Population Status and Trends of Northern Bobwhite (*Colinus virginianus*) in Ohio: 1984-2004

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Abstract. We assessed the status and trends of northern bobwhite (*Colinus virginianus*) populations in Ohio from 1984-2004 (21 years). Bobwhite abundance indices were obtained from surveys conducted on secondary roads. The number of roads surveyed per year ranged from 69 to 209 (with 12 stops each). We used Poisson regression with generalized estimating equations and a Generalized Additive Model to analyze bobwhite population trends. Bobwhite populations in Ohio declined 9.3% / year (95% CI = 7.3% -11.2%). Overall, populations declined 76% (95% CI=68-82%) over the 21-year period. We also compared annual trends during the same period among 10 weather regions in the state. At least six weather regions showed declining population trends, but analyses for the remaining four regions were inconclusive. We mapped the distribution and abundance of bobwhites in Ohio using abundance indices from surveys conducted during 1985, 1992, and 2002. These maps revealed that the bobwhite range contracted as populations declined during 1984-2004. The current core area of bobwhite abundance is located in Southwestern Ohio, where 16 counties are open for hunting. However, bobwhite distribution shifted eastward within Southwestern Ohio during 1984-2004. Adjacent counties that are currently closed to hunting lie mostly outside the highest abundance zone. We recommend bobwhite population surveys of high resolution on counties open to hunting, as well as surrounding counties where hunting has recently been closed. However, lower resolution efforts, such as site occupancy surveys, should be conducted outside those areas to detect range expansion.

INTRODUCTION

The northern bobwhite (*Colinus virginianus*) is one of the most important upland game species in North America. However, northern bobwhite (hereafter bobwhite) populations have declined range wide since the 1930s (Leopold 1931, Errington and Hamerstrom 1936) to the present (Williams and others 2004). These population declines have been associated with the loss of grasslands caused mainly by urbanization and intensive agriculture (Brennan 1991, Brennan and Kuvlesky 2005). Additionally, bobwhite populations in northern latitudes may suffer the cumulative effect of substantial winter mortality due to severe winter weather (Peterjohn 2001). Thus, the decline of bobwhite population has been a concern of game management.

In Ohio, bobwhites probably did not appear until the nineteenth century (Wheaton 1882, Peterjohn 2001). However, the conversion of forest land to open farmland in combination with mild winters allowed bobwhites to expand northward into the Great Lakes region during 1840s and 1850s (Peterjohn 2001). By the 1880s, bobwhites were considered an abundant resident in Ohio, and populations peaked between 1875 and 1900 (Wheaton 1882, Peterjohn 2001). Early in the 20th century, bobwhite populations experienced noticeable cyclic fluctuations, and by the first half of the 1930s, populations reached "the peak of the century" (Kendeigh 1933, Hicks 1935). But the severe winter of 1935-1936 decimated bobwhite populations and never since have they reached previously attained densities (Baird 1936, Trautman 1940).

By the second half of the 20th century, bobwhites became locally distributed in northern counties and were common only in some southern counties in Ohio (Campbell 1968, Newman 1969, Peterjohn 2001). Relatively mild winters during 1970-1975, favored bobwhite populations when the birds became fairly numerous, particularly in the southern half of Ohio (Peterjohn and Rice 1991). However, the severe winters of 1976-1977 and 1977-1978 dramatically reduced bobwhite populations by more than 90% (Peterjohn 2001). Consequently, bobwhites maintained only low numbers in the southern and eastern counties. In subsequent years, the populations slowly recovered but remained scarce in most of the state.

In 1984, the Ohio Department of Natural Resources, Division of Wildlife (ODW) initiated a monitoring program to assess the status of bobwhite populations in the state to inform management practices for the species. In this article, we examine the population status and trends of bobwhites in Ohio for the last two decades. We also give recommendations to better monitor bobwhite populations according to specific management objectives.

MATERIALS AND METHODS

Count Surveys

The target population was the northern bobwhite population of Ohio. The Ohio Department of Natural Resources, Division of Wildlife conducted bobwhite surveys on 308 survey routes established throughout the state during 1984-2004. However, all routes were not surveyed each year. Some routes were discontinued and new ones were added after the first year of the monitoring program. Each route consisted of 12 stops, separated by ≥ 1.6 km, where one observer recorded all bobwhites seen and heard during a three-minute period. The sum of counts on a survey route was used as an index of bobwhite abundance.

