

COMPUTER MODEL PROJECTIONS OF BALD EAGLE NESTING IN TENNESSEE

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ABSTRACT

From 1980 through 1990, 146 young Bald Eagles were released at five hack sites in Tennessee in an effort to reestablish a breeding population. By the end of the 1993 season, 74 additional eagles are scheduled to be released at three of the old sites and at one new site. Based on actual nesting through 1990 and computerized population projections, it is estimated that 62 successful nests could be achieved by the year 2000 in the area of influence of these hacking projects, including an estimated 41 in Tennessee.

INTRODUCTION

Modern hacking techniques used with Bald Eagles (*Haliaeetus leucocephalus*) are based on the successful protocol developed at Cornell University (Sherrod and Cade 1978) for reintroducing natural nesting of Peregrine Falcons (*Falco peregrinus*) in areas from which they have been extirpated. The technique assumes that eagles, falcons, and other raptors tend to return to nest in the general area of their maiden flights.

The Bald Eagle once nested along the major river systems in Tennessee (Alsop 1979). Until 1983, however, Tennessee's last documented successful nesting (i.e., at least one fledged young) was in 1961 (Crews 1980).

Following the banning of DDT's use in the United States in 1972, Tennessee's January Bald Eagle population increased from an annual average of 251 during 1979-84 to 287 during 1985-90. But since no Bald Eagles were nesting in the area until 1983, all were returning to the vicinities of their fledging to nest. Thus a hacking program was initiated to accelerate the return of natural nesting in Tennessee.

During the 11 years from 1980 through 1990, 146 young Bald Eagles were released from five hack sites in Tennessee (Figure 1). As many as 74 more eagles are scheduled for release during 1991-93. The goal is 61 successful nests within 120 km of the six hack sites by the

year 2007 (Table 1), and there is a potential for reaching this goal as early as the year 2000 (Table 2).

Table 1. Locations, periods of activity, and numbers of birds released or scheduled for release in Tennessee's Bald Eagle hacking projects, 1980-1993.

| Hack site | Active period | Releases made through 1990 | Releases scheduled 1991-93 | Nest goals* | Target year |
|------------------------|---------------|----------------------------|----------------------------|-------------|-------------|
| Land Between The Lakes | 1980-88 | 44 | 0 | 15 | 1997 |
| Reelfoot Lake | 1981-88 | 43 | 0 | 12 | 1999 |
| Dale Hollow Lake | 1987-91 | 32 | 10 | 8 | 1998 |
| Chickamauga Lake | 1989-92 | 20 | 22 | 10 | 2005 |
| Scottsboro | 1990-92 | 7 | 12 | 6 | 2006 |
| South Holston Lake | 1991-93 | 0 | 30 | 10 | 2007 |
| Totals | | 146 | 74 | 61 | |

*Estimated nest carrying capacity within 120 km of hack site.

In order to plan for the most effective and efficient hacking methods, there was a need to forecast resultant nesting success. Nye (1980a) projected, by calculator, the number of Bald Eagle nests that could be expected over a 13-year period in New York from hacked and wild birds. From 1981 through 1984, I made similar projections in Tennessee. Prior to computerized modeling, preparation of such forecasts was cumbersome and time-consuming.

