MONITORING TRENDS IN BIRD POPULATIONS: ADDRESSING BACKGROUND LEVELS OF ANNUAL VARIABILITY IN COUNTS

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ABSTRACT: Point counting has been widely accepted as a method for monitoring trends in bird populations. Using a rigorously standardized protocol at 210 counting stations at the San Joaquin Experimental Range, Madera Co., California, we have been studying sources of variability in point counts of birds. Vegetation types in the study area have not changed during the 11 years of the study, so annual variability in counts must refelect some normal range of variation associated with other factors. Here we show that counts of breeding species varied markedly from year to year, we suspect primarily in response to annual variation in precipitation and secondarily to variation in temperature. With ample data, practitioners can examine various periods of time for creating running averages to smooth background levels of annual variation in counts, thus establishing a baseline abundance for comparative purposes. We have explored running averages in our data, based on 2- to 7-year periods, with the objective of attaining a coefficient of variation of 10% or less in mean annual counts. Twenty-two of 34 species met this criterion, based on 7-year running averages. Linear and exponential extrapolations from observed data suggested that 11-22 years would be needed to obtain baseline data for all breeding species in our dataset.

Key words: California, oak-pine woodlands, monitoring, bird numbers, baseline data

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Point counting has been used for decades as a method to quantify the abundance of birds. The method was developed in a rigorous way by French ornithologists (Blondel et al. 1970, 1981; Ferry 1974; Blondel 1975, 1977) and has since become one of the standard methods for monitoring trends in bird populations. Probably its most extensive application is in the North American Breeding Bird Survey (BBS) (Robbins and Van Velzen 1967, Bystrak 1981). More recently it was adopted as the method of choice under the Partners in Flight program to be used in the development of local or regional monitoring programs (Ralph et al. 1995).

An essential part of interpreting count data relative to population trends is the normal range of annual variation in the population. For this reason, practitioners have endeavored to establish baseline estimates of this variation, which can then be taken into account when attempting to determine whether observed trends are more than normal, annual variation in abundance. Here we report observed annual variation in counts of bird species during 11 years of point counting at 210 stations in oak-pine (*Quercus-Pinus*) woodlands at the San Joaquin Experimental Range (SJER) in foothills of the western Sierra Nevada. The environment sampled has not undergone evident change during that period, so observed variations in species' abundances are assumed to result from other factors. The primary objective of our paper is to explore the range of annual variation in counts in terms of the number of years needed to establish a useful baseline period. Although this is an exploratory analysis in an ongoing study, we think that 11 years of data should provide some meaningful insights into the question of an adequate baseline period.

STUDY AREA

SJER is located in the western foothills of the Sierra Nevada, approximately 31 km northeast of Madera, Madera, Co., California. It has an area of approximately 1,875 ha and ranges in elevation from 215 to 520 m. The climate is characterized as Mediterranean, with cool, wet winters and hot, dry summers. Mean annual precipitation from 1934 to 1994 was 46.7 cm, with about 95% of that falling as rain from October through April. Snow is unusual, and daily maximum temperatures have exceeded freezing on all but 2 days in 57 years of weather data taken at the headquarters area. A sparse woodland overstory of blue oak (*Quercus douglasii*), interior live oak (*Q. wislizenii*), and foothill pine (*Pinus sabiniana*) covered most of SJER. An understory of scattered shrubs included mainly buckbrush (*Ceanothus cuneatus*), chapparral whitehorn (*C. leucodermis*), redberry (*Rhamnus crocea*), and Mariposa manzanita (*Arctostaphylos mariposa*). In a few smaller patches, the overstory was primarily blue oak, and a shrub understory was meager or missing. Some areas of typical annual grassland extended throughout the remainder of SJER where the overstory and understory were not dense enough to shade them out or were lacking altogether. SJER has been lightly to moderately grazed since about 1900.

METHODS

Seven lines with 30 counting stations each were established primarily in oak-pine vegetation throughout SJER, with the aid of aerial photos and topographic maps (scale = 13,500:1; contour interval = 38 m). Counting stations were at least 200 m apart along the same line and between the separate lines. Although this was closer spacing than is ideal for independent samples, it was used here to allow 6 counts per hour. All counting stations were clearly identified by placement of large plastic tags wired to trees, shrubs, fences, and occasionally to steel fence posts set in open areas specifically for that purpose. Numerous additional tags placed between stations along a line gave directions for continuing along the line; a booklet described in detail the location of each tag, what it was wired to, and the distance and direction to the next tag along the line. With this system, observers unfamiliar with the lines were able to follow them quickly and locate the counting stations.

