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Research Article

Closing the Loop: Autumn Departure Dates of Maine Migratory Breeding Birds

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Abstract

This compilation of autumn departure dates for 103 species of Maine migratory breeding birds is a companion study to the recently completed 24-year study on the spring arrival dates of those same migratory breeding birds. Using eBird data from 1994 through 2017, geographic differences in departure date are documented along a latitudinal gradient. Most species show the expected earlier departures from more northerly portions of the state. Foraging type influences the departure of fall birds with aerial insectivores departing first, then leaf-gleaning insectivores and lastly granivorous birds. The data provide a baseline for gauging the effects of climate change on departure schedules as the globe continues to warm.

Keywords: Autumn; Birds; Global warming; Migration

Introduction

Incontrovertible evidence for global climate change exists in monotonic increases in carbon dioxide concentrations over the past 170 years, melting of polar ice caps and consequent sea level rise, and record high temperatures around the world [1-4]. A wealth of phenological data on leaf-out dates, emergence of insects, first calling of frogs in the spring and other biological processes add to this body of evidence [5-13]. Changing migration schedules of birds provide some of the strongest indications that the natural world is being influenced by climate change. Birds are unique sentinels of climate change because of the rich database on migration contributed in large part by lay citizens [5,8,13,14]. Recent reviews of the large quantity of data make a compelling case for fundamental impact of climate change on bird migration [15-17]. In 1994, a citizen-science project was launched to document the spatial and temporal patterns of spring arrival and fall departures of 103 species of Maine migratory breeding birds.

Prior to this study, some information was available on these phenological events in Maine [18-19] but the data were primarily from heavily populated areas in the state (extreme southern Maine, central Maine from Augusta to Bangor) and were insufficient to examine spatial variation in arrival and departure dates, particularly viewed through the lens of global warming.

The spring arrival project was terminated in 2017, yielding a 24-year dataset of arrival dates. Over 400 volunteers submitted over 65,000 arrival dates with the Biophysical Region [20] of each observation noted as well. The results of this project [21-27] greatly extended our knowledge of the patterns of spring arrivals across the state on both temporal and spatial scales. The work produced clear evidence for the impact of spring-time temperatures and the North Atlantic Oscillation (a driver of hemispheric climate).

The arrival date project met with success because of the ease of data acquisition. Each observer was simply asked to record the first arrival of any species on a list along with the Biogeographic Region of the observation. The analogous departure date project was problematic [28]. Determining the last date of observation of migratory breeding birds demands continuous record-keeping. The more onerous task of determining the last sighting date deterred most observers. This approach to a departure date project was abandoned after the first attempt in 1994.

Since the initiation of the project, eBird (https://ebird.org/home) was developed by the Cornell Laboratory of Ornithology (CLO) as a depository for bird sightings throughout the world. For this project, eBird data were mined for records of fall sightings of Maine migratory birds to examine temporal and spatial patterns of departure throughout Maine. This work establishes a baseline for assessing the effects of global climate change on the fall migration of Maine migratory breeding birds.

Materials and Methods

The CLO provided access to all Maine records. Only data from 1994 to 2017 were used to ensure complementarity with the spring arrival project. The Last Safe Dates provided by the Maine Breeding

Bird Atlas (https://www.maine.gov/ifw/fish-wildlife/maine-bird-atlas/resources-materials.html) were used to define the beginning of the fall migration season. For purposes of the Maine Breeding Bird Atlas, any observation later than the Last Safe Date cannot be used as evidence of breeding for a species because fall migrants will already have started to pass through the state. The operational end date of fall migration for all species was December 31.

To examine spatial variation in departure dates, the state was divided into three equal bands of latitude. The South region extended north to 42.6° N and the North region was at or above 45.7° N with the Central Region in between. For most species, the number of records in the North region was substantially lower than the other two regions, reflecting the higher human population densities in the southern parts of the state.

