Initial Deployment of Archival Light-Level Geolocators on Northern Waterthrushes (*Parkesia noveboracensis*) at Jobos Bay, Puerto Rico

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Abstract. The effective conservation of long-distance migratory birds requires the identification and protection of the birds, nesting habitat as well as their stop-over and wintering habitats. This project provides the first implementation of archival light-level geolocator data logger technology by a Puerto Rican institution to study the migratory connectivity of Neotropical migratory birds in Puerto Rico and complements existing information derived from banding returns and stable isotope analyses to determine the geographic origins in North America of birds that occur in Puerto Rico during the non-breeding seasons. We apply this technology, only recently made available to the general public, to help establish the specific intercontinental migratory connectivity of the 15-20 g Northern Waterthrush (*Parkesia noveboracensis*), a species breeds in North America and passes the winter in the Caribbean, Central and South America. We deployed 40 data loggers on Northern Waterthrushes at Jobos Bay in Salinas, Puerto Rico in coastal dry forest habitat from September 2015 through April 2016 as birds wintered in Puerto Rico and prepared for their return to nesting grounds in North America. This report provides a preliminary analysis of the results obtained from the data loggers recovered from birds that returned to Puerto Rico from September 2016 through April 2017. Of these 11 (28%) were recovered from September 2016 to April 2017 – a success rate that compares favorably with previous studies elsewhere. 

**Keywords:** Migratory connectivity, Northern Waterthrush (*Parkesia noveboracensis*), light archival level geolocators, Puerto Rico, Jobos Bay.

Despliegue Inicial de Geolocalizadores Archivales de Nivel de Luz en la Pizpita de Mangle (*Parkesia noveboracensis*) en la Bahía de Jobos, Puerto Rico

Resumen. La conservación efectiva de las aves migratorias de larga distancia requiere la identificación y protección de las aves, el hábitat de anidación, así como sus hábitats de parada e invernada. Este proyecto provee la primera implementación de tecnología de registro de datos de geolocalizador archivable de nivel de luz por una institución puertorriqueña para estudiar la conectividad migratoria de aves migratorias neotropicales en Puerto Rico y complementa la información existente derivada de retornos de bandas y análisis de isótopos estables para determinar los orígenes geográficos en América del Norte de las aves que ocurren en Puerto Rico durante las estaciones no reproductivas. Aplicamos esta tecnología, recientemente puesta a disposición del público en general, para ayudar a establecer la conectividad migratoria intercontinental específica de los 15-20 g de la pizpita de mangle (*Parkesia noveboracensis*), una especie que se cria en América del Norte y pasa el invierno en el Caribe, Centro Y Sudamérica. Desplegamos 40 madereros de datos en la Bahía de Jobos en Salinas, Puerto Rico, en el hábitat de bosque seco costero desde septiembre de 2015 hasta abril de 2016, cuando las aves inviernaron en Puerto Rico y se
prepararon para su regreso a las áreas de anidación en Norteamérica. Este informe proporciona un análisis preliminar de los resultados obtenidos de los registros recuperados de aves que regresaron a Puerto Rico de septiembre de 2016 a abril de 2017. De estos 11 (28%) fueron recuperados de septiembre de 2016 a abril de 2017 – una tasa de recuperación que compara favorablemente con estudios previos en otros lugares.

**Palabras clave**: Conectividad migratoria, Pizpita de Mangle (Parkesia noveboracensis), geolocalizadores archivales de nivel de luz, Puerto Rico, Bahía de Jobos.

**Introduction**

A recent comprehensive analysis by Nytch et al. 2015 indicated that according to the most recent analysis of conservation planning priorities conducted by a joint task force of internationally recognized experts from the US Fish and Wildlife Service (Florida/Caribbean Migratory Bird Field Office), and the USDA Forest Service International Institute of Tropical Forestry (Nytch et al. 2015), Jobos Bay Estuary National Research Reserve (Figure 1) is among those habitats and designated stewardship areas that stand out as top priority habitats in which to focus additional conservation efforts, yet insufficient substantive information is available (Nytch et al. 2015).

