Variability of Arrival Dates of Maine Migratory Breeding Birds: Implications for Detecting Climate Change

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Abstract - Many authors have recently used changes in arrival dates of migratory breeding birds as a measure of environmental change due to global warming. In this paper, I present a comparative analysis of the intra-annual variability in first arrival dates for 107 species of migratory breeding birds in Maine. Data come from volunteer observers in the southern two-thirds of the state from 1994 through 2005. Using the Julian date for each first arrival, standard deviations were tabulated for each species in each year. The results indicate that some species, specifically leaf-gleaning insectivores and aerial insectivores, have relatively low variance of first arrival dates while other species show more protracted migrations and hence greater variability around the mean arrival date. Post hoc considerations of the patterns of variability suggest that diet may be an important determinant of variance in arrival date. The data indicate that researchers should concentrate on species with lower variances of arrival date to increase the statistical power for testing changes in arrival dates as global warming proceeds.

Introduction

The science of phenology began in the early 1700s in Britain with the first systematic collection of the records of the arrivals and departures of migratory British birds (Kingston 1988, Sparks and Carey 1995). These observations held more than academic interest as farmers were encouraged to start various agricultural activities only after the arrival of particular migratory birds. The analysis of the phenology of arrival dates has permitted the elucidation of migratory patterns of many species of birds (e.g., Wilson et al. 1997).

With the specter of global warming looming, ornithologists have begun to use arrival dates of migratory birds as a detection tool for climate change. A number of studies have demonstrated earlier arrival times and earlier nesting times for European and North American migratory breeding birds (Bradley et al 1999, Butler 2003, Cotton 2003, Dunn and Winkler 1999, Ledneva et al. 2004, Marra et al. 2005, Mason 1995, Mills 2005, Sparks 1999, Sparks et al. 2007).

Despite the wealth of phenological data on arrival dates for migratory birds, I am unaware of any systematic analysis of differences in the variance of first arrival dates for a regional avifauna (but see Hagan et al. 1993). In this contribution, I compare the variability of first arrival dates of 107 species of Maine migratory breeding birds over 12 springs (1994 through 2005).

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The data analysis is predicated on the notion that species that arrive in a restricted time frame will be detected by observers around the same time. Species in which more variation in arrival time is common will be characterized by a wider variance of first arrival dates across the region. If that is the case, future phenological studies would benefit by focusing on species known to have the lowest variances in arrival time.

Materials and Methods

Since 1994, I have been coordinating a volunteer network of Maine birders to monitor the arrival date of 141 species of migratory breeding birds in the state. Observers are asked to report their first record of any of these 141 species they encounter along with their observation location. Wilson et al. (1997) demonstrated that bird arrival dates do not differ throughout the southern two-thirds of the state within a given spring. The relatively few data reported from the northern third of Maine, at times significantly later than more southerly arrival dates, were excluded from the study. During the 12 years of this study, over 200 birders contributed arrival date data. Twenty-seven birders participated in all 12 years of the project and account for over 40% of all observations. Observations ranged from the southern limit of Maine (43°06'N) to a latitude of 45º10'N.

To quantify variability in arrival dates, I first converted each arrival date to Julian date. I then calculated the standard deviation of first arrival date for each species for each of the 12 years of the study. With adequate replicates, this measure is independent of the mean. By randomly reducing the dates one at a time for a particular year and species, I found that the standard deviation was stable until the sample size was six records or lower. Accordingly, I removed the 34 species from the analysis that did not have at least ten arrival dates for each year. For most species, the number of arrival dates each spring was greater than 20 and often greater than 30.

