Historical Analysis of the Spring Arrival of Migratory Birds to Dutchess County, New York: A 123-year Record

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Abstract - Through an examination of historical records maintained by a local bird club, consisting of naturalist diaries, daily check-lists, and informal bird surveys, we found that 44 springtime migrant bird species show evidence of an increasingly early first arrival date (FAD) during a 123-year record (1885 to 2008) in Dutchess County, NY. Ninety-one percent of the species showed a significant advance in FAD over this period, with the mean advance being 11.6 days/century. Using truncations of the full data-set corresponding to available data for changes in observer effort and population trends, we found that adding these ancillary independent variables to a multiple linear regression contributed little to explain the change in FAD in recent years. The advance in FAD is potentially an index of global climate change in this region.

Introduction

Numerous recent studies have examined changes in the spring arrival of migrant songbirds in response to ongoing changes in climate. Whereas some studies show little change in springtime arrival in the eastern and midwestern United States (Marra et al. 2005, Strode 2003, Wilson 2007, Wilson et al. 2000), others show significantly earlier arrival in recent years (Butler 2003, Dunn and Winkler 1999, Miller-Rushing et al. 2008a, Van Buskirk et al. 2009). For the initiation of spring migration, most birds respond to changes in day length on the wintering grounds; however, changes in temperature and in the springtime phenology of vegetation are likely to alter the rate of northward movement (Bauer et al. 2008). Changes in the date of spring arrival on traditional breeding grounds, not accompanied by similar changes in the emergence of insects and other food resources, could have significant impacts on breeding success of harbinger individuals (e.g., Møller et al. 2008, Van der Jeugd et al. 2009, Visser et al. 1998), posing a significant challenge to the conservation of threatened species. For *Ficedula hypoleuca* Pallas (Pied Flycatcher) in the Netherlands, mistiming between food and migration times led to a local population decline (Both et al. 2006).

Given year-to-year variations in climate conditions, synoptic changes in the phenology of migration are difficult to ascertain without quantitative long-term field studies. Unfortunately, these are few, so some workers have relied on records of first arrival date (FAD) as reported from volunteer and amateur bird-watchers (e.g., Ledneva et al. 2004). Significant biases may accompany these analyses; nevertheless, the naturalists' data are often useful to test and extend the record of systematic field studies (Miller-Rushing et al. 2008b). Often extending over

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multiple decades, the records of amateur birdwatchers are sometimes the only data available. Increases in birdwatching activity and bird population numbers potentially confound the reported trends in FAD, since both make the detection of early individuals more likely (Miller-Rushing et al. 2008a, van Strien et al. 2008). Conversely, declining population numbers make it more difficult to ascertain the first arrival of a species, potentially masking trends due to climate change (Miller-Rushing et al. 2008a).

In this study, we used data from a variety of sources to compile an exceptionally long record (123 years) for the FAD of 44 spring migrants to Dutchess County, located in the Hudson River valley of eastern New York. The objectives of this work were: 1) to use unique, long-term, multi-source records from a local bird club in Dutchess County to examine and test for changes in the spring arrival of migrants during the past century, and 2) to examine the causes of any changes observed, using rigorous statistical analysis to evaluate the effect of alternative factors and potential biases causing earlier FAD.

Field Site Description

Dutchess County embraces nearly 2100 km^2 of rolling hills, with patchy deciduous forests dominated by maple and oak, interspersed with farmland, exurban development, ponds, and streams on a landscape of glacial till (DeOrsey and Butler 2006). The continental climate consists of short, warm summers and long, cold winters, with average temperatures of +22 °C and -4.2 °C during July and January, respectively. During the 123-year period of our study, the vegetation of much of the eastern United States and Dutchess County has changed from a landscape dominated by agriculture in the late 1800s to one dominated by mixed-age stands of forest today (DeOrsey and Butler 2006).

