CONSERVATION STATUS OF THE ENDANGERED OZARK BIG-EARED BAT
(CORYNORHINUS TOWNSENDII INGENS) – A 34-YEAR ASSESSMENT

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ABSTRACT.—Direct counts of Ozark big-eared bat (Corynorhinus townsendii ingens) in hibernacula and maternity roosts were analyzed from 1977 to 2010. We compiled data from 1,330 survey events at 268 sites: 77 sites known to be used in Arkansas, 84 in Oklahoma, 9 in Missouri, and 98 potential use sites. Survey techniques were standardized, and baseline population indices established. Rank correlation techniques of population indices (Mann-Kendall Test) at 19 essential sites revealed important demographic trends over this 34-year period: 7 colonies have a significantly increasing trend—3 maternity sites (Cave No. AD10, AD17/18, and CW29BT3) and 4 hibernacula (AD14/125, AD3, ADT1, and WA31T complex); 3 colonies are decreasing—the maternity sites AD125 and AD13/24/25, and hibernaculum MR0702/9702/979a; and the remaining essential sites are data deficient. Historic total abundance estimates of Ozark big-eared bats ranged widely from less than 100 in 1973 to 2,500 individuals in 1990; the current population estimate is 1,600 to 1,800 bats. When all site counts are pooled by year, trend analyses indicate an increase in all maternity and hibernaculum counts over the last 34 years. Confounding this apparent increase is the discovery of new maternity colonies and hibernacula. Human disturbance and habitat loss appear to be the most important limiting factors, as the behavior and life history of this species make it inherently vulnerable to anthropogenic disturbances. Colony protection (primarily via cave gating), habitat protection (via conservation easement and fee title acquisition), and landowner management agreements have been particularly effective, yet additional time is needed before this bat’s conservation status can be upgraded.

INTRODUCTION

The challenge of protecting rare mammals from extinction is typified by the efforts to manage the Ozark big-eared bat (Corynorhinus townsendii ingens) Handley 1955; Figure 1). Historical population baselines are lacking for most vertebrate species, which impedes the creation of appropriate restoration targets or management plans (Pauly 1995). Enigmatic species such as cave-dwelling bats are difficult to census or even to define in discrete population units (Ellison et al. 2003, Kunz 2003). Bat monitoring is further challenged by the lack of standardization of census methods (Kunz 2003). Where sufficiently large datasets of rare vertebrate population surveys do exist, biologists have relied too often upon linear regression to test against declining or increasing trends; this statistical method requires assumptions that are not often met in endangered species’ time series (e.g. normally distributed errors, constant variance) and outliers may change results dramatically (USEPA 2006). Nonparametric rank correlation methods, used for decades in other disciplines such as hydrology (Hipel and McLeod 1994, USEPA 2006), are now increasingly used by zoologists to test for trends in time series; such ranking procedures are preferable when exact estimates of population size are not known, when data gaps are present, etc. (Thompson et al. 1998). Even with the use of the appropriate statistic, significant

Figure 1. Photograph of the Ozark big-eared bat roosting in a cave in Adair County, Oklahoma. Photo by Richard Stark.

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upward trends in population surveys over time are difficult to attribute specifically to population recovery/growth when such increases may also be due to improved survey methods or discovery of new subpopulations.

Recovery of rare mammals is also impeded by the specificity of their life history requirements and their vulnerability to human activities. In response to a petition by MJH and J. Hall, the United States Fish and Wildlife Service (USFWS) listed the Ozark big-eared bat as endangered due in large part to the few existing suitable subterranean roost habitats that met its biological needs, and to its extreme sensitivity to human disturbance, including simple visual counts at roosts (USFWS 1977). This study analyzed the current conservation status of this bat based on 34 years of monitoring and recovery efforts. We also report on the establishment of a standardized survey protocol, baseline population data, and survey trend analyses using a non-parametric rank procedure.

