HISTORICAL ANALYSIS OF THE SPRING ARRIVAL OF MIGRATORY BIRDS TO DUTCHESS COUNTY, NEW YORK, IN RELATION TO CLIMATE CHANGE

JESSICA VITALE
Brandeis University, Waltham MA 02453 USA

MENTOR SCIENTIST: DR. WILLIAM H. SCHLESINGER
Cary Institute of Ecosystem Studies, Millbrook, NY 12545 USA

Abstract. Phenological studies often use historical data to investigate the effects of climate change on various biological processes. Bird migration in particular can serve as an indicator of climate change because many bird species base the onset of their migration on springtime temperatures. This study investigates whether bird species have changed their spring arrival to Dutchess County, New York, from 1885 to 2008 in response to climate change. Through examination of meticulous historical records maintained by a local bird club, first appearance data for 44 species were collected and evaluated by linear regression analysis. All species under study showed trends toward early arrival—91% of which were statistically significant. After taking into account potential confounding factors, as changes in the number of observers and trends in bird populations, we conclude that at least 21 species have earlier arrivals influenced by climate change. Significant changes in migration found in this study highlight the importance of further investigation into the specific effects of climate change on the species' fitness and biological processes.

Global warming is a significant force altering biological processes in natural ecosystems (Walther et al. 2002, Parmesan and Yohe 2003). The 1.5°C increase in mean annual temperature in Boston, MA, USA has advanced the springtime flowering of many plants by an average of 8 days during the past 117 years (Primack et al. 2004). British plants show advances in flowering by 4.5 days in the past decade (Fitter and Fitter 2002). Due to recent warming of the climate, many bird species have advanced their migration to arrive earlier in the spring (Dunn and Winker 1999, Strode 2003, Ledneva et al. 2004, Jonzen et al. 2006, Miller-Rushing et al. 2008), although this finding is not universal (e.g., Wilson et al. 2000). The earlier arrival could be due to either an increase in speed of migration or advancement of the onset of migration (Jonzen et al. 2006, Bauer et al. 2008). Like plants, birds provide a surrogate and serendipitous measure of climate change that supplements the historical records from meteorological stations, tree rings, and ice cores (Penuelas and Filella 2001).

Changes in spring arrival can have various effects on birds. For instance, Tree Swallows (*Tachycineta bicolor)* in the northern United States have advanced egg-laying date by a mean of 9 days from 1959 to 1991 (Dunn and Winkler 1999). This advance in reproduction accompanies an earlier emergence of insects in response to warming, and as a result, Tree Swallows are producing larger clutch sizes (Dunn and Winkler 1999). On the other hand, studies of the Great Tit *(Parus major)* in the United Kingdom have revealed an uncoupling of egg-laying and the availability of food for nestlings, which could have serious consequences for the species (Visser et al. 1998). Data from the British Trust for Ornithology have shown that many birds in the United Kingdom have advanced their egg-laying by 8 days (Crick et al. 1997). Depending on the species and their food, these shifts in reproductive timing have the potential to be either beneficial or detrimental for juveniles.

A similar mismatch in migration and food availability has occurred in species of wood warblers in the midwestern United States. Here, some species of warblers have hastened their springtime migration arrival, while other species show no tendency to arrive earlier despite the warming temperatures (Strode 2003). Since food resources are synchronized with warming temperatures, the latter species are not arriving at their breeding grounds at the peak of food availability. This uncoupling of long-term phenological synchrony can have several negative effects on the bird population: reducing the species' ability to reproduce, generating a mismatch between offspring requirements and food availability, and decreasing the fitness of the species (Strode 2003). Changes in migration due to warming of the climate not only have the potential to affect the synchrony of bird arrival and food availability, but also could disrupt other evolutionary interactions of species in natural communities (Root et al. 2003).

Phenological studies of bird migration help establish these trends and stimulate further study of the specific effects of earlier migration on individual species. This study investigated whether 44 species of migratory birds have changed their springtime arrival in Dutchess County, New York, during the past 123 years in response to changes in climate. We also examined potential differences in the response of groups of species, using categories based on wintering habitat, breeding status and habitat in Dutchess County, and other natural history attributes.

Analyses of historical migration data are affected by potential biases, derived from changes in the number of observers and in the size of the migrating population (Miller-Rushing et al. 2008). We used several approaches to evaluate the impacts of such factors on our analysis and conclusions.

