Caylor, P. A., S. H. Augustine, and C. Rota. 2023. No effect of geolocators on apparent return rates of a declining Neotropical migrant, the Canada Warbler (*Cardellina canadensis*).. Journal of Field Ornithology 94(3):5. https://doi.org/10.5751/JFO-00276-940305

Avian Conservation and Management

No effect of geolocators on apparent return rates of a declining Neotropical migrant, the Canada Warbler (*Cardellina canadensis*).

Ningún efecto de los geolocalizadores en las tasas de retorno aparentes de un migrante neotropical en declive, la reinita del Canadá (*Cardellina canadensis*)

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ABSTRACT. Canada Warblers (*Cardellina canadensis*) are small Neotropical migrants whose populations are declining across most of their range. Understanding factors limiting Canada Warbler populations requires knowledge of population ecology across the full annual cycle, including migratory pathways and over-winter locations. Light-level geolocator tags have offered unprecedented insight into migratory ecology for many species, but previous studies suggest that geolocators may influence apparent return rates. We sought to determine if geolocators influence apparent return rates of adult male Canada Warblers breeding in West Virginia, USA. In 2020, we deployed geolocators on 32 birds and color banded an additional 78 birds without geolocators. The following year, 13 of 32 (40.6%) geolocator birds and 37 of 78 (47.4%) color-banded birds were detected with no significant difference in apparent return rates between groups ($\chi^2 = 0.19$, $p = 0.66$). Although further evaluation of additional groups will be valuable, the lack of significant effect on adult male Canada Warblers suggests that the slightly lower return rate does not preclude the use of geolocators as a tool to assess the migration ecology of this small songbird of conservation concern.

RESUMEN. La reinita del Canadá (*Cardellina canadensis*) es un pequeño migrante neotropicales cuyas poblaciones están disminuyendo en la mayor parte de su área de distribución. Comprender los factores que limitan las poblaciones de la reinita del Canadá requiere del conocimiento ecológico poblacional a lo largo de todo el ciclo anual, las rutas migratorias y las localidades durante el invierno. Los sensores de geolocalización de nivel de luz han ofrecido una visión sin precedentes en la ecología migratoria de muchas especies, pero estudios anteriores sugieren que los geolocalizadores pueden influir en las tasas de retorno aparentes. Buscamos determinar si los geolocalizadores influyen en las tasas de retorno aparentes de machos adultos de la reinita del Canadá que se reproducen en Virginia Occidental, EE. UU. En 2020, colocamos geolocalizadores en 32 individuos y marcamos con anillos de colores 78 individuos que no tenían geolocalizadores. Al año siguiente, se detectaron 13 de los 32 (40,6 %) individuos con geolocalizadores y 37 de los 78 (47,4 %) individuos con anillos de colores, sin diferencias significativas en las tasas de retorno aparente entre estos dos grupos ($\chi^2 = 0{,}19$, $p = 0{,}66$). Si bien evaluaciones adicionales de estos dos grupos serán valiosas, la falta de un efecto significativo en los machos adultos de la reinita del Canadá sugiere que la tasa de retorno ligeramente más baja no impide el uso de geolocalizadores como herramienta para evaluar la ecología de la migración de esta pequeña ave cantora para generar una preocupación para su conservación.

Key Words: *apparent return rate; Canada Warbler; Cardellina canadensis*; geolocator; impact

INTRODUCTION

Migratory and nonbreeding season ecology remains one of the least understood aspects of Nearctic-Neotropical migratory bird life history (Faaborg et al. 2010). Avian survival may be lowest during migration than at any other point in the annual cycle (Sillett and Holmes 2002), and conditions during the nonbreeding season may create carryover effects on survival and reproduction during the breeding season (González-Prieto and Hobson 2013), potentially contributing to population declines (Sherry and Holmes 1995). Many species that breed in North America and migrate to Central and South America have exhibited marked declines in abundance for at least the past 50 years (Rosenberg et al. 2019). Given that many of these species spend at least half of the annual cycle migrating or on nonbreeding grounds, a better understanding of migratory and nonbreeding season ecology is critical for effective conservation.

