migrate Technology Ltd on Red Knots. This model records the maximum light-level detected every two minutes, the number of times the unit is "wet" each hour (up to 14), and the minimum and maximum temperature and maximum conductivity detected in each four-hour period. Devices were mounted to a small red flag such that the light sensor would face outward from the bird when attached to the right leg (Fig. 1). A small spacer ring was added below the mounted device to alleviate potential restriction of normal movement of the leg. All geolocators underwent a pre-deployment calibration period in February 2017, in order to refine location estimates for recovered devices.

Data from recovered geolocators was downloaded and processed using an interface and the IntiProc software obtained from the manufacturer. Since geolocators are inherently imprecise, various methods for refining location accuracy and interpretation of data were employed as recommended by Porter and Smith (2013). To estimate minimum flight speeds of migratory flights, the times of departure and arrival (to the hour) were inferred from wet/dry and conductivity data when they could be corroborated with light-level data, and their difference was divided by a standard estimated distance between departure and arrival sites.

RESULTS

Captures and Deployment

A total of 54 Red Knots were captured on Grand Isle between April 23-27, 2017. Of these, eight had been trapped and marked by us in previous years. Forty-five were "after second year" (ASY) birds based on plumage characteristics, meaning they were in the process of preparing for migration to Arctic breeding grounds within the coming weeks. Nine were in the "second-year" (SY) age class, meaning they were hatched the previous summer so were nearly one year old. Most knots do not go to Arctic breeding grounds to breed in their first full summer, but typically remain in temperate latitudes. We deployed geolocators on all birds with the exception of three ASY and one SY bird.

Summary statistics of morphometric measures are provided in Table 1. Differences of means between ASY and SY birds were not significant. There was a much wider range in mass of ASY birds compared to SY birds. Since SY birds generally do not go to the Arctic to breed, they have no need to "fatten up" prior to a major migratory flight, and their masses are typical of a fat-free winter weight. The range in mass of ASY birds was considerably greater (Fig. 2). Since breeding age knots probably do not depart on their next migratory journey for at least three weeks after the week of these captures, this range may be indicative of a range of migratory strategies. Birds at low weight at capture may have only recently arrived from distant wintering areas, while higher weight birds may have arrived earlier (or wintered locally) and been fattening for several weeks before capture.

Table 1. Summary statistics of morphometric measures from Red Knots captured during geolocator deployment April 23-27, 2017 at Grand Isle, Louisiana.

	After-Second-Year (n = 45)		Second-Year (n = 9)	
	Mean (s.d)	Range	Mean (s.d)	Range
Culmen (mm)	35.5 (1.9)	[30.0, 39.5]	34.5 (1.5)	[32.0, 36.7]
Head (mm)	64.8 (2.2)	[60.7, 70.0]	63.0 (2.8)	[59.8, 69.7]
Wing (mm)	168.6 (4.9)	[157, 178]	160.0 (6.0)	[152, 173]
Mass (g)	144.2 (14.1)	[106.7, 169.4]	123.2 (8.2)	[110.1, 135.6]

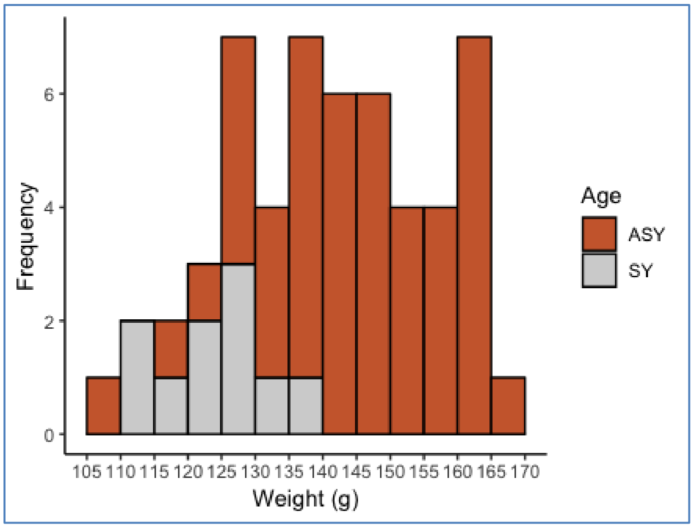

Figure 2. Histogram of masses of ASY and SY birds captured during geolocator deployment, April 23-27, 2017 at Grand Isle, Louisiana.