Trend Analysis

Abundance estimates based on count data were affected, among other factors, by data quality, missing data, and data aggregation by routes (James and others 1990). Thus, we restricted our analyses to a subset of routes that met certain criteria to enhance the reliability of our results. Thus, a route was considered for analysis only if, 1) the route was surveyed for at least seven years, and the time-series included at least one year of data in each of three seven-year periods (1984-1990, 1991-1997, and 1998-2004); and 2) the route had a non-zero count for at least one year.

Population trend estimates are the simplest measure of population change over time. They are typically expressed as

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percent change per year. We performed trend analyses with Poisson Regression and Generalized Estimating Equations (GEEs) to correct for over-dispersion and serial correlation that characterize counts of animals over time (Pannekoek and van Strien 2004). Our model included the number of quail per survey route as the response variable, and year as the predictor variable. We also incorporated observer effects in the model as another predictor variable to prevent bias associated with differences in observer ability and change in observer ability over time (Sauer and others 1994). Our estimates included an overall population trend for the state of Ohio, and population trends for each of 10 weather regions within the state (Fig. 1). Trend analyses were performed using the program ESTEQNINDEX, developed by Brian Collins of the Canadian Wildlife Service.

We also examined the bobwhite population trajectory in Ohio using a Generalized Additive Models (GAMs). We used a GAM with a Poisson distribution and log link function to model the trend as a smooth, nonlinear function of time and test for significant changes in rates of bobwhite population growth. We modeled the smoothing function using six degrees of freedom (d). The criterion for the selection of d was 0.3 times the length of the time series analyzed, (21 years) as suggested by Fewster and others (2000). Ninety-five percent confidence intervals for the trend curve were calculated by percentile bootstrap using 399 replicates (Fewster and others 2000).

We used the second derivatives of the curve to identify significant changes in population trajectory (Fewster and others 2000). The second derivative of the curve was a measure of the curvature in the population trend line at time t. If the second derivative was greater than zero, the curve turned upward; conversely, if it was less than zero, the curve turned downward. Values of approximately zero mean that the curve was fairly linear, and the population trajectory was changing at a constant rate. The significance of the curve turned upward and downward was determined through 95% confidence intervals calculated by percentile bootstrap (399 replicates). The upward and downward changes were considered

significant when the 95% CIs did not include zero. We implemented the GAM analysis in R (R Development Core Team 2004) using the functions provided by Rachel Fewster (http://www.stat.auckland.ac.nz/~fewster/trends.html).

Abundance Distribution

We developed bobwhite abundance maps for Ohio during 1985, 1992, and 2002 to assess changes in abundance distribution through time. These maps were based on counts obtained on 3620, 3584, and 1966 route stops, respectively. Counts were considered as an index of bobwhite abundance. We used ordinary kriging to develop prediction maps for bobwhite abundance (Newson and Noble 2003). Kriging is a geostatistical method that models autocorrelation and generates an estimated surface from measured attributes (in this case counts; Isaaks and Srivastava 1989). We used a spherical semivariogram model to measure spatial autocorrelation between samples. The estimated semivariogram, which represented the semivariances as a function of distance between samples, was used to determine the weights needed to define the contribution of each sampled point to the interpolation. We conducted Kriging with ArcGIS version 9.1 (ESRI, Redlands, California, USA).

RESULTS

A total of 308 routes were surveyed from 1981 to 2004, however only 209 (68 %) routes were considered suitable for our analyses. The number of routes surveyed per year ranged from 63-209. The overall mean number of bobwhites recorded per route was 4.6, with the highest mean observed in 1987 (7.0 birds/route) and the lowest mean in 1996 (2.6 birds/route).

Population Trend

Overall, bobwhite populations declined in Ohio during 1984-2004 at a mean annual rate of -9.3% (95% CI = -11.2, -7.3). Six weather regions also had significantly declining trends (Table 1). The population decline in the West Central, Northeast, and North Eastern Hills regions were more pronounced than the overall trend, while the Central, Southwest, and South Central regions showed a decline similar to the overall trend. The annual trends obtained for the remaining regions showed inconclusive results due to sparse data (Table 1).

Population Trajectory

Bobwhite populations in Ohio experienced a significant overall decline of 76% (95% CI = 68-82) during 1984-2004. However, the bobwhite population decline was not constant over this time period. Bobwhite populations were mostly stable during 1984-1992, but began a significant downward trend in 1993, and the decline slowed significantly during 1995-1998 (Fig. 2). This was followed by a short period of population stability during 1998-2001 before the population began declining again through 2004 (Fig. 2).

