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Photo: Andrew Dobson

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Mass fallout and stopover duration of migratory Blackpoll Warblers (*Setophaga striata*) in Bermuda after Hurricane Nicole

Miguel A. Mejías[1] and Albert J. Mejías[2]

Abstract Strong weather systems can force large numbers of migrating songbirds to take refuge in areas they would otherwise fly over, an event called a "fallout." On 13 October 2016, Hurricane Nicole made landfall over Bermuda during the fall songbird migration, and provided an opportunity to document a potential fallout. We visited 10 sites in order to (1) compare the abundance of migrant songbirds immediately before and after the hurricane, (2) identify the most abundant fallout songbird species, and (3) record the stopover duration of the most abundant fallout songbird(s). We found a significant increase in the number of migrant songbirds at three sites when comparing before (n = 40 individuals) with after (n = 93 individuals) Hurricane Nicole. Blackpoll Warblers (*Setophaga striata*) were absent at all five sites sampled before Nicole, but present at seven of the eight sites (88%) sampled after Nicole. Peak Blackpoll Warbler abundance (n = 173) was recorded the day after the storm followed by a significant reduction in numbers over a 2-week period. Our study emphasizes the disruptive nature of hurricanes on migrating Blackpoll Warblers en route to their wintering grounds, and the importance of remote oceanic islands to fallout migrants taking transoceanic routes.

Keywords Bermuda, Blackpoll Warbler, fallout, hurricanes, islands, migration, *Setophaga striata*, weather

Resumen Irrupción extraordinaria masiva y duración de la escala migratoria de *Setophaga striata* en las Bermudas después del huracán Nicole—Fuertes eventos climatológicos pueden obligar a un gran número de paseriformes migratorios a refugiarse en áreas sobre las que normalmente pasarían de largo, un evento conocido como irrupción extraordinaria o fallout. El 13 de octubre de 2016, el huracán Nicole tocó tierra sobre las Bermudas durante la migración otoñal de paseriformes y proporcionó una oportunidad para documentar una posible irrupción de este tipo. Se visitaron 10 sitios para (1) comparar la abundancia de paseriformes migratorios inmediatamente antes y después del huracán; (2) identificar las especies de paseriformes más abundantes y (3) registrar la duración de la escala migratoria de los paseriformes más abundantes durante dicha irrupción. Encontramos un aumento significativo en el número de paseriformes migratorios en tres sitios, al comparar antes (n = 40 individuos) con después (n = 93 individuos) del huracán Nicole. *Setophaga striata* estuvo ausente en los cinco sitios muestreados antes de Nicole, pero presente en siete de los ocho sitios (88%) muestreados después del huracán. La abundancia máxima de esta especie (n = 173) se registró el día siguiente de la tormenta seguido de una disminución significativa de ese valor durante un período de 2 semanas. Nuestro estudio enfatiza la naturaleza disruptiva de los huracanes en individuos migratorios de *Setophaga striata* en ruta a sus áreas de invernada y la importancia de islas oceánicas remotas para individuos irruptores migratorios que tienen rutas transoceánicas.

Palabras clave Bermudas, clima, huracanes, irrupción extraordinaria, islas, migración, *Setophaga striata*

Résumé Importance et durée des haltes migratoires forcées des Parulines rayées (*Setophaga striata*) aux Bermudes après le cyclone Nicole — Des évènements météorologiques puissants peuvent obliger un grand nombre de passereaux migrateurs à se réfugier dans des zones qu'ils auraient seulement survolées dans d'autres conditions. Il s'agit alors de haltes migratoires forcées parfois appelées « tombées » ou « pluies » d'oiseaux. Le 13 octobre 2016, le cyclone Nicole a touché les Bermudes au cours de la migration automnale des passereaux, ce qui a ensuite permis de documenter des haltes migratoires forcées. Nous avons visité 10 sites afin de : (1) comparer l'abondance des passereaux migrateurs immédiatement avant et après l'ouragan ; (2) identifier les espèces de passereaux les plus abondantes ; et (3) enregistrer les durées de halte des espèces de passereaux les plus abondants. Nous avons constaté une augmentation significative du nombre de passereaux migrateurs sur trois sites en comparant les effectifs avant (n = 40 individus) et après (n = 93 individus) le passage du cyclone Nicole. Les Parulines rayées (*Setophaga striata)* étaient absentes des cinq sites échantillonnés avant le cyclone, mais présentes dans sept des huit sites (88 %) échantillonnés après. L'abondance maximale des Parulines rayées (n = 173) a été enregistrée le lendemain du passage du cyclone, elle a été suivie d'une réduction importante des effectifs sur une période de 2 semaines. Notre étude met l'accent sur l'effet perturbateur des cyclones sur les Parulines rayées en migration vers leurs

