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Light-level geolocation reveals the migration route and non-breeding location of an Antillean Nighthawk (*Chordeiles gundlachii*)

Noah Perlut[1] and Anthony Levesque[2]

Abstract The Antillean Nighthawk's (*Chordeiles gundlachii*) migration routes and non-breeding location were previously unknown. We deployed a geolocator on a female Antillean Nighthawk found breeding on the Lesser Antilles island of Guadeloupe and tracked her annual movements between 2013 and 2014. Her journey included a 2-month stopover on Isla La Tortuga, Venezuela, during southward migration, and a non-breeding season in the remote forestlands of the state of Amazonas, Brazil, approximately 2,100 km south of her breeding grounds. Her migration route was geographically similar in both the fall and spring, following a north-south trajectory, but lacked a prolonged stopover in the spring.

Keywords Amazonas, Antillean Nighthawk, *Chordeiles gundlachii*, geolocator, Guadeloupe, migration, non-breeding period

Resumen El uso de geolocalizadores ligeros revela la ruta migratoria y la ubicación de las áreas no reproductivas de *Chordeiles gundlachii*—Las rutas migratorias y las áreas no reproductivas de *Chordeiles gundlachii* no se conocían previamente. Utilizamos un geolocalizador en una hembra de esta especie que fue encontrada criando en la isla de Guadalupe, Antillas Menores, y monitoreamos sus movimientos anuales entre 2013 y 2014. Su viaje incluyó una parada de 2 meses en isla La Tortuga, Venezuela, durante la migración hacia el sur. Pasó la temporada no reproductiva en bosques remotos del estado de Amazonas, Brasil, aproximadamente 2.100 km al sur de sus áreas de cría. Su ruta migratoria fue geográficamente similar tanto en el otoño como en primavera, siguiendo una trayectoria norte-sur, pero carecía de una parada prolongada en la primavera.

Palabras clave Amazonas, *Chordeiles gundlachii*, etapa no reproductiva, geolocalizador, Guadalupe, migración

Résumé La géolocalisation révèle la route migratoire et les zones d'hivernage d'un Engoulevent piramidig (*Chordeiles gundlachii*) — Les routes migratoires et les zones d'hivernage de l'Engoulevent piramidig (*Chordeiles gundlachii*) étaient auparavant inconnues. Nous avons fixé un dispositif de géolocalisation sur une femelle d'Engoulevent piramidig qui nichait en Guadeloupe (Petites Antilles) et nous avons suivi ses déplacements annuels entre 2013 et 2014. Son voyage comprenait une halte migratoire de deux mois sur l'Isla La Tortuga, au Venezuela pendant la migration vers le sud, et une période d'hivernage dans les forêts reculées de l'État d'Amazonas, au Brésil, à environ 2100 km au sud de sa zone de nidification. Sa route migratoire, géographiquement semblable à l'automne et au printemps, suivait une trajectoire nord-sud, mais ne présentait pas de halte migratoire prolongée au printemps.

Mots clés Amazonas, *Chordeiles gundlachii*, Engoulevent piramidig, géolocalisation, Guadeloupe, hivernage, migration

Miniaturized tracking devices, including light-level geolocators, archival GPS tags, and nanotags are rapidly expanding our understanding of the life histories of migratory birds (Wilmers *et al.* 2015, McKinnon and Love 2018). For example, these tracking devices have explored migratory connectivity within a given species (Stanley *et al.* 2015) and through cross-species meta-analysis (Finch *et al.* 2015). They have helped to identify sex-specific carry-over effects of migration phenology and overwintering habitat on fecundity (Saino *et al.* 2017), as well as the movements of birds during non-breeding periods when those birds were previously thought to be stationary (Renfrew *et al.* 2013, Heckscher *et al.* 2015, McKinnon and Love 2018). The majority of tracking studies have focused on describing migratory connectivity in the context of the full annual cycle (Rushing *et al.* 2014) and quantifying natural history (McKinnon and Love 2018), since the basic ecology of many common and rare species remains unknown.

The Antillean Nighthawk (*Chordeiles gundlachii*) is a relatively common species (BirdLife International 2016) and its breeding behavior is documented (Stevenson *et al.* 1983, Delannoy 2005). However, little is known about its life cycle outside of the breeding period (May–July). Notably, the migratory behavior of this species—including whether it migrates at all—is unknown.

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Fig. 1. We deployed a 0.65-g solar geolocator on a female Antillean Nighthawk using a leg-loop backpack harness made of Teflon tape.

