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The disproportionate effect of global warming on the arrival dates of short-distance migratory birds in North America

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Recent studies have shown that, in response to global climate change, diverse avian taxa are now nesting measurably earlier (< 10 days) in both the United States and Britain. Similarly, several studies on European birds have now demonstrated that a variety of species (although not all) are arriving increasingly early. However, surprisingly, widespread changes in North American migrant phenology have not been demonstrated. It is hypothesized that short-distance migrants (birds that winter in the southern United States) may be quicker to adapt to climate change than long-distance migrants (birds that winter south of the United States), as short-distance migrants can respond to meteorological cues indicating weather conditions to the north whereas long-distance migrants must rely on photoperiod. This study examined the first arrival dates of 103 migrant birds in New York and Massachusetts and found that, on average, all migrants arrived significantly earlier during the period 1951–1993 than the period 1903–1950. From 1951–1993 birds wintering in the southern United States arrived on average 13 days earlier while birds wintering in South America arrived 4 days earlier. Although a change in observer effort cannot be quantified and may be a source of bias, a comparison of the numbers of reporting observers during the 1930s and the 1980s revealed no significant difference. These results are consistent with those expected under a scenario of global warming.

Over the past century, the Earth has warmed by approximately 0.5 °C (von Stoch & Navarra 1995, IPCC 1998). During the past 10 years, a variety of studies have shown that global climate change is affecting the world's flora and fauna. The active growing season of plants has advanced by 8 days in northern latitudes (Myneni *et al.* 1997); six out of 15 spring wildflowers sampled in upstate New York now bloom significantly earlier than they did in 1925 (Oglesby & Smith 1995); leaf buds are breaking earlier in England (Sparks *et al.* 1997); populations of Edith's Checkerspot Butterfly *Euphydryas editha* have shifted their range north and further upslope (Parmesan 1996); moth emergence phenology in England has advanced (Woiwod 1997); amphibians in Britain have advanced their egg-laying dates 2–7 weeks (Beebe 1995); and marmots have begun emerging from hibernation more than a month earlier in Colorado (Inouye *et al.* 2000). Studies on birds have shown that diverse avian taxa are now nesting significantly earlier in both the United States and Europe (Kruk *et al.* 1996, Crick *et al.* 1997, Forchhammer *et al.* 1998, McCleery & Perrins 1998, Visser *et al.* 1998, Brown *et al.* 1999, Crick & Sparks 1999, Dunn & Winkler 1999). Surprisingly, however, a widespread change towards an earlier arrival date in migrant birds, although demonstrated on the European continent (e.g. Sokolov *et al.* 1998, Sparks *et al.* 1999, Sparks & Mason 2001, Tryjanowski *et al.* 2002), has not been demonstrated on the North American continent. Although a few studies have shown that individual species are altering the timing of their migration (Bildstein 1998, Inouye *et al.* 2000, Pulido *et al.* 2001), studies examining the arrival or departure dates of multiple species have shown that whereas some species are arriving significantly earlier, others are arriving significantly later (Mason 1995, Oglesby & Smith 1995, Bradley *et al.* 1999, Wilson *et al.* 2000, Zalakevicius & Zalakeviciute 2001). In order to eliminate some of the 'noise' associated

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with sampling from a single location (Tryjanowski *et al.* 2002), and to examine the 'big picture' (Sparks & Mason 2001) to determine whether species are arriving significantly earlier or later across a wide front, or whether arrival dates are affected by local factors, it is necessary to examine first arrival data from at least two locations.

The annual data collected on the first arrival dates of migrant birds in the Cayuga Lake Basin, New York, and Worcester County, Massachusetts, provide an excellent opportunity to analyse the effects of global warming on migrants. First arrival dates have been recorded since 1903 in the Cayuga Lake Basin, and since 1932 in Worcester County. In addition, these two areas are located at approximately the same latitude (42°N) and so the same species of migrants arrive at approximately the same time.

METHODS

Study area and data sources

Observations on the first arrival dates (FAD) of migrant birds were compiled by the Cayuga Bird Club for the Cayuga Lake Basin (42°27′N, 76°27′W) and the Worcester County Ornithological Society for Worcester County (42°22′N, 71°54′W) for most of the twentieth century. The FAD for 103 spring migrants were abstracted from the annual lists of first arrival dates compiled by the Cayuga Bird Club from 1903 to 1993, and from *The Chickadee*, published by the Worcester County Ornithological Society, for the period 1932–1993. Monthly air temperature data for the period 1903–2002 for Ithaca, New York, and the period 1920–2002 for Boston Logan International Airport were obtained from the North-eastern Regional Climate Center.

Statistical analysis

Temperatures during February to May for Boston and Ithaca were regressed against year to determine whether a trend towards warmer springs was evident in these locations. The average temperature per month, as well as the average temperature for the period February–May, was regressed against the year.

The average FAD for each species during the period 1903–1993 was calculated (see Appendix 1) and a comparison was made between the FAD of migrants in Worcester County and the FAD of migrants in the Cayuga Lake Basin. As the spring temperature change in Boston can best be described as a linear function, the Julian dates of the FAD were linearly regressed against the year. In contrast, the temperature changes in Ithaca can best be described by a cubic function, and so average arrival dates before and after the point of inflection were compared (i.e. the period 1903–1950 was compared to the period 1951–1993) using Mann–Whitney tests. Species were also grouped by habitat type (e.g. forest, scrub, grassland, aquatic, aerial) to examine whether the changes in FAD were more pronounced in various habitats. Species were grouped into population-change categories (e.g. significant decline, non-significant decline, non-significant increase or significant increase) on the basis of breeding bird survey data compiled by Sauer *et al.* (2001). In addition, species were broken down into short- or long-distance migrants. Although it is impossible to quantify changes in observer skill and effort, an attempt was made to determine whether observer numbers had changed over time, by comparing the number of observers during the 1930s and the 1980s in the Cayuga Lake Basin. Just as more observers are likely to find more birds during census work (Bibby *et al.* 2000), more observers should find more early migrants. Means are given ±1 standard deviation (sd) and all statistics were calculated with SPSS v.11.0.

RESULTS

Temperature trends

The temperatures in Boston and Ithaca showed a general trend towards a warmer February–May period. A linear regression of the temperature during this period over the year for Boston approaches significance (R^2 = 3.7%, P = 0.083; Fig. 1). Although

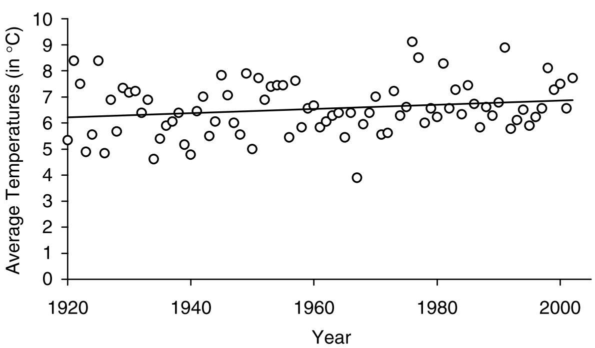

Figure 1. The mean temperature during February to May in Boston, MA, for the period 1920–2002. The trend towards higher temperatures can best be described as a linear function [$f(x) = 0.0807 \times \text{Year} - 9.29$, $F_{1,81} = 3.07$, $R^2 = 0.037$, $P = 0.083$].