Figure 3. Red Knot LA(180) upon recapture one year since deployment. Photo credit: Delaina LeBlanc.

Recapture/Recovery

In spring 2018, CBBEP and BTNEP returned to the site to attempt retrapping of knots to recover geolocators. Two individuals with geolocators ("LA(180)" and "LA(198")) were retrapped (Fig. 3) and their geolocators removed. Other birds with geolocators were present in the area but not retrapped during this expedition. One additional geolocator was removed from a bird captured on the island of Chiloé, in southern Chile on the Pacific coast, by an unaffiliated researcher. The geolocator was returned to us and received on 27 December 2018. The data has been downloaded, and includes a 15 month continuous light record. It was not possible to fully process and interpret the data from this device in time to be integrated into this report, but some comments on this specific individual are provided as an addendum due to the uniqueness of the routes taken relative to the other two.

Full annual-cycle migratory tracks

The important dates, locations, and other information that could be derived from the two geolocators are summarized in Table 2, and maps illustrating the annual migratory movements are provided in Fig. 4 (LA(180)) and 5 (LA(198)). Neither of these individuals spent the winter in Louisiana, though LA(198) used the Louisiana coast both in spring as well as for a month during southbound migration before moving on to its wintering area in Ecuador. LA(180) flew direct from its post-Arctic stopover to its wintering site in Panama. Both of these patterns are consistent with patterns described from a previous geolocator project conducted in Texas (Newstead et al 2014, Newstead, unpubl. data).

The use of the James Bay/Hudson Bay area both prior to and following the duration in the Arctic strongly supports the assertion that these birds are of the threatened *C. c. rufa* subspecies. This is further corroborated by the fact that the last location prior to the Arctic and the first location following it were both oriented more or less due north of this area rather than to the northwest (towards the direction of breeding area of *C. c. roselaari*). Both birds spent the same amount of time in the Arctic (38 days).

Table 2. Dates, durations, minimum flight speeds, key locations, and mass-at-capture of two Red Knots.

	LA(180)	LA(198)
deployment date	4/24/2017	4/26/2017
mass at deployment (g)	136.6	149.8
spring flight to pre-Arctic stopover	5/20/2017 - 5/22/2017	5/26/2017 - 5/28/2017
minimum flight speed	52.4 km/h	62.0 km/h
pre-Arctic stopover location	James Bay	James Bay
pre-Arctic stopover duration	9 d	11 d
depart for/return from Arctic	6/1/2017 - 7/9/2017	6/9/2017 - 7/17/2017
days in Arctic	38 d	38 d
post-Arctic stopover location	James Bay	Hudson Bay/NRD
post-Arctic stopover duration	22 d	14 d
post-Arctic stopover departure/arrival	7/31/2017 - 8/4/2017	8/1/2017 - 8/4/2017
minimum flight speed	53.9 km/h	55.4 km/h
fall stopover destination	Panama	Louisiana
fall stopover duration	-	35 d
fall departure/winter arrival	-	9/8/2017 - 9/12/2017
winter location	Panama	Ecuador
dates at wintering site	8/4/2017 – 4/20/2018	9/12/2017 – 4/9/2018
winter duration	259 d	209 d
spring departure from winter/arrive Louisiana	4/20/2018 - 4/22/2018	4/9/2018 - 4/12/2018
minimum flight speed	52.9 km/h	58.0 km/h
recovery date	4/26/2018	4/24/2018
mass at recovery (g)	126.1	118.4
total km in migratory flight (excluding Arctic)	10,443	13,225

The temperature, wet/dry and conductivity signals recorded by the geolocator provide ancillary information that is helpful in corroborating initiation of departure and arrival as inferred from light levels. In many cases, it is possible to identify the hour (or a range of four hours or less) of departure or arrival. This makes it possible to estimate minimum flight speed, as a function of the total direct (Great Circle) distance between points divided by the number of hours in flight. The estimated distances of migratory flights used in the calculations were: Louisiana-James Bay – 2,725km; James Bay-Panama – 5,179km; Panama-Louisiana – 2,539km; Hudson Bay/Nelson River Delta-Louisiana – 3,100km; Louisiana-Ecuador – 3,715km.

