Int J Biometeorol
DOI 10.1007/s00484-012-0598-7

ORIGINAL PAPER

Weekend bias in Citizen Science data reporting: implications for phenology studies

Jason R. Courter · Ron J. Johnson · Claire M. Stuyck · Brian A. Lang · Evan W. Kaiser

Received: 3 April 2012 / Revised: 31 July 2012 / Accepted: 6 October 2012

Abstract Studies of bird phenology can help elucidate the effects of climate change on wildlife species but observations over broad spatial scales are difficult without a network of observers. Recently, networks of citizen volunteers have begun to report first arrival dates for many migratory species. Potential benefits are substantial (e.g., understanding ecological processes at broad spatial and temporal scales) if known biases of citizen data reporting are identified and addressed. One potential source of bias in bird phenology studies is the tendency for more "first" migratory arrivals to be reported on weekends than on weekdays. We investigated weekend bias in data reporting for five common bird species in North America (Baltimore Oriole, *Icterus galbula*; Barn Swallow, *Hirundo rustica*; Chimney Swift, *Chaetura pelagica*; Purple Martin, *Progne subis*; and Ruby-throated Hummingbird, *Archilochus colubris*), and assessed whether this bias affected mean arrival dates reported using data from historical (1880–1969; N= 25,555) and recent (1997–2010; N=63,149) Citizen Science databases. We found a greater percentage of first arrivals reported on weekends and small but significant differences in mean arrival dates (approximately 0.5 days) for four of five species. Comparing time periods, this weekend bias decreased from 33.7 % and five species in the historical time period to 32 % and three species in the recent, perhaps related to changes in human activity patterns. Our results indicate that weekend bias in citizen data reporting is decreasing over time in North America and including a 'day of week' term in models examining changes in phenology could help make conclusions more robust.

Keywords Bird phenology · Climate change · Detectability · First arrival dates · Spring migration · Volunteers

Introduction

Studies of phenology, such as first arrival dates for migratory bird species, can help in understanding the impacts of climate change on wildlife species and potential asynchronies with habitat or food resources. Phenological information could help identify how climate change influences the rate of bird migration (Lehikoinen et al. 2004), when and where asynchronies between birds and their food resources might occur (Visser and Both 2005), and how adaptive management strategies could be implemented (Miller-Rushing 2010). Birds are charismatic, easy to identify, and long-term monitoring efforts have been in place for more than a century (Dickinson et al. 2010). Phenological bird data has long been collected by amateur naturalists and is continuing in the present day with web-based Citizen Science programs that track annual first arrival dates across species' ranges (e.g., hummingbirds.net, Journey North, eBird). As advancing technology makes Citizen Science programs more accessible to the general public, an increasing number of people with wide-ranging levels of expertise are contributing to growing databases (Dickinson et al. 2010; Beaubien and Hamann 2011). These data improve

R. J. Johnson · C. M. Stuyck · B. A. Lang · E. W. Kaiser
School of Agricultural, Forest, and Environmental Sciences,
Clemson University,
261 Lehotsky Hall,
Clemson, SC 29634, USA

Present Address:
J. R. Courter (✉)
Department of Earth and Environmental Science,
Taylor University,
236 W. Reade Ave.,
Upland, IN 46989, USA
e-mail: jason_courter@taylor.edu

Published online: 28 October 2012

our understanding of how climate change affects wildlife species if known biases associated with data collection methods are accounted for and addressed (Silvertown 2009; Miller-Rushing et al. 2008).