Light-level geolocator tags are archival devices that record patterns of twilight and day length used to determine geographic location (Lisovski et al. 2020) and are the most precise widely available method for tracking individuals as small as 9.0 g (Streby et al. 2015). Geolocators allow inference regarding wintering and breeding ground locations (Kramer et al. 2017, Larkin et al. 2017), stopover dynamics (Cooper et al. 2017), habitat suitability (Justen et al. 2021), and migration timing (Renfrew et al. 2019). After deployment, devices must be recovered the following year. A representative sample of birds with geolocators would require that addition of the device not affect return probability.

Geolocator effects have previously been researched for a variety of old and new world warbler species of similar size with mixed results. Procházka et al. (2018) reported no significant effect of geolocators on recapture rates of Eurasian Reed Warblers (*Acrocephalus scirpaceus*) in Germany, although there was a significantly greater recapture rate for the birds without geolocators in the Czech Republic and Bulgaria. Return rates, body mass, and migration chronology were not significantly different between birds with and without geolocators in Golden-winged Warblers (*Vermivora chrysoptera*; Peterson et al. 2015), and weights of Great Reed Warblers (*Acrocephalus arundinaceus*)

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did not significantly differ between birds with and without geolocators after migration (Malmiga et al. 2021). Alternatively, other studies reported decreased return rates for Prairie Warblers (*Setophaga discolor*; Campbell et al. 2021), Aquatic Warblers (*Acrocephalus paludicola*; Salewski et al. 2019), and Cerulean Warblers (*Setophaga cerulea*; Raybuck et al. 2017). These varying results suggest geolocator impacts could be species-dependent, necessitating investigation into geolocator effects on a diversity of species.

The Canada Warbler (*Cardellina canadensis*) is a Neotropical migrant with recorded population declines across its range (Sauer et al. 2021). Canada Warblers breed in the boreal forests of southern Canada and in the northeastern U.S. and winter in southern Central America and northwestern South America. Migration routes appear to be primarily overland, converging along eastern Central America into South America (Roberto-Charron et al. 2020). Major threats to their wintering grounds include land conversion (Etter et al. 2006a), deforestation (Dávalos et al. 2011), and agriculture (Etter et al. 2006b). Compared to other migratory bird species in North America, Canada Warblers have one of the shortest breeding seasons, generally arriving to breeding grounds in May and departing in August and raising only a single brood (Flockhart 2007, Reitsma et al. 2020). This brief period represents just a fraction of Canada Warbler life history; therefore, it is crucial to incorporate the full annual cycle to understand factors limiting populations. To develop full annual cycle models, fundamental population-specific life history data including migratory routes, wintering ground locations, and population connectivity can be described using data from geolocators. Because geolocators have impacted birds of similar size and may have biased geolocator results (Raybuck et al. 2017), we believe it is important to assess the potential effects of geolocators on this migratory bird of conservation concern. We compared apparent return rates of Canada Warblers with and without geolocators in the Monongahela National Forest (MNF), West Virginia, USA. We aimed to assess the potential effects of geolocators on apparent return rates of a declining species of conservation concern.

METHODS

Field work occurred in the MNF, West Virginia, USA, from May to July in the 2020 and 2021 breeding seasons. Six study sites were located within the Appalachian Plateau Physiographic Province in the western MNF. Within this region, forest types below 900 m include mixed oak and mixed mesophytic, with northern hardwood forests occurring above 900 m and remnant boreal red spruce occurring above 1150 m (USDA 2011).

The sites within the MNF were stratified across 3 elevation bands: < 853 m, 853-1158 m, and > 1158 m. The lower limit was suggested by Harding et al. (2017) as the lower limit of Canada Warbler occurrence within the Appalachians, and the middle band was used to create three equal elevation divisions. Two sites were assigned to each elevation stratum and placed in areas where Dimmig et al. (2022) reported relatively high Canada Warbler detection rates. These sites were characterized by proximity to riparian areas and high densities of rhododendron (*Rhododendron maximum*), mountain laurel (*Kalmia latifolia*), and other understory shrubs (Augustine 2022, Dimmig et al. 2022).