Wintering sites

Red Knot LA(180) spent the "winter" (259 days) in Panama. Though this stretch of Central America is very narrow, the cluster of fixes described by the geolocator data suggest the bird was on the Pacific coast. This is consistent with what is known regarding potential habitat, and supported by the fact that there are virtually no records of the species on the Caribbean coast at the inferred longitude. The average longitude of fixes during the winter period is 79.87 W (s.d. 0.85). Within the range of one standard deviation from the mean longitude there are several areas that may provide good habitat for knots. These include the salt evaporation ponds and estuary around Chitré on the Azuero Peninsula, the Bahía de Chamé, and the vast Panamá Bay just to the east of Panama City. Knots marked in the northwest Gulf have been observed at wetlands around Chitré and in Panama Bay.

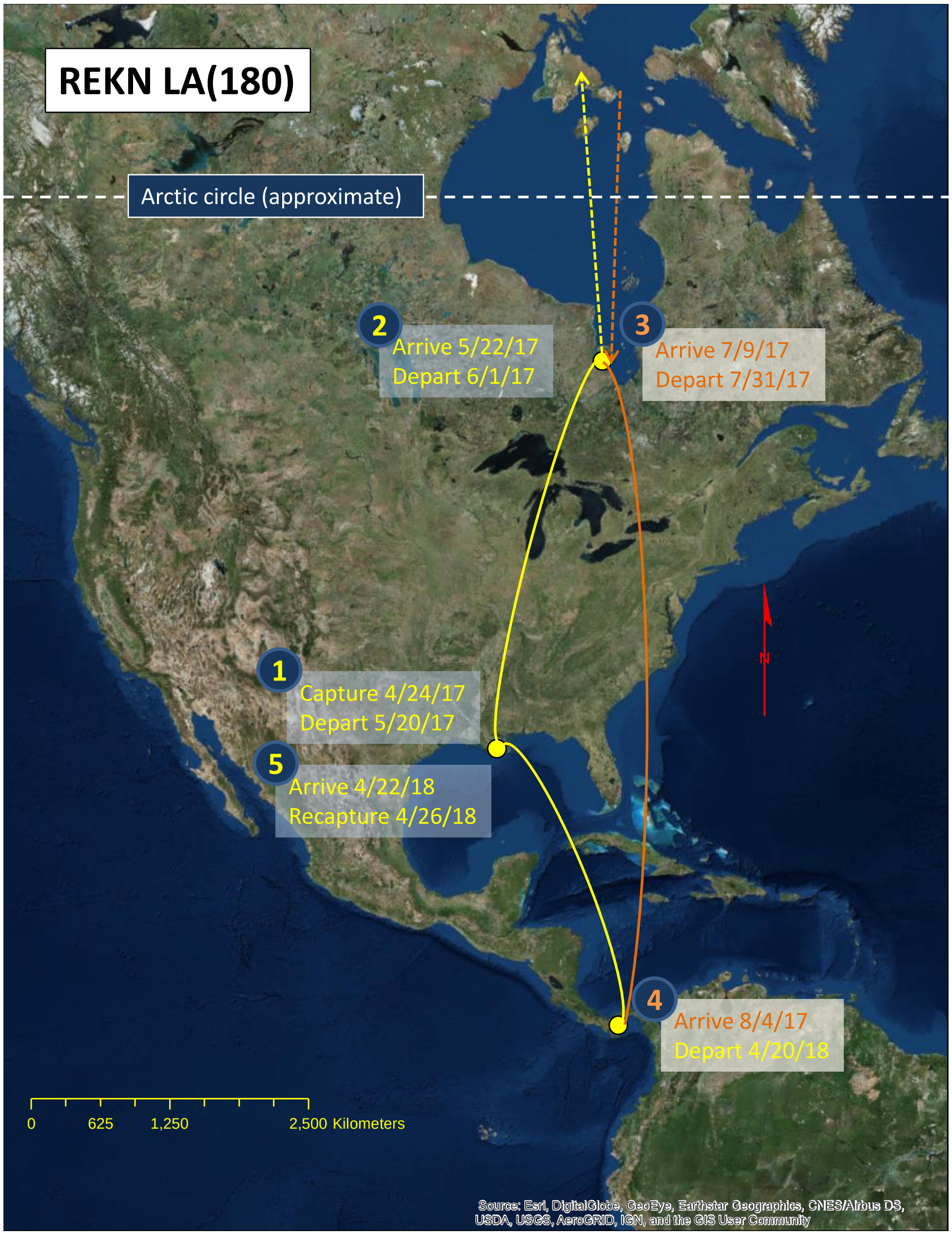

Figure 4. Full annual migration cycle of REKN LA(180). Main locations are approximate, and numbered in chronological order of migratory movements. Northbound movements are described by yellow lines/text; southbound movements by orange lines/text. Dotted arrows going north and south through Arctic Circle simply indicate movement beyond range where geolocator data can be used to accurately infer position. Lines connecting main sites are to emphasize direction of migratory flight (not actual flight path).