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aires d'hivernage et sur l'importance des îles océaniques éloignées pour les haltes migratoires forcées des oiseaux empruntant des routes transocéaniques.

Mots clés Bermudes, conditions météorologiques, cyclones, haltes migratoires forcées, îles, migration, Paruline rayée, *Setophaga striata*

Weather can disrupt migrating songbirds en route to their wintering grounds. For example, rain and strong winds create adverse flying conditions, forcing songbirds down from migratory altitudes as high as 1,500 m (Able 1970, Gauthreaux 1971, Gauthreaux and Belser 1998). In response, migrants may take refuge in areas they would otherwise bypass, allowing them to replenish fat reserves before resuming their migration in favorable weather (Gannes 2001, Deppe *et al.* 2015). The sudden descent of an unusually large number of birds following strong weather systems is called a "fallout" (Hameed *et al.* 2009). Fallouts, especially in North America, are well documented in the ornithological literature. McLaren *et al.* (2000) describe a fallout in southern Nova Scotia, where a large array of grounded fall migrants, including vireos (Vireonidae), warblers (Parulidae), and buntings (Passerellidae), were found immediately after strong winds and rain. Another fallout was recorded in the southern United States, where hundreds of spring migrants en route to their northern breeding grounds took immediate shelter in coastal vegetation along the Gulf of Mexico during stormy conditions (Lowery 1945).

Weather imposes high risks on songbirds taking transoceanic flyways, where small, remote, oceanic islands are their only haven; Bermuda is a good example. Bermuda (32°17'N, 64°45'W) lies in the western region of the North Atlantic, approximately 1,070 km from Cape Hatteras, its closest neighboring land mass. Despite being only roughly 53 km², Bermuda boasts a surprisingly large array of habitats, including beaches, mudflats, brackish ponds, mangroves, and woodlands (Amos 1991). This, coupled with its location in the center of flight paths of many North American songbirds, makes it an ideal refuge for migrant and vagrant birds (Scholander 1955, Larkin *et al.* 1979, Amos 1991). In fact, Bermuda receives an average of 200 migratory bird species annually, with 90–100 being annual wintering residents (Amos 1991).

Bermuda also lies within the Caribbean hurricane belt (Lugo 2000). At least one tropical storm passes within ~340 km of the island annually, and a severe hurricane directly impacts the island every 6 or 7 yr on average (Bermuda Weather Service unpubl. data). The impacts of hurricanes on island-dwelling birds are well documented. For example, severe declines in bird abundance immediately after hurricanes have been reported on Puerto Rico (Danforth 1936, Waide 1991), the British Virgin Islands (Wauer and Wunderle 1992), and Cuba (Huntington and Barbour 1936). These declines may have been caused by exposure to high winds, rainfall, and falling objects (Clark 1906, Kennedy 1970). Hurricanes also blow migrants into atypical ranges and remove previously available food sources, causing temporary changes in the distribution and composition of avian communities (LeGrand 1990, Waide 1991, Wauer and Wunderle 1992, Wunderle *et al.* 1992, Wiley and Wunderle 1993, Dionne *et al.* 2008).

In 2016, the North Atlantic saw some of the strongest hurricanes on record. On 13 October 2016, Hurricane Nicole made landfall on Bermuda as a Category 3 storm on the Saffir-Simpson scale (i.e., ~200 km/hr winds; Kantha 2006). Hurricane Nicole's arrival in Bermuda overlapped with the North American songbird migration, providing an ideal opportunity to record a potential hurricane-induced songbird fallout. We used a common before-after approach to accomplish three study objectives: (1) compare migrant songbird abundance in specific localities across Bermuda immediately before and after Hurricane Nicole, (2) identify the most abundant fallout songbird(s) immediately after Hurricane Nicole, and (3) determine if the most abundant fallout songbird(s) showed a prolonged stay or rapid departure from Bermuda.

