SHORT COMMUNICATIONS

Diurnal Timing of Bird Surveys

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Despite a massive literature on methods of surveying terrestrial birds (see Ralph and Scott 1981), there has been little quantitative analysis of what time of day such surveys should start. Surveys relying on aural detection traditionally have been started at or before sunrise, because birds are most vocal then (Robbins 1981a), but Dawson (1981) has pointed out that accurate counts are often difficult at this time, due, in part, to the number of species and individuals singing. He has recommended that surveys avoid the early morning and extend later into the day than is usual.

Most authors commenting on the timing of bird surveys have emphasized the number of birds recorded during different periods (Dawson and Bull 1975, Shields 1977, Bystrak 1981, Dawson 1981, Robbins 1981a). If the purpose is to find every individual, then this is reasonable. In most analyses, however, a proportional rather than an absolute change in density is estimated. This is necessarily true if absolute density is unknown and is often true even if absolute density can be estimated. For example, investigators may conclude that a 10% decline followed some treatment or that density was 20% lower in one habitat. If sample sizes are large enough that the normal model applies, then the relevant statistic is the coefficient of variation (cv),[(SD/$\bar{y}$)100], where $\bar{y}$ is the survey mean, and it is less clear how much advantage accrues from maximizing the number of individuals recorded. It is true that if all else were equal, a larger $\bar{y}$ would produce a smaller cv, but other things are not equal. In ecological data, the SD usually changes when the mean changes. Thus, to determine the statistical advantage of early starts, the change through time in SD/$\bar{y}$, not just the change in $\bar{y}$, must be determined.

Methods.—Two studies were conducted to measure the diurnal trends in SD/$\bar{y}$, where $\bar{y}$ = average number of individuals recorded per station. In the first study we surveyed Common Yellowthroats (*Geothlypis trichas*) and House Wrens (*Troglodytes aedon*) in east-central Ohio in rolling farmland interspersed with abandoned agricultural fields and deciduous woodlots. The wrens were nesting in boxes put up as part of a different study; yellowthroats were selected by recording all individuals within 0.35 km of stations on randomly selected roadside routes. Eight surveys—4 for yellowthroats, 4 for wrens—were conducted during 8-23 June 1982. Each survey began at 0530 and ended at 2000. One observer recorded most of the data but was relieved for 1.5-2.0 h during the middle of the day. Observers recorded the number of individuals singing during 3-min listening periods at five stations where the species was known to be present from past fieldwork. Each station was visited once every 50 min. On each day a different group of five stations was monitored. Surveys were not conducted on days when there was rain or the wind exceeded 15 km/h for more than 30 min. These restrictions are generally sufficient to insure that variation in weather has little or no effect on numbers of birds singing (Robbins 1981b).

The second data set was obtained from the North American Breeding Bird Survey (BBS) (Bystrak 1981), a continent-wide network of roadside routes, each consisting of 50 stations at which observers record all birds seen or heard for 3 min. The surveys are made in the same location each year; they are run once per year, primarily during June. Results for yellowthroats, House Wrens, Field Sparrows (*Spizella pusilla*), Indigo Buntings (*Passerina cyanea*), and Red-eyed Vireos (*Vireo olivaceus*) from all BBS routes in Ohio and West Virginia surveyed during 1978-1981 were analyzed. The sample incuded 68 routes surveyed a total of 261 times.

We calculated diurnal trends in the cv's for both data sets. In the field data, each species occurred at every station visited, which would not normally be true. To simulate stations without House Wrens or yellowthroats, we added zeroes to the data sets until the mean number of records for each species equalled the mean number of records in the BBS data (at 0630). These changes make the data sets more realistic and have a slight effect on the change in cv with time, but varying $\bar{y}$ 15-20% from the values we used does not change any of the conclusions reached below. Thus, the exact magnitude of the adjustment is of little importance.

To determine how the cv's changed with the timing of the surveys, the numbers of birds recorded per station were divided into 50 groups: those recorded at the first station of all routes, the second station, etc. The variance of the entire data set was partitioned into its within-group and between-group components, and the cv was then expressed as,

$$\mathrm{cv} = \frac{\sqrt{EV_t + V(E\bar{y}_t)}}{\bar{\bar{y}}\sqrt{n}}, \tag{1}$$

where V_t = variance of number recorded on all routes at station t, $t = 1, \ldots, 50$; EV_t = average V_t; $\bar{\bar{y}}$ = mean per station for entire data set; and n = number of stations per survey (50).