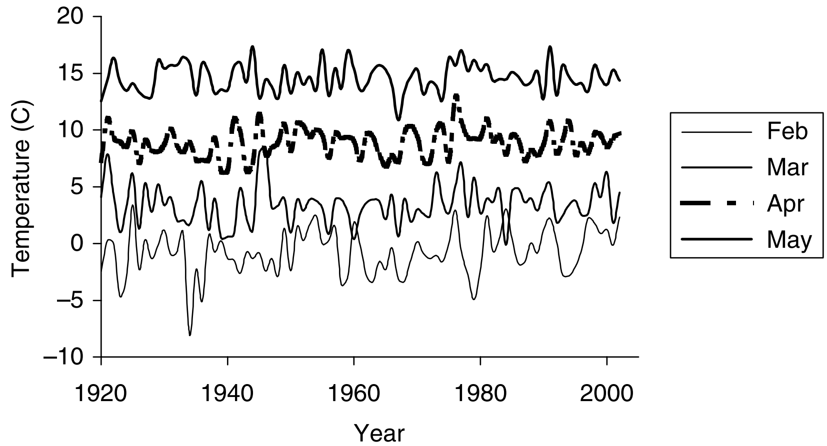

Figure 2. Mean monthly temperatures from February to May at Boston, MA. Each month exhibits a slight but non-significant ($P > 0.05$) linear trend towards higher temperatures, with the temperature for February approaching significance [$f(x) = 0.0181 \times \text{Year} - 36.3$, $F_{1,82} = 3.79$, $R^2 = 4.5\%$, $P = 0.055$].

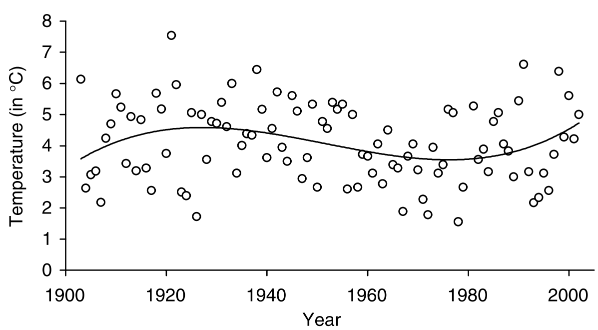

Figure 3. The average temperature during February to May in Ithaca, NY, for the period 1903–2002. The cubic trend towards warmer temperatures is significant [$f(x) = 1.77 \times 10^{-5} \times \text{Year}^3 - 0.103733 \times \text{Year}^2 + 202.415 \times \text{Year} - 131\,633$, $F_{3,95} = 3.00$, $R^2 = 8.7\%$, $P = 0.0344$]. A solution to $f''(x)$ yields a point of inflection at 1951.

the linear change in February temperatures over time approached significance ($R^2 = 4.5\%$, $P = 0.055$), none of the trends observed in monthly temperatures was statistically significant (see Fig. 2).

In contrast, the change in temperature in Ithaca could best be described by a significant cubic function ($R^2 = 8.7\%$, $P = 0.0344$; Fig. 3) with the point of inflection occurring in 1951. Although the cubic function that describes the changes in February temperatures over time is significant ($R^2 = 10.2\%$, $P = 0.015$), none of the other months exhibits a significant trend (Fig. 4).

FAD trends

The average arrival dates for the 103 species did not differ significantly between the Cayuga Lake Basin

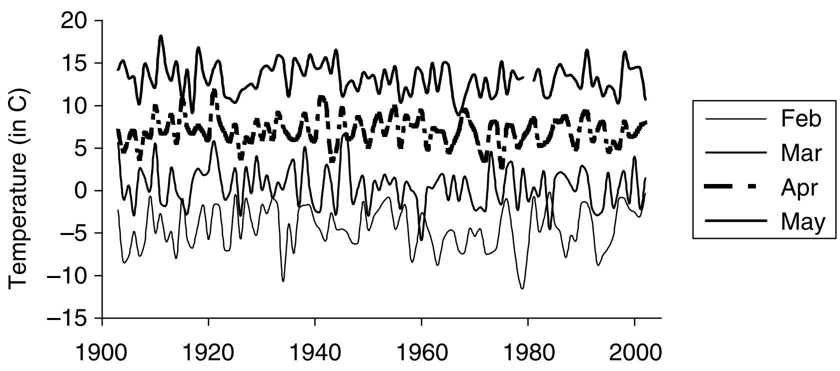

Figure 4. The average monthly temperature for February to May in Ithaca, NY, for the period 1903–2002. February exhibits a significant cubic trend towards warmer temperatures [$f(x) = 4.33 \times 10^{-5} \times \text{Year}^3 - 0.253 \times \text{Year}^2 + 4.94 \times \text{Year} - 321\,673$, $F_{3,96} = 3.65$, $R^2 = 10.2\%$, $P = 0.015$], whereas the other months do not exhibit a significant trend.

and Worcester County; birds on average arrived in the Cayuga Lake Basin less than a day before they arrived in Worcester County (Mann–Whitney, $U = 5201.50$, $P = 0.810$). Forty-nine (47.6%) of the species in Worcester County showed a significant ($P < 0.05$) linear trend towards earlier arrivals (see Table 1) whereas three of the species (Red-eyed Vireo *Vireo olivaceus*, Northern Parula *Parula americana* and Palm Warbler *Dendroica palmarum*) showed a significant trend towards later arrivals. In the Cayuga Lake Basin, 45 (43.7%) species arrived significantly earlier during the period 1951–1993 than during the period 1903–1950 (see Table 2) and two species (Louisiana Waterthrush *Seiurus motacilla* and Mourning Warbler *Oporornis philadelphia*) arrived significantly later. In total, 28 (27.2%) species showed a significant ($P < 0.05$) trend toward earlier arrival at both locations during the twentieth century (see Table 3), whereas no species showed a significant trend toward later arrival at both locations.

A recent paper on Red-backed Shrikes *Lanius collurio* has demonstrated that an increase in the size of the population leads to individuals arriving increasingly early (Tryjanowski & Sparks 2001). However, no correlation between population changes and changes in phenology could be demonstrated in the present study (linear regression, $P = 0.718$, $R^2 = 0.1\%$, $F_{1,98} = 0.131$, d.f. = 1).

A species' FAD was strongly influenced by habitat type (Kruskal–Wallis, $H = 21.43$, d.f. = 4, $P < 0.001$). Of the five habitat types into which species were grouped (forest, scrub, grassland, aquatic and aerial), the greatest change in FAD was in grassland species (18.32 ± 5.10 days earlier, $n = 13$; see Table 4); forest species exhibited the least amount of change (4.71 ± 1.03 days earlier).

During the second half of the twentieth century, migrants in both locations arrived 8.4 ± 0.98 days earlier than during the first half. This change was statistically significant (Mann–Whitney, $U = 17130.5$, $P = 0.0007$). Moreover, short-distance migrants (those that winter in the southern United States) arrived disproportionately earlier during the period 1951–1993 (13.04 ± 1.84 days earlier) than long-distance migrants (those that winter south of the United States), which arrived 4.68 ± 0.80 days earlier during the same period. This difference was statistically highly significant (Mann–Whitney, $U = 3623.5$, $P = 0.0001$).

One problem with using these data sets is that no effort was made to record observer effort. However, the number of observers responsible for most spring arrival reports has typically been relatively small. During the period 1931–1939 an average (± sd) of 56.9 ± 9.5 people in the Cayuga Lake Basin reported a first arrival date. During the period 1980–1989 (excluding the years 1984 and 1989, during which records were not kept) an average (± sd) of 68.6 ± 4.4 observers reported a first arrival date. These two means did not differ significantly (Mann–Whitney, $U = 17.5$, $P = 0.074$), suggesting that bias due purely to increased numbers of observers is unlikely. In reality, a true accounting for observer bias in studies of this kind is extremely difficult, with no clear procedures for assessing changes in observer skill or effort for single-date observations over several decades (Bibby *et al.* 2000, Morrison 2001).

DISCUSSION

Twenty-eight of the 103 species that were examined showed a significant trend towards earlier arrivals in both the Cayuga Lake Basin and Worcester County. No species showed a significant trend towards later arrival at both locations. Given that temperatures in both of these locations exhibited an upward trend, these increasingly early FADs are consistent with a global warming scenario.

