<u>**Electronic Supplementary Material**</u>

Transocеanic migration by a 12 g songbird

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1. Estimation of sun elevation angles

To estimate sun elevation angles, we conducted on-board calibration using filtered twilight times from the time geolocators were deployed (range = 13-18 June) to 15 July 2013 when individuals were at a known breeding location. For the geolocator that was deployed on Seal Is. later in the breeding season, we used twilight times from the period of 25 August to 01 September 2013 to estimate a sun angle. With one exception, sun angles for the breeding period were then used to derive position estimates for the entire year. For one individual from Vermont (figure 1B) we derived position estimates from 5 August 2013 to 20 March 2014 using a sun angle estimated from light data for the period of 5-25 August 2013. We estimated a separate sun angle for this individual because the quality of light recordings deteriorated in early August, such that using the June/July sun angle resulted in a severe northerly bias in position estimates up until ~ 10 March 2014, after which the light recordings returned to their original quality. Errors in position estimates derived for the June/July calibration period are summarized in table S1. In addition, error in location estimates are illustrated by presenting raw position estimates in figure S1. We did not use Hill-Ekstrom calibration [1,2] to estimate separate sun elevation angles for the non-breeding season because this method is highly sensitive to movements and unstable shading conditions during the calibration period [3], and little is known about habitat use and behaviour of blackpolls in the winter.

Table S1. Mean (± SD) latitudinal, longitudinal, and total deviation (km) of positions derived from light-level geolocators from known breeding locations of five blackpoll warblers in northeastern North America. Estimates of SD were calculated using flight distances in table S2. Latitudinal and total deviation could not be calculated for the Seal Is. individual because the geolocator was deployed too close to autumnal equinox. Letters in the left column correspond to the panel labels in figure 1, figure S1 and figure S2.

ID	Site	n	Latitude	Longitude	Total
A	Vermont	60	124 ± 98	84 ± 77	169 ± 99
B	Vermont	52	116 ± 95	86 ± 57	167 ± 73
C	Bon Portage Is.	58	107 ± 91	62 ± 42	135 ± 85
D	Seal Is.	13	--	59 ± 50	--
E	Vermont	52	135 ± 102	95 ± 69	183 ± 95

2. Alternative fall migration route for 'Bird E'

Estimating fall migration routes for birds A-D (figure 1, table S2) was relatively straightforward, even when individuals were travelling during the fall equinox (latitude estimates were not reliable) because we were able to combine information from longitudinal estimates and the quality of the light transitions to infer overwater flights over multiple days. However, reconstructing the fall migration of 'Bird E' was more challenging. It was apparent from the quality of the light transitions that this individual undertook three day/night flights between its breeding grounds in VT and wintering grounds in Venezuela (figure S2, S3) and that the last of these three flights was from a Caribbean island to the wintering grounds. Thus, if there was an overwater flight from North America to the Caribbean it was likely the second flight. However, this flight lasted only 18 hrs as opposed to 49-73 hrs for the longest flights of the others birds (table S2). Our first explanation of the fall route that is presented in the main text is that, for this day/night flight, the bird departed from an area around Cape Hatteras and flew 18 hrs to Turks and Caicos. The longitude estimates match this interpretation well (figure S2E, S3). However, the issue with this interpretation is that the migratory speed of the bird would have to be approximately 23.1 m/s, which is extremely fast for a bird of this size, although perhaps possible given tail wind assistance [4]. An alternative explanation is that this bird first travelled overland further south than Cape Hatteras, potentially as far south as Florida (figure S4). There are some longitude estimates for this bird in late Oct that appear to be as far west as -80 degrees (figure S3), which would be consistent with Florida. The bird then could have made a short flight to the Bahamas (e.g. Andros Island), which is at a similar longitude as Cape Hatteras. We would have not been able to detect this short migratory flight because it likely would have occurred only at night. After arriving in Bahamas, it could have then undertook the second day/night flight (18 hrs) to Hispaniola (figure S4). This is a distance of ~675 km, which results in a reasonable flight speed of ~10.4 m/s. Although this interpretation seems reasonable, it fails to offer an explanation for the first day/night flight (first yellow band in figure S2E, S3) that appeared to last between 6-12 hrs and occurred much further east than Florida. It is possible that this was not a flight and, instead, the bird was out in open habitat where the quality of light readings improved dramatically, although we didn't see evidence of this at other times of the year or in other birds that were tracked. We also examined historical weather data that coincided spatially and temporally with the proposed overwater flights of 'Bird E' to identify potential tail winds or weather patterns that would impede an overwater flight. The data did not reveal any clear weather patterns that would identify a more likely migratory route. Nevertheless, given the very fast flight speed in the first explanation, we offer this as an alternative possibility. Either way, it is clear that this bird did not make as long of an overwater flight as the other four birds that were tracked.