**MATERIALS AND METHODS**

*Population surveys/roost counts.* Ideally surveys are performed at each site during the maternity and hibernation seasons, but count frequency was reduced by shortages of personnel, weather conditions, denial of access by landowners, or reports of stress to certain colonies from caving activities (recreational or scientific). USFWS (1995) guidelines suggest that maternity roosts be annually surveyed externally, and that hibernation roosts (hibernacula) be surveyed internally at most every 2 years, with a limit of 5 minutes spent directly under any roost. We used the definition of a roost count as defined by Ellison et al. (2003): “a generic term for how many bats were found in a particular location on a unique date. Methods used to obtain a ‘count’ varied...sometimes a count is a survey, or ‘best guess’ of the original investigator and is not a census.” A population is defined as a group of bats of the same species living in a specific area, and may consist of multiple colonies with spatial boundaries varying within and among years (Ellison et al. 2003). These “specific areas” are subterranean roosting sites, whose locations are protected by the use of an alpha-numeric code (provided by state cave registries maintained by the National Speleological Society).

Figure 2. Photograph of an Ozark big-eared bat colony in Devil’s Den State Park, Arkansas. Photo by Harry Harnish.
Hibernating colonies were surveyed by counting bats using battery-powered helmet lights, ideally attenuated with infra-red filters (USFWS 1995). Where clusters were too dense to count individuals (Figure 2), ceiling coverage of the colony was estimated, and then multiplied by a density estimate of 180 bats/foot² (1,938 bats/m²), which is thought to be more accurate than Grigsby and Puckette’s (1982) estimate of 150 bats/foot². The hibernacula survey ignored any bats roosting independently in auxiliary (or limited use) sites, and assumed that neonates have matured into virile adults, and that male and female bats are equally represented—sex ratios are near unity for hibernating conspecifics and congenerics (Twente Jr. 1955; Rippy and Harvey 1965; Humphrey and Kunz 1976; Harvey et al. 1981).

Maternity colonies were surveyed between late May and mid-June before pups were volant by conducting emergence counts at cave entrances at the crepuscular period; declining ambient light was augmented by battery-powered incandescent lights fitted with infrared filters (wavelength > 700 nm) (Kunz 1982, Bagley and Jacobs 1985, USFWS 2008). Infrared light is not known to disrupt bat behavior (Hope and Bhatnagar 1979, Mistry and McCracken 1990). Passive night vision field glasses were used to count emerging bats, although we are testing videography as a supplemental interpretative device. Ozark big-eared bats are differentiated from other vespertilionids by their conspicuously large ears, larger body size, and distinctive flight pattern (USFWS 1984). A population index was derived by doubling the emergence count to account for solitary males, assuming a 1:1 sex ratio (USFWS 2008).

Data acquisition and analyses. Data were compiled primarily from unpublished annual survey reports by WLP, MJH, RKR, H. Harnish (Devil’s Den State Park, West Fork, Arkansas), and colleagues, but

Figure 3. Current global range of Townsend’s big-eared bat (Corynorhinus townsendii) and Rafinesque’s big-eared bat (C. rafinesquii) in relation to North American countries (Piaggio and Perkins 2005; Medlin Jr. et al. 2006).
also museum collections and Natural Heritage Network databases maintained by the Arkansas Natural Heritage Commission, Oklahoma Biological Survey, and Missouri Department of Conservation. Corynorhinids collected in northwest Arkansas by Sealander Jr. (1951) were originally assigned to Rafinesque’s big-eared bat (C. rafinesquii [Lesson 1827]); these were reassigned to C. t. ingens by Handley (1955). Since Handley’s (1959) taxonomic revision, it is understood that these species’ ranges do not overlap (Figure 3), although recent mist-netting studies of Arkansas bottomlands confirms their parapty at the ecoregion boundary between the Ozark Plateaus and the Arkansas River Valley (Medlin Jr. et al. 2006).

