Issues and Perspectives

Florida's Strategic Position for Collaborative Automated Telemetry Tracking of Avian Movements Across the Americas

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Introduction

A central challenge to understanding the ecology of migratory animals stems from their dependence on environmental conditions and resources spread across vast spatial scales (Webster et al. 2002; Martin et al. 2007). By definition, migrants inhabit not only the two worlds of breeding and nonbreeding grounds (sensu Greenberg and Marra 2005) but also diverse migratory routes and stopover locations between those worlds (Faaborg et al. 2010; Bayly et al. 2018). The study of animal migration and movement ecology has experienced a renaissance over the past two decades spurred by innovations that help tackle this central challenge, including advances in tracking via satellite-based (e.g., Argos, global positioning system [GPS], and ICARUS systems), cellular-based, position or light-level logging (e.g., GPS logger, geolocator), and tag technology (for reviews, see Wikelski et al. 2007; Bridge et al. 2011; McKinnon and Love 2018). These innovations and associated data portal initiatives (Movebank: Kranstauber et al. 2011; Wikelski and Kays 2012) have enabled new insights into the movement patterns of migratory animals worldwide.

Such technological advances give unprecedented access to the annual cycle of many migratory species (Bayly et al. 2018; Cohen et al. 2018), although they have limitations, related mainly to the relatively large size of satellite- and cellular-based tags (>5 g) and the necessity of recapturing individuals to retrieve logging tags (Bridge et al. 2011; Kays et al. 2015). More traditional very high or ultrahigh frequency transmitters and their digitally encoded descendants (Taylor et al. 2017) remain as the primary option for tracking small-bodied migratory animals on the move, particularly when used in the context of collaborative or cooperative automated telemetry (Bridge et al. 2011; Kays et al. 2015; Taylor et al. 2017). Our objectives are to advance the collective goal of studying the ecology of migratory animals by using this collaborative approach and to stimulate further research that illuminates animal movements across the Americas. Specifically, we 1) document and encourage the filling of infrastructure and research gaps