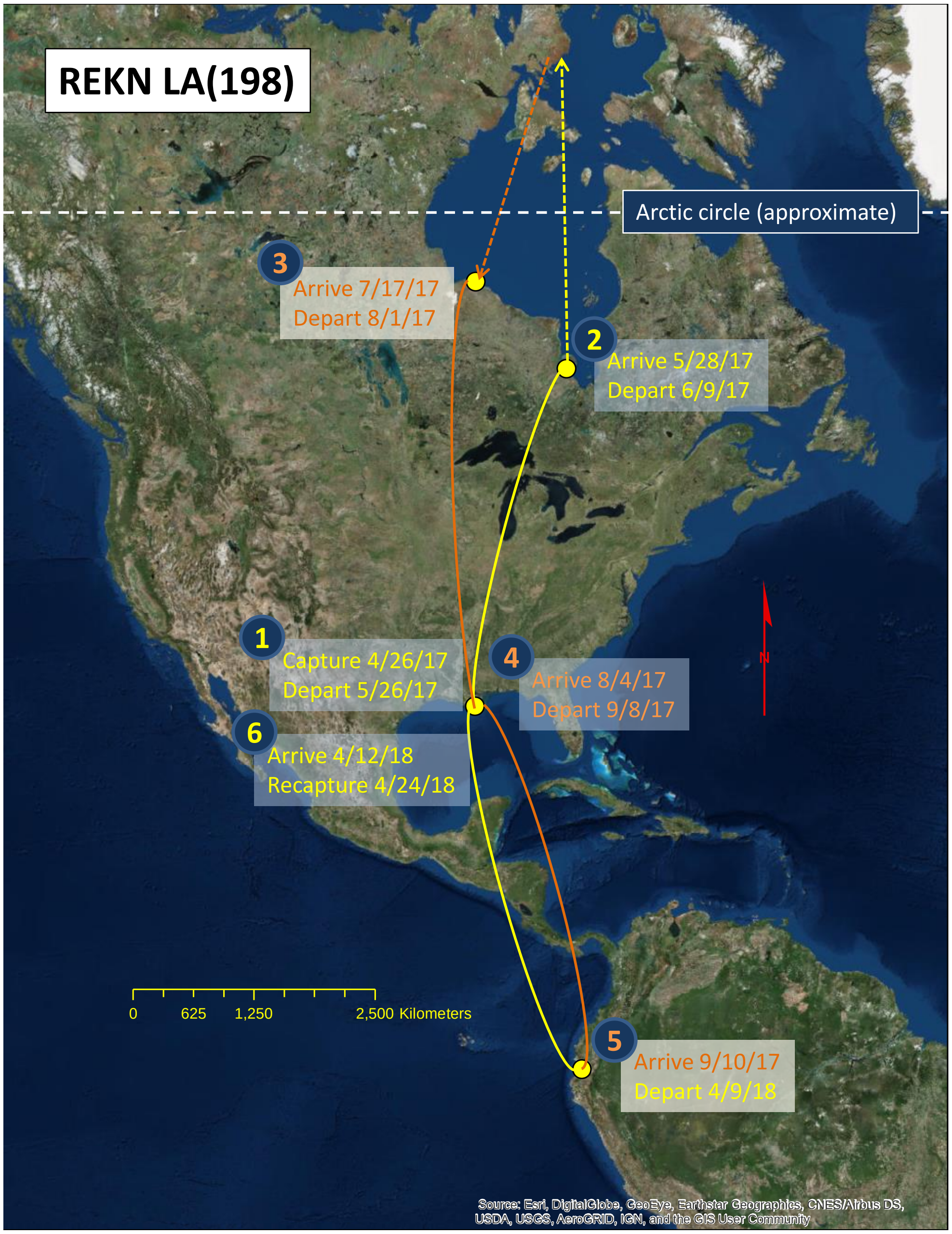

Figure 5. Full annual migration cycle of REKN LA(198). Main locations are approximate, and numbered in chronological order of migratory movements. Northbound movements are described by yellow lines/text; southbound movements by orange lines/text. Dotted arrows going north and south through Arctic Circle simply indicate movement beyond range where geolocator data can be used to accurately infer position. Lines connecting main sites are to emphasize direction of migratory flight (not actual flight path).

Red Knot LA(198) wintered in Ecuador after a stopover of 35 days in Louisiana following the breeding season and a stopover near the Nelson River Delta in Hudson Bay. Much of the Ecuadoran coastline is either rocky or steep coarse-sand beaches that does not provide likely habitat for knots. This knot spent the winter (209 days) somewhere in the vast wetland complex of the estuary of the Río Guayas, seaward of Guayaquil. This part of the Ecuadoran coast has experienced massive conversion of intertidal areas for shrimp farming in the past several decades, though there appear to be several areas with operational salt evaporation ponds towards the Pacific side of the estuary. Knots are known to utilize salt evaporation ponds in other parts of Latin America, and may also be doing so here.

These two knots departed Louisiana for spring migration in the last two weeks of May 2017, approximately 24 and 32 days since their capture and geolocator deployments. In studies in spring on Delaware Bay, it has been estimated that knots failing to attain a threshold departure mass of 180-220 g are less likely to survive or arrive to the Arctic in good breeding condition (Baker et al 2004). Knots passing through Delaware Bay typically make their next migratory flight to the same areas in James Bay as these two knots, yet James Bay is approximately 1,000 km closer to Delaware Bay than to Louisiana. Based on their mass at capture, and a threshold departure mass of a minimum 180g, LA(180) would have needed to average a mass increase of 2.3 g/d and LA(198) would have needed to increase on average 1.9 g/d in order to reach target departure mass for the date of their respective departures. If the threshold departure mass for knots in Louisiana is on the upper end of the range (220g), the average rates of mass increase for these two birds would be 3.2 g/d and 2.3 g/d, respectively. Knots are known to be able to increase mass at rates in excess of 4 g/d when feeding on horseshoe crab eggs on Delaware Bay in the spring, which is regarded as one of the most rapid fattening events in birds. However, that phenomenon is associated