Short-distance migrants arrived disproportionately earlier than long-distance migrants during the second half of the twentieth century (13 days earlier vs. 4 days earlier for long-distance migrants). An explanation for this may be that birds that winter in the southern United States are affected more directly by the passage of cold fronts that bring colder weather to the north-east United States during the spring. Consequently, they can move gradually northward in response to favourable conditions. Alerstam and Högstedt (1980) advanced a similar explanation to describe the correlation between the arrival of short-distance waders and weather patterns in the Western Palearctic. In contrast, long-distance migrants overwintering in Central or South America are affected far less by the weather conditions in the north-east United States. With no way of judging the weather conditions on their breeding grounds, they exhibit less plasticity in their ability to respond to warmer conditions earlier in the season. The Pied Flycatcher *Ficedula hypoleuca*, a European long-distance migrant, has advanced its laying date over the last 20 years, but has not advanced its spring arrival date, presumably for the same reason (Both & Visser 2001).

Table 1. Species that exhibit a significant ($P < 0.05$) trend in their first arrival date (FAD) over time in Worcester County, MA, USA. Of the 52 species in this table, 49 exhibit a linear trend towards significantly earlier arrivals (Red-eyed Vireo, Northern Parula and Palm Warbler are the exceptions). Type indicates the migration strategy employed by each species: s = short-distance migrants (those that winter in the US) and l = long-distance migrants (those that winter south of the US). Niche indicates primary feeding habitat: a = aerial, g = grassland; s = scrub, f = forest, and w = wetlands. Species are arranged in taxonomic order.

Species	Type & niche	Mean FAD	sd (days)	*n*	Regression (1932–1993)	Significance
Green Heron *Butorides virescens*	s w	26 Apr.	11.8	54	−0.318	$P < 0.001$
Turkey Vulture *Cathartes aura*	s g	25 Mar.	26.4	46	−1.210	$P < 0.001$
Blue-winged Teal *Anas discors*	s w	29 Mar.	17.1	45	−0.751	$P < 0.001$
Virginia Rail *Rallus limicola*	s w	27 Apr.	25.3	38	−0.608	$P = 0.004$
Killdeer *Charadrius vociferus*	s g	06 Mar.	13.4	55	−0.392	$P < 0.001$
Solitary Sandpiper *Tringa solitaria*	l w	03 May	10.2	57	−0.311	$P < 0.001$
Spotted Sandpiper *Actitis macularia*	s w	27 Apr.	7.9	53	−0.268	$P < 0.001$
Pectoral Sandpiper *Calidris melanotos*	l w	11 Apr.	20	31	−0.647	$P = 0.020$
Common Snipe *Gallinago gallinago*	s w	24 Mar.	20.8	39	−0.604	$P = 0.001$
American Woodcock *Scolopax minor*	s f	17 Mar.	8	59	−0.203	$P < 0.001$
Chimney Swift *Chaetura pelagica*	l a	25 Apr.	5.1	56	−0.102	$P = 0.004$
Ruby-throated Hummingbird *Archilochus colubris*	l f	09 May	5.4	57	−0.104	$P = 0.008$
Yellow-bellied Sapsucker *Sphyrapicus varius*	s f	07 Apr.	19.9	54	−0.409	$P = 0.004$
Eastern Wood-Pewee *Contopus virens*	l f	13 May	5.9	58	−0.137	$P = 0.001$
Alder Flycatcher *Empidonax alnorum*	l s	21 May	7.4	36	−0.135	$P = 0.042$
Great Crested Flycatcher *Myiarchus crinitus*	s f	05 May	6.7	58	−0.197	$P < 0.001$
Yellow-throated Vireo *Vireo flavifrons*	s f	10 May	10.3	50	−0.209	$P = 0.010$
Warbling Vireo *Vireo gilvus*	l f	05 May	5.6	58	−0.156	$P < 0.001$
Red-eyed Vireo *Vireo olivaceus*	l f	08 May	4.7	58	0.070	$P = 0.035$
Purple Martin *Progne subis*	l a	24 Apr.	24.1	45	−0.848	$P < 0.001$
Tree Swallow *Tachycineta bicolor*	s a	21 Mar.	7.6	56	−0.184	$P = 0.001$
Northern Rough-winged Swallow *Stelgidopteryx serripennis*	s a	22 Apr.	13.1	43	−0.490	$P < 0.001$
Bank Swallow *Riparia riparia*	l a	27 Apr.	10.5	50	−0.254	$P < 0.001$
Barn Swallow *Hirundo rustica*	l a	14 Apr.	7.2	47	−0.236	$P < 0.001$
Marsh Wren *Cistothorus palustris*	s w	15 May	13.51	43	−0.613	$P < 0.001$
Wood Thrush *Hylocichla mustelina*	l f	29 Apr.	6.1	59	−0.099	$P = 0.020$
Brown Thrasher *Toxostoma rufum*	s s	23 Mar.	45.1	57	−1.260	$P < 0.001$
Blue-winged Warbler *Vermivora pinus*	l s	06 May	6.6	41	−0.289	$P < 0.001$
Tennessee Warbler *Vermivora peregrina*	l f	11 May	6.5	46	−0.254	$P < 0.001$
Nashville Warbler *Vermivora ruficapilla*	l f	30 Apr.	5.1	58	−0.112	$P = 0.001$
Northern Parula *Parula americana*	l f	08 May	5.4	55	0.088	$P = 0.025$
Yellow Warbler *Dendroica petechia*	l f	30 Apr.	4.8	57	−0.149	$P < 0.001$
Magnolia Warbler *Dendroica magnolia*	l f	07 May	3.9	58	−0.090	$P = 0.001$
Cape May Warbler *Dendroica tigrina*	l f	08 May	5.4	45	−0.192	$P < 0.001$
Yellow-rumped Warbler *Dendroica coronata*	s f	05 Mar.	45.6	57	−0.877	$P = 0.004$
Blackburnian Warbler *Dendroica fusca*	l f	05 May	5.1	58	−0.104	$P = 0.008$
Palm Warbler *Dendroica palmarum*	s f	20 Apr.	8.6	57	0.315	$P < 0.001$
Bay-breasted Warbler *Dendroica castanea*	l f	12 May	5.2	48	−0.168	$P < 0.001$
Northern Waterthrush *Seiurus noveboracensis*	l f	01 May	7.1	58	−0.161	$P = 0.001$
Louisiana Waterthrush *Seiurus motacilla*	l f	03 May	13.2	46	−0.351	$P = 0.002$
Mourning Warbler *Oporornis philadelphia*	l f	15 May	7.3	28	−0.295	$P = 0.002$
Scarlet Tanager *Piranga olivacea*	l f	06 May	4	58	−0.066	$P = 0.023$
Field Sparrow *Spizella pusilla*	s g	18 Feb.	43.2	57	−1.710	$P < 0.001$
Savannah Sparrow *Passerculus sandwichensis*	s g	07 Apr.	12.2	57	−0.403	$P < 0.001$
Grasshopper Sparrow *Ammodramus savannarum*	s g	12 May	15.1	50	−0.383	$P = 0.001$
Henslow's Sparrow *Ammodramus henslowii*	s g	12 May	16.2	43	−0.387	$P = 0.008$
Fox Sparrow *Passerella iliaca*	s f	16 Feb.	31.3	56	−0.555	$P = 0.015$
Lincoln's Sparrow *Melospiza lincolnii*	s s	10 May	9.6	39	−0.223	$P = 0.014$
White-crowned Sparrow *Zonotrichia leucophrys*	s s	13 Apr.	45.6	56	−1.160	$P < 0.001$
Indigo Bunting *Passerina cyanea*	l g	10 May	5.2	57	−0.084	$P = 0.026$
Bobolink *Dolichonyx oryzivorus*	l g	03 May	3.8	58	−0.135	$P < 0.001$
Brown-headed Cowbird *Molothrus ater*	s g	18 Jan.	27.6	57	−0.962	$P < 0.001$

Table 2. Species that exhibit a significant ($P < 0.05$) difference in their first arrival date (FAD) during the periods 1903–1950 and 1951–1993 in the Cayuga Lake Basin, New York, USA. Of the 47 species in this table, 45 arrived significantly earlier during the second half of the twentieth century (Louisiana Waterthrush and Mourning Warbler were the two exceptions). Type indicates the migration strategy employed by each species: s = short-distance migrants (those that winter in the US) and l = long-distance migrants (those that winter south of the US). Niche indicates primary feeding habitat: a = aerial, g = grassland, s = scrub, f = forest and w = wetlands. Species are arranged in taxonomic order.