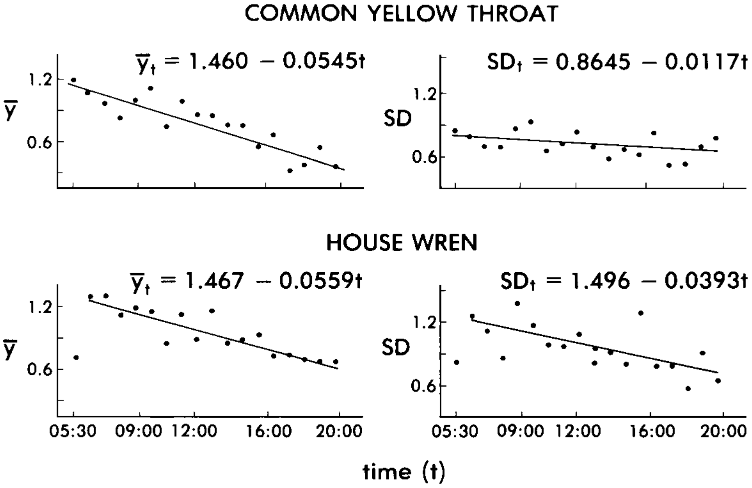

Fig. 1. Diurnal variation in $\bar{y}_t$ = average number of individuals singing per 3-min period and SD($\bar{y}_t$) for House Wrens and Common Yellowthroats estimated from all-day surveys in Ohio. Each species was present in every listening period.

To estimate the cv as a function of time, we needed to estimate EV_t and $V(E\bar{y}_t)$. In the field study, the temporal trends in SD_t and $\bar{y}_t$ were approximately linear throughout the day (Fig. 1). We therefore used a simple linear model to estimate ESD_t (and thus EV_t) and $E\bar{y}_t$ from which the cv's were estimated. In the BBS data, the trends were variable during the first hour of daylight and thereafter were approximately linear (Fig. 2). Consequently, we used the simple data during the first hour and a linear regression thereafter to estimate ESD_t and $E\bar{y}_t$.

Although BBS surveys usually end by 1030, we estimated the cv's of surveys lasting until 1230, assuming that trends in $\bar{y}_t$ and SD_t remained approximately linear. The 2-h extrapolation of the linear trends seems justified, because our fieldwork on House Wrens and yellowthroats showed that the linear trends persist far beyond 1030 (Fig. 2). Furthermore, there is no suggestion of nonlinearity around 1030 in the BBS data (Fig. 1), and, in any case, a 4.5-h survey ending at 1230 is based largely on the period before 1030 for which we do have empirical estimates of the trends.

Results.—Surveys starting at 0530 and 0600 had nearly identical cv's; none of the differences exceeds 0.01 (Table 1). Delaying the start until 0700 caused little or no increase in 4 of the 7 data sets, an increase of about 0.02 in one case (Field Sparrows), and increases of 0.033 and 0.045 in the remaining two cases. Delaying until 0800 caused virtually no increase in the cv in some cases but more than 0.10 increase in others. We were able to assess surveys starting at 1200 only from our field data; the increases were about 0.05 and 0.07. The most important of these results is that in all of the data sets a delay in starting until 0700 did not substantially reduce precision.

How large an increase should an investigator be willing to tolerate? The answer depends partly on how the difference in cv's is interpreted. Because the confidence interval, expresed as a proportion of the mean, is a simple multiple of the cv, then the change in confidence interval is equal to the change in cv. Thus, the cv for Field Sparrows increased 6.5% from 0.338 to 0.360, and this means that the confidence interval would be 6.5% longer if the survey started at 0800. Thus, one basis for deciding whether or not to start at 0800 is whether or not an increase of 5–10% in the confidence interval is tolerable.

A second way of evaluating the difference is to determine how much more time would have to be spent sampling to achieve comparable precision. The answer is approximately the square of the ratio of the cv's. In the example, $(0.360/0.338)^2 = 1.13$, indicating that 13% more time would have to be spent if the survey started at 0800 to achieve precision equal to a survey starting at 0530. The reason this is only an approximate result is that extending the survey increases the within-survey variance, tending to increase the cv. Simulations showed that this was a small effect as long as the increase in survey time was less than 15–20%. We suspect that most investigators have not firmly established the particular level of precision they require and that therefore the first interpretation will be more meaningful.