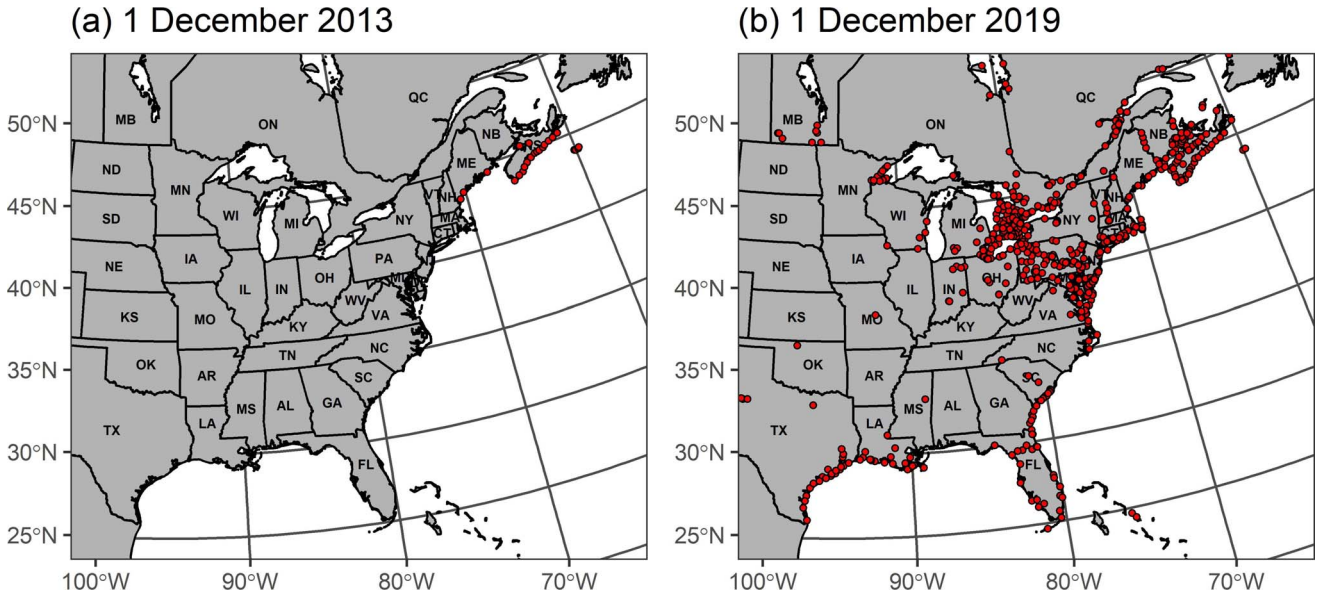

Figure 1. Distribution of Motus Wildlife Tracking System's automated telemetry stations in eastern North America that were active on **(a)** 1 December 2013 and **(b)** 1 December 2019. Point size is not indicative of the detection range of each station, which varies with the type and arrangement of antennae. Note that not all stations from 2013 were active in 2019, because not all stations in the network are permanent (stations can be activated strategically for shorter term studies). Receiver station location data obtained from Birds Canada (2019b); also see Data S1 (*Supplemental Material*). The precise locations and metadata for any stations, throughout the System's history, can be accessed at https://motus.org/data/receiversMap (Motus 2019).

within an expanding automated telemetry system in North America that is available to study the movement ecology of small migratory animals and 2) highlight the strategic position of Florida as a bridge between the Atlantic and Gulf coasts of the United States and between North and South America via the Caribbean. Our comments focus on birds because that is our primary study system, although these principles pertain more generally to flying migratory species including bats and insects. Although we share common goals with a broad array of colleagues, throughout this paper the word "we" refers specifically to the authors (i.e., the viewpoint of two collaborating researchers of avian migration).

Coordinated automated telemetry via Motus

The Motus Wildlife Tracking System is a recent but well-established and well-supported application of cooperative automated telemetry. The purpose of Motus is to facilitate landscape-scale research and education on the ecology and conservation of migratory animals. It is a program of Birds Canada in partnership with collaborating researchers, organizations, educators, and citizens to undertake impactful ecological research and education in support of that shared goal. Sometimes mistaken for an acronym, the name Motus is simply the Latin word for movement or motion (Birds Canada 2019a).

Within the system or network, small (0.25–3 g) digitally coded transmitters on single VHF frequencies are used to detect and infer the trajectory of animal movements within a collaboratively maintained and ever-growing global array of more than 700 monitoring stations (Taylor et al. 2017; Mackenzie 2018). Although other large-scale automated telemetry systems have been used elsewhere (Kays et al. 2011; Řeřucha et al. 2015; Toledo et al. 2016), Motus is the most accessible and fastest growing system in the Americas. It has facilitated new insights into the migration routes, rates, and stopover behavior of individual migratory birds. Assessments have been made of phenomena such as the full life cycle of the formerly endangered Kirtland's warbler *Setophaga kirtlandii* (Cooper et al. 2018), migratory staging behavior of the vulnerable rusty blackbird *Euphagus carolinus* (Wright et al. 2018), individual migratory flight decisions of songbirds (Baldwin et al. 2018), and the dispersal and staging of terns throughout the Western North Atlantic (Loring et al. 2017, 2019).

What is now Motus began as a regional network of custom-built receiving stations, founded and coordinated by Acadia University (Nova Scotia, Canada) and other partners in northeastern North America in 2012–2013 (Taylor et al. 2017) who established initial receiving stations in Nova Scotia, southern Ontario, and around the Gulf of Maine. Thus, in its early stages circa 2014–2015, few receiving stations existed in the southeastern United States (Figure 1a). Since then, Motus partners such as the United States Fish and Wildlife Service's (USFWS's) National Wildlife Refuge System and Migratory Birds Program, Louisiana Department of Fish and Wildlife, the Gulf Coast Bird Observatory in Texas, and others have established nearly 50 stations and partnered with other federal, state, university, and nonprofit organizations to improve coverage along the south Atlantic and Gulf of Mexico coasts (Figure 1b). Despite

these improvements, the continued low density of receiving stations in that region and within peninsular Florida misses an important opportunity to enhance our ability to track continental animal movements via the Motus network.