with an exceptionally rich food source with extremely efficient conversion to mass, whereas consumption of bivalves (the probable prey source for Red Knots in Louisiana) is comparatively less efficient. Obviously, we know that these two individuals specifically *did* in fact reach a mass sufficient to fuel their next migratory flight to James Bay but for now it is not possible to conclude that all or even most knots are reaching sufficient mass at departure (i.e. we cannot know the fate of birds that were not retrapped that may have died whether as a result of insufficient pre-migratory condition or a different unrelated factor). Much more marking and weighing – combined with more intensive surveying – at different times during spring fattening would be necessary to identify a threshold departure mass relevant for Louisiana.

One potential cause of concern is that the knots seem highly dependent on Grand Isle beaches. The Grand Isle beaches see a drastic increase in recreational activity beginning around mid-May when public schools begin summer break. It is obvious that shorebird distributions are affected by human usage of the beach, as groups of birds are typically spaced *between* groups of people rather than directly in front of them. As the number of groups of people increases and the distance between the groups decreases, there may be a threshold beyond which knots and other shorebirds are unable to compensate for energy expended avoiding human activity and possibly being forced into less profitable feeding areas. This would be even more critical as knots are trying to “top up” pre-migratory stores in the weeks leading up to departure at the same time recreational activity is limiting their ability to do so. Additionally, the town of Grand Isle recently began allowing residents and visitors to use golf carts on the beach whereas previously vehicular access was restricted to infrequent visits by law enforcement, resource agencies and their contractors, maintenance crew and equipment, and researchers. Recreational visitation on the beaches was mostly concentrated in areas of the island within a short distance of beach walkover access points. However, golf carts are now able to run along beaches on the entire length of the island with the exception of Grand Isle State Park. Very often the carts are traveling along the water’s edge which inevitably causes birds to flush and expend energy until they can resettle and commence feeding again. As this source of disturbance increases, the ability of knots to prepare adequately for migration may be further impinged especially if the activity persists during times of optimal feeding conditions.

