Age-Ratios and Condition of En Route Migrant Blackpoll Warblers in the British Virgin Islands

Author(s): Clint W. Boal
Source: The Wilson Journal of Ornithology, 126(3):568-574. 2014.
Published By: The Wilson Ornithological Society
DOI: http://dx.doi.org/10.1676/13-113.1
URL: http://www.bioone.org/doi/full/10.1676/13-113.1

The Wilson Journal of Ornithology 126(3):568–574, 2014

Age-Ratios and Condition of En Route Migrant Blackpoll Warblers in the British Virgin Islands

Clint W. Boal[1]

ABSTRACT.—The en route migration ecology of Blackpoll Warblers (*Setophaga striata*) is poorly understood, yet intriguing. Blackpoll Warblers undertake the longest open water migration of any wood warbler species, traveling from northeastern North America to South America, with the first potential landfall being the West Indies. This migration requires substantial energy reserves and subjects Blackpoll Warblers to unpredictable weather events, which may influence survival. Few studies have examined age ratios or condition of Blackpoll Warblers while the warblers are en route through the Caribbean region. I captured and banded Blackpoll Warblers in the British Virgin Islands over 10 consecutive autumn migrations. Ratios of hatch-year to adult Blackpoll Warblers were variable but averaged lower than the ratios reported at continental departure locations. Average mass of Blackpoll Warblers was less than that reported at continental departure locations, with 26% of adults and 40% of hatch-year birds below the estimated fat free mass; hatch-year birds were consistently in poorer condition than adults. Blackpoll Warblers captured in the British Virgin Islands were also in poorer condition than those reported from the Dominican Republic and Barbados; this may be because of the British Virgin Islands being the first landfall after the transatlantic crossing, whereas Blackpoll Warblers arriving at the other Caribbean study locations may have had opportunities for stopover prior to arrival or have departed from farther south on the continent. However, this suggests that the British Virgin Islands likely provide important stopover habitat as a first landfall location for Blackpoll Warblers arriving from the transatlantic migration route. *Received 22 July 2013. Accepted 25 March 2014.*

Key words: Blackpoll Warbler, Caribbean, condition, migration, *Setophaga striata*.

The breeding ecology of many Neotropical migrant landbirds is relatively well studied, but there is a substantive lack of information for their en route ecology during migration (Rappole 1995, Latta et al. 2003, Heglund and Skagen 2005, Latta 2012). Understanding en route ecology of migrant landbirds is foundational to developing a more

[1] U.S. Geological Survey, Texas Cooperative Fish and Wildlife Research Unit, Texas Tech University, Lubbock, TX 79409, USA; e-mail: clint.boal@ttu.edu

complete understanding of life histories and, hence, critical to developing sound conservation strategies (Rappole 1995, Heglund and Skagen 2005). Long-distance migration requires both the physiological ability to store large energy reserves and the availability of suitable stopover habitat to replenish expended energy stores, all while crossing broad spatial scales over relatively short temporal periods (Heglund and Skagen 2005, Kelly and Hutto 2005). Sex, age, and physiological condition may all relate to migration timing, success, and survival (Rappole 1995, Butler 2000, Kelly and Hutto 2005). Unfavorable weather may force migrants to expend their energy reserves more quickly, change direction, or seek stopover locations (McNair et al. 2002). Such situations may be particularly influential on migrants during long-distance over-water flights that afford few opportunities to land if necessitated by weather or energy depletion. For example, breeding abundances of three migrant species were negatively correlated with previous autumn storm frequency in the Caribbean (Butler 2000).

Several studies have examined various aspects of Neotropical migrant landbird ecology during spring (Moore et al. 1990, Kuenzi et al. 1991, Rodewald and Brittingham 2007) and autumn (Morris et al. 1996, Woodrey and Moore 1997, Davis 2001) on mainland and near shore islands of North America. Additionally, there are numerous studies of over-wintering Neotropical migrant landbirds in the Caribbean (e.g., Ewert and Askins 1991, Wunderle 1995, Dugger et al. 2004), but studies are lacking for en route migrants through the region (Latta et al. 2003, Latta 2012).