This study was conducted in conjunction with a mark-resight project to estimate Canada Warbler demographic rates (Augustine 2022), which required capturing and individually marking adult male birds with color bands. To find unmarked birds in 2020, we listened for the songs of males and used conspecific audio playback to trigger territorial responses if no birds were initially detected. Unmarked birds were captured in mist nets (6 m x 2.6 m; 30 mm mesh) using the same conspecific audio lure. We deployed 32 geolocators (FL6057 fLight Lotek Wireless) equally across the six sites on adult male birds that met the weight requirement of ≥ 10.7 g to ensure geolocators were < 5% of a bird's mass (Fair et al. 2010). Geolocators were mounted with superglue onto figure-eight leg loop harnesses made from 0.5 mm Stretch Magic elastic cord (Rappole and Tipton 1991, Streby et al. 2015) attached to the bird so the device sat snugly on the synsacrum (Fig. 1). In contrast to Streby et al. (2015), the elastic of the harnesses was intended to last at least a year for annual retrieval. Birds with geolocators were marked with a unique combination of aluminum U.S. Geological Survey (USGS) band and two-color bands, which allowed rapid differentiation from non-geolocator birds in the field. Birds captured after all geolocators were deployed, or those which did not meet the weight threshold, were marked with a unique combination of aluminum USGS band and three-color bands (n = 78). In this project, only male birds were considered because females are not generally responsive to territorial calls (Reitsma et al. 2018) and therefore geolocator recovery rates were expected to be low.

Fig. 1. Light-level geolocator (FL6057 fLight Lotek Wireless) attached via leg-loop harness to an adult male Canada Warbler (*Cardellina canadensis*) in the Monongahela National Forest, West Virginia, USA, in 2020. Inset shows the geolocator pre-deployment with the harness made from 0.5 mm elastic cord. Photo credit: Stephanie Augustine.

We assessed return rates in 2021 by systematically searching study sites using a modification of typical territory spot mapping (Bibby et al. 2000). We searched for returning birds at regularly placed grid points within the boundaries of the study areas. Grid points were placed 150 m apart to account for aural detection limits of Canada Warblers (60-200 m; Matsuoka et al. 2012, Hunt et al. 2017). We listened for Canada Warbler songs between grid points and broadcast songs for up to three minutes at grid points if no birds were detected. When we located a marked bird, we recorded the location and identity of the individual. If a marked bird was located that had been deployed with a geolocator, we recaptured the bird using the previously described capture protocol and retrieved the geolocator tag.

To determine if detecting a bird marked the previous year was independent of whether it carried a geolocator, we used a chi-square test with Yate's continuity correction. We set a type-I error threshold of $\alpha = 0.05$ to determine the statistical significance. Analyses were completed in program R v.4.2.0 (R Core Team 2022).

RESULTS

We marked 110 birds in 2020, of which 32 received geolocators. Of those marked birds, we detected 50 in 2021 (apparent return probability = 0.45). Of the 78 birds without geolocators, 37 were detected (apparent return probability = 0.47). Of the 32 birds that received geolocators, 13 were detected (apparent return probability = 0.41) and subsequently recaptured with their tag. No birds that were fitted with geolocators were resighted without their harness, and all resighted birds that were fitted with geolocators were recaptured. Despite the slightly lower observed return rate of birds that received geolocators, the difference was not statistically significant ($\chi^2 = 0.19$, $p = 0.66$, $DF = 1$).

DISCUSSION

Deployment of geolocators on Canada Warblers produced a small but nonsignificant reduction in apparent return rate compared to control birds. This result is consistent with other studies that also found no effect of geolocators (Peterson et al. 2015, van Wijk et al. 2016, Bell et al. 2017), including another study evaluating return rates of Canada Warblers (Roberto-Charron et al. 2020). However, our results are also consistent with a meta-analysis that determined a weak negative effect of geolocators on apparent survival (Brlík et al. 2020). A weak effect, coupled with a modest sample size, may have precluded our ability to detect a significant effect. Regardless, our failure to detect an effect of geolocators on apparent return rates suggests they may be a reliable tool for assessing migration ecology of Canada Warblers.