METHODS

Dutchess County is located in eastern New York in the Hudson River valley, embracing nearly 2100 km^2 of rolling hills, with farmland and deciduous forest. There is one large urban area in the county, the city of Poughkeepsie, NY. The region has had an active birding community for more than a century, including early observations by Franklin D. Roosevelt, recorded in a personal bird diary for the year 1896. With the establishment of the Ralph T. Waterman Bird Club (WBC) in 1958, a detailed record of birds has been maintained over an extensive period.

Fifty-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 no history of sporadic winter records, had an abrupt period of arrival during spring migration, and are not uncommon or rare in Dutchess County during the migration period. This reference was also used to determine whether the selected species were summer residents in the county or transient species passing through the region. Wintering locations for each species were ascertained from the Cornell Lab of Ornithology (www.birds.cornell.edu/AllAboutBirds), and each species was subsequently categorized as migrating northward from: “North America” (north of Florida’s tip), the “Caribbean” (Central America and West Indies), or “South America” (mainland South America).

The 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, the WBC monthly newsletter, *Wings Over Dutchess*, and other sources (Table 1). Migration data from 1885 to the present were compiled for each species by reviewing all data sources for the first mention of a species in each year; each year’s earliest reports were then entered into an Excel file along with the number of birds seen on the date recorded.

After completing the initial data compilation, we deleted 10 of the original 54 species from further analysis due to insufficient data. The remaining 44 species are all spring migrants that return to Dutchess County after wintering in southern regions. Linear regression analysis of Julian Day of arrival versus year of record was performed in Microsoft Excel in order to determine whether or not 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=.05 level following Snedecor and Cochran (1967). SYSTAT was used to test for outliers from least-squares linear regressions at a confidence level of 0.99 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.

Analysis of the timing of first appearance is at risk of biases which may influence the data and obscure arrival trends, specifically changes in the number of birders and changes in the abundance of a species over time (van Strien et al. 2008, Miller-Rushing et al. 2008). Increases in birdwatching activity and bird population numbers potentially confound trends in first-appearance, since both make the detection of early individuals more likely. 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. 2008).

The long record of data for Dutchess County is a unique and valuable resource, but there are no simultaneous local measures of abundance that can be used to correct for changes in bird populations through time, as done elegantly by Miller-Rushing et al. (2008). Rather, we used published data on population trends across North America from Sauer et al. (2007) to examine their effect on 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. For earlier years, we used records of individuals participating in an annual spring bird census to assess changes in observation effort from 1919 to 1957.

RESULTS AND DISCUSSION

The Earth's climate has warmed 0.6°C over the past 100 years, with two main warming periods from 1910 to 1945 and 1976 to the present (Walther et al. 2002). The New England region and New York have warmed an average of 1.11°C over this same 100-year time period (Trombulak and Wolfson 2004).

The slope of the linear regression of arrival date versus time since 1885 is an indication of the advance of spring arrival (Fig. 1). 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.

The two largest changes in migration are a springtime advance of 53 days for Killdeer (*Charadrius vociferous*) and 51 days for American Woodcock (*Scolopax minor*). The average advance in arrival is 11.6 days per century, and more than half of the species studied showed greater advances than that calculated for the Great Crested Flycatcher (*Myiarchus crinitus)*, which we used as a benchmark species, since it has suffered little or no change in population numbers as reported by Sauer et al. (2007). Some of the species which traditionally are first to arrive in spring showed the greatest change; conversely species arriving later [e.g., Black-billed Cuckoo (*Coccyzus erythropthalmus)* and Yellow-billed Cuckoo (*C. americanus*)] show the least.

The average slopes for species based on wintering grounds were: -0.208 for those wintering in North America, -0.116 for South America, and -0.098 for the Caribbean. After normalizing the data using a log function, SYSTAT was used to conduct an ANOVA, showing that there is no significant difference between slopes of species related to different wintering grounds, although the comparisons just miss the critical value of significance ($F = 2.922$, $p = 0.066$). By comparison, Butler (2003) and Miller-Rushing et al. (2008) found that for several species in North America, those migrating shorter distances tend to show the greatest trends toward earlier arrival.