Species	Type & niche	Mean FAD	sd (days)	*n*	Mean FAD 1903–195	Mean FAD 1951–1993	Significance
Turkey Vulture *Cathartes aura*	s g	03 Apr.	27.2	63	20 Apr.	22 Mar.	$P < 0.001$
Blue-winged Teal *Anas discors*	s w	01 Apr.	20.1	60	10 Apr.	25 Mar.	$P < 0.001$
Northern Shoveler *Anas clypeata*	s w	31 Mar.	21.5	49	14 Apr.	23 Mar.	$P < 0.001$
Osprey *Pandion haliaetus*	s w	05 Apr.	27.1	78	13 Apr.	26 Mar.	$P < 0.001$
Virginia Rail *Rallus limicola*	s w	24 Apr.	22.6	75	30 Apr.	17 Apr.	$P = 0.038$
Sora *Porzana carolina*	s w	02 May	13	72	04 May	29 Apr.	$P = 0.046$
Killdeer *Charadrius vociferus*	s g	23 Feb.	28.8	83	13 Mar.	01 Feb.	$P < 0.001$
Semipalmated Sandpiper *Calidris pusilla*	l w	15 May	9.1	51	20 May	12 May	$P < 0.001$
Least Sandpiper *Calidris minutilla*	s w	13 May	8.4	63	16 May	10 May	$P = 0.005$
Common Snipe *Gallinago gallinago*	s w	29 Mar.	24.3	74	08 Apr.	17 Mar.	$P < 0.001$
American Woodcock *Scolopax minor*	s f	23 Mar.	22	67	05 Apr.	11 Mar.	$P < 0.001$
Common Tern *Sterna hirundo*	l w	04 May	12.5	64	11 May	27 Apr.	$P < 0.001$
Yellow-billed Cuckoo *Coccyzus americanus*	l f	14 May	17.6	76	19 May	09 May	$P = 0.004$
Chimney Swift *Chaetura pelagica*	l a	24 Apr.	5.7	84	26 Apr.	22 Apr.	$P < 0.001$
Yellow-bellied Sapsucker *Sphyrapicus varius*	s f	11 Mar.	40.6	81	30 Mar.	15 Feb.	$P = 0.002$
Eastern Wood-Pewee *Contopus virens*	l f	10 May	8.9	77	13 May	07 May	$P = 0.030$
Eastern Phoebe *Sayornis phoebe*	s s	21 Mar.	19.6	79	26 Mar.	15 Mar.	$P = 0.032$
Red-eyed Vireo *Vireo olivaceus*	l f	06 May	6	81	07 May	04 May	$P = 0.016$
Purple Martin *Progne subis*	l a	23 Apr.	16	74	02 May	14 Apr.	$P < 0.001$
Tree Swallow *Tachycineta bicolor*	s a	29 Mar.	19.6	82	05 Apr.	19 Mar.	$P < 0.001$
Northern Rough-winged Swallow *Stelgidopteryx serripennis*	s a	20 Apr.	6.9	82	22 Apr.	16 Apr.	$P < 0.001$
Bank Swallow *Riparia riparia*	l a	26 Apr.	8.2	82	28 Apr.	23 Apr.	$P = 0.006$
Barn Swallow *Hirundo rustica*	l a	14 Apr.	10.2	85	16 Apr.	10 Apr.	$P = 0.006$
House Wren *Troglodytes aedon*	s s	23 Apr.	10.3	82	25 Apr.	19 Apr.	$P = 0.008$
Ruby-crowned Kinglet *Regulus calendula*	s f	27 Mar.	36.8	80	10 Apr.	07 Mar.	$P = 0.001$
Eastern Bluebird *Sialia sialis*	s g	19 Feb.	31.2	82	10 Mar.	26 Jan.	$P < 0.001$
Gray-cheeked Thrush *Catharus minimus*	l f	16 May	8.9	54	19 May	13 May	$P = 0.016$
Hermit Thrush *Catharus guttatus*	s f	26 Mar.	34.1	80	08 Apr.	09 Mar.	$P = 0.045$
Wood Thrush *Hylocichla mustelina*	l f	30 Apr.	8.5	83	02 May	27 Apr.	$P = 0.006$
Gray Catbird *Dumetella carolinensis*	s s	09 Apr.	44	81	01 May	12 Mar.	$P < 0.001$
Brown Thrasher *Toxostoma rufum*	s s	12 Apr.	35.6	77	26 Apr.	24 Mar.	$P < 0.001$
Blue-winged Warbler *Vermivora pinus*	l s	06 May	6.9	39	16 May	05 May	$P = 0.010$
Golden-winged Warbler *Vermivora chrysoptera*	l s	13 May	8.7	60	17 May	10 May	$P = 0.001$
Tennessee Warbler *Vermivora peregrina*	l f	09 May	5.3	79	11 May	08 May	$P = 0.022$
Nashville Warbler *Vermivora ruficapilla*	l f	01 May	4.2	84	02 May	30 Apr.	$P = 0.037$
Yellow-rumped Warbler *Dendroica coronata*	s f	13 Mar.	47.9	77	17 Apr.	30 Jan.	$P < 0.001$
Northern Waterthrush *Seiurus noveboracensis*	l f	27 Apr.	6.9	83	28 Apr.	25 Apr.	$P = 0.023$
Louisiana Waterthrush *Seiurus motacilla*	l f	15 Apr.	6.4	82	13 Apr.	18 Apr.	$P < 0.001$
Mourning Warbler *Oporornis philadelphia*	l f	15 May	6.6	76	13 May	18 May	$P = 0.009$
Wilson's Warbler *Wilsonia pusilla*	l f	12 May	5.1	78	13 May	10 May	$P = 0.002$
Field Sparrow *Spizella pusilla*	s g	10 Mar.	39.9	80	30 Mar.	11 Feb.	$P < 0.001$
Fox Sparrow *Passerella iliaca*	s f	18 Mar.	21.4	80	25 Mar.	09 Mar.	$P = 0.002$
Lincoln's Sparrow *Melospiza lincolnii*	s s	08 May	11.2	57	11 May	04 May	$P = 0.024$
White-crowned Sparrow *Zonotrichia leucophrys*	s s	08 Apr.	49.2	79	02 May	08 Mar.	$P < 0.001$
Rose-breasted Grosbeak *Pheucticus ludovicianus*	l f	02 May	14.6	81	06 May	28 Apr.	$P < 0.001$
Indigo Bunting *Passerina cyanea*	l g	09 May	5.5	82	11 May	06 May	$P < 0.001$
Bobolink *Dolichonyx oryzivorus*	l g	03 May	5.3	84	04 May	01 May	$P = 0.012$
Brown-headed Cowbird *Molothrus ater*	s g	18 Feb.	38.4	83	17 Mar.	14 Jan.	$P < 0.001$

Table 3. Species that exhibit a significant ($P < 0.05$) change in their first arrival date (FAD) during the twentieth century. Type indicates the migration strategy employed by each species: s = short-distance migrants (those that winter in the US) and l = long-distance migrants (those that winter south of the US). Niche indicates primary feeding habitat: a = aerial, g = grassland, s = scrub, f = forest and w = wetlands. Species are arranged in taxonomic order.