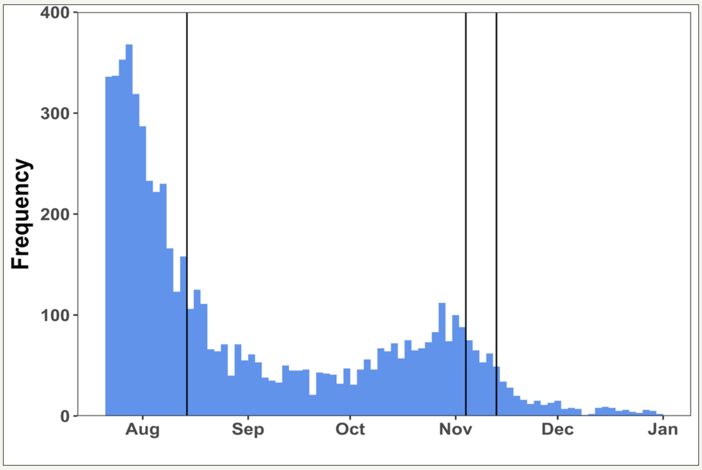

Figure 1: Records of red-winged blackbird (Agelaius phoeniceus) after the last safe date (July 31 for this species) as an example of the fall records for a representative species. The vertical lines represent the 50% quantile, 90% quantile and 95% quantiles.

The distribution of the fall records (from Last Safe Date for a species through the end of the year) was typically strongly positively skewed for each species (Figure 1). This non-normal distribution precluded the use of parametric analysis of variance to examine departure dates among the three latitudinal bands. The non-parametric Kruskal-Wallis test was used instead. Because of the large number of tests conducted, the Benjamini-Hochberg correction was applied to reduce the critical value of p for an individual test to ensure an experiment-wise critical value of p=0.05. This procedure minimizes false discoveries due to many tests.

If the Kruskal-Wallis test showed a significant difference among the three regions, pair-wise Dunn tests were used to determine where the significant differences lay. All the statistical analysis was performed with the R Programming Language.

To determine dates representing the autumn departures of each species, three increasingly restrictive quantiles of the distribution were examined. These were the upper half of the distribution (from the median to the last departure date), the upper 10% of the dates and the upper 5% of the dates.

Because of fewer data for the North region, consideration of only the upper 90% and 95% of the dates resulted in low, inadequate sample sizes. Data for the North region were not included in a test if fewer than 10 records were present.

Results and Discussion

Table 1: Summary of median departure dates using the upper 50%, upper 90% and upper 95% of the distribution for each species. The Last Safe Date defines the beginning of the fall migration season for each species. The count, n, is the number of records between the Last Safe Date and the end of the calendar year. For each portion of the distribution, the median date of departure in each region is provided. The results of Dunn tests to test for significance of differences in median dates are denoted by letters. Medians sharing the same letter are not statistically different; medians with different letters are significantly different (p < 0.05 using the Benjamini-Hochberg correction for false discoveries). Medians for the upper 5% subset are missing because of insufficient data in the North region for some species.

Species	Last Safe Date	n	Upper 50%			Upper 10%			Upper 5%		
			South	Central	North	South	Central	North	South	Central	North
Family Anatidae											
Wood Duck *(Aix sponsa)*	8/7	3253	9/27 a	9/11 b	9/12 b	10/30 d	10/20 e	10/6 f	11/8 g	10/29 h	10/17 i
Green-winged Teal *(Anas crecca)*	8/7	4312	10/6 a	10/7 a	10/1 c	11/15 d	11/10 e	10/26 f	12/1 g	11/19 h	11/3 i