Strategic importance of Florida as a crossroads

The southeast region of the United States figures prominently in the pathways of migrating birds; landscapes around the Gulf of Mexico alone provide habitats for billions of Nearctic–Neotropical migrants that travel between their breeding grounds in North America and tropical nonbreeding grounds in the Caribbean and Central and South America (Lafleur et al. 2016; Cohen et al. 2017; Horton et al. 2019). Ensuring robust Motus coverage across the eastern Gulf of Mexico and throughout Florida is essential for the network to reach its full potential because of this region's importance to migratory birds. Florida effectively functions as a crossroads, bridging East–West and North–South. Florida is located within a major path for North American migratory birds, that is, the Atlantic flyway. We additionally infer that Florida's adjacent panhandle and peninsula function as a land extension for southbound migrants reaching the Gulf Coast en route to the Caribbean and South America (or avoiding northbound flights across the Gulf) at the administrative "end" of the Mississippi flyway (USFWS 2019). So, roughly speaking, these two of the continent's major flyways overlap longitudinally along the state's length (see Lovette and Fitzpatrick 2016, figure 12.17). Motus data demonstrate that Florida's migration catchment area extends well beyond these two flyways: to date, Motus stations have detected more than 300 tagged animals moving through the state, representing at least 35 species spread among tagging locations around the Americas (data from Motus 2019; Figure 2).

Moreover, the state forms a critical connection by straddling north and south: "its latitudinal position astride the northern edge of the tropics fosters mingling of, and competition between, temperate and tropical biotas" (Webb 1990, p. 70). The distinctly subtropical climate of the southern tip of the state highlights this linkage to the tropical south. For example, the prevalence of mangrove forests (Stevens et al. 2006) and the presence of bird species more associated with the tropics, such as the magnificent frigatebird *Fregata magnificens* and the swallow-tailed kite *Elanoides forficatus*, further illustrate Florida's significant position as a "bridge" within the Americas.

The coastlines of the southeast play a particularly important role in "funneling" migrants south through the Caribbean and figure prominently in the migration pathways of Neotropical migrants. For southbound migrants, these coasts culminate in the long and flat, narrow peninsula of Florida, stretching at most a mere 150 km from its Atlantic to Gulf of Mexico coasts with a maximum elevation of 120 m. Owing to a geography paralleled in Central America, migrants are much more concentrated in their nonbreeding areas compared with on their northern breeding grounds, as demonstrated by big-data models based on eBird sightings (Rodewald and Rosenberg 2018).

The increased concentration of migrants moving through Florida also conveys a potential for increased susceptibility to multiple environmental stressors. Impacts of global climate change may disproportionately affect low-lying areas that provide important stopover habitats (Lester et al. 2016). Other factors such as rapid coastal development (Johnson and Barbour 1990; Kautz 1993) and recently heightened harmful algal blooms (Perkins 2019) make Florida's coastal birds particularly vulnerable. More generally, shifts in avian distributions and movements, whether due to altered climate or food distributions or their synergistic effects, are being documented by both amateur and scientific observers (Wilson et al. 2013; Hovick et al. 2016). Informed and efficient conservation efforts will therefore depend on a better understanding of how habitats throughout Florida are used by numerous species of migrating birds. Noteworthy recent examples include the demonstration that the most important nonbreeding node across the Americas for the widespread tree swallow *Tachycineta bicolor* is South Florida (Knight et al. 2018) and that areas across Florida provide important stopover areas for the formerly endangered Kirtland's warbler (Cooper et al. 2017).

Given this strategic importance of Florida for migratory birds, surprisingly limited resources are devoted to ongoing monitoring of populations. Coastal birds are well studied in select locations, owing to collaborations of state agencies, nonprofit groups, and other organizations, through regional partnerships that comprise the Florida Shorebird Alliance. Yet much of the ongoing effort depends on community volunteers, such as Audubon Florida's shorebird stewardship programs. These citizen efforts stitch together the patchwork of scant resources for bird monitoring, and they are laudable and invaluable. However, we argue that they should be bolstered by more dedicated funding to support research and management initiatives for avian conservation.

More evidence of a gap in research attention and resources is the fact that the Western Hemisphere Shorebird Reserve Network includes no site within Florida, despite the state's extensive coastline available to shorebirds. We infer a possible explanation: shorebird populations may be more diffuse across Florida, attributable to the expanse of available habitat. The lack of standout sites with concentrations of shorebirds can make monitoring even more challenging, underscoring the value and effectiveness of bolstering Motus coverage to better understand movements and site use throughout the state.