The average slopes for species based on status in Dutchess County were: -0.148 for summer residents and -0.092 for transient species. There is no significant difference between these groups ($F = 1.243$, $p = 0.272$). The average slopes for species based on their habitat were: -0.255 for wetland species, -0.231 for field species, -0.105 for forest species, -0.104 for shrubland species, and -0.058 for urban species. Here, the ANOVA revealed a significant difference between the slopes of species residing in the five habitats ($F = 3.021$, $p = 0.031$); however, a post-hoc Tukey pairwise comparison showed no significant difference between these habitats, possibly due to the small and uneven sample size among categories ($p = 0.081$).

Although all 44 species showed a negative slope for the regression, suggesting that each species is arriving earlier, there are several potential confounding factors which may have led to this pattern among the data. First, any change in the population size of a species may have an effect on its perceived 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. This and other factors could affect the slope of a regression between arrival date and time. A decline in bird population should lead to a positive slope, whereas an increase in bird population, an increase in the number of observers, or warmer springtime climate would all lead to a negative slope, indicating earlier arrival.

Many (66%) of the species studied have declining populations, including 68% of the species with significant earlier arrival (Sauer et al. 2007). The average slope (i.e. earlier arrival in days/century) for species with significant negative population trends is -0.145. The average slope for species with significant positive population trends is -0.108. Despite declining populations for many species, 91% of the species we examined are arriving significantly earlier, presumably due to climate change.

Two species have declined significantly in the past few decades. Bobolink (*Dolichonyx oryzivorus*) has a population trend of -1.77 percent per year yet has a spring arrival 14 days earlier over the past century, and Wood Thrush (*Hylocichla mustelina*) has a declining population of -1.75 percent per year with a 9.6-day earlier arrival (Fig. 1). Our analysis shows that these two species have advanced their spring arrivals, which may lead to additional consequences for their survival and fitness.

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 show an earlier arrival trend due to an increased likelihood of observation as opposed to changes solely due to climate change. Data for the number of observers were obtained from the WBC from two records: the number of participants in the May Census from 1919-1957 (Fig. 2), and the number of people submitting springtime records to the WBC from 1958-2008 (Fig.3). The latter shows a significant increase with time, which may affect our analysis of arrival date.

The effect of an increase in observers over time was taken into account by choosing a species, the Great Crested Flycatcher, which shows virtually no trend in population in eastern North America (+0.0002 percent/year; Sauer et al. 2007), and by assuming, conservatively, that its trend of earlier arrival (slope = -0.0930, Table 2) is entirely due to the increase in birdwatchers. Then the 21 species with significantly greater negative slopes than that of the Great Crested Flycatcher are likely affected by global warming.

A second avenue of analysis shows that the increase in observers over time does not have a large effect on the data. For the years 1958 to the present, we plotted number of members submitting springtime reports to the WBC against the Julian Day of first arrival for each species in the same year. Among the five species with the greatest negative slopes and as well as for the Great Crested Flycatcher, there were no significant relationships between these parameters.

Some species that display earlier arrivals may be affected by other human actions. For example, the use of nest boxes by Tree Swallows and House Wrens and birdfeeders by hummingbirds may result in earlier arrivals due to two factors. First, it is possible that nest boxes and birdfeeders encourage the birds to arrive earlier in the spring season to take advantage of habitat opportunities. Second, nest boxes and birdfeeders make it easier for observers to find the birds and may detect their earlier presence as a result. For these species the trend toward earlier springtime arrival must be interpreted with caution.

Further, we note that the vegetation of the eastern United States and Dutchess County has changed from a landscape dominated by agriculture in the late 1800s to one dominated by recovering forest today. For woodland species, the continuous expanse of favorable habitat could lead to greater population numbers and an appearance of earlier arrivals in recent years. Many of the species we studied showed the greatest advance in springtime arrival in the period from 1930 to 1960, with smaller changes in most recent years. This pattern would be consistent with the pattern of agricultural abandonment and forest regrowth in Dutchess County (DeOrsey and Butler 2006). Nevertheless, the mean arrival for field species (23 days earlier) is greater than for forest or shrubland species (each 10 days earlier) over the duration of the historical record.

Despite these potential biases, there is remarkable similarity in the conclusions we draw and those presented by Miller-Rushing et al. (2008). For 33 years of data for 32 species in eastern Massachusetts, they deduce a 7.8-day average advance in spring arrival using mean arrival dates. For 123 years of data for 44 species in Dutchess County, we find an average advance of migration of 11.6 days, and no evidence that changes in population sizes or birdwatching effort have a great influence on this conclusion.