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Ring-necked Duck *(Aythya collaris)*	8/7	1512	11/2 a	10/30 b	9/29 c	12/10 e	11/29 e	10/21 f	12/19 g	12/8 h	11/7 i
Family Podicipedidae											
Pied-billed Grebe *(Podilymbus podiceps)*	7/31	1124	10/14a	10/5 b	9/9 c	11/10 d	11/3 e	10/17 f	11/18	11/12 g	10/21 h
Family Cuculidae											
Black-billed Cuckoo *(Coccyzus erythropthalmus)*	8/7	241	9/15 a	8/21 b	8/18 c	10/10 d	9/28 d	8/30 d	10/24 g	10/13 h	9/2 i
Family Caprimulgidae											
Common Nighthawk *(Chordeiles minor)*	7/31	667	8/30 a	8/21 b	8/21 b	9/15 d	9/4 e	8/30 f	9/21 g	9/8 h	9/5 h
Eastern Whip-poor-will *(Caprimulgus vociferus)*	7/31	53	9/3 a	8/12 b	8/8 b	9/14 a	9/11 a	8/21 a	9/15 g	9/16 g	
Family Apodidae											
Chimney Swift *(Chaetura pelagica)*	8/7	656	8/17 a	8/18 a	9/8 b	9/3 d	9/1 e	8/26 f	9/7 g	9/7 g	8/26 h
Family Trochilidae											
Ruby-throated Hummingbird *(Archilochus colubris)*	8/7	6447	9/1 a	8/25 b	8/24 c	9/11 d	9/12 d	9/9 f	9/24 g	9/16 h	9/15 i
Family Rallidae											
Virginia Rail *(Rallus limicola)*	8/7	179	9/15 a	8/18 b		10/16 d	9/14 d		10/22 g	9/19 h	
Sora *(Porzana carolina)*	8/7	202	9/20 a	8/22 a		10/5 d	9/17 d		10/10 g	9/24 g	
Family Charadriidae											
Killdeer *(Charadrius vociferous)*	21/7	3299	8/19 a	8/26 b	8/30 c	10/9 d	10/5 e	10/13 f	10/20 g	10/16 h	10/24 i
Family Scolopacidae											
Wilson's Snipe *(Gallinago delicata)*	7/31	840	10/9 a	10/3 b	9/9 c	11/7 d	11/1 e	10/19 f	11/15 g	11/8 h	10/20 i
American Woodcock *(Scolopax minor)*	7/31	412	10/11 a	10/1 b	10/3 b	11/10 d	11/1 e	10/28 f	11/25 g	11/6 h	10/28 h
Spotted Sandpiper *(Actitis macularia)*	7/31	8701	8/2 a	8/19 b	8/17 c	9/11 d	9/17 e	9/26 f	9/22 g	9/26 h	10/3 i
Family Laridae											
Least Tern *(Sterna antillarum)*	8/7	400	9/8 a	8/21 b		8/29 d	8/26 e		9/1 g	8/27 h	
Common Tern *(Sterna hirundo)*	7/31	5551	8/13 a	8/18 b	9/8 c	9/3 d	9/12 e	9/5 f	9/11 g	9/20 h	9/9 i
Arctic Tern *(Sterna paradisaea)*	7/31	781	8/7 a	8/10 b		8/20 d	8/22 d		8/24 g	8/26 g	
Family Gaviidae											
Common Loon *(Gavia immer)*	7/21	25290	10/23 a	9/21 b	9/5 c	12/19 d	12/1 e	11/6 e	12/26 g	12/16 h	11/17 i
Family Ardeiidae											
American Bittern *(Botaurus lentiginosus)*	7/31	456	9/23 a	8/27 b	8/30 b	11/7 e	9/27 e	10/7 e	11/10 g	10/9 h	10/12 h
Great Blue Heron *(Ardea herodias)*	8/14	13876	9/24 a	9/15 b	9/26 c	11/9 e	10/29 e	10/23 e	11/24 g	11/8 h	10/21 i
Green Heron (*Butorides virescens*)	8/21	466	9/5 a	9/3 a	9/8 a	9/27 d	9/24 e	9/22 f	10/5 g	9/28 h	9/22 i
Family Cathartidae											
Turkey Vulture *(Catharus aura)*	08/7	5079	9/5 a	9/15 b	9/8 c	10/28 e	10/17 e	10/8 f	11/7 g	10/26 h	10/15 i
Family Accipitridae											
Osprey *(Pandion haliaetus)*	7/31	6729	9/1 a	8/24 b	8/24 b	10/1 d	9/18 e	9/18 e	10/8 g	9/27 h	9/27 h