Antillean Nighthawk observations recorded in eBird between November and March, during the non-breeding period (eBird 2018), correspond with much of the species' breeding distribution within the Caribbean islands (BirdLife International 2016). The known non-breeding distribution spans western Cuba to the eastern side of St. Thomas in the United States Virgin Islands (eBird 2018), and reaches from Bermuda in the north to Aruba in the south. These data suggest that Antillean Nighthawks may spend their entire annual cycle in the Caribbean islands and Bermuda. Nonetheless, we aimed to better understand the movements and non-breeding location of Antillean Nighthawks through the use of light-level geolocation. In July 2013, we deployed a geolocator on a single female Antillean Nighthawk and retrieved the unit in July 2014. Here we describe the migration, stopover, and non-breeding location of this bird.

Methods

In early June 2013, we discovered an Antillean Nighthawk nest in the region of Pointe des Chateaux, at the far eastern end of Grand-Terre, Guadeloupe (16°15'02.8"N, 61°11'05.3"W). We used a mist net to catch the female near her single-egg nest on 14 July 2013, and identified her sex by plumage, the presence of a brood-patch, and subsequent incubation behavior (Fig. 1). We attached a 0.65-g Intigeo®-P65C2-7 solar geolocator (Migrate Technology Ltd., Cambridge, UK) using a leg-loop backpack harness made of 0.254-cm Teflon® tape (Bally Ribbon Mills, Bally, PA, USA; Fig. 1). Before the geolocator was attached, the female weighed 62.1 g. The following breeding season, the female laid a new single-egg nest in the same area, and on 27 July 2014, we recaptured her near her nest, removed the geolocator, and offloaded the data. We did not weigh the female in 2014. We processed the raw light-level data and conducted analyses following Perlut (2018).

We downloaded and formatted the data in IntiProc v1.03 (Migrate Technology Ltd.). Using the BAStag package (Wotherspoon *et al.* 2016) within program R (R Core Team 2016), we estimated daily twilight times (light threshold = 1) and then used FLightR (Rakhimberdiev *et al.* 2017) to convert estimates of twilight times into estimates of longitude and latitude. We calibrated the data during the late 2013 (15 July–31 August) and early 2014 (20 May–20 June) breeding periods, when the female was likely on her breeding grounds in Guadeloupe. We then used FLightR to map migration routes and identify the posterior distribution for the non-breeding location, including a linear model to adjust for decay in the light-gathering capability of the geolocator (Rakhimberdiev *et al.* 2015). FLightR uses a "template fit" method (Ekstrom 2004) to estimate the geographic locations of migrating animals based on the time and duration of sunrise and sunset. Specifically, it uses a particle filter algorithm to probabilistically estimate location across a spatial grid. It includes optional user-defined behavioral and spatial masks that can limit movement to, for example, a certain speed or direction (Rakhimberdiev *et al.* 2017). We ran FLightR with 106 particles with the outlier routine turned on and the behavioral and spatial masks turned off. We identified the onset of the female's fall migration as the first movement of at least 45 km (the default FLightR minimum distance for movement), used the "stationary.migration.summary" function in FLightR, with a 5% minimum movement probability, to identify stationary (≥ 2 consecutive twilights) and movement periods throughout the fall migration, and combined nearby stopover sites (< 45 km apart; adopted from Hahn *et al.* 2014, Jacobsen et al. 2017). We manually assessed the light data for each (quartile) departure and arrival date retrieved from the "stationary.migration.summary" function. In cases where this manual inspection of the light data indicated that the bird arrived or departed on a date that differed from the median, we reported the date from our manual inspection. However, we included all of the quartile dates in Table 1.

Results

The female Antillean Nighthawk left her breeding grounds at Pointe des Chateaux, Guadeloupe on 4 September 2013, and arrived at her stopover location, Isla La Tortuga, Venezuela, on 17 September 2013 (Table 1, Fig. 2). Isla La Tortuga is located approximately 80 km from the northern coast of mainland Venezuela and 720 km southwest of Guadeloupe. The female remained around the island until 16 November, and arrived at her non-breeding grounds in the state of Amazonas, Brazil on 20 January 2014 (Table 1). The non-breeding grounds were remote forestland approximately 2,100 km south of the breeding grounds in Guadeloupe (Fig. 2).

This entire southward migration, including the 60-day stopover on Isla La Tortuga, took 138 days. After 66 days in Brazil, the female departed the non-breeding grounds on 1 April 2014 and returned to the Guadeloupe breeding grounds 8 days later, on 9 April 2014 (Table 1, Fig. 3). She appeared to follow a similar route during south- and northward migrations, but her northward migration did not include a lengthy stopover.