Bobwhite populations experienced significant reductions in all weather regions. These declines exceeded 50%, except in the Southeast region, where results were inconclusive (Table 2). Although populations in the southern half of the state were severely reduced, populations in the northern half declined even more. Populations approached extirpation in the North central and Northeastern regions.

Distribution and Abundance

The maps obtained with Kriging show predicted counts which are indexes of abundance. The northern bobwhite range in Ohio

FIGURE 1. Map of the 10 weather regions of Ohio.

contracted as population declined from 1984 to 2004. In 1985, the bobwhite core range was located in Southwest Ohio and low population densities occurred in the Western, Central, and Eastern regions of the state (Fig. 3). By 1992, the core range shifted southeast and the population abundance experienced an overall decrease (Fig. 3). During the following years, the range contraction continued and by 2002 the northern bobwhites appeared to be practically extirpated from the northern third of the state (Fig. 3). The core

area of northern bobwhite abundance still remains in Southwestern Ohio, where 16 counties are open to hunting. Adjacent counties that are currently closed to hunting lie mostly outside the highest abundance zone.

DISCUSSION

Northern bobwhite populations declined noticeably in Ohio during 1984-2004. Our study detected a trend similar to the United States Breeding Bird Survey (BBS; Sauer and others 2005). The BBS detected a 7.9% (95% CI= -7.5, -8.3) annual population decline for bobwhites in Ohio during 1984-2004 (Sauer and others 2005). However, the routes we analyzed had greater spatial coverage and a larger number of routes (n = 209) than the BBS (n = 47) for the same period. Therefore, we believe that our assessment conveys a more thorough analysis of northern bobwhite population trends in Ohio.

The population trend of northern bobwhites in Ohio followed the pattern of change observed throughout the species' range. Information collected by long-term and broad-scale surveys, such as the Christmas Bird Count (Brennan 1991) and the BBS (Peterson et al. 2002), showed that northern bobwhite populations have declined since the late 1960s. However, the trends in bobwhite abundance vary spatially and some populations in the western and northern portions of the species range have been stable or even increasing (Peterson et al. 2002).

According to the population trajectory, bobwhite populations did not decline at a constant rate. We detected periods of relative stability in bobwhite abundance during 1984-1992 and again during 1998-2002. However, the apparent abundance stability during 1984-1992 could have resulted from the release of 65,000 pen-raised bobwhites throughout the state in the late 1970s and

Table 1

Annual trend (%) of bobwhite populations in 10 Weather Regions in Ohio

Weather Region[1]	Period	No. Routes	Annual Trend	95% CI	
C	1984-2004	26	-9.1	-16.8	-0.7
CH	1984-2002	13	-10.3	-23.1	4.6
NC	1984-2002	13	-15.2	-43.0	26.1
NE	1985-2002	16	-26.5	-37.4	-13.7
NEH	1984-2002	19	-20.3	-26.4	-13.7
NW	1984-2002	14	-30.3	-58.6	17.1
SC	1984-2004	28	-7.7	-11.5	-3.7
SE	1984-2004	23	-5.2	-21.5	14.7
SW	1984-2004	28	-8.4	-11.1	-5.6
WC	1984-2004	29	-15.9	-19.4	-12.3

[1]C = Central; CH = Central Hills; NC = North Central; NE = Northeast; NEH = North Eastern Hills; NW = Northwest; SC = South Central; SE = South East; SW = Southwest; WC = West Central.
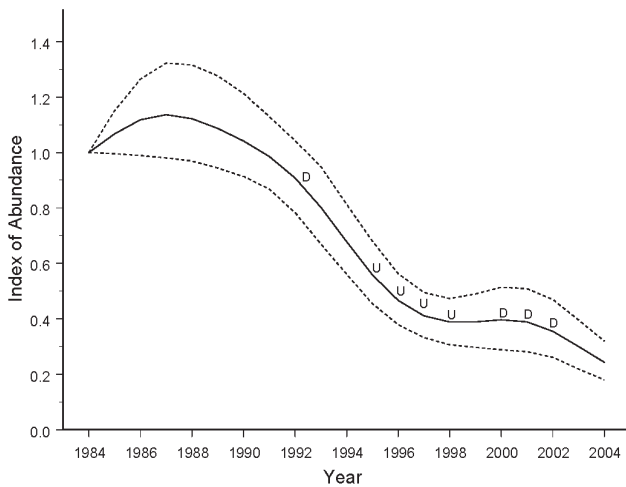

FIGURE 2. Trajectory of bobwhite population in Ohio, 1984-2004. Dotted lines are 95% lower and upper limits calculated by percentile bootstrap. The D and U on the trajectory line indicates significant downturns (D) and upturns (U) in the trajectory (significantly negative (D) and significantly positive (U)). Population trajectories are calculated from the second derivatives of the curve.