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Northern Harrier (*Circus hudsonicus*)	8/7	4504	9/28 a	9/18 b	10/1 c	11/19 d	11/3 e	11/1 e	12/11 g	11/23 h	11/7 i
Broad-winged Hawk *(Buteo platypterus)*	7/31	2073	9/4 a	8/29 b	8/26 c	9/26 d	9/18 e	9/15 f	10/4 g	9/5 h	9/5 h
Family Alcedinidae											
Belted Kingfisher *(Megaceryle torquatus)*	8/7	10554	9/22 a	9/10 b	9/5 c	10/29 d	10/18 e	10/7 f	11/22 g	11/3 h	10/15 i
Family Picidae											
Yellow-bellied Sapsucker *(Sphyrapicus varius)*	8/7	3116	10/3 a	9/14 b	9/5 c	10/17 d	10/9 e	9/5 f	10/25 g	10/12 h	10/1 i
Northern Flicker *(Colaptes auratus)*	7/31	10521	9/26 a	9/12 b	9/1 c	10/29 d	10/10 e	9/24 f	11/16 g	10/19 h	10/9 i
Family Falconidae											
American Kestrel *(Falco sparverius)*	7/31	2887	9/23 a	9/11 b	9/7 c	10/15 d	10/7 e	9/9 f	10/25 g	10/19 h	10/9 i
Family Tyrannidae											
Olive-sided Flycatcher *(Contopus cooperi)*	7/31	274	8/29 a	8/22 b	8/20 c	9/22 d	9/10 d		9/22 g	9/12 h	
Eastern Wood-Pewee *(Contopus virens)*	8/14	1546	9/10 a	8/27 b	8/24 c	9/28 d	9/15 e	9/8 f	10/3 g	9/20 h	9/9 i
Yellow-bellied Flycatcher *(Empidonax flaviventris)*	7/31	383	9/9a	8/23 b	8/11 c	9/26 d	9/10 e	8/29 f	9/9 g	9/14 h	
Alder Flycatcher *(Empidonax alnorum)*	7/31	583	8/18 a	8/8 b	8/6 c	9/16 d	8/23 e	8/13 f	9/17 g	8/29 h	8/19 i
Willow Flycatcher *(Empidonax trailii)*	7/31	158	8/11 a	8/12 a	8/6 a	9/1 d	9/1 d		9/20 g	9/5 g	
Least Flycatcher *(Empidonax minimus)*	08/7	1049	9/10 a	8/26 b	8/22 c	9/26 d	9/13 e	9/3 f	9/29 g	9/18 h	9/12 i
Eastern Phoebe *(Sayornis phoebe)*	08/7	10135	9/20 a	9/9 b	8/30 c	10/12 d	10/6 e	9/24 f	10/18 g	10/11 h	10/5 i
Great Crested Flycatcher *(Myiarchus crinitus)*	08/7	368	8/28 a	8/22 b	8/15 c	9/15 d	9/8 e	8/26 e	9/23 g	9/12 h	8/29 h
Eastern Kingbird *(Tyrannus tyrannus)*	08/7	1727	8/23 a	8/18 b	8/16 c	9/19 d	8/30 e	8/30 e	9/23 g	9/4 h	8/30 i
Family Vireonidae											
Philadelphia Vireo *(Vireo pheladelphia)*	08/7	1003	9/18 a	9/7 b	8/26 c	9/9 d	9/21 e	9/8 f	10/4 g	9/5 h	9/13 h
Warbling Vireo *(Vireo gilvus)*	08/7	694	9/16 a	8/30 b	9/3 c	9/9 e	9/17 e	9/11 f	10/5 g	9/20 h	9/13 i
Red-eyed Vireo *(Vireo olivaceus)*	08/7	7687	9/16 a	8/29 b	8/25 c	10/5 d	9/23 e	9/8 f	10/10 g	9/28 h	9/13 i
Blue-headed Vireo (*Vireo solitarius*)	08/7	3958	10/6 a	9/17 b	9/1 c	10/12 d	10/9 e	9/26 f	10/20 g	10/13 h	9/9 i
Family Hirundinidae											
Purple Martin *(Progne subis)*	7/21	107	8/5 a	8/1a		8/25 d	8/9 d		9/5 g	9/8 g	
Tree Swallow *(Tachycineta bicolor)*	7/31	3309	8/5 a	8/7 b	8/8 c	9/21 d	8/29 e	8/30 e	10/2 g	9/3 h	9/3 h
Bank Swallow *(Riparia riparia)*	7/21	1049	8/4 a	8/7 a	8/3 a	8/28 d	8/28 d	8/24 d	9/3 g	9/3 g	8/31 h
Cliff Swallow *(Hirundia pyrrhonota)*	7/21	469	8/5 a	8/7 ab	8/8 b	8/23 d	8/31d	8/23 d	8/29 g	9/6 g	8/26 g
Barn Swallow *(Hirundo rustica)*	7/21	5959	8/7 a	8/8 b	8/9 c	9/2 d	8/30 e	8/25 f	9/7 g	9/5 h	8/30 h
Northern Rough-winged Swallow (*Stelgidopteryx serripennis*)	7/21	206	8/5 a	8/12 b	8/24 c	8/25 d	9/1 d		8/31 g	9/1 g	