CONCLUSION

All species in this study have negative slopes for a linear regression of date of first springtime observation versus year since 1885, which indicates earlier spring arrivals over the past century. If we assume that the change seen for the Great Crested Flycatcher derives solely from changes in numbers of birdwatchers, 53% of all study species have significant arrival trends that are likely explained by changes in climate.

These shifts in migration date may have negative consequences on various species, as shown in past phenological studies. It will be important to study the effects of climate change on migratory birds in order to determine how their earlier spring arrivals affect their overall fitness and survival. Are species showing an appropriate adjustment to ongoing global warming or will changes in their migratory timing lower overall population numbers?

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LITERATURE CITED

Bauer, S., P. Gienapp, and J. Madsen. 2008. The relevance of environmental conditions for departure decision changes en route in migrating geese. Ecology 89:1953-1960.

Butler, C.J. 2003. The disproportionate effect of global warming on the arrival dates of short-distance migratory birds in North America. Ibis 145:484-495.

Cornell University Lab of Ornithology. 2008. All About Birds. <http://www.birds.cornell.edu/AllAboutBirds>. Accessed July 22, 2008.

Crick, H.Q.P., C. Dudley, D.E. Glue, and D.L. Thomson. 1997. UK birds are laying eggs earlier. Nature 388:526.

DeOrsey, S. and B. Butler. 2006. *The Birds of Dutchess County New York*. Grinnell and Lawton Publishing, Millbrook, NY

Dunn, P.O. and D.W. Winkler. 1999. Climate change has affected the breeding date of tree swallows throughout North America. Proceedings of the Royal Society of London 266B:2487-2490.

Eaton, E. H. 1910. *Birds of New York.* University of the State of New York, Albany, NY.

Fitter, A.H. and R.S.R. Fitter. 2002. Rapid changes in flowering time in British plants. Science 296:1689-1691.

Griscom, L. 1933. The Birds of Dutchess County New York, from records compiled by Maunsell S. Crosby. The Linnaean Society of New York 3:68-174.

Jonzen, N., A. Linden, T. Ergon, E. Knudsen, J.O. Vik, D. Rubolini, D. Piacentini, C. Brinch, F. Spina, L. Karlsson, M. Stervander, A. Andersson, J. Waldenstrom, A. Lehikoinen, E. Edvardsen, R. Solvang, and N.C. Stenseth. 2006. Rapid advance of spring arrival dates in long-distance migratory birds. Science 312:1959-1961.

Ledneva, A., A.J. Miller-Rushing, R.B. Primack, and C. Imbres. 2004. Climate change as reflected in a naturalist's diary, Middleborough, Massachusetts. Wilson Bulletin 116:224-231.

Miller-Rushing, A.J., T.L. Lloyd-Evans, R.B. Primack, and P. Satzinger. 2008. Bird migration times, climate change, and changing population sizes. Global Change Biology 14:1959-1972.

Parmesan, C. and G. Yohe. 2003. A globally coherent fingerprint of climate change impacts across natural systems. Nature 421:37-42.

Primack, D., C. Imbres, R. Primack, A. Miller-Rushing and P.D. Tredici. 2004. Herbarium specimens demonstrate earlier flowering times in response to warming in Boston. American Journal of Botany 91:1260-1264.

Penuelas, J. and I. Filella. 2001. Responses to a warming world. Science 294:793-795.

Root, T.L., J.T. Price, K.R. Hall, S.H. Schneider, C. Rosenzweig, and J.A. Pounds. 2003. Fingerprints of global warming on wild animals and plants. Nature 421:57-60.

Sauer, J. R., J. E. Hines, and J. Fallown. 2007. The North American Breeding Bird Survey, Results and Analysis 1966-2006. Version 10.13.2007. USGS Patuxent Wildlife Research Center, Laurel, Maryland. www.mbr-pwrc.usgs.gov/bbs/bbs.html (last accessed 15 August 2008)

Snedecor, G.W. and W.G. Cochran. 1967. Statistical methods. The Iowa State University Press, Ames, Iowa

Strode, P.K. 2003. Implications of climate change for North American wood warblers (Parulidae). Global Change Biology 9:1137-1144.

Trombulak, S.C. and R. Wolfson. 2004. Twentieth-century climate change in New England and New York, USA. Journal of Geophysical Research 31: doi:10.1029/2004GL020574.