Methods

During the period 11–28 October 2016, we conducted fieldwork at 10 birdwatching hotspots across the island of Bermuda where migrant songbirds are often found (Fig. 1). Our study sites were composed of either woodland habitat (Ferry Reach, Cooper's Island, Spittal Pond, and Tudor Hill), green space habitat (Bermuda Institute of Ocean Sciences [BIOS], Kindley Field, Mid Ocean Club, Riddell's Bay Golf and Country Club, and Port Royal Golf Course), or both (Coney Island). Vegetation on the island now consists almost entirely of exotic plant species, a consequence of rampant plant introductions dating back to the 1700s (Britton 1965, Sterrer *et al.* 2004). Therefore, we were unable to

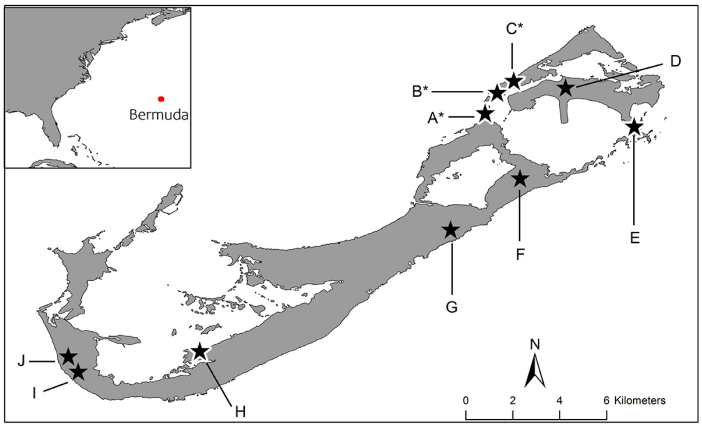

Fig. 1. Location of our bird surveying sites across Bermuda. Sites with an asterisk were surveyed both before and after Hurricane Nicole; all other sites were surveyed only once, either before or after the hurricane. A = Coney Island, B = Ferry Reach, C = BIOS, D = Kindley Field, E = Cooper's Island, F = Mid Ocean Club, G = Spittal Pond, H = Riddell's Bay Golf and Country Club, I = Port Royal Golf Course, J = Tudor Hill.