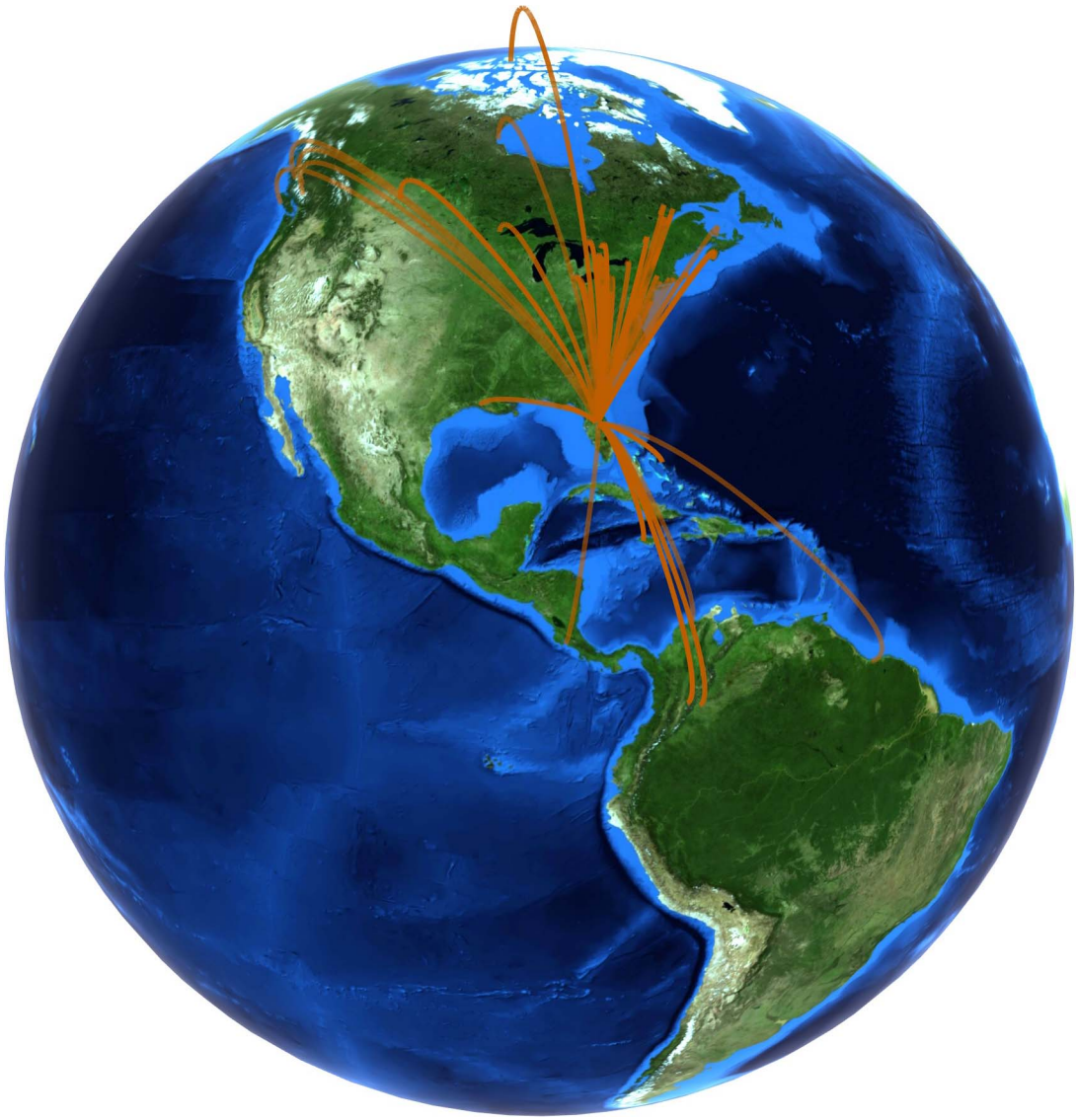

Figure 2. Schematic representation of the approximate tagging locations for 296 of the birds cumulatively detected by Motus receiving stations in Florida from the network's inception in 2013 through 1 December 2019. Arcs are stylized and do not indicate migratory paths. Additional detected birds ($n = 55$) are not displayed due to incomplete metadata or issues of data privacy. Motus tag detection data obtained from Birds Canada (2019c); also see Data S1 (*Supplemental Material*). Earth topobathy from National Aeronautics and Space Administration (2004).