Results reported here are based on counts, with unlimited distance, by 3-7 observers each year from 1985 through 1995. Observers were carefully selected to be expert birders and especially to be expert in the identification of birds by sound. In addition, they successfully completed an intensive training period to sharpen their identification skills and to familiarize them with details of the method to be used. Observers were randomly assigned to lines (lattice design) in such a way that all sampled different lines each day and eventually sampled all 7 lines. Each observer's hearing was tested each field season.

Recording of birds at the counting stations along a line began at the first station on the line at 10 min after official sunrise. At each station, observers recorded the date, time, wind velocity, percent cloud cover, and rain activity. Temperature was recorded at the first and last counts each day. After completing a 5-min count, an observer moved quickly to the next station and began

Table 1. Point counts of breeding birds at the San Joaquin Experimental Range, Madera County, California, including only those species with mean annual counts of 25 or more. Data for 1986 and 1987 are means of two full samples of the point-counting array.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
RESIDENTS										
Red-tailed hawk	45.7	55.9	49.2	83.5	62.7	65.1	85.3	76.3	80.3	79.8
California quail	84.3	134.4	171.7	338.5	274.3	246.4	231.0	437.8	322.0	396.5
Mourning dove	157.3	139.9	181.5	317.5	225.6	208.4	224.0	256.3	189.8	249.5
Anna's hummingbird	24.7	24.0	21.2	36.5	23.3	33.4	29.8	39.5	44.8	31.8
Acorn woodpecker	252.0	363.8	504.5	907.8	685.4	427.9	481.5	747.5	916.0	813.8
Nuttall's woodpecker	10.0	22.9	51.5	40.0	33.3	45.3	30.3	52.5	45.5	58.0
Western scrub-jay	126.0	158.6	166.9	418.3	232.0	252.6	253.0	266.8	313.0	277.0
Common raven	17.0	21.9	30.8	51.5	62.9	67.7	64.8	100.8	140.3	83.3
Plain titmouse	208.3	282.8	356.3	531.3	422.7	449.4	502.0	624.0	503.0	433.3
Bushtit	36.3	86.5	92.5	110.3	23.3	57.0	49.8	107.0	123.3	122.8
White-breasted nuthatch	65.3	122.4	150.0	248.8	164.0	122.9	110.3	154.8	178.3	194.8
Bewick's wren	96.7	112.2	63.9	111.3	88.4	89.6	33.8	57.0	35.0	75.8
Western bluebird	40.3	61.5	70.2	93.3	55.4	56.7	60.0	67.5	55.5	65.5
European starling	97.7	163.8	177.9	259.8	132.7	155.0	190.8	216.0	242.0	281.5
California towhee	76.7	77.7	69.4	117.0	96.6	76.1	87.5	102.3	113.8	117.8
Lark sparrow	24.0	27.1	29.4	45.8	20.1	17.3	33.0	45.0	33.0	33.3
Western meadowlark	33.7	57.6	65.8	79.0	73.7	68.7	64.3	49.8	41.0	43.5
Brown-headed cowbird	77.3	54.7	65.1	108.8	58.7	49.6	36.3	49.0	54.5	54.0
House finch	18.0	29.9	74.8	140.3	107.1	105.9	208.8	223.0	188.5	173.8
Lesser goldfinch	66.7	144.9	202.2	134.5	120.4	113.3	248.0	214.5	141.3	110.3
MIGRANTS										
Turkey vulture	51.0	53.3	60.2	81.3	88.1	73.3	97.0	55.3	116.3	50.8
Ash-throated flycatcher	167.7	159.7	132.0	279.8	189.7	177.4	159.8	239.0	276.5	168.0
Western kingbird	44.7	58.3	55.8	115.3	63.6	49.6	44.5	91.8	62.3	64.3
Violet-green swallow	138.0	174.1	202.7	223.5	195.1	271.9	199.8	162.5	225.0	142.5
House wren	120.3	138.5	91.2	88.8	45.1	22.4	29.0	131.5	116.8	146.8
Bullock's oriole	82.0	61.3	56.4	82.8	49.4	40.3	39.5	76.8	66.3	59.8