		Cayuga Lake Basin, NY						Worcester County, MA				
Species	Type & niche	Mean FAD	sd	*n*	Mean FAD 1903–50	Mean FAD 1951–93	Significance	Mean FAD	sd	*n*	Regression (1932–93)	Significance
Turkey Vulture *Cathartes aura*	s g	03 Apr.	27.2	63	20 Apr.	22 Mar.	$P < 0.001$	25 Mar.	26.4	46	−1.2099	$P < 0.001$
Blue-winged Teal *Anas discors*	s w	01 Apr.	20.1	60	10 Apr.	25 Mar.	$P < 0.001$	29 Mar.	17.1	45	−0.7509	$P < 0.001$
Virginia Rail *Rallus limicola*	s w	24 Apr.	22.6	75	30 Apr.	17 Apr.	$P = 0.038$	27 Apr.	25.3	38	−0.6075	$P = 0.004$
Killdeer *Charadrius vociferus*	s g	23 Feb.	28.8	83	13 Mar.	01 Feb.	$P < 0.001$	06 Mar.	13.4	55	−0.3924	$P < 0.001$
Common Snipe *Gallinago gallinago*	s w	29 Mar.	24.3	74	08 Apr.	17 Mar.	$P < 0.001$	24 Mar.	20.8	39	−0.6042	$P = 0.001$
American Woodcock *Scolopax minor*	s f	23 Mar.	22	67	05 Apr.	11 Mar.	$P < 0.001$	17 Mar.	8	59	−0.2029	$P < 0.001$
Chimney Swift *Chaetura pelagica*	l a	24 Apr.	5.7	84	26 Apr.	22 Apr.	$P < 0.001$	25 Apr.	5.1	56	−0.1016	$P = 0.004$
Yellow-bellied Sapsucker *Sphyrapicus varius*	s f	11 Mar.	40.6	81	30 Mar.	15 Feb.	$P = 0.002$	07 Apr.	19.9	54	−0.4089	$P = 0.004$
Eastern Wood-Pewee *Contopus virens*	l f	10 May	8.9	77	13 May	07 May	$P = 0.030$	13 May	5.9	58	−0.137	$P = 0.001$
Purple Martin *Progne subis*	l a	23 Apr.	16	74	02 May	14 Apr.	$P < 0.001$	24 Apr.	24.1	45	−0.8477	$P < 0.001$
Tree Swallow *Tachycineta bicolor*	s a	29 Mar.	19.6	82	05 Apr.	19 Mar.	$P < 0.001$	21 Mar.	7.6	56	−0.1835	$P = 0.001$
Northern Rough-winged Swallow *Stelgidopteryx serripennis*	s a	20 Apr.	6.9	82	22 Apr.	16 Apr.	$P < 0.001$	22 Apr.	13.1	43	−0.4896	$P < 0.001$
Bank Swallow *Riparia riparia*	l a	26 Apr.	8.2	82	28 Apr.	23 Apr.	$P = 0.006$	27 Apr.	10.5	50	−0.2539	$P < 0.001$
Barn Swallow *Hirundo rustica*	l a	14 Apr.	10.2	85	16 Apr.	10 Apr.	$P = 0.006$	14 Apr.	7.2	47	−0.2363	$P < 0.001$
Wood Thrush *Hylocichla mustelina*	l f	30 Apr.	8.5	83	02 May	27 Apr.	$P = 0.006$	29 Apr.	6.1	59	−0.0987	$P = 0.020$
Brown Thrasher *Toxostoma rufum*	s s	12 Apr.	35.6	77	26 Apr.	24 Mar.	$P < 0.001$	23 Mar.	45.1	57	−1.26	$P < 0.001$
Blue-winged Warbler *Vermivora pinus*	l s	06 May	6.9	39	16 May	05 May	$P = 0.010$	06 May	6.6	41	−0.2887	$P < 0.001$
Tennessee Warbler *Vermivora peregrina*	l f	09 May	5.3	79	11 May	08 May	$P = 0.022$	11 May	6.5	46	−0.2543	$P < 0.001$
Nashville Warbler *Vermivora ruficapilla*	l f	01 May	4.2	84	02 May	30 Apr.	$P = 0.037$	30 Apr.	5.1	58	−0.112	$P = 0.001$
Yellow-rumped Warbler *Dendroica coronata*	s f	13 Mar.	47.9	77	17 Apr.	30 Jan.	$P < 0.001$	05 Mar.	45.6	57	−0.877	$P = 0.004$
Northern Waterthrush *Seiurus noveboracensis*	l f	27 Apr.	6.9	83	28 Apr.	25 Apr.	$P = 0.023$	01 May	7.1	58	−0.161	$P = 0.001$
Field Sparrow *Spizella pusilla*	s g	10 Mar.	39.9	80	30 Mar.	11 Feb.	$P < 0.001$	18 Feb.	43.2	57	−1.71	$P < 0.001$
Fox Sparrow *Passerella iliaca*	s f	18 Mar.	21.4	80	25 Mar.	09 Mar.	$P = 0.002$	16 Feb.	31.3	56	−0.555	$P = 0.015$
Lincoln's Sparrow *Melospiza lincolnii*	s s	08 May	11.2	57	11 May	04 May	$P = 0.024$	10 May	9.6	39	−0.2233	$P = 0.014$
White-crowned Sparrow *Zonotrichia leucophrys*	s s	08 Apr.	49.2	79	02 May	08 Mar.	$P < 0.001$	13 Apr.	45.6	56	−1.16	$P < 0.001$
Indigo Bunting *Passerina cyanea*	l g	09 May	5.5	82	11 May	06 May	$P < 0.001$	10 May	5.2	57	−0.0838	$P = 0.026$
Bobolink *Dolichonyx oryzivorus*	l g	03 May	5.3	84	04 May	01 May	$P = 0.012$	03 May	3.8	58	−0.1349	$P < 0.001$
Brown-headed Cowbird *Molothrus ater*	s g	18 Feb.	38.4	83	17 Mar.	14 Jan.	$P < 0.001$	18 Jan.	27.6	57	−0.962	$P < 0.001$

Table 4. A breakdown of the breeding habitats for the 103 species considered in this paper. Mean change in first arrival date (FAD) and standard error are given.

	n	Mean ± se
Aquatic	16	−11.84 ± 2.77
Grassland	13	−18.32 ± 5.10
Scrub	14	−11.92 ± 3.56
Forest	52	−4.62 ± 1.04
Aerial	8	−7.99 ± 2.37

A few long-distance migrants employ a similar strategy to that of short-distance migrants, and are able to respond more rapidly to changes in climate. Purple Martins *Progne subis*, for example, arrive on the coast of Florida during late January and early February and gradually work their way north as conditions improve (Brown 1997). During the second half of the twentieth century, their FAD had advanced by nearly 18 days. This is a much greater change than most of the rest of the long-distance migrants, whose average FAD advanced by only 4 days during this period.

Taken to its extreme, the disproportionate effect of global warming on short-distance migrants may eventually lead to some species spending the winter on their breeding grounds, rather than migrating south for the winter. This has apparently happened in the UK, with Blackcaps *Sylvia atricapilla* and Chiffchaffs *Phylloscopus collybita* now regularly overwintering (Lack 1986). The FADs recorded for the Cayuga Lake Basin indicate that five species included in the analysis (Eastern Bluebird *Sialia sialis*, Yellow-rumped Warbler *Dendroica coronata*, White-throated Sparrow *Zonotrichia albicollis*, Field Sparrow *Spizella pusilla* and Brown-headed Cowbird *Molothrus ater*) have now begun to overwinter there regularly. A century ago, these species were unknown during winter in the Cayuga Lake Basin (Reed & Wright 1909).

