Possible Migration Routes through Maine by Vernal Migrants

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Abstract
In this study we evaluate the possibility of two routes of migration into the state of Maine. The first possible route would be for migrants to continue along the coast, north of the Maine/New Hampshire border, and later swinging inland across the interior. The second path is for migrants who come up the east coast and straight into Maine, spreading across the state as they move north. In order to evaluate these possible routes we utilize a citizen-science project that measures the spring arrival dates of migrants according to the biophysical regions of Maine (Wilson 2007). Independent t-Tests and maps indicate that there is a trend of birds continuing along the coast before moving inland; six of the nine species show this pattern. Of the nine birds studied only the eastern phoebe showed a significant trend of moving directly inland and moving across the state. Two birds show non-significant patterns of migration which could indicate insufficient data, or random migration patterns. The results are not conclusive because several of the biophysical regions have less reporting, and so the relationships among regions regarding arrival dates are skewed. Continued data collection and analysis is recommended.

Introduction
Each spring vast numbers of birds leave their southern wintering grounds and head north towards breeding grounds. The northern hemisphere provides more land mass and space, and so also a vast abundance of food and space for territories. There are many hypotheses regarding the evolution of migration, but almost certainly part of the explanation lies in the huge amount of resources that become seasonally available in the summers of the northern hemisphere. Many of the birds making their way north each spring are destined to settle in the boreal forests of Maine. However, without any prior knowledge of the weather to the north migrants must balance arriving early enough to access suitable breeding territories with arriving late enough that food resources are available and temperatures are not too cold. For some birds this means arriving before the ice is off of the lakes, and others will wait until the trees begin to flower in May.

Across Maine, there are spatial differences in climate that may influence the ways that birds infiltrate the state. McMahon (1990) divides Maine into 15 biophysical regions based on climatic and vegetation data as shown in Figure 1. As Wilson (2007) notes, there are profound differences in the climates of the different regions. For instance, Region 1, the Boundary Plateau in the northwest, experiences only 80 frost-free days, while Region 12, the South Coastal region, experiences 160 days (Wilson 2007). The coastal regions, including the South Coastal, Midcoast. Penobscot, and East Coastal Regions, have more moderate climates when compared to the inland biophysical regions. It has been demonstrated that many birds migrate along coastlines because of important orientation and direction cues. It is also probable that birds migrate along coastlines because weather tends to be milder due to the influence of the ocean. Maine is no exception.

In this study we evaluate two possible migration routes into the state of Maine. The first possibility is that migrants come up the east coast, arrive in Maine in regions 12 and 9, and then proceed northward spreading out across the state as they go. In the second possibility, migrants capitalize on the moderate coastal temperatures and proceed up the coastal regions – 12, 13, 14, and 15 – before moving to the interior of the state. Our own hypothesis is that spring migrants will follow the second migration path upon arriving in Maine. In order to evaluate the two hypotheses we examined and mapped the spring arrival dates of nine species over a ten year period. If birds continue to move up the coast we would expect the earlier arrival dates to be clustered in regions 12-15, with later arrivals inland. In contrast, earlier dates collected in regions 9, 12, and 10 would indicate that birds are moving straight into the state and not continuing along the coast.

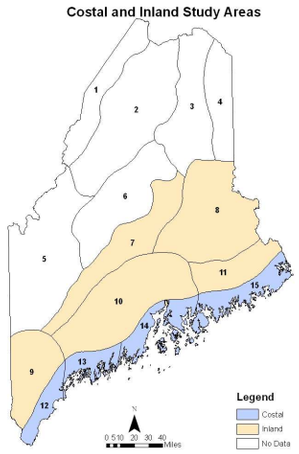


Figure 1. Biophysical Regions of Maine: (1)Boundary Plateau, (2) saint Johns Uplands, (3) Aroostook Hills, (4) Arostook Lowlands, (5) Western Mountains, (6) Central Mountains, (7) Western Foothills, (8) Eastern Lowlands, (9) Southwest Interior, (10) Central Interior, (11) Eastern Interior, (12) South Coastal Region, (13) Midcoast Region, (14) Penobscot Bay Region, (15) east Central Region.