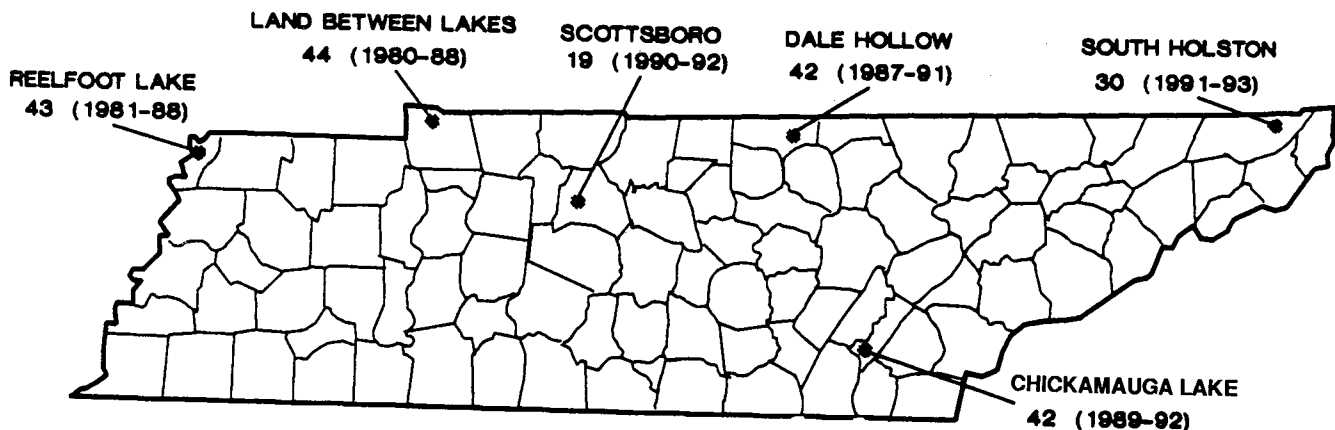


Figure 1. Tennessee Bald Eagle hack sites. Numbers indicate accomplished and proposed releases for the period 1980-1993.

Table 2. Bald Eagle population model¹ projections for the combined area of influence of Tennessee's six hack sites, 1980-2000.

| Year | Birds hacked | Breed. adults ² | No. birds by year class | | | | Succ. nests ² | |
|-------|--------------|----------------------------|-------------------------|------|------|------|--------------------------|--------------------|
| | | | 1st ² | 2nd | 3rd | 4th | All | in TN ³ |
| 1980 | 2 | 0.0 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1981 | 6 | 0.0 | 6.0 | 1.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1982 | 4 | 0.0 | 4.0 | 3.3 | 1.0 | 0.0 | 0.0 | 0.0 |
| 1983 | 5 | 2.0 | 6.0 | 2.2 | 3.0 | 0.9 | 1.0 | 1.0 |
| 1984 | 10 | 4.0 | 12.0 | 3.3 | 2.0 | 2.7 | 2.0 | 2.0 |
| 1985 | 11 | 4.0 | 14.0 | 6.6 | 3.0 | 1.8 | 2.0 | 2.0 |
| 1986 | 16 | 8.0 | 23.0 | 7.7 | 5.9 | 2.7 | 4.0 | 4.0 |
| 1987 | 22 | 10.0 | 31.0 | 12.7 | 6.9 | 5.3 | 5.0 | 5.0 |
| 1988 | 19 | 16.0 | 34.0 | 17.1 | 11.4 | 6.2 | 8.0 | 8.0 |
| 1989 | 20 | 16.0 | 35.0 | 18.7 | 15.3 | 10.2 | 8.0 | 6.0 |
| 1990 | 31 | 18.0 | 51.0 | 19.3 | 16.8 | 13.8 | 9.0 | 6.0 |
| 1991 | 34 | 28.6 | 51.2 | 28.1 | 17.3 | 15.1 | 14.3 | 9.6 |
| 1992 | 28 | 39.4 | 51.6 | 28.1 | 25.2 | 15.6 | 19.7 | 13.2 |
| 1993 | 12 | 49.5 | 41.7 | 28.4 | 25.3 | 22.7 | 24.7 | 16.6 |
| 1994 | 0 | 65.0 | 39.0 | 22.9 | 25.6 | 22.8 | 32.5 | 21.8 |
| 1995 | 0 | 79.0 | 47.4 | 21.4 | 20.6 | 23.0 | 39.5 | 26.4 |
| 1996 | 0 | 91.8 | 55.1 | 26.1 | 19.3 | 18.6 | 45.9 | 30.8 |
| 1997 | 0 | 99.4 | 59.6 | 30.3 | 23.5 | 17.4 | 49.7 | 33.3 |
| 1998 | 0 | 105.1 | 63.0 | 32.8 | 27.3 | 21.1 | 52.5 | 35.2 |
| 1999 | 0 | 113.6 | 68.1 | 34.7 | 29.5 | 24.5 | 56.8 | 38.0 |
| 2000 | 0 | 124.3 | 74.6 | 37.5 | 31.2 | 26.6 | 62.1 | 41.6 |
| TOTAL | 220 | | | | | | | |

¹Parametric values used in the model: survival first year = 0.55, later years = 0.9; fledgling production per nest = 1.2; first year of model = 1980.