Methods

Forty-four species with discrete dates of spring arrival were chosen for analysis by examining the species-specific migration graphs published in *The Birds of Dutchess County, New York* (DeOrsey and Butler 2006). Species were selected if they showed a limited history of sporadic winter records, had an abrupt period of arrival during spring migration, and are not listed by DeOrsey and Butler (2006) as uncommon or rare in Dutchess County during the migration period. This reference was also used to classify the birds as breeders or transients in Dutchess County. Each species was categorized as migrating northward from: "North America" (north of Florida's tip), the "Caribbean" (Central America and the West Indies), or "South America" (mainland South America). Wintering range for each species was ascertained from the Cornell Lab of Ornithology (2008), based on the position of the northern winter range boundary. We categorized the breeding-season habitat of each species based on the personal experience of the junior author in Dutchess County.

The Ralph T. Waterman Bird Club (WBC) provided many of the historical records of the first spring arrival of migratory birds, taken from the original birding records of Maunsell Crosby and Ralph T. Waterman, prominent figures in the birding community in the 1900s. We also gleaned FAD from the WBC monthly newsletter, *Wings Over Dutchess* and a variety of other sources (Table 1). These data were found in a variety of formats, ranging from narrative diaries, checklists from field trips, reports from a systematic spring survey held annually by members of the Waterman Bird Club, and computerized records maintained on Cornell's eBird website. The data for FAD from 1885 to 2008 were compiled for each species by reviewing all data sources for the first mention of a species in each year.

Linear regressions of Julian Day of arrival versus year of record were calculated to determine whether the date of first arrival of each species has changed during the past 123 years covered in the historical records. The correlation coefficient (r) given by the regression output was evaluated for significance at the P = 0.05 level following Snedecor and Cochran (1967). SYSTAT was used to identify data lying beyond the 0.99 confidence interval of the least-squares linear regression for each species. The test identified 28 species with outliers in the data, but removal of these outliers did not affect the significance of the regression for any species, so the complete data set was kept for further analysis.

The long record of data for Dutchess County is a unique and valuable resource, but there are no simultaneous measures of local abundance that can be

Table 1. Sources of published and unpublished data used in this study.

Time period	Sources
1885–1905	Hyatt, Mary. Original field notes from the Waterman Bird Club. (N.B., data for 1900 and 1905 are also included in Eaton 1910).
1896	Roosevelt, Franklin D. Original field notes at Franklin D. Roosevelt Presidential Library, Hyde Park, NY.
1887–1932	Griscom, Ludlow. 1933. *The Birds of Dutchess County New York from records compiled by Maunsell S. Crosby*. The Linnaean Society of New York 3:68–174.
1900, 1905	Eaton, Elon Howard. 1910. *Birds of New York*. University of the State of New York at Albany, Vol. 1, pp.73–75.
1901–1917	DeOrsey, Stan. 2001. *Historic Bird Lists of Dutchess County*. Waterman Bird Club, Inc.
1909–1916	Crosby, Maunsell S. A Yearbook of bird-life at Rhinebeck and Dutchess County, New York. Original field notes at Franklin D. Roosevelt Presidential Library, Hyde Park, NY.
1922–1929	Crosby, Maunsell S. Original bird diaries at Franklin D. Roosevelt Presidential Library, Hyde Park, NY.
1930–1966	Baker, John H. Original field notes from the Waterman Bird Club.
1933–1964	Pink, Eleanor, and Otis Waterman. 1967. *Birds of Dutchess County 1933–1964*. Waterman Bird Club, Inc.
1945–1952	Waterman, Ralph T. Original field notes from the Waterman Bird Club.
1958–1982	Pink, Eleanor. Summaries of original Dutchess County Bird Records of the Waterman Bird Club from the Waterman Bird Club.
1964–1979	Pink, Eleanor, and Otis Waterman. 1980. *Birds of Dutchess County 1964–1979*. Waterman Bird Club, Inc.
1982–2008	*Wings Over Dutchess* monthly newsletter of the Waterman Bird Club (2001–present, available at www.watermanbirdclub.org).
2000–2008	eBird online database for arrivals and departures including Dutchess County, available at ebird.org.

used to correct for changes in bird populations, as done so elegantly by Miller-Rushing et al. (2008a), who combined local mist-net samples of population size with observations for FAD for a 33-year period in Massachusetts. Rather, we used published data from the USGS FWS Breeding Bird Survey (BBS) showing bird population trends for New York State since 1966 (Sauer et al. 2007) to investigate their relationship with the records of first arrival.