Many of the biases in first arrival reporting by citizen scientists such as unequal sampling effort across space and time and difference in detectability among species are becoming well-understood (Tryjanowski et al. 2005; Dickinson et al. 2010; Miller-Rushing et al. 2008). One potential source of bias that is easily identified, but often overlooked, is the tendency for "first" arrivals to be reported on weekends (Fraser 1997). Sparks et al. (2008) examined over 14,000 first arrival reports from the United Kingdom between 1947 and 2004 and found that 44 % of reports were made on weekends, instead of the to 28.6 % or '2 out of 7' expected to occur by chance; "familiar" species (i.e., those with familiar songs, that fly in groups, or that have populations with over 1 million pairs) showed slightly less weekend bias (41.4 %). While they did not completely rule out the possibility that migration patterns could be influenced by environmental conditions such as traffic and pollution levels that differ slightly on weekends (Qin et al. 2004; Marani 2010), they found it most likely that an increase in observer effort on weekends explained this difference. To our knowledge, a similar investigation has not been conducted in North America, which is somewhat surprising given the number of studies that use Citizen Science data to assess changes in bird phenology (Miller-Rushing et al. 2008; DeLeon et al. 2011; Swanson and Palmer 2009; Wilson 2007). In addition, no study has quantified the degree to which weekend bias affects first arrival dates reported.

Our study objectives were to determine the extent of weekend bias in first arrival reports made in North America and whether this pattern has changed over time. We also wanted to identify characteristics of species more likely to be reported on weekends in North America, and to examine differences in weekend reporting between North America and Europe.

Methods

We chose five species that were familiar to most birders, easily detectable, and had broad monitoring schemes in place during historical (1880–1969) and recent (1997–2010) time periods. Our focal species included Baltimore Oriole (*Icterus galbula*), Barn Swallow (*Hirundo rustica*), Chimney Swift (*Chaetura pelagica*), Purple Martin (*Progne subis*), and Ruby-throated Hummingbird (*Archilochus colubris*).

Historical spring migration data (1880–1969) for all species were transcribed from arrival cards provided by the North American Bird Phenology Program (NABPP; http://www.pwrc.usgs.gov/bpp/) by the senior author and student volunteers. Recent first arrival reports (1997–2010) were accessed from popular online Citizen Science databases that recruit amateur naturalists to submit annual first arrival observations. First arrivals for Ruby-throated Hummingbird, Baltimore Oriole, and Barn Swallow were provided by Journey North (http://www.learner.org/jnorth/), Purple Martin arrivals were reported from the Purple Martin Conservation Association (http://purplemartin.org/), and Chimney Swift arrivals were accessed from the Driftwood Conservation Association (http://www.chimneyswifts.org/). In sum, we analyzed 88,794 first arrival records in eastern North America (24°N–49°N, 67–94°W; Fig. 1).

Arrival dates were converted into day of week using the 'weekday' function in Microsoft Excel 2010 and grouped into weekend and weekday observations. We compared the percentage of weekend arrivals observed with those expected to occur by chance (i.e., 28.6 % or '2 out of 7') with all species and years combined and also by species and time period (i.e., 1880–1969 and 1997–2010), using Pearson chi-square tests and contingency analysis. Mean first arrival dates were then calculated by species to assess possible differences in weekend and weekday arrival reports. We included latitude, longitude, altitude, and time period as covariates, along with all two-way interaction terms; outliers were removed at 3 standard deviations. Least square means were compared using one-tailed t-tests (JMP 9.0, SAS Institute).

Results

Among species and time periods, we found that 32.5 % of first arrivals in North America were reported on weekends, compared to 28.6 % (or 2 out of 7) expected by chance (χ^2= 420.9, P<0.0001; Fig. 2). Overall, differences decreased between time periods with 33.7 % of observations reported on weekends, historically (1880–1969), and 32 % of observations reported on weekends in our recent time period (1997–2010; χ^2=24.6, P<0.0001). Most notably, the percentage of observations made on Sundays decreased between time periods (17.8 % vs. 15.9 %; Fig. 3). When examining trends among species, a greater number of observations were made on weekends for all species in our historical time period, and for 3 of 5 species in our recent time period (Table 1). In general, weekend bias in data reporting decreased over time, particularly among Chimney Swifts (χ^2=7.6, P=0.006), Purple Martins (χ^2=8.8, P=0.003), and Ruby-throated Hummingbirds (χ^2=28.1, P<0.0001; Table 1). Small, but significant, differences (appx. 0.5 days) were noted in mean first arrival dates when comparing first arrivals calculated from weekend and weekday reports for four of five species, including Baltimore Oriole, Barn Swallow, Purple Martin and Ruby-throated Hummingbird (Table 2).