Each autumn, Blackpoll Warblers (*Setophaga striata*) undertake the longest migration (up to 8,000 km) of any North American warbler (Baird 1999, Hunt and Eliason 1999). Blackpolls distributed across the coniferous forests of northern North America first migrate eastward to congregate along the northeastern seaboard (Morse 1989, Hunt and Eliason 1999). From the northeastern seaboard, blackpolls depart on an ~2,500–3,500-km transatlantic flight to their wintering grounds in South America (Hunt and Eliason 1999). Along this route, they have the opportunity to make first landfall among the Caribbean islands to rest and feed before continuing on to South America (Nisbet et al. 1995, Hunt and Eliason 1999). However, their status during migration ranges from consideration as common to uncommon transients in the large islands of the western Greater Antilles and the small islands of the eastern Lesser Antilles (Arendt 1992, Raffaele et al. 1998).

Latta and Brown (1999) point out that, despite the importance of understanding stopover habitat and other factors of migration (Moore et al. 1990, Hagan and Johnston 1992), the majority of papers addressing Blackpoll Warblers' migration have focused on the migratory route used (Murray 1989, Nisbet et al. 1995). Hunt and Eliason (1999), Latta et al. (2003) and McNair et al. (2002) called for a more systematic sampling of blackpolls and other warblers in the West Indies, including a focus on migration timing, movements, and physiological condition. However, little additional information has been compiled since McNair et al. (2002). Herein, I report annual variation in numbers captured, timing of migration, age ratios, and physiological conditions of migrant Blackpoll Warblers during autumn migrations in the British Virgin Islands, 2003–2012.

METHODS

My study site was on Guana Island (18° 30′ N, 64° 30′ W), a small (3 km^2) island located ~0.5 km north of Tortola, British Virgin Islands. The British Virgin Islands, along with the U.S. Virgin Islands, form an archipelago of ~76 islands and cays located roughly 150 km east of Puerto Rico that, combined with Puerto Rico, constitute the Puerto Rican Bank (Lazell 2005). Temperature in the British Virgin Islands normally ranges from 28–33 °C, with annual mean rainfall for Guana Island estimated at 92 cm (Lazell 2005).

Guana Island is topographically rugged with an elevation range from sea level to 246 m. It is privately owned and has undergone little development or habitat fragmentation. A resort area occupies ~5% of the island; the remainder of the island is a *de facto* nature preserve. The majority of the island is vegetated with ~90% subtropical dry forest and 5% mesic forest. The primary native vegetation on Guana Island is *Tabebuia heterophylla*, *Bursera simaruba*, *Pisonia subcordata*, *Conocarpus erectus*, *Plumeria alba*, *Acacia muricata*, and *Coccoloba uvifera*. *Leucaena leucocephala* is common in disturbed areas. Other introduced species include *Cocos nucifera*, *Tamarindus indica*, and *Delonix regia* (Lazell 2005).

I have operated a banding station on Guana Island each October of 2003–2012. As many as

12, 32-mm mesh nets were opened from 0630–1100 hrs Atlantic Standard Time; nets were open all daylight hours during fallouts. The duration of netting and number of nets opened were contingent upon local weather conditions and the number of individuals to assist with net monitoring. Nets were located in the same locations along a northeast–southwest ridge on the west side of the island at ca. 70 m elevation each year. Exceptions occurred when vegetation changes or operations of the island staff necessitated slight shifts of net locations. The location takes advantage of south and south-east bound migrants crossing a north-west facing saddle of the island.

All captured birds were placed in cotton holding bags and transported to a central banding station for processing. I determined species identification, age, and sex to the extent possible based on Pyle (1997) and Raffaele et al. (1998). I recorded unflattened wing chord with a stopped wing ruler. I weighed birds with Pesola spring scales in 2003, and with an electronic scale accurate to 0.1 g (Ohaus Model CS200) from 2004–2012. I estimated fat using the five categories presented by the North American Banding Council (2001). An aluminum leg band provided by the U.S. Geological Survey Bird Banding Laboratory was attached to each bird prior to release.