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Family Troglodytidae										
House Wren *(Troglodytes aedon)*	7/21	745	9/19 a	9/11 b	8/20 c	10/8 d	9/27 e	8/22 e	10/14 g	10/5 h	8/22 h
Marsh Wren (*Cistothorus palustris*)	08/7	541	9/21 a	9/6 b	8/23 c	10/20 d	10/9 e	8/30 f	11/12 g	10/21 g	8/31 g
Winter Wren *(Troglodytes troglodytes)*	08/7	1267	10/4 a	9/1 b	8/31 c	11/12 d	10/21 e	9/26 f	12/5 g	11/17 h	10/2 h
Family Regulidae										
Ruby-crowned Kinglet *(Regulus calendula)*	8/21	4026	10/8 a	10/7 b	9/21 c	11/4 d	10/27 e	10/7f	11/18 g	11/1 h	10/11 i
Family Turdidae										
Eastern Bluebird *(Sialia sialis)*	8/21	4136	10/29 a	10/8 b	9/9 c	12/19 d	11/10 e	10/9 f	12/27 g	12/6 h	10/12 i
Veery *(Catharus fuscescens)*	08/7	500	8/30 a	8/28 b	8/30 a	9/22 d	9/26 d	9/8 e	9/26 g	9/26 g	9/10 h
Swainson's Thrush *(Catharus ustulatus)*	7/31	1049	9/24 a	9/15 b	9/16 b	10/10 d	10/7 e	9/18 f	10/16 g	10/15 g	9/21 h
Hermit Thrush *(Catharus guttatus)*	08/7	4678	10/17 a	9/26 b	9/4 c	11/11 d	10/24 e	10/2 f	11/30 g	10/21 h	10/9 i
Wood Thrush (*Hylocichla mustelina*)	08/7	177	8/27 a	8/25 a		9/5 d	9/24 d		9/28 g	9/28 g	
American Robin *(Turdus migratorius)*	08/7	17484	10/10 a	10/5 b	10/3 c	11/2 d	11/16 e	11/4 f	12/20 g	12/7 h	11/15 i
Family Mimidae										
Gray Catbird *(Dumatella carolinensis)*	8/14	10787	9/17 a	9/9 b	9/5 c	10/9 d	10/4 e	9/24 f	10/16 g	10/9 h	10/1 i
Brown Thrasher *(Toxostoma rufum)*	8/14	681	9/24 a	9/15 a		10/9 d	10/23 e		10/17 g	11/2 g	
Family Parulidae										
Ovenbird *(Seiurus aurocapilla)*	08/7	846	8/31 a	8/27 b	8/20 c	9/27 d	9/13 e	9/13 e	10/5 g	9/19 h	9/13 i
Northern Waterthrush *(Parkesia novaeboracensis)*	7/31	1035	9/3 a	9/8 b	8/8 c	9/27 d	9/11 e	8/22 f	10/3 g	9/15 h	8/28 i
Black-and-white Warbler *(Mniotilta varia)*	08/7	5018	9/11 a	8/28 b	8/26 c	9/9 d	9/17 e	9/12 f	10/5 g	9/23 h	9/13 i
Tennessee Warbler *(Leiothlypis peregrina)*	7/31	884	9/24 a	9/1 b	8/29 c	9/26 d	9/22 e	9/14 f	10/7 g	10/1 h	9/17 i
Nashville Warbler *(Leiothlypis ruficapilla)*	08/7	2512	9/26 a	9/3 b	8/25 c	10/28 d	9/26 e	9/15 f	10/6 g	10/3 h	9/19 i
Mourning Warbler *(Geothlypis philadelphia)*	08/7	174	9/21 a	9/4 b	8/22 c	10/5 d	9/22 d		10/7 g	9/9 g	
Common Yellowthroat *(Geothlypis trichas)*	8/21	7824	9/18 a	9/8 b	9/4 c	10/10 d	10/1 e	9/23 f	10/17 g	10/7 h	9/29 i
American Redstart *(Setophaga ruticilla)*	08/7	4229	9/10 a	8/27 b	8/24 c	9/9 d	9/15 e	9/11 f	10/5 g	9/20 h	9/15 i
Cape May Warbler *(Setophaga tigrina)*	7/31	996	9/20 a	9/2 b	8/24 c	10/6 d	9/15 e	9/5 f	10/10 g	9/22 h	9/8 i
Northern Parula *(Setophaga parula)*	7/31	4416	9/18 a	9/2 b	8/24 c	10/6 d	9/22 e	9/14 f	10/12 g	9/28 h	9/16 i
Magnolia Warbler *(Setophaga magnolia)*	08/7	2589	9/18 a	9/12 b	8/26 c	10/5 d	9/21 e	9/13 f	10/9 g	9/5 h	9/15 i
Bay-breasted Warbler *(Setophaga castanea)*	7/31	606	9/17 a	9/2 b	8/23 c	10/1 d	9/22 e	9/13 f	10/5 g	9/27 h	9/18 i
Blackburnian Warbler *(Setophaga fusca)*	7/31	1167	9/10 a	8/24 b	8/25 b	10/4 d	9/15 e	9/13 f	10/7 g	9/21 h	9/16 i

