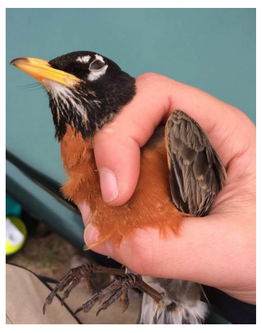

Harbingers of Earlier Spring in Aroostook County

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Abstract

Maine's three degrees of latitude have a climate gradient similar to the twenty degrees of latitude from southern Europe through Scandinavia. Given this steep gradient, the impacts of climate change may proceed more rapidly across Maine's diverse ecosystems, impacting management of all of our natural resources. The Acadian Forest is a unique forest community that occurs along this gradient and comprises a mix of more southerly and boreal species. The birds and other non-commercial species that inhabit this region are facing considerable changes. We highlight three studies conducted in northern Maine that have tested hypotheses related to shifting ranges, phenology, or migratory arrival to this region. In one study observations from the 1940's and 1950's were compared to current observations and temperature data. Leafout and flowering of many species of trees and herbaceous plants was earlier in response to April temperatures, although bird arrival was not significantly earlier. In a second a study that analyzed citizen scientist data from 1969-2013, the majority of short-distance migratory birds was significantly earlier, while most long-distance migrants did not arrive earlier. A third study used DNA metabarcoding to test whether arthropod species consumed underlies the northward range shift of a suite of resident or migratory birds; preliminary analyses are presented. Overall, there is evidence from both birds and plants that changes in weather patterns over multiple decades have resulted in adaptive responses, with the exception of some migratory birds. These findings add to a growing body of literature from Maine with similar conclusions, implicating agricultural, marine, freshwater, and other natural systems, as well as associated social and economic well-being.

Maine's Extraordinary Range in Climate

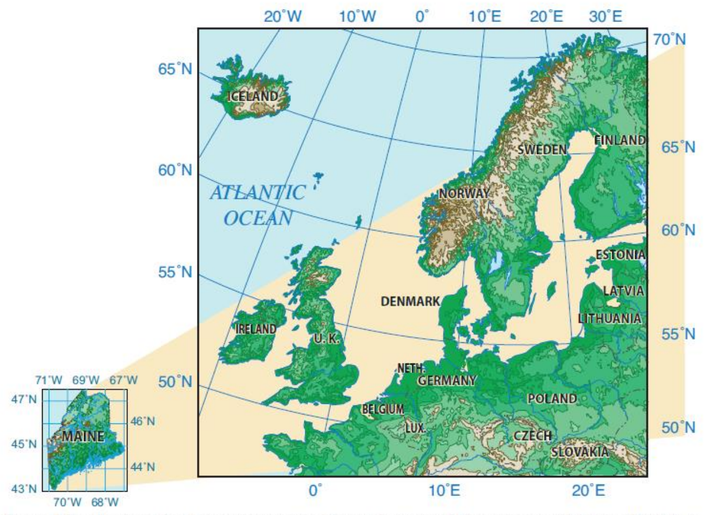
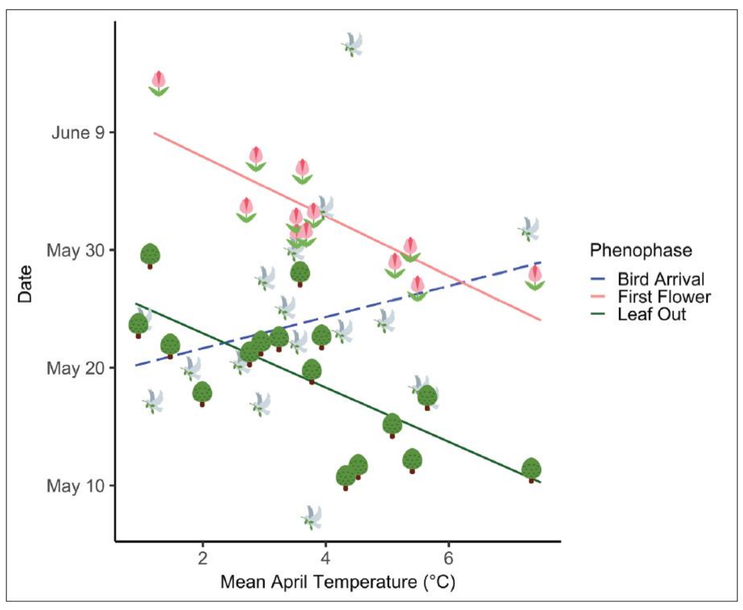


Figure 4 The climate gradient that exists in just three degrees of latitude in Maine occurs over 20 degrees of latitude in Europe, a distance approximately twice the length of California. Figure by K. Maasch.