Results

A summary of the distribution of the 12 standard deviations by species over the course of the study is provided in Appendix 1. The frequency distributions of the standard deviations for each species are presented as the number of years falling into five size-classes of the standard deviation (0–5, 5–10,10–15, 15–20, 20–25, and >25). The grand mean arrival date for each species is also provided. Note that for some species, the number of data points is <12 because of insufficient data for some years (e.g., *Charadrius melodus* [Piping Plover]). A regression of mean annual standard deviation against median arrival date produced a significant relationship (y = -0.17054 + 32. 278, $P < 0.001$, $r^2 = 0.5112$), indicating that later-arriving birds have the lowest deviation around first arrival date.

Examination of the data shows differences among orders of birds and among the many families within the Order Passeriformes (perching birds or passerines). *Gavia immer* (Common Loon), *Podilymbus podiceps*

(Pied-billed Grebe), herons, waterfowl, and diurnal birds of prey exhibit relatively high variation in their first arrival dates among the various observers. Most shorebirds have high variability with the exception of *Actitis macularia* (Spotted Sandpiper) and, to a lesser degree, *Scoloplax minor* (American Woodcock). *Ceryle alcyon* (Belted Kingfisher), *Sphyrapicus varius* (Yellow-bellied Sapsucker), and *Colaptes auratus* (Northern Flicker) also show high variability in most years. *Coccyzus erythropthalmus* (Black-billed Cuckoo), *Caprimulgus vociferus* (Whip-poor-will), *Chordeiles minor* (Common Nighthawk), and *Archilochus colubris* (Ruby-throated Hummingbird) show relatively less variability than the other non-passerine taxa.

For the passerines, the most obvious pattern is the strikingly low variability in arrival date for most of the wood warblers, the exceptions being *Dendroica coronata* (Yellow-rumped Warbler) and (Pine Warbler). These latter two species show the same distribution of variances, but differ in all cases from the remaining wood warblers. Some other passerine species are similar to the wood warblers in their low variability of arrival date: the vireos, *Piranga olivacea* (Scarlet Tanager), and *Pheucticus ludovicianus* (Rose-breasted Grosbeak). Most of the flycatchers are only slightly more variable than the passerines above. The wrens, kinglets, and thrushes have distributions of standard deviations that differ from those of wood warblers and vireos and show more variability, with at least some standard deviations in the 20–25 range or higher. Even more striking is the high variability for species in the sparrow family and the blackbird family. With the exception of *Icterus galbula* (Baltimore Oriole), the blackbirds have standard deviations >10, and quite often >15, contrasting strikingly with the wood warblers and vireos.

Discussion

A commonly held principle of bird migration is that the arrival dates of birds on the breeding grounds are subject to stabilizing selection. The benefits of arriving early enough to successfully claim a territory or mate select for early arrival (Kokko 1999). However, the availability of food counteracts selection to arrive early; birds must not arrive before their food is available (Ricklefs 1980). Hence, these two different selective pressures combine to restrict the arrival dates of birds. This model can be profitably applied to the data in this study.

The data (Appendix 1) demonstrate taxonomic and temporal patterns of variation around arrival date. The species with the most restricted windows of arrival as measured by the standard deviation of first arrival dates for each year (*Parulidae* spp. [wood warblers], *Troglodytidae* spp. [wrens], *Vireonidae* spp. [vireos] and *Thraupidae* spp. [tanagers]) stand in striking contrast to most of the other taxa in Appendix 1. Two fundamental differences are apparent. First, the species that show low variability in first arrival date tend to arrive later in the spring migration (Appendix 1). In large part, these species are long-distance Neotropical migrants. Secondly, these species tend to be foliage-gleaners, often feeding on lepidopteran larvae and other insect herbivores on deciduous trees. Arrival on the breeding grounds before leaf-out (usually in the first two weeks of May in the study area) would be maladaptive (Slagsvold 1976). On the other hand, late arrival on the breeding grounds runs the risk of failing to find a suitable territory or a mate.