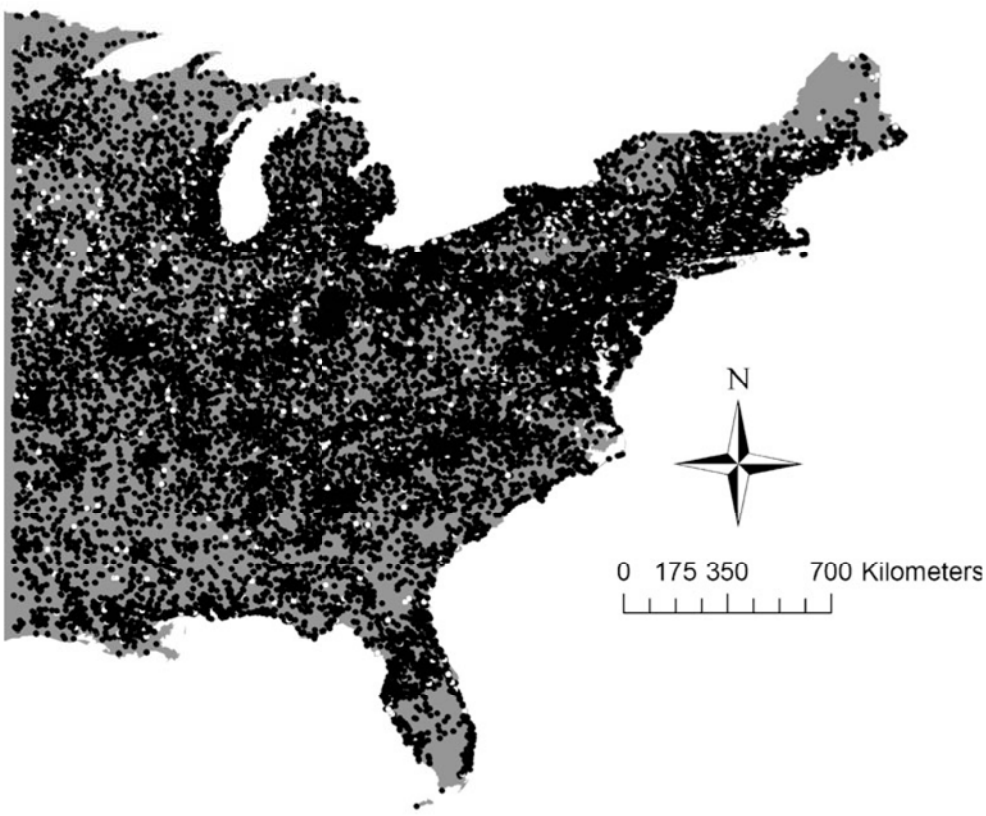

Fig. 1 Locations within our study region (24–49°N, 67–94°W) reporting first arrivals (N=88,794) from the North American Bird Phenology Program (1880–1969; *white circles*) and recent Citizen Science databases (1997–2010; *black circles*)

Discussion

Our results demonstrate a tendency for first arrivals of common species to be reported on weekends in North America. The degree of bias, however, is less than has been reported in Europe by Sparks et al. (2008; Fig. 2). Overall, 43 % of first arrivals were reported on weekends in Europe between 1947 and 2004, whereas 32.5 % of observations were reported on weekends in North America between 1880 and 2010 (both higher than 28.6 % of observations that would be expected if first arrival were reported uniformly throughout the week). Even among "familiar species" in Europe, weekend bias was higher (i.e., 41.4 %) than for any of the five species we report (Table 1). The only species