Trends in the number of birdwatchers were provided by the WBC member records, but those extend only to the founding of the Club in 1958. To estimate changes in observation effort before 1958, we used reports of the number of birdwatchers participating in a local, informal annual census of spring birds, organized in 1919 by Maunsell Crosby, Allen Frost, and Ralph T. Waterman (see *Wings over Dutchess*, April 2010). We used these records of population trends and birdwatching effort in multiple linear regressions with truncations of the full 123-year dataset to ascertain their influence on the general observation of an advance in spring arrival in recent years.

Results

For each species, the slope of the linear regression of first arrival date (FAD) versus time since 1885 is an indication of the advance of spring arrival (e.g., Fig. 1). Species with negative slopes are arriving earlier; species with positive slopes are arriving later. Our study found that 40 of the 44 species examined had significant changes in migration towards earlier spring arrival during the past 123 years (Table 2). Specifically, the negative slope of the regression multiplied by -100 is equivalent to the advancement in spring arrival, measured in days per century.

During the past century, two of the largest changes in migration are a springtime advance of 53 days for *Charadrius vociferous* L. (Killdeer) and 51 days for *Scolopax minor* Gmelin (American Woodcock). For all 44 species, the average advance in arrival is 11.6 days per century. Some of the species, which traditionally are first to arrive in spring (e.g., *Tachycineta bicolor* Vieillot [Tree Swallow]), showed large advances in spring migration, but *Dendroica striata* Forster (Blackpoll Warbler), often considered a sign of the end of spring migration, also showed a significant advance in FAD of about 10.0 days per century. In contrast, other traditionally late migrants (e.g., *Coccyzus erythropthashow* Wilson [Black-billed Cuckoo] and *C. americanus* L. [Yellow-billed Cuckoo]; DeOrsey and Butler 2006) show little change.

The change in FAD for species based on wintering grounds was 21 days/century for those wintering in North America (n = 13), 12 days/century for South America (n =15), and 10 days/century for the Caribbean (n = 16). ANOVA showed no significant difference between mean slopes of species related to different wintering grounds (F = 2.9, P = 0.07).

The average advance in FAD for species based on their status in Dutchess County was 15 days/century for breeding species (n = 37) and 9 days/century for transients (n = 7). There is no significant difference between these groups (F = 1.2, P = 0.27). The average change in FAD for species based on their habitat was: 25.5 days/century for wetland species (n = 6), 23.1 days/century for field species

(n = 3), 10.5 days/century for forest species (n = 24), 10.4 days/century for shrubland species (n = 8), and 5.8 days/century for urban species (n = 2). Here, the ANOVA revealed a significant difference among the slopes of species residing in