Table S2. Departure and stopover longitudes, minimum flight distances and durations, and approximate flight speeds of five blackpoll warblers making fall overwater migratory flights from northeastern North America to stopover sites in the Carribbean Ocean. Minimum distances and durations were estimated due to uncertainty in departure latitude and departure time (i.e., exact departure times cannot be known for individuals that depart after sunset), respectively. Letters in the ID column correspond to the panel labels in figure 1 and figure S1.

ID	Site	Departure longitude	Stopover longitude	Minimum distance (km)	Duration (hrs)	Flight speed (ms^{-1})
A	Vermont	-67.7	-71.5	2750	64	11.9
B	Vermont	-70.1	-71.8	2370	49	13.4
C	Bon Portage Is.	-66.1	-66.4	2770	60	12.8
D	Seal Is.	-73.8	-72.8	2270	73	10.7
E	Vermont	-75.6	-71.5	1500	18	23.1

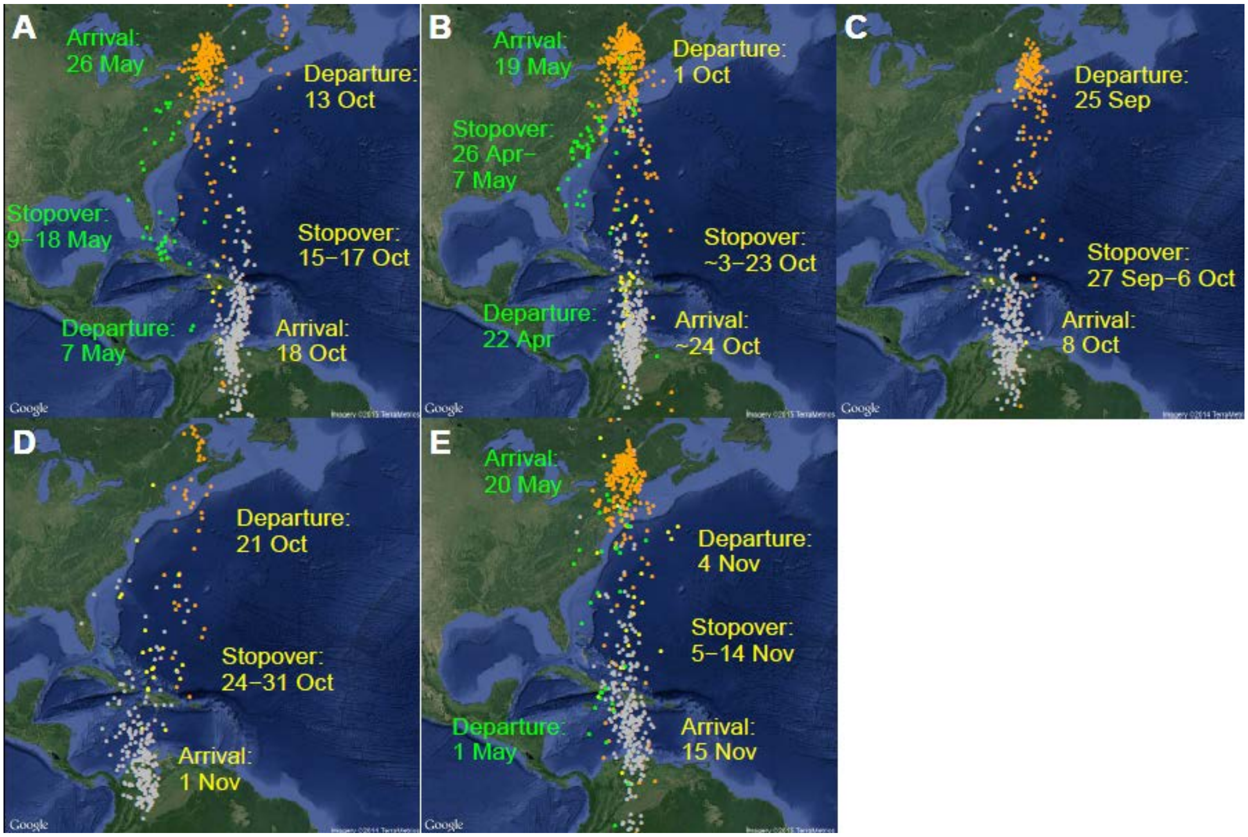
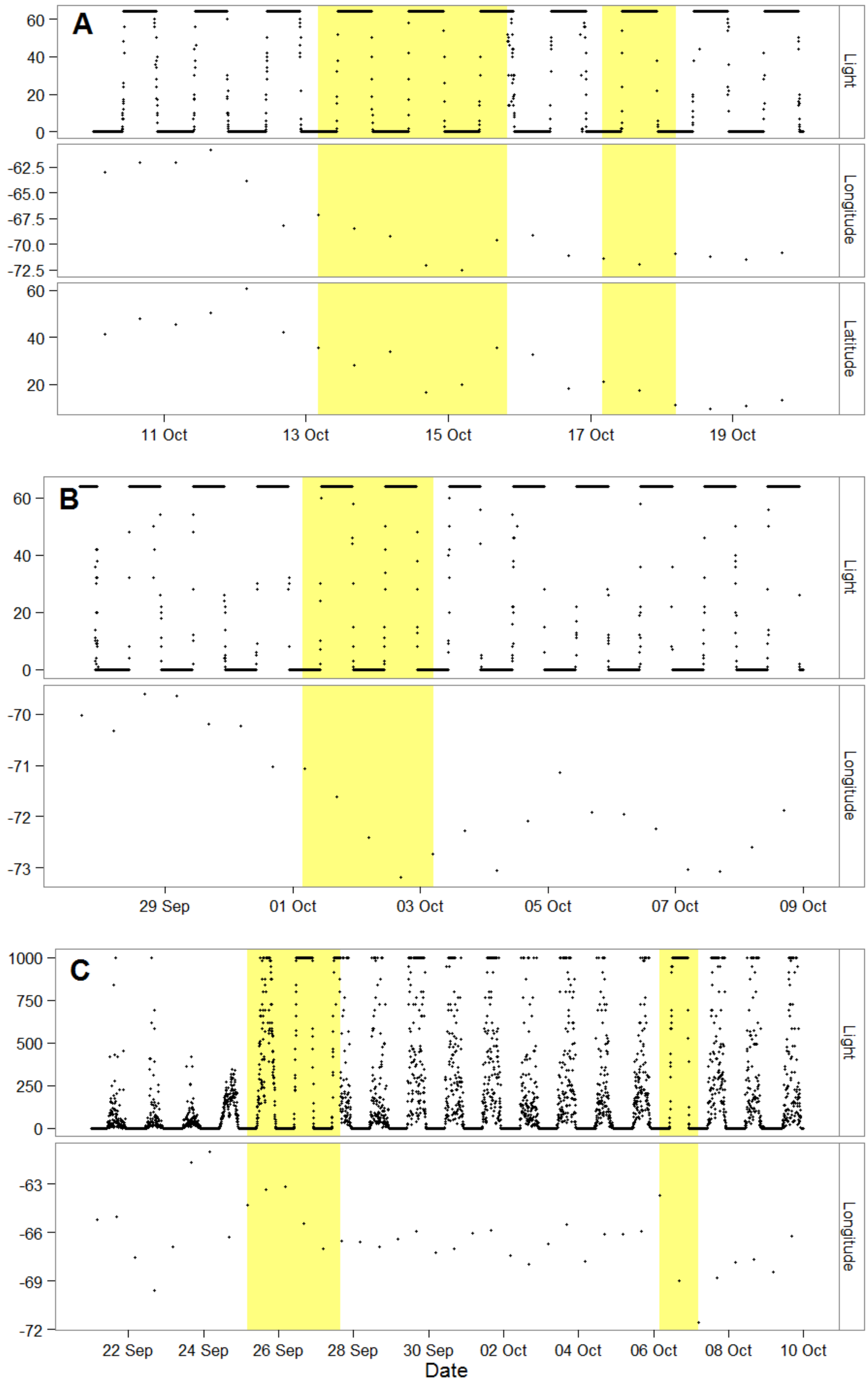