This interplay of diet and arrival date is supported by consideration of the two wood warblers in Appendix 1 that show higher variability in arrival dates than their confamilials. The Yellow-rumped Warbler has a broader diet than most North American wood warblers, subsisting in the winter largely on berries (Hunt and Flaspohler 1998, Place and Stiles 1992, Wilz and Giampa 1978). The Pine Warbler also has a relatively broad diet and forages largely on conifers whose needles are present in April (Rodewald et al. 1999). The Baltimore Oriole, the only blackbird with low standard deviations, depends on nectar from apples and other trees upon arrival (Rising and Flood 1998).

Flycatchers and swallows show more variability than the three families above. The flying insects these species feed on may become abundant before caterpillars, allowing earlier arrivals of at least some individuals. The most variable passerines (the sparrows and the blackbirds) have broad diets including seeds that should be available before leaf-out. It is not surprising that these species often arrive earlier than the wood warblers, vireos, and wrens. It is not clear why there is so much variability in arrival date for these species. Among the non-passerines, the four species with small standard deviations depend on food that only begins to become available toward the middle of May. Ruby-throated Hummingbirds require flowers (Robinson et al. 2006), Common Nighthawk and Whip-poor-will require large flying insects (Cink 2002, Poulin et al. 1996), and Black-billed Cuckoos leaf-glean for caterpillars (Hughes 2001).

The remaining non-passerines may be released from the stabilizing selection discussed above. There likely is still directional selection to arrive early on the breeding grounds, but the factors determining how early seem to be weak. One expects that early arriving birds are capable of finding sufficient food.

These results can be compared to the data from Hagan et al. (1993), who reported captures of 27 migratory bird species during 19 springs. Their data were based on mist-net captures of birds at banding stations operated throughout the entire spring migration. They therefore documented the full migration of those 27 species rather than simply first arrival. However, some of the species they sampled were passage migrants; all of the species in the present study were breeding birds. Hagan et al. (1993) also found that variability of migration was less for long-distance migrants than for short-distance migrants. It is not clear if migration distance is the selective agent because migration distance and foraging behavior are conflated. Long-distance migrants are usually foliage-gleaning insectivores. Their reliance on insects explains the necessity of wintering in tropical areas where insects are active. Nonetheless, my results agree with the results of Hagan et al. (1993).

I can reject the notion that long-distance migrants (i.e., the leaf-gleaning insectivores) have their migration determined solely by endogenous control and hence might show strong concordance. Wilson (2007) showed that significant variation in median arrival date for all of the leaf-gleaners occurred over the 12 years of the study. The range of median dates among years for the different wood warbler species varied from six to 17 days. The results suggest that weather effects may delay or speed the migration, but that the individuals in the population tend to migrate over a short period of time.

These results have implications for researchers who wish to use the phenology of arrival dates as a measure of climate change. The relatively low variance around arrival date for leaf-gleaners like the wood warblers and vireos (or ecological equivalents in Eurasia) will make these species more sensitive indicators of climate change. For example, it is much more likely that differences in arrival date will be statistically detected for *Parula Americana* (Northern Parula) than for *Aix sponsa* (Wood Duck) or (Red-winged Blackbird). The strong dependence of these foliage-gleaners makes these birds strongly susceptible to changes in leaf phenology (regrettably not studied systematically in Maine over the study period). The leaf-gleaning species may therefore be the first to show declines in abundance because of mis-timed reproduction or rapid evolution of changes in arrival and nesting dates.

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Appendix 1. Mean arrival date, mean annual standard deviation, and distribution of annual standard deviations of arrival date for the 107 species migratory breeding species in the study. The twelve years of data yield twelve standard deviations for most species. A few species had insufficient data in one or more years to calculate a meaningful standard deviation, yielding a total of less than twelve data points. The symbols represent the number of standard deviations in each of the six size-classes, with larger circles indicating higher frequencies. Key to a subset of the symbols: ⬤ = 10; ● = 7; • = 4; · =1.