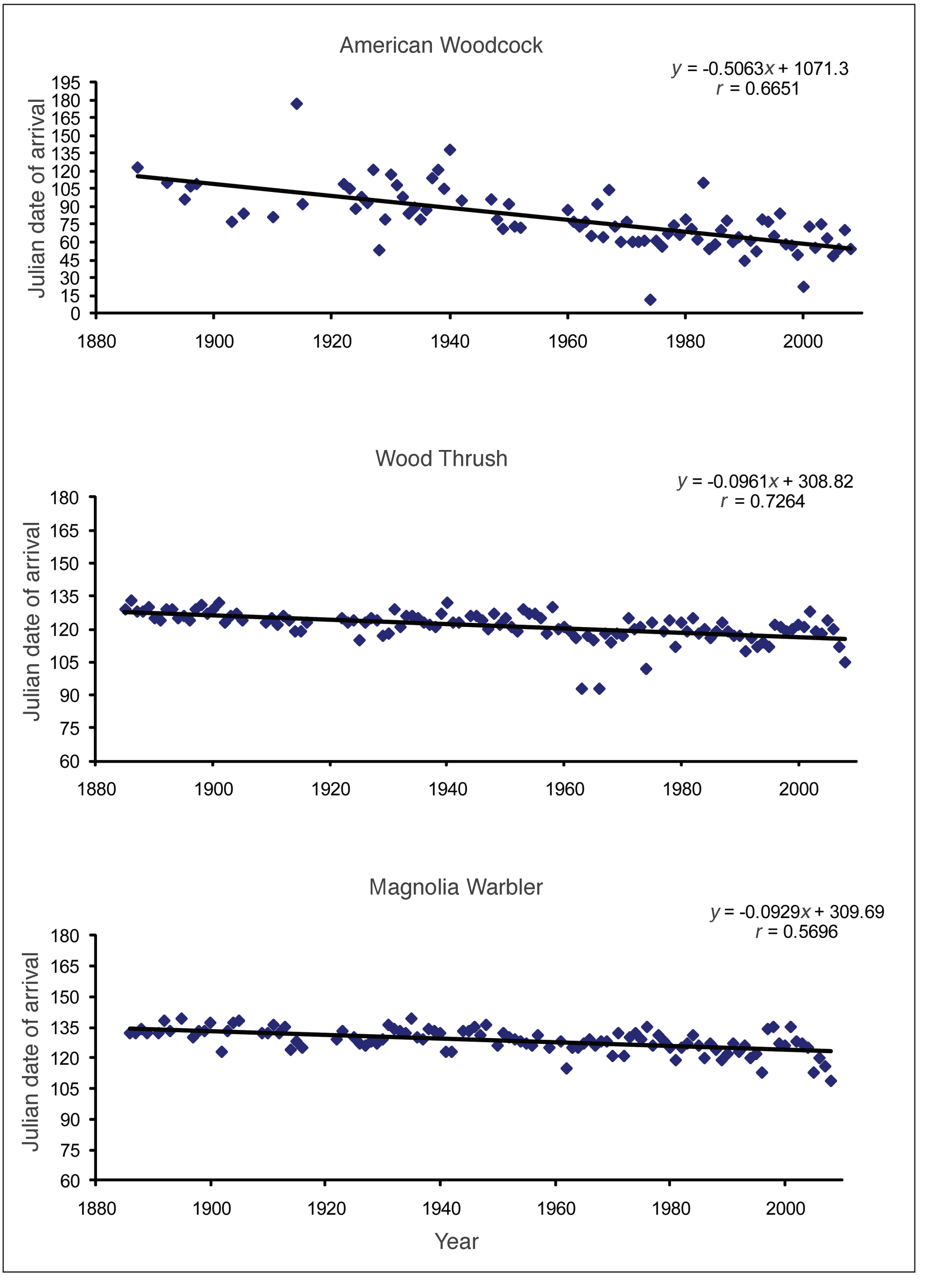

Figure 1. These scatterplots show the arrival trends for 3 representative species of the 44 species studied. All trends are significant.

the five habitats ($F = 3.0$, $P = 0.03$); however, a post-hoc Tukey pairwise comparison showed no significant difference among these various habitats, possibly due to the small and uneven sample size among categories ($P = 0.08$).

Data for the number of observers, as an index of bird-watching effort, were obtained from two records of the WBC. There was no significant trend ($P = 0.12$) in the number of participants in the May Census from 1919–1957 (Fig. 2). In contrast, the number of people submitting springtime records to the WBC increased significantly ($P < 0.0001$) from 1958–2008 (Fig. 3), which may affect our analysis of arrival date.