[1]Project #1: Local 'citizen scientist' data from Oxbow, ME, from the 1940's-1950's

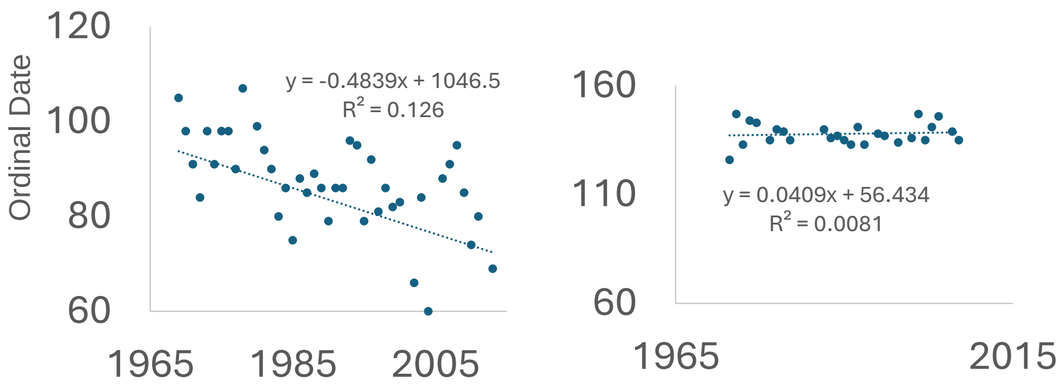


Earlier leafout and flowering times but not earlier bird arrival illustrates **ecological mismatch** for several migratory birds (left) and correlations to spring temperatures for trees and flowering plants (below).

Species	Mean arrival date	Model	*P* value	R^2	Days/°C	*n*
Leaf-out						
Paper Birch	12 May	April	0.000*	0.65	-4.5 (0.9)	16
Quaking Aspen	11 May	April	0.001*	0.57	-4.3 (1.0)	16
Sugar Maple	15 May	April	0.017*	0.53	-2.2 (0.8)	10
American Hophornbeam	15 May	April	0.021*	0.43	-2.4 (0.9)	12
Striped Maple	17 May	April	0.024*	0.41	-2.4 (0.9)	12
Ash	31 May	May	0.044*	0.38	-3.0 (1.3)	11
Balsam Fir	24 May	April	0.074	0.34	-2.1	10
Large-tooth Aspen	28 May	May	0.125	0.24	-2.8	11
Red Oak	23 May	April	0.177	0.16	-1.2	13
American Beech	20 May	April	0.316	0.13	-1.2	10

Species	Mean arrival date	Model	*P* value	R^2	Days/°C	*n*
Flowering						
Red Trillium	12 May	April	0.000*	0.86	-3.9 (0.5)	12
Shadbush	19 May	April	0.000*	0.75	-4.5 (0.8)	12
Wild Strawberry	21 May	April	0.002*	0.69	-3.1 (0.7)	11
White Violet	21 May	April	0.005*	0.64	-3.9 (1.0)	10
Apple	28 May	April	0.011*	0.53	-2.9 (0.9)	11
Bunchberry	6 Jun	April	0.016*	0.54	-3.7 (1.2)	10
Dandelion	24 May	April	0.016*	0.50	-3.0 (1.0)	11
Canada Mayflower	7 Jun	April	0.021*	0.46	-3.5 (1.2)	11
Daisy	21-Jun	May	0.023*	0.46	-3.5 (1.3)	11
Red Osier Dogwood	11 Jun	May	0.027*	0.44	-4.8 (1.8)	11
Wild Rose	20-Jun	May	0.028*	0.43	-4.4 (1.7)	11
Buttercup	9 Jun	April	0.041*	0.39	-2.1 (0.9)	11
Wild Carrot	12 Jun	April	0.062	0.34	-1.6	11
Blue Violet	22 May	April	0.188	0.18	-1.5	11
Blue-eyed-grass	15 Jun	May	0.268	0.13	-2.8	11