Discussion

Here we present the first data describing the migration route and timing, stopover location, and non-breeding location of an Antillean Nighthawk. After leaving the breeding grounds,

Table 1. The timing and latitude associated with movement by a female Antillean Nighthawk. SD, standard deviation; Q25, 25th quartile; Q50, 50th quartile; Q75, 75th quartile; Q97.5, 97.5th quartile.

	Date	Q25	Q50	Q75	Q97.5	Mean Latitude	SD	Mean Longitude	SD
Left Breeding Grounds	4 Sep 2013	1 Sep 2013	4 Sep 2013	7 Sep 2013	11 Sep 2013				
Arrived Stopover Location	17 Sep 2013	16 Sep 2013	17 Sep 2013	22 Sep 2013	7 Oct 2013	10.739	1.135	−64.914	0.819
Left Stopover Location	16 Nov 2013	15 Nov 2013	21 Nov 2013	22 Nov 2013	NA				
Arrived Non-Breeding Grounds	20 Jan 2014	20 Jan 2014	21 Jan 2014	27 Jan 2014	20 Feb 2014	−2.330	2.332	−64.413	0.785
Departed Non-Breeding Grounds	1 Apr 2014	1 Apr 2014	1 Apr 2014	5 Apr 2014	6 Apr 2014				
Arrived Breeding Grounds	9 Apr 2014	7 Apr 2014	10 Apr 2014	12 Apr 2014	6 Apr 2014				

this individual had a 2-month stopover on a coastal island of Venezuela and then moved south to a forested region in the state of Amazonas, Brazil. To our knowledge, there are no capture or observation records of this species in Brazil or mainland South America. Citizen science observations through eBird (2018) have only recorded this species as far south as the island of Aruba. The single observation described in Aruba (10 October 2016) may have been a bird on stopover, as it corresponds with the data presented here in terms of both timing and latitude (Aruba is ~500 km west of Isla La Tortuga). Additionally, there have been a number of winter observations (November–March) made as far east as the United States Virgin Islands, as far west as Cuba, and as far north as Bermuda (eBird 2018). However, the citizen science birding lists for Brazil, Suriname, and French Guiana show no records for this species (Birds in Suriname 2018, Oiseaux.net 2019, WikiAves 2019), and there are no South American records of this species in the global museum collection database (VertNet 2019) or the Global Biodiversity Information Facility (GBIF Secretariat 2017). We do not know if the migration route and stopover and non-breeding locations presented here are metapopulation-specific or anomalous. Assuming that these data describe the metapopulation, there are possible explanations for why this species has not been documented in South America: 1) the bird watching community might not visit the region where the Antillean Nighthawk overwinters due to the remote nature of the Amazon; 2) it is difficult to distinguish the Antillean Nighthawk from closely related species by plumage or vocalizations.

In contrast to the apparently similar migration route taken by the female in our study for both south- and northward migration, Eurasian Nightjars (*Caprimulgus europaeus*) follow a loop migration route. Yet, like the female described in our work, they too have been shown to rely on a stopover site, though only for 2 to 3 weeks (Evens *et al.* 2017) instead of 2 months. Canada-breeding Eastern Whip-poor-wills (*Antrostomus vociferus*) use stopover sites north of the Gulf of Mexico for 4 to 15 days before migrating to their non-breeding grounds between central Mexico and Costa Rica (English *et al.* 2017). The Eurasian Nightjar and Eastern Whip-poor-will both selected stopover regions just prior to encountering significant ecological barriers, which include the Sahara and the Gulf of Mexico, respectively (English *et al.* 2017, Evens *et al.* 2017). However, two other tracking studies of Eurasian Nightjars found stopovers after crossing an ecological barrier rather than before (Jacobsen *et al.* 2017, Norevik *et al.* 2017). Recent tracking work identified the migration route and non-breeding location for the Common Nighthawk (*Chordeiles minor*), which travels from northern Canada to Brazil's Cerrado and Amazon biomes, approximately 1,900 km southwest of the non-breeding location of the Antillean Nighthawk (Ng *et al.* 2018). Although Ng *et al.* (2018) used a different method, collecting tracking tag data every 10 days, they found that Common Nighthawks did not appear to have an extended stopover either before or after crossing the Gulf of Mexico.

The Antillean Nighthawk is known to nest in the same regions as other similar species (Puerto Rican Nightjar [*Antrostomus noctitherus*], Delannoy 2005; Common Nighthawk, Stevenson *et al.* 1983), and the results of this study suggest that Antillean Nighthawks may spend the non-breeding season in regions similar to those used by closely related species like the Common Nighthawk (English *et al.* 2017, Ng *et al.* 2018). Future work should identify the migration and non-breeding locations of other Antillean Nighthawk populations and, with a known focal region, explore habitat selection and niche partitioning with other related species.