Visser, M.E., van Noordwijk, A.J., Tinbergen, J.M. and Lessells, C.M. 1998. Warmer springs lead to mistimed reproduction in great tits (*Parus major*). Proceedings of the Royal Society of London. 265B:1867-1870.

Van Strien, A.J., W.F. Plantenga, L.L. Soldaat, C.A.M. van Swaay, and M.F. WallisDeVries. 2008. Bias in phenology assessments based on first appearance data of butterflies. Oecologia 156:227-235.

Walther, G.-R., E. Post, P. Convey, A. Menzel, C. Parmesan, T.J.C. Beebee, J.-M. Fromentin, O. Hoegh-Guldberg, F. Bairlein. 2002. Ecological responses to recent climate change. Nature 416:389-395.

Wilson, W.H., D. Kipervaser, and S.A. Lilley. 2000. Spring arrival dates of Maine migratory breeding birds: 1994-1997 vs. 1899-1911. Northeastern Naturalist 7:1-6.

APPENDIX

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.

TABLE 2: The 44 species investigated ranked in descending order of change in the date of first arrival (day/year) since 1885.

Species	Winter Habitat	Status in Dutchess County	Habitat	Slope	R
Killdeer (*Charadrius vociferous*)	N. America	Summer resident	Field	-0.531	0.48*
American Woodcock (*Scolopax minor*)	N. America	Summer resident	Wetland	-0.506	0.67*
Tree Swallow (*Tachycineta bicolor*)	N. America	Summer resident	Wetland	-0.458	0.64*
Green Heron (*Butorides virescens*)	N. America	Summer resident	Wetland	-0.253	0.52*
Broad-winged Hawk (*Buteo platypterus*)	S. America	Summer resident	Forest	-0.238	0.34*
Chipping Sparrow (*Spizella passerina*)	N. America	Summer resident	Forest	-0.205	0.40*
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)	Caribbean	Summer resident	Forest	-0.203	0.49*
Prairie Warbler (*Dendroica discolor*)	Caribbean	Summer resident	Shrubland	-0.187	0.50*
Barn Swallow (*Hirundo rustica*)	S. America	Summer resident	Field	-0.163	0.51*
Blue-winged Warbler (*Vermivora pinus*)	Caribbean	Summer resident	Shrubland	-0.156	0.57*
Baltimore Oriole (*Icterus galbula*)	N. America	Summer resident	Forest	-0.152	0.26*
Solitary Sandpiper (*Tringa solitaria*)	S. America	Transient	Wetland	-0.151	0.45*
Bobolink (*Dolichonyx oryzivorus*)	S. America	Summer resident	Field	-0.140	0.55*
Indigo Bunting (*Passerina cyanea*)	Caribbean	Summer resident	Shrubland	-0.130	0.56*
Blue-headed Vireo (*Vireo solitarius*)	N. America	Summer resident	Forest	-0.121	0.38*
Ruby-throated Hummingbird (*Archilochus colubris*)	Caribbean	Summer resident	Forest	-0.116	0.46*
House Wren (*Troglodytes aedon*)	N. America	Summer resident	Shrubland	-0.107	0.39*
Palm Warbler (*Dendroica palmarum*)	N. America	Transient	Wetland	-0.104	0.36*
Blackpoll Warbler (*Dendroica striata*)	S. America	Transient	Forest	-0.100	0.46*
Red-eyed Vireo (*Vireo olivaceus*)	S. America	Summer resident	Forest	-0.099	0.49*
Wood Thrush (*Hylocichla mustelina*)	Caribbean	Summer resident	Forest	-0.096	0.53*
Great-crested Flycatcher (*Myiarchus crinitus*)	N. America	Summer resident	Forest	-0.093	0.49*
Magnolia Warbler (*Dendroica magnolia*)	Caribbean	Transient	Forest	-0.093	0.57*
Eastern Wood-Pewee (*Contopus virens*)	S. America	Summer resident	Forest	-0.093	0.32*
Eastern Kingbird (*Tyrannus tyrannus*)	S. America	Summer resident	Field	-0.092	0.46*
Scarlet Tanager (*Piranga olivacea*)	S. America	Summer resident	Forest	-0.086	0.55*
Black-throated Green Warbler (*Dendroica virens*)	Caribbean	Summer resident	Forest	-0.084	0.44*
Black-throated Blue Warbler (*Dendroica caerulescens*)	Caribbean	Summer resident	Forest	-0.082	0.32*
Yellow Warbler (*Dendroica petechia*)	Caribbean	Summer resident	Shrubland	-0.080	0.54*
Warbling Vireo (*Vireo gilvus*)	Caribbean	Summer resident	Forest	-0.077	0.40*
Chestnut-sided Warbler (*Dendroica pensylvanica*)	Caribbean	Summer resident	Shrubland	-0.066	0.42*
Ovenbird (*Seiurus aurocapilla*)	N. America	Summer resident	Forest	-0.066	0.46*
Tennessee Warbler (*Vermivora peregrina*)	Caribbean	Transient	Forest	-0.063	0.33*
Common Yellowthroat (*Geothlypis trichas*)	N. America	Summer resident	Shrubland	-0.063	0.42*
Chimney Swift (*Chaetura pelagica*)	S. America	Summer resident	Urban	-0.058	0.33*
Yellow-throated Vireo (*Vireo flavifrons*)	Caribbean	Summer resident	Forest	-0.057	0.31*
Spotted Sandpiper (*Actitis macularius*)	S. America	Summer resident	Wetland	-0.055	0.21*
Black-and-white Warbler (*Mniotilta varia*)	N. America	Summer resident	Forest	-0.045	0.24*
American Redstart (*Setophaga ruticilla*)	Caribbean	Summer resident	Forest	-0.042	0.33*
Nashville Warbler (*Vermivora ruficapilla*)	Caribbean	Transient	Shrubland	-0.040	0.21*
Black-billed Cuckoo (*Coccyzus erythropthalmus*)	S. America	Summer resident	Forest	-0.040	0.16
Veery (*Catharus fuscescens*)	S. America	Summer resident	Forest	-0.039	0.17
Yellow-billed Cuckoo (*Coccyzus americanus*)	S. America	Summer resident	Forest	-0.016	0.04
Common Nighthawk (*Chordeiles minor*)	S. America	Transient	Urban	-0.014	0.09