Discussion.—It is well known that even the best observer does not record all of the birds audible during a 3-min period. There is also a strong suspicion that the fraction of birds recorded is lower during the "dawn chorus" (Bystrak 1981), and there is now experimental evidence that the fraction of birds recorded changes with the number of conspecifics singing during the period (Bart and Schoultz 1984). Thus,

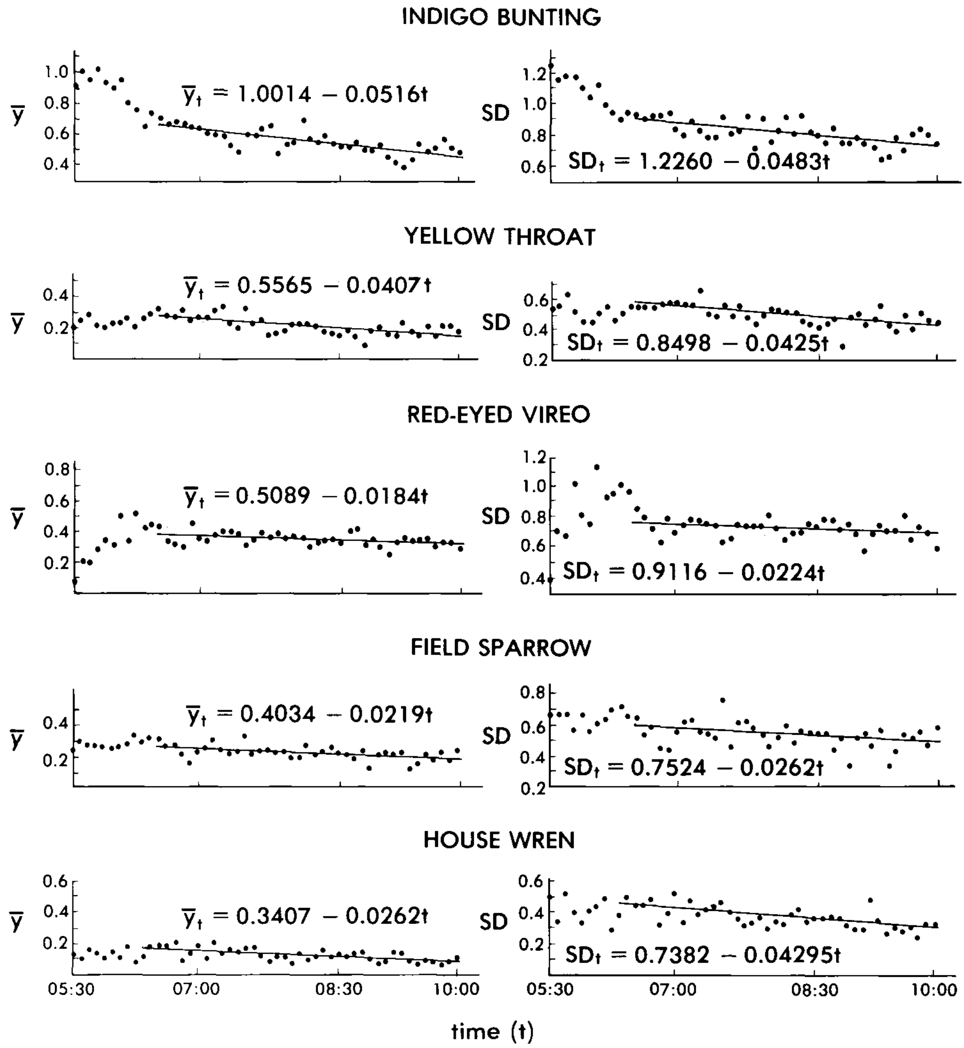

Fig. 2. Diurnal variation in $\bar{y}_t$ = average number of individuals singing per 3-min period and SD($\bar{y}_t$) for five species. Data obtained from the Breeding Bird Surveys in Ohio and West Virginia, 1978–1981.

Table 1. Effect of survey timing on the coefficient of variation of the number of individuals recorded per 3-min period. Each survey has 50 periods and lasts 4.5 h.

Species	Number of records	Starting time				
		0530	0600	0700	0800	1200
Yellowthroat						
BBS	2,966	0.318	0.325	0.363	0.426	—
This study	277	0.296	0.298	0.304	0.310	0.347
House Wren						
BBS	1,644	0.465	0.473	0.498	0.595	—
This study	332	0.534	0.537	0.545	0.554	0.607
Field Sparrow	3,091	0.338	0.342	0.360	0.383	—
Red-eyed Vireo	4,816	0.305	0.295	0.295	0.302	—
Indigo Bunting	8,376	0.199	0.203	0.211	0.220	—

observer efficiency in recording the audible birds is usually less than 100% and sometimes varies in response to the number of birds present. One reason for carrying out two studies was to determine whether or not this variation has a strong effect on conclusions about timing of surveys. In the field study, all birds singing were recorded, whereas the Breeding Bird Survey data were collected under standard field conditions. The similarity of the conclusions reached in the two studies indicates that, perhaps surprisingly, the coefficient of variation is not affected substantially by changes in observer efficiency. Of course, changing observer efficiency does cause bias in estimates of population change, and this alone may be sufficient reason to avoid the dawn chorus.