Table 2

Population change (%) in 10 Weather Regions in Ohio

Weather Region[1]	Period	No. Routes	Percent Population Change	95% CI
C	1984-2004	26	-65.4	-94.1, -31.7
CH	1984-2002	13	-99.9	-100.0, -99.4
NC	1984-2002	13	-100.0	-100.0, -99.9
NE	1985-2002	16	-100.0	-100.0, -99.8
NEH	1984-2002	19	-96.6	-99.8, -84.4
NW	1984-2002	14	-91.7	-100.0, -59.4
SC	1984-2004	28	-74.3	-85.6, -57.3
SE	1984-2004	23	32.5	-71.1, 225.6
SW	1984-2004	28	-78.4	-85.6, -71.6
WC	1984-2004	29	-92.2	-97.7, -78.8

[1]C = Central; CH = Central Hills; NC = North Central; NE = Northeast; NEH = North Eastern Hills; NW = Northwest; SC = South Central; SE = South East; SW = Southwest; WC = West Central.

Individuals per stop in 1985

- 0 - 0.27
- 0.27 - 1.0
- 1.0 - 2.03
- 2.03 - 3.26
- 3.26 - 5.7

Individuals per stop in 1992

- 0 - 0.20
- 0.20 - 0.67
- 0.67 - 1.35
- 1.35 - 2.28
- 2.28 - 4.0

Individuals per stop in 2002

- 0 - 0.25
- 0.25 - 0.75
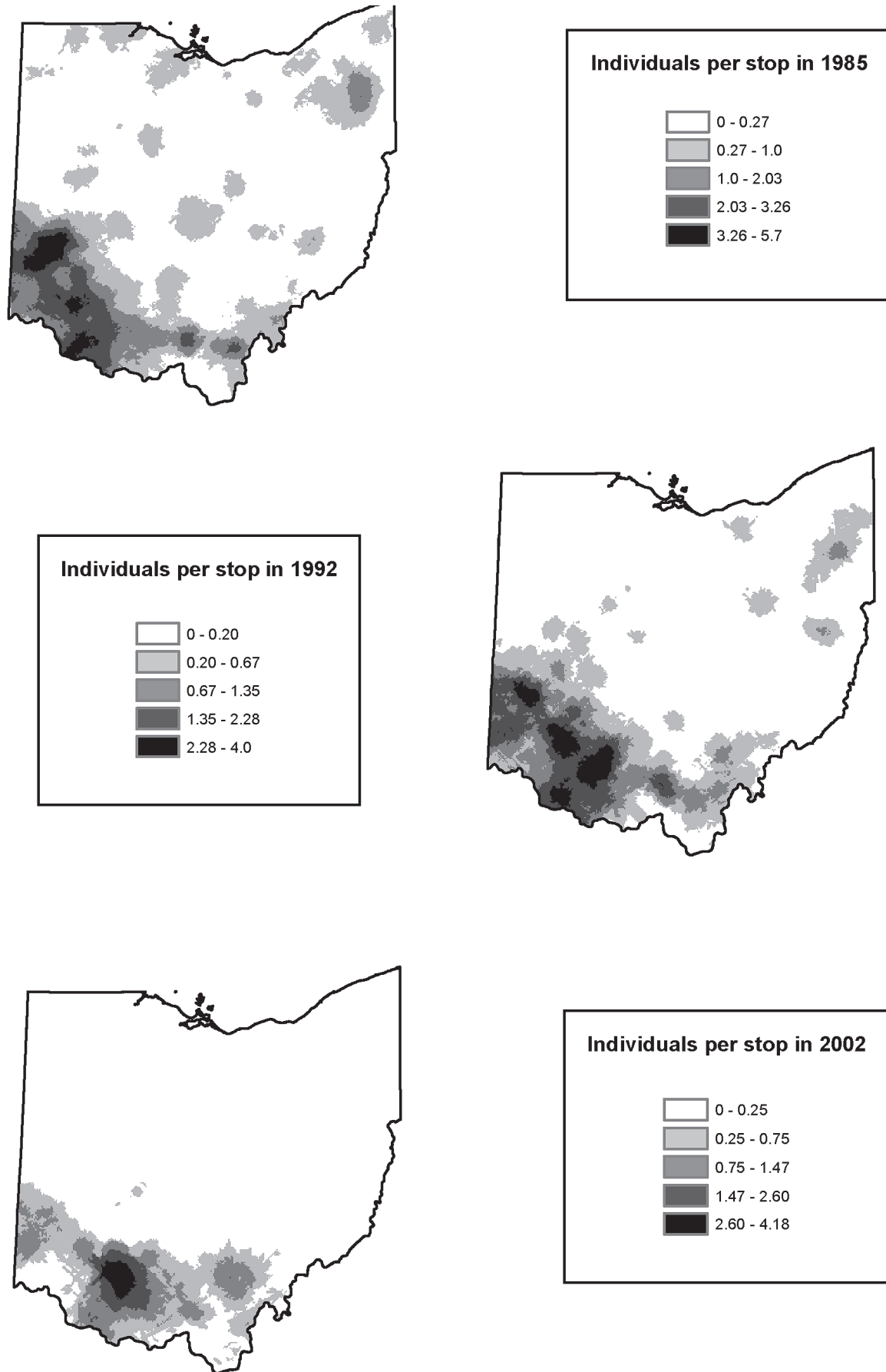- 0.75 - 1.47
- 1.47 - 2.60
- 2.60 - 4.18