An important factor to consider is the rise in sea level that is projected to accompany increased global temperatures associated with climate change, and the effects this will have on coastal dry forest habitat. One anticipated outcome of rising seas and mutable coastal morphology is that mangroves will successfully accrete peat and migrate inland (where human infrastructure is not a barrier), thereby encroaching on dry forest habitat (McKee et al. 2007; Kerr 2009; Blunden et al. 2011; McKee 2011). Management and conservation require knowledge on the timing and pattern of migration, details on demography and habitat use patterns on the wintering sites, and the awareness of, and will to conserve migratory species at their nesting, stop-over and wintering sites.

If dry forest does not expand into new areas at the same rate it is converted to estuarine habitats, native and migratory birds that rely on dry forest for breeding and overwintering could be at risk (PRCCC 2013a, 2013b). Rodríguez-Colón (2012), for example, studied North American migrant songbirds that depend on interconnected mangrove and dry forest habitat in Puerto Rico’s southern coastal region of Jobos Bay National Estuarine Research Reserve, concluding that these populations will be jeopardized by sea level rise if dry forest habitat is reduced, degraded, or eliminated. Avian populations in other coastal dry forest areas in Puerto Rico may face a similar threat, resulting in compromised reproduction and overwintering survival. Thus, and adequate assessment of habitat quality and avian populations in these and adjacent areas is essential (Rice et al. 2007; Jacobs et al. 2012a, 2012b; Rodríguez-Colón 2012; Nytch et al. 2015).
Long-distance migratory organisms are under strong selection to migrate efficiently. Long distance flights of thousands of km in Neotropical migratory songbirds, highlight the key importance of stopover sites and efficient migratory routes to the migration strategy of this species (Forschler and Bairlein 2011; Stanley et al. 2012, 2014; Arlt et al. 2013; Bridge et al. 2013; Cotina et al. 2013; McKinnon et al. 2013, 2014, 2015; Renfrew et al. 2013; Hobson et al. 2014; DeLuca et al. 2015; Cooper et al. 2017; Gómez et al. 2017; Snijders et al. 2017). Neotropical migrant birds can be limited in size by factors such as reproductive success and parental survival rates during the breeding season, and by individual survival during the non-breeding season (see also Marra et al. 1993), as well as during the long-distance migration between sites (see Paxton et al. 2007; 2008; Faaborg et al. 2010a, 2010b, Hobson et al. 2014). Moreover, a species may occur in distinct populations that winter in different locations or whose departure and return dates may be quite different, and these differences may be key to understanding population trends. For example, Rubenstein et al. (2002), using stable isotopic methods demonstrated that northern populations of the Black-throated Blue Warbler (Setophaga caerulescens) with stable population trends wintered in Cuba and the Western Greater Antilles, while declining populations nesting in the southern portion of their range tended to winter in eastern Hispaniola.

Kelly et al. (2002) and Kelly (2006) used isotopic methods to examine migratory patterns and dispersal distances in multiple species and contrasted distinct patterns of migration timing of birds passing through their stop-over site in New Mexico: (1) “chain migration” (which may be typical of medium distance migrants) in which all nesting populations begin moving at about the same time such that southern nesters arrive before more northern nesters and “leap frog
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migration" (which may be characteristic of very long distance migrants) in which northern populations begin moving earlier, overflying southern populations. A similar pattern of leapfrog migration also has been recently revealed in Ovenbirds (*Seiurus aurocapilla*) by Hallworth and Marra (2015) using Miniaturized GPS tags and demonstrate the potential of using geolocator technology to elucidate connectivity and patterns of migration.

Our mist netting recoveries compare favorably with those of Hallworth et al.'s (2013) geolocator study wherein they recaptured 20 of 50 (40%) Ovenbirds on the nesting grounds; and, they also recaptured 12 of 46 (26%) Ovenbirds in route or on the wintering grounds in Florida and Jamaica, and also compare well to recovery rates of geolocators in previous studies elsewhere (Table 1). Though not encumbered with a geolocator, the ability to predictably recapture Northern Waterthrushes at JBNERR makes these birds excellent candidates for a geolocator study of the nesting origins of the Reserve's winter visitors, as well as possible winter movements further south.