In general, it seems difficult to predict the exact change in cv with starting time from an inspection of the trends in singing behavior. Red-eyed Vireos in the BBS data and House Wrens in our field data both showed depressed song in the first hour, but this increased the vireo's cv slightly while not seeming to affect the House Wren's. Indigo Buntings sang very actively during the first hour, which might be expected to decrease their cv, but this did not happen (Table 1), apparently due to the increase in within-survey variance.

If the trends are linear and have small slopes, however, then it does seem possible to make reliable predictions about the effect on precision of a change in survey time. In such cases, the cv can be written

$$\mathrm{cv} = \frac{\sqrt{(a + bt)^2 + (l^2/12)(b^2 + d^2)}}{\sqrt{ml}\,(c + dt)} \simeq \frac{a + bt}{\sqrt{ml}\,(c + dt)}, \qquad (2)$$

where a, c = intercept of linear regression of SD_t and $\bar{y}_t$, respectively; b, d = slope of linear regression of SD_t and $\bar{y}_t$, respectively; l = length of route in hours; m = number of listening periods per hour; and t = mid-point of survey.

It may be verified from our regression coefficients (Figs. 1, 2) that the error caused by the approximation above is less than 2% in all cases. The point of equation 2 is that the cv can be estimated to a reasonable level of accuracy from the standard deviation of numbers recorded in a small time period in the middle of the survey and the mean number recorded in that period. Furthermore, the SD is easily calculated, because the number heard is a multinomial random variable, and the cv can therefore be written

$$\mathrm{cv}_t = \sqrt{\frac{1}{ml}\left(\frac{\Sigma\, y^2 p_{ty}}{\bar{y}_t^2} - 1\right)} \qquad (3)$$

where $y = 1, 2, 3, \ldots,$ maximum number heard at a station; and p_{ty} = proportion of stations with y birds recorded.

Investigators can test the assumptions underlying equation 3 and determine the change in cv with starting times (if the assumptions hold) by determining p_i, $i = 1, 2, \ldots$ for each of several times during the day. For each period calculate the mean number heard, ($\bar{y}_t = \Sigma\, ip_i$) and its standard deviation, $(\Sigma\, i^2p_i - \bar{y}_t^2)^{0.5}$, and plot them. If the trends are approximately linear, as occurred in this study, then the cv's for any proposed survey are given by equation 3, evaluated at the mid-point of the survey, and the change in cv provides a means of evaluating the effect of starting time on the precision of the survey.

It is difficult to be certain how general the results of this study are. Robbins (1981a) reported the change in the number of individuals reported during the 5 h of the BBS for several dozen species. Most passerines showed patterns similar to the ones shown by the species we studied. This suggests that, in many other species, starting the survey 1-2 h after dawn probably has little effect on the cv. There are certainly exceptions, however (e.g. many thrushes), so, when possible, cases should be investigated individually.

In summary, the effect of starting time involves the variance of station totals as well as the mean. Because the variance tends to decrease with the mean, it is difficult to predict the effect of starting later, when fewer birds are singing, without studying the issue quantitatively. In this study, the cost of starting 30-60 min after dawn, rather than 30 min before dawn, appeared to be slight. This may not always be the case, however, and we present a simple means for investigating the problem.

LITERATURE CITED

BART, J., & J. D. SCHOULTZ. 1984. Reliability of singing bird surveys: changes in observer efficiency with avian density. Auk 101: 307-318.

BYSTRAK, D. 1981. The North American breeding bird survey. Pp. 34-41 *in* Estimating the numbers of terrestrial birds (C. J. Ralph and J. M. Scott, Eds.). Stud. Avian Biol. 6.

DAWSON, D. G. 1981. Counting birds for a relative measure (index) of density. Pp. 12-16 *in* Estimating the numbers of terrestrial birds (C. J. Ralph and J. M. Scott, Eds.). Stud. Avian Biol. 6.

———, & P. C. BULL. 1975. Counting birds in New Zealand forests. Notornis 22: 101-109.

RALPH, C. J., & J. M. SCOTT, Eds. 1981. Estimating the numbers of terrestrial birds. Stud. Avian Biol. 6.

ROBBINS, C. S. 1981a. Effect of time of day on bird activity. Pp. 275-286 *in* Estimating the numbers of terrestrial birds (C. J. Ralph and J. M. Scott, Eds.). Stud. Avian Biol. 6.

———. 1981b. Bird activity levels related to weather. Pp. 301-310 *in* Estimating the numbers of terrestrial birds (C. J. Ralph and J. M. Scott, Eds.). Stud. Avian Biol. 6.

SHIELDS, W. M. 1977. The effect of time of day on avian census results. Auk 94: 380-383.

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