FIGURE 3. Maps of bobwhite index of abundance (individuals heard per stop) during 1985, 1992, and 2002 in Ohio.

early 1980s (Henry 1993). Thus, the stocking of bobwhites may have masked naturally declining trends in wild northern bobwhite populations during the study period.

Bobwhite populations did not decline uniformly across Ohio during 1984-2004. Bobwhite populations in Northern and Central regions showed a more noticeable decline than Southern regions. This pattern followed overall bobwhite abundance: Northern and Central regions had lower densities than Southern regions that are considered to comprise the core of bobwhite distribution in Ohio (Peterjohn and Rice 1991). Spatial variation in population trends could be explained by differences in bobwhite abundance. Areas with low density are most likely to exhibit a larger percent change in abundance than areas with a high population density. Our results suggest that bobwhites have severely declined or even been extirpated in some areas of Northern and Central Ohio.

The current survey protocol to assess bobwhite populations has two major caveats: 1) the survey relies on convenience sampling and 2) the survey used uncalibrated indexes. The use of convenience sampling by conducting surveys on secondary roads excludes inference for bobwhites occupying other portions of the landscape. Therefore, to make valid inferences to the target population (i.e., bobwhite in Ohio) a sound survey protocol should include a probabilistic sampling design. Another flaw in the current survey protocol is the use of abundance indexes not adjusted by detection probability. Therefore, we suggest that route surveys should use model-based methods such as double-observer (Nichols and others 2000) or time of detection (Farnsworth and others 2002) to estimate detection probability and adjust indexes of abundance. Either method could be implemented with little extra effort in bobwhite surveys to obtain reliable indexes. However, the time of detection method would involve half the number of observers in the surveys compared to the double-observer method.

Our findings suggest that a management response is needed to reverse the decline of bobwhite population in Ohio. The declining trend is higher than the standard objective recommended for monitoring land birds (50% decline). To overturn this situation, a statewide plan is required to implement a management response to increase bobwhite population abundance in Ohio. Habitat management, such as the maintenance and/or restoration of a grassland habitat, is crucial to reverse the declining trend in bobwhite populations (Williams and others 2004). The implementation of grassland restoration will not only benefit bobwhite populations but also many other grassland bird populations that have been declining in Ohio (Earnst and Andres 1996, Brennan and Kuvlesky 2005).

The allocation of the sampling effort to monitor the bobwhite population in Ohio should be modified. We suggest the implementation of lower and higher resolution monitoring efforts. The lower resolution effort would attempt to detect, for example, range expansion and should be conducted in areas of low bobwhite density. Methods such as occupancy estimation, using detection/no detection type of data, could be used for this purpose (MacKenzie and others 2003). The higher resolution effort would attempt to assess population abundance and should be conducted in areas of higher and medium densities where bobwhites are legally harvested. This effort could be carried out using bobwhite counts adjusted by detection probability.

We strongly recommend the continuation of the bobwhite monitoring program within the framework of adaptive management. Consequently, the monitoring effort should be used as a measure of progress toward or success at meeting an objective and provide the evidence for management change or continuation. Accordingly, management objectives should be established in relation to specific management actions. Bobwhite monitoring could be used to evaluate the implementation of management practices to enhance habitat for grassland birds.

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