Canada Warblers, with an average mass of 10.6 g (males, range 8.7-13.5 g; Reitsma et al. 2020), are among the smallest birds that can be fitted with light-level geolocators, and we were only able to deploy devices on a subset of birds that were heavy enough to reach the 5% threshold (Fair et al. 2010). Brlík et al. (2020) found that increasing relative load of geolocators and use of elastic bands to attach geolocators led to lower apparent survival, and that the effects of geolocators were stronger on smaller species. We may have reduced the relative load on Canada Warblers by only placing geolocators on the heaviest individuals, perhaps offsetting potential negative effects of elastic bands and the small overall body size of Canada Warbler in contributing to no strong effect on apparent return rates.

Although placing geolocators on the heaviest individuals may have contributed to our finding of no strong effect, this may also lead to biased inferences regarding migratory ecology. Indeed, we further restricted geolocators to adult males, due to low resight and recapture rates of females and hatch-year birds. Although geolocators offer data on migratory ecology of average to large adult male Canada Warblers, such conclusions may not be applicable to other size, age, and sex classes. For example, birds may exhibit differential migration based on age (Cristol et al. 1999), and females may exhibit different migratory behavior than males (Catry et al. 2005). Further study of Canada Warbler migratory ecology should continue the assessment of geolocator effects on apparent return rates of smaller and female birds.

Author Contributions:

S. H. A., and C. T. R. conceived the idea, design, and formulated the hypothesis. S. H. A., and P. A. C. conducted the research. P. A. C. analyzed the data and wrote the manuscript. S. H. A., and C. T. R. edited the manuscript.

Acknowledgments:

Thank you to S. Augustine, R. Kaiser, C. Rausch, A. Scheibe, and C. Worley for the many field contributions. The Monongahela National Forest staff provided logistical assistance and site access. Additional thanks to L. and K. Warner for field support. Funding statement: USDA National Institute of Food and Agriculture McIntire-Stennis project WVA00124 and WVA00818, Blake-Nuttall Grant from the Nuttall Ornithological Club, Eastern Bird Banding Association, American Ornithological Society, WVU's Summer Undergraduate Research Experience, and the West Virginia University David and Catherine Samuel Wildlife Fund provided financial support for this research. None of the funders required approval of the manuscript before submission or publication.

Data Availability:

Data can be found in the Results section. The software used to analyze the data can be found in the Methods section.

LITERATURE CITED

Augustine, S. H. 2022. Population and migratory ecology of Canada Warblers (*Cardellina canadensis*) in the Central Appalachian Mountains, West Virginia, USA. Thesis. West Virginia University, Morgantown, West Virginia, USA. https://doi.org/10.33915/etd.11251

Bell, S. C., M. E. Harouchi, C. M. Hewson, and M. D. Burgess. 2017. No short- or long-term effects of geolocator attachment detected in Pied Flycatchers (*Ficedula hypoleuca*). Ibis 159 (4):734-743. https://doi.org/10.1111/ibi.12493

Bibby, C., M. Jones, and S. Marsden. 2000. Bird surveys - expedition field techniques. BirdLife International, Girton, Cambridge, UK.

Brlík, V., J. Koleček, M. Burgess, S. Hahn, D. Humple, M. Krist, J. Ouwehand, E. L. Weiser, P. Adamík, J. A. Alves, D. Arlt, S. Barišić, D. Becker, E. J. Belda, V. Beran, C. Both, S. P. Bravo, M. Briedis, B. Chutný, D. Ćiković, N. W. Cooper, J. S. Costa, V. R. Cueto, T. Emmenegger, K. Fraser, O. Gilg, M. Guerrero, M. T. Hallworth, C. Hewson, F. Jiguet, J. A. Johnson, T. Kelly, D. Kishkinev, M. Leconte, T. Lislevand, S. Lisovski, C. López, K. P. McFarland, P. P. Marra, S. M. Matsuoka, P. Matyjasiak, C. M. Meier, B. Metzger, J. S. Monrós, R. Neumann, A. Newman, R. Norris, T. Pärt, V. Pavel, N. Perlut, M. Piha, J. Reneerkens, C. C. Rimmer, A. Roberto-Charron, C. Scandolara, N. Sokolova, M. Takenaka, D. Tolkmitt, H. van Oosten, A. H. J. Wellbrock, H. Wheeler, J. van der Winden, K. Witte, B. K. Woodworth, and P. Procházka. 2020. Weak effects of geolocators on small birds: a meta-analysis controlled for phylogeny and publication bias. Journal of Animal Ecology 89(1):207-220. https://doi.org/10.1111/1365-2656.12962