Figure S1. Raw position estimates of five blackpoll warblers (A-E) breeding in northeastern North America, as inferred from light-level geolocators. Points represent breeding (orange), migratory (yellow: fall migration; green: spring migration), and winter (grey) locations. Maps (courtesy of Google Earth) were created using the R package 'ggmap'.



A
B
C
Light
Longitude
Latitude
11 Oct
13 Oct
15 Oct
17 Oct
19 Oct
29 Sep
01 Oct
03 Oct
05 Oct
07 Oct
09 Oct
22 Sep
24 Sep
26 Sep
28 Sep
30 Sep
02 Oct
04 Oct
06 Oct
08 Oct
10 Oct
Date

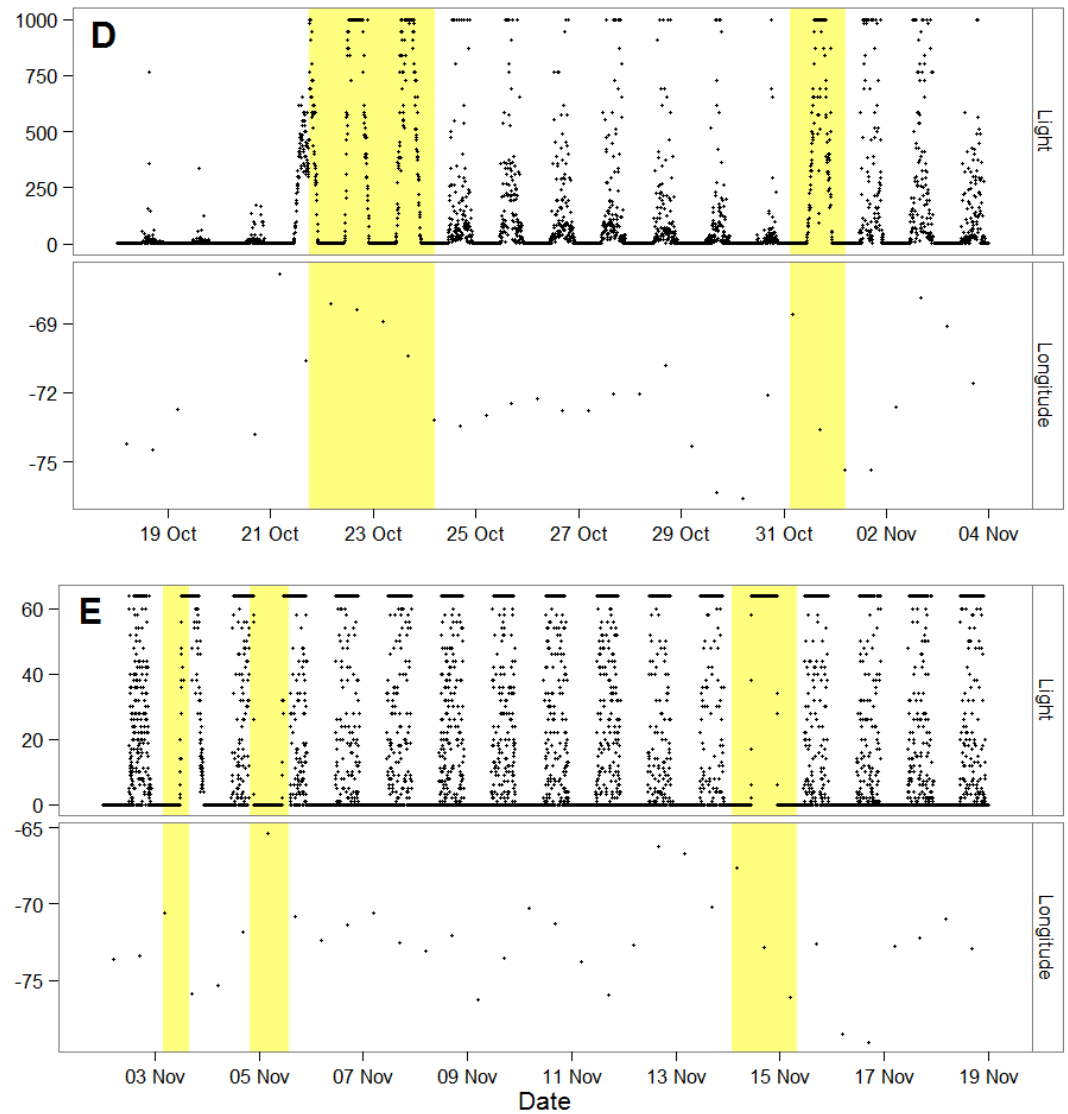


Figure S2. Plots of light, longitude, and (for one individual) latitude derived from light-level geolocator data used to determine the fall migration routes of five blackpoll warblers breeding in northeastern North America. Highlighted areas