*correlation significant at P<0.05

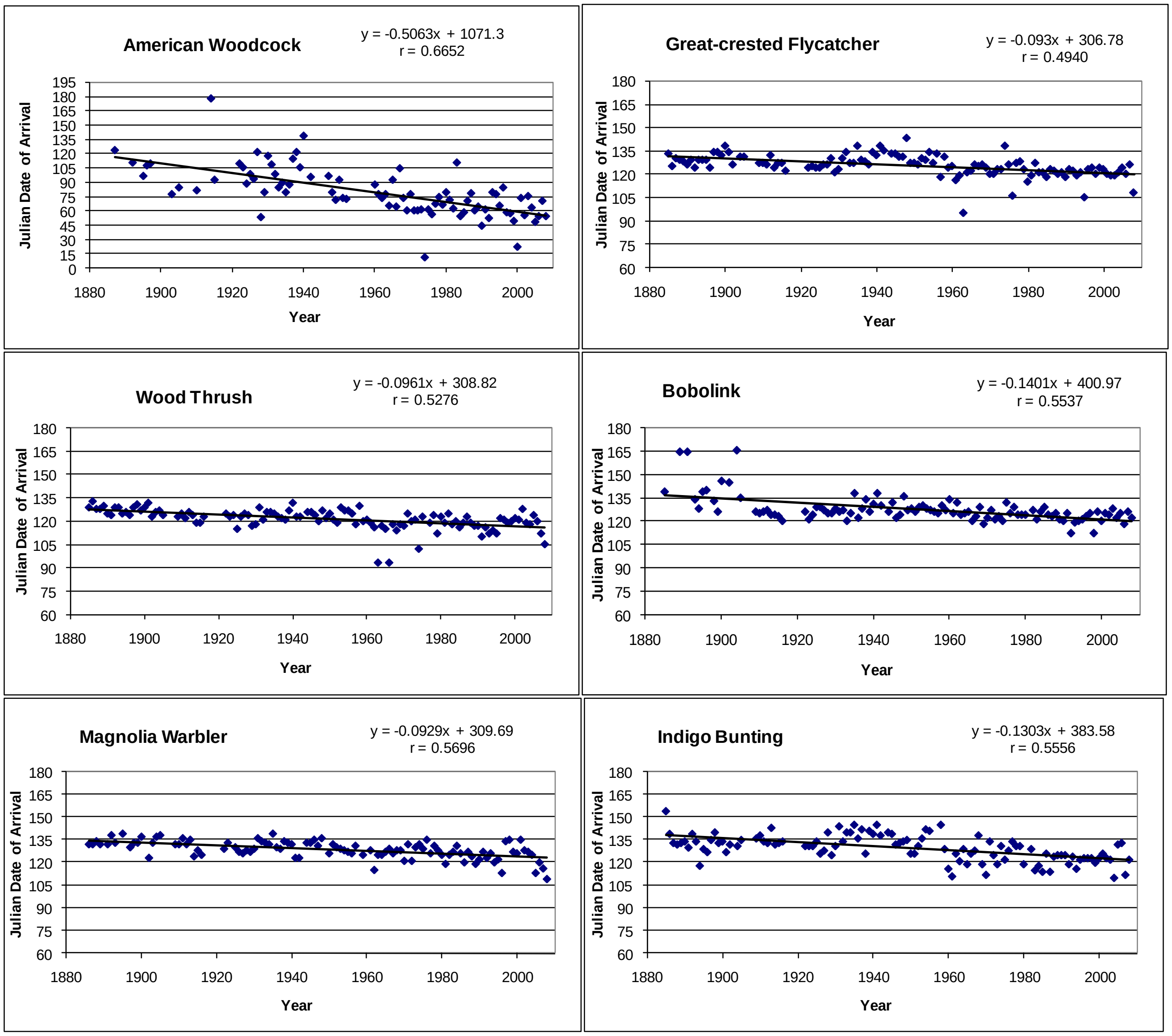

FIGURE 1: The above scatterplots show the arrival trends for 6 of the 44 species studies. All trends are significant.

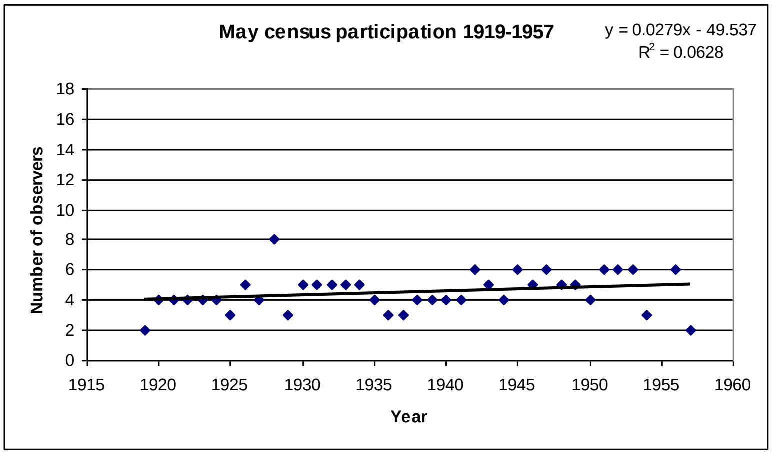

FIGURE 2: Participants in the May Census of the Waterman Bird