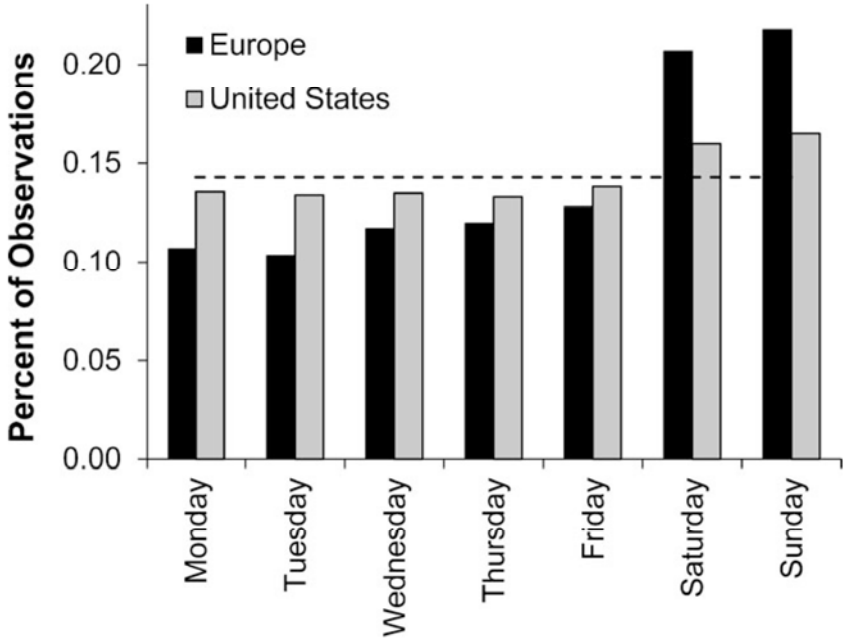

Fig. 2 Percentage of first arrivals reported on each day of the week in the United States compared with European records reported by Sparks et al. (2008). All species and time periods are included. Horizontal reference line indicates percentage of observations expected at random (i.e., 14.3 %)

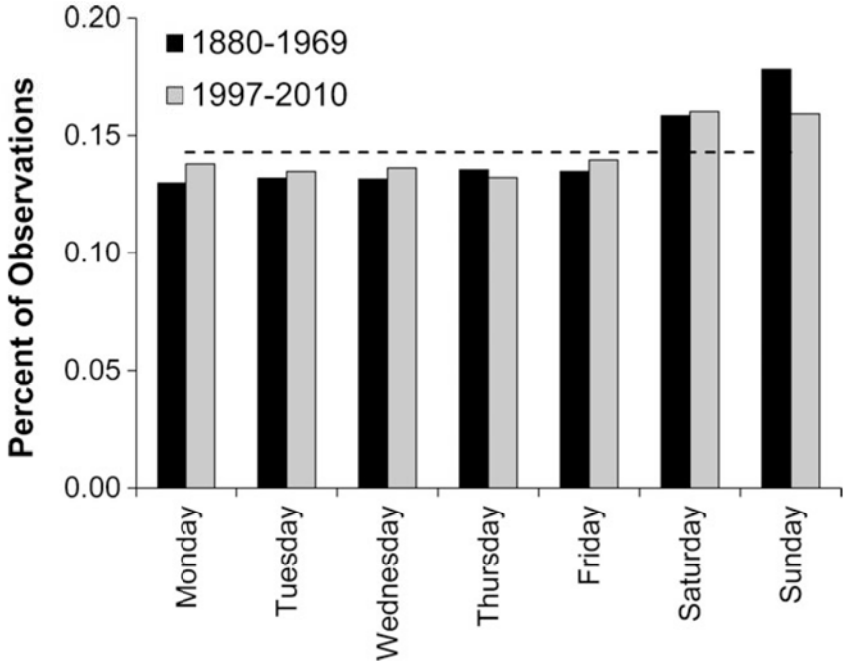

Fig. 3 Percentage of observations reported on each day of the week during our historical (*black*) and recent (*gray*) time periods in North America for all species. Note the decrease in percentage of Sunday observations between time periods. *Horizontal reference line* indicates percentage of observations expected at random (i.e., 14.3 %)

reported in both studies was the Barn Swallow; we report 39.3 % of observations made on weekends, whereas Sparks et al. (2008) report 43.8 %. There are a number of possible explanations for this disparity. First, arrival data from Europe were from "county" bird reports, perhaps being reported by bird club members gathering for weekend field trips; whereas many of the early reports from the United States (1880–1969) were made by farmers or wildlife managers observing birds during their daily routines (Merriam 1885; J. Zelt, personal comm.). Many of the recent arrivals in the United States were reported and immediately posted online (compared to county bird reports that were likely submitted by mail and later published), perhaps allowing enthusiastic birders to know when to expect charismatic species, such as hummingbirds (L. Chambers, personal comm.). Unfortunately, data used in this study did not include detailed observer information that may have allowed for demographic comparisons to be made between American and European data contributors, such as differences in observer age, income, and gender (Cooper and Smith 2010), factors that may contribute to the discretionary time observers have during the week to look for birds.