Summary statistics of roost counts were performed using SPSS statistical software (version 15.0, SPSS, Inc.). Consistent with other bat survey data analyses (e.g. Ellison et al. 2003), a time series of counts required at least four annual counts (but not necessarily consecutive years) that were conducted using similar methods and at the same season of year. Where a roost count was reported as a range, the mean of the lower and upper bound was used. None of the counts included estimates of sampling-based variation, and most lacked replicate counting; both are suggested for future counts, where possible. The MAKESENS software created by Salmi et al. (2002) was used to perform the nonparametric Mann-Kendall Test (Kendall 1938, Mann 1945) and Sen’s Slope Estimator Method (Sen 1968a,b), which tests for a monotonic trend in the time series and the magnitude of the trend, respectively, at significance level \( \alpha = 0.05 \). The Mann-Kendall test involves computing the \( Z \) statistic (or \( S \) statistic for time series with less than 10 observations), which is the difference between the number of pairwise differences that are positive minus the number that are negative (USEPA 2006). If \( Z \) is a large positive value and the probability value is less than 0.05, then there is evidence of an increasing trend in the data, and vice versa. The null hypothesis is that there is no temporal trend in the time series (USEPA 2006). The coefficient of variation (CV, ratio of standard deviation to its mean, expressed as a percent) was used to further evaluate potential trends because it is a dimensionless measure of precision and can compare data sets of unequal variance (Thompson et al. 1998; Ellison et al. 2003). Ellison et al. (2003) explains its application in bat roost count time series: “in cases where CVs are relatively high, failure to reject the null hypothesis may be due to high variability in counts. In cases where CVs are low, the trend may be stable.” Where a time series did not have a significant upward or downward trend, we followed Ellison et al. (2003)’s use of an arbitrary CV cutoff point of 50% to interpret its meaning. Where the CV was less than 50%, the count was inferred to stabilize around a mean value; where a time series had a larger CV, we inferred that the counts were too variable to interpret any trend (until a later date when the time series dataset was large enough to reduce the CV). Sen’s Slope Estimator Method provides a simple linear equation where the number of years between bat counts, year(x) – year(0), is multiplied by a slope \( Q \) (bats/yr) and a y-axis intercept \( B \) to yield the number of bats estimated for that future year(x).

Each site was assigned a bat use category refined from the recovery plan (USFWS 1995) definitions: 1) essential—a site particularly crucial to the continuing existence of Ozark big-eared bats, including major maternity and hibernacula sites, or other currently active, large roosts consistently being used by at least 10 bats; 2) limited use—sites used by singletons or small groups, typically less than 10, including “transient use” sites; 3) historic use—a site used by the Ozark big-eared bat in the past but for which recent surveys indicate is no longer used or where the habitat has become unsuitable for bats; or 4) potential use—a site having the requisite habitat parameters and the presence of bat guano accumulations with culled insect remains, especially moth wings, but no confirmed Ozark big-eared bat sightings. Geographic information system software (ArcGIS 9.3, Environmental Systems Research Institute, Inc.) was used to explore potential zoogeographical patterns.

**RESULTS**

**Site inventory.** Compilation of records from all known sources yielded a dataset of 1,330 Ozark big-eared bat survey events (including zero counts and observations of bat sign only). In total, 170 confirmed sites and 98 potential use sites were identified. Confirmed sites numbered 77 in Arkansas, 84 in Oklahoma, and 9 in Missouri (Figure 4), and were categorized further as 59 historic, 92 limited use, and 19 essential. Of the sites deemed essential (7 in Arkansas and 12 in Oklahoma), some are used as transitional fall roosts (AD16, CZ18), as maternity roosts (AD13, AD17, AD18, AD24, AD25, AD3, CW21BT1, CW29BT3, MR9702), as hibernacula (AD3, AD1T, WA31T complex), or for multiple functions (AD10, AD14, AD125, MR0702, and MR979a).
Figure 4. Current distribution of *C. t. ingens*: radial buffers of 7.3 km (maximum nightly foraging distance of the subspecies) around current sites (essential use and limited use), where dots show generalized locations with geographical uncertainty added to protect actual site locations.

**Population trends at essential sites and rangewide.** Trends of population counts were analyzed at each essential site grouping that housed relatively discrete colonies (Table 1, Figure 5, and Figure 6). Published total abundance estimates of Ozark big-eared bats range from 100 to 2,500 individuals, using various survey techniques and estimate methods (Harvey 1975, 1986, 1992, 1995, 1996, Humphrey and Kunz 1976, Harvey et al. 1978, Grigsby and Puckette 1982, Jacobs and Bagley 1983, Bagley 1984, 1985, 1987, Mathews and Mosely 1990, Harvey and Barkley 1990, Clark et al. 1997b, USFWS 1973, 1977, 1979, 1984, 1995, 2008). Total population estimates calculated for the last 5 maternity seasons were 1,900 bats in 2006, 1,600 in 2007, 1,800 in 2008, 1,500 in 2009, and 1,200 in 2010.