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Yellow Warbler *(Setophaga petchia)*	08/7	3339	9/4 a	8/21 b	8/15 c	9/27 d	9/11 e	8/30 f	10/3 g	9/17 h	9/3 i
Chestnut-sided Warbler *(Setophaga pensylvanica)*	08/7	1509	9/6 a	8/27 b	8/22 c	9/27 d	9/14 e	9/8 f	10/3 g	9/19 h	9/8 i
Blackpoll Warbler *(Setophaga striata)*	08/7	2616	9/5 a	9/17 b	8/28 c	10/12 d	10/7 e	9/20 f	10/19 g	10/13 h	9/26 i
Black-throated Blue Warbler *(Setophaga caerulescens)*	08/7	1435	9/29 a	9/4 b	8/28 c	10/17 d	9/9 e	9/15 f	10/25 g	10/9 h	9/18 i
Palm Warbler *(Setophaga palmarum)*	08/7	3030	10/5 a	9/26 b	9/13 c	10/23 d	10/16 e	10/1 f	10/29 g	10/21 h	10/1 i
Pine Warbler *(Setophaga pinus)*	08/7	226	9/23 a	9/12 b	8/28 c	10/15 d	10/14 e	9/10 f	10/21 g	10/6 h	9/20 i
Yellow-rumped Warbler *(Setophaga coronata)*	8/14	13832	10/7 a	9/26 b	9/15 c	11/6 d	10/21 e	10/10 f	11/20 g	10/28 h	10/15 i
Prairie Warbler *(Setophaga discolor)*	08/7	604	9/17 a	8/29 b		10/6 e	9/13 e		10/12 g	9/16 h	
Black-throated Green Warbler *(Setophaga virens)*	08/7	4299	9/15 a	9/1 b	8/27 c	10/6 d	9/23 e	9/17 f	10/12 g	9/27 h	9/21 i
Canada Warbler *(Cardellina canadensis)*	08/7	643	8/30 a	8/22 b	8/15 c	9/22 d	9/6 e	8/29 f	9/5 g	9/10 h	9/3 i
Wilson's Warbler *(Cardellina pusilla)*	08/7	1030	9/20 a	9/5 b	8/26 c	10/4 d	9/20 e	9/2 f	10/8 g	9/24 h	9/3 i
Family Emberizidae											
Eastern Towhee (*Pipilo erythrophthalamus*)	8/14	733	9/9 a	9/9 a		10/22 d	10/20 d		10/21 g	11/7 g	
Chipping Sparrow *(Spizella passerina)*	08/7	7875	9/24 a	9/11 a	9/6 c	10/21 d	10/16 e	10/17 f	10/27 g	10/22 h	10/22 h
Field Sparrow *(Spizella pusilla)*	08/7	502	10/8 a	10/19 b		10/29 d	10/18 e		11/3 g	11/23 g	
Vesper Sparrow *(Chondestes gramineus)*	7/31	320	10/4 a	9/16 b		10/15 d	10/17 d		10/21 g	10/23 g	
Savannah Sparrow *(Passerculus sandwichensis)*	08/7	6486	10/6 a	9/26 b	9/18 c	11/1 d	10/24 e	10/20 f	11/9 g	10/30 h	10/24 i
Fox Sparrow *(Passerella iliaca)*	08/7	922	11/11 a	11/4 b	10/21 c	12/22 d	11/22 e	11/5 f	12/28 g	12/5 h	11/8 h
Song Sparrow *(Melospiza melodia)*	8/21	22827	10/8 a	10/1 b	9/27 c	11/30 d	11/6 e	10/21 f	12/17 g	11/29 h	10/25 i
Lincoln's Sparrow *(Melospiza lincolni)*	8/14	1602	9/28 a	9/26 b	9/14 c	10/15 d	10/14 d	10/11 d	10/23 g	10/20 h	10/15 h
Swamp Sparrow *(Melospiza georgiana)*	8/21	4750	10/7 a	10/2 b	9/21 c	10/29 d	10/24 e	10/9 f	11/4 g	10/29 h	10/13 i
White-throated Sparrow *(Zonotrichia albicollis)*	8/21	12574	10/17 a	10/12 b	9/20 c	12/12 d	12/4 e	10/24 f	12/1 g	12/18 h	11/10 i
Family Cardinalidae											
Scarlet Tanager *(Piranga olivacea)*	8/14	674	9/23 a	9/6 b	8/26 c	10/7 d	9/5 e	9/17 f	10/11 g	9/9 h	9/21 h
Rose-breasted Grosbeak *(Pheucticus ludovicianus)*	08/7	1330	9/14 a	8/29 b	9/3 c	9/29 d	9/19 e	9/15 f	10/5 g	9/26 h	9/17 i
Indigo Bunting *(Passerina cyanea)*	8/21	887	9/9 a	9/12 b	9/4 c	10/18 d	10/27 e	9/13 d	10/27 g	11/6 h	9/14 i
Family Icteridae											
Bobolink *(Dolichonyx oryzivorus)*	7/31	1869	9/3 a	8/27 b	8/26 c	9/29 d	9/20 e	9/4 f	10/5 g	9/9 h	9/6 i
Red-winged Blackbird *(Agelaius phoeniceus)*	7/31	3385	9/9 a	8/29 a	9/27 b	11/10 d	11/4 e	10/25 f	11/19 g	11/11 h	11/4 i
Brown-headed Cowbird *(Molothrus ater)*	7/31	920	9/7 a	9/8 b		11/7 d	12/8 e		11/26 g	12/19 g	