Club from 1919-1957, from data accessed at http://www.watermanbirdclub.org/RecordsMay1919-58_2006_0725.pdf. The trend is not significant.

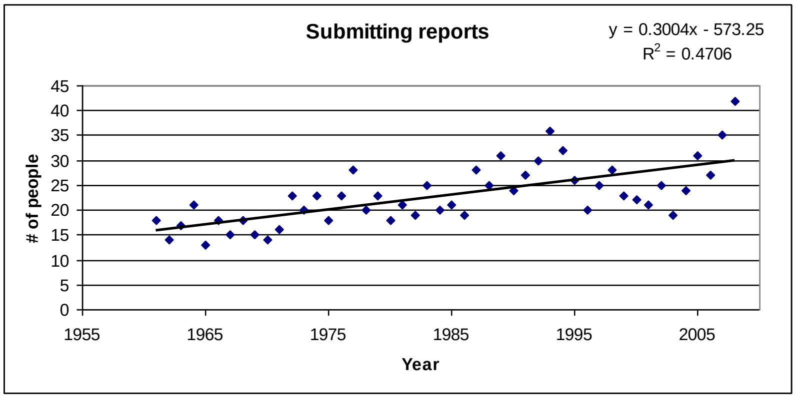

FIGURE 3: Number of observers submitting springtime observations to the WBC from 1958-2008. The trend is significant.