Over the four decades that colonies have been surveyed, there has been a significant increase in all pooled raw maternity counts and all winter counts (Figure 7). The mean of all pooled maternity counts ($n = 33, \bar{x} = 766$ bats, CV = 48%) is significantly higher than the mean of pooled winter counts ($n = 32, \bar{x} = 496$ bats, CV = 49%), according to a Mann-Whitney U test for independent samples ($n = 65, U = 250.500, z = -3.904, P = 0.001$).

**DISCUSSION**

**Current population status.** Trend analyses of the entire 34-year data set suggest increasing trends for pooled maternity site counts and pooled hibernaculum site counts. These significant increases have been attributed to the discovery of cryptic populations resulting from increased field search efforts by WLP, MJH, and colleagues, and not necessarily to population growth or recovery (USFWS 2008). Figure 8 demonstrates the increase in total population size simply by the addition of new maternity sites to the running total.

Most of these individual datasets are highly variable, and may be due in part to movement between sites, making interpretations about the status of each colony difficult (Clark et al. 1997a). Our data and previous analyses show that total summer population counts are higher than total winter population counts even though juveniles are counted in winter, suggesting that some important hibernacula have not yet been located (USFWS 1995; Clark et al. 1997a).

While we have standardized the survey method, the majority of our data is from counts in only the last two decades. This is consistent with observations for Nearctic bats in general; the majority of observations...
Table 1. Results of statistical trends analysis of bat counts of essential sites indicating habitat, survey dates, mean counts with variation, and trend analysis statistics.