<table>
<thead>
<tr>
<th>Study</th>
<th>Species</th>
<th>Recovery</th>
<th>Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stutchbury et al. 2009</td>
<td>Purple Martin</td>
<td>3/16</td>
<td>19%</td>
</tr>
<tr>
<td>Stutchbury et al. 2009</td>
<td>Purple Martin</td>
<td>2/18</td>
<td>11%</td>
</tr>
<tr>
<td>Stutchbury et al. 2009</td>
<td>Wood Thrush</td>
<td>2/14</td>
<td>14%</td>
</tr>
<tr>
<td>Bairlein et al. 2012</td>
<td>N Wheatear</td>
<td>5/30</td>
<td>16%</td>
</tr>
<tr>
<td>Bairlein et al. 2012</td>
<td>N Wheatear</td>
<td>2/16</td>
<td>13%</td>
</tr>
<tr>
<td>MacDonald et al. 2012</td>
<td>Snow Bunting</td>
<td>13/90</td>
<td>14%</td>
</tr>
<tr>
<td>Contina et al. 2013</td>
<td>Painted Bunting</td>
<td>5/11</td>
<td>15%</td>
</tr>
<tr>
<td>Hallworth et al. 2013</td>
<td>Ovenbird</td>
<td>20/51</td>
<td>39%</td>
</tr>
<tr>
<td>Hallworth et al. 2013</td>
<td>Ovenbird</td>
<td>12/46</td>
<td>26%</td>
</tr>
<tr>
<td>Renfrew et al. 2013</td>
<td>Bicknell's Thrush</td>
<td>4/45</td>
<td>9%</td>
</tr>
<tr>
<td>Renfrew et al. 2013</td>
<td>Bicknell's Thrush</td>
<td>13/60</td>
<td>22%</td>
</tr>
<tr>
<td>McKinnon et al. 2014</td>
<td>Wood Thrush</td>
<td>62/355</td>
<td>18%</td>
</tr>
<tr>
<td>Stanley et al. 2014</td>
<td>Wood Thrush</td>
<td>102/733</td>
<td>14%</td>
</tr>
<tr>
<td>DeLuca et al. 2015</td>
<td>Blackpoll Warblers</td>
<td>5/37</td>
<td>11%</td>
</tr>
<tr>
<td>Peterson et al. 2015</td>
<td>Gldn-wgd Warblers</td>
<td>18/39</td>
<td>39%</td>
</tr>
</tbody>
</table>

**Mist Netting and Banding**

We continued mist netting and banding during 2015-2016 as in previous seasons and noted a considerable increase in Northern Waterthrushes from nearly 200 the previous season 2014-2016 to about 300 in 2015-2016 (Table 2). This included our first “Foreign” recapture. This was a
Northern Waterthrush captured at the mesquite site (La Poza) on 12 December 2015 that had been originally banded on 3 September 2013 by Michelle J Davis at Bill Baggs State Park in Miami, Florida. Additional and more detailed analyses of the season’s and long term and banding data are underway, including species richness, diversity and dominance.

Table 2. Total numbers of encounters, new bands, and recaptures of passerines and near passerines, as well as the number of Northern Waterthrush (NOWA) new captures (New Bands) and recaptures for 2014-15 and 2015-16. Recaptures include same day and subsequent recaptures (thus total captures are slightly lower).

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Total Encounters</td>
<td>1008</td>
<td>1150</td>
</tr>
<tr>
<td>Total Banded</td>
<td>643</td>
<td>712</td>
</tr>
<tr>
<td>Total Recaptures</td>
<td>298</td>
<td>394</td>
</tr>
<tr>
<td>Unprocessed</td>
<td>53</td>
<td>44</td>
</tr>
<tr>
<td>NOWA New Bands</td>
<td>83</td>
<td>174</td>
</tr>
<tr>
<td>NOWA Recaptures</td>
<td>117</td>
<td>138</td>
</tr>
</tbody>
</table>

Stable Isotopic Analysis

Preliminary results from feather deuterium analyses have been reported (see previous article in this volume of Ambientis) and presented in various fora, including the Birds Caribbean meeting in Jamaica in 2015. Subsequently, a total of over 640 feathers collected in 2013-2014 have undergone laboratory analysis and statistical analyses are now underway. Additional samples from 2015-2016 have still await laboratory analyses.