Species	Mean arrival date	Mean s.d.	Distribution of annual s.d. 0–5	5–10	10–15	15–20	20–25	>25
Wood Duck (*Aix sponsa* L.)	Apr 7	17.82			•	●	•	·
Green-winged Teal (*Anas crecca* L.)	Apr 21	17.53			●	●		·
Blue-winged Teal (*A. discors* L.)	Apr 4	13.46		•	•	•	·	
Ring-necked Duck (*Aythya collaris* (Donovan))	Mar 29	15.69			●	●		·
Common Loon (inland only) (*Gavia immer* (Brünnich))	Apr 16	14.38		•	●	•	•	
Pied-billed Grebe (*Podilymbus podiceps* (L.))	Apr 15	13.49	•	•	·	●		·
American Bittern (*Botaurus lentiginosus* (Rackett))	Apr 30	13.60		•	●	•		
Great Blue Heron (*Ardea Herodias* L.)	Apr 9	16.69			•	●	•	
Green Heron (*Butorides virescens* (L.))	May 6	11.98		●	●	·	·	
Black-crowned Night-Heron (*Nycticorax nycticorax* (L.))	May 5	12.65	·	•	•	●		
Glossy Ibis (*Plegadis falcinellus* (L.))	Apr 16	18.22		·	•	●	·	·
Turkey Vulture (*Cathartes aura* (L.))	Apr 8	16.70			•	●	•	
Osprey (*Pandion haliaetus* (L.))	Apr 15	13.52			⬤	•		
Northern Harrier (*Circus cyaneus* (L.))	Apr 12	19.75			•	●		
Broad-winged Hawk (*Buteo platypterus* (Vieillot))	Apr 26	14.20		•	•	●		
American Kestrel (*Falco sparverius* L.)	Apr 3	13.95			⬤	•		
Virginia Rail (*Rallus limicola* Vieillot)	May 9	11.89		•	●	·		
Sora (*Porzana carolina* (L.)	May 12	8.39	•	●	•			
Piping Plover (*Charadrius melodus* Ord)	May 3	20.23		·	•	·		
Killdeer (*C. vociferous* L.)	Mar 28	15.94			●	●		

Species	Mean arrival date	Mean s.d.	Distribution of annual s.d. 0–5	5–10	10–15	15–20	20–25	>25
Willet (*Catoptrophorus semipalmatus* (Gmelin))	May 8	11.57	●	●	●	●		
Upland Sandpiper (*Bartramia longicauda* (Bechstein))	May 12	15.06		●	●	●		
Spotted Sandpiper (*Actitis macularia* (L.))	May 14	8.52	●	●	●			
Wilson's Snipe (*Gallinago delicata* Ord)	Apr 19	15.51			●	●		
American Woodcock (*Scolopax minor* Gmelin)	Mar 29	11.57		●	●			
Common Tern (*Sterna hirundo* L.)	May 24	9.22	●	●	●			
Black-billed Cuckoo (*Coccyzus erythropthalmus* (Wilson))	May 27	10.89	●	●	●	●		
Common Nighthawk (*Chordeiles minor* (Forster))	May 26	9.21		●	●			
Whip-poor-will (*Caprimulgus vociferous* Wilson)	May 19	11.08	●	●	●	●		
Chimney Swift (*Chaetura pelagica* (L.))	May 11	7.76	●	●	●			
Ruby-throated Hummingbird (*Archilochus colubris* (L.))	May 10	6.78	●	●	●			
Belted Kingfisher (*Ceryle alcyon* (L.))	Apr 19	20.12			●	●		
Yellow-bellied Sapsucker (*Sphyrapicus varius* (L.))	Apr 19	14.26		●	●	●		
Northern Flicker (*Colaptes auratus* (L.))	Apr 14	14.28		●	●	●		
Olive-sided Flycatcher (*Contopus cooperi* (Nuttall))	May 25	10.34	●	●	●	●		
Eastern Wood-Pewee (*C. virens* (L.))	May 24	8.92	●	●	●	●		
Yellow-bellied Flycatcher (*Empidonax flaviventris* (Baird and Baird))	May 23	7.52	●	●	●	●		
Alder Flycatcher (*E. alnorum* Brewster)	May 25	6.46	●	●				
Willow Flycatcher (*E. traillii* (Audubon))	May 26	11.57	●	●	●	●		
Least Flycatcher (*E. minimus* (Baird and Baird))	May 13	8.14	●	●	●			
Great Crested Flycatcher (*Myiarchus crinitus* (L.))	Apr 30	9.94		●	●	●		
Eastern Phoebe (*Sayornis phoebe* (Latham))	Apr 7	12.41	●	●	●	●		
Eastern Kingbird (*Tyrannus tyrannus* (L.))	May 14	10.02		●	●	●		
Purple Martin (*Progne subis* (L.))	May 8	14.41		●	●	●		