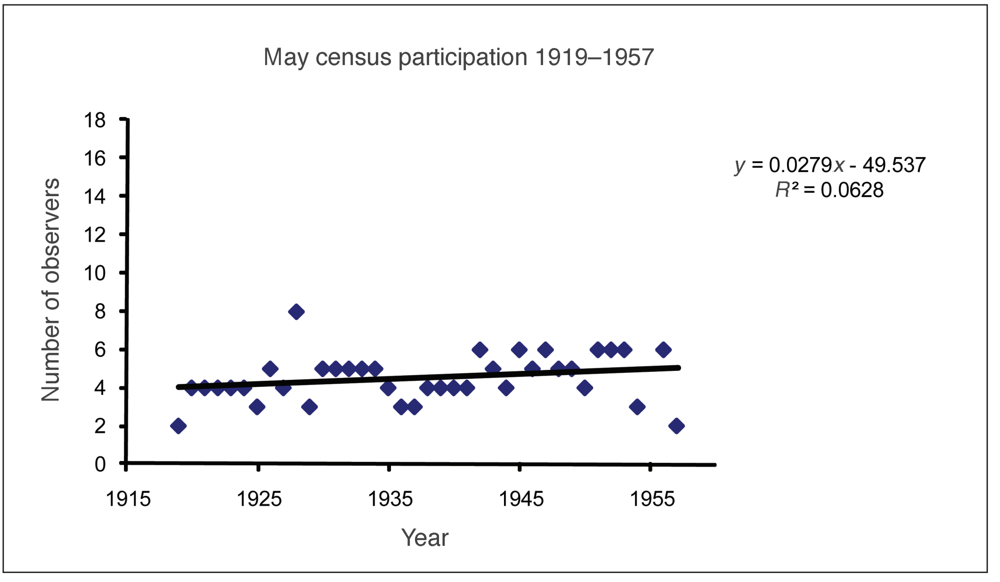

Figure 2. Participants in the May Census of the Waterman Bird Club from 1919–1957, from data accessed at http://www.watermanbirdclub.org/RecordsMay1919-58_2006_0725.pdf. The trend is not significant.

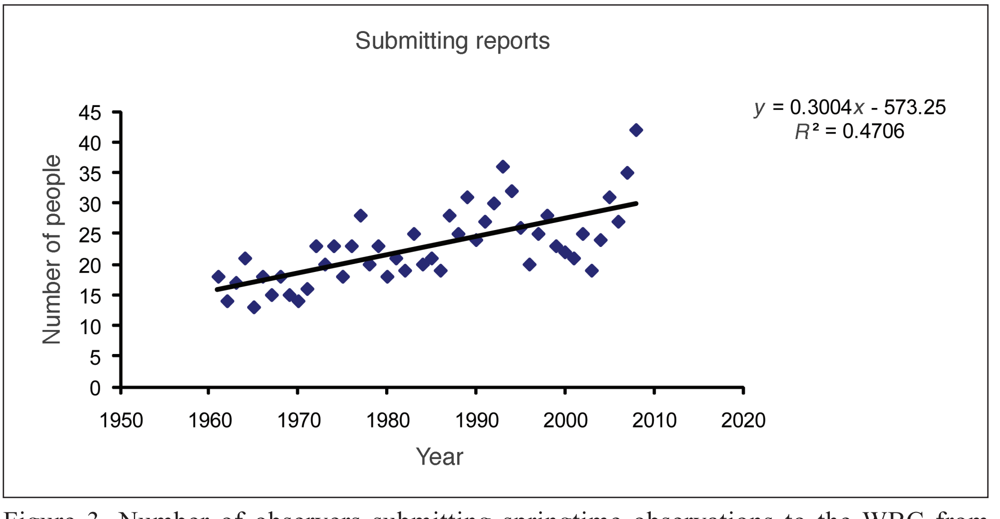

Figure 3. Number of observers submitting springtime observations to the WBC from 1958–2008. The trend is significant.

We used a truncated subset of the FAD data (1958–2008) to analyze the effect of year and observer number on the arrival date for each species in linear and multiple linear regressions. For this 50-year period, only 14 of the 44 species show significant changes in arrival date in a simple linear regression with year, and three of these (*Hirundo rustica* L. [Barn Swallow], *Chaetura pelagic* L. [Chimney Swift], and *Chordeiles minor* Forster [Common Nighthawk]) showed positive slopes, indicating a tendency towards later spring arrival. In this truncated dataset, 12 of these species also had a significant negative correlation in a simple linear regression between arrival date and birdwatcher effort. In multiple linear regressions, all 14 species showed a significant relationship between arrival date as the dependent variable and both year and birdwatcher numbers (1958–2008) included as independent variables, but birdwatcher effort is a significant component in the regression for only two species (Tree Swallow and Chimney Swift).