Our results suggest that weekend bias has lessened over time in North America (Fig. 3, Table 1), a finding similar to what Sparks et al. (2008) report in Europe. Weekend habits of many have changed over time, with a greater percentage of people working on weekends (Presser 1999). We suspect that, historically, people spent more time outside on Saturday and Sunday afternoons, potentially observing birds; whereas today a 'day off' may also occur during the week. It is also possible that, in recent time periods, everyday encounters with birds have increased as backyard

Table 1 Percentage of first-arrival observations reported on weekends for five species and changes in weekend bias between time periods, assessed using contingency analysis and Pearson chi-squared tests

Species	1880–1960			1997–2010			Diff.[c]	$\chi 2$	*P*-Value
	N	% Weekend[a]	Bias?[b]	*N*	% Weekend	Bias?			
Baltimore Oriole	6,085	31.2	Yes	1,293	28.9	No	2.3	2.6	0.11
Barn Swallow	2,698	40.4	Yes	726	38.4	Yes	2.0	0.1	0.33
Chimney Swift	7,070	31.8	Yes	1,230	27.9	No	3.9	7.6	0.006
Purple Martin	4,802	33.6	Yes	17,363	31.3	Yes	2.3	8.8	0.003
R.-t. Hummingbird	4,900	35.9	Yes	42,537	32.4	Yes	3.5	28.1	< 0.001
Total	25,555	33.71	Yes	63,149	31.39	Yes	2.32	35.2	< 0.001

[a] Percentage of first arrivals reported on Saturday or Sunday

[b] A difference exists between the percentage of weekend observations reported and those expected to occur at random (i.e., 28.6 %)

[c] Difference in percentage weekend observations reported between 1880–1969 and 1997–2010 time periods

Table 2 Differences in mean first arrival dates of five species calculated using weekend and weekday arrival dates. Latitude, longitude, altitude, and time period variables included as covariates in each model along with possible two-way interaction terms. Least square means compared using one-tailed t-tests

Species	Weekend arrivals[a]			Weekday arrivals[b]			Days Diff.[d]	SE Diff.	*t*-value	*P*-Value
	N	Arrival DoY[c]	SE	N	Arrival DoY	SE				
Baltimore Oriole	2,223	123.8	0.15	5,015	123.4	0.11	0.47	0.15	3.1	< 0.001
Barn Swallow	1,362	107.5	0.34	2,031	106.9	0.29	0.61	0.38	1.6	0.05
Chimney Swift	2,557	116.0	0.20	5,624	116.0	0.16	−0.03	0.2	−0.1	0.55
Purple Martin	6,929	83.1	0.16	14,944	82.8	0.13	0.3	0.17	1.8	0.04
R.-t. Hummingbird	15,335	118.8	0.09	31,517	118.6	0.08	0.3	0.08	3.6	< 0.001

[a] First arrivals reported on Saturday or Sunday

[b] First arrivals reported on Monday, Tuesday, Wednesday, Thursday, or Friday

[c] Mean arrival 'day of year' accounting for leap years; for example, '100' correlates to April 10

[d] Difference in mean first arrival date when comparing weekend and weekday first arrival reports

feeding has increased in popularity and allowed many to view birds during their daily routines (Robb et al. 2008). Weekday observations may also be increasing as more Citizen Science programs are being geared toward school-age youth (Bombaugh 2000; Delaney et al. 2008; Bonney et al. 2009), perhaps increasing the chance that first arrivals would be reported during the school week. The availability of regularly updated migration reports online (e.g., hummingbirds.net, Journey North) may encourage some contributors to be more vigilant during the week (L. Chambers, personal comm.) and increase effort among competitive birders that seek to report the first arriving bird for a given area (Schaffner 2009; Cooper and Smith 2010). Regardless of the mechanism(s) explaining this trend, we interpret a decrease in weekend first arrival reporting over time as a positive sign that first arrivals are being reported more accurately in recent time periods.