Species	Mean arrival date	Mean s.d.	Distribution of annual s.d. 0–5	5–10	10–15	15–20	20–25	>25
Tree Swallow (*Tachycineta bicolor* (Vieillot))	Apr 13	11.64		•	⬤	·		
N. Rough-winged Swallow (*Stelgidopteryx serripennis* (Audubon))	May 5	12.34		•	●	•		
Bank Swallow (*Riparia riparia* (L.))	May 17	10.93		●	●	·		
Cliff Swallow (*Petrochelidon pyrrhonata* Vieillot)	May 14	10.43		•				
Barn Swallow (*Hirundo rustica* L.)	May 5	11.21		•	⬤			
Blue-headed Vireo (*Vireo solitarius* (Wilson))	May 12	9.10		⬤	·			
Warbling Vireo (*V. gilvus* (Vieillot))	May 19	6.52	•	⬤				
Red-eyed Vireo (*V. olivaceus* (L.))	May 16	7.78	·	⬤	•			
House Wren (*Troglodytes aedon* Vieillot)	May 9	11.00		●	●	·		·
Winter Wren (*T. troglodytes* L.)	Apr 19	13.36		•	●	•	·	
Marsh Wren (*Cistothorus palustris* (Wilson))	May 17	5.48	·	●	•	·	·	
Ruby-crowned Kinglet (*Regulus calendula* (L.))	Apr 21	10.83		●	●			·
Blue-gray Gnatcatcher (*Polioptila caerulea* (L.))	May 8	9.14	·	●	•	·		
Eastern Bluebird (*Sialia sialis* (L.))	Apr 7	19.71			•	•	●	·
American Robin (*Turdus migratorius* L.)	Mar 21	19.22			·	●	●	·
Veery (*Catharus fuscescens* (Stephens))	May 16	8.70		⬤	•			
Swainson's Thrush (*C.ustulatus* (Nuttall))	May 18	9.60	·	●	•	•		
Hermit Thrush (*C. guttatus* (Pallas))	Apr 22	14.19		·	●	●		
Wood Thrush (*Hylocichla mustellina* (Gmelin))	May 12	9.57		●	●			
Gray Catbird (*Dumetella carolinensis* (L.))	May 11	8.73		⬤	•			
Brown Thrasher (*Toxostoma rufum* (L.))	May 8	11.11		●	●			