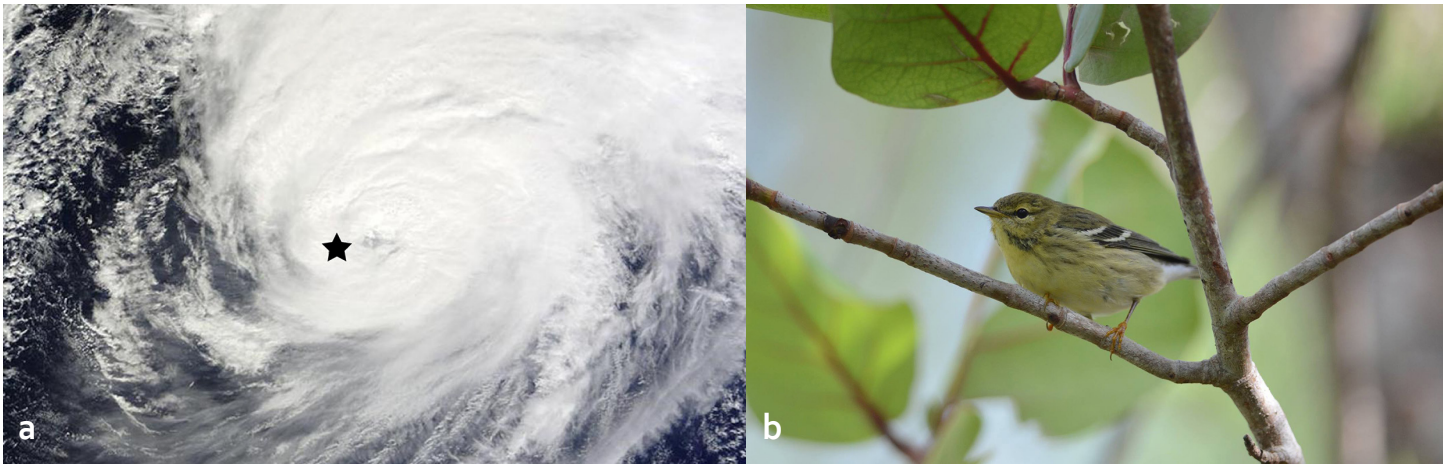

Fig. 2. (a) Satellite image of Hurricane Nicole, a Category 3 storm, making landfall over Bermuda (marked by star); photograph by the National Aeronautics and Space Administration (NASA). (b) A Blackpoll Warbler in fall plumage, perched in a sea grape tree (*Coccoloba uvifera*) in Bermuda; photograph by Andrew Dobson.

obtain a good measure of native habitat. At sites characterized by woodland habitat, casuarina (*Casuarina equisetifolia*) was the dominant canopy tree, while the Brazilian peppertree (*Schinus terebinthifoli*a), jumbie bean *(Leucaena leucocephala*), natal plum (*Carissa macrocarpa*), *Clerodendrum* spp., and Chinese fan palm (*Livistona chinensis*) formed understory thickets beneath the canopy. Green space habitat included spacious lawns with introduced and native trees planted sparsely across the landscape. Native trees present in green space habitat included Bermuda cedar (*Juniperus bermudiana*), Bermuda olivewood (*Cassine laneana*), Bermuda palmetto (*Sabal bermudana*), and black mangrove (*Avicennia germinans*). Introduced flora within green space habitat included casuarina, Chinese fan palm, coconut palm (*Cocos nucifera*), Indian laurel (*Ficus microcarp*a), royal poinciana (*Delonix regia*), and oleander (*Nerium oleande*r).

Hurricane Nicole initially approached Bermuda from the south as a Category 1 storm (i.e., ~120 km/hr winds), briefly obtained Category 4 status (i.e., ~210 km/hr winds), then downgraded to a Category 3 storm (i.e., ~200 km/hr winds) prior to landfall on Bermuda on 13 October 2016 (Bermuda Weather Service 2016). The storm's eye—approximately 48 km wide—passed directly over the 53-km² island (Fig. 2a). Following Hurricane Nicole, most trees across our study sites had reddish-brown, salt-burned leaves, and some were completely denuded. Other trees were uprooted; at our study sites, most were casuarinas and young Bermuda cedars.

Songbird Surveys

Our two-person team worked together as a single unit to opportunistically count migrant songbirds at five sites on 11 October 2016, just before Hurricane Nicole's arrival in Bermuda. These sites included Coney Island, Ferry Reach, BIOS, Cooper's Island, and Spittal Pond (hereafter "pre-Nicole sites;" $n = 5$). We visited each pre-Nicole site one time between 0900 and 1800. On 14 October 2016, immediately after Hurricane Nicole, we conducted counts at Coney Island, Ferry Reach, BIOS, Kindley Field, Mid Ocean Club, Riddell's Bay Golf and Country Club, Port Royal Golf Course, and Tudor Hill (hereafter "post-Nicole sites;" $n = 8$). The two-person team performed counts by walking unhurriedly along a surveying route and counting all migrant songbirds seen on the ground and in the foliage. One individual did all the counting and identification, using binoculars, while the second individual recorded all the birds seen. We are aware that songbird abundance is more rigorously estimated by using standardized point counts or line transects (Ambuel and Temple 1982, Dobkin and Rich 1998, Thomsen and Green 2016, Leu *et al.* 2017). However, we did not use point counts because fall migrant songbirds usually do not sing as much as spring migrants or breeders at breeding sites, which reduces their overall detectability (Slater and Mann 2004, Catchpole and Slater 2008). Similarly, we opted not to use transect surveys because we anticipated limited mobility within sites due to the debris that would result from Hurricane Nicole. Our expectation of limited mobility was borne out, and was also the reason that we managed to collect both pre- and post-Nicole data at only three of our study sites (Coney Island, Ferry Reach, and BIOS). To better quantify the most abundant fallout songbirds and the length of their stay on the island, we incorporated an additional five sites (Kindley Field, Tucker's Point Golf Club, Riddell's Bay Golf and Country Club, Port Royal Golf Course, and Tudor Hill) after Hurricane Nicole. We were able to access all eight of our post-Nicole sites for the remainder of the study. At each of our eight post-Nicole sites, we counted migrant songbirds between 0900 and 1800 on 14 October, 18 October, 23 October, and 28 October 2016. During these counts, we followed the same surveying route established on our first visit to any given site; we also visited sites in the same order and conducted counts at similar times.