Moving forward: More collaboration and embracing new tools

A multisectoral effort to grow Motus receiving network coverage around the Gulf of Mexico and the Atlantic continues: in southern Florida, many new stations became operational in 2018 and 2019, fueled by USFWS efforts to install stations on coastal National Wildlife Refuges, and to engage and support potential land management, conservation, and academic partners. Large gaps persist, but every new receiving station grows our capacity to better understand the region's importance to migratory animals. For example, detections of several Kirtland's warblers by multiple Motus stations in southwest Florida advocate for an expanded Florida network: those tagged birds were not detected by other stations in the region (N. Cooper, pers. comm.), demonstrating how a modest investment in additional monitoring efforts can generate important ecological insights. Continuing to fill the gap in station coverage within the southeastern USA—particularly in Florida—will improve our ability to assess the roles that this region plays in the annual cycle of migratory species. It will in turn spur regional-to-international initiatives for monitoring mobile species that depend on the habitats along the Gulf of Mexico and south Atlantic Coast of North America.

The lack of dedicated funding means that creative partnerships are essential. For example, the growing contribution of zoos and aquaria to migratory bird research (Hutchins et al. 2018) can also enhance

collaborative efforts such as Motus, and this is indeed transpiring in Florida: Zoo Miami, the Florida Aquarium, and Vero Beach High School (School District of Indian River County) now operate Motus stations. In addition to bolstering basic research, this provides opportunities to enhance public education and awareness of bird migration and conservation. Such initiatives also demonstrate how Motus functions as a positive feedback loop: the effective tracking of migratory movements over large scales depends on a solid, widespread detection network that is "built" (both figuratively and literally) by partners. Birds Canada spearheaded the initial capital investment to establish and maintain the technological framework and network infrastructure; they manage the central data repository and remain integral to the network's functionality. Now, as the collaborative infrastructure grows, the improved capacity and efficiency in turn generate more awareness of and participation in the network. Nonetheless, increased resolution will require thoughtful expansion of the network's receiving "footprint," which depends on new collaborators willing to establish and maintain additional receiving stations, in some cases altruistically. With the support of many Motus colleagues, we continue to work in that role by developing stations in the southeastern United States and sharing knowledge with (and lowering potential entry barriers to) new partners who are interested in participating.

An exciting outcome of this feedback loop is that the resolution of insights about migration ecology grows with the network, from both the expansion of the receiving footprint and the development of compatible technologies. Motus is poised to grow effectively because it is based on open source software and widely accessible components. One emerging advance is the integration of Motus systems with coded transmitters from Cellular Tracking Technology LLC (Mackenzie 2018). This is an example of the progress that can happen when organizations and individuals with a stake in the network commit to openly and collaboratively explore new tools and avenues.

In sum, there is a demonstrated need for bolstered resources to study migratory animals in the southeastern region of the United States, Florida in particular. In this era of cuts to budgets and staff for environmental management and protection, we acknowledge that there is no simple solution. More effective conservation will depend on increased funding and enhanced cooperation among diverse partners. Furthermore, monitoring of species' movements with a collaborative approach can lead to a more efficient use of resources and hence more effective conservation action: benefits include the ability to direct funding and effort where birds need it most, identification of new areas for attention that might have escaped prior notice, and better prioritization of areas for protection. Continued investment in a more robust Motus network in the U.S. southeast is a key piece of the puzzle. Beyond providing improved insights about avian ecology in this region, more broadly this will enhance understanding of movement linkages between the north and south and critical areas of habitat across the Americas, to bolster the basic data collection that is integral to sound management and conservation of migratory animals.

Supplemental Material

Please note: The *Journal of Fish and Wildlife Management* is not responsible for the content or functionality of any supplemental material. Queries should be directed to the corresponding author for the article.

Data S1. Motus receiving station location data (Birds Canada 2019b), basic deployment data for Motus tags detected by receiving stations in Florida (Birds Canada 2019c), and associated R code (R Core Team 2019) to access the data and reproduce Figures 1 and 2.

Found at DOI: https://doi.org/10.3996/082019-JFWM-068.S1 (2.27 MB ZIP).

Reference S1. Loring, PH, Paton PWC, McLaren JD, Bai H, Janaswamy R, Goyert HF, Griffin CR, Sievert PR. 2019. Tracking offshore occurrence of common terns, endangered roseate terns, and threatened piping plovers with VHF arrays. Sterling, Virginia: U.S. Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 17.

Found at DOI: https://doi.org/10.3996/082019-JFWM-068.S2 (5.45 MB PDF); also available at https://espis.boem.gov/final%20reports/BOEM_2019-017.pdf.

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