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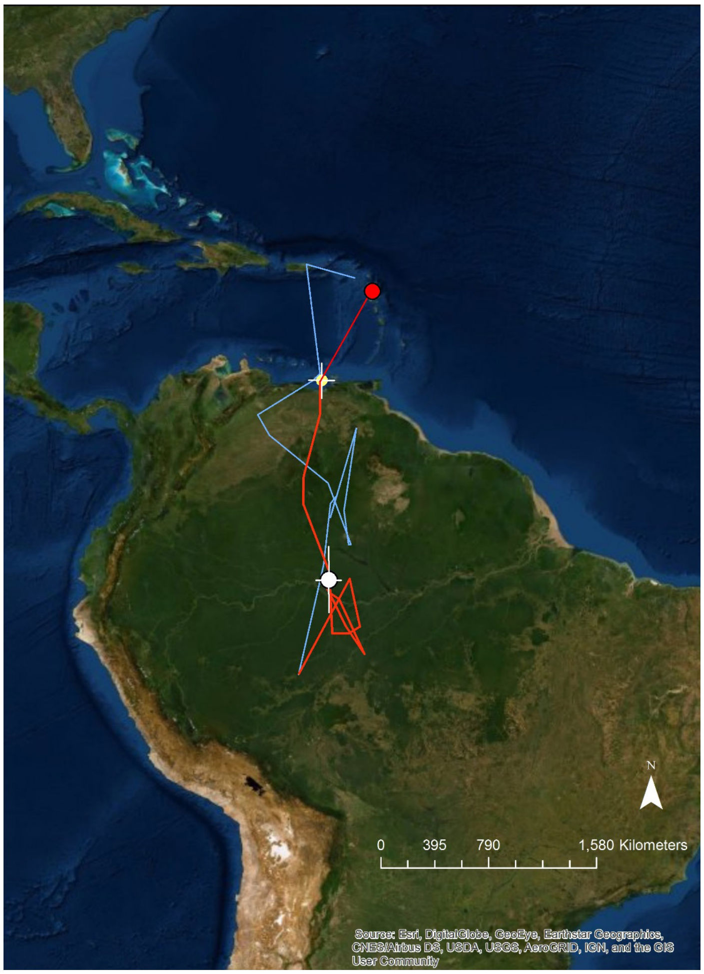

Fig. 2. A female Antillean Nighthawk's stopover grounds on Isla La Tortuga (yellow dot) and Brazilian non-breeding grounds (white dot) were approximately 720 km southwest and 2,100 km south, respectively, of her breeding grounds on Guadeloupe (red dot). Daily median positions are shown with a blue line for fall migration and a red line for spring migration. The error bars indicate 1 SD around the mean stopover and non-breeding grounds locations.

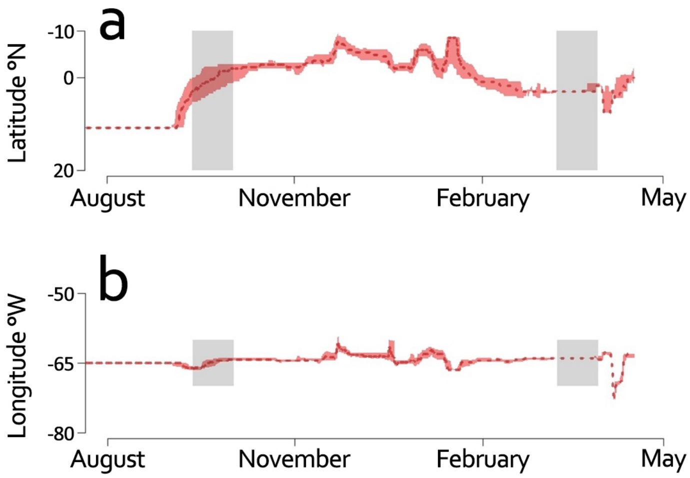

Fig. 3. Geographic locations of a female Antillean Nighthawk during the non-breeding season in 2013–2014. Median latitude (a) and median longitude (b) are shown as dotted lines and interquartile ranges as red shaded areas, gray shaded boxes represent 20-day intervals around the fall (12 September 2013 to 2 October 2014) and spring (10–30 March 2014) equinoxes when latitude is less certain.

Title Page Illustration

Photo taken by Marine Bely on 14 July 2013 at Pointe des Châteaux, St François, Guadeloupe.

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