Methods

Data Collection
Data was collected in a citizen-science project regarding the arrival dates of spring migrants in Maine. The project is managed by Dr. Herb Wilson, and is detailed in Wilson (2007). In general, individuals within each biophysical region record the arrival date of any bird they encounter – i.e. by sight, ear, etc. Twelve years of reports have been compiled into a list of arrival dates for over 100 species. From these we selected nine species based on their broad arrival dates: early, middle, and late arrivers. Red Wing Black Bird, Woodcock, and Common Grackle comprised the early arrival group, Phoebe, Northern Flicker, and Chipping Sparrow made up the middle, and Common Yellowthroat, Bobolink, and Black Throated Green were selected as late arrivals. Data from 1995-2005 was analyzed.

Mapping
Using ArcGIS 9.3 software we mapped the earliest arrival date for each species, in each of the reported biophysical regions (Maine Office of GIS), for each of the ten years. The earliest arrival dates for each species were averaged over the ten year span, 1995-2005, by biophysical region. The maps displayed in Figures 2, 3, and 4 display these averages. Dark colors indicate early arrivals, and light colors indicate later arrivals. The regions with no data were not included.

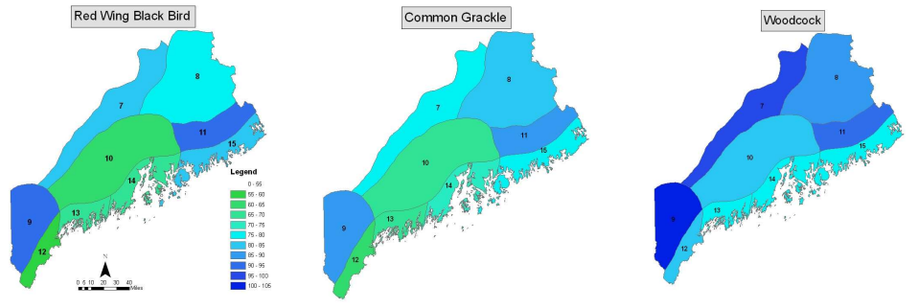


Figure 2. Maps of spring arrival dates for early arriving migrants. Arrival dates (in Julian days) averaged by biophysical regions.

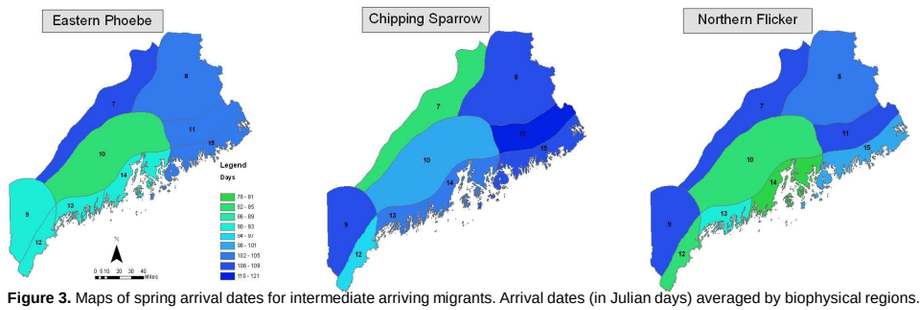


Figure 3. Maps of spring arrival dates for intermediate arriving migrants. Arrival dates (in Julian days) averaged by biophysical regions.

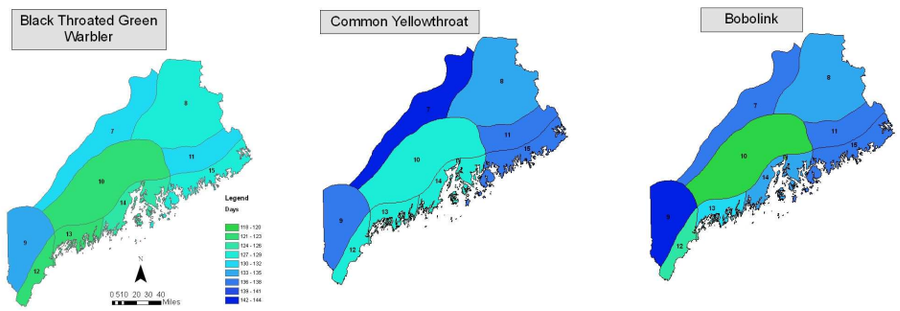
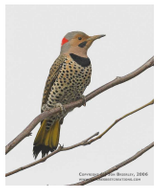


Figure 4. Maps of spring arrival dates for late arriving migrants. Arrival dates (in Julian days) averaged by biophysical regions.