Campbell, S. P., M. E. Akresh, N. A. Gifford, and D. I. King. 2021. Effects of light-level geolocators on return rates and inter-annual territory fidelity of Prairie Warblers (*Setophaga discolor*). Bird Study 68(3):396-407. https://doi.org/10.1080/00063657.2022.2103514

Catry, P., M. Lecoq, A. Araújo, G. Conway, M. Felgueiras, M. B. King, S. Rumsey, H. Salima, P. Tenreiro, P. Catry, M. Lecoq, A. Arauijo, G. Conway, M. Felgueiras, J. M. B. King, S. Rumsey, H. Salima, and P. Tenreiro. 2005. Differential migration of Chiffchaffs *Phylloscopus collybita* and *P. ibericus* in Europe and Africa. Journal of Avian Biology 36:184-190. https://doi.org/10.1111/j.0908-8857.2005.03445.x

Cooper, N. W., M. T. Hallworth, and P. P. Marra. 2017. Light-level geolocation reveals wintering distribution, migration routes, and primary stopover locations of an endangered long-distance migratory songbird. Journal of Avian Biology 48:209-219. https://doi.org/10.1111/jav.01096

Cristol, D. A., M. B. Baker, and C. Carbone. 1999. Differential migration revisited. Pages 33-38 in V. Nolan, E. D. Ketterson, and C. F. Thompson, editors. Current Ornithology. Volume 15. Springer, Boston, Massachusetts, USA. https://doi.org/10.1007/978-1-4757-4901-4_2

Dávalos, L. M., A. C. Bejarano, M. A. Hall, H. L. Correa, A. Corthals, and O. J. Espejo. 2011. Forests and drugs: coca-driven deforestation in tropical biodiversity hotspots. Environmental Science and Technology 45(4):1219-1277. https://doi.org/10.1021/es102373d

Dimmig, G., C. Rota, P. Wood, and C. Lituma. 2022. Understory structure and heterospecifics influence occupancy of a ground-nesting species of conservation concern, the Canada Warbler. Avian Conservation and Ecology 17(1):20. https://doi.org/10.5751/ACE-02079-170120

Etter, A., C. McAlpine, D. Pullar, and H. Possingham. 2006a. Modelling the conversion of Colombian lowland ecosystems since 1940: drivers, patterns, and rates. Journal of Environmental Management 79(1):74-87. https://doi.org/10.1016/j.jenvman.2005.05.017

Etter, A., C. McAlpine, K. Wilson, S. Phinn, and H. Possingham. 2006b. Regional patterns of agricultural land use and deforestation in Colombia. Agriculture, Ecosystems and Environment 114(2-4):369-386. https://doi.org/10.1016/j.agee.2005.11.013

Faaborg, J., R. T. Holmes, A. D. Anders, K. L. Bildstein, K. M. Dugger, S. A. Gauthreaux Jr., P. Heglund, K. A. Hobson, A. E. Jahn, D. H. Johnson, S. C. Latta, D. J. Levey, P. P. Marra, C. L. Merkord, E. Nol, S. I. Rothstein, T. W. Sherry, T. S. Sillett, F. R. Thompson III, and N. Warnock. 2010. Recent advances in understanding migration systems of New World land birds. Ecological Monographs 80(1):3-48. https://doi.org/10.1890/09-0395.1

Fair, J., E. Paul, and J. Jones. 2010. Guidelines to the use of wild birds in research. Ornithological Council, Washington, D.C., USA. https://birdnet.org/wp-content/uploads/2022/09/guidelines_august2010.pdf

Flockhart, D. T. T. 2007. Migration timing of Canada Warblers near the northern edge of their breeding range. Wilson Journal of Ornithology 119(4):712-716. https://doi.org/10.1676/06-111.1

González-Prieto, A. M., and K. A. Hobson. 2013. Environmental conditions on wintering grounds and during migration influence spring nutritional condition and arrival phenology of Neotropical migrants at a northern stopover site. Journal of Ornithology 154:1067-1078. https://doi.org/10.1007/s10336-013-0975-y