I refer to all adult Blackpoll Warblers (i.e., after-hatch-year) as AHY and all young-of-the-year (i.e., hatch-year) as HY. I used Pearson's correlation analysis to examine correlations between capture rate and net hours. I then used analysis of variance (ANOVA) to examine relationships between day of capture and year. Three leap years occurred during our study so I transformed dates to Julian dates for analysis. Migrants typically depart on southbound migration following passage of low pressure systems (Williams et al. 1977). Weather systems and winds encountered en route presumably influence the time migrants arrived at the field station, or whether they miss the island completely or choose to continue flying southward. However, identifying the meteorological conditions that result in stopover is challenging. Williams (1985) found that birds migrating over Antigua flew at an average of 2,100–3,090 m above sea level; the wind speed and direction data available for my study area were at sea level, suggesting analysis of wind and arrival of migrants was not promising. Temperature in the tropics is fairly static and unlikely to be predictive of warbler migration. However, Latta and Brown (1999) reported that fallouts on the Dominican Republic were associated with a drop in barometric pressure (hereafter, BP). I accessed BP records for each October of 2003–2012 from the weather stations at Lameshur Bay, St. John and Charlotte Amalie, St. Thomas, U.S. Virgin Islands (National Oceanographic and Atmospheric Administration 2013). These stations, operated by the National Oceanographic and Atmospheric Administration, are located ~23 km and 40 km away from the field site, respectively, but are the closest weather stations to the study area that collect these data. I used hourly BP readings to calculate an average for each day of each October, and then used Pearson's product-moment correlation to explore patterns between BP and arrival of blackpolls.

Because size among individuals in a species is variable, it is common to calculate an adjusted mass (mass/wing length) for analysis of condition (Latta and Brown 1999, Dunn 2000). However, Francis and Wood (1989) reported young wood warblers have shorter wing chords solely because of their shorter feathers. Jones et al. (2002) surmised that calculations of adjusted mass may therefore lead to interpreting HY individuals of a mass similar to AHY individuals as being in better relative condition. To alleviate this concern, I examined age-specific differences in both mass and adjusted mass among years with factorial analysis of variance tests. I used Shapiro-Wilk tests for normality in data sets, and Levene's test for equal variance. I used log transformations when data did not meet assumptions of normality. When ANOVAs indicated differences were present, I conducted post-hoc analyses with Tukey HSD tests to identify where differences occurred among the years. I used Mann-Whitney *U*-tests to assess age-specific differences in categorical fat scores and Sign tests to examine among year variation in fat scores for AHY and for HY birds. I report means ± SE for all descriptive statistics, set statistical significance at $\alpha = 0.05$, and conducted all analysis in Statistica 6.1 (Stat Soft, Inc., Tulsa, OK).

RESULTS

I captured and banded 717 Blackpoll Warblers during the Octobers of 2003–2012 while conducting an average of 348.2 (± 28.7) net hrs of mist-netting per year. The number of Blackpoll

TABLE 1. Mean mass and mean fat scores (scale of 0–4) for adult (AHY) and juvenile (HY) Blackpoll Warblers captured during migration, Guana Island, British Virgin Islands, October 2005–2012. The average mass of AHY birds was significantly greater than HY birds ($F_{1,656} = 21.157$, $P < 0.001$), and mass varied among years ($F_{7,656} = 7.841$, $P < 0.001$). The results of assessing adjusted mass among age classes and years was similar to that for raw mass; there were significant differences between age classes ($F_{1,646} = 13.731$, $P = 0.002$) and among years ($F_{7,646} = 6.6007$, $P < 0.001$).

	AHY			HY		
Year	*n*	Mass (SE)	Fat (SE)	*n*	Mass (SE)	Fat (SE)
2005	76	11.5 (0.13)	2.1 (0.15)	94	10.9 (0.12)	1.9 (0.13)
2006	38	10.6 (0.19)	0.7 (0.21)	24	10.4 (0.24)	0.7 (0.27)
2007	13	11.9 (0.20)	1.5 (0.23)	77	11.4 (0.13)	1.3 (0.15)
2008	17	11.4 (0.28)	1.0 (0.31)	35	10.6 (0.20)	0.9 (0.22)
2009	10	11.9 (0.37)	2.3 (0.41)	18	11.3 (0.28)	1.8 (0.31)
2010	50	11.1 (0.17)	1.3 (0.18)	129	10.4 (0.10)	0.8 (0.11)
2011	11	11.8 (0.35)	2.8 (0.39)	36	10.8 (0.20)	1.1 (0.22)
2012	9	11.3 (0.39)	1.6 (0.41)	15	11.1 (0.30)	1.3 (0.34)
All	224	11.4 (0.10)	1.6 (0.25)	428	10.9 (0.07)	1.2 (0.16)

Warblers captured ranged from 7–185 individuals per year (mean = 71.7 ± 20.3/year) with a mean capture rate of 19.1 birds/100 net hours (± 5.1). Although there was some variability in net hrs conducted among years, there was no correlation between capture rate and net hrs ($r^2 = 0.14$, $P = 0.28$). Adult Blackpoll Warblers accounted for 36.9% and HY accounted for 63.1% of the 710 (99%) individuals that were aged.