The purposes of this paper are to: (1) project numbers of future successful nests in the area influenced by Tennessee's combined hacking activities, (2) compare earlier projections with actual nesting through 1990, and (3) demonstrate the computerized techniques used.

METHODS

Population Model Variables and Assumptions

Survival Rate. For the purpose of computer projections via population modeling, I assumed that 55% of hacked Bald Eagles survive their first year and 90% each year thereafter. This model therefore projects 36% survival by five years of age.

The survival rate of hacked Bald Eagles is poorly known. By 1988 in North America, of 265 hacked Bald Eagles that had been released five or more years previously, 33 (12%) were known to have reached adulthood, and 38 (14%) were known to be dead or disabled. Survival must therefore have been between 12% and 86%, with a median of 49% (Nye 1989). The actual survival rate is probably nearer the higher rate, considering the fact that leg bands are usually much more accessible to read on dead or disabled eagles than on healthy ones.

Seventeen (12%) of the 146 young Bald Eagles released in Tennessee from 1980 through 1990 are known to be dead; four were electrocuted, four shot, two collided with vehicles, two starved, one was trapped, one died of fowl pox, and three died of unknown causes.

Age of First-time Successful Parents. Some fraction of adult Bald Eagles are expected to be nonbreeders (Grier et al. 1983). Nye (1989) assumed breeding at five years of age in New York, where 198 Bald Eagles were released from 1976 through 1988. But to partially compensate for some natural nesting recruitment, I have assumed that all surviving eagles five years old or older will be successful parents (i.e., fledging young).

At least five of Tennessee's eight successful nesting pairs of 1983-1990 have one or more leg bands. Two of those bands have been read to date, both on birds recruited from Tennessee's hacking project

Table 3. Eagle population model, displaying representative cell formulas for Table 2, total number of hacked eagles through 1987, and known number of eagles and nests through 1985.

| | A | B | C | D | E | F | G | H |
|----|-------|--------|-------------------|-----------------------------|--------|------------------|--------|-------|
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | Survival —1st yr: 0.55, | | | | |
| 5 | | | | —later yrs: 0.90; | | First year: 1980 | | |
| 6 | | | | | | | | |
| 7 | | | Fledged/nest: 1.2 | | | | | |
| 8 | | | | | | | | |
| 9 | | | | | | | | |
| | | | Number | Number birds by year class: | | | | All |
| 10 | Year: | No. | breed. | 1st: | 2nd: | 3rd: | 4th: | succ. |
| 11 | | birds: | adults: | | | | | nests |
| 12 | G4 | 2 | 0.0 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 13 | G4+1 | 6 | 0.0 | 6.0 | D3*D12 | D4*E12 | D4*F12 | 0.0 |
| 14 | G4+2 | 4 | 0.0 | 4.0 | D3*D13 | D4*E13 | D4*F13 | 0.0 |
| 15 | G4+3 | 5 | 2.0 | 6.0 | D3*D14 | D4*E14 | D4*F14 | 1.0 |
| 16 | G4+4 | 10 | 4.0 | 12.0 | D3*D15 | D4*E15 | D4*F15 | 2.0 |
| 17 | G4+5 | 11 | 4.0 | 14.0 | D3*D16 | D4*E16 | D4*F16 | 2.0 |
| 18 | G4+6 | 16 | D4*(C17+G17) | B18+C18/2*C6 | D3*D17 | D4*E17 | D4*F17 | C18/2 |
| 19 | G4+7 | 22 | D4*(C18+G18) | B19+C19/2*C6 | D3*D18 | D4*E18 | D4*F18 | C19/2 |

in Land Between The Lakes (LBL) (Floyd 1990); one nested successfully at only three years of age in 1984, and the other initiated nest building when it was three and successfully nested in 1986 at age six. In addition, in 1989 a seven-year-old banded male eagle produced its first young (which died at five weeks of age) on Lake Monroe in south central Indiana, approximately 288 km north of its LBL hack site of 1982.

Fledglings Per Nest. The Tennessee computer model assumes 1.2 fledglings for each two adults of at least five years of age.