The significant difference in the arrival times of birds in different habitats was unexpected. The much earlier arrival of grassland birds in New York and Massachusetts may be due to the fact that they feed predominantly on seeds (Ehrlich 1988). The earlier arrival of spring implies that snow cover might melt sooner, allowing these birds to arrive much earlier. In contrast, many forest species feed predominantly on insects and the slight increase in temperature might not advance insect phenology at the same rate.

Finally, it is worth noting that first arrival dates may be subject to some observer bias. An increase in observer effort may result in birds being detected increasingly early. Although the numbers of observers in the Cayuga Lake Basin did not differ significantly between the 1930s and the 1980s, it is impossible to determine whether observer effort remained unchanged during this same period. Nonetheless, the observed difference in FAD of short- and long-distance migrants cannot be due to this potential bias as changes in observer skill and effort should not preferentially affect the detection rates of short-distance migrants over long-distance migrants (or vice versa).

Nevertheless, it appears that migrant birds in the north-east are arriving an average of 8 days earlier, which is consistent with a global warming scenario. Short-distance migrants are affected disproportionately by global warming because they are subjected to the same weather systems that affect the north-east United States and so are able to respond more quickly to slightly more favourable conditions than long-distance migrants. Indeed, a 0.5 °C increase in temperatures during the twentieth century was sufficient for a few short-distance migrants to begin wintering in the north-east.

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Appendix 1. Species analysed in this paper. Type indicates the migration strategy employed by each species: s = short-distance migrants (those that winter in the US) and l = long-distance migrants (those that winter south of the US). Niche indicates primary feeding habitat: a = aerial, g = grassland, s = scrub, f = forest, and w = wetlands. Species are arranged in taxonomic order.

		Cayuga Lake Basin, NY						Worcester County, MA				
Species	Type & niche	Mean FAD	sd	*n*	Mean FAD 1903−50	Mean FAD 1951−93	Significance	Mean FAD	sd	*n*	Regression (1932–93)	Significance
Green Heron *Butorides virescens*	s w	21 Apr.	13.7	79	23 Apr.	18 Apr.	$P = 0.111$	26 Apr.	11.8	54	−0.3178	$P < 0.001$
Turkey Vulture *Cathartes aura*	s g	03 Apr.	27.2	63	20 Apr.	22 Mar.	$P < 0.001$	25 Mar.	26.4	46	−1.2099	$P < 0.001$
Blue-winged Teal *Anas discors*	s w	01 Apr.	20.1	60	10 Apr.	25 Mar.	$P < 0.001$	29 Mar.	17.1	45	−0.7509	$P < 0.001$
Northern Shoveler *Anas clypeata*	s w	31 Mar.	21.5	49	14 Apr.	23 Mar.	$P < 0.001$	15 Mar.	19.1	31	0.1311	$P = 0.637$
Osprey *Pandion haliaetus*	s w	05 Apr.	27.1	78	13 Apr.	26 Mar.	$P < 0.001$	02 Apr.	15.5	54	0.1523	$P = 0.185$
Broad-winged Hawk *Buteo platypterus*	l f	18 Apr.	14.8	72	21 Apr.	15 Apr.	$P = 0.082$	16 Apr.	12.2	52	−0.0552	$P = 0.571$
Virginia Rail *Rallus limicola*	s w	24 Apr.	22.6	75	30 Apr.	17 Apr.	$P = 0.038$	27 Apr.	25.3	38	−0.6075	$P = 0.004$
Sora *Porzana carolina*	s w	02 May	13	72	04 May	29 Apr.	$P = 0.046$	30 Apr.	16.6	25	−0.5467	$P = 0.068$
Killdeer *Charadrius vociferus*	s g	23 Feb.	28.8	83	13 Mar.	01 Feb.	$P < 0.001$	06 Mar.	13.4	55	−0.3924	$P < 0.001$
Solitary Sandpiper *Tringa solitaria*	l w	29 Apr.	12.3	80	30 Apr.	28 Apr.	$P = 0.204$	03 May	10.2	57	−0.3109	$P < 0.001$
Spotted Sandpiper *Actitis macularia*	s w	19 Apr.	9.6	81	21 Apr.	17 Apr.	$P = 0.299$	27 Apr.	7.9	53	−0.2678	$P < 0.001$
Upland Sandpiper *Bartramia longicauda*	l g	27 Apr.	10.9	32	04 May	27 Apr.	$P = 0.186$	01 May	18.7	30	−0.2963	$P = 0.181$
Semipalmated Sandpiper *Calidris pusilla*	l w	15 May	9.1	51	20 May	12 May	$P < 0.001$	16 May	12.9	35	0.0778	$P = 0.584$
Least Sandpiper *Calidris minutilla*	s w	13 May	8.4	63	16 May	10 May	$P = 0.005$	07 May	16.7	50	−0.0913	$P = 0.519$
Pectoral Sandpiper *Calidris melanotos*	l w	23 Apr.	18.8	37	28 Apr.	21 Apr.	$P = 0.229$	11 Apr.	20	31	−0.6474	$P = 0.020$
Common Snipe *Gallinago gallinago*	s w	29 Mar.	24.3	74	08 Apr.	17 Mar.	$P < 0.001$	24 Mar.	20.8	39	−0.6042	$P = 0.001$
American Woodcock *Scolopax minor*	s f	23 Mar.	22	67	05 Apr.	11 Mar.	$P < 0.001$	17 Mar.	8	59	−0.2029	$P < 0.001$
Common Tern *Sterna hirundo*	l w	04 May	12.5	64	11 May	27 Apr.	$P < 0.001$	10 Apr.	24.3	20	0.0718	$P = 0.886$
Black-billed Cuckoo *Coccyzus erythropthalmus*	l f	14 May	10.4	78	14 May	14 May	$P = 0.280$	12 May	4.9	55	−0.06	$P = 0.099$
Yellow-billed Cuckoo *Coccyzus americanus*	l f	14 May	17.6	76	19 May	09 May	$P = 0.004$	18 May	10.2	37	−0.0902	$P = 0.341$
Common Nighthawk *Chordeiles minor*	l a	15 May	9.9	81	16 May	15 May	$P = 0.397$	11 May	6.5	48	0.0261	$P = 0.631$
Whip-poor-will *Caprimulgus vociferus*	l f	10 May	16.8	66	09 May	10 May	$P = 0.259$	03 May	8.7	54	0.1206	$P = 0.068$
Chimney Swift *Chaetura pelagica*	l a	24 Apr.	5.7	84	26 Apr.	22 Apr.	$P < 0.001$	25 Apr.	5.1	56	−0.1016	$P = 0.004$
Ruby-throated Hummingbird *Archilochus colubris*	l f	10 May	4.6	81	11 May	09 May	$P = 0.051$	09 May	5.4	57	−0.104	$P = 0.008$
Yellow-bellied Sapsucker *Sphyrapicus varius*	s f	11 Mar.	40.6	81	30 Mar.	15 Feb.	$P = 0.002$	07 Apr.	19.9	54	−0.4089	$P = 0.004$
Olive-sided Flycatcher *Contopus cooperi*	l f	21 May	7.8	46	22 May	20 May	$P = 0.078$	23 May	9.3	42	−0.1317	$P = 0.129$
Eastern Wood-Pewee *Contopus virens*	l f	10 May	8.9	77	13 May	07 May	$P = 0.030$	13 May	5.9	58	−0.137	$P = 0.001$
Yellow-bellied Flycatcher *Empidonax flaviventris*	l f	20 May	7.7	54	20 May	21 May	$P = 0.993$	22 May	8.6	29	−0.0015	$P = 0.988$
Alder Flycatcher *Empidonax alnorum*	l s	17 May	6.8	71	19 May	16 May	$P = 0.062$	21 May	7.4	36	−0.1351	$P = 0.042$
Least Flycatcher *Empidonax minimus*	l f	02 May	7.3	84	02 May	02 May	$P = 0.302$	01 May	3.1	59	0.0044	$P = 0.841$
Eastern Phoebe *Sayornis phoebe*	s s	21 Mar.	19.6	79	26 Mar.	15 Mar.	$P = 0.032$	19 Mar.	12.7	57	0.0272	$P = 0.772$
Great Crested Flycatcher *Myiarchus crinitus*	s f	04 May	8.8	80	04 May	04 May	$P = 0.526$	05 May	6.7	58	−0.1968	$P < 0.001$
Eastern Kingbird *Tyrannus tyrannus*	l f	02 May	6.7	81	03 May	02 May	$P = 0.465$	30 Apr.	6.4	57	−0.0291	$P = 0.532$
Yellow-throated Vireo *Vireo flavifrons*	s f	04 May	6.8	81	04 May	05 May	$P = 0.099$	10 May	10.3	50	−0.2089	$P = 0.010$
Blue-headed Vireo *Vireo solitarius*	s f	25 Apr.	6.1	81	26 Apr.	24 Apr.	$P = 0.143$	24 Apr.	6.9	55	−0.0593	$P = 0.227$
Warbling Vireo *Vireo gilvus*	l f	30 Apr.	6.5	84	30 Apr.	02 May	$P = 0.882$	05 May	5.6	58	−0.1564	$P < 0.001$