Blackpoll Warblers were captured as early as 8 and as late as 29 October, with the mean day of capture being 16 October (± 0.95 days); the modal arrival date was 18 October. Day of capture varied among years ($F_{9,707} = 55.5$, $P < 0.001$), with captures occurring significantly later in 2008 ($n = 56$) and 2012 ($n = 25$), and significantly earlier in 2009 ($n = 28$) compared to all other years (Tukey HSD tests $P < 0.05$). Based on day of capture, there was no correlation between the estimated blackpoll arrival and barometric pressure ($r^2 = 0.001$, $P = 0.66$).

I only included data from years 2005–2012 for analysis of age-related condition among years; I excluded data from 2003 because I used a spring scale rather than the digital scale accurate to 0.1 grams in other years, and I excluded data from 2004 because only 7 birds were captured. Mass, adjusted mass, and wing lengths were not normally distributed within age classes. Log transformations successfully normalized mass and adjusted mass but not wing length. However, visual inspection of histograms suggested log transformed data for wing length were normally distributed. The average mass of 244 AHY birds (11.4 g ± 0.10) was significantly greater ($F_{1,656} = 21.157$, $P < 0.0001$) than that of 428 HY birds (10.9 g ± 0.07). However, mass of blackpolls varied among years ($F_{7,656} = 7.8$, $P < 0.001$). Blackpolls captured in 2005, 2007, and 2009 were significantly heavier than those in 2006 ($P = 0.003$, $P < 0.001$, $P = 0.006$, respectively) or 2010 ($P < 0.001$, $P < 0.001$, $P = 0.003$, respectively); average mass of blackpolls was also greater in 2007 than 2008 ($P = 0.019$; Table 1). Despite there being differences in mass between age classes and among years, there was no significant interaction of these two explanatory variables ($F_{7,656} = 0.8$, $P = 0.58$).

Similar to age related differences in mass, the wing chord of 251 AHY birds (73.0 mm ± 0.16) was significantly longer ($F_{1,675} = 20.1$, $P < 0.001$) than that of 426 HY birds (72.1 mm ± 0.12). The results of assessing adjusted mass among age classes and years was similar to that for raw mass; there were significant differences between age classes ($F_{1,646} = 13.7$, $P = 0.002$) and among years ($F_{7,646} = 6.6$, $P < 0.001$), but there was no apparent interaction between the two explanatory variables ($F_{7,646} = 0.9$, $P = 0.52$).

The overall average mass for AHY and for HY birds were, respectively, 9.3% and 4.4% greater than the estimated 10.34 g fat free mass (FFM) of Blackpoll Warblers (Odum in Dunning 2008). Proportionally fewer AHY (26.2%) than HY (40.2%) blackpolls were below the estimated fat free mass for the species (Table 2). Although the average mass of Blackpoll Warblers was consistently above the estimated FFM, there was substantial variance among years ranging from all AHY birds being above the FFM in 2011 to 56% of HY being below FFM in 2010 (Table 2). When pooled,

TABLE 2. Number adult (AHY) and juvenile (HY) Blackpoll Warblers above and below the estimated fat-free mass (FFM) for the species, and the percent of individuals below the FFM, Guana Island, British Virgin Islands, Octobers 2005–2012.

	AHY			HY		
Year	N above FFM	N below FFM	% Total below FFM	N above FFM	N below FFM	% Total below FFM
2005	65	11	14.5	66	28	29.8
2006	18	22	55.0	13	11	45.8
2007	25	8	24.2	54	23	29.9
2008	13	4	23.5	19	16	45.7
2009	9	2	18.2	11	7	38.9
2010	37	18	32.7	56	73	56.6
2011	11	0	0.0	23	13	36.1
2012	8	1	11.1	14	1	6.7
All	186	66	26.2	256	172	40.2

AHY blackpolls scored significantly better (U = 45788.5, $P = 0.001$) in fat score than HY blackpolls. When examining fat scores (Sign Test) within age classes, there were also significant differences among years for both AHY ($Z = 15.7$, $P < 0.001$) and HY ($Z = 20.7$, $P < 0.001$) blackpolls (Table 1).