Statistical Analysis

We ran a generalized linear model to test if our dependent variable, total migrant abundance, was affected by our independent variable, sampling period (pre-Nicole vs. post-Nicole). We ran this model only for the three sites for which we had both pre- and post-Nicole songbird count data. For our abundance model, we used the number of songbirds detected at each of the three sites during the single pre-Nicole visit and during the first

visit to the same three sites after Nicole. We ran another generalized linear model to test if the number of the most abundant fallout songbird species significantly changed during the repeated counts at our eight post-Nicole sites. More specifically, we built a generalized linear model with the abundance of the most common species, our dependent variable, against sampling period (i.e., days post-Nicole), our independent variable. We fitted a Poisson distribution to all of our models because all of our dependent variables are based on count data (McCullagh and Nelder 1989). Results from all tests were considered significant if $p < 0.05$. All linear models were run in R 2.12 (R Core Team 2010).

Results

Pre- and Post-Hurricane Nicole Songbird Abundance

In total, we counted 47 migrant songbirds across our five pre-Nicole sites and 300 migrant songbirds during the first survey of our eight post-Nicole sites. New World warblers (Parulidae) comprised the majority of the total songbird species detected before (67%, 8 of 12 species) and after (62%, 16 of 26 species) the storm. For the remainder of this section, we discuss only the species abundance of migrant songbirds at the three sites for which we have both pre- and post-Nicole data. We found 12 species (67% Parulidae) and 13 species (77% Parulidae) at the three sites before and after the storm, respectively (Table 1). We counted 40 migrant songbirds at the three sites before the storm and 93 migrant songbirds at the three sites immediately after the storm (Table 1). Our generalized linear model indicated the difference was significant (Wald statistic: $W = 4.46$, df = 32, $p < 0.001$). Since Blackpoll Warblers (*Setophaga striata*) comprised the majority of our post-Nicole sample, we reran our songbird abundance model excluding this species. The resulting generalized linear model showed that songbird abundance did not differ significantly between before and after Hurricane Nicole at our three sites ($W = -0.52$, df = 29, $p = 0.61$).

Blackpoll Warbler Abundance and Departure

The Blackpoll Warbler was the most abundant fallout migrant detected after Nicole (Table 1, Fig. 2b). Blackpoll Warblers were absent from all five pre-Nicole sites, but were present at seven of the eight (88%) post-Nicole sites. With respect to the three sites we checked both before and after the storm, Blackpoll Warblers were absent at pre-Nicole sites but present at post-Nicole sites (Table 1). Their peak abundance ($n = 173$) was observed the day immediately after Hurricane Nicole, and their numbers significantly declined over the subsequent 2 weeks (Fig. 3; $W = -11.2$, df = 2, $p < 0.001$).

Discussion

Our study highlights the disruptive effect hurricanes have on migrating songbirds taking transoceanic routes near Bermuda. At our three sites with both pre- and post-Nicole data, there was a large difference in the numbers of Blackpoll Warblers present before Hurricane Nicole ($n = 0$) compared to immediately after Hurricane Nicole ($n = 64$). We did not find evidence of fallout for any other species. The effects of hurricanes on the abundance of migratory songbirds residing on islands are variable. For example, the overall abundance of wintering birds in the United States Virgin Islands (Askins and Ewert 1991) and Jamaica

Table 1. Numbers of migrant songbirds detected before and after Hurricane Nicole at three of our sampling sites—Coney Island, Ferry Reach, and BIOS—in Bermuda, on 11 October 2016 ("Before") and 14 October 2016 ("After").