<table>
<thead>
<tr>
<th>Site Name (Habitat Type)</th>
<th>Survey Period</th>
<th>Mean Count (coefficient of variation, CV)</th>
<th>Maximum Count and Year</th>
<th>Population trends per year inferred by Mann-Kendall Test of Population Trends and Sen’s Slope Estimator (n = number, Z = test score, p = significance level, Q = slope, B = y-intercepts of fitted line)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maternity Sites</strong></td>
<td></td>
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<tr>
<td>AD10 (limestone cave)</td>
<td>1983 to 2010</td>
<td>255 bats (20%)</td>
<td>339 in 1998 and 338 in 2006</td>
<td>increase, 4 bats/yr (n = 27, Z = 2.7, p = 0.007, Q = 3.5, B = 215.0)</td>
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<tr>
<td>AD 13, 24, or 25 (limestone cave complex)</td>
<td>1984 to 2010</td>
<td>69 bats (46%)</td>
<td>148 in 1989</td>
<td>decrease, 2 bats/yr (n = 27, Z = -2.4, p = 0.015, Q = -1.8, B = -103.3)</td>
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<tr>
<td>AD125 (limestone cave)</td>
<td>1987 to 2010</td>
<td>94 bats (87%)</td>
<td>276 in 1989</td>
<td>decrease, 3 bats/yr (n = 23, Z = -2.9, p = 0.004, Q = -6.5, B = 159.5)</td>
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<tr>
<td>AD17 + AD18 (limestone cave complex)</td>
<td>1987 to 2010</td>
<td>129 bats (41%)</td>
<td>252 in 2007</td>
<td>increase, 4 bats/yr (n = 27, Z = 3.3, p = 0.002, Q = 4.9, B = 26.2)</td>
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<tr>
<td>CW29BT3 (sandstone talus cave complex)</td>
<td>1997 to 2008</td>
<td>175 bats (39%)</td>
<td>300 in 2006 and 2008</td>
<td>increase, 9 bats/yr (n = 10, Z = 3.0, p = 0.002, Q = 8.5, B = -70.8)</td>
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<tr>
<td>MR9702 + MR0702 + MR979a (limestone cave complex)</td>
<td>1978 to 2009</td>
<td>140 bats (61%)</td>
<td>336 in 2003</td>
<td>no trend (n = 31, p = 0.54)</td>
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<tr>
<td>WA5202 (limestone cave)</td>
<td>1995 to 2010</td>
<td>31 bats (52%)</td>
<td>53 in 2006</td>
<td>no trend (n = 16, p = 0.82)</td>
</tr>
<tr>
<td>All maternity sites combined</td>
<td>1978 to 2010</td>
<td>766 bats (48%)</td>
<td>1,497 in 2009</td>
<td>increase, 30 bats/yr (n = 33, Z = .9, p = &lt; 0.001, Q = 30.0, B = 150.3)</td>
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<tr>
<td><strong>Hibernacula</strong></td>
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<tr>
<td>AD10</td>
<td>1983 to 2010</td>
<td>33 bats (263%)</td>
<td>300 in 2009</td>
<td>no trend (n = 21, P = 0.497)</td>
</tr>
<tr>
<td>AD14 + AD125 (limestone cave complex)</td>
<td>1987 to 2010</td>
<td>48 bats (160%)</td>
<td>247 in AD125 in 1988 and 128 in AD14 in 2004</td>
<td>increase, 3 bats/yr (n = 22, Z = 3.2, p &lt; 0.001, Q = 2.5, B = -6.6)</td>
</tr>
<tr>
<td>AD3 (limestone cave)</td>
<td>1981 to 2009</td>
<td>306 bats (30%)</td>
<td>435 in 2003 and 2009</td>
<td>increase, 10 bats/yr (n = 25, Z = 5.3, p &lt; 0.001, Q = 9.5, B = 178.0)</td>
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<tr>
<td>ADT1 (sandstone talus cave)</td>
<td>1994 to 2010</td>
<td>10 bats (70%)</td>
<td>24 in 2006</td>
<td>increase, 1 bat/yr (n = 11, Z = 2.4, p = 0.012, Q = 0.8, B = 2.1)</td>
</tr>
<tr>
<td>CW21BT1a-g (sandstone talus cave complex)</td>
<td>1998 to 2010</td>
<td>9 bats (86%)</td>
<td>18 in 2010</td>
<td>no trend (n = 6, insufficient data)</td>
</tr>
<tr>
<td>MR0702 + MR9702 + MR979a (limestone cave complex)</td>
<td>1979 to 2009</td>
<td>134 bats (67%)</td>
<td>420 in 1980</td>
<td>decrease of about 6 bats/yr (n = 27, Z = -3.6, p &lt; 0.001, Q = -5.1, B = 206.9)</td>
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<tr>
<td>WA31T (sandstone crevice cave complex)</td>
<td>1975 to 2009</td>
<td>39 bats (75%)</td>
<td>116 in 2005</td>
<td>increase, 3 bats/yr (n = 30, Z = 4.6, p &lt; 0.001, Q = 2.5, B = -9.4)</td>
</tr>
<tr>
<td>All hibernacula combined</td>
<td>1975 to 2010</td>
<td>439 bats (62%)</td>
<td>1,057 in 2010</td>
<td>increase, 12 bats/yr (n = 37, Z = 3.2, p &lt; 0.001, Q = 12.4, B = 132.8)</td>
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Figure 5. Time series of essential maternity sites; lines fitted where time series had significant trends.
Figure 6. Time series of essential hibernacula; lines fitted where time series had significant trends.

were made after 1990; Ellison et al. (2003) attributed this to the increase in conservation interest in bat populations. Similar to the Ellison et al. (2003) analysis of bat population datasets nationwide, variance was high in bat counts and many survey data sets were not yet sufficiently long to detect a trend.

Current distribution / zoogeographic patterns. Handley (1955) reported the distribution of Ozark big-eared bats to be the “Ozark Highlands” (i.e. the Ozark Plateaus ecoregion). USFWS (1984, 1995) restricted the range to the western half of this ecoregion (northeastern Oklahoma, northwestern Arkansas, and southwestern Missouri). The Ozark big-eared bat has not been reported from Missouri since 1971 (unpublished data, Missouri Department of Conservation Natural Heritage database), and is currently understood to be extirpated from the state (Figg and Lister 1989, Elliott et al. 1999). Ozark big-eared bats are paradoxically absent from the eastern and northern portions of this ecoregion even though this area is rich in suitable cave habitat and no specific dispersal barriers have been identified.