DISCUSSION

Studies assessing migration of Blackpoll Warblers have largely been limited to banding stations across northern North America, with an emphasis on the northeastern region of the continent (Hunt and Eliason 1999). Condition of autumn migrant Blackpoll Warblers has been examined via mist-netting in Massachusetts (Nisbet et al. 1963), Maine (Morris et al. 1996), Nova Scotia (Davis 2001), and on Bermuda (Nisbet et al. 1963). Compared to the robust samples from most of these studies, the few mist-netting studies conducted on blackpolls en route through the Caribbean have been limited to single migrations and typically of small (<100 birds) samples (Latta and Brown 1999, McNair et al. 2002). In contrast, I have been able to assess aspects of timing, age ratios, and condition of a comparatively larger number of Blackpoll Warblers among multiple years through the previously unsampled British Virgin Islands. The number of Blackpoll Warblers captured in my study was not related to net hrs. Hence, I suspect the annual variance in captures may be explained by ease or difficulty in the transatlantic crossing, and how winds may have shifted landfall east or west of the study site. I do not believe my study location receives comparatively more blackpolls on migration, only that I was fortunate in being able to sample across 10 autumn migrations and detect the variability.

Prior to southbound migration from coastal departure points, HY blackpolls typically outnumber AHY birds (Nisbet et al. 1963, Ralph 1981), accounting for 72.4% of blackpolls captured on Bon Portage Island, Nova Scotia (Davis 2001), 76.5% of blackpolls captured on Appledore Island, Maine (Morris et al. 1996), and 90.4% of blackpolls captured on Island Beach, New Jersey (Murray 1966). Thus, age ratios of blackpolls aggregating on the continental staging grounds compared to that detected at stopover locations in the Caribbean may be indicative of age-specific success of transatlantic passage. Unfortunately, the data with which to assess this are sparse. Mist-netting activities on Bermuda, midway between the continental departure points of North America and the Caribbean islands, revealed only 56% of blackpolls were HY (Ralph 1981). In contrast, 73% of blackpolls arriving on the Dominican Republic were HY birds (Latta and Brown 1999). I found 62% of 638 aged blackpolls arriving in the British Virgin Island were HY birds, but that there was substantial variability among years, with HY accounting for 35–71% of blackpolls. This annual variability in age ratios suggests that studies from only one year may be misleading.

One explanation for lower proportions of HY blackpolls arriving in the Caribbean in some years is lower survival of the open water crossing. This would be consistent with my findings of HY blackpolls being consistently lower in mass, lower in fat scores, and in poorer condition than AHY birds. Indeed, average mass across years was lower for both AHY and HY birds than averages reported on the continent at Florida (Murray 1989), Maine (Morris et al. 1996), and Nova Scotia (Davis 2001), and at the transatlantic midway point of Bermuda (Nisbet et al. 1963). However, blackpolls captured in the Dominican Republic (Latta and Brown 1999) and on Barbados (McNair et al. 2002) also averaged greater mass than those in the British Virgin Islands. This may be explained by Latta and Brown (1999) and McNair et al. (2002) presenting data from only one migration and thus not capturing annual variability. Alternatively, the relatively better condition of blackpolls on the Dominican Republic could have been a result of migration from a more southerly departure point and less open ocean to cross, or migration across the Bahamas where the opportunity for stopover was available if needed. Occurrence of Blackpolls on Eleuthra, Bahamas is inconsistent and is thought to be associated with storms or headwinds (J. M. Wunderle Jr., pers. comm.). Similarly, blackpolls arriving on Barbados could have made earlier landfall anywhere north among the islands of the Lesser Antilles to feed and rebuild fat reserves.

In contrast to the Dominican Republic and Barbados, there is nothing between the British Virgin Islands and departure points in northeastern North America that would provide blackpolls a stopover location except for 53.2 km^2 Bermuda, a virtual needle in a haystack. Thus, the archipelago of the Virgin Islands was probably the first landfall for arriving blackpolls since leaving the continent. Variance in weather encountered in different years over a long open-water crossing may explain the annual variability in the number and the generally poorer condition of blackpolls captured at my station.