[1] Lowest annual count/highest annual count x 100. This standardizes the range of variation across species on a high count of 100 individuals. Note that high counts are more than twice the low counts for 23 of the 26 species.

counting 10 min after counting began at the first station. By adhering to this schedule, an observer recorded birds at 6 stations per hour, so all 30 stations on a line were sampled within 5 hours, and the entire system was sampled by each observer in 7 mornings. Counts were not done during rainy mornings, and counts done during days when wind consistently exceeded 32 km/hour (by Beaufort scale) were repeated the following count day. Windy-day counts were not included in the present analysis. The counting period usually began in the last week of March and continued through April, although it extended into the first week of May in 2 years. This corresponded with the peak period of nesting by most resident breeders at SJER.

Annual counts are means of the total numbers of each species tallied over all 210 counting stations each year, averaged across all observers. The coefficient of variation (CV) is our primary measure of variability, as it is a relative measure that standardizes variation across a range of samples that differ in absolute value. The majority of CVs taken from anatomical measures range from 4 to 10%, with larger values tending to indicate nonhomogenous samples (Simpson et al. 1960:89-95).

1995	Mean	SD	L/H[1]
91.3	70.5	15.5	50.1
397.8	275.9	115.0	19.3
217.8	215.2	49.4	44.1
50.8	32.7	9.5	41.7
739.3	621.8	226.5	27.5
65.3	41.3	16.2	15.3
292.0	250.6	81.3	30.1
116.0	68.8	39.1	12.1
475.5	435.3	117.0	33.4
121.5	84.6	36.9	18.9
164.5	152.4	48.1	26.3
77.3	76.5	270.6	30.1
74.3	63.7	13.4	43.2
236.0	195.7	56.8	34.7
99.3	94.0	17.4	58.9
23.5	30.1	9.2	37.8
48.8	56.9	14.6	42.7
58.5	60.6	19.0	33.4
243.3	137.6	77.0	7.4
129.0	147.7	52.9	26.9
94.3	74.6	22.4	43.7
202.8	195.7	49.1	47.2
70.0	65.5	21.2	38.6
217.3	195.7	39.6	50.8
150.3	98.2	47.0	14.9
52.3	60.6	15.2	47.7

For this reason, we accept a CV of 10% or less as a basis for determining the number of years needed to establish a baseline abundance for a monitoring program.

RESULTS

During the counts over the 11 years of our study, we detected 57 of the 58 species of birds that are known or believed to breed at SJER; 47 of those species were detected in all years, and 4 were detected in 10 of the 11 years. Mean total counts ranged from a high of 621.8 for acorn woodpeckers (scientific names in Appendix 1) to a low of 0.01 for western screech-owls. Thirty-four species averaged at least 10 detections per year and 26 averaged at least 25 detections (Table 1). CVs ranged from a high of 331% for western screech-owls to a low of 20.3% for violet-green swallows, and they were negatively correlated with mean annual counts ($r = -0.31$, $P = 0.081$). Because species with mean annual counts of 10 or less tended to have high to very high CVs (Fig. 1), our estimates of the number of years needed in a sample to attain a CV $\leq$ 10 have been based on the subset of 34 species with annual counts of at least 10.

Annual Variability Within Species

Mean total counts of individual species varied markedly across years, with high-count years exceeding low-count years by as much as 104 times (red-winged blackbird); 23 of the 26 species with mean annual counts of at least 25 had high counts more than double the low counts. Counts of most permanent resident breeders showed 2 marked peaks and 2 low points (e.g., acorn woodpecker, Fig. 2A). Although absolute values of the total counts usually differed markedly among species (Fig. 2A), scaling values to percentage changes revealed that relative amplitudes of change tended to be similar (Fig. 2B). Similar results were observed for migrant