Harding, C., L. Reitsma, and J. D. Lambert. 2017. Guidelines for managing Canada Warbler habitat in the Northeast and Mid-Atlantic regions. High Branch Conservation Services, Hartland, Vermont, USA. https://highbranchconservation.com/wp-content/uploads/2017/02/Guidelines-for-Managing-Canada-Warbler-Habitat-in-the-Northeast-and-Mid-Atlantic-Regions-2017.pdf

Hunt, A. R., E. M. Bayne, and S. Haché. 2017. Forestry and conspecifics influence Canada Warbler (*Cardellina canadensis*) habitat use and reproductive activity in boreal Alberta, Canada. Condor 119(4):832-847. https://doi.org/10.1650/CONDOR-17-35.1

Justen, H., J. A. Lee-Yaw, K. E. Delmore, and C. Sheard. 2021. Reduced habitat suitability and landscape connectivity in a songbird migratory divide. Global Ecology and Biogeography 30 (10):2043-2056. https://doi.org/10.1111/geb.13367

Kramer, G. R., H. M. Streby, S. M. Peterson, J. A. Lehman, D. A. Buehler, P. B. Wood, D. J. McNeil, J. L. Larkin, and D. E. Andersen. 2017. Nonbreeding isolation and population-specific migration patterns among three populations of Golden-winged Warblers. Condor 119(1):108-121. https://doi.org/10.1650/CONDOR-16-143.1

Larkin, J. L., D. Raybuck, A. Roth, L. Chavarría-Duriaux, G. Duriaux, M. Siles, and C. Smalling. 2017. Geolocators reveal migratory connectivity between wintering and breeding areas of Golden-winged Warblers. Journal of Field Ornithology 88 (3):288-298. https://doi.org/10.1111/jofo.12210

Lisovski, S., S. Bauer, M. Briedis, S. C. Davidson, K. L. Dhanjal-Adams, M. T. Hallworth, J. Karagicheva, C. M. Meier, B. Merkel, J. Ouwehand, L. Pedersen, E. Rakhimberdiev, A. Roberto-Charron, N. E. Seavy, M. D. Sumner, C. M. Taylor, S. J. Wotherspoon, E. S. Bridge, and G. Street. 2020. Light-level

geolocator analyses: a user's guide. Journal of Animal Ecology 89(1):221-236. https://doi.org/10.1111/1365-2656.13036

Malmiga, G., M. Tarkam, T. Alerstam, B. Hansson, and D. Hasselquist. 2021. Individual and sex-related patterns of prolonged flights during both day and night by Great Reed Warblers crossing the Mediterranean Sea and Sahara Desert. 2021. Journal of Avian Biology 52:1-15. https://doi.org/10.1111/jav.02549

Matsuoka, S. M., E. M. Bayne, P. Sólymos, P. C. Fontaine, S. G. Cumming, F. K. A. Schmiegelow, and S. J. Song. 2012. Using binomial distance sampling models to estimate the effective detection radius of point-count surveys across boreal Canada. Auk 129(2):268-282. https://doi.org/10.1525/auk.2012.11190

Peterson, S. M., H. M. Streby, G. R. Kramer, J. A. Lehman, D. A. Buehler, and D. E. Andersen. 2015. Geolocators on Golden-winged Warblers do not affect migratory ecology. Condor 117 (2):256-261. https://doi.org/10.1650/CONDOR-14-200.1

Procházka, P., V. Brlík, E. Yohannes, B. Meister, J. Auerswald, M. Ilieva, and S. Hahn. 2018. Across a migratory divide: divergent migration directions and non-breeding grounds of Eurasian Reed Warblers revealed by geolocators and stable isotopes. Journal of Avian Biology 49:1-9. https://doi.org/10.1111/jav.01769

R Core Team. 2022. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Rappole, J. H., and A. R. Tipton. 1991. New harness design for attachment of radio transmitters to small Passerines. Journal of Field Ornithology 62(3):335-337. https://sora.unm.edu/sites/default/files/journals/jfo/v062n03/p0335-p0337.pdf