Although weekend bias was not uniform across species, it tended to decrease over time in each of the species we analyzed although change was significant for only three of the five species (Table 1). The percentage of Ruby-throated Hummingbird arrivals reported on weekends declined from 35.9 to 32.4 % between historical and recent time periods (Table 1), perhaps because of the increase in backyard bird feeding in past decades (Robb et al. 2008) and a growing interest in this species by Citizen Science monitoring projects (e.g., Journey North, hummingbirds.net, eBird), both of which could increase the likelihood that a hummingbird would be detected upon arrival (Tryjanowski et al. 2005). A similar increase in monitoring interest among Purple Martin enthusiasts (e.g., members of Purple Martin Conservation Association) may also explain the decline in first arrivals reported on weekends (i.e., 33.6 % to 31.3 %) in this species (Table 1). Baltimore Orioles and Chimney Swifts showed only a small degree of weekend bias in our historical time period and no bias in our recent time period (Table 1), perhaps because both are highly detectable. For example, Chimney Swifts fly in flocks, give notable trill calls, and occur in urban areas near people (Cink and Collins 2002); similarly, Baltimore Orioles have a unique song and are easily recognized by their bright plumage (Rising and Flood 1998).

When comparing mean first arrival dates from weekends and weekdays, we found that mean arrival dates tended to be later on weekends for four of five species (Table 2). This result supports our hypothesis that weekend bias could influence the accuracy of first arrival dates reported in many phenology studies; we also interpret this to mean that weekday arrival reports more closely approximate true first arrival dates. While we find it somewhat unlikely that a bias as small as a fraction of a day would change conclusions made in most phenology studies, including a "weekend/weekday" term as a covariate in models that assess phenology would be a simple way to account for potential weekend bias among species and make conclusions more robust. Although Sparks et al. (2008) report a weekend bias in Europe, to our knowledge, ours is the first study that quantifies the effects of weekend bias (~0.5 days) in a study of phenology. Moreover, this method may also be used to identify and account for potential weekday bias in phenology studies conducted by professional ecologists who may be more likely to sample during the week.

Many scientists are skeptical of using Citizen Science data in research unless biases associated with data collection techniques are understood and accounted for (Dickinson et al. 2010). Here, we demonstrate how a bias associated with Citizen Science data collecting can be identified and overcome, a finding that may reduce barriers to incorporating Citizen Science data into future phenology studies.

Acknowledgments We thank L. Chambers and hummingbirds.net, E. Howard and Journey North (with funding from the Annenberg Foundation), J. Tautin and the Purple Martin Conservation Association, and P. D. and G. Z. Kyle and the Driftwood Wildlife Association, for collecting and compiling thousands of recent first arrival reports. We are also grateful to the countless contributors to these Citizen Science projects for more than a decade of careful observation, without which, a study of this magnitude would not be possible. We thank J. Zelt and S. Droege for their commitment to providing and protecting historical migration records through the North American Bird Phenology Program (USGS, Patuxent Wildlife Research Center) and for their expertise and support, which underscores the vision of the hundreds of early naturalists who faithfully contributed arrival cards from 1880 to 1970. We thank Clemson University students K. Auman, C. Boaman, J. Burroughs, J.H. Collins, B. Crawford, M. Kynoch, E. Purcell, D. Stone, M-K. Spillane, and S. Taylor for transcribing arrival cards and for help with our analysis. This study was funded primarily by Clemson University and the Clemson University Creative Inquiry Program, with additional support from a Carolina Bird Club grant.