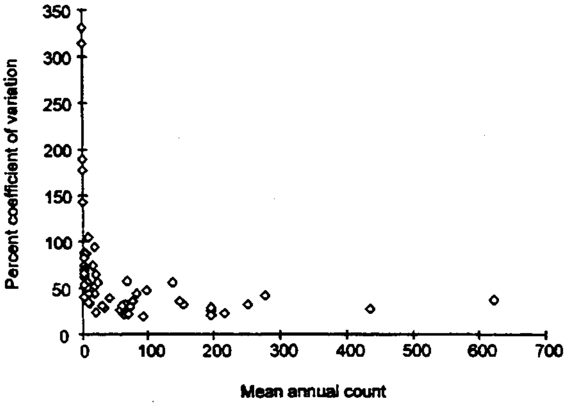

Fig. 1. Relationship between percent coefficient of variation and the mean annual count of 57 bird species known or believed to breed at the San Joaquin Experimental Range, Madera County, California. Values are significantly correlated ($r = -0.31$, $P = 0.0181$).

breeders. Although a few species did not exhibit changes coinciding with the patterns shown in Figure 2, most did, and the pooled counts of resident breeders and migrant breeders produced similar patterns (Fig. 3A,B).

Smoothing Annual Variability

Running averages provided a relatively simple way to smooth the sort of variability observed in these counts. We explored this option by noting the effect on CVs associated with running averages of 1, 2, 3, 4, 5, 6, and 7 years for the 34 species with a mean annual count ≥ 10 (Fig. 4). Sample sizes ranged from 11 (years) for CVs based on a single year to 5 for CVs based on a 7-year running average. We did not extend this analysis to running averages of 8 or more years because of the small sample sizes involved.

Violet-green swallows, western bluebirds, and canyon wrens attained CVs <10 with 3-year running averages, and CVs for 22 of the 34 species had dropped to 10 or below with running averages of 7 or fewer years. Estimating the baseline period needed for the 13 remaining species, however, was problematic because it required extrapolation from the existing data. We explored 3 curve-fitting methods linear, log, and exponential to predict the number of years needed in the running average to lower the CV to 10 or less (Fig. 5) for all 34

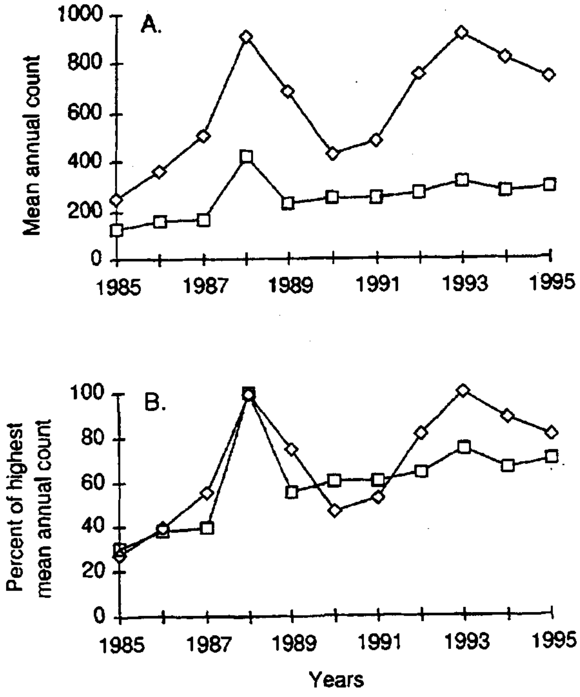

Fig. 2. Variability in mean annual counts of acorn woodpeckers (diamonds) and western scrub-jays (squares) at the San Joaquin Experimental Range, Madera County, California. Actual counts are plotted in A, and these are adjusted to the same proportional scale in B.