Fifi Island

The spring 2018 expedition was the fifth consecutive year of our trapping efforts in Louisiana. The planning for initial efforts were largely informed by BTNEP surveys which gave clues to the timing of peak numbers of birds, and the specific areas they were most frequently encountered. This has benefitted the project considerably. During the expeditions, we have noticed patterns of presence on the beach often change throughout the day. Uniquely-marked birds are often seen in multiple consecutive days, suggesting the pattern is not related specifically to migratory arrivals/departures. During the trapping effort of the week of April 23-27, 2018, knots often decreased in abundance on the beach rather sharply by mid-day. We were able to enlist a very generous volunteer with a boat to go out to "search" for the site(s) where these birds were going during these slow times. The full front (Gulf) beaches of Elmer's Island, Grand Isle, and Grand Terre were surveyed, as well as several broad flats along the northern shoreline of Grand Terre. Virtually no knots were found on these surveys until finally some large flocks of shorebirds were located on the rock breakwaters surrounding Fifi Island across the channel from Grand Isle (Fig. 4). Several hundred knots were present, roosting together with large numbers of Black-bellied Plovers, Marbled Godwits, Willets, and some dowitchers. Remaining very still in the boat we were able to approach quite closely and survey the flock using a small trolling motor and several volunteers with high-quality camera equipment. This resulted in many additional resights of uniquely-marked individuals that had not otherwise been detected during beach surveys, and we were able to repeat this on subsequent days. If this is a common habit for knots at Grand Isle, this is a significant finding for several reasons. First, we know that they can be effectively surveyed (both counted as well as scanned for uniquely-marked individuals) and this will be critical for improving estimates of survival, as well as turnover rates and the total passage population. Second, the wet/dry signals from the recovered geolocators indicate a pattern that suggests extended bouts of feeding followed by a period of rest. These data can be used both to determine factors that drive their usage of the beach vs. the Fifi rock roost (i.e. tide, time of day, human presence on beach), as well as predict their occurrence to optimize when they are likely to be encountered on the beach for improving success of trapping efforts (and recovery of additional geolocators).


Figure 2. Red Knots roosting on breakwater rocks around Fifi Island, Louisiana. The birds are in various stages of molt into alternate plumage. Photo credit: Barbara Keeler.

Wintering Red Knots in Louisiana

Red Knots are known to winter in Louisiana in small numbers, but a thorough deliberate survey to derive an estimate of the winter population has not previously been conducted. However, during the International Piping Plover Census in January 2016, a team of surveyors encountered several hundred Red Knots on the Chandeleur Islands. In January 2018, we conducted a field expedition to attempt to survey the offshore barrier islands from Isles Dernieres in the west to Cat Island to the east by low-flying fixed-wing aircraft, and then conduct a ground-based visit to the Chandeleurs with a team of qualified observers.

On January 19, 2018, we conducted aerial surveys departing and returning from New Orleans in a Cessna 172. The flights covered nearly all of the habitat considered to have potential to support wintering knots. Some large concentrations of shorebirds were detected west of the Mississippi River on the landward side of barrier islands, but most of these were smaller calidrid sandpipers. Several groups of medium-sized shorebirds thought to be knots were detected, mostly west of Port Fourchon at West Belle Pass. Far more knots were detected in the afternoon flight along the Chandeleur Islands. The tidal conditions at the time left vast areas of intertidal flats exposed, so shorebirds of many species were scattered in all directions. Knots are not easily distinguishable from the air until they fly. In several instances, shorebirds took flight and a quick estimate of flock composition was possible to discern knots from other species. Groups of between 20-100 knots were encountered; however, due to the dimensionality of habitat, speed of the plane, mixed species composition of flocks, and limit on time/fuel it was not possible to develop an accurate estimate of the total numbers with any precision. Nevertheless, it is clear that the Chandeleur Islands do indeed support at minimum several hundred wintering Red Knots and possibly up to 1,000.