Using geographic information system software, each currently used site (essential or limited use) was given a radial buffer of 7.3 km (Figure 4); the longest tracked movement of the Ozark big-eared bat was 7.3
Figure 7. Significant increases detected in time series of all pooled colony site counts of *C. t. ingens* during maternity season and during hibernation.

Figure 8. The significant increase in pooled maternity counts may be explained by the discovery of new maternity sites in 1982-1984, 1986, 1995, and 1998, which add greatly to the average yearly total of bats counted, regardless of the temporal trend in any particular colony.

km (Clark et al. 1993), although typical foraging distances traveled over a 24-hour period were within 2 km of the roosting site (Clark et al. 1993, Wethington et al. 1996, Wilhide et al. 1998). Any references (e.g. Wethington et al. 1996, Weyendt et al. 2005) attributed to Harvey (1992) stating that Ozark big-eared bats traveled up to 8 km in Arkansas are erroneous, as are references (e.g. USFWS 1995, Weyendt et al 2005) stating that Ozark big-eared bats moved up to 20 miles (32 km)—MJH was referring to banded Virginia big-eared bats in Harvey (1992).

These confirmed sites are neatly grouped by the 7.3 km radial buffers suggesting 3 discrete subpopulations: a cluster of essential and limited use caves within the Bull Shoals Reservoir watershed in Marion County, Arkansas, named the “Yellville population”; a large cluster of essential and limited use caves and crevices on the Arkansas/Oklahoma border within the watershed of the Illinois River/Lee Creek named the “Stateline population”; and a cluster of essential and limited use caves in the Frog Bayou/Mulberry River watershed. A fourth cluster of limited use caves and mines occurs in the Buffalo River watershed, but this cluster does not yet include any known essential maternity or hibernaculum sites. These 3 subpopulations might constitute a metapopulation, because the criteria defined by Hanski and Gilpin (1991) are probably met: the habitat occurs in discrete patches occupied by local breeding populations; even the largest (core) populations have a substantial extinction risk; habitat patches are not too isolated to prevent recolonization; and the dynamics of local populations are not known to be synchronized.

Radial buffers of 64 km, which represent a hypothetical maximum potential dispersal distance of the species, were also fitted around each confirmed site.
Barbour and Davis (1969) reported that the longest recorded movement for the Townsend’s big-eared bat species complex was “…up to 40 miles” (64 km) in Kentucky and Virginia, and they cited other tracked movements of over 20 miles. Furthermore, Piaggio and Perkins (2005) documented gene flow in this species across distances greater than limitations invoked by their wing morphology or mark-recapture evidence; they suggested that this species can travel farther than previously documented, and cited a recent report of a western big-eared bat (C. t. townsendii) movement of over 150 km. Almost all of the remaining historic and potential use sites fall within these 64 km buffers, suggesting that the 3 subpopulations have the potential to disperse to numerous suitable patches of unoccupied habitat and establish satellite populations.

Where this dispersal area is truncated by the extent of suitable geomorphology (the edge of the Boston Mountain Plateau to the south), we spatially described the current maximum range of this subspecies (Figure 9). However, Piaggio and Perkings (2005) suggested that dispersal to such suitable habitat is not the limiting factor of this species. Weyendt et al. (2005) performed a genetic study of 5 Ozark big-eared bats sites in Oklahoma, and confirmed that Ozark big-eared bats have high site fidelity. Weyendt et al. (2005) warned that such philopatry may impede colonization of proximal suitable habitat.