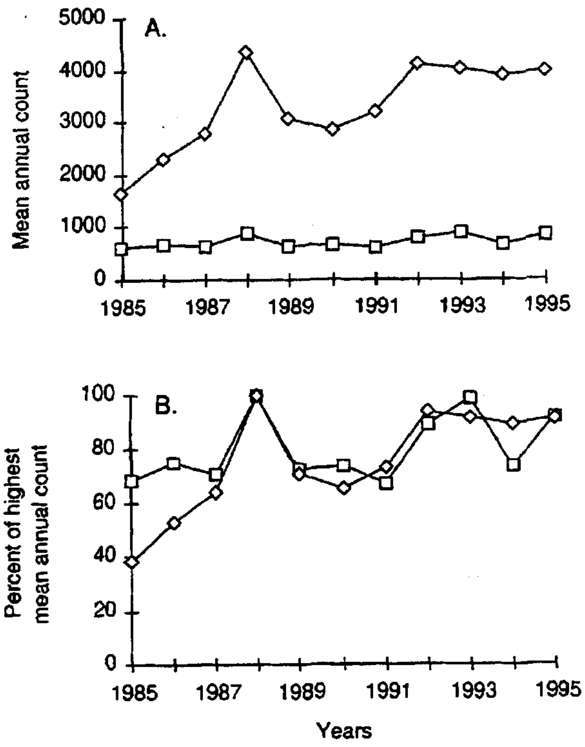

Fig. 3. Variability in mean annual counts of all resident breeders (diamonds) and all migrant breeders (squares) at the San Joaquin Experimental Range, Madera County, California. Actual counts are plotted in A, and these are adjusted to the same proportional scale in B.

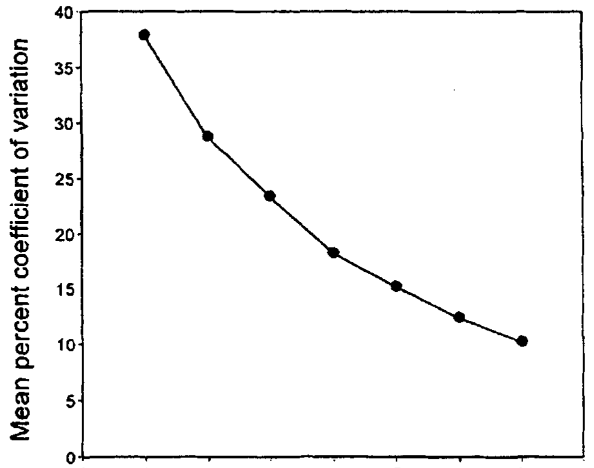

Fig. 4. Mean percent coefficient of variation in counts at the SanJoaquin Experimental Range, Madera County, California, as a function of the number of years in a running average. Results are the means of the 22 species that attained a CV≤ 10 within a 7-year running average. The sample size was 11 for the 1-year average and declined by 1 for each increase in the number of years in the running average.

species in our sample. Among that group, the number of years needed to attain a CV ≤ 10 was not correlated with mean annual count for any of the extrapolation models explored (linear: $r = -0.10$, $P = 0.59$; log: $r = -0.11$, $P = 0.55$; exponential: $r = -0.09$, $P = 0.60$).

Highest R^2 values were produced for 7 species by the exponential model, for 1 species by the log model, and for 4 species by the linear model; R^2 values averaged 0.956 for the exponential fits, 0.944 for the log fits, and 0.915 for the linear fits. Linear curve-fitting produced the shortest running averages, exponential curve-fitting produced the longest, and the fits by log curve-fitting were intermediate. Because our objective was to find a range of possibilities that bracketed the true period needed to attain a CV ≤ 10, we report here only the results of the exponential and linear modeling.