show periods of clean sunrise and sunset light transitions indicative of migratory flight along with corresponding longitude estimates, which we used to estimate the timing and location of departures from eastern North America, stopover areas, and migratory trajectories for each individual. Panel lettering corresponds to figure S1. Light values in panels C and D were truncated at 1000 lux.

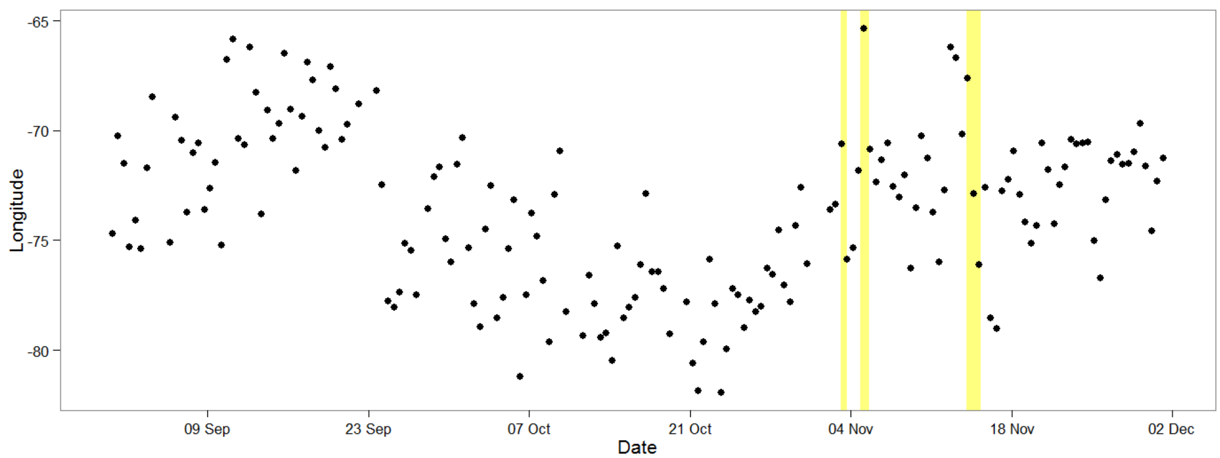


Figure S3. Plots of longitude by date derived from light-level geolocator data used to determine the fall migration routes of ‘Bird E’ (figure 1E). Highlighted areas show longitude estimates corresponding to periods of clean sunrise and sunset light transitions indicative of migratory flight. Details of the figure are the same as figure S2 but the range of dates has been expanded.