Species	Mean arrival date	Mean s.d.	Distribution of annual s.d. 0–5	5–10	10–15	15–20	20–25	>25
Tennessee Warbler (*Vermivora peregrina* (Wilson))	May 20	6.28	•	●				
Nashville Warbler (*V. ruficapilla* (Wilson))	May 10	6.54	•	●				
Northern Parula (*Parula Americana* (L.))	May 9	7.09		●				
Yellow Warbler (*Dendroica petechia* (L.))	May 12	6.65	•	●				
Chestnut-sided Warbler (*D. pensylvanica* (L.))	May 12	7.33	•	●	•			
Magnolia Warbler (*D. magnolia* (Wilson))	May 15	5.48	●	●				
Cape May Warbler (*D. tigrina* (Gmelin))	May 15	6.44	•	●				
Black-throated Blue Warbler (*D. caerulescens* (Gmelin))	May 13	6.84	•	●	•			
Yellow-rumped Warbler (*D. coronata* (L.))	Apr 28	13.55		●	●	•		
Black-throated Green Warbler (*D. virens* (Gmelin))	May 8	5.78	●	●				
Blackburnian Warbler (*D. fusca* (Müller))	May 16	6.76	•	●				
Pine Warbler (*D. pinus* (Wilson))	Apr 20	12.51		•	●	●		
Palm Warbler (*D. palmarum* (Gmelin))	Apr 22	10.63		●	●			
Bay-breasted Warbler (*D. castanea* (Wilson))	May 19	6.95	•	●	•			
Blackpoll Warbler (*D. striata* (Forster))	May 20	7.36	•	●	•			
Black-and-white Warbler (*Mniotilta varia* (L.))	May 6	7.92	•	●	•			
American Redstart (*Setophaga ruticilla* (L.))	May 15	6.72	•	●	•			
Ovenbird (*Seirus aurocapillus* (L.))	May 9	6.58	●	●				
Northern Waterthrush (*S. novebaracensis* (Gmelin))	May 9	9.07		●	●			
Mourning Warbler (*Oporornis philadelphia* (Wilson))	May 27	6.96	●	●	•			
Common Yellowthroat (*Geothlypis trichas* (L.))	May 7	6.76	•	●				

Species	Mean arrival date	Mean s.d.	Distribution of annual s.d. 0–5	5–10	10–15	15–20	20–25	>25
Wilson's Warbler (*Wilsonia pusilla* (Wilson))	May 16	6.32	●	●	·			
Canada Warbler (*W. Canadensis* (L.))	May 20	5.87	●	●	·			
Scarlet Tanager (*Piranga olivacea* (Gmelin))	May 17	6.30	●	●				
Rose-breasted Grosbeak (*Pheucticus ludovicianus* (L.))	May 12	6.67	●	●	·			
Indigo Bunting (*Passerina cyanea* (L.))	May 19	9.16		●	●			
Eastern Towhee (*Pipilo erythrophthalmus* (L.))	May 4	10.44		●	●		·	
Chipping Sparrow (*Spizella passerina* (Bechstein))	Apr 25	12.38		●	●			
Field Sparrow (*S. pusilla* (Wilson))	May 4	15.64		·	●	●	●	
Vesper Sparrow (*Poocetes gramineus* (Gmelin))	May 1	15.86			●	●	●	
Fox Sparrow (*Passerella iliacaI* (Merrem))	Mar 28	10.68	·	●	●	●		
Savannah Sparrow (*Passerculus sandwichensis* (Gmelin))	Apr 24	14.85		·	●	·	·	·
Lincoln's Sparrow (*Melospiza lincolnii* (Audubon))	May 14	15.52	·	●	●	·	●	●
Song Sparrow (*M. melodia* (Wilson))	Mar 28	17.82	·	·	●	●		
Swamp Sparrow (*M. Georgiana* (Latham))	Apr 29	12.80		·	●	●		
White-throated Sparrow (*Zonotrichia albicollis* (Gmelin))	Apr 20	17.82			●	●	●	·
Bobolink (*Dolichonyx oryzivorus* (L.))	May 15	10.19	·	●	·	·	·	
Eastern Meadowlark (*Sturnella magna* (L.))	Apr 19	20.52			●	●	·	
Red-winged Blackbird (*Agelaius phoeniceus* (L.))	Mar 23	16.57			●	●	·	
Rusty Blackbird (*Euphagus carolinus* (Müller)	Apr 10	20.66		·	●	●	●	●
Common Grackle (*Quiscalus quiscula* (L.))	Mar 21	16.08			●	●	·	
Baltimore Oriole (*Icterus galbula* (L.))	May 12	8.59	●	●	●	·		