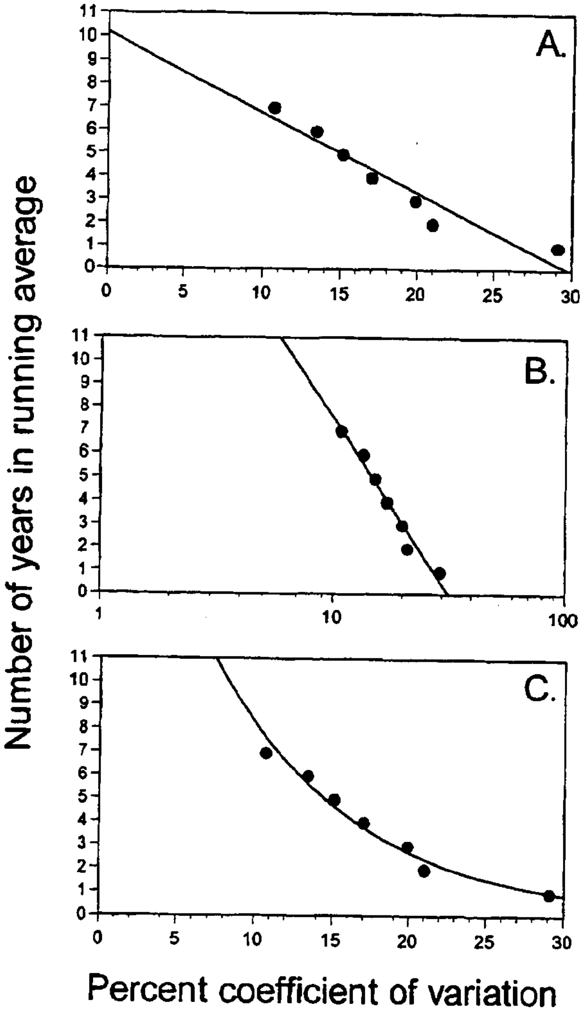

Fig. 5. An example from Anna's hummingbird of the best fits of the results from running averages to a linear model (A), a logarithmic model (B), and an exponential model (C) at the San Joaquin Experimental Range, Madera County, California.

If the extrapolated linear and exponential curves actually bracketed the true variability in the period required to reach baseline, 50% of the 34 species with annual counts of at least 10 would reach baseline (CV ≤ 10) within 6-7 years, 90% would reach it within 8-12 years, and all species would reach it within 10-22 years (Fig. 6). Both models, however, appeared to be optimistic when compared with the empirical results. Six species that did not reach a CV ≤ 10 within the calculated 7-year running average should have done so according to the linear model, and 3 should have done so according to the exponential model. Because the observed curve for the 1- to 7-year running averages suggested an exponential curve (Fig. 4) and the exponential model generated the highest R^2 values, we suspect that the true period to baseline is best projected by an exponential model.

DISCUSSION

Annual Variability in Counts

It was not an objective of our paper to explore possible reasons for the marked variability in annual counts of these species. The major factor, however, was probably annual variation in precipitation (Verner et al., in prep.), and we think that annual variation in temperature may sometimes be a factor for some species. We also suspected that the density of a breeding population, itself, resulted in biased counts that tended to amplify the real swings in abundance noted in these populations. Several studies have shown that territorial defense and advertisement, especially singing, are more intense at high densities than at low densities (e.g., LePerrier and Haugen 1972; Marion 1974; Sorola 1984; Verner, pers.

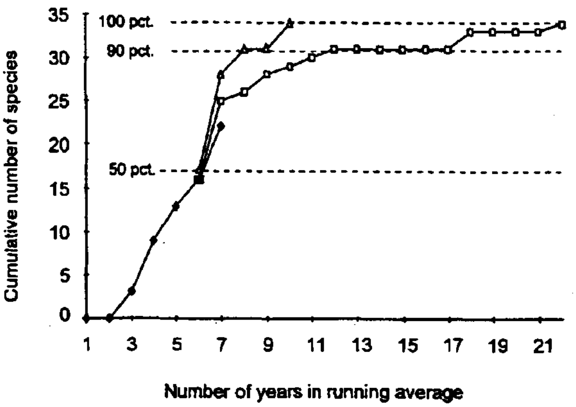

Fig. 6. Species accumulation curves at the San Joaquin Experimental Range, Madera County, California, based on the number of species attaining a CV = 10 as a function of the number of years in the running average. Solid diamonds are based on empirical results. Open triangles depict results of extrapolating from a linear model; open squares depict results of extrapolating from an exponential model.

obs.). This could lead to double counting of some individuals during population highs and to missing individuals at population lows. In combination, then, these effects may tend to inflate counts when populations are high and conditions are good, and to deflate counts when populations are low and conditions are poor.

We cannot completely rule out observer effects, but we think that this source of bias was well controlled in this study (e.g., Verner and Milne 1989). In addition, annual variability in the counts of 2 persons who were on the census team over a series of years follows the same patterns shown by all observers combined.

Accounting for Background Variation When Monitoring Population Trends

The magnitude of population changes observed over short periods in our study caution against reaching conclusions about the meaning of population trends without many years of sampling. A fundamental need of any monitoring program is sufficient knowledge about the typical level of a population the baseline against which any observed future trends can be interpreted. Many monitoring efforts lack a baseline or rely on a single year of pretreatment data before monitoring begins. When asked by managers what we would recommend as a minimum baseline period, we usually respond with something like "As many years as you can, but at least 5 years." Based on the data from this study, neither of those options seems very helpful.