Statistical Analyses
In order to test our hypotheses we formed two different groups: (1) regions 12-15 comprise the coastal regions, and (2) regions 7-11 comprise the inland regions (see Figure 1). We did this so that we could compare the coastal arrival dates to the inland arrival dates. Earlier coastal arrivals would indicate that birds tend to move up the coast before moving inland and across Maine. On the other hand, earlier arrival in the inland states would indicate that there is not a preference to move up the coast. Using SPSS statistical software (PC) we performed an independent-samples t-Test for each species at a 95% confidence interval.

Table 1. Results of t-Test for the means of coastal and inland region arrival dates. *Significant difference at p<.05 value

Species	Costal (Mean, SE)	Inland (Mean, SE)	t value
Red Wing Black Bird	69.75, 1.916	81.33, 2.518	(91) = -3.597*
Common Grackle	69.68, 1646	61.02, 4.900	(97) = 1.526
Woodcock	78.58, 1.307	87, 1.970	(62) = -3.706*
Northern Flicker	87.39, 3.165	100.87, 2.343	(87) = -3.434*
Chipping Sparrows	98.75, 2.977	107.16, 2.020	(87) = -2.346*
Eastern Phoebe	93.27, 1.380	74.58, 6.149	(53.901) = 2.966*
Bobolink	131.65, 1.911	132.20, 2.621	(81) = -.171
Common Yellowthroat	129.26, 0.919	134.33, 1.622	(86) = -2.690*
Black Throated Green	123.86, .666	127.8, .966	(87) = -3.340*



Discussion
In general, the results provide support for our hypothesis. Six out of the seven t-Tests show that the birds move up the coast of Maine before moving inland, and spreading across the state. The eastern phoebe was the only bird showing a pattern in which they arrive in the interior of Maine prior to reaching the coast. The common grackle, and the bobolink showed no significant relationship either way. This may indicate that there was insufficient data, or it may indicate that some birds, like these two species, follow random paths as they enter Maine.

Interestingly, there was no pattern with regard to the migration routes of birds arriving at different times. It may have been expected that early arrivals, those appearing in March, would rely on the moderate coastal climates, and late arrivers, those arriving in May, would not be as dependent on the moderating climatic effects of the coast. However, such a pattern is not demonstrated in the maps, or in the results of the t-Tests. The maps in Figures 2, 3, and 4 provide a visual sense which supports our hypothesis. Although not quantitative, the maps support the data. The regions along the coast tend to be darker indicating earlier arrivals compared to the interior regions.

However, the data is influenced by its collection methods. Because this is citizen-science in which the data is collected by volunteers there is bound to be error introduced. For instance Regions 1-6 reported no observations at all, and Region 9 was reported in only 60% of the possible observations. If the data in Region 9 is insufficient than the analysis is compromised. To that extent, this analysis will be bolstered by more years of collection, but also more collections in each biophysical region. In contrast, Region 10 has the highest rate of reporting, and it frequently is among the earlier arrivals. It is reasonable to infer that more data collectors will yield earlier, and more accurate arrival dates. More data will also allow for more sophisticated quantitative and spatial analyses, which will yield more precise results about the migration routes of birds through Maine.

Conclusion
In six out of nine cases the statistical analysis indicated that birds were seen significantly earlier on the coast compared to inland regions. The eastern phoebe was the only bird illustrating a significant pattern of arriving inland before being seen on the coast. Two others showed no statistical difference between the two regions. While this points to a trend, the results aren't definitive due to a relatively small sample sizes, imperfect citizen science, and insufficient data in many of the regions. Our analysis lends support to the hypothesis that vernal migrants tend to migrate up Maine's coast, but further research is needed.

Acknowledgements
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