		Coney Island		Ferry Reach		BIOS	
Common Name	**Scientific Name**	*Before*	*After*	*Before*	*After*	*Before*	*After*
Red-eyed Vireo	*Vireo olivaceus*	0	0	5	0	1	6
Cedar Waxwing	*Bombycilla cedrorum*	0	0	3	0	0	0
Baltimore Oriole	*Icterus galbula*	0	0	0	2	0	0
Ovenbird	*Seiurus aurocapilla*	0	0	2	0	0	0
Worm-eating Warbler	*Helmitheros vermivorum*	0	0	1	1	0	0
Northern Waterthrush	*Parkesia noveboracensis*	3	2	0	0	1	0
Black-and-white Warbler	*Mniotilta varia*	3	0	0	0	0	0
Common Yellowthroat	*Geothlypis trichas*	0	1	0	0	0	0
Hooded Warbler	*Setophaga citrina*	0	0	1	0	0	0
American Redstart	*S. ruticilla*	0	0	0	1	0	0
Northern Parula	*S. americana*	0	0	5	7	2	0
Bay-breasted Warbler	*S. castanea*	0	0	0	1	0	0
Blackpoll Warbler	*S. striata*	0	10	0	50	0	4
Yellow-rumped Warbler	*S. coronata*	0	0	0	1	0	0
Prairie Warbler	*S. discolor*	0	0	0	1	0	0
Black-throated Green Warbler	*S. virens*	0	0	1	2	1	1
Canada Warbler	*Cardellina canadensis*	1	0	0	0	0	0
Scarlet Tanager	*Piranga olivacea*	0	0	0	1	0	2
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	0	0	1	0	0	0
Indigo Bunting	*Passerina cyanea*	5	0	4	0	0	0
Total Number of Individuals Detected		**12**	**13**	**23**	**67**	**5**	**13**

(Wunderle *et al.* 1992) were found to be similar before and after hurricanes, whereas a notable decline in bird abundance after hurricanes was found in Puerto Rico (Waide 1991). Possible factors that could explain this variation include storm-related mortality (Newton 2006), physical hurricane attributes (i.e., category and hurricane path), island habitat structure, and temporal factors (i.e., duration of hurricane presence and degree of overlap with fall migration).

Most of the migrant songbirds we found in Bermuda both before and after Hurricane Nicole were New World warblers. This was not surprising, as Bermuda receives at least 37 migratory New World warbler species annually (Amos 1991). Rarities also occur, including the Kirtland's Warbler *(Setophaga kirtlandii*; D.B. Wingate pers. comm.) and the Arctic Warbler (*Phylloscopus borealis*; MAM pers. obs.), which is an Old World species. Besides Blackpoll Warblers, Northern Parulas (*S. americana*) and Black-throated Green Warblers (*S. virens*) were the most abundant warblers we saw both before and after Nicole. After the storm, most of the warblers observed were feeding in mixed-species flocks, a behavior which is common among wintering warblers (Eaton 1953, Ewert and Askins 1991).

The number of warblers we detected in Bermuda after Hurricane Nicole were lower than expected. Hurricane Nicole passed through Bermuda when most warblers reach their peak abundance on the island, namely September–October (Amos 1991). Despite this, we found only Blackpoll Warblers in significant numbers. Arguably the most significant recorded fallout in Bermuda occurred after Hurricane Emily (Category 2, ~145 km/hr winds) made landfall on 25 September 1987; grounded migrants included 15,000–20,000 Bobolinks (*Dolichonyx oryzivorus*), 83 American Redstarts (*Setophaga ruticilla*), and 50 Cape May Warblers (*S. tigrina*), to name a few (Amos 1991). Despite Hurricanes Emily and Nicole occurring at the same time of year—only approximately 2 weeks apart in calendar days, though separated by 29 yr—the former storm undoubtedly intercepted more migrant birds than the latter, suggesting annual differences in either the number of migrating birds or timing of migration (Robbins *et al.* 1989, Sillett and Holmes 2002, Jenni and Kéry 2003, Van Buskirk *et al.* 2009). An additional factor to consider is when and where a hurricane last made landfall before reaching the location of a fallout event. It is possible for migrants to become trapped within the eye of a hurricane and carried away (Dionne *et al.* 2008), thereby influencing the species compositions of different hurricane-based fallouts.