The following day, a flotilla consisting of two boats provided by Louisiana Department of Wildlife and Fisheries along with a crew of 9 volunteers and staff from CBBEP and BTNEP departed Hopedale in the early morning to conduct the ground survey. Unfortunately, upon arrival to South Chandeleur and disembarking one survey team, the motor on one of the boats suffered a catastrophic engine failure so the survey effort had to be aborted in order to get all people and equipment to safety.

Prior to embarking on the return voyage though, the survey team that had first disembarked on South Chandeleur Island had encountered a flock of 60 knots shortly after beginning the survey route on the sound (western) side of the island, and were able to determine that no less than five of these were uniquely-marked birds (one whose flag had broken was not uniquely identifiable). All of the other birds were knots marked in the same catch on April 28, 2015 on Grand Isle on one of our previous expeditions. None of them had previously been reported to the resight database (www.bandedbirds.org) since the initial capture. This finding is important because it indicates that the "population" of knots using Louisiana is not confined to the Grand Isle area and that an understanding of how knots are using the Chandeleurs will be critical to assessing population size and dynamics going forward. The fact that none of these had been seen since initial capture on Grand Isle in the previous two fall/winter/spring periods suggests the islands may be an additional departure location for knots migrating northward in spring. Given the obvious value of the habitat to knots and the extent of the islands, this may be as important for knots as Grand Isle appears to us now. Historically, habitats on Breton, the Chandeleurs, the Curlews and others, likely supported many more knots than they do now, and that may also have been the case for the other islands west of the birds' foot delta of the Mississippi River prior to the many impacts that resulted in vast loss of barrier islands and wetlands.

ADDENDUM: REKN LA(172)

Another bird with a geolocator from this project – REKN LA(172) – was observed several times in winter 2017/18 on Chiloe Island on the Pacific coast of Chile by a researcher working in the area. In November 2018 it was captured there by the researcher (Dr. Juan Navedo of the Universidad Austral de Chile), who removed the device and later returned it to us. The record contains over fifteen continuous months of light data (April 2017 – October 2018), including two spring migrations from Louisiana and two fall migrations in addition to the winter inbetween. The route (stopover sites) and approximate timing following the Arctic breeding period were consistent between years. From the James Bay region (Manitoba, Canada), the bird flew directly to Suriname on the northern coast of South America where it stayed approximately a month, then passed over the Amazon basin and the Andes mountains to an area near Paracas, Peru for several weeks. Following this, it moved to its wintering area on Chiloe Island. In April 2018, the bird flew direct from Chiloe back to Louisiana.

This is remarkable for several reasons. First, to our knowledge this is the first confirmation from a tracking device of a trans-Andean migratory flight of a Red Knot (though some other shorebird species are known to do so). Most knots in the area of Suriname and the Guianas in fall are thought to either remain on the coast of northern South America, or move much further south to Tierra del Fuego for the winter. We know of only one other geolocator recovered from a bird that wintered in Chiloe (Newstead, unpubl. data). That bird was originally captured and later recaptured on the Texas coast. However, it used a different spring stopover in Saskatchewan, went to breed in northwest Alaska (in the range of *C. c. roselaari*) and in fall migrated down the Pacific coast until reaching Chiloe. It also returned direct from Chiloe to the northwest Gulf of Mexico (Texas) in spring.

REKN LA(172) had the lowest mass (106.7g) of all knots captured during the geolocator deployment in 2017. Assuming it had previously wintered in Chiloe and that its flight timing prior to spring 2017 arrival were the same as that known from the geolocator data in spring 2018, it would have only arrived five days prior to capture. Having recently arrived from a 5+ day direct flight would explain the low mass, and also highlights the critical importance of both Chiloe (which provides the fuel for the first migratory leg) and Louisiana (which provides fuel to reach the Arctic).

Another notable revelation from this geolocator is that the bird appeared to enter the Arctic in the range of the *C. c. rufa* subspecies. This is the same as the other two geolocator recoveries from Louisiana, but different from that of the previous Texas geolocator recovery of a knot that wintered in Chiloe (which went to Alaska to breed in the range of *C. c. roselaari*). This suggests that Chiloe is used by both subspecies as a wintering site. Further analysis of genetic samples is necessary to clarify the relative proportions of the subspecies using the site.