**Threats.** There is disagreement as to whether historic populations of Ozark big-eared bats have actually declined due to anthropogenic stresses (Barbour and Davis 1969, USFWS 1995), whether the subspecies is...
simply rare (Sealander 1951), or whether it is an isolated "relict" due to climate change since the Pleistocene epoch (Handley 1959, Humphrey and Kunz 1976, Kunz and Martin 1982). The primary stressors causing population decline are understood to be human disturbance of colonies and loss of habitat (Harvey 1975, USFWS 1984). The behavior and life history strategies of C. townsendii make it inherently vulnerable to human disturbance at roosting sites. The bats are frequently encountered by cavers because the bats prefer to roost in the twilight zone, in places easily reached by flying such as open ceilings, and on low hanging ceilings where cold air is trapped (Barbour and Davis 1969, Humphrey and Kunz 1976). The bats are aroused easily, and Humphrey and Kunz (1976) reported that disturbance of hibernating pale lump-nosed bats (C. t. pallescens) could result in increased mortality due to depletion of fat reserves, a phenomenon well documented for other bats (reviewed by Davis 1970). Townsend’s big-eared bats are disturbed by flashlights and cave visitation; disturbed colonies have been documented to move to more remote portions of caves, exit caves, or abandon sites permanently, often to less optimal sites (Barbour and Davis 1969).

Corynorhiniids are also sensitive to research activities. After mistnetting and the fitting of radio transmitters on Ozark big-eared bats in AD125, Clark and Clark (1995) reported lowered maternity counts for the next 6 years. Yet, Clark et al. (1997a) reported tolerance of Ozark big-eared bats to later research activities. Humphrey (1969) and Humphrey and Kunz (1976) report that pale lump-nosed bats were extremely sensitive to disturbance by human visitation, and in 2 instances in Cimarron County, Oklahoma, the colony abandoned the roosting site after disturbance from their mark/recapture research, and subsequent population censuses decreased. However, wing bands and mark / recapture techniques have improved since these early studies, and mark / recapture techniques should be reconsidered for corynorhiniid population monitoring. With at least 19 specimens catalogued in museums (Sealander 1951, Glass 1961), scientific collection may prove impractical to gate because they have extremely large horizontal bars) increased retention of gray bats, and gate design continues to evolve (Martin et al. 2000). Gates may alter microclimates or increase predation (Clark et al. 1996; Martin et al. 2006), and some sites are impractical to gate because they have extremely large or numerous openings. Diligent monitoring and maintenance of these gates places a considerable and perpetual stewardship burden on conservation agencies.

Conservation efforts. Here we summarize efforts to date to implement recovery actions specified in the Recovery Plan. Protection of cave entrances and bat flyways are obvious and necessary actions, but development of other best management practices has been hampered by scientific uncertainty of this subspecies’ habitat requirements. Wethington (1994) and Wethington et al. (1996) recommend that protection efforts be focused upon lands within 8 km radii of all used caves. Wethington et al. (1996, 1997) reported no preference of Ozark big-eared bats in foraging habitat or land use, and conclude that previous studies documenting habitat preferences (Clark 1991, Clark et al. 1993) were attributable primarily to variations in prey availability. Prather and Briggler (2002) concluded that no landscape-level variables significantly affected occupancy. Dodd (2006) noted a preponderance of forest tree-associated moths in the diet, suggesting that the maintenance of this vegetation community type is important. Wilhide et al. (1998) recommended preserving existing vegetation structure (primarily forest), and Dodd et al. (2008) recommended preserving habitat heterogeneity to maximize moth prey resources and protecting forested riparian corridors for foraging habitat.

Colony disturbance has been reduced by modification of research techniques and by restricting recreational access to important caves. Early gate designs (e.g. external placement, vertical bars) caused gray bat (Myotis grisescens) colony abandonment; improved designs (e.g. placement in aphotic zone, emphasis on horizontal bars) increased retention of gray bats, and gate design continues to evolve (Martin et al. 2000). Gates may alter microclimates or increase predation (Clark et al. 1996; Martin et al. 2006), and some sites are impractical to gate because they have extremely large or numerous openings. Diligent monitoring and maintenance of these gates places a considerable and perpetual stewardship burden on conservation agencies.
The search for additional Ozark big-eared bats populations focuses upon escarpments / bluffs within 7 km of known habitats. Another focus area should be mining districts: mines have not been sufficiently inventoried for bat populations (Tuttle and Taylor 1998). Ozark big-eared bats are occasionally seen roosting in mines within the Buffalo River watershed (C. Bitting, US National Park Service, pers. comm.), and their westerly conspecifics are known to populate mines in large numbers (Kunz and Martin 1982, Tuttle and Taylor 1998).