In simple linear regressions using a further truncation of the data (1966–2007), which corresponds to the available data for population trends (Sauer et al. 2007), 6 species show a significant negative relationship between date of first arrival and bird population numbers in New York State. Twenty-six species show a significant advance in FAD in a multiple linear regression with the same dataset, with 3 species showing significant effects associated with year, 4 species associated with birdwatcher effort, and one (*Vermivora ruficapilla* Wilson [Nashville Warbler]) associated with population trend.

Discussion

Although all 44 species showed a negative slope for the regression of FAD versus year, suggesting that each species is showing earlier springtime arrival, there are several potential confounding factors which may have led to this pattern. First, any change in the population size of a species may have an effect on its perceived first arrival date. For a species with a decrease in population, one might expect to perceive a delay in migration, since there would be fewer birds present to observe each spring. Many (52%) of the species studied have declining populations in New York (Sauer et al. 2007), including 49% of the species for which we report significant earlier arrival (Table 2). The advance in FAD for species with significant declining populations is 14.1 days/century ($n = 20$). The average for species with significant positive population trends is 11.8 days/century ($n = 24$). Despite declining populations for many species, 91% of all the species we examined are observed to arrive significantly earlier.

Several species have had well-publicized population declines in North America during the past few decades (NABCI 2009). Among these, *Dolichonyx oryzivorus* L. (Bobolink) has a population trend of -0.36% per year in New York State and a spring arrival 14 days earlier over the past century, and the Wood Thrush, has a 9.6-day earlier arrival and a population trend of -1.54% per year (Fig. 1).

Changes in the number of observers, their skills, and the quality of their equipment could also obscure true arrival trends. An increase in the number of observers has the same effect as an increase in bird population: the data would

Table 2. The 44 species investigated ranked in descending order of change in the date of first arrival (day/year) since 1885. (*correlations significant at $P < 0.05$). For northernmost winter habitat: NA = North America, CAR = Carribean, SA = South America. For status in Dutchess County (Status): B = Breeds, T = Transient. Population trend (%/yr) is from Breeding Bird Survey routes in New York, 1966–2007 (Sauer et al. 2007).

Species	Winter habitat	Status	Habitat	Slope	*R*	Population trend (%/yr)
Killdeer (*Charadrius vociferous* L.)	NA	B	Field	-0.531	0.48*	-0.739*
American Woodcock (*Scolopax minor* Gmelin)	NA	B	Wetland	-0.506	0.67*	-1.379
Tree Swallow (*Tachycineta bicolor* Vieillot)	NA	B	Wetland	-0.458	0.64*	1.547*
Green Heron (*Butorides virescens* L.)	NA	B	Wetland	-0.253	0.52*	-1.376*
Broad-winged Hawk (*Buteo platypterus* Vieillot)	SA	B	Forest	-0.238	0.34*	2.072
Chipping Sparrow (*Spizella passerine*, Bechstein)	NA	B	Forest	-0.205	0.40*	0.537*
Rose-breasted Grosbeak (*Pheucticus ludovicianus* L.)	CAR	B	Forest	-0.203	0.49*	-1.049*
Prairie Warbler (*Dendroica discolor* Vieillot)	CAR	B	Shrubland	-0.187	0.50*	2.558*
Barn Swallow (*Hirundo rustica* L.)	SA	B	Field	-0.163	0.51*	-1.118*
Blue-winged Warbler (*Vermivora pinus* L.)	CAR	B	Shrubland	-0.156	0.57*	2.908*
Baltimore Oriole (*Icterus galbula* L.)	NA	B	Forest	-0.152	0.26*	-1.336*
Solitary Sandpiper (*Tringa solitaria*, Wilson)	SA	T	Wetland	-0.151	0.45*	-1.562
Bobolink (*Dolichonyx oryzivorus* L.)	SA	B	Field	-0.140	0.55*	-0.361
Indigo Bunting (*Passerina cyanea* L.)	CAR	B	Shrubland	-0.130	0.56*	0.997*
Blue-headed Vireo (*Vireo solitarius* Wilson)	NA	B	Forest	-0.121	0.38*	8.730*
Ruby-throated Hummingbird (*Archilochus colubris* L.)	CAR	B	Forest	-0.116	0.46*	42.810*
House Wren (*Troglodytes aedon* Vieillot)	NA	B	Shrubland	-0.107	0.39*	-0.633*
Palm Warbler (*Dendroica palmarum* Gmelin)	NA	T	Wetland	-0.104	0.36*	No data
Blackpoll Warbler (*Dendroica striata* Forster)	SA	T	Forest	-0.100	0.46*	-1.282
Red-eyed Vireo (*Vireo olivaceus* L.)	SA	B	Forest	-0.099	0.49*	3.081*
Wood Thrush (*Hylocichla mustelina* Gmelin)	CAR	B	Forest	-0.096	0.53*	-1.540*