Given that at least eight other knots marked in Louisiana have been seen at Chiloe – and one marked in Chiloe seen in Louisiana – there appears to be a strong connection between that unique wintering population and the northwest Gulf of Mexico coast. Since that population is relatively small, probably numbering in the low hundreds, further exploration of the Chiloe wintering population is warranted since it appears to be an analogue of the long-distance migrant *C. c. rufa* population that winters in Tierra del Fuego on the Atlantic coast (based on overall migratory distance and presumed similarities in molt strategy), and may represent a similarly distinct genetic lineage. Chiloe is a relatively small site, separated from other suitable Red Knot habitat by substantial distances, but is of hemispheric importance to shorebirds such as Whimbrel and Hudsonian Godwit according to Western Hemisphere Shorebird Reserve Network (https://www.whsrn.org/humedales-orientales-de-chiloe). The habitats that support knots in Chiloe are also known to be facing a growing number of threats related to developments such as wind energy, human recreation, salmon farming and other industrial activities that may impact water (and prey) quality.

RECOMMENDATIONS

1. Continue trapping effort to recover geolocators in Louisiana. The full life-cycle data obtained from each of these geolocators is invaluable in understanding the variety in migratory strategies

exhibited by knots in Louisiana, and will be critical in directing appropriate emphasis on necessary conservation actions there.

2. Increase survey efforts focused on resights and proportions or marked:unmarked knots on beaches of Grand Isle and the Fifi Island breakwater roost during spring (April-May). This will facilitate estimation of turnover rates, annual apparent survival, and population size – key metrics for assessing current status and impacts of conservation actions in the future. Surveys should be conducted following a protocol that also allows estimation of the influence of various environmental and anthropogenic factors on distribution and occupancy.
3. Conduct ground-based survey of Chandeleur Island and others associated with the Breton National Wildlife Refuge to determine the composition and size of the population that remains in Louisiana through the winter.
4. Initiate discussion with representatives of the Town of Grand Isle regarding the importance of their beaches to this species especially during the spring months, and the potential impacts from their own activities as well as activities of the public under their scope of management influence. Consider supporting partnerships with schools and civic groups to raise awareness and engage them in conservation efforts such as signage and public outreach to beachgoers.
5. Encourage international partnerships focused on the implementation of conservation measures (and research where it is lacking) across the network of sites that are demonstrated to be of significance to the knots that occur in Louisiana.

ACKNOWLEDGMENTS

A tremendous amount of volunteer time and expense has been contributed to this project and previous expeditions by a vast cadre of wonderful and passionate people. In particular, we especially wish to thank Casey Wright and Michael Seymour of Louisiana Department of Wildlife and Fisheries, and Brigette Firmin of US Fish & Wildlife Service Louisiana Ecological Services Field Office for supporting the ongoing research. Many thanks to Greg Lamulle for providing the boat excursions that led us to discover the Fifi breakwater roost, to Barbara Keeler and Eric Hernández Molina for their substantial photographic contributions, and to Dr Juan Navedo of the Universidad Austral de Chile for returning the geolocator recovered from Chiloe Island.

LITERATURE CITED

Baker, A.J., P.M. González, T. Piersma, L.J. Niles, I. de Lima Serrano do Nascimento, P.W. Atkinson, N.A. Clark, C.D.T. Minton, M.K. Peck & G. Aarts. 2004. Rapid population decline in red knots: fitness consequences of decreased refueling rates and late arrival in Delaware Bay. *Proc. R. Soc. London B.* 271:875-882.

Newstead, D.J., Niles, L.J., Porter, R.R., Dey, A.D., Burger, J. & Fitzsimmons, O.N. 2013. Geolocation reveals mid-continent migratory routes and Texas wintering areas of Red Knots *Calidris canutus rufa*. *Wader Study Group Bull.* 120(1): 53–59.

Porter, R. & Smith, P.A. 2013. Techniques to improve the accuracy of location estimation using light-level geolocation to track shorebirds. *Wader Study Group Bull.* 120(3):147-158.