References

Beaubien E, Hamann A (2011) Plant phenology networks of citizen scientists: recommendations from two decades of experience in Canada. Int J Biometerol 55:833–841. doi:10.1007/s00484-011-0457-y

Bombaugh R (2000) From citizen scientists to engineers. J Prof Iss Eng Ed Pr 126:64–68

Bonney R, Cooper CB, Dickinson J, Kelling S, Phillips T, Rosenberg KV, Shirk J (2009) Citizen Science: a developing tool for expanding science knowledge and scientific literacy. Bioscience 59:977–984. doi:10.1525/bio.2009.59.11.9

Cink CL, Collins CT (2002) Chimney Swift (*Chaetura pelagica*). In: Poole A (ed) The birds of North America online. Cornell Lab of Ornithology, Ithaca, http://bna.birds.cornell.edu/bna/species/646. Accessed 11 October 2012. doi:10.2173/bna.646

Cooper CB, Smith JA (2010) Gender patterns in bird-related recreation in the USA and UK. Ecol Soc 15:4

Delaney D, Sperling C, Adams C, Leung B (2008) Marine invasive species: validation of Citizen Science and implications for national monitoring networks. Biol Invasions 10:117–128. doi:10.1007/s10530-007-9114-0

DeLeon RL, DeLeon EE, Rising GR (2011) Influence of climate change on avian migrants' first arrival dates. Condor 113:915–923. doi:10.1525/cond.2011.100223

Dickinson JL, Zuckerberg B, Bonter DN (2010) Citizen Science as an ecological research tool: challenges and benefits. Ann Rev Ecol Evol S 41:149–172. doi:10.1146/annurev-ecolsys-102209-144636

Fraser P (1997) How many rarities are we missing?: weekend bias and length of stay revisited. Brit Birds 90:94–101

Lehikoinen ESA, Sparks TH, Zalakevicius M (2004) Arrival and departure dates. Adv Ecol Res 35:1–31

Marani M (2010) The detection of weekly preferential occurrences with an application to rainfall. J Climate 23:2379–2387. doi:10.1175/2009jcli3313.1

Merriam CH (1885) Committee on the migration and geographical distribution of North American birds. Auk 2:117–120

Miller-Rushing AJ (2010) Wildlife watchers aid climate research: a new effort to monitor changes in wildlife phenology. Wildlife Prof 3:58–61

Miller-Rushing AJ, Primack RB, Stymeist R (2008) Interpreting variation in bird migration times as observed by volunteers. Auk 125:565–573

Presser HB (1999) Toward a 24-hour economy. Science 284:1778–1779

Qin Y, Tonnesen G, Wang Z (2004) Weekend/weekday differences of ozone, NOx, CO, VOCs, PM10 and the light scatter during ozone season in southern California. Atmos Environ 38:3069–3087

Rising J, Flood N (1998) Baltimore Oriole (*Icterus galbula*). In: Poole A (ed) The birds of North America online. Cornell Lab of Ornithol, Ithaca, http://bna.birds.cornell.edu/bna/species/384. Accessed 11 October 2012. doi:10.2173/bna.384

Robb GN, McDonald RA, Chamberlain DE, Bearhop S (2008) Food for thought: supplementary feeding as a driver of ecological change in avian populations. Front Ecol Environ 6:476–484

Schaffner S (2009) Environmental sporting. J Sport Soc Issues 33:206–229. doi:10.1177/0193723509338862

Silvertown J (2009) A new dawn for Citizen Science. Trends Ecol Evol 24:467–471

Sparks T, Huber K, Tryjanowski P (2008) Something for the weekend? Examining the bias in avian phenological recording. Int J Biometerol 52:505–510. doi:10.1007/s00484-008-0146-7

Swanson DL, Palmer JS (2009) Spring migration phenology of birds in the Northern Prairie region is correlated with local climate change. J Field Ornithol 80:351–363. doi:10.1111/j.1557-9263.2009.00241.x

Tryjanowski P, Kuzniak S, Sparks TH (2005) What affects the magnitude of change in first arrival dates of migrant birds? J Ornithol 146:200–205. doi:10.1007/s10336-005-0079-4

Visser ME, Both C (2005) Shifts in phenology due to global climate change: the need for a yardstick. P Roy Soc B-Biol Sci 272:2561–2569

Wilson WH (2007) Spring arrival dates of migratory breeding birds in Maine: sensitivity to climate change. Wilson J Ornithol 119:665–677