Gray bat fatalities from insecticide exposure prompted USFWS biologists to investigate this threat in other endangered bat species. Martin (1992) detected alphatic hydrocarbons, polycyclic aromatic hydrocarbons, and heavy metals in Ozark big-eared bat guano in caves AD10 and AD17, and concluded that bats were being exposed to a variety of environmental contaminants. Adornato (2005) detected organochlorine pesticide residues in eastern pipistrelle (Periomyotis subflavus) tissue and gray bat guano in caves of the Ozark Plateau National Wildlife Refuge. Sasse (2005) analyzed gray bat guano collected from 4 caves in Arkansas and detected organochlorine pesticide residues in all of the sites. Sasse (2005) and Martin (2007) recommended continued periodic monitoring of pesticide residues in guano and carcasses of dead bats.

Significant progress has been made toward permanent protection of Ozark big-eared bat habitat. The Ozark Plateau National Wildlife Refuge was established in 1986 by SJH with a focus upon protecting endangered species dependent upon caves (including AD10, AD14, AD18, and AD125), and now consists of 8 units with 3,748 acres in a combination of fee title, conservation easements, and management agreements. USFWS also cooperates with the Cherokee Nation (who owns caves AD17, AD51, and AD65), the City of Tulsa (cave DL4), the National Speleological Society (caves AD3, CZ18 and CZ19), and private landowners (caves AD13, AD16, AD24, AD25, ADT1, CW21BT1, WA5202) to protect endangered bats. The Arkansas Natural Heritage Commission (ANHC) and The Nature Conservancy continue to expand protection for the foraging area of the Yellville subpopulation, and are implementing a site conservation plan for the MR0702/9702/979a cave complex which are protected within ANHC’s 536-acre Slippery Hollow Natural Area, the Conservancy’s 450-acre preserve, and by private landowner management agreements. Arkansas Department of Parks and Tourism manages the Ozark big eared-bats within the 2,000-acre Devil’s Den State Park. Cave CW29BT3 is protected within USFS’ Ozark National Forest. In all, 72 confirmed sites are protected. However, some sites are still lacking protection measures: for example, only 21 of the 161 confirmed sites are gated (or fenced or wired with alarms).

**Conservation status.** Important recovery accomplishments have occurred over the past 3 decades since federal designation of the Ozark big-eared bat as endangered. Gray bat colonies have rebounded from similar conservation efforts over the same time period (Martin 2007, Sasse et al. 2007). This provides optimism that continued implementation of conservation measures for the Ozark big-eared bat will continue to facilitate recovery. Yet our current population estimate is 1,600 to 1,800 total individuals. In their most recent status review, USFWS (2008) concluded that the overall population has stabilized since 1997—the year when the latest essential maternity site (CW29BT3) was added to the annual surveys, and the time period for which the time series is most complete. However, USFWS (2008) found that the recovery criteria have not been fully met and therefore upgrading the bat’s status to threatened or recovered was not yet warranted. Additional study is needed to determine the limiting factors of the Ozark big-eared bat, and additional recovery time is needed for this animal to proliferate.

**ACKNOWLEDGMENTS**

The views described herein are those of the authors, and do not necessarily reflect the views of the USFWS. Funding for these conservation efforts have been provided over several decades primarily by the USFWS (Oklahoma and Arkansas Ecological Services Offices and the Ozark Plateau National Wildlife Refuge) and the US Forest Service Ozark National Forest; financial support has also been provided by The Nature Conservancy’s Oklahoma and Arkansas Field Offices, Arkansas Game and Fish Commission, Oklahoma Department of Wildlife Conservation, Oklahoma State University, Rogers State University, Northeastern State University, and Tennessee Technological University. The MAKESENS software was made available courtesy of the Finnish Meteorological Institute at Helsinki. We are grateful to the landowners who graciously allow access to caves on their properties and who continue to protect the bat colonies. We are indebted to the colleagues that assisted with surveys over the years, but there are too many to list here. We thank M. Brigham (University of Regina) and anonymous reviewers for constructive comments.
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