Geolocator Deployment

This project provides the first implementation of archival light-level geolocator technology in Puerto Rico to better understand the migratory connectivity of migrant songbirds, especially the Northern Waterthrush (Parkesia noveboracensis). This is one of the most significant species occurring in our coastal dry forest and may be an important indicator of habitat quality. Complete understanding of population trends in this habitat and for all migratory species requires understanding of phenomena that occur on the nesting, stop-over and wintering areas.

Migratory connectivity is an important concept for understanding the biology of migratory birds (most species are declining) and for better implementation of strategies for their conservation and protection of their habitat. While general information exists on the overall nesting, migratory and wintering areas of many species, specific details that can connect a specific population’s wintering area with its breeding that population’s specific nesting location and migratory stop-over areas is lacking for most species. Approaches to resolve these mysteries involve the use of (1) visual
observations, mist netting and color banding returns, (2) stable isotopic analyses, and (3) remote sensing or electronic tracking data. This more precise characterization exists for only a few species and populations, none of which occur in Puerto Rico or the eastern Caribbean.

Archival light level geolocators are a relatively new technology, originally developed by the British Antarctic Survey to track long distance animal movements. This technology makes use of on-board miniature data loggers to determine latitude and longitude based on day length and date, and time of solar apogee (noon) relative noon at GMT (ZULU time). The sensors are activated and placed on the bird. The bird is then released and the data are downloaded from the data logger upon recapture. This technology was first made available to the public in 2007 and first used on large species, but recent advances in miniaturization have produced geolocators sufficiently small (about 0.5 g) for use on tiny songbirds.

We initially obtained 20 geolocators and placed our first geolocator on a Northern Waterthrush on Monday, Sept. 21st, 2015 – one of the first geotagged birds in Puerto Rico and the first placed by a Puerto Rican institution (Figure 2). However, with recapture probabilities substantially less than 100%, we felt we needed additional units in order to achieve sufficient returns to determine the proportions of birds that use Puerto Rico as a transit (stop-over) location versus those that use our site as a complete wintering area. Although these first-deployed units (Migrate Technology Integeo-P50B1-7-dip, ca. 0.5 g) offered the advantage of an 11-month estimated battery life, their greater weight meant that we had to be very selective and only deploy on birds ov

![Figure 2. First geolocator placed on a Northern Waterthrush (Parkesia noveboracensis) in Salinas, Puerto Rico, 21 Sep 2015.](image)

Some 20 additional units were purchased with in March 2016. These newer units were the Migrate Technology Integeo-P30Z-7- DIP Light-level Geolocator model, with an estimated battery life of 6-7 months (vs 11 months for the previous units). They have the advantage of being light enough (less than 0.40 g) to be placed on any sized Northern Waterthrush (Figure 3), but the disadvantage they present is that they cannot be activated or deactivated on board (on the bird) and data cannot be downloaded onboard. However, the estimated battery life of these newer units

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should be sufficient enough to capture the birds’ return trips to their nesting grounds and most of their flights back from their nesting grounds.

Both the previous units and the new units were mounted on the birds using a modification of the leg-loop harness of Rappole and Tipton (1981) and Streby et al. (2015) (Figure 4). The previous units also could be activated in the field and all but two (2) were mounted with a custom-fitted braided nylon cord provided by the manufacturer (Figure 5). In contrast to the previous units, the new units must be activated and the contacts cut and sealed with adhesive prior to deployment on the bird (Figures 6 and 7).
Figure 5. Field activation of the older model geolocator. Also shown is the braided nylon cord used to custom-fit the units to the bird.

Figure 6. Activation of the Migrate Technology Integeo-P30Z-7-DIP geolocator.
In contrast to most (all but 2) of the previous units we used 0.8 mm or 0.7 mm “Stretch Magic” flexible clear plastic cord to construct the leg loop harness for the new units. The cord was joined by heating the cut ends with a common soldering iron and then joining the melted ends together. The “span”, or leg to leg distance of the harness was initially established based on regression equations of Naef-Daenzer (2007), which were developed for multiple species (Figures 8-10). After some experimentation, for many birds we conducted fitting and activation in the field by setting up a “mini-lab” by connecting the soldering iron to a vehicle battery through an inverter and activation as usual with a laptop computer (Figures 11 and 12).
Figure 8. Laboratory set-up for fitting leg loop harnesses and activating geolocators.