In only 2 (residents) or 3 years (migrants), populations of both migrant and resident breeders in our study area declined to an average of 66% of their peak levels (Fig. 3), then rebounded to near the previous peak levels in another 2 years. A 5-year baseline period seems of little value, at least in this instance. Assuming that CVs of annual counts provide a useful way to estimate the needed baseline period, and further assuming that attaining a CV of 10% or less will assure a useful baseline period, we would have to recommend baseline periods on the order of 10-22 years. Excluding species whose numbers increased steadily through the study (common raven and house finch) and species strongly dependent on wetland conditions (red-winged blackbird) allows a more optimistic recommendation of 8-12 years for a baseline period. Note, however, that 12 years of sampling were needed to attain 5 samples for the 8-year running average, and a sample size of only 5 is probably marginal.

Among other issues, our result argues forcefully against the value of studies that compare only pre- and post-treatment counts to evaluate effects of a treatment on birds. This is true because few if any such monitoring efforts last long enough to establish a good baseline, either before or after the treatment. Moreover, if the treatment substantially alters the environment in question, and post-treatment sampling must last up to 12 years, the vegetation will be undergoing seral change during that period. Over time, the procedure mixes data relevant to the treatment with data relevant to seral changes in the habitat. The solution, of course, is to identify treated and untreated (control) areas and to monitor populations in both areas before and after treatment. Controls in space can be very useful in accounting for variability in time.

Uncommon to Rare Species

Our analysis was based on the subset of 34 breeding species in our database with mean annual counts of at least 10. This left another 23 species that were not examined because their counts were too small and too variable for analysis. And yet it is species such as these that are likely to raise concerns because of their low numbers. Routine monitoring, based on annual counts designed to sample whole bird communities, such as that reported here, probably has little value for an understanding of the status of rare and uncommon species. More direct and more intensive studies of the individual populations of such species would be needed to ascertain their status. Such is the case, for instance, with northern goshawks, peregrine falcons, willow flycatchers, least Bell's vireos, and many other species that are believed to be declining in abundance.

Conclusions

In spite of the cautions apparently raised by results of our study, it is not realistic to suggest that we discontinue all monitoring efforts that cannot be continued long enough for us to understand the frequency and extent of background variation in population numbers. Instead, we encourage careful consideration and appreciation of what these results mean to a monitoring program. Every effort should be made to obtain useful baseline data, and practitioners should be cautious about drawing inferences from data based on just a few years of sampling. It is evident from our study that the populations studied here had the resiliency to bounce back quickly from what appeared to be severe declines in abundance.

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Appendix 1. Common and scientific names of species mentioned in the text.

Common name	Scientific name
Turkey vulture	*Cathartes aura*
Northern goshawk	*Accipiter gentilis*
Red-tailed hawk	*Buteo jamaicensis*
Peregrine falcon	*Falco peregrinus*
California quail	*Callipepla californica*
Mourning dove	*Zenaida macroura*
Western screech-owl	*Otus kennicottii*
Anna's hummingbird	*Calypte anna*
Acorn woodpecker	*Melanerpes formicivorus*
Nuttall's woodpecker	*Picoides nuttallii*
Willow flycatcher	*Empidonax traillii*
Ash-throated flycatcher	*Myiarchus cinerascens*
Western kingbird	*Tyrannus verticalis*
Violet-green swallow	*Tachycineta thalassina*
Western scrub-jay	*Aphelocoma californica*
Common raven	*Corvus corax*
Plain titmouse	*Parus inornatus*
Bushtit	*Psaltriparus minimus*
White-breasted nuthatch	*Sitta carolinensis*
House wren	*Troglodytes aedon*
Bewick's wren	*Thryomanes bewickii*
Western bluebird	*Sialia mexicana*
European starling	*Sturnus vulgaris*
Least Bell's vireo	*Vireo bellii pusillus*
California towhee	*Pipilo crissalis*
Lark sparrow	*Chondestes grammacus*
Red-winged blackbird	*Agelaius phoeniceus*
Western meadowlark	*Sturnella neglecta*
Brown-headed cowbird	*Molothrus ater*
Bullock's oriole	*Icterus bullockii*
House finch	*Carpodacus mexicanus*
Lesser goldfinch	*Carduelis psaltria*