Table 2, continued.

Species	Winter habitat	Status	Habitat	Slope	*R*	Population trend (%/yr)
Great-crested Flycatcher (*Myiarchus crinitus* L.)	NA	B	Forest	-0.093	0.49*	-0.401*
Magnolia Warbler (*Dendroica magnolia* Wilson)	CAR	T	Forest	-0.093	0.57*	1.136*
Eastern Wood-pewee (*Contopus virens* L.)	SA	B	Forest	-0.093	0.32*	-0.307
Eastern Kingbird (*Tyrannus tyrannus* L.)	SA	B	Field	-0.092	0.46*	-1.140*
Scarlet Tanager (*Piranga olivacea* Vieillot)	SA	B	Forest	-0.086	0.55*	-0.821*
Black-throated Green Warbler (*Dendroica virens* Gmelin)	CAR	B	Forest	-0.084	0.44*	4.780*
Black-throated Blue Warbler (*Dendroica caerulescens* Gmelin)	CAR	B	Forest	-0.082	0.32*	1.018
Yellow Warbler (*Dendroica petechia* L.)	CAR	B	Shrubland	-0.080	0.54*	0.313
Warbling Vireo (*Vireo gilvus* Vieillot)	CAR	B	Forest	-0.077	0.40*	2.170*
Chestnut-sided Warbler (*Dendroica pensylvanica* L.)	CAR	B	Shrubland	-0.066	0.42*	0.104
Ovenbird (*Seiurus aurocapilla* L.)	NA	B	Forest	-0.066	0.46*	5.040*
Tennessee Warbler (*Vermivora peregrina* Wilson)	CAR	T	Forest	-0.063	0.33*	-38.461*
Common Yellowthroat (*Geothlypis trichas* L.)	NA	B	Shrubland	-0.063	0.42*	0.430*
Chimney Swift (*Chaetura pelagic* L.)	SA	B	Urban	-0.058	0.33*	-0.814*
Yellow-throated Vireo (*Vireo flavifrons* Vieillot)	CAR	B	Forest	-0.057	0.31*	-0.994*
Spotted Sandpiper (*Actitis macularia* L.)	SA	B	Wetland	-0.055	0.21*	-3.061*
Black-and-white Warbler (*Mniotilta varia* L.)	NA	B	Forest	-0.045	0.24*	0.818
American Redstart (*Setophaga ruticilla* L.)	CAR	B	Forest	-0.042	0.33*	-0.220
Nashville Warbler (*Vermivora ruficapilla* Wilson)	CAR	T	Shrubland	-0.040	0.21*	1.959*
Black-billed Cuckoo (*Coccyzus erythropthalmus* Wilson)	SA	B	Forest	-0.040	0.16	-0.563
Veery (*Catharus fuscescens* Stephens)	SA	B	Forest	-0.039	0.17	-1.015*
Yellow-billed Cuckoo (*Coccyzus americanus* L.)	SA	B	Forest	-0.016	0.04	0.659
Common Nighthawk (*Chordeiles minor* Forster)	SA	T	Urban	-0.014	0.09	-0.661*