The Blackpoll Warbler was by far the most abundant fallout songbird in Bermuda after Hurricane Nicole, with 173 individuals counted the day after the hurricane passed. Blackpoll Warbler fallouts appear to be common during the continent-wide migration of this species. Blackpoll Warbler fallouts have occurred on coastal islands off New England (Morris *et al.* 1996), in the Dominican Republic (Latta and Brown 1999) and Barbados (McNair *et al.* 2002), and on ships off the Eastern Seaboard (Cherry *et al.* 1985)—these events all occurred during bad weather in October, circumstances comparable to those in our study. Blackpoll Warblers have been detected in Bermuda as early as the 1960s (Nisbet *et al.* 1963), and a recent geolocator study indicates that some Blackpoll Warblers fly directly over the island in the fall, en route to South America (DeLuca *et al.* 2015). Their nonstop migration is likely the cause of the frequent Blackpoll Warbler fallouts mentioned above.

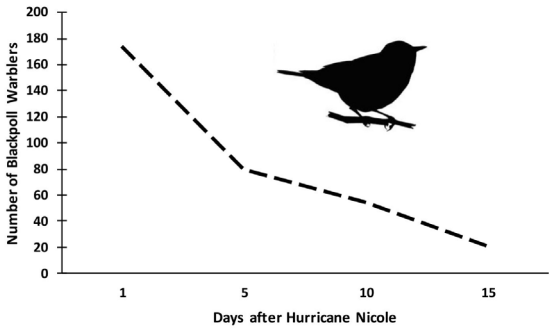

Fig. 3. Total numbers of fallout Blackpoll Warblers counted across our eight post-Nicole sites after Hurricane Nicole (14–28 October 2016). Peak abundance (n = 173) was recorded the day after the storm, and Blackpoll Warbler numbers steadily declined over the following 2-week period.

The loss of foliage at post-Nicole sites likely made detecting songbirds easier, but we are confident that the Blackpoll Warblers we observed were not present in Bermuda before the hurricane. First, this species is seldom encountered in Bermuda except when extreme weather conditions in the fall disrupt migration (Amos 1991). Second, the grounded Blackpoll Warblers were notably vocal, with individuals frequently calling and making bill-snapping sounds while feeding; these sounds often betrayed their whereabouts. A final testament to their post-Nicole presence were the numerous island-wide reports of Blackpoll Warblers from the public to the Bermuda Audubon Society. This organization estimated that Hurricane Nicole likely grounded at least 1,000–2,000 Blackpoll Warblers (A. Dobson pers. comm.). The absence of Blackpoll Warblers immediately before Hurricane Nicole, followed by their abrupt fallout post-Nicole, suggests that most of these birds would have flown nonstop over Bermuda had Hurricane Nicole not disrupted their migration.

We found that the stopover duration of grounded Blackpoll Warblers in Bermuda was brief. Their peak abundance (n = 173) occurred the day after the storm. Four days later it had declined by 54% (n = 80). By the end of our 2-week monitoring period, we only found 21 Blackpoll Warblers, an 88% decrease from their peak abundance. This brief stopover duration is consistent with other short Blackpoll Warbler stopovers seen in Barbados and the Dominican Republic (Latta and Brown 1999, McNair *et al.* 2002). Our last sighting of Blackpoll Warblers in Bermuda was 24 November 2016 (n = 2), and no Blackpoll Warblers were found during the Christmas Bird Count on 16 December 2016 (MAM unpubl. data, Bermuda Audubon Society unpubl. data). It is interesting that Blackpoll Warblers do not winter in Bermuda, even though the island supports many species of wintering warblers and is situated closer to the North American breeding grounds of Blackpoll Warblers than their actual wintering areas in South America (DeLuca *et al.* 2015). Nonetheless, our study highlights the importance of remote, oceanic islands as a refuge for grounded, migrant songbirds taking transoceanic flyways in

adverse weather.

Acknowledgments

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Title Page Illustration

Blackpoll Warbler (*Setophaga striata*); photograph by Andrew Dobson.

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