continued

Appendix 1. continued.

Species	Type & niche	Cayuga Lake Basin, NY: Mean FAD	sd	*n*	Mean FAD 1903–50	Mean FAD 1951–93	Significance	Worcester County, MA: Mean FAD	sd	*n*	Regression (1932–93)	Significance
Philadelphia Vireo *Vireo philadelphicus*	l f	14 May	7.2	58	16 May	12 May	*P* = 0.137	14 May	6.9	30	−0.1119	*P* = 0.177
Red-eyed Vireo *Vireo olivaceus*	l f	06 May	6	81	07 May	04 May	*P* = 0.016	08 May	4.7	58	0.07	*P* = 0.035
Purple Martin *Progne subis*	l a	23 Apr.	16	74	02 May	14 Apr.	*P* < 0.001	24 Apr.	24.1	45	−0.8477	*P* < 0.001
Tree Swallow *Tachycineta bicolor*	s a	29 Mar.	19.6	82	05 Apr.	19 Mar.	*P* < 0.001	21 Mar.	7.6	56	−0.1835	*P* = 0.001
Northern Rough-winged Swallow *Stelgidopteryx serripennis*	s a	20 Apr.	6.9	82	22 Apr.	16 Apr.	*P* < 0.001	22 Apr.	13.1	43	−0.4896	*P* < 0.001
Bank Swallow *Riparia riparia*	l a	26 Apr.	8.2	82	28 Apr.	23 Apr.	*P* = 0.006	27 Apr.	10.5	50	−0.2539	*P* < 0.001
Cliff Swallow *Petrochelidon pyrrhonota*	l a	01 May	10.8	77	01 May	30 Apr.	*P* = 0.368	27 Apr.	8.7	54	0.0186	*P* = 0.779
Barn Swallow *Hirundo rustica*	l a	14 Apr.	10.2	85	16 Apr.	10 Apr.	*P* = 0.006	14 Apr.	7.2	47	−0.2363	*P* < 0.001
House Wren *Troglodytes aedon*	s s	23 Apr.	10.3	82	25 Apr.	19 Apr.	*P* = 0.008	24 Apr.	5.5	56	−0.0487	*P* = 0.224
Sedge Wren *Cistothorus platensis*	s w	14 May	14.6	33	11 May	18 May	*P* = 0.548	26 May	15.6	30	0.213	*P* = 0.183
Marsh Wren *Cistothorus palustris*	s w	04 May	21	70	04 May	03 May	*P* = 0.760	15 May	13.51	43	−0.6128	*P* < 0.001
Ruby-crowned Kinglet *Regulus calendula*	s f	27 Mar.	36.8	80	10 Apr.	07 Mar.	*P* = 0.001	18 Mar.	39.1	56	0.058	*P* = 0.844
Blue-gray Gnatcatcher *Polioptilla caerulea*	s f	22 Apr.	7.4	42	25 Apr.	22 Apr.	*P* = 0.294	24 Apr.	9.6	30	−0.1644	*P* = 0.243
Eastern Bluebird *Sialia sialis*	s g	19 Feb.	31.2	82	10 Mar.	26 Jan.	*P* < 0.001	24 Feb.	29.6	56	−0.399	*P* = 0.067
Veery *Catharus fuscescens*	l f	30 Apr.	13.4	79	28 Apr.	03 May	*P* = 0.054	04 May	4	58	−0.0476	*P* = 0.093
Gray-cheeked Thrush *Catharus minimus*	l f	16 May	8.9	54	19 May	13 May	*P* = 0.016	14 May	5.9	37	−0.0428	*P* = 0.473
Swainson's Thrush *Catharus ustulatus*	l f	08 May	7.5	80	10 May	06 May	*P* = 0.063	09 May	9	56	−0.0931	*P* = 0.156
Hermit Thrush *Catharus guttatus*	s f	26 Mar.	34.1	80	08 Apr.	09 Mar.	*P* = 0.045	24 Mar.	35.3	56	0.015	*P* = 0.954
Wood Thrush *Hylocichla mustelina*	l f	30 Apr.	8.5	83	02 May	27 Apr.	*P* = 0.006	29 Apr.	6.1	59	−0.0987	*P* = 0.020
Gray Catbird *Dumetella carolinensis*	s s	09 Apr.	44	81	01 May	12 Mar.	*P* < 0.001	04 Apr.	44.8	57	−0.064	*P* = 0.847
Brown Thrasher *Toxostoma rufum*	s s	12 Apr.	35.6	77	26 Apr.	24 Mar.	*P* < 0.001	23 Mar.	45.1	57	−1.26	*P* < 0.001
Blue-winged Warbler *Vermivora pinus*	l s	06 May	6.9	39	16 May	05 May	*P* = 0.010	06 May	6.6	41	−0.2887	*P* < 0.001
Golden-winged Warbler *Vermivora chrysoptera*	l s	13 May	8.7	60	17 May	10 May	*P* = 0.001	09 May	5.2	57	−0.0677	*P* = 0.077
Tennessee Warbler *Vermivora peregrina*	l f	09 May	5.3	79	11 May	08 May	*P* = 0.022	11 May	6.5	46	−0.2543	*P* < 0.001
Orange-crowned Warbler *Vermivora celata*	s f	13 May	6.9	35	14 May	11 May	*P* = 0.245	12 May	5.7	22	−0.037	*P* = 0.726
Nashville Warbler *Vermivora ruficapilla*	l f	01 May	4.2	84	02 May	30 Apr.	*P* = 0.037	30 Apr.	5.1	58	−0.112	*P* = 0.001
Northern Parula *Parula americana*	l f	06 May	6	80	06 May	05 May	*P* = 0.434	08 May	5.4	55	0.0883	*P* = 0.025
Yellow Warbler *Dendroica petechia*	l w	27 Apr.	6.5	84	28 Apr.	26 Apr.	*P* = 0.294	30 Apr.	4.8	57	−0.1492	*P* < 0.001
Chestnut-sided Warbler *Dendroica pensylvanica*	l s	05 May	4.5	63	06 May	04 May	*P* = 0.2744	05 May	4.1	59	0.0057	*P* = 0.847
Magnolia Warbler *Dendroica magnolia*	l f	06 May	5	83	06 May	06 May	*P* = 0.869	07 May	3.9	58	−0.09	*P* = 0.001
Cape May Warbler *Dendroica tigrina*	l f	06 May	5.2	77	07 May	06 May	*P* = 0.265	08 May	5.4	45	−0.1923	*P* < 0.001
Black-throated Blue Warbler *Dendroica caerulescens*	l f	04 May	4.2	83	05 May	04 May	*P* = 0.194	05 May	4.7	58	−0.0447	*P* = 0.188
Yellow-rumped Warbler *Dendroica coronata*	s f	13 Mar.	47.9	77	17 Apr.	30 Jan.	*P* < 0.001	05 Mar.	45.6	57	−0.877	*P* = 0.004
Blackburnian Warbler *Dendroica fusca*	l f	04 May	3.9	81	04 May	04 May	*P* = 0.553	05 May	5.1	58	−0.1035	*P* = 0.008
Pine Warbler *Dendroica pinus*	s f	23 Apr.	9.3	70	21 Apr.	26 Apr.	*P* = 0.069	16 Apr.	19	54	−0.0026	*P* = 0.985
Prairie Warbler *Dendroica discolor*	s s	11 May	10.3	37	09 May	12 May	*P* = 0.883	07 May	6.2	56	0.0573	*P* = 0.365
Palm Warbler *Dendroica palmarum*	s f	28 Apr.	8.7	78	28 Apr.	29 Apr.	*P* = 0.713	20 Apr.	8.6	57	0.3152	*P* < 0.001
Bay-breasted Warbler *Dendroica castanea*	l f	12 May	4.3	79	13 May	12 May	*P* = 0.420	12 May	5.2	48	−0.1675	*P* < 0.001