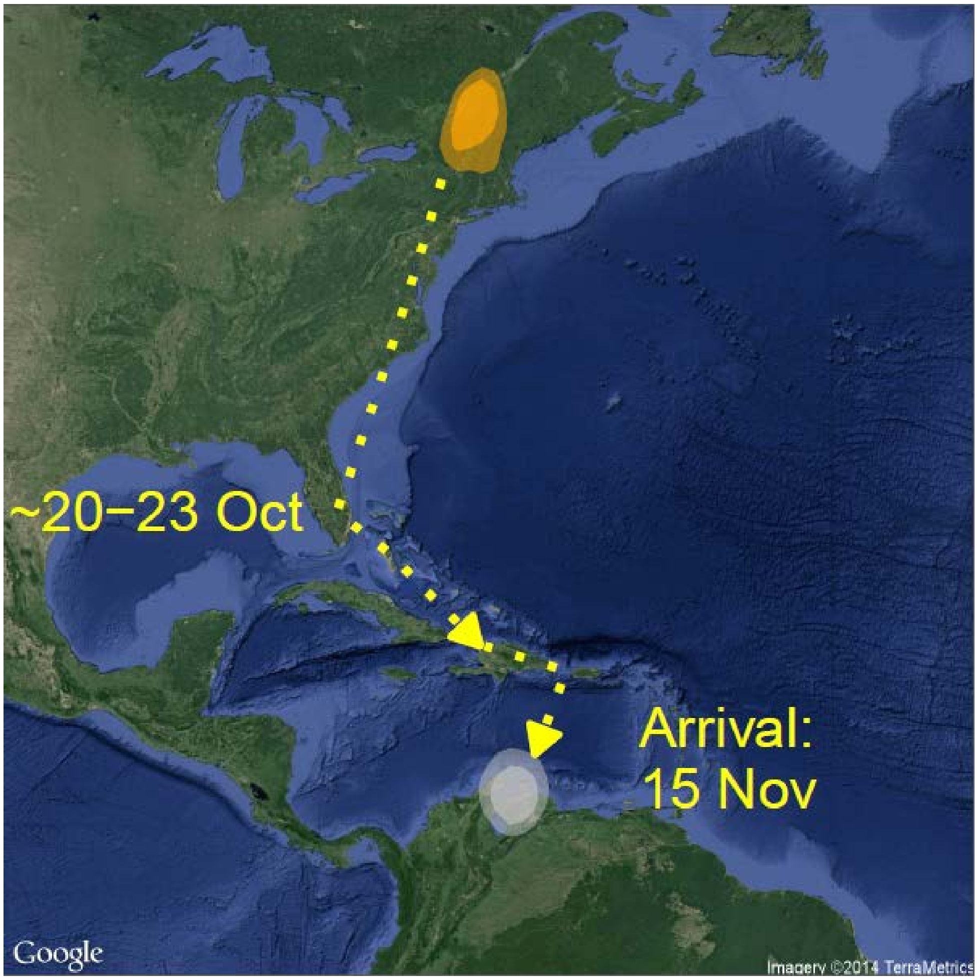


Figure S4. An alternative fall migration route, stopover locations and winter distributions of 'Bird E' (figure 1E) breeding in VT inferred from a light-level geolocator. Dashed yellow lines show movements that occurred around the equinoxes when latitude estimates were not reliable. Kernel densities (estimated using the R package 'adehabitatHR' [5]) encompass 30% and 50% of positions estimated during the breeding season (orange; 13-18 June to autumnal equinox), winter (grey; 15 December to 15 February). For stopovers of less than 7 days kernels were not estimated but arrows point to estimated stopover locations. Maps (courtesy of Google Earth) were created using the R package 'ggmap' [6].

3. Flight range calculation

We estimated the maximum flight range and duration of blackpoll warblers using the program FLIGHT v1.24 [7], which simulates avian migration using information on body composition, wing morphology, and the flight environment. We simulated migration for blackpolls of three weights (13.1 g, 16.6 g, and 21.1 g), which respectively represented the lower 5%, mean, and upper 5% of weights of fall migrant blackpolls with fat scores between 4 and 7 that were captured at the Atlantic Bird Observatory (ABO) on Bon Portage Island from 2006-2012 (n = 324). For each simulation, we assumed a fat free mass of 10.4 g, which corresponds to the lower 5% of weights of blackpolls captured at ABO over the same time period with a fat score of 0 (n = 404) and is very similar to the fat free mass of 10.3 g (n = 19) previously reported [8]. For all simulations, we used fixed values of wing span (0.208 m) and wing area (0.00839 m^2), which represented the average values from ten blackpolls captured and measured at Long Point Bird Observatory, ON, Canada in October 2014. For the flight environment, we used a fixed cruising altitude of 500 m asl and a standard acceleration due to gravity (-9.81 m/s^2) for all simulations. Although blackpolls likely reach altitudes of greater than 500 m asl during migration[7], by using a relatively low altitude we provide conservative estimates of their potential flight range.

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