If there is typically no difference in condition among AHY and HY blackpolls departing on migration (Morris et al. 1996, Davis 2002), some aspect of en route flight behavior may lead to the differences observed among those individuals making landfall. One possible explanation is a higher energetic demand experienced by HY birds because of their shorter wing lengths imposing an increased wing loading. McNair et al. (2002) found AHY blackpolls preceded HY by a median of 12–13 days in Barbados. In contrast, I found no such pattern in arrival based on day of capture. This may be explained by flocks of blackpolls arriving at first landfall during similar time periods but HY birds, being in comparatively poorer condition, may take longer to replenish their reserves before continuing on migration.

ACKNOWLEDGMENTS

I thank the Jarecki family, the Falconwood Foundation, and The Conservation Agency for their continued access to Guana Island and support for this research, and to the USGS Cooperative Research Units for facilitating this research. Any use of trade, firm, or products names is for descriptive purposes only and does not constitute endorsement by the U.S. Government. Special thanks to J. D. Lazell and G. Perry for coordinating research opportunities on Guana Island. Capture and banding was conducted under Texas Tech University Animal Care and Use Committee approved protocol No. 2053-07. Mist-netting efforts could not have been accomplished without the assistance of many volunteers, especially T. S. Estabrook, T. Willard, S. Valentine-Cooper, B. D. Bibles, and E. P. Estabrook. This manuscript has benefited from the reviews of B. N. Grisham, S. C. Latta, K. Linner, B. Perkins, B. Welch, J. Wunderle, and two anonymous referees.

LITERATURE CITED

ARENDT, W. J. 1992. Status of North American migrant landbirds in the Caribbean region: a summary. Pages 143–171 *in* Ecology and conservation of Neotropical migrant landbirds (J. M. Hagen III and D. W. Johnston, Editors). Smithsonian Institution Press, Washington, D.C., USA.

BAIRD, J. 1999. Returning to the tropics: the epic autumn flight of the Blackpoll Warbler. Pages 63–77 *in* Gatherings of angels: migrating birds and their ecology (K. P. Able, Editor). Cornell University Press, Ithaca, New York, USA.

BUTLER, R. W. 2000. Stormy seas for some North American songbirds: are declines related to severe storms during migration? Auk 117:518–522.

DAVIS, A. K. 2001. Blackpoll Warbler (*Dendroica striata*) fat deposition in southern Nova Scotia during autumn migration. Northeastern Naturalist 8:149–162.

DUGGER, K. M., J. FAABORG, W. J. ARENDT, AND K. A. HOBSON. 2004. Understanding survival and abundance of overwintering warblers: does rainfall matter? Condor 106:744–760.

DUNN, E. H. 2000. Temporal and spatial patterns in daily mass gain of Magnolia Warblers during migratory stopover. Auk 117:12–21.

DUNNING JR., J. B. 2008. CRC handbook of avian body masses. CRC Press, Boca Raton, Florida, USA.

EWERT, D. N. AND R. A. ASKINS. 1991. Flocking behavior of migratory warblers in winter in the Virgin Islands. Condor 93:864–868.

FRANCIS, C. M. AND D. S. WOOD. 1989. Effects of age and wear on wing length of wood-warblers. Journal of Field Ornithology 52:97–111.

HEGLUND, P. J. AND S. K. SKAGEN. 2005. Ecology and physiology of en route Nearctic-Neotropical migratory birds: a call for collaboration. Condor 107:193–196.

HUNT, P. D. AND B. C. ELIASON. 1999. Blackpoll Warbler (*Dendroica striata*). The birds of North America. Number 31.

JONES, J., C. M. FRANCIS, M. DREW, S. FULLER, AND M. W. S. NG. 2002. Age-related differences in body mass and rates of mass gain of passerines during autumn migratory stopover. Condor 104:49–58.

KELLY, J. F. AND R. L. HUTTO. 2005. An east-west comparison of migration in North American wood warblers. Condor 107:197–211.

KUENZI, A. J., F. R. MOORE, AND T. R. SIMONS. 1991. Stopover of Neotropical landbird migrants on East Ship Island following trans-gulf migration. Condor 93:869–883.