continued

Appendix 1. continued.

Species	Type & niche	Cayuga Lake Basin, NY Mean FAD	sd	*n*	Mean FAD 1903–50	Mean FAD 1951–93	Significance	Worcester County, MA Mean FAD	sd	*n*	Regression (1932–93)	Significance
Blackpoll Warbler *Dendroica striata*	l f	15 May	4.1	83	15 May	15 May	*P* = 0.765	16 May	6.4	56	0.0195	*P* = 0.681
Black-and-white Warbler *Mniotilta varia*	s f	27 Apr.	5.1	84	28 Apr.	26 Apr.	*P* = 0.474	26 Apr.	5.5	58	0.0579	*P* = 0.142
American Redstart *Setophaga ruticilla*	l f	02 May	5.2	83	02 May	02 May	*P* = 0.894	05 May	3.9	51	−0.0235	*P* = 0.406
Prothonotary Warbler *Protonotaria citrea*	l f	15 May	13.6	30	17 May	14 May	*P* = 0.656	15 May	9.6	24	0.0903	*P* = 0.473
Worm-eating Warbler *Helmitheros vermivorus*	l f	12 May	6.2	13	10 May	13 May	*P* = 0.391	08 May	8.4	12	−0.126	*P* = 0.407
Ovenbird *Seiurus aurocapillus*	s f	03 May	4.2	84	04 May	03 May	*P* = 0.258	03 May	3.3	59	−0.037	*P* = 0.115
Northern Waterthrush *Seiurus noveboracensis*	l f	27 Apr.	6.9	83	28 Apr.	25 Apr.	*P* = 0.023	01 May	7.1	58	−0.161	*P* = 0.001
Louisiana Waterthrush *Seiurus motacilla*	l f	15 Apr.	6.4	82	13 Apr.	18 Apr.	*P* < 0.001	03 May	13.2	46	−0.3509	*P* = 0.002
Mourning Warbler *Oporornis philadelphia*	l f	15 May	6.6	76	13 May	18 May	*P* = 0.009	15 May	7.3	28	−0.2949	*P* = 0.002
Common Yellowthroat *Geothlypis trichas*	s s	23 Apr.	32.2	79	01 May	13 Apr.	*P* = 0.143	04 May	3.9	57	−0.0517	*P* = 0.067
Hooded Warbler *Wilsonia citrina*	l f	15 May	8.4	42	16 May	15 May	*P* = 0.930	10 May	6.2	28	−0.1028	*P* = 0.329
Wilson's Warbler *Wilsonia pusilla*	l f	12 May	5.1	78	13 May	10 May	*P* = 0.002	13 May	5.5	51	−0.0412	*P* = 0.348
Canada Warbler *Wilsonia canadensis*	l f	11 May	4.1	81	11 May	10 May	*P* = 0.257	10 May	4.5	57	−0.012	*P* = 0.714
Yellow-breasted Chat *Icteria virens*	l s	14 May	5.6	74	13 May	14 May	*P* = 0.956	10 May	30.6	36	0.1257	*P* = 0.676
Scarlet Tanager *Piranga olivacea*	l f	07 May	4.4	80	08 May	06 May	*P* = 0.130	06 May	4	58	−0.0663	*P* = 0.023
Chipping Sparrow *Spizella passerina*	s s	24 Mar.	32.9	83	03 Apr.	12 Mar.	*P* = 0.064	29 Mar.	32.7	57	−0.009	*P* = 0.969
Field Sparrow *Spizella pusilla*	s g	10 Mar.	39.9	80	30 Mar.	11 Feb.	*P* < 0.001	18 Feb.	43.2	57	−1.71	*P* < 0.001
Vesper Sparrow *Pooecetes gramineus*	s g	28 Mar.	22.5	82	01 Apr.	23 Mar.	*P* = 0.245	05 Apr.	13.5	52	−0.0926	*P* = 0.381
Savannah Sparrow *Passerculus sandwichensis*	s g	22 Mar.	29.3	83	31 Mar.	11 Mar.	*P* = 0.717	07 Apr.	12.2	57	−0.4033	*P* < 0.001
Grasshopper Sparrow *Ammodramus savannarum*	s g	27 Apr.	21.9	79	25 Apr.	29 Apr.	*P* = 0.197	12 May	15.1	50	−0.3834	*P* = 0.001
Henslow's Sparrow *Ammodramus henslowii*	s g	04 May	16	57	01 May	07 May	*P* = 0.234	12 May	16.2	43	−0.3871	*P* = 0.008
Fox Sparrow *Passerella iliaca*	s f	18 Mar.	21.4	80	25 Mar.	09 Mar.	*P* = 0.002	16 Feb.	31.3	56	−0.555	*P* = 0.015
Lincoln's Sparrow *Melospiza lincolnii*	s s	08 May	11.2	57	11 May	04 May	*P* = 0.024	10 May	9.6	39	−0.2233	*P* = 0.014
White-crowned Sparrow *Zonotrichia leucophrys*	s s	08 Apr.	49.2	79	02 May	08 Mar.	*P* < 0.001	13 Apr.	45.6	56	−1.16	*P* < 0.001
Rose-breasted Grosbeak *Pheucticus ludovicianus*	l f	02 May	14.6	81	06 May	28 Apr.	*P* < 0.001	03 May	6.3	58	−0.0551	*P* = 0.226
Indigo Bunting *Passerina cyanea*	l g	09 May	5.5	82	11 May	06 May	*P* < 0.001	10 May	5.2	57	−0.0838	*P* = 0.026
Bobolink *Dolichonyx oryzivorus*	l g	03 May	5.3	84	04 May	01 May	*P* = 0.012	03 May	3.8	58	−0.1349	*P* < 0.001
Brown-headed Cowbird *Molothrus ater*	s g	18 Feb.	38.4	83	17 Mar.	14 Jan.	*P* < 0.001	18 Jan.	27.6	57	−0.962	*P* < 0.001
Orchard Oriole *Icterus spurius*	l f	15 May	9	46	15 May	15 May	*P* = 0.895	19 May	13.6	29	0.0466	*P* = 0.777