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Common Grackle *(Quiscalus quiscala)*	08/7	4074	10/4 a	9/26 b	9/13 c	11/9 d	11/6 e	10/30 f	11/18 g	11/14 h	11/6 i
Baltimore Oriole *(Icterus galbula)*	7/21	1039	9/23 a	9/9 b	8/15 c	10/23 d	10/6 e	8/29 f	11/15 g	10/19 h	9/12 i

Table 1 presents the analyses of the Kruskal-Wallis and subsequent Dunn tests, testing for latitudinal differences in median departure date for the upper 50%, 90% and 95% of the fall records. For each species. the Last Safe Date, designating the end of the definitive breeding season, is provided along with the number of records from the last safe date to the end of year. As an example, the dataset has 3,253 records of Wood Duck from the last safe date to the end of the year. Half of those records (1,627) were used for the upper 50% analysis. Only 325 records were used for the upper 10% analysis and 162 for the 95% analysis.

The prediction is that the median departure date among the three regions should reflect the climatic differences among the regions. Accordingly, one expects the earliest median departure dates in the North region and the latest in the South region. For the 89 species with enough data to compare all three regions, 60 show the predicted pattern of latest departures in the South region and earliest departures in the North Region. Twelve additional species show no difference among regions (two species), no difference between the Central and North regions but earlier departure in the South region (seven species) or no difference between the South and Central region but earlier departure from the Northern region (three species).

The remaining 14 species show patterns that are inconsistent with the prediction of later departure from more southerly areas. Four species of swallows (Family Hirundinidae) show anomalous patterns but the three medians differ by only a few days, indicating the differences are probably not ecologically significant even if they are statistically different. Latest departures from the Central region were found for Turkey Vulture, Spotted Sandpiper, Northern Harrier, Very, Northern Water thrush and Indigo Bunting.

Twelve species occurred too rarely in the Northern Region to include in the analysis. Seven of these species departed later from the South regions than from the Central region. One species showed no difference between regions. Common Terns, Purple Martins, Field Sparrows and Brown-headed Cowbirds departed later from the Central region although the difference in medians was never more than four days.

Using only the upper 10% of the data, 64 of 85 species conformed to the expectation of later departures from the South region and earlier departures from the North region. Two species did not differ between the South and Central regions but did depart later than birds in the North region. Four species showed no difference between the Central and North regions but did depart earlier than birds in the South region. Three species showed no differences in departure date among the three regions. Eleven species failed to conform to the general prediction of earlier departures from more northerly areas. Spotted Sandpipers departed latest from the North region. Nine species departed last from the Central region.

Sixteen species could only be compared between South and Central regions because of low sample sizes in the North region. Nine of these species departed later from the South region, fitting the prediction. Another two showed no difference in median departure date between the two regions. Common Terns, Northern Rough-winged Swallows, Wood Thrushes, Brown Thrashers and Brown-headed Cowbirds showed earlier departures from the South region.