Project #2: Local 'citizen scientist' data from Hammond, ME, from 1969-2013



Forty year patterns (above) in migratory bird arrival are exemplified by a negative trend of the short-distance migrant American Robin (*Turdus migratorius*) compared to a flat response by the Bobolink *(Dolichonyx oryzivorus),* which winters in the high Andean plains of southern South America. Overall patterns showing the rate of change per year are summarized below.

Bird Species	Year
American Robin	**-0.52**
American Woodcock	**0.62**
Brown-headed Cowbird	**-0.62**
Chipping Sparrow	**-1.3**
Common (Purple) Grackle	**-0.49**
Eastern Phoebe	-0.11
Gray Catbird	-0.11
American Kestrel	**0.34**
Killdeer	0.13
Magnolia Warbler	**-0.46**
Mourning Dove	0.056
Ruby-crowned Kinglet	-0.13

Short-distance migrants arrival date change in #days/year (1969-2013); **bold**: p<0.05 by linear regression

Red-winged Blackbird	**-0.22**
Song Sparrow	**-0.48**
Tree Swallow	**-0.54**
Wilson's (Common) Snipe	-0.089
Winter Wren	**-1.2**
White-throated Sparrow	-0.054
Northern Flicker (Yellow-sh	-0.097

Long-distance migrants arrival date change in #days/year (1969-2013); **bold**: p<0.05 by linear regression

Bird Species	Migratory Strategy	Year
Baltimore Oriole	long	**0.26**
Barn Swallow	long	**0.224**
Black-billed Cuckoo	long	-0.02
Bobolink	long	0.057
Broad-winged Hawk	long	-0.37
Black-and-white Warbler	long	0.021
Chestnut-sided Warbler	long	0.11
Eastern Kingbird	long	**0.22**
Northern Harrier (Marsh Hawk)	long	0.049
Ovenbird	long	**-0.14**
Rose-breasted Grosbeak	long	**-0.3**
Ruby-throated Hummingbird	long	**-0.33**
Veery	long	-0.02

The ovenbird (*Seiurus aurocapilla)* is a common migratory warbler to Eastern deciduous and mixed forests with decent canopy closure.

Project #3: DNA metabarcoding of arthropod food use by forest birds

While bioinformatic data analyses are still ongoing, of the 32 bird samples in a preliminary analysis, there were 115 species of arthropods total, with a range of 6-38 species per bird sampled ($\bar{x} = 20.4$). The average number of arthropod species by habitat type was not different (p=0.59) among boreal birds ($\bar{x} = 22.4$), deciduous birds ($\bar{x} = 18.8$), and generalists ($\bar{x} = 20.2$). The six orders with the highest percentage of arthropods include: Diptera (33%); Lepidoptera (30.1); Araneae (11%); Coleoptera (10.1%); Hemiptera (4.0%); Hymenoptera (3.1%) (Figure 4). Another preliminary analysis found that the Spruce Budworm (*Choristoneura fumiferana*) was found in 10 of the 281 bird samples collected during 2016-2018.

[1]McDonough Caitlin MacKenzie, Jason Johnston, Abraham Miller-Rushing, William Sheehan, Robert Pinette, and Richard Primack. 2019. Advancing Leaf Out and Flowering Phenology is not Matched by Migratory Bird Arrivals Recorded in Hunting Guide's Journal in Aroostook County, Maine. **Northeastern Naturalist** 26(3):561-579.

Acknowledgements

We thank L.S. Quackenbush and David Saunders for data collected for Projects #1 and #2, respectively. Project #3 was funded by NSF award 1548112 to Jason Johnston, Larry Feinstein, and Judith Roe. All photos by J.C. Johnston.

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