Raybuck, D. W., J. L. Larkin, S. H. Stoleson, and T. J. Boves. 2017. Mixed effects of geolocators on reproduction and survival of Cerulean Warblers, a canopy-dwelling, long-distance migrant. Condor 119(2):289-297. https://doi.org/10.1650/CONDOR-16-180.1

Reitsma, L. R., J. A. Jukosky, A. J. Kimiatek, M. L. Goodnow, and M. T. Hallworth. 2018. Extra-pair paternity in a long-distance migratory songbird beyond neighbors' borders and across male age classes. Canadian Journal of Zoology 96(1):49-54. https://doi.org/10.1139/cjz-2016-0277

Reitsma, L. R., M. T. Hallworth, M. McMahon, and C. J. Conway. 2020. Canada Warbler (*Cardellina canadensis*). Version 2.0. In P. G. Rodewald and B. K. Keeney, editors. Birds of the world. Cornell Lab of Ornithology, Ithaca, New York, USA. https://doi.org/10.2173/bow.canwar.02

Renfrew, R., D. Kim, N. Perlut, and M. D. Cadman. 2019. Migration tactics of a long-distance migratory songbird from across a continental breeding range. Wilson Journal of Ornithology 131(4):735-749. https://doi.org/10.1676/1559-4491-131.4.735

Roberto-Charron, A., J. Kennedy, L. Reitsma, J. A. Tremblay, R. Krikun, K. A. Hobson, J. Ibarzabal, and K. C. Fraser. 2020. Widely distributed breeding populations of Canada Warbler (*Cardellina canadensis*) converge on migration through Central America. BMC Zoology 5:10. https://doi.org/10.1186/s40850-020-00056-4

Rosenberg, K. V., A. M. Dokter, P. J. Blancher, J. R. Sauer, A. C. Smith, P. A. Smith, J. C. Stanton, A. Panjabi, L. Helft, M. Parr, and P. P. Marra. 2019. Decline of the North American avifauna. Science 366(6461):120-124. https://doi.org/10.1126/science.aaw1313

Salewski, V., M. Flade, S. Lisovski, A. Poluda, O. Iliukha, G. Kiljan, U. Malashevich, and S. Hahn. 2019. Identifying migration routes and non-breeding staging sites of adult males of the globally threatened Aquatic Warbler *Acrocephalus paludicola*. Bird Conservation International 29(4):503-514. https://doi.org/10.1017/S0959270918000357

Sauer, J. R., W. A. Link, and J. E. Hines. 2021. The North American breeding bird survey, analysis results 1966-2019. U.S. Geological Survey, Laurel, Maryland, USA. https://www.sciencebase.gov/catalog/item/5f1836a482cef313ed843104

Sherry, T. W., and R. T. Holmes. 1995. Summer versus winter limitation of populations: what are the issues and what is the evidence? Pages 85-120 in T. E. Martin and D. M. Finch, editors. Ecology and management of Neotropical migratory birds: a synthesis and review of critical issues. Oxford University Press, New York, New York, USA. https://www.academia.edu/21252521/Summer_versus_winter_limitation_of_populations_What_are_the_issues_and_what_is_the_evidence

Sillett, T. S., and R. T. Holmes. 2002. Variation in survivorship of a migratory songbird throughout its annual cycle. Journal of Animal Ecology 71(2):296-308. https://doi.org/10.1046/j.1365-2656.2002.00599.x

Streby, H. M., T. L. Mcallister, S. M. Peterson, G. R. Kramer, J. A. Lehman, and D. E. Andersen. 2015. Minimizing marker mass and handling time when attaching radio-transmitters and geolocators to small songbirds. Condor 117(2):249-255. https://doi.org/10.1650/CONDOR-14-182.1

U.S. Department of Agriculture (USDA). 2011. Monongahela National Forest land and resource management plan. USDA, Washington, D.C., USA. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5330420.pdf

van Wijk, R. E., G. Souchay, S. Jenni-Eiermann, S. Bauer, and M. Schaub. 2016. No detectable effects of lightweight geolocators on a Palaearctic-African long-distance migrant. Journal of Ornithology 157:255-264. https://doi.org/10.1007/s10336-015-1274-6