show an earlier arrival trend due to an increased likelihood of observation of early arriving individuals. Fourteen species show a significant change in FAD in our regression analysis of the truncated dataset (1958 to 2008), corresponding to the record of WBC members (Fig. 3). For the remaining 30 species, which show a significant advance in FAD only in the full 123-year dataset, the trend must largely stem from the greater degrees-of-freedom in the longer regression, since observer number was relatively constant from 1919 to 1958 (Fig. 2). The fact that only about one-third (14) of the species show an advance in FAD during this period suggests that the increase in birdwatching effort was of relatively minor importance as a bias-affecting trend in FAD with time.

Multiple linear regression analyses of the 1958–2008 data (corresponding to data for observer number) and the 1966–2007 data (corresponding to data for observer number and population trends) suggest that in both cases the influence of observer effort was relatively minor—affecting only 2–3 species in the multiple-linear regression analysis.

Although many local site factors may affect the selection of breeding habitat by birds (Betts et al. 2008), a continuous expansion of favorable habitat for woodland species during the past century in Dutchess County could lead to greater population numbers and a greater likelihood of early detection of such species. However, there is no indication that species nesting in young forest habitats are arriving earlier, and being detected more easily, as a result of a greater distribution of such habitats on land abandoned from agriculture in Dutchess County (DeOrsey and Butler 2006). Similarly, the provision of nest boxes for Tree Swallows and *Troglodytes aedon* Vieillot (House Wrens) and birdfeeders for *Archilochus colubris* L. (Ruby-throated Hummingbirds) may make it easier for birdwatchers to watch for and detect the first arrival of these species. All three species show a significant increase in the FAD in Dutchess County—Tree Swallows by 46 days/century (Table 2).

We found a slight tendency ($P = 0.07$) for a greater advance in FAD for species wintering in the southeastern US than for those wintering in more distant locales. Butler (2003) and Miller-Rushing et al. (2008a) also found that among North American species, those migrating shorter distances tend to show the greatest trends toward earlier FAD (cf. Végvári et al. 2010 for Europe).

For 123 years of data for 44 species in Dutchess County, we find an average advance of migration of 0.12 days/year, with no evidence that changes in population sizes and only modest evidence that the total effort of birdwatchers has a great influence on this conclusion. In other studies, Tree Swallows in the northern United States have advanced their egg-laying date by a mean of 9 days between 1959 and 1991 (Dunn and Winkler 1999). Using 33 years of data for 32 species in eastern Massachusetts, Miller-Rushing et al. (2008a) deduced a 7.8-day average advance in spring arrival using mean arrival dates (i.e., 0.24 days/year). Van Buskirk et al. (2009) report a mean springtime advance of 0.71 days/year for 78 species in a 46-year study in western Pennsylvania.

The average annual temperature in New England and New York has warmed by 1.1 °C during the past century (Trombulak and Wolfson 2004), and temperatures in Poughkeepsie, NY (in Dutchess County) have increased by 0.0135 °C/yr during the past 119 years (NEISA 2011). While many factors may be involved, at least part of the advance in FAD for springtime migrant birds may be due to global warming over this period. Most birds breeding in New York State also show northward shifts in their distribution during the past 20 years (Zuckerberg et al. 2009). Changes in migration due to climate change have the potential not only to affect the synchrony of bird arrival and food availability, but also to disrupt other evolutionary interactions of species in natural communities (Root et al. 2003).

Conclusions

All 44 species in this study exhibit negative linear relationships between the date of first springtime observation and year since the beginning of our time series (1885), which indicates earlier spring arrivals during the past century. This change in migratory phenology, if not accompanied by similar changes in the availability of food, could contribute to population decline for the affected species (cf. Both et al. 2006).

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