LATTA, S. C. AND C. BROWN. 1999. Autumn stopover ecology of the Blackpoll Warbler (*Dendroica striata*) in thorn scrub forest of the Dominican Republic. Canadian Journal of Zoology 77:1147–1156.

LATTA, S. C. 2012. Avian research in the Caribbean: past contributions and current priorities. Journal of Field Ornithology 83:107–121.

LATTA, S. C., A. TOSSAS, A. SUTTON, H. GONZALEZ, P. B. HAMEL, AND D. DESANTE. 2003. Research, monitoring, and conservation of Neotropical migratory land birds in the West Indies. Journal of Caribbean Ornithology 16:1–19.

LAZELL, J. 2005. Island: fact and theory in nature. University of California Press, Berkeley, USA.

MCNAIR, D. B., E. B. MASSIAH, AND M. D. FROST. 2002. Ground-based migration of Blackpoll Warblers at Harrison Point, Barbados. Caribbean Journal of Science 38:239–248.

MOORE, F. R., P. KERLINGER, AND T. R. SIMONS. 1990. Stopover on a Gulf Coast barrier island by spring trans-gulf migrants. Wilson Bulletin 102:487–500.

MORRIS, S. R., D. W. HOLMES, AND M. E. RICHMOND. 1996. A ten-year study of stopover patterns of migratory passerines during fall migration on Appledore Island, Maine. Condor 98:395–409.

MURRAY, B. G. 1966. Migration of age and sex classes of passerines on the Atlantic Coast in autumn. Auk 83:352–360.

MURRAY JR., B. G. 1989. A critical review of the transoceanic migration of the Blackpoll Warbler. Auk 106:8–17.

NATIONAL OCEANOGRAPHIC AND ATMOSPHERIC ADMINISTRATION. 2013. Center for Operational Oceanographic Products and Services. www.co-ops.nos.noaa.gov/index.html (accessed 30 May 2014).

NISBET, I. C. T., W. H. DRURY JR., AND J. BAIRD. 1963. Weight-loss during migration part I: deposition and consumption of fat by the Blackpoll Warbler *Dendroica striata*. Bird-Banding 34:107–138.

NISBET, I. G. T., D. B. MCNAIR, W. POST, AND T. C. WILLIAMS. 1995. Transoceanic migration of the Blackpoll Warbler: summary of scientific evidence and response to criticisms by Murray. Journal of Field Ornithology 66:612–622.

NORTH AMERICAN BANDING COUNCIL. 2001. The North American banders' manual for banding passerines and near passerines (excluding hummingbirds and owls). North American Banding Council, Point Reyes Station, California, USA. (accessed 31 May 2014).

PYLE, P. 1997. Identification guide to North American birds: part I. Columbidae to Ploceidae. Slate Creek Press, Bolinas, California, USA.

RAFFAELE, H., J. WILEY, O. H. GARRIDO, A. KEITH, AND J. I. RAFFAELE. 1998. A guide to the birds of the West Indies. Princeton University Press, Princeton, New Jersey, USA.

RALPH, C. J. 1981. Age ratios and their possible use in determining autumn migration routes of passerine migrants. Wilson Bulletin 93:164–188.

RAPPOLE, J. H. 1995. The ecology of migrant birds: a Neotropical perspective. Smithsonian Institution Press, Washington D.C., USA.

RODEWALD, P. G. AND M. C. BRITTINGHAM. 2007. Stopover habitat use by spring migrant landbirds: the roles of habitat structure, leaf development, and food availability. Auk 124:1063–1074.

WILLIAMS, T. C., J. M. WILLIAMS, L. C. IRELAND, AND J. M. TEAL. 1977. Autumnal bird migration over the western North Atlantic Ocean. American Birds 31:251–267.

WILLIAMS, T. C. 1985. Autumnal bird migration over the Windward Caribbean Islands. Auk 102:163–167.

WOODREY, M. S. AND F. R MOORE. 1997. Age-related differences in the stopover of fall landbird migrants on the coast of Alabama. Auk 114:695–707.

WUNDERLE JR., J. M. 1995. Population characteristics of Black-throated Blue Warblers wintering in three sites on Puerto Rico. Auk 112:931–946.