Figure 9. Joined leg loop harness joined after heating with a soldering iron.

Figure 10. Measuring the leg loop harness "span".
Figure 11. Field “mini-lab” setup for custom fitting of geolocator harnesses for individual birds, including a conventional soldering iron connected via an AC inverter to a vehicle battery.

Figure 12. Joining a leg loop harness harnesses in the field.

A total of 21 Geolocator units were placed on birds from February 27th through April 3rd, 2015, in addition to the 19 units deployed Sep-Dec 2015 – a total of 40 units were deployed on birds in the environment. Three birds tagged during Sep-Dec 2015 were recaptured on Feb. 7, 27 and 28, 2016 (birds 29906, 5287 and 3307, respectively), and bird 29906 was recaptured again on April 10th, 2016. All were found to be in excellent physical condition and bird 52874 had increased it body mass by 10% at the time of recapture (18.0 g on Dec. 12th to 19.9 g on Feb. 27th, not including the tag). On Feb. 28th, 2016 the heavier tag that bird 39307 carried since October 4th, 2015 was replaced with the newer, lighter model unit (Figure 13). By the end of the season (May 1st, 2015) 19 birds had been fitted with the older units in (Sep-Dec 2015) and released – 17 with braided cord harnesses and two with plastic harnesses. Nine of these were birds that had been captured and
banded in a previous year or previously during the same season (Recaptures), while 10 were birds captured for the first time (New Bands). All geolocator deployed birds were captures at either the mesquite site (“La Poza”) or at the interhabitat corredor site (“El Corredor”).

Figure 13. Comparison of the lighter model Integeo-P30Z-7-DIP (left) with the older model unit removed from bird 39307 on 28 Feb 2016.

Of a total of 1 older model and 20 new model Integeo-P30Z-7-DIP geolocators were deployed from Feb. 27th through April 3rd, 2015 (Figures 14-15), five were recaptured birds while 16 were new captures. Of this combined group (of 21 birds) six were subsequently captured on seven occasions and all had gained weight (not counting the geolocator). Bird 54269 showed a dramatic body mass increase from 15.65 g to 24.09 g, suggesting that it had adapted well to carrying the unit. These observations suggested that the 40 tagged birds were tolerating the geolocators well and we look forward to field work again on August 27th, 2016 in hopes of recapturing a substantial proportion of them, downloading their data and learning specific details of
Recoveries

Of the 40 geolocators deployed, 11 were recovered. The first geolocator recovered was a larger model tag (X047) on 11 Sep 2016 at Site 5 (Poza), and which was deployed at the same site on 3 Apr 2016. The last geolocator recovered was a smaller model tag (X338) on 2 Apr 2017, also at Site 2 (Corridor), and which was deployed at the same site on 5 Mar 2016 (Table 3). The overall recovery rate of 28% compares favorably with previous studies. However, the recovery rates for Sep-Dec 2016 deployments were low, with no recoveries of the units (larger model) deployed at Site 5. Recoveries of units deployed Jan-Apr 2016 were notably higher, with 50% recovery of the smaller units deployed in Jan-Apr 2016.
Table 3. Summaries of recoveries of geolocators from Northern Waterthrushes. All 19 units deployed Sep-Dec 2016 were the larger model while 20 of the 21 units deployed Jan-Apr 2016 were the smaller model. The final unit deployed in Apr 2016 was a larger model.

<table>
<thead>
<tr>
<th>Deployment Dates</th>
<th>Site 2</th>
<th>Site 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sep-Dec 2016</td>
<td>2 of 9 (22%)</td>
<td>0 of 10 (0%)</td>
</tr>
<tr>
<td>Jan-Apr 2017</td>
<td>4 of 8 (50%)</td>
<td>5 of 13 (38%)</td>
</tr>
<tr>
<td></td>
<td>6 of 17 (35%)</td>
<td>5 of 23 (17%)</td>
</tr>
</tbody>
</table>

Complete analyses of light-level and geographic data currently are underway. However, preliminary analyses indicate that our birds summered widely in the area of the northeastern USA and southeastern Canada from Massachusetts to Ontario, Quebec and New Brunswick.

Acknowledgements

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