The analysis using only the latest 5% of departure dates provides the best estimate of last departure date at the expense of reduced sample size. Seventy-three species were sufficiently abundant in all three Regions to compare. Sixty-three of those species showed the expected pattern of increasing departure moving from north to south. Median departures of four species did not differ between the South and Central regions but were earlier than the median departure from the North region. Six species did not differ in median departure between the Central and North region but were earlier than median departure from the South region.

Nine species failed to conform to the prediction of earlier departures from northerly areas. Common Terns, Cliff Swallows, Canada Warblers, White-throated Sparrows and Baltimore Orioles had the latest departures from the Central region. Killdeer and Spotted Sandpipers departed last from the north region. Philadelphia Vireos and Yellow Warblers departed from the North region later than from the Central region. Twenty-nine species could only be compared between the South and Central regions. Nine had earlier departures from the Central region and two species showed no difference between the two regions. Nine species (Common Tern, Yellow-bellied Flycatcher, Purple Martin, Northern Rough-winged Swallow, Brown Thrasher, Eastern Towhee, Field Sparrow, Vesper Sparrow and Brown-headed Cowbird) departed from the South region before the Central region.

The typical pattern of fall departure conforms to expectation: the median date increases from the North region through the Central region to the South region. The strength of the relationship increases as smaller portions of the distribution are considered. For the upper 50% of the data, 77.7% of the species conform to the prediction of earlier departure from more northerly areas. The fit increases to 81.6% of all species for the upper 10% of the data and 92.0% of all species for the upper 5% of the data.

Why do some species show patterns that differ from the prediction? Because of the high sample size for many species, these non-conforming patterns are real patterns, not artifacts of high variance due to low sample sizes. One possible explanation for these unexpected patterns is differences in habitat quality for particular species. Prime habitat for a particular species might be more prevalent in the North or Central region. Some birds might use that area as a staging area and linger in the region. Those

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species might pass through the South region more quickly and are less likely to be detected than in areas where habitat is better [14].

Diet has strong effects on the fall departure dates (Table 1). Aerial insectivores (Apodidae, Caprimulgidae, Tyrannidae, Hirundinidae) collectively have early departures from the state. For the swallows (Hirundinidae), departure from the state appears to be almost synchronous with regional medians differing by only a day or two. Leaf-gleaning insectivores (Cuculidae, Vireonidae, Parulidae, Scarlet Tanager) are next to depart. The granivorous birds (Emberizidae, Indigo Bunting) have the latest fall departures, presumably because the supply of seeds is adequate to allow the birds to meet their metabolic demands well into the fall after flying insects and folivorous caterpillars have disappeared.

A major goal of this study was to determine the last departure dates of Maine migratory breeding birds along a latitudinal gradient. Ideally, each datum in the dataset would be an observer's last observation of each species in each region. The eBird data represent all the observations of any participating birder, not the last departure date. As a result, this analysis likely underestimates the true last departure data because many data fall well before the last departure. Using only the upper 5% of the data provides the best estimate of last departure but comes at the expense of reduced statistical power because the sample size in the dataset is reduced by 95%.

A major goal of the study was to develop a tool to examine changes in departure data as a function of global climate change. Unfortunately,eBird is not currently a useful repository for older data as the eBird website was launched in 2002. Although data from any year may be added to the database, most observations date from 2002 forward. As an example, 94.6% of the over four million records for the state of Maine date from 2002 forward. At present, eBird data currently are therefore not useful for looking at long-term trends. The present analysis does provide a baseline against which future data may be compared to gauge effects of global warming and other environmental insults. The fact that fall migration for most species proceeds in a regular pattern with birds departing the colder North region before the more moderate South region (Table 1) indicates that the phenology of fall migration will be responsive to global warming.

The effect of global warming on autumn departure dates is varied. Some species do show a delay in their departures in recent years with warmer climates [10]. The ameliorating climate may allow post-breeding birds to linger longer on the breeding grounds. However, we know that many migratory species are now arriving earlier on the breeding grounds [15-17,24,27]. Some birds are departing for their wintering grounds earlier than in past years [28-30]. These migratory birds spend the same amount of time on the breeding grounds, but their arrivals and departures are shifted forward in time [31]. The present data provide a baseline for gauging those changes in the future.

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