In his New York model, Nye (1980a) assumed 1.2 fledglings per pair of nesting Bald Eagles. In 1989 New York's 9 occupied nests (an occupied nest is defined as a nesting attempt in which the mated pair provides nest building material as a minimum of activity) fledged 10 young from 6 successful nests, or 1.1 per occupied nest and 1.7 per successful nest. Wood et al. (1990) reported Bald Eagle fledgling productivity per nest in 1988 as: Virginia and Maryland – 1.4, and Florida – 1.1 per occupied nest. Sindelar (1988) reported that in 1988 Wisconsin had 326 occupied nests, up 11% from 1987. Wisconsin also had an average of 1.3 young per occupied nest and 1.7 per successful nest in that same year (Sindelar 1988).

From 1983 through 1990, Tennessee had a total of 34 successful nests. Their productivity was 1.0 fledgling per occupied nest and 1.8 per successful nest (Table 4).

Table 4. Bald Eagle nesting in Tennessee, 1983-1990.

| | '83 | '84 | '85 | '86 | '87 | '88 | '89 | '90 | Total |
|---------------------|-----|-----|-----|-----|-----|-----|-----|-----|-------|
| Number fledged | 1 | 2 | 3 | 7 | 9 | 15 | 10* | 14* | 61 |
| Successful nests | 1 | 2 | 2 | 4 | 5 | 8 | 6* | 6* | 34 |
| Occupied nests | 1 | 3 | 6 | 8 | 8 | 10 | 12 | 14 | 62 |
| Fledgl./succ. nest | 1.0 | 1.0 | 1.5 | 1.8 | 1.8 | 1.9 | 1.7 | 1.7 | 1.8 |
| Fledgl./occup. nest | 1.0 | 0.7 | 0.9 | 0.9 | 1.1 | 1.5 | 0.8 | 1.0 | 1.0 |

*During 1989 and 1990, a total of four nests had seven additional young; four nestlings were killed and three had unknown fates.

Carrying Capacity. This variable concerns the number of nesting pairs that the environment could potentially support within a 120 km radius of the hack site(s). Natural nesting recruitment is assumed to compensate for Tennessee-hacked eagles that nest farther away.

Nye (1980a) estimated a carrying capacity of 40 pairs of nesting Bald Eagles for New York. In 1988, Virginia and Maryland had 65 and 77 successful nests, respectively, with growth of the nesting population occurring at a rate of approximately 9% per year for the period 1982–1988. In 1988, Florida had 275 successful nests, representing about a 2.5% annual growth rate since 1982 (Wood et al. 1990).

Limited data suggest that male Bald Eagles are establishing breeding territories in North America significantly closer to their release sites than are females. Nye (1989) reported that, of 14 eagles of known sex, 8 males nested an average of only 53 km from their hack sites, while the average of that figure for 6 females was 183 km.

Reelfoot Lake, in northwestern Tennessee, had 14 "active nests" (undefined) in both 1954 and 1955 (Crews 1980). Tennessee's fish prey base was enhanced from the 1930s through the 1970s by the development of 34 man-made reservoirs totaling over 214 thousand ha

of surface area.

The carrying capacity of Tennessee hack site vicinities is assumed to vary from 6 to 15 successful nests within 120 km of each site. In the Tennessee area of influence (which includes portions of nearby states), I have subjectively estimated carrying capacity at 61 successful nests (Table 1).

Computer and Software

An equivalent of an IBM AT model computer with 640K internal memory was used. The software used was PC-Calc (ButtonWare, Inc. 1984), then PC-Calc+ (ButtonWare, Inc. 1987), one of many applicable spreadsheet programs. In 1985 (Hatcher 1986) I initiated this first known computerized spreadsheet program for quickly calculating future Bald Eagle populations resulting primarily from hacking activities. It enabled testing of the effects of modifying any of several variables. This model was especially applicable to a population matrix, or deterministic type of model, within which a new variable would change the values of all components of the table.

RESULTS

Evidence of the Return of Hacked Eagles

In Tennessee. In 1990, 13 (93%) of Tennessee's 14 occupied eagle nests were within 70 km of the two oldest hack sites—LBL and Reelfoot Lake. This included five (83%) of six successful nests. Reelfoot Lake had five occupied nests within 70 km of the hack site in 1990, and LBL had eight within 80 km. The average distance from hack site to nest site was 19 km in the case of Reelfoot Lake, and 43 km in the case of LBL.

In 1990, two eagle parents (both males) successfully nested within 24 km of their hack sites in LBL. Three other banded adults (possibly "hack returnees") nested in Tennessee in 1990 within 78 km of the LBL and Reelfoot Lake hack sites.

Outside Tennessee. In 1990 there were six occupied nests in Kentucky within 96 km of Tennessee hack sites. Three of these nests fledged a total of six birds. One mated pair, both members of which had leg bands, fledged two young 29 km north of the LBL hack site. There were two occupied, but later abandoned, nests in Ballard County, Kentucky, approximately 80 and 96 km north of the Reelfoot Lake hack site.

A male eagle that was hacked at LBL in 1982 occupied a nest in 1989 and 1990 in south-central Indiana, 288 km to the north.

Population Projections

The Bald Eagle population model used for these projections is a deterministic one (Grier 1980); that is, the output of the model is determined by a fixed set of values, with no room for chance, and only one possible outcome for each set of variables.

Population models were developed for the six Tennessee hack sites listed in Table 1. By the year 2000, there is projected to be a *potential* of 62 successful Bald Eagle nests (Table 2) within the area primarily influenced by Tennessee's hacking program (within approximately 120 km of the several hack sites). This includes some habitat in adjacent states.

In 1990 three of the nine successful nests located within 96 km of Reelfoot Lake or LBL hack sites were in Kentucky. If two-thirds of the hack-related nests were to continue to be sited in Tennessee, there is a *potential* for 41 successful nests in the Volunteer State by the year 2000 (Table 2). But if expanding eagle populations should find better nesting sites available in nearby states, Tennessee's percentage of nests

resulting from birds hatched or hacked in Tennessee would gradually decline.

Table 3 is a representation of a computerized spreadsheet that produced the projections of Table 2. Its purpose is to enable other eagle workers to duplicate (or modify as appropriate) each spreadsheet cell formula for application with their eagle populations. The author can also provide the model on a 5.25-inch diskette upon request.

Figure 2 compares two projections for successful nests within Tennessee's area of influence (within 120 km of hack sites). Both use actual numbers of eagles released through 1990, and projected hack

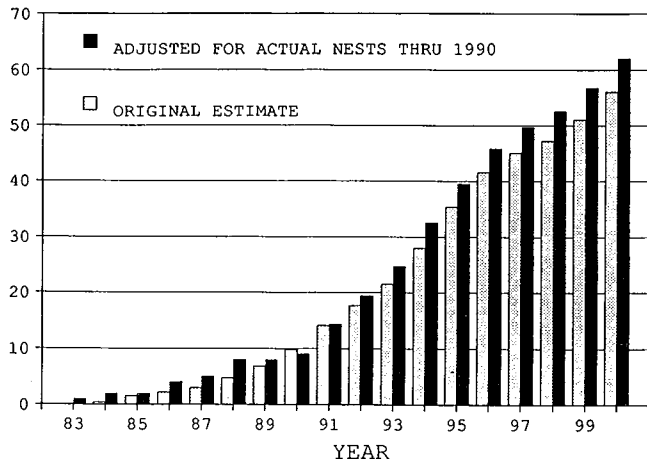


Figure 2. Computerized Projections For Bald Eagle Successful Nests In Tennessee Area Of Influence

Figure 2. Computer-generated projections for successful Bald Eagle nests in the combined areas of influence of Tennessee's six hack sites.

releases through 1993. One projection is adjusted for the actual number of successful nests through 1990; the other is unadjusted and represents original projections. The actual number of successful nests was slightly ahead of original projections through 1989, and less than one nest lower than projections in 1990.

SUMMARY AND CONCLUSIONS

Hacking of Bald Eagles in Tennessee was begun in 1980¹ in an effort to reestablish a breeding population in the state (no nesting of the species is known to have occurred in Tennessee from 1961 until 1983). Since the fledging of one Tennessee-hatched eagle in 1983, nesting activity increased through 1990 at a rate at or above earlier model projections. The computer model projects 62 successful nests within 120 km of six hack sites by approximately the year 2000. There is a potential for 41 of these nests to be in Tennessee. The actual numbers of successful nests in the future will be determined by such factors as availability of habitat, human